COMMENTS (INCLUDING RESOURCE MATERIALS) ON THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY REGION 2 FINAL REMEDIAL INVESTIGATION REPORT AND FOCUSED FEASIBILITY STUDY FOR THE LOWER EIGHT MILES OF THE PASSAIC RIVER AND SUPERFUND PROPOSED PLAN

Submitted by:

Maxus Energy Corporation and Tierra Solutions, Inc., individually and on behalf of Occidental Chemical Corporation.

Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

August 19, 2014

TABLE OF CONTENTS

Comments on the Proposed Plan for the Lower Passaic River Focused Feasibility Study — Maxus Energy Corporation and Tierra Solutions, Inc., individually and on behalf of Occidental Chemical Corporation

Key Lower Passaic River Focused Feasibility Study Issues and Uncertainties — David A. Jay and Stefan A. Talke; Portland State University

Lower Passaic River Focused Feasibility Study: Analysis and Issues — James L. Best, Ph.D. and Marcelo H. Garcia, Ph.D.; University of Illinois

Comments on the Passaic River Focused Feasibility Study (FFS) and Related Documents — Charles S. Melching, Ph.D., P.E., D.WRE, BCEE; Marquette

Lower Eight Miles of the Passaic River Focused Feasibility Study (FFS) Report: Human Health Risk Assessment — Paul T. Kostecki, Ph.D. and Edward J. Calabrese, Ph.D.; AEHS

FFS Human Health Risk Assessment – Comments on Use of TEFs — William H. Farland, Ph.D.

Comments on Navigational Dredging in Louis Berger Group, Inc. Focused Feasibility Study Report — Jim Opaluch; University of Rhode Island

ARCADIS Comments on the Passaic River FFS Reports (April 2014) Regarding Ecological Risk and Preliminary Remediation Goals — Timothy J. Iannuzzi, Jacqueline Iannuzzi and Melissa Beauchemin; ARCADIS

Comments on EPA's Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River — Matthew Bingham and Jason C. Kinnell; Veritas

Comments on the Lower Eight Miles of the Lower Passaic River Focused Feasibility Study Report — Mark Harris, Ph.D., Daniele Wickoff, Ph.D., Jon Urban, Ph.D., Camarie Perry, M.S. and Liz Abraham, M.S.; ToxStrategies

Comments on Organic Carbon and Chemical Fate & Transport Models in EPA's Focused Feasibility Study Report for the Lower Eight Miles of the Passaic River — Pravi Shrestha and Steave H. Su; Exponent

Remedy, Engineering and Cost Related Comments — Paul J. Bluestein, P.E. and Robert Romagnoli, P.E.; Tierra

Source-Related and Sediment Chemistry Trends — Dennis Farley and Robert Romagnoli, P.E.; The Intelligence Group

Confined Aquatic Disposal — Philip A. Spadaro, LG; The Intelligence Group

Application of a Net Environmental Benefit Analysis Framework to USEPA Region 2's Focused Feasibility Study for the Lower Eight Miles of the Passaic River — Joseph P. Nicolette, M.S.; ENVIRON

Policy Issues Raised by the Proposed Plan Issued for the Lower Passaic River — Thomas C. Voltaggio; Voltaggio Consulting

RESOURCE MATERIALS:

Copyrighted

Non-Copyrighted

EPA Guidance Documents

A Common Tragedy: History of an Urban River

2000-2001 Passaic River Creel/Angler Survey

COMMENTS

Comments on the United States Environmental Protection Agency Region 2 Final Remedial Investigation Report and Focused Feasibility Study for the Lower Eight Miles of the Passaic River and Superfund Proposed Plan

August 19, 2014

Submitted by:
Maxus Energy Corporation
and
Tierra Solutions, Inc.,
individually and on behalf of
Occidental Chemical Corporation

Table of Contents

I. Introduction 1

II. A Brief History of the Passaic River and Maxus and Tierra's Actions.....6

A. From Peaceful Valley to Superfund Site.....6

B. Maxus and Tierra's 30-Year Track Record of Action and Accomplishment. 7

III. The FFS is inconsistent with the NCP and fails to follow EPA policies and guidance, rendering the Proposed Plan arbitrary, capricious, and not in accordance with law. 8

A. Region 2's use of the Focused Feasibility Study Process violates the NCP. 9

B. The FFS is not transparent concerning key technical assumptions and likely adverse community and environmental impacts resulting from the interim remedial action. 12

C. The FFS incorrectly screened out bioremediation and other potential in situ treatment approaches without conducting the necessary evaluation required by the NCP. 16

D. The FFS is inconsistent with EPA's guidance for remediating sediment sites. 17

E. The FFS is inconsistent with EPA's guidance for interim actions.....19

F. The FFS did not properly evaluate monitored natural recovery ("MNR") and its ability to achieve risk-based goals. 20

IV. The FFS and the Proposed Plan are based on a technically flawed analysis buttressed by inaccurate, incomplete, and misleading model results to establish risk reduction goals that the proposed remedial alternatives cannot achieve. 22

A. The FFS is based on a flawed conceptual model and a fundamental misunderstanding of LPRSA hydrodynamics, sediment dynamics, and hydrology. 23

B. The FFS provides a flawed analysis of spatial trends and natural recovery that is inconsistent with existing data. 24

C. The FFS neglects the magnitude of ongoing sources of contaminants, basing the proposed remedy on an inaccurate analysis of environmental conditions in the FFS Study Area. 26

D. The FFS modeling does not demonstrate either the need for or the likely benefit of the proposed remedial action. 30

E. The FFS fails to thoroughly evaluate uncertainty, which makes the likely consequences of the remedy unknown and prevents decision makers

from meaningfully evaluating the projected performance or the risks associated with remedial alternatives. 35

F. Resuspension of dredged materials and sediments from unremediated portions of the LPRSA and Newark Bay will recontaminate capped areas. 37

V. The FFS overstates the current and future risks and hazards associated with Lower Passaic River sediments; when the risks and hazards are correctly calculated, there is no justification for a bank-to-bank remediation program to address the contaminants of concern evaluated in the FFS. 38

A. The FFS approach to human health risk and hazard from fish and crab consumption is flawed and excessively conservative. 39

B. The FFS approach to dioxin risk is technically indefensible. 42

C. The FFS approach to ecological risk is flawed. 44

D. Correct analysis of human health and ecological risks demonstrates that there is no need for immediate remedial action to address the COCs evaluated in the FFS. 45

E. The FFS ignored risks presented by polycyclic aromatic hydrocarbons ("PAHs") that would substantially affect the risk assessment. 45

F. The risk-related documents submitted with these comments correct the analysis used in the FFS. 46

VI. The Proposed Plan is not implementable and will not result in environmental benefits. 48

A. The interim remedy described in the Proposed Plan is not practically implementable. 49

B. The FFS overstates the future benefits and understates the potential risks associated with the Proposed Plan. 54

VII. The Proposed Plan should not include navigational dredging, which is unwarranted for commercial reasons and increases the risk, environmental and community impact, and cost of the proposed remedy. 56

VIII. A CAD would be environmentally protective, implementable, and efficient. 60

IX. Conclusion 62

Table of Acronyms and Abbreviations

AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
CAD	Confined Aquatic Disposal
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminants of Concern
CSO	Combined Sewer Overflow
CSTAG	Contaminated Sediments Technical Advisory Group
CY	Cubic Yard
EPA	Environmental Protection Agency
ETM	Estuarine Turbidity Maximum
FFS	Focused Feasibility Study
FS	Feasibility Study
HHRA	Human Health Risk Assessment
LPRSA	Lower Passaic River Study Area
RI/FS	Remedial Investigation/Feasibility Study
NBC	Newark Bay Complex
NCP	National Contingency Plan
NEBA	Net Environmental Benefits Analysis
NPL	National Priorities List
NRRB	National Remedy Review Board
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
QAPP	Quality Assurance Project Plan
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PPB	Parts Per Billion
PPM	Parts Per Million
PPT	Parts Per Trillion
RD	Remedial Design
RI	Remedial Investigation

RM	River Mile
TCDD	2,3,7,8 Tetrachlorodibenzo-p-dioxin
TEF	Toxicity Equivalence Factor
TEQ	Toxic Equivalent
USACE	United States Army Corps of Engineers

COMMENTS ON THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY REGION 2 FINAL REMEDIAL INVESTIGATION REPORT AND FOCUSED FEASIBILITY STUDY FOR THE LOWER EIGHT MILES OF THE PASSAIC RIVER AND SUPERFUND PROPOSED PLAN

I. Introduction

On April 11, 2014, U.S. EPA Region 2 ("Region 2") announced its proposed cleanup plan for the Lower Eight Miles of the Passaic River located in Essex and Hudson Counties, New Jersey (the "FFS Study Area") and invited public comment on the following documents and their supporting materials: the Superfund Proposed Plan[1] ("Proposed Plan"), the Remedial Investigation Report ("RI Report"),[2] and the Focused Feasibility Study Report (the "FFS").[3] Maxus Energy Corporation ("Maxus") and Tierra Solutions, Inc. ("Tierra"), individually and on behalf of Occidental Chemical Corporation ("OxyChem"), appreciate the opportunity to provide these comments in response to Region 2's invitation and request that these comments and all documents included or attached herewith, or referenced herein, be made available to the public and added to the administrative record.[4]

Maxus and Tierra recognize the extensive body of work that Region 2 has amassed over the past decade with respect to the Lower 17 Miles of the Passaic River that comprises the Lower Passaic River Study Area ("LPRSA"), but that work is at risk of being wasted if Region 2 selects and implements the Proposed Plan based on the RI Report and the FFS, which are technically deficient and inconsistent with the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), the National Oil and Hazardous Substances Pollution Contingency Plan (the "NCP"), and EPA policy and guidance. Not only is Region 2 proposing the wrong approach to the Lower Passaic River, it has followed the wrong process to

---

[1] *Superfund Proposed Plan – Lower Eight Miles of the Lower Passaic River, Part of the Diamond Alkali Superfund Site, Essex and Hudson Counties, New Jersey* (2014).

[2] Louis Berger Group Inc., *et al.*, *Remedial Investigation Report for the Focused Feasibility Study for the Lower 8 Miles of the Lower Passaic River* (2014).

[3] Louis Berger Group Inc., *et al.*, *Focused Feasibility Study Report for the Lower 8 Miles of the Lower Passaic River* (2014).

[4] Given the scope and scale of the site and proposed remedy along with the extraordinary amount and complexity of information, data, reports, and studies presented in the FFS and Proposed Plan, even a 120-day public comment period limits meaningful opportunity for public input, and Maxus and Tierra, individually and on behalf of OxyChem, reserve their rights to supplement the administrative record with additional material after the close of the public comment period. Further, Maxus and Tierra assume that Region 2 intends to include in the administrative record all data generated in connection with the RI/FS for the LPRSA—given the obvious relevance those data have to the justification for and potential consequences of remedial action in the FFS Study Area—and Maxus and Tierra formally request that this be done.

reach that proposal. Both deficiencies render Region 2's course arbitrary, capricious, and not in accordance with law.

Based upon the review of the RI Report, the FFS, and the Proposed Plan by a team of academic and technical experts, Maxus and Tierra, on behalf of OxyChem, respectfully urge that Region 2 withhold—for a comparatively short period of time relative to the many years of remedial design and construction that will be required—any decision regarding the Proposed Plan. Region 2 should complete the ongoing Remedial Investigation/Feasibility Study ("RI/FS") process for the LPRSA, evaluate the effects of the large-scale removal actions that have already been conducted in the LPRSA, and then in selecting further remedial actions proceed with an adaptive management approach pursuant to EPA guidance.

The comments set forth in this document and in the appended reports provide many reasons for Region 2 to modify its proposed course and achieve better results for the environment and community, but the most important reasons can be summarized simply:

- Region 2's approach is inconsistent with the NCP, relevant EPA guidance, and important EPA policies;
- The presumed risk reduction to be attained by remedial action will be delayed and will be less than anticipated by Region 2, if it ever occurs;
- Region 2's analysis demonstrates neither sufficient risk nor sufficient benefit to justify an enormous and disruptive interim remedial action, nor does this analysis demonstrate that Region 2's preferred alternative provides greater risk reduction than other alternatives;
- The Proposed Plan poses a significant risk of causing more harm than good; and
- Community impacts will be both more protracted and more significant than Region 2 acknowledges or discloses.

Maxus and Tierra's comments on the RI Report, FFS, and the Proposed Plan are set forth in this document and in the detailed reports appended to it, which are generally summarized and discussed below. These comments were developed by subject matter experts in an array of disciplines including risk assessment, modeling, uncertainty analysis, and

engineering. These experts are acknowledged leaders in their various disciplines, and information on the academic background and qualifications of each expert is provided in the attached reports. The authors of some of the most significant of the appended reports include:

- Dr. David A. Jay and Dr. Stefan A. Talke, Portland State University, *Key Lower Passaic River Focused Feasibility Study Issues and Uncertainties*.
- Dr. James L. Best and Dr. Marcelo H. García, University of Illinois, *Lower Passaic River: Analysis and Issues.*
- Dr. Charles S. Melching, Marquette University (retired), *Comments on the Passaic River Focused Feasibility Study ("FFS") and Related Documents*.
- Dr. Paul Kostecki and Dr. Edward Calabrese, AEHS Foundation, *Comments – Lower Eight Miles of the Passaic River Focused Feasibility Study (FFS) Report: Human Health Risk Assessment*.
- Dr. William H. Farland, Colorado State University, *Human Health Risk Assessment – Comments on the Use of TEFs*.
- Dr. James J. Opaluch, University of Rhode Island, *Comments on Navigational Dredging in Louis Berger Group, Inc. FFS Report*.
- Thomas C. Voltaggio, Former Deputy Regional Administrator and Hazardous Waste Management Division Director, EPA Region 3, *Policy Issues Raised by the Proposed Plan Issued for the Lower Passaic River*.

The comments are organized into discrete subject matter areas, with separate reports providing comments addressing major topics (e.g., human health risk, ecological risk, modeling). In some cases, several reports address separate areas within these major topics. Maxus and Tierra, individually and on behalf of OxyChem, have appended additional materials and request that these materials be included in the administrative record. These materials support and substantiate the comments. The remainder of this document provides legal and policy comments on the FFS and the Proposed Plan. It also summarizes the technical comments but does not discuss every one.

To summarize, Region 2's Proposed Plan is inconsistent with the NCP and EPA guidance. The deviations from accepted process in the Proposed Plan cannot support selection of an interim remedy for the lower eight miles of the Passaic River. Significantly, Region 2 misapplied the FFS process to a situation for which it should not be used and for which it was not designed or intended. In so doing, Region 2 contravened important EPA policies and guidance regarding the remediation of sediment sites, risk assessment, quality assurance, interim actions, and transparency. If Region 2 selects and implements a remedy based on the FFS, it will have acted inconsistently with the NCP and applicable EPA guidance, and its actions would be arbitrary, capricious, and not in accordance with the law. As a result, Region 2 will face substantial challenges to any attempts to enforce such a decision or to recover its costs.

Contrary to CERCLA and the NCP, the FFS also improperly screened out bioremediation and in situ treatment options as potential remedial technology. Bioremediation, in particular, is a promising technology that may achieve risk reductions similar to the Proposed Plan but would do so without the negative environmental impacts of dredging. At a minimum, bioremediation would likely reduce concentrations of contaminants of concern ("COCs") in LPRSA sediments more quickly and with less community disruption than could be accomplished through dredging or capping alternatives. This technology should have been considered in the FFS, and Region 2 should consider the results of the implementation of Dr. John Pardue's[5] *Draft: Newark Bay/Lower Passaic River In Situ Bioremediation Pilot Study Work Plan* before selecting the remedy for the FFS Study Area.

Region 2's analysis is replete with technical deficiencies, such as the unjustified exclusion of key site-specific data. These deficiencies all skewed the FFS remedy selection process in the same direction: in favor of large-scale, bank-to-bank remedial action to be implemented in the near term, before the Lower Passaic River-Newark Bay system is sufficiently understood to support a decision. Region 2 proposes that this substantial remedy be implemented <u>before</u> ongoing sources of contaminants have been controlled. These ongoing sources will undermine the effectiveness of any remedial action. The RI Report and the FFS are premised on an inaccurate conceptual site model and demonstrate that Region 2 does not have a complete or accurate understanding of the system, including its physical, ecological, geological, chemical, and navigational aspects, which must be understood before a remedial

[5] John Pardue, Ph.D., Louisiana State University; Elizabeth Howell Stewart Professor, Department of Civil and Environmental Engineering.

action is selected. More data and more refined modeling and uncertainty analysis are needed before a remedy is selected for the FFS Study Area.

The risks Region 2 seeks to address are overstated and, when properly calculated, are already in the range that Region 2 seeks to achieve for the contaminants of concern evaluated in the RI Report and the FFS. Even if Region 2's assessment of the risks were correct, the Proposed Plan is not implementable and is based on unreliable modeling and analysis, which provides an erroneous evaluation of both the costs and benefits of the proposed remedy and which disregards the overwhelming uncertainties surrounding these analyses—uncertainties that may be so substantial as to render it impossible to differentiate the relative costs and benefits of any of the alternatives under consideration from one another. The FFS also dramatically understates time, cost, and risk of the remedial alternative that Region 2 proposes. In addition, the extent of dredging that Region 2 proposes is greater than necessary to implement the proposed interim remedy due to errors in Region 2's assessment of navigational needs. Finally, Region 2's proposal to use off-site disposal for dredged material management rather than a confined aquatic disposal facility ("CAD") renders the proposed remedy even less implementable than it otherwise would be.

CERCLA's RI/FS process exists for a reason—to ensure that significant issues are fully understood <u>before</u> remedial action is taken. This process will soon be completed for the entire LPRSA. Because of its numerous technical flaws, errors, and uncertainties, the FFS is not a proper substitute for this process, and the many errors in the RI Report and the FFS must be corrected to allow decision makers to consider the important issues inherent in remedy selection, as required by the NCP. No decision made on the current record can achieve the rigor necessary to comply with the NCP. The decisions that will result after completion of the RI/FS process for the full 17-mile LPRSA, however, may correct various technical shortcomings identified in these comments. Additional knowledge gained from an evaluation of the effect of the removal actions performed to date, which was not included in the FFS, will allow for a more accurate understanding of the LPRSA before a final decision is made.

Given the high remediation costs and the significant uncertainties surrounding both the potential effectiveness and the potential risks of implementing the Proposed Plan, Region 2 should follow EPA's 2005 *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* and employ its iterative, adaptive management process to impose source control, gain the

necessary understanding of risk and contaminant fate and transport, and otherwise accomplish what is needed to develop an effective and implementable plan.

In light of these considerations, Region 2 should allow the RI/FS process for the full 17-mile LPRSA to be completed before making any further decisions regarding the Proposed Plan. If Region 2 nevertheless decides to proceed at this time with a Record of Decision based on the FFS, it should select monitored natural recovery ("MNR") as part of an iterative approach to addressing risks in the LPRSA. This is the most prudent course of action and is encouraged in EPA guidance. Should Region 2 forego this preferred approach, it should select monitored natural recovery in combination with a targeted remedy. Further, if Region 2 chooses a remedy that involves substantial dredging, it should forego navigational dredging and also select a CAD or confined disposal facility ("CDF") as suggested by the EPA National Remedy Review Board ("NRRB") and Contaminated Sediments Technical Advisory Group ("CSTAG"). A CAD is the most efficient and lowest risk approach to dredged materials management, which will minimize the impact of the remedy upon nearby communities and the environment.

II. A Brief History of the Passaic River and Maxus and Tierra's Actions.

A. From Peaceful Valley to Superfund Site

The Passaic River, a name derived from the Native American – Algonquin – word meaning "peaceful valley," traverses 80 miles of suburban and urban areas to its confluence with the tidal waters of Newark Bay. It drains an area of approximately 935 square miles with seven major tributaries flowing into the main stem, which is used for water supply, recreation, navigation and wastewater assimilation.[6] During the 1800s, the area surrounding the Lower Passaic River became a focal point for our nation's industrial revolution, and during the War of 1812, the Paterson area was the nation's major industrial center. A byproduct of this industrial revolution was pollution entering the Lower Passaic River from upstream. Meanwhile, New Jersey's largest city, Newark, was having the same negative environmental impacts within the lower reaches of the River.[7] Newark was a major center of shoe and leather production beginning as early as 1800, and other industries soon followed and thrived in the Newark area.

---

[6] U.S. Army Corps of Engineers, New York District, Fact Sheet: The Lower Passaic River Restoration Project (Oct. 2003) ("USACE Fact Sheet").

[7] Art Silverman, The Dirty Truth About That Other Jersey Shore, Nov. 2010.

By the 1890s, environmental conditions in the Passaic River were already substantially degraded, with the river used for disposal of industrial wastes, raw municipal sewage, storm water run-off, and raw wastes and trash from the marine shipping industry. By 1900, recreational use of the Lower Passaic River had been all but eliminated, and improvements to local sewer infrastructure proved unable to materially improve river conditions.[8] In 1902, public officials recognized the historic destruction of the environment in the Passaic River when then-Governor Franklin Murphy publicly acknowledged that the Passaic River had been "destroyed" by "pollution . . . from the adjacent population."[9]

Two centuries of urban and industrial development surrounding the Lower Passaic River, combined with associated population growth, have resulted in poor water quality, contaminated sediments, bans on fish and shellfish consumption, lost wetlands, and degraded habitat.[10] The environmental contamination and degradation that Region 2 seeks to address has a history that is centuries long and is societal in nature. Region 2's intended use of CERCLA to force a relatively small number of companies to spend billions of dollars to remediate the consequences of two centuries of urban and industrial waste in the Passaic River overreaches and abuses CERCLA's statutory scheme.

B. Maxus and Tierra's 30-Year Track Record of Action and Accomplishment.

The Diamond Alkali Superfund Site was listed on EPA's National Priorities List in 1984 and, for most of the three decades that followed, Maxus and Tierra, on behalf of OxyChem, were the only parties actively addressing the environmental conditions caused by historic activities in the Lower Passaic River and in Newark Bay. Although their efforts have been performed pursuant to a consent decree and six administrative orders to satisfy EPA procedure, Maxus and Tierra undertook their work voluntarily. In the 30 years that Maxus and Tierra have been performing on OxyChem's behalf, they have spent approximately $300 million performing environmental investigations and remediation activities, both on the upland site at 80 Lister Avenue and in the Lower Passaic River[11] and Newark Bay.

---

[8] Timothy J. Iannuzzi, *et al.*, *A Common Tragedy: History of an Urban River* (Amherst Scientific 2002) at 42-44.

[9] "Gov. Murphy's Inaugural," *New York Times* (1/22/1902).

[10] USACE Fact Sheet.

[11] *See, e.g.*, Tierra Solutions, Inc., *Executive Summary – Passaic River Study Area Preliminary Findings* (January 2003).

These activities, which continue today, have not been limited to studies. Pursuant to the terms of a 2008 Administrative Order on Consent ("AOC"), Maxus and Tierra conducted, on behalf of OxyChem, a Non-Time Critical Removal Action in the LPRSA near 80/120 Lister Avenue, Phase I of which was completed in 2012,[12] and Phase II of which awaits Region 2 approval. Work to complete the Time Critical Removal Action at River Mile 10.9 is underway as well. Most recently, in March 2014, Maxus and Tierra proposed to EPA the concept of a large, field-scale pilot study to demonstrate the recent scientific advancements in in situ sediment biodegradation as a potential viable alternative remedial technology for the Lower Passaic River and Newark Bay. Maxus and Tierra followed this proposal with submittal of a written Statement of Work to EPA and Region 2 in May 2014; this in turn was followed with a detailed *Draft: Newark Bay/Lower Passaic River In Situ Bioremediation Pilot Study Work Plan*, transmitted to Region 2 on July 1, 2014. As of the submittal date of these comments, Maxus and Tierra await Region 2's review of the Pilot Study Work Plan.

The actions of Maxus and Tierra, as well as the actions of parties who later joined in these efforts a decade ago, have contributed to available knowledge of the complex environmental conditions in the LPRSA and have addressed significant areas of contamination in and around the FFS Study Area. These past actions have been consistent with the iterative, adaptive management framework EPA guidance recommends at complex sediment sites, and this process will continue. Phase II of the Non-Time Critical Removal Action will address an additional area of contaminated sediment, and further data and analysis will be generated by both the LPRSA and the Newark Bay RI/FS processes. Region 2 should embrace this iterative process rather than depart from it by prematurely selecting an interim remedy for eight miles of the LPRSA that will foreclose meaningful adaptive management.

III. The FFS is inconsistent with the NCP and fails to follow EPA policies and guidance, rendering the Proposed Plan arbitrary, capricious, and not in accordance with law.

The fundamental flaws in Region 2's approach to the Proposed Plan include, among many others, an inapplicable and unlawful focused feasibility study process; a predetermined focus on bank-to-bank remediation; incomplete, flawed, and inconsistent use of data and

[12] Tierra Solutions, Inc., *Final Construction Report – Lower Passaic River Study Area Phase I Removal Action* (March 2013).

analysis; overstated and miscommunicated risks, and understated and miscommunicated effects of continuing sources of contaminants, recontamination, and community impacts. These flaws are so pervasive as to entirely undermine Region 2's analysis and conclusions regarding the FFS Study Area. Region 2 has disregarded its obligations under CERCLA, failed to comply with the detailed procedures of the NCP, and ignored EPA's own policies and guidance. The unfortunate end result is a Proposed Plan that is arbitrary, capricious, and not in accordance with law.

A. Region 2's use of the Focused Feasibility Study Process violates the NCP.

One of the most fundamental violations of the NCP is Region 2's misuse of a tool intended for acceleration of simple interim actions and presumptive remedies—the focused feasibility study process—to advance the Proposed Plan, which is procedurally defined as an "interim remedy," but which in reality represents the major component of a yet-to-be-identified-and-selected "final remedy" to which Region 2 proposes to commit both itself and the public before completion of the RI/FS process.

CERCLA §105(a) provides that the NCP "shall specify procedures . . . to be employed in . . . remedying releases of hazardous substances . . .." It further provides that "the response to and actions to minimize damage from hazardous substances releases shall, to the greatest extent practicable, be in accordance with the provisions of the plan." The NCP at 40 C.F.R. § 300.1 sets forth its purpose as being "to provide the organizational structure and procedures for . . . responding to . . . releases of hazardous substances, pollutants, and contaminants." These include "procedures for undertaking response actions pursuant to CERCLA." Those procedures set forth at § 300.430 nowhere provide for the focused feasibility study process Region 2 followed here.

Indeed, the NCP does not contain the term "focused feasibility study." The first use of the concept appears to be in EPA's 1994 *Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities*, which was intended to support the "accelerat[ion] and develop[ment of] streamlined approaches to the cleanup of hazardous waste" at federal facilities. This guidance memorandum encourages the development of presumptive remedies as standardized methods to approach similar or recurring contamination problems: "[f]ollowing site characterization, a focused Feasibility Study ("FS") or Engineering Evaluation/Cost Analysis

("EE/CA") may be sufficient when employing the presumptive remedy approach."[13] Notably, EPA's 1994 guidance memorandum was issued to provide specific guidance for federal facilities as a companion to an earlier directive for privately owned facilities.[14] This earlier directive mentions neither presumptive remedies nor the use of a focused feasibility study.

EPA has not issued subsequent guidance on why and when it is preferable to initiate a focused feasibility study rather than an FS. An evaluation of EPA practice, however, demonstrates that the use of the focused feasibility study process has grown over time to exceed the limited circumstances outlined in the 1994 guidance memorandum, expanding into three primary situations in which focused feasibility studies have been used:

- Simple Interim Remedial Actions: Focused feasibility studies have been used to evaluate alternatives for simple interim remedial actions in situations where a full remedy will follow. When a focused feasibility study is used to implement an interim remedy it is critical that any actions taken under the focused feasibility study be consistent with the broader RI/FS.[15] An example of such an interim remedy would be installing and operating wells to intercept contaminated groundwater leaving a site and threatening nearby communities while an RI/FS is underway.[16]

- Implementation of a Presumptive Remedy: This use of a focused feasibility study was outlined in the original EPA guidance memorandum. Presumptive remedies are

[13] EPA, *Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities* at 6 (Aug. 22, 1994) (click title to access document).

[14] EPA, *Guidance on Implementation of the Superfund Accelerated Cleanup Model (SACM) under CERCLA and the NCP*, OSWER Directive 9203.1-03 (1992) (click title to access document).

[15] *See, e.g.,* 40 C.F.R. § 300.5 (describing that feasibility studies generally use data gathered during a remedial investigation, which "are used to define the objectives of the response action, to develop remedial action alternatives, and to undertake an initial screening and detailed analysis of the alternatives"); 40 C.F.R. § 300.430(e)(1) (requiring that the development and evaluation of alternatives in a feasibility study "reflect the scope and complexity of the remedial action under consideration and the site problems being addressed" and requiring that the "[d]evelopment of alternatives shall be fully integrated with the site characterization activities of the remedial investigation").

[16] *See* EPA, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* 8-3, Highlight 8-3 (July 1999) (hereinafter "Decision Documents Guidance") (including, among several examples of interim actions, "Installing and operating extraction wells in an aquifer to restrict migration of a contaminated ground-water plume with the intention of later installing additional wells (or taking other action) to address the contamination in a final action"), *available at* http://www.epa.gov/superfund/policy/remedy/rods/pdfs/guide_decision_documents_071999.pdf.

implemented at sites where there are no significant, site-specific technical issues that require evaluation before implementation of a remedy.[17]

- Implementation of a Remedy at a Similar Operable Unit ("OU") within a Larger Site: When significant amounts of data have been obtained and analyzed during previous RIs, Remedial Designs ("RDs"), or RI/FSs performed at other OUs at a site, a focused feasibility study may be used to implement a remedy at a newly-addressed, but similar, OU.[18] In practice, however, a focused feasibility study will only be used at a later OU when a full RI/FS has already been conducted for the earlier remediated OU.[19]

Each of these applications demonstrates that the focused feasibility study process can be an important tool, in limited scenarios, to increase efficiency and decrease cost when further data collection and analysis are not required to develop and choose among a set of interim remedial alternatives. This is, however, demonstrably not the case for the lower eight miles of the Passaic River. None of these categories is even remotely applicable to the Proposed Plan, which selects an extraordinary remedy for an eight-mile stretch of river before completion of the RI/FS and as to which Region 2 has announced will result in the removal of enough sediment to "fill Giants Stadium two times"[20] and on its own would be "one of the largest volumes ever to be dredged under the EPA's Superfund program."[21]

Even if the focused feasibility study approach were applicable, there are major defects in the investigation and analysis underlying the Proposed Plan for the FFS Study Area. There is no justification for use of an abbreviated process given the scale of the remedy, the inadequate analysis and understanding of important hydrological, oceanographic, environmental, and societal processes influencing the LPRSA, and the unprecedented geographic scale and complexity of the Site. Indeed, the many technical problems discussed in these comments underscore the fundamental errors that Region 2 is making in attempting to apply the

---

[17] *See generally* EPA, *Presumptive Remedies: Policy and Procedures* (Dec. 12, 2011), http://www.epa.gov/superfund/policy/remedy/presump/pol.htm.

[18] Report of Thomas C. Voltaggio, *Policy Issues Raised by the Proposed Plan Issued for the Lower Passaic River* at 2-3.

[19] *Id.*

[20] EPA, Fact Sheet: *Cleaning up the Lower Passaic River – An Overview of EPA's Proposal for the Lower 8 Miles* (April 2014).

[21] EPA, Press Release: *EPA Proposes Plan to Remove Toxic Sediment from the Passaic River; Largest Cleanup in EPA History Will Protect People's Health and Create Jobs* (April 2014).

abbreviated focused feasibility study process to the FFS Study Area. Instead of continuing its current course, which has created significant problems, Region 2 should follow the NCP and select a remedy for the FFS Study Area following the completion of the ongoing RI/FS process, supplemented by the additional information and analysis required to create an accurate, technically defensible understanding of current conditions in the LPRSA and the likely effects of various remedial alternatives.

B. The FFS is not transparent concerning key technical assumptions and likely adverse community and environmental impacts resulting from the interim remedial action.

EPA guidance recognizes the importance of transparency as it relates to risk assessments. For example, the EPA Science Policy Council's *Risk Characterization Handbook* establishes transparency as its first criterion for effective risk characterization.[22] This document explains that the goal of transparency is to ensure that "any reader understands all the steps, logic, key assumptions, limitations, and decisions in the risk assessment, and comprehends the supporting rationale that lead[s] to the outcome" and it speaks explicitly in terms of "full disclosure" of matters such as the approach taken, the use of models, and uncertainty.[23] Indeed, according to EPA's Science Policy Council: "Transparency is the principal value . . . because, when followed, it leads to clarity, consistency and reasonableness."[24]

Further, CERCLA mandates public participation in the remedy selection process and such participation cannot be conducted in a meaningful way where EPA is not transparent regarding the analysis supporting its conclusions and decisions. Moreover, since Region 2's actions for the FFS Study Area have been Fund financed, the NCP requires that "the lead agency shall, to the extent practicable, be sensitive to local community concerns."[25] Here, Region 2 has neglected this obligation, omitting and obscuring key assumptions that drive the outcome of the FFS and bias it toward the unjustifiable and disruptive interim remedial action.

---

[22] EPA, Office of Science Policy (December 2000) (EPA 100-B-00-002), available at http://www.epa.gov/spc/pdfs/rchandbk.pdf.

[23] *Id.* at 16. While this guidance document provides that resource constraints may also be a factor, in the context of a proposed multi-billion dollar interim remedy, the failure of the FFS to meet this goal and follow this guidance cannot be justified.

[24] *Id.* at 17.

[25] 40 C.F.R. § 300.400(c)(4).

The breakdown of transparency in the FFS process undermines the clarity, consistency, and reasonableness of Region 2's FFS and Proposed Plan. A few important examples illustrate the problem:

- **Social Costs:** The FFS does not transparently analyze the social costs of the various remedial alternatives it evaluated.[26]

- **Truck Traffic:** The FFS does not fully disclose the likelihood of substantial truck traffic associated with the upland processing facility required to implement the proposed interim remedy, which could involve as many as 100 truck trips per day, for five to ten years, through local neighborhoods, nor does it disclose the related risks to local residents.[27] The FFS's failure in this regard is surprising. In situation after situation throughout the country, communities have been outraged by the siting of upland waste disposal facilities and the attendant impacts of traffic, noise, emissions, odors and safety risks from significant new truck traffic. Siting such a facility will be difficult under any circumstances, but it will be even more so if Region 2 is perceived as not having fully disclosed the scale of this impact to affected communities. It also does not disclose the likely traffic impacts upon the areas where dredged sediments would ultimately be disposed.

- **Quality of Life:** The FFS does not fully disclose the significant quality-of-life impacts that implementation of the proposed interim remedy will impose on local residents, such as noise, odors, and strain on local infrastructure such as roads and bridges.[28] It also does not disclose the similar impacts likely in the areas where dredged sediments would ultimately be disposed.

- **Remedy Duration:** The FFS does not fully disclose the likelihood that the design and implementation of the remedy will take far longer than the FFS suggests,[29]

---

[26] Veritas Economic Consulting, *Comments on EPA's Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River* (hereinafter "Veritas"), Comment 5.

[27] This estimate assumes 4.3 million cubic yards of dredging, 50% reduction in volume from dewatering, five years of dredging with 273 days per year of production (due to fish windows and weather conditions), and 15 cubic yards of sediment per truckload. These assumptions are conservative and actual truck traffic could be much higher.

[28] Tierra Solutions, Inc., *Remedy, Engineering, and Cost-Related Comments, Lower Passaic River Focused Feasibility Study, April 2014* (hereinafter, "Tierra Solutions, Inc."), Comment 11(b).

[29] Tierra Solutions, Inc., Comment 11.

creating a higher level of risk to the environment and far greater duration of community disruption. For example, storms during dredging or capping could distribute throughout the river and into Newark Bay the currently isolated, more highly contaminated sediments exposed during construction, and the dredging work itself will inevitably resuspend contaminated sediments as well. The longer the duration of construction, the greater these risks will be.

- **Recreational Use:** The FFS does not fully disclose the significant impacts that the implementation of the proposed interim remedy could have on recreational use of the river, including long-term access restrictions, risks due to increased river traffic, and alteration of significant stretches of river bottom by armoring.[30] Nor does the FFS fully disclose that the Proposed Plan will yield essentially no improvement in the fishable, swimmable, or boatable condition of the FFS Study Area,[31] contrary to stated public perceptions during the comment period.

- **Risk Reduction/Recontamination:** The FFS, despite its extended discussion of current risk levels and risk-reduction goals, does not clearly acknowledge the significant uncertainty regarding whether and to what extent risk reduction goals will actually be achieved.[32] The FFS does not acknowledge that recontamination in and around armored areas is inevitable and will be difficult or impossible to address after the interim remedy is constructed. This is especially important because the Proposed Plan states that the results of the RI/FS for the full 17 miles may well require further action in the lower eight miles to further reduce risk and attain applicable or relevant and appropriate requirements ("ARARs").

- **Analytical Quality:** Overall, the FFS descriptions of work to be performed are often poorly crafted and ambiguous, or key information or steps are omitted, such that even subject-matter experts cannot determine what analyses were performed, what assumptions were used, and how Region 2 arrived at certain conclusions.

---

[30] Veritas, Comment 5 and Appendix B.

[31] Veritas, Comment 7.

[32] *See generally*, Dr. Charles S. Melching, Marquette University (retired), *Comments on the Passaic River Focused Feasibility Study ("FFS") and Related Documents (Uncertainty Analysis)* (hereinafter "Melching").

- **Site Definition:** The FFS and the Proposed Plan are not transparent regarding the varying and inconsistent definitions of the Site, where the LPRSA is defined as an approximately 55-square mile site in the Proposed Plan but as an approximately 110-square mile site in the FFS. The FFS Study Area size and shape also varies greatly between the FFS and Proposed Plan.[33]

- **Project Goals:** Further, the FFS and the Proposed Plan are not transparent regarding the relationship between the site and the United States Army Corps of Engineers ("USACE") "Lower Passaic River Restoration Project," the goals of which are expressly referenced in the RI Report.[34] Given the significant and unusual focus on navigation issues in the Proposed Plan, Region 2 must be transparent regarding whether and how it is attempting to use the CERCLA process to further unrelated goals, such as navigational improvements.

- **CAD Benefits:** The FFS does not fully disclose that the CAD alternative will allow for completion of the proposed interim remedy or a more implementable or cost-effective remedy much faster than the selected alternative of off-site disposal, with a lesser degree of risk and a reduced impact on local residents.[35]

Overall, public transparency is a critical area in which Region 2's processes and procedures fall short of NCP consistency and violate EPA policy and guidance. The transcripts from Region 2's Public Meetings (held on May 7, 2014, May 21, 2014, and June 23, 2014) confirm that a large portion of the public likely does not have a sufficient understanding of the Proposed Plan to allow for informed participation that would satisfy the community acceptance criterion. Further compounding these transparency issues is Region 2's emphasis on the hypothetical jobs creation aspects in its public media launch for the Proposed Plan.[36] Common areas in which there is apparent public misunderstanding resonating within the transcripts include: remediation goals, environmental impact, and community impact. Inadequate transparency, coupled with (as briefly mentioned in the Proposed Plan) a narrowly focused post-Record of Decision adaptive management plan, cannot provide a decision maker with any

---

[33] *Compare* Proposed Plan, Figure 1 *with* FFS, Figure 1-1.

[34] RI Report at 1-2 n.8.

[35] Tierra Solutions, Inc., Comment 14-16.

[36] EPA, Press Release: *EPA Proposes Plan to Remove Toxic Sediment from the Passaic River; Largest Cleanup in EPA History Will Protect People's Health and Create Jobs* (April 2014).

degree of confidence of adequate community support for the Proposed Plan. The public simply lacks sufficient information and understanding of the Proposed Plan, and Maxus and Tierra are concerned that much of the apparent public support is rooted in misunderstanding arising from Region 2's failures of transparency.

C. The FFS incorrectly screened out bioremediation and other potential in situ treatment approaches without conducting the necessary evaluation required by the NCP.

Bioremediation is a promising remedial technology likely to achieve equal or better risk reduction more quickly than the FFS alternatives, without the negative impacts of dredging. Region 2's decision to screen this in situ treatment technology from detailed consideration was based on an outdated and inaccurate understanding of this promising 21st-Century technology,[37] which has been applied by EPA at other sites.[38] This violates CERCLA's mandate that EPA investigate and make use of innovative technologies where possible.[39] EPA guidance also identifies several advantages of amendments, like carbon, which would be particularly beneficial to the FFS Study Area.[40] Region 2 should have retained in situ remedial alternatives such as bioremediation and sequestration technologies for inclusion in the remedial alternative analysis.[41] Indeed, given the universally acknowledged and significant environmental impacts

---

[37] *See generally* EPA, *A Citizen's Guide to Bioremediation* (Sept. 2012) (hereinafter "*Citizen's Guide to Bioremediation*"), available at http://www.epa.gov/tio/download/citizens/a_citizens_guide_to_bioremediation.pdf; EPA, Use of Bioremediation at Superfund Sites (September 2001), available at http://epa.gov/tio/download/remed/542r01019.pdf.

[38] *See id.* at Appendix A (setting forth selected information regarding 104 bioremediation projects at Superfund remedial action sites); *Citizen's Guide to Bioremediation* at 2 ("Bioremediation has successfully cleaned up many polluted sites and has been selected or is being used at over 100 Superfund sites across the country.").

[39] *See* 42 U.S.C. § 9660(b) (directing the Administrator to establish an alternative or innovative treatment technology research and demonstration program); 40 C.F.R. § 300.430(a)(iii)(E) ("EPA expects to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies."); EPA, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, OSWER Directive 9355.3-01 (October 1988) at 2-9 (stating that, when developing preliminary remedial action alternatives, "Innovative technologies and resource recovery options should be included if they appear feasible"), available at http://www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf.

[40] EPA, *Use of Amendments for* In Situ *Remediation at Superfund Sites*, OSWER Directive 9200.2-128FS (April 2013), available at http://www.epa.gov/superfund/health/conmedia/sediment/pdfs/In_situ_AmendmentReportandAppendix_FinalApril2013.pdf.

[41] Tierra Solutions, Inc., Comment 1.

of large-scale dredging or capping,[42] this technology should be thoroughly evaluated—including through implementation of the *Draft: Newark Bay/Lower Passaic River In Situ Bioremediation Pilot Study Work Plan*[43]—before a remedy is selected for the FFS Study Area.

D. The FFS is inconsistent with EPA's guidance for remediating sediment sites.

Region 2's FFS and Proposed Plan are demonstrably inconsistent with EPA's guidance for remediation of contaminated sediments. EPA's 2005 guidance document *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (hereinafter, "Sediment Guidance")[44] sets forth EPA policy that contaminated sediment sites should follow an "adaptive management" approach, especially in light of the substantial costs of sediment remedies and the major uncertainties that can be associated with risk, chemical fate and transport, and implementation of the remedy.[45] This guidance document outlines eleven guiding principles necessary for the successful management of sites similar to the FFS Study Area. Among these principles are to control sources early, involve the community early and often, coordinate with states, local governments, tribes, and natural resource trustees, and to use an iterative approach in a risk-based framework.[46]

Rather than following EPA policy and process, Region 2 has abandoned it: Several significant interim actions have already been performed, including both the Tierra Phase I Removal Action, which removed 40,000 cubic yards ("cy") of contaminated sediments adjacent to the former manufacturing facility at 80 Lister Avenue, and the RM 10.9 dredge/cap operations that followed, which removed an additional 16,000 cy of contaminated sediments along the Lyndhurst shoreline. The iterative management approach set forth in EPA guidance requires that Region 2 evaluate the effect of these significant interim remedial measures through data collection and analysis before deciding the next step. Region 2 has dispensed with these principles of adaptive management and proposes to prematurely select a massive sediment remedy for the FFS Study Area <u>before</u> evaluating the effect of the interim actions performed to date. Region 2's suggestion that the "adaptive management" required by EPA policy can be

---

[42] EPA, *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, OSWER Directive 9355.0-85 (December 2005) at 6-21 -23, available at http://www.epa.gov/superfund/health/conmedia/sediment/pdfs/guidance.pdf.

[43] John H. Pardue, Ph.D., on behalf of Maxus Energy Corporation (July 1, 2014).

[44] OSWER Directive 9355.0-85 (December 2005) at 6-21 -23.

[45] Sediment Guidance at 2-22.

[46] Sediment Guidance at 1-5.

implemented during the remedial design phase[47] misapplies the principles of the Sediment Guidance, which make it clear that adaptive management and iterative approaches are critical for remedy selection decisions at the feasibility study stage, not merely addressed in the remedial design.[48]

Region 2 should not implement a decision so manifestly contrary to law and EPA policy. The potential for iterative remediation of hot spots and assessment of the effect of such remediation would be consistent with EPA guidance and with the practice of many EPA Regions at other large sediment sites.[49] Region 2 should evaluate this approach further and follow the iterative management principles set forth in EPA policy.

In addition, neither Alternative 2 nor Alternative 3 will significantly improve protection of human health or the environment. Taking the FFS's analysis of residual risks—which is flawed for the many reasons described below—on its own terms, the Proposed Plan would not attain EPA's risk criteria for cancer risk, non-cancer hazard, and ecological risk.[50] The residual cancer risk would be higher than the acceptable level of $1x10^{-4}$.[51] Regarding non-cancer hazards, the Proposed Plan states that: "[T]he non-cancer health hazard for the adult would be 8 and 6 for fish and crab consumption, respectively, and for the child would be 18 and 13 for fish and crab consumption, respectively. The non-cancer health hazards would be above EPA's goal of a hazard index of one."[52] The proposed remedy will not meet ecological risk goals either. The Proposed Plan states: "Thirty years after construction, total ecological hazards for benthic invertebrates would range from 3 to 30, for fish would range from 2 to 20 and for wildlife would range from 0.8 to 30."[53] This is also far greater than the desired risk range of a hazard quotient of less than one.[54]

---

[47] Proposed Plan at 12.

[48] Sediment Guidance at 2-22.

[49] For example, EPA Region 10 recently released its proposed plan for the Lower Duwamish Waterway, which follows the approach laid out by the Sediment Guidance, as it includes truly targeted interim actions (29 acres vs. 650 acres for the LPRSA FFS), and the implementation of a significant source control strategy before proceeding to full-scale remedial action. *See* EPA Region 10, *Lower Duwamish Waterway Proposed Plan Summary* (April 2013), available at http://www.epa.gov/region10/pdf/sites/ldw/pp/duwamish_pp_sum_0413.pdf.

[50] Proposed Plan at 27-28.

[51] *Id.*

[52] Proposed Plan at 27-28.

[53] *Id.*

[54] *Id.*

There is no justification for proceeding with an interim remedy that falls short of meeting CERCLA risk goals at this time. Region 2 itself acknowledges that additional future actions would be required to meet risk goals. Rather than developing a comprehensive strategy for the LPRSA that would accomplish these goals, Region 2 instead proposes to require an interim remedy—for which Region 2 estimates that $1.7 billion will be spent—without any idea how that interim remedy actually fits into an ultimate strategy for the LPRSA and Newark Bay as a whole, because that strategy has not yet been devised or evaluated. The Proposed Plan's interim remedy would permanently foreclose targeted approaches that may well meet risk goals, with less environmental disruption and quicker and more efficient completion, if implemented on an LPRSA-wide basis, especially if done so in combination with the source control measures EPA guidance requires for sediment sites, but which Region 2 has chosen not to pursue at this time. Rushing to select the Proposed Plan as an interim remedy shortly before the full LPRSA RI/FS process is completed, which would allow consideration of these important issues, is arbitrary and capricious. Region 2 should await completion of the RI/FS, which will allow for a more thorough evaluation of risk issues and enable Region 2 to make more fully informed risk management decisions.

E. The FFS is inconsistent with EPA's guidance for interim actions.

The Proposed Plan, which is (ambiguously) described in the FFS as an interim remedy,[55] is inconsistent with EPA guidance for such remedies. Both the NCP and EPA guidance provide that interim remedies are to be limited in scope and quickly implemented.[56] An interim remedy is meant to provide quick, interim relief while the complex and sometimes lengthy RI/FS process proceeds at a pace consistent with iterative acquisition and interpretation of data to inform decision-making. Typically, interim remedies are used to prevent the spread of contamination while an area is being studied, or to remediate a threat that can be eliminated from further study.

EPA guidance includes examples of possible interim actions:

---

[55] Proposed Plan at 11.

[56] 40 C.F.R. § 300.430(a)(1)(ii)(A); EPA, Early Action and Long-Term Action Under SACM – Interim Guidance 1 (Dec. 1992).

- Installing extraction wells to pump a groundwater aquifer to restrict migration of a contaminant plume with the intention of later installing additional wells (or taking other action) to address the contamination in a final action.

- Providing a temporary alternate source of drinking water with the intention of later, in a subsequent action, remediating the source of contamination and/or the aquifer.

- Constructing a temporary cap to control or reduce exposures until a subsequent action is taken.

- Relocating contaminated material from one area of a site (e.g., residential yards) to another area of the site for temporary storage until a decision is made on how best to manage site wastes.[57]

As is evident from this list, a remedial action as complex, technically challenging, and costly as the Proposed Plan goes far beyond the remedies that EPA guidance indicates are properly implemented as an interim action. The Proposed Plan is a massive remedy for a portion of the LPRSA that is itself one of the largest contaminated sediment sites in the United States, which will take more than a decade to implement. Such a remedy should only be selected on the basis of a full RI/FS, not shoehorned into the "interim remedy" category to allow Region 2 to circumvent the NCP process and to select a remedy based on inadequate information.

F. The FFS did not properly evaluate monitored natural recovery ("MNR") and its ability to achieve risk-based goals.

As set forth in the detailed technical comments, Region 2's analysis is inadequate to demonstrate the superiority of the Proposed Plan or other active remediation alternatives to MNR. EPA policy recognizes that MNR is a viable remedial approach at sediment sites,[58] and Region 2 should implement that alternative as an interim action while the RI/FS process is completed and more robust modeling is performed to evaluate the relative benefits of more intrusive remedial alternatives as compared to MNR.

---

[57] EPA, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents 8-3*, Highlight 8-3 (July 1999), available at http://www.epa.gov/superfund/policy/remedy/rods/pdfs/guide_decision_documents_071999.pdf.

[58] Sediment Guidance at 7-3.

In fact, many sediment sites can reach targeted risk levels over time via MNR or enhanced MNR without the additional risks created by dredging and associated resuspension. The issue is not the ultimate protectiveness of MNR, but rather the relative speed of MNR as compared to more intrusive alternatives that, as here, often create risks of their own. Accordingly, EPA guidance recognizes the use of MNR as an appropriate remedial alternative for Superfund sites, especially where remediation costs are extremely high, as is also the case here. Region 2 has not evaluated whether its preferred alternative is truly cost-effective in light of the effectiveness and cost of MNR as a stand-alone remedy at the Site, especially since Region 2's conclusion as to the inadequate protectiveness of MNR is based on inadequate and unreliable modeling. Although MNR might take more time to achieve the desired results than a more active remedy, it would do so at a cost Region 2 itself concedes is "relatively low," and the level of community disruption and incremental risk of MNR are indisputably nonexistent.

Comparing the additional length of time it would take for MNR to achieve results to the substantial costs, disruption, and risk of the truly extraordinary remedial actions considered in the FFS would be the precise analysis of trade-offs that the NCP is designed to facilitate. The decision maker should balance the cost of various alternative remedies against the time it will take to achieve risk reduction goals. Because neither CERCLA nor the NCP establish hard and fast rules governing the timing to achieve remediation goals, it is important for the decision maker to weigh all the relevant factors, including how much money should be spent, how much disruption the community should endure, and how much incremental risk should be created by a remedial action in order to reduce the time it might take to achieve remediation goals. This is especially true because the data suggest that natural recovery processes in the FFS Study Area are much more effective than Region 2 acknowledges, as explained in more detail below. Ultimately, the issue that must be considered is whether it is consistent with CERCLA and the NCP and good public policy to require the expenditure of enormous resources to implement the intrusive dredging and capping remedies to achieve remediation goals if it takes "x" years, when perhaps a much less costly MNR or enhanced MNR remedy will only take "y" years longer. Region 2's failure to address these questions squarely in the FFS renders it inconsistent with the NCP.

IV. The FFS and the Proposed Plan are based on a technically flawed analysis buttressed by inaccurate, incomplete, and misleading model results to establish risk reduction goals that the proposed remedial alternatives cannot achieve.

As set forth in the FFS, several key conclusions drive Region 2's overall assessment that a bank-to-bank remedial program, such as the Proposed Plan, is needed to address contaminated sediments and will be effective in so doing. Region 2 believes that contamination is relatively uniformly distributed in the FFS Study Area sediments with no apparent spatial trend,[59] that resuspension of FFS Study Area sediments is the principal ongoing "source" of hazardous substances to the LPRSA, that this "source" both is preventing natural recovery and is much more significant than ongoing inputs of hazardous substances from elsewhere,[60] and that the proposed dredging and capping can be completed in a reasonable time frame with only modest resuspension of contaminants.[61] From these premises, Region 2 concludes that its Proposed Plan will substantially reduce risk associated with FFS Study Area sediments.

Each of these premises is incorrect. Spatial trends in the data support the potential value—and, indeed, superiority—of targeted approaches, and the data also demonstrate that natural recovery is occurring. Region 2's erroneous analysis of these issues undermine the Proposed Plan in its entirety. Remedial decisions cannot and should not rest on analysis that is demonstrably inconsistent with the existing data. Further, FFS Study Area sediments are not the only significant source of hazardous substances to the LPRSA, and Region 2's decision to ignore external sources condemns to failure its analysis and proposed interim remedy. Any capped or dredged surface will quickly be recontaminated. The modeling Region 2 relied on is not reliable for many reasons and cannot serve as the basis to conclude that the interim remedy set forth in the Proposed Plan will be effective in reducing risk. Accordingly, Region 2 should not select a remedy at this time. The ongoing RI/FS process for the full LPRSA, soon to be completed, should add to Region 2's understanding of the River. Region 2 should complete this process before selecting a remedy.

---

[59] *See* FFS at 1-12-1-18 (describing the lateral and vertical extent of sediment contamination within the FFS Study Area).

[60] *See, e.g.,* FFS at 3-15-3-16 ("[T]he FFS Study Area is the major source of contaminants to the river above RM8.3 and to Newark Bay; so remediation of the FFS Study Area would reduce the major source of contamination to those areas, thereby reducing the contamination brought back into the FFS Study Area from those areas over time, resulting in MNR being a more effective mechanism for reducing risk under the active remedial alternatives.").

[61] FFS at 4-38, 4-41.

A. The FFS is based on a flawed conceptual model and a fundamental misunderstanding of LPRSA hydrodynamics, sediment dynamics, and hydrology.

It is apparent from the FFS that Region 2's conceptual model of the LPRSA is flawed and does not accurately reflect relevant riverine processes. Region 2 erroneously determined that uniform, large-scale scour is the major source of contemporary movement of LPRSA sediments and embarked on an approach to modeling that excluded or cannot represent other relevant mechanisms.[62] Region 2 underestimated the likelihood of extreme hydrological events (e.g., the 100-year storm event),[63] made an inaccurate evaluation of circulation and sediment transport processes,[64] and inaccurately assumed that the LPRSA is approaching equilibrium conditions.[65] Region 2 also neglected the likelihood of future sea level rise,[66] the increasing risk of storm surge,[67] and misevaluated the effect that the Estuarine Turbidity Maximum ("ETM") has on sediment and chemical fate and transport processes.[68] Further, Region 2 did not analyze the distribution of turbidity around the ETM, and it did not consider the possibility that contaminants can accumulate in local traps driven by particular features anywhere within this area of elevated turbidity.[69]

As an example, Region 2's analysis of LPRSA hydrology misinterprets the available data, seriously underestimating the frequency and scale of large storm and flood events.[70] The practical implication of this is underestimation of the risks of cap erosion or a catastrophic redistribution of contaminated sediment during dredging.[71] Region 2 runs the substantial risk of creating a problem that may not, at this time, exist. Such a misstep cannot be undone. Region 2 has neither explained nor fully considered the risks attendant upon the large-scale remedial alternatives evaluated in the FFS.

---

[62] Dr. David A. Jay and Dr. Stefan A. Talke, Portland State University, *Key Lower Passaic River Focused Feasibility Study Issues and Uncertainties* (hereinafter, "Jay/Talke"), Comment 1.2(n).

[63] Jay/Talke, Comment 1.8(a) and Appendix B.

[64] Jay/Talke, Comment 1.2(k) and 1.4; Dr. James L. Best and Dr. Marcelo H. García, University of Illinois, *Lower Passaic River: Analysis and Issues* (hereinafter, Best and García), General Comment 11.

[65] Jay/Talke, Comment 1.2(c).

[66] Jay/Talke, Comment 1.2(l)(i).

[67] Jay/Talke, Comment 1.2(l)(ii) and Appendix B.

[68] Jay/Talke, Comment 1.4.

[69] Jay/Talke, Comment 1.4(d).

[70] Jay/Talke, Comment 1.6 and Appendix B.

[71] Jay/Talke, Comment 1.6(h).

The collective effect of these and similar errors is to premise the Proposed Plan on an inaccurate understanding of how environmental processes in the LPRSA actually work, undermining Region 2's technical justification for the Proposed Plan and greatly increasing the risk of remedy failure or the worsening of environmental conditions as a result of remedial action. Region 2 must correct these errors and develop and convey a technically accurate understanding and transparent explanation of these complex issues before selecting a remedy for the FFS Study Area. Considering the results of the RI/FS process is a necessary prerequisite to selection of a responsible and effective remedial action for the FFS Study Area.

B. The FFS provides a flawed analysis of spatial trends and natural recovery that is inconsistent with existing data.

The core assumption underlying Region 2's conclusion that bank-to-bank remedial action is needed in the FFS Study Area is its belief that the entire FFS Study Area is uniformly contaminated and that ongoing resuspension of legacy sediments is preventing natural recovery. These erroneous assumptions form the basis of Region 2's conclusion that monitored natural recovery is not protective and that targeted remediation is insufficiently protective.[72] Both of these conclusions are demonstrably incorrect as shown by available data. As a result, Region 2's proposed alternative cannot be justified.

First, the data demonstrate the existence of readily identifiable hot spots of contamination in the lower eight miles. For example, a spatial analysis derived from the data for many of the principal COCs demonstrates the existence of discrete areas of elevated contamination that could be addressed through targeted remedial action,[73] as has been done in other portions of the LPRSA and numerous sites across the country. Region 2 itself has acknowledged the wide variation of contamination in the lower eight miles, stating, for instance, that 2,3,7,8-tetrachlorodibenzo-*p*-dioxin ("TCDD") concentrations can vary over four orders of magnitude within a single river mile.[74] The spatial distribution of other COCs, including PCBs, PAHs, and metals, is similar.[75] Thus, Region 2's uniform-contamination-requiring-bank-to-bank-remediation hypothesis is contradicted by the data and Region 2's own assessment of the data.

---

[72] FFS at 2-15-2-16, 3-15-3-16.
[73] The Intelligence Group, *Source-Related and Sediment Chemistry Trends* (hereinafter "TIG") at 5-6.
[74] RI Report at 4-3.
[75] RI Report at 4-10 (PCBs), 4-16 (PAHs), 4-17 (metals).

Region 2 should revisit this hypothesis and consider a broader suite of potential targeted remedies that could achieve risk reductions more quickly and with less risk than the one-size-fits-all bank-to-bank approach it proposes.

Second, and perhaps more importantly, Region 2's conclusion that natural recovery is not occurring in the FFS Study Area rests on a number of indefensible errors. When those errors are corrected, the data demonstrate ongoing recovery and support monitored natural recovery as a meaningful remedial option.[76] Indeed, MNR is likely to be the preferable alternative once the impacts of dredging and the uncertainties associated with the success of dredging or capping are fully taken into account.

The most straightforward illustration of Region 2's errors in this regard is the inclusion of the Cooperating Parties Group's ("CPG's") 2012 Low Resolution Coring ("LRC") Supplemental Coring Program in the assessment of contaminant trends in the LPRSA.[77] That data set is intentionally targeted on known or suspected areas of elevated contamination and is therefore not spatially representative.[78] The CPG's LRC data cannot, therefore, properly be used in the analysis that Region 2 conducted. When this error is corrected, the data demonstrate an ongoing decline in the levels of contamination in the LPRSA and the efficacy of ongoing natural recovery processes.[79] This baseline of ongoing decline also reduces the relative benefit of the more intrusive remedial measures favored by Region 2, and Region 2's comparison of the various alternatives must incorporate this reality before selecting a remedy for the FFS Study Area. At a minimum, before Region 2 requires implementation of a decade-long, multi-billion-dollar remedy on the basis of its hypothesis of "no natural recovery"—a hypothesis that is inconsistent with its EMB report, which assumes reduction in TCDD and PCB concentrations by a factor of 2 every 25-26 years[80]—Region 2 should collect a spatially-representative data set to confirm whether or not its view is correct.

The erroneous use of the LRC data is only one example of defects in Region 2's analysis, which often uses irrelevant data in ways that have substantial consequences for the

---

[76] ARCADIS, *Comments on the Passaic River FFS Reports (April 2014) Regarding Ecological Risk and Preliminary Remediation Goals* (hereinafter, "ARCADIS"), Attachment 1, *Evaluation of Historical Data and Trends and Development of a Bioaccumulation Tool for Lower Passaic River Study Area (LPRSA)*.

[77] ARCADIS, General Comment 2.

[78] ARCADIS, General Comment 2.

[79] ARCADIS, General Comment 2.

[80] FFS, Appendix C, Table 5.2.

outcome. For example, Region 2 incorporated into the bioaccumulation modeling/analysis data from Jamaica Bay, a totally unrelated waterbody, which had the effect of driving PRGs to levels several times lower than justified by the use of LPRSA data alone.[81] Similar errors exist in Region 2's analysis of LPRSA fish and crab tissue data,[82] and in its reliance on arbitrarily-adjusted TCDD data.[83] Region 2 chose to arbitrarily adjust the TCDD data to show increased concentrations—on a basis that is not justified as a technical matter and which is inconsistent with what Region 2 did for every other COC being studied in the LPRSA—thereby masking this ongoing decline in TCDD concentrations.[84] This adjustment of the data had significant consequences on both the risk assessment and the analysis of contaminant trends related to TCDD that formed a basis for the remedy selection decision.[85] Region 2's reliance on arbitrarily altered data to perform important aspects of the analysis in support of the Proposed Plan is itself sufficient to demonstrate the arbitrary and capricious nature of the FFS. At minimum, additional data collection is needed to resolve the question of temporal decline in TCDD concentrations due to this controversial data adjustment.

These issues are not merely data gaps or minor errors: they call into question the fundamental premises upon which Region 2 relies to select its preferred alternative from among the many other potential approaches, and if Region 2's analysis of these issues is incorrect—as it is—the entire FFS remedy selection process is arbitrary and capricious, especially because near-term further data collection would correct these errors.[86]

C. The FFS neglects the magnitude of ongoing sources of contaminants, basing the proposed remedy on an inaccurate analysis of environmental conditions in the FFS Study Area.

Region 2's focus on contaminated sediments in the lower eight miles of the LPRSA circumvents EPA policy regarding contaminated sediment sites, which sensibly calls for source control <u>before</u> remedial action,[87] and neglects the many ongoing sources of hazardous

---

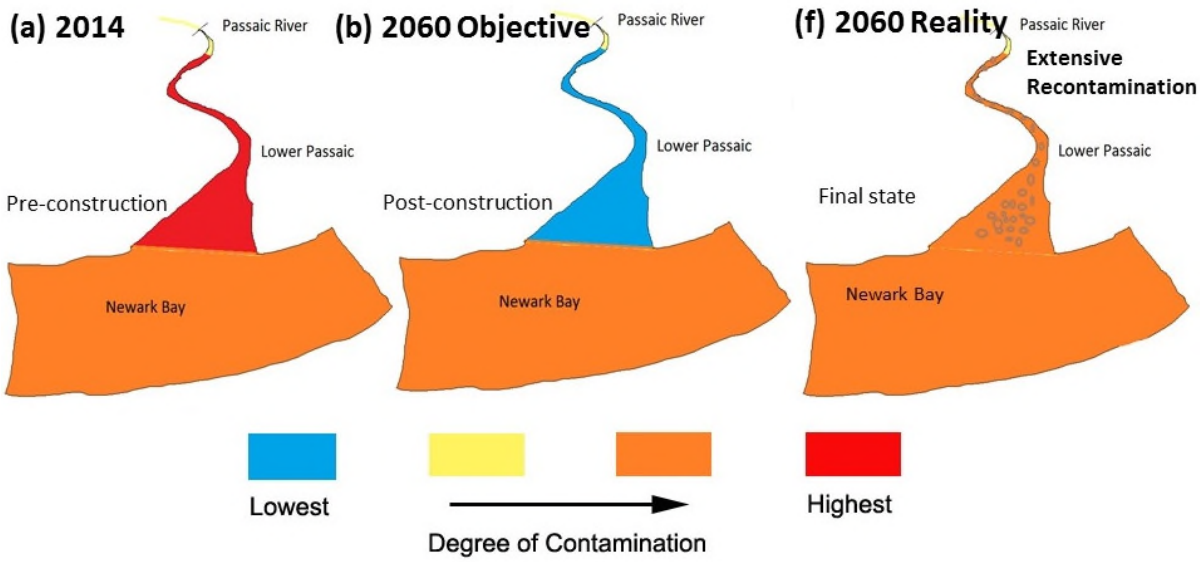
[81] ARCADIS, General Comment 3, Specific Comment A4.
[82] *See, e.g.,* ARCADIS, Specific Comment A3.
[83] ARCADIS, General Comment 2.
[84] ARCADIS, General Comment 2.
[85] ARCADIS, General Comment 2.
[86] ARCADIS, Attachment 2, *Conceptual Fish and Crab Sampling Plan for Lower Passaic River Study Area*.
[87] Sediment Guidance at 1-5.

substances that provide a more plausible explanation for the current levels of contamination in surface sediment.[88] These ongoing sources ensure that any dredging or capping program will fail to meet risk reduction goals. Region 2's toleration of data gaps regarding these ongoing sources means that a definitive assessment of those sources cannot be provided. Even so, what is known about these sources demonstrates Region 2's neglect of source control and the likely failure of a capping or dredging remedy due to recontamination. These sources should be characterized and controlled before a bank-to-bank remedial action, particularly one as intrusive as dredging, is implemented, both as called for in EPA guidance and as a matter of common sense.

The LPRSA is a tidally-influenced river that will likely be impacted by movement of contaminated sediments both from downstream Newark Bay and from the not-fully-remediated upstream portions of the river outside the FFS Study Area (RM 8-16 as well as from above Dundee Dam), as well as from the tributaries.[89] There will also be ongoing surface water discharges containing hazardous substances, as well as ongoing migration from unremediated upland sites, including a number of Superfund sites, many of which have not been remediated or even characterized. A few examples suffice to illustrate the point. Upstream of the FFS Study Area, surface water inputs from above Dundee Dam provide an ongoing source of PAHs, pesticides, PCBs, mercury, lead, chromium, and copper.[90] Downstream in Newark Bay, contaminated sediments will also enter and contaminate the FFS Study Area due to known tidal processes.[91] Indeed, the proposed deepening of the Lower Passaic River navigation channel would exacerbate the flux of contaminated sediments from Newark Bay into the FFS Study Area.[92] This dynamic is depicted in the figure below:[93]

---

[88] TIG, General Comment 1.
[89] Jay/Talke, Comment 1.5(b); Best and García, General Comment 12.
[90] TIG, General Comment 2.
[91] Jay/Talke, Comment 1.5(b); Best and García, General Comment 12.
[92] TIG, General Comment 2.
[93] Jay/Talke, Figure 16. The version presented in this document provides excerpts from the more detailed figure in the report.



Schematic view of the results of dredging and capping in the LPR. **Because Newark Bay is contaminated and there is considerable upstream transport from Newark Bay, contamination will return to the LPR from downstream sources, regardless of which of the active alternatives is chosen (Alternatives 2-4). The deeper the final channel depth, the stronger the upstream transport of contaminants is likely to be.**

While the tributaries and upland sources are largely not understood due to their having been neglected by Region 2 in the FFS analysis, currently-available information demonstrates their substantial contaminant load to the FFS Study Area.[94] Finally, contaminants will continue to enter the Lower Passaic River from high-volume Combined Sewer Overflow ("CSO") and Storm Water Outfall ("SWO") discharges, which have not yet been adequately characterized.[95]

There are also upstream areas of contaminated sediments with levels of TCDD likely to make them ongoing sources to the lower eight miles,[96] <u>especially</u> if Region 2's legacy-sediments-as-source hypothesis is correct.[97] For example, the data demonstrate that there is a

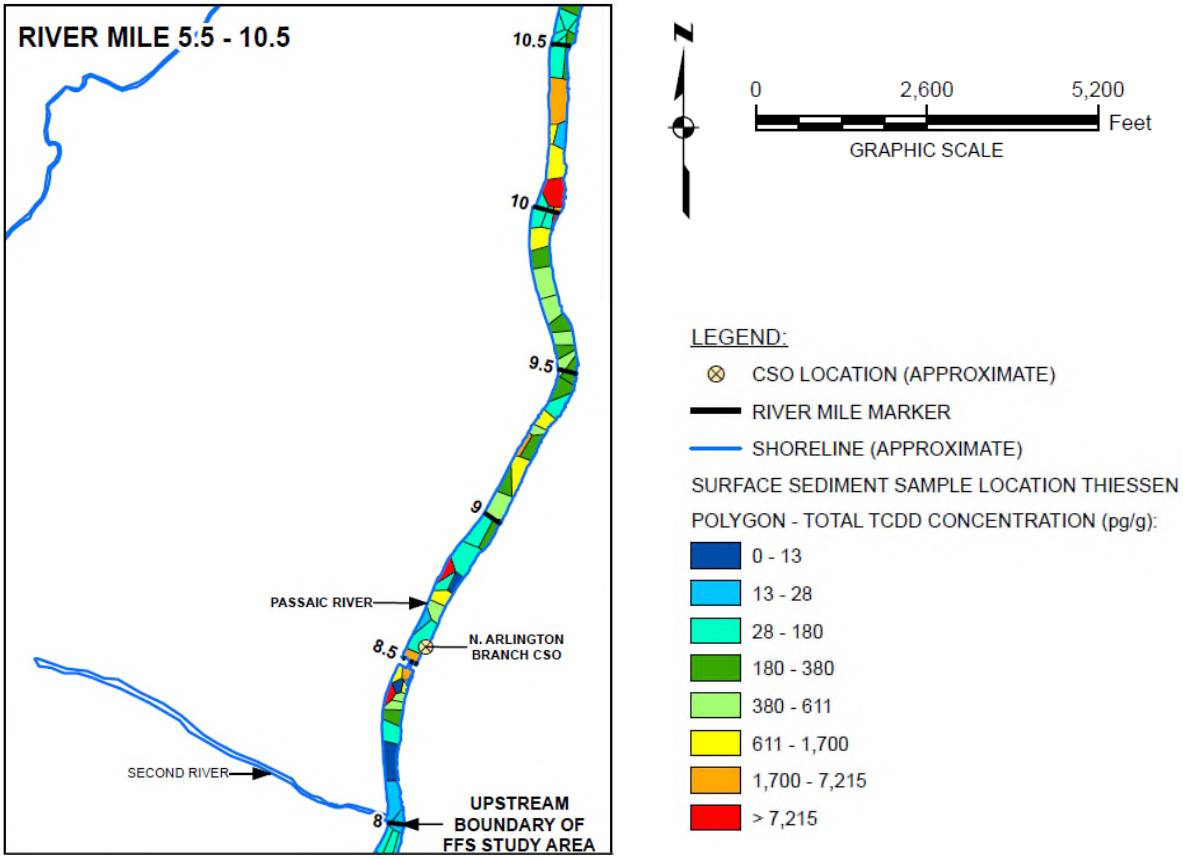
[94] TIG, General Comment 2.

[95] *Id.*

[96] *Id.*

[97] *See, e.g.,* FFS at 3-15-3-16 ("[T]he FFS Study Area is the major source of contaminants to the river above RM8.3 and to Newark Bay; so remediation of the FFS Study Area would reduce the major source of contamination to those areas, thereby reducing the contamination brought back into the FFS Study Area from those areas over time . . . .").

significant area of elevated TCDD concentrations in LPRSA sediments outside of the FFS Study Area, as shown in the following figure:[98]



Indeed, there are likely significant and uncontrolled sources of TCDD in the upper nine miles of the LPRSA that will, via known sediment transport processes, recontaminate the FFS Study Area.[99] Some of these potential dioxin sources, such as a former manufacturing plant in the vicinity of RM 10.9, remain under investigation by Region 2,[100] as set forth in *Quality Assurance Project Plan, Givaudan: Transport Pathway to Passaic River, Clifton, NJ*.[101] At a minimum, no interim remedy should be implemented for the FFS Study Area until this source, and other potential additional sources, are characterized and controlled.

---

[98] TIG, Figure 2-D (excerpt).
[99] TIG, General Comment 2.a.
[100] *Id.*
[101] EPA/Lockheed Martin (November 2013).

All told, the future recontamination of capped or dredged areas with the entire suite of COCs driving the proposed remedy is inevitable.[102] It will happen, and when it does, the claimed risk reduction benefits of the proposed interim remedy simply will prove false, confidence in Region 2's decision making will be gravely undermined, and the private resources available to participate in remedial actions in the LPRSA will be exhausted implementing an interim remedy that has no real benefit.

D. The FFS modeling does not demonstrate either the need for or the likely benefit of the proposed remedial action.

Region 2's efforts to model current and future environmental conditions in the FFS Study Area do not demonstrate either the need for, or the benefits of, the proposed massive remedial action. Region 2's modeling is based on inadequate environmental data,[103] utilizes outdated models and techniques,[104] incorporates baseless assumptions,[105] propagates a cascade of uncertainties that are incorrectly evaluated to the extent that they are evaluated at all,[106] and ignores a considerable amount of site-specific water level data,[107] and sediment concentration and load data,[108] rendering it inadequate to demonstrate any future benefit from the proposed remedial action. Additionally, the coarseness of the grid resolution used in Region 2's modeling,[109] which blurs localized differentiation, made it impossible for Region 2 to accurately evaluate the targeted remedy[110] that it nevertheless arbitrarily rejected—a less disruptive and more quickly implemented remedy that must be thoroughly considered before selecting a remedy for the FFS Study Area.[111] Region 2's modeling demonstrates only the great uncertainty surrounding all of the proposed remedial options. Region 2 is overly optimistic regarding the prospects for success and, until the uncertainty is more fully analyzed, there is <u>no</u>

---

[102]Best and García, General Comment 12.
[103]Jay/Talke, Comment 1.3.
[104]Jay/Talke, Comment 1.3; Best and García, General Comment 2, 3.
[105]Jay/Talke, Comment 1.3.
[106]Jay/Talke, Comment 1.3, 2.4, and 2.5; Melching, Comment 4.
[107]Jay/Talke, Table 2.
[108]Jay/Talke, Appendix A.
[109]Best and García, General Comment 1.
[110]Jay/Talke, Comment 1.2(g)(2).
[111]Sediment Guidance at 7-3, 7-4.

basis for Region 2 to conclude that its proposed alternative is demonstrably better than any other from a risk reduction perspective.[112]

Modeling is a complex discipline. To simplify, Region 2's FFS modeling begins with uncertain hydrologic boundary conditions that drive the hydrodynamic model; hydrodynamic model results combined with sediment load boundary conditions are then input into the sediment transport model, and sediment transport model results then drive the chemical fate and transport model. These highly uncertain results are then used in human health impact evaluations. In other words, this chain of models is used by Region 2 to evaluate remedy performance. The FFS also made use of a mass balance model and a number of regression models for bioaccumulation. The accuracy of each link in this chain is essential to Region 2's ultimate conclusion that the Proposed Plan is needed and will achieve risk reduction. Unfortunately, each and every one of these linked models is flawed—with each flaw multiplied in a subsequent model—to the point where the modeling exercise as a whole generates no useful information regarding the need for, and the prospect for success of, any of the remedial alternatives considered in the FFS. Indeed, Region 2's models provided inconsistent results regarding the likely performance of remedial alternatives.[113] The results of EPA's modeling also show both implausibly high residual contaminants in sediment and limited acceleration of the attainment of remediation targets by the Proposed Plan as compared to MNR.[114]

To provide a few examples, both suites of models used by Region 2 are incomplete and inadequate, due to deficiencies such as the failure to calibrate those models for past conditions, failure to perform a mass balance diagnostic analysis, exclusion of important physical processes, and use of unrealistic sediment and contaminant loadings.[115] Further, the chemical fate and transport model excluded important COCs, such as PAHs, and the sensitivity analysis that was performed was limited to an inadequate number of COCs.[116] Adequate data have not been collected to reasonably support hydrodynamic, sediment transport, and contaminant transport modeling.[117] Despite the fact that the FFS Study Area is a generally data-poor

---

[112]Jay/Talke, Comment 2.5 ("A night in which all cows are black.").

[113]Jay/Talke, Comment 1.3(n), 2.7(a).

[114]Exponent, Inc., *Comments on Organic Carbon and Chemical Fate & Transport Models in EPA's FFS Report for the Lower Eight Miles of the Passaic River* (hereinafter "Exponent"), Comments 17-18.

[115]Exponent, Comments 1-6; Melching, Comment 5.

[116]Exponent, Comments 10-11.

[117]Jay/Talke, Comment 1.3(h)(i), 2.4(a), 2.5(a); Melching, Comment 17.4.

environment, important existing and available data sets have not been used, and no justification for this failure to use existing data has been provided.[118] These errors ensure that the models are insufficient to demonstrate protectiveness.

Key model inputs such as the input of sediment from the Passaic River and its tributaries that demonstrably affect model predictions are so uncertain that the FFS models have little, if any, predictive reliability.[119] The hydrodynamic and sediment transport numeric models provide insufficient grid resolution to evaluate the flow and sedimentation patterns that drive the transport of sediment in the FFS Study Area.[120]Startlingly, the hydrodynamic model ECOM and sediment transport model ECOMSED are not fully coupled.[121] Thus, as the modeled flows erode the sediment surface in the sediment transport model, there is no attendant feedback to the hydrodynamic model so the new flows can be modified based on the changed bathymetry. While running such coupled models can be challenging, for a project of this size and potential environmental impact, such fundamental approximations are unacceptable. Further, the modeled predictions are poor compared to existing bathymetry, demonstrating that the model is not reliably replicating important processes in the FFS Study Area.[122] The boundary conditions used in the hydrodynamic and sediment transport models are poorly represented and inadequate, essentially giving no reliable COC flux into the LPRSA.[123] Major environmental factors like sea level rise and the impact of wind-generated waves were neglected.[124] Anthropogenic impacts like propwash and resuspension of sediment during and after project construction have not been considered.[125] Indeed, a single one of Region 2's errors—its apparent use of an erroneous sediment loading curve for the Saddle River, which overstated sediment loading by more than an order of magnitude in certain conditions and which was then also applied to other tributaries—is sufficient to demonstrate the unreliability of Region 2's modeling exercise.[126]

---

[118]Jay/Talke, Comment 2.3(b).

[119]Jay/Talke, Comment 2.5 (b),(c),(d) and Appendix A; Best and García, General Comment 13; Melching, Comment 5, 6, 11, 16.

[120]Best and García, General Comment 1; Jay/Talke. Comment 2.4(c), (d), (e), and 2.5(g), (h).

[121]Best and García, General Comment 2.

[122]Best and García, General Comment 5.

[123]Best and García, General Comment 13.

[124]Jay/Talke, Comment 1.2(c),(i), (j).

[125]Jay/Talke, Comment 1.3(m)(iii); Best and García, General Comment 6.

[126]Jay/Talke, Comment 1.3(h), 2.5(c), Appendix A at A-81.

Importantly, the adverse effects of extreme events during construction have been ignored, leaving significant open questions regarding the magnitude of the risks presented to the environment should a major storm occur during construction, when much more contaminated sediment currently isolated from the environment will be exposed. The 100-year flood and 100-year storm surge have been significantly underestimated separately, and completely ignored when combined, which undermines the evaluation of the remedial alternatives and the success of the cap design.[127] Long-term trends and climate variability suggest that future risk may be underestimated in the FFS. The return intervals of flood events must be quantified as accurately as possible, since this determines the occurrence of large-magnitude events and their associated sediment transport, deposition and scour. Since sediment transport varies non-linearly as a function of the applied bed shear stress, extreme events can have an inordinate influence on sediment transport in a strongly non-stationary system like the Lower Passaic River.[128] Yet, in the RI report and the FFS the magnitude of both the 100 and 500 year flood have been considerably underestimated,[129] with the 100-year event in the Lower Passaic River likely being 20% larger than that estimated in the FFS.[130] The magnitude and impact of Hurricanes Irene and Sandy show that many aspects of the FFS analysis are incorrect because extreme event risks are underestimated.[131]

Leaving aside these substantive errors, the modeling performed by Region 2 deviates from accepted standards. Surprisingly for modeling in support of such a significant decision, the results of Region 2's models are compared to non-standard and lenient performance and accuracy criteria, ignoring currently-accepted modeling practices, to demonstrate "acceptable" results.[132] This leniency is tacit acknowledgement that the FFS modeling cannot attain the level of accuracy essential to similar modeling applications, such as the Hudson River, where the sediment transport model predictions were compared with the 95% confidence interval of the mean of the data, or the Housatonic River, which used a calibration target of predictions being within ± 30 % of the data.[133]

---

[127] Jay/Talke, Comments 1.6, 2.9, and Appendix B.
[128] Jay/Talke, Comment 1.2(f), 1.6(d).
[129] Jay/Talke, Comment 1.6(a) and Appendix B.
[130] Jay/Talke, Comment 1.6(a) and Appendix B.
[131] Jay/Talke, Comment 1.6 and Appendix B.
[132] Melching, Comment 1.
[133] Melching, Comment 1.5, 1.6.

Additionally, Region 2 was required, but failed, to develop a Quality Assurance Project Plan ("QAPP") pursuant to the Uniform Federal Policy for Quality Assurance Project Plans ("UFP-QAPP").[134] This is required by Region 2's own guidance for "fund-lead and responsible party lead environmental investigations for CERCLA, RCRA and Brownfields projects in Region 2."[135] Such a QAPP is not merely a paperwork exercise. In the case of the FFS Study Area, it is clear that not developing a QAPP pursuant to the UFP-QAPP requirements contributed to the many deficiencies and deviations from standard practices embedded in Region 2's modeling, for instance in its calibration of those models to arbitrary standards developed after the fact.

Ultimately, Region 2's remedy decisions are founded on unproven and indefensible models that are not reliable. Selecting a multi-billion dollar remedy on the basis of modeling of such questionable reliability would be arbitrary and capricious.

This is not a new problem for the LPRSA. In negotiation of the 1994 AOC, modeling was the subject of considerable discussion, and Region 2 selected the sediment transport model Tierra was required to use for the Six-Mile Study Area RI/FS. Having dedicated significant funds and effort to modeling, in October of 2000 Tierra advised Region 2 that it had identified technical problems that rendered the Region's selected model useless. Thereafter, by letter dated in January of 2001, Region 2 directed Tierra to cease work on modeling until further notice, which was never given. Region 2 has yet to solve the problems that made the modeling of the LPRSA intractable in the late 1990s, and proceeding with a remedy selection that so critically depends on unreliable models—the only basis Region 2 has to support its view that the proposed interim remedy will reduce risk rather than increase it—would be arbitrary and capricious.

---

[134] Intergovernmental Data Quality Task Force, *Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual* (Mar. 2005), available at http://www2.epa.gov/sites/production/files/documents/ufp_qapp_v1_0305.pdf.

[135] Region 2, *Quality Management Plan* (April 14, 2011), http://www.epa.gov/region2/science/qmp/qmp.html.

E. The FFS fails to thoroughly evaluate uncertainty, which makes the likely consequences of the remedy unknown and prevents decision makers from meaningfully evaluating the projected performance or the risks associated with remedial alternatives.

The unreasonableness of EPA's approach to modeling is further demonstrated by its minimal uncertainty analysis. Because Region 2 engaged in insufficient analysis of uncertainty, selection of a remedy on the basis of the current analysis is essentially flying blind, with no reason to believe that the proposed alternative is better than any of the other alternatives or better than no action at all. Proceeding with a remedy selection absent a rigorous uncertainty analysis would be arbitrary and capricious.

The FFS modeling bases predictions on a sequence of chained models, each of which has major flaws.[136] As outputs of one model—which themselves have some inherent uncertainty due to a model's inability to fully capture all real-world conditions—become inputs to a subsequent model, the uncertainty surrounding the modeling results necessarily increases.[137]That is, uncertainties in hydrodynamic boundary conditions and the results of a hydrodynamic model will create additional uncertainty in the results of a sediment transport model to which they are necessary inputs. Similar amplifications in uncertainty will occur in each subsequent modeling analysis that is conducted to evaluate potential remedies. Substandard uncertainty and sensitivity analyses were carried out at each modeling step, without recognition that input data have uncertainty and bias.[138] The propagation of errors from one modeling step to the next was neither recognized nor analyzed.[139]

Moreover, the modeling approach did not use, as it should have, a properly calibrated watershed model to estimate unmeasured tributary inputs of water and sediment, leading to unnecessarily high uncertainty (and possible bias) in model boundary conditions for the circulation, sediment transport, and chemical fate and transport models.[140] All told, the compounded errors of the circulation, sediment transport, and chemical fate and transport models are significant. Thus, when these flawed models are used to evaluate the performance

---

[136]*See, e.g.,* Jay/Talke, Comment 1.3.
[137]Jay/Talke, Comment 1.3; Melching, Comment 4.
[138]Jay/Talke, Comment 1.3, 2.3-2.6; Melching, Comment 4.
[139]Jay/Talke, Comment 1.3; Melching, Comment 5.
[140]Jay/Talke, Comment 2.5(d); Melching, Comment 4.

of remedial alternatives to achieve a risk reduction that is based on another series of flawed models (bioaccumulation, mass balance, organic carbon), the resulting uncertainty makes this modeling analysis irrelevant and inadequate to support a remedy selection decision. The combined errors of the modeling system mean that, evaluated correctly, the results of the remedial alternatives considered in the FFS likely have overlapping uncertainty ranges—i.e., their performance cannot be reliably distinguished one from another.[141]

Rather than evaluate this issue in a rigorous way—which would allow decision makers, local governments, other stakeholders, and the public to understand that the basis for the Proposed Plan and its probable consequences are largely unknown—Region 2 claimed that such an analysis of uncertainty was too computationally intensive to be performed.[142] This is unacceptable—as explained in the detailed comments, there are many techniques that can reasonably be performed to understand this issue,[143] and uncertainty should be analyzed before selecting a remedy where so little is known about the future consequences. By not performing such an analysis, Region 2 is not performing its statutory functions in selecting a remedy and is acting inconsistently with the NCP. This is especially so given the significant environmental consequences and costs that are associated with the Proposed Plan. Because of the complexity of the FFS Study Area, and the high stakes of remedial action, it would be arbitrary and capricious for Region 2 to select and implement a remedy without further analysis of these important issues, so that decision makers have some real sense of the bounds of uncertainty surrounding the decision under consideration.

Indeed, after accounting for the uncertainty, there may be no technical basis to support Region 2's claim of meaningful risk reduction from the Proposed Plan as compared to current conditions or to other alternatives, including monitored natural recovery or targeted remedial action. There is no reason to believe that the Proposed Plan would reduce rather than increase risk or that it is any better than less-intrusive, more-implementable, and more cost-effective remedies improperly rejected or screened out by the FFS. It is manifestly inconsistent with the NCP, arbitrary, and capricious for Region 2 to select a remedy that its own analysis, properly understood, determines to be equally protective as other options that are indisputably superior in terms of cost-effectiveness and implementability. Nor can Region 2 demonstrate the superior

---

[141]Jay/Talke, Comment 2.6(j), (l).
[142]FFS at Appendix C, Fate and Transport 4.5.
[143]Jay/Talke, Comment 1.3 (a), (b); Melching, Comment 4, 5.

protectiveness of the Proposed Plan as compared to the other alternatives. Indeed, as explained elsewhere in these comments, the proposed alternative may well be less protective than MNR or targeted remedies.

F. Resuspension of dredged materials and sediments from unremediated portions of the LPRSA and Newark Bay will recontaminate capped areas.

A compelling example of the deficiencies in EPA's approach is the failure to correctly evaluate the potential extent of recontamination of capped areas by the dredging itself. Region 2's plan is for highly contaminated sediments deep below the surface to be dredged in certain areas. For example, some of the highly contaminated sediments in areas to be subject to navigational dredging under the Proposed Plan are currently isolated from the environment by many feet of cleaner sediment. An unavoidable consequence of the dredging process is the release and resuspension of this material into the water column, where it will migrate both upstream and downstream and settle on remediated areas, as well as areas upstream and downstream of the lower eight miles.[144] The release and resuspension of contaminants will be exacerbated by other aspects of the dredging work, such as propwash and anchoring, and, as noted above, capped areas will also be affected by COCs from unremediated areas.

Indeed, EPA's own National Remedy Review Board and Contaminated Sediments Technical Advisory Group reached the same conclusion, commenting that "…recontamination could prevent the attainment and maintenance of 5 ppt [changed to 7 ppt with no difference in the conclusion] of dioxin in sediment over time; potential sources of recontamination include, but are not limited to, resuspension caused by the cleanup itself and transport from the yet-to-be remediated parts of the LPR and Newark Bay."[145]These conclusions were provided to Region 2 in compliance with EPA's National Remedy Review Board guidance.[146] The NRRB's comments must be considered prior to the issuance of the FFS and Proposed Plan. Rather than meaningfully engaging with the NRRB's comments, Region 2's dismissive response to these

---

[144]Tierra Solutions, Inc., Comment 11; Best and García, General Comment 12.

[145]EPA, *National Remedy Review Board and Contaminated Sediments Technical Advisory Group Recommendations for the Diamond Alkali Superfund Site, Lower Eight Miles of the Lower Passaic River (Focused Feasibility Study Area)* (April 11, 2014) at 6.

[146]"The Board is a technical and policy review group made up of members that have experience with both regional and Headquarters perspectives in the Superfund remedy selection process. Its members include senior managers and technical experts from each EPA region, as well as senior technical and policy experts from other EPA offices," which reviews proposed Superfund cleanup decisions to "assure they are consistent with Superfund law, regulations, and guidance." http://www.epa.gov/oerrpage/superfund/programs/nrrb/faqs.htm.

comments merely reasserted its faith in its modelling approach[147]—a modeling approach that wider scrutiny now reveals to be fundamentally unreliable.

The risk associated with resuspension of contamination is even greater than Region 2 acknowledges in the FFS. The dredging and capping program in the Proposed Plan will take far longer to construct than Region 2 predicts.[148] During this time, there will be an increased risk that more highly contaminated, currently isolated sediments will be spread throughout the Lower Passaic River, due in large part to Region 2's underestimation of the frequency and magnitude of extreme storm and flood events, as well as the proposed deepening of the navigation channel. Region 2's modeling of the construction period did not simulate extreme surges or floods during the construction period,[149] which means that if Region 2 selects and implements the Proposed Plan based on the FFS analysis, it will have no understanding of the potential consequences of this inherent risk from its preferred remedy.

V. The FFS overstates the current and future risks and hazards associated with Lower Passaic River sediments; when the risks and hazards are correctly calculated, there is no justification for a bank-to-bank remediation program to address the contaminants of concern evaluated in the FFS.

While Region 2 claims there is substantially elevated risk and hazard requiring an early or interim action, this conclusion is based on an inaccurate evaluation of risk and hazard that disregards important site-specific data. When these errors are corrected, the risk presented by the FFS Study Area sediments, based on the available data, already meets the goals that Region 2 is attempting to achieve with the Proposed Plan for the COCs evaluated in the FFS. There is thus no legitimate basis to move forward with a remedy at this time, particularly when the RI/FS process will soon be completed for the entire LPRSA. Utilizing the RI/FS process, as intended, will allow a more thorough and objective consideration of risk and hazard than presented in Region 2's FFS and allow the LPRSA to be evaluated as a whole for potential remedial action.

---

[147]EPA Region 2, *Responses to National Remedy Review Board and Contaminated Sediments Technical Advisory Group Recommendations for the Lower Eight Miles of the Lower Passaic River, part of the Diamond Alkali Superfund Site in Newark, New Jersey* (April 11, 2014) at 18.

[148]Tierra Solutions, Inc., Comment 11.

[149]FFS, Appendix C, Fate and Transport at 6; *see also* Jay/Talke, Comment 1.6(h) and 2.8(b).

A. The FFS approach to human health risk and hazard from fish and crab consumption is flawed and excessively conservative.

Region 2's proposed remedy is primarily intended to reduce risk and hazard associated with fish and crab consumption, with the dredging components intended to allow placement of a cap without increasing flood risk or obstructing navigation. But Region 2's analysis of the risk and hazard arbitrarily dismisses site-specific data,[150] in other respects is based on inadequate data,[151] and results in an excessively conservative analysis that overstates the risk and hazard by relying on models that are uncertain.[152] The numerous deficiencies in Region 2's analysis are discussed in more detail in the supporting technical reports appended to this document. But, again, a few examples demonstrate the flawed nature of Region 2's approach to these issues.

The FFS is based on a limited quantity of fish tissue data that is both less extensive than EPA has used to assess other sediment sites and inadequate to support the conclusions Region 2 has drawn. In calculating exposure point concentrations in the Human Health Risk Assessment ("HHRA"), Region 2 relied on only 39 fish samples, disregarding a large quantity of additional data that would have allowed a more refined analysis of exposure.[153] This compares unfavorably to other major sediment sites, including Portland Harbor (100 samples), the Housatonic River (250 samples), the Upper Columbia River (150 samples), the Fox River (400 samples), and the Hudson River (database of more than 10,000 samples), where far more data were employed to conduct similar analyses.[154] Additional LPRSA data should be collected and analyzed before remedial action is taken, especially given the declining temporal trend in COC concentrations in tissue samples.[155] Further, Region 2's fish consumption assumptions are based on studies that are both technically wrong and inapplicable, and Region 2 has chosen to disregard more representative studies and site-specific data that show far less consumption

---

[150]ToxStrategies, *Comments on the Lower Eight Miles of the Lower Passaic River Focused Feasibility Study Report* (hereinafter "ToxStrategies"), Comment 2-7, 2-8.

[151]ToxStrategies, Comment 2-3.

[152]ToxStrategies, Comment 2-9, 2-10, 2-11, 2-23.

[153]ToxStrategies, Comment 2-3.

[154]ToxStrategies, Comment 2-3.

[155]ARCADIS, Supplemental Data Collection Attachment.

than it has assumed. Region 2 also chose not to use extensive site specific data regarding fish ingestion rates, species fraction ingested, exposure duration, and angling population size.[156]

Region 2 disregarded not one but two peer-reviewed creel-angler surveys[157] that directly studied fish and crab consumption in the LPRSA and came to conclusions that are far different from Region 2's analysis, which is based on data from a different and dissimilar waterbody.[158] Not only is the failure to consider reliable site-specific data contrary to EPA guidance, which requires use of local consumption data "wherever possible,"[159] it had the effect of greatly overstating consumption rates and therefore risk.[160] Region 2's failure to use site-specific data did not adhere to the Risk Assessment Guidance for Superfund.[161] Further, Region 2's stated concerns about "suppression" of fish consumption due to health advisories can be addressed through analysis of the existing data and do not justify Region 2's decision to ignore the rigorous, peer-reviewed studies conducted on this issue.[162] In fact, once these factors are correctly analyzed, fish consumption levels remain vastly lower than Region 2's erroneous approach suggests.[163] Compounding this, Region 2 applied a number of unreasonable and implausible assumptions regarding fish consumption, such as those related to cooking losses and the fraction of Lower Passaic River fish ingested by nearby populations, which again greatly overstates the risks of fish and crab consumption.[164]

Rather than rely on the peer-reviewed literature, the fish consumption rates used in the FFS HHRA were taken from an anonymous and non-peer-reviewed Region 2 document,

---

[156]ToxStrategies, Comment 2-7.

[157]*See* Kinnell, Jason C., *et al*., *A Survey Methodology for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1)*, Journal of Toxicology and Environmental Health, Part A 70:477–495 (2007); Ray, Rose, *et al*., *A Statistical Method for Analyzing Data Collected by a Creel/Angler Survey* (Part 2), Journal of Toxicology and Environmental Health, Part A 70:496–511 (2007); Ray, Rose, *et al*., *Human Health Exposure Factor Estimates Based Upon a Creel/Angler Survey of the Lower Passaic River (Part 3)*, Journal of Toxicology and Environmental Health, Part A 70:512–528 (2007); Finley, Brent L., *et al*., *The Passaic River Creel/Angler Survey: Expert Panel Review, Findings, and Recommendations*, Human and Ecological Risk Assessment 9(3):829–855 (2003); Law, Robert H, Letter to Stephanie Vaughn, Remedial Project Manager, EPA Region 2 Regarding Final Creel/Angler Survey Work Plan and Expert Review Panel Comments—Lower Passaic River Study Area (LPRSA), CERCLA Docket No. 02-2007- 2009 (2011).

[158]ToxStrategies, Comment 2-8.

[159]EPA, Office of Marine and Estuarine Protection/Office of Water Regulations and Standards, *Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual* (503/8-89-002) (1989) at 59.

[160]Veritas, Comment 3.

[161]Veritas, Comment 1.

[162]Veritas, Comment 2.

[163]Veritas, Comment 2, 3.

[164]ToxStrategies, Comment 2-9, 2-10.

cryptically identified as a "Technical Memorandum." This memorandum does not identify its author or authors or describe their qualifications, nor does it describe why or how it was prepared. It has no identified provenance, and it provides neither a complete nor technically accurate evaluation of the existing data. For example, the Anonymous Technical Memorandum cites to the *Risk Assessment Guidance for Superfund (RAGS) - Part A* to argue that the ingestion rates calculated in the first creel-angler survey are incorrect, referencing language defining "RME as the maximum exposure that is reasonably expected to occur…" Left unexplained is any reason why the creel-angler survey-derived calculation is incorrect, an omission that is both inexplicable and fatal given that EPA used this approach to calculate the default ingestion rates in in its 1997 Exposure Factors Handbook and these ingestion rates were in fact used by Region 2 itself in the 2007 version of the FFS. It is arbitrary and capricious for Region 2 to deviate from an established approach used at this site in the past without some reasoned explanation that has never been provided; relying on an anonymous and non-peer reviewed memorandum further exacerbates this problem.

Given that the fish and shellfish ingestion rates proposed in this anonymous memorandum drive the risk assessment results and the billion dollar-plus remediation alternative proposed by Region 2, it is of the utmost importance that such an influential document undergo scientific scrutiny by independent experts as is contemplated by EPA guidance.[165] It would be arbitrary, capricious, and inconsistent with the NCP for Region 2 to rely on an anonymous document of unknown provenance, with no known author nor any indicia of technical reliability, as arguably the single most important document supporting its remedy decision. While EPA has broad discretion in determining what information to consider, that discretion is not limitless and there must be some "satisfactory indicia of reliability"[166] before an agency can do so. Unlike in past cases where the authors of such material have been identified,[167] there is nothing here that provides any indicia of reliability for this critical document, and it is accordingly unlawful for Region 2 to rely on it.

Put simply, the high risk and hazard levels from fish and crab consumption calculated by Region 2 are illusory because site-specific data are ignored and conservative assumption is

---

[165]EPA, Office of Science and Policy, Office of Research and Development, *Science Policy Council Handbook. Peer review. 3rd Edition*. EPA/100/B-06/002 (2012), available at http://www.epa.gov/peerreview/pdfs/peer_review_handbook_2012.pdf.

[166]*EchoStar Commc'ns Corp. v. FCC*, 292 F.3d 749, 753 (D.C. Cir. 2002).

[167]*See Honeywell Int'l, Inv. v. EPA*, 372 F.3d 441 (D.C. Cir. 2004).

layered upon conservative assumption to a point that is arbitrary and capricious and which yields a calculated level of risk level that is implausible given the existing data, which Region 2 then relies upon to justify an unnecessarily massive interim remedial action.

B. The FFS approach to dioxin risk is technically indefensible.

Region 2's HHRA is based on outdated science and inapplicable or unsupported studies, especially for dioxin-related risk and hazard. Incorporating up-to-date science would greatly reduce the estimate of dioxin-related risk and hazard and accurately characterize risk and hazard for other chemicals present in the FFS Study Area.

For example, Region 2 used a cancer slope factor for dioxin that is based on outdated pathology classification guidelines, which in turn are based on a nearly thirty-year-old study that is known to be wrong and has been updated in the literature.[168] Similarly, Region 2 incorrectly asserts that TCDD acts via a mutagenic mode of action,[169] when it has long been known that this is not the case and that a non-linear approach for deriving toxicity criteria for dioxin should instead be used to reflect that fact.[170] Furthermore, Region 2's conclusions regarding the non-cancer hazard of dioxin are grossly inflated,[171] as the TCDD Oral Reference Dose (RfD) is based on two poorly implemented studies conducted in Italy and a flawed analysis of the information presented in those papers.[172] Region 2 also did not make use of the up-to-date, internationally accepted approach to non-cancer risk for dioxins.[173]

Region 2's approach to dioxin-related ecological risk is similarly inaccurate. Region 2 incorrectly calculated an ecological remediation goal for dioxin "toxicity" to benthic organisms.[174] As the science has conclusively established, dioxin is not toxic to such organisms.[175]There is no technical basis for a benthic invertebrate community sediment screening benchmark for dioxin, and Region 2's proposed establishment of cleanup levels for dioxin based on sediment

[168]ToxStrategies, Comment 2-12.
[169]ToxStrategies, Comment 2-13.
[170]ToxStrategies, Comment 2-13.
[171]ToxStrategies, Comment 2-14.
[172]ToxStrategies, Comment 2-15.
[173]ToxStrategies, Comment 2-16, 2-17.
[174]ARCADIS, General Comment 4.
[175]ARCADIS, General Comment 4.

screening criteria cannot be justified.[176] Additionally, given the apparently decreasing temporal trend in dioxin concentrations in ecological samples,[177] additional sampling should be performed to evaluate the extent of natural recovery before interim remedial action is taken.[178]

All told, Region 2's approach disregards the current science regarding dioxin toxicity and greatly overstates dioxin risks, both human and ecological. Moreover, in keeping with its failure to address uncertainty issues in the FFS, Region 2 failed to conduct a toxicity equivalence factor ("TEF") uncertainty analysis.[179] EPA guidance recommends this, and Region 2 provided no explanation of why it declined to conduct this analysis.[180]

Finally, there is ample reason for Region 2 to reconsider its risk analysis because the conclusions regarding risk reached by Region 2 are implausible. The daily dose of TCDD Toxic Equivalent ("TEQ") calculated by EPA for ingestion of fish in the LPRSA, which is used by Region 2 to justify an extraordinary interim remedy for the FFS Study Area, is substantially lower than other background exposures of TCDD TEQ experienced by certain age groups in the general population, such as nursing infants, with no apparent ill effects.[181] Identification of this disconnect leads to the conclusion that Region 2's technical errors have materially overstated dioxin risk. Even Region 2's overstated dioxin risks yield population-level risk that is very small, suggesting that once the technically improper assumptions that exaggerate the risk are stripped away, there is no reason to believe that current conditions are likely to cause even a single cancer case from LPRSA fish or crab consumption.[182] At a minimum, this means that there is no reason to rush to select and implement an extremely costly interim remedial action. Instead, it demonstrates that there is sufficient time to implement and evaluate MNR and targeted remedies in the "adaptive management" approach set forth in EPA guidance.

All these factors demonstrate the inherent unreliability of Region 2's risk assessment for this site and the TCDD toxicity criteria utilized. Region 2's proposed dioxin PRGs are

---

[176]ARCADIS, General Comment 4.

[177]ARCADIS, General Comment 3.

[178]ARCADIS, Supplemental Data Collection Attachment.

[179]ToxStrategies, Comment 2-20.

[180]EPA, *Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds* (2010), EPA/100/R -10/005, available at http://www.epa.gov/raf/files/tefs-for-dioxin-epa-00-r-10-005-final.pdf.

[181]ToxStrategies, Comment 2-18.

[182]ToxStrategies, Comment 2-19.

technically indefensible and, if applied during remedy selection, would lead to unnecessary and disruptive remediation.[183] Acceptable risk and hazard may well be achievable for TCDD using much higher sediment PRGs.[184] Region 2 should correct these technical problems before selecting a remedy for the FFS Study Area and consult with internal EPA experts regarding these complex scientific questions before selecting a remedy based in part on its assessment of TCDD risks.

C. The FFS approach to ecological risk is flawed.

Much as for human health issues, Region 2's Baseline Ecological Risk Assessment ("BERA") greatly overstates ecological risk, and, in fact, there are no apparent fish, bird, or mammalian wildlife risks from 2,3,7,8-TCDD ("dioxin") in the FFS Study Area.[185] The major deficiency of the BERA, however, is its unjustified failure to use sufficient and readily available site-specific data. Despite the vast amount of ecological data that have been generated for the LPRSA, both in the published, peer-reviewed literature and through the ongoing development of the RI/FS, the BERA remains essentially a screening-level exercise, in which default values are wrongly used to evaluate ecological risk, contrary to EPA guidance.[186] Indeed, there is little change in the BERA from the 2007 draft, despite the significant body of additional data generated since that time.[187] The BERA also has other flaws, such as its limited use of fish and crab tissue data, which preclude adequate trend assessment and evaluation of remedy effectiveness,[188] as well as the flawed bioaccumulation modeling.[189] Region 2 should prepare a meaningful BERA before selecting any remedial action that is allegedly required, in whole or in part, based on ecological risk.

---

[183]ToxStrategies, Comment 4-1 to 4-5, 5-1.
[184]ToxStrategies, Comment 4-23, 5-1.
[185]ARCADIS, General Comment 4.
[186]ARCADIS, General Comment 1.
[187]ARCADIS, General Comment 1.
[188]ARCADIS, General Comment 1.
[189]ARCADIS, General Comment 3.

D. Correct analysis of human health and ecological risks demonstrates that there is no need for immediate remedial action to address the COCs evaluated in the FFS.

Even accepting its erroneous evaluation of current risk on its own terms, Region 2's Proposed Plan will not accomplish its goals and will result in no meaningful risk reduction as compared to current conditions or to other alternatives, including monitored natural recovery or targeted remedies. Further, once Region 2's errors are corrected (errors such as its use of outdated statistical software,[190] its failure to incorporate available fish and crab data,[191] and its failure to comply with EPA guidelines regarding analysis of receptors and exposure pathways,[192] among others), the current level of risk associated with the Lower Passaic River is already below what Region 2 hopes to achieve by implementing the Proposed Plan for the COCs evaluated in the FFS.[193] There is thus no need for a large-scale dredging remedy to achieve those goals. The corrected analysis also demonstrates that PCBs account for 66% of the non-cancer risk present from the COCs analyzed in the FFS Study Area, making PCBs the most important chemical class to address from this perspective.[194] This proper understanding further demonstrates the consequences of Region 2's decision to neglect ongoing sources of such COCs, which will prevent significant risk reduction from the interim remedy.

E. The FFS ignored risks presented by polycyclic aromatic hydrocarbons ("PAHs") that would substantially affect the risk assessment.

While, as demonstrated by the risk assessment documents provided with these comments, the cancer risks associated with dioxins, furans, PCBs and other COCs fall within the acceptable risk range, based on the available data, the same is not true if risks related to PAHs are included in the analysis. Indeed, the significant risk presented by PAHs alone would be sufficient to require independent evaluation and consideration of potential remedial action, even if no other COCs were present in the LPRSA at all.[195] Ultimately, Region 2 should either acknowledge that the COCs considered in the FFS do not present a level of risk that is sufficient

[190] ToxStrategies, Comment 2-2.
[191] ToxStrategies, Comment 2-3.
[192] ToxStrategies, Comment 2-7, 2-11.
[193] ToxStrategies, Comment 3-1, 3-2, 3-3.
[194] ToxStrategies, Comment 3-1, 3-2, 3-3.
[195] ToxStrategies, Comment 3-1, 3-2, 3-3.

to justify interim remedial action, and allow the RI/FS process to take its course before selecting a remedy for the FFS Study Area, or it should revise its risk assessment to include all COCs and pathways presenting risk, and evaluate additional remedial options to address those COCs and pathways before an interim action is selected or implemented. A correct analysis of this issue would require Region 2 to revisit its views on the importance of ongoing sources as a risk driver and the value of implementing an interim remedy before controlling such sources.

F. The risk-related documents submitted with these comments correct the analysis used in the FFS.

To confirm this evaluation of risk assessment issues, provided herewith is a full set of risk assessments and related documents. These documents are provided to facilitate Region 2's analysis of these complex issues and to illustrate the most straightforward way for Region 2 to resolve the technical deficiencies in its analysis to date. This work is more comprehensive than Region 2's analysis, incorporates up-to-date science and all relevant data and exposure pathways, corrects the flaws in Region 2's risk assessment, and demonstrates, based on the available data, that interim action is simply not supportable and that the RI/FS process should be completed before a remedy is selected for the LPRSA. These materials include:

- Estimates of baseline risk fish ingestion using the available site-specific LPRSA data;[196]
- A new, correctly calculated human health risk assessment, which includes a TEF uncertainty analysis, probabilistic risk assessment, and an analysis of PAHs and their potential effect on Region 2's baseline risk assessment;[197]
- A corrected ecological bioaccumulation analysis;[198]
- An evaluation of the "correction" factors EPA erroneously applied to the dioxin data;[199]

[196]Veritas, Comment 2, 3.
[197]ToxStrategies, Comment 3-1, 3-2, 3-3.
[198]ARCADIS, Attachment 1, *Evaluation of Historical Data and Trends and Development of a Bioaccumulation Tool for Lower Passaic River Study Area (LPRSA)*.

- A technical memorandum explaining the errors in the FFS approach to dioxin toxicity and ecological risk;[200]

- An alternate, correctly calculated approach to ecological risk resulting from the available data regarding 2,3,7,8-TCDD;[201] and

- Proposed additional fish and crab tissue sampling and analysis, which are necessary for an accurate assessment of temporal trends in ecological and human health risk over time.[202]

The analyses contained in these documents demonstrate the need for significant changes in the Proposed Plan before a remedy is selected for the FFS Study Area. For example, these analyses have developed health-protective preliminary remediation goals ("PRGs") for TCDD and PCBs developed using a state-of-the-science approach based on available site-specific data. The series of iterative analyses included in these materials demonstrates that a PRG of 1ppb TCDD would be protective for cancer risks and noncancer hazards associated with fish and crab consumption, while a PCB sediment PRG of 0.7 ppm was found to be protective for cancer risks and noncancer hazards associated with both PCBs and with all dioxin-like congeners for consuming anglers.[203] A spatial analysis reveals that a sediment remediation scenario based on a PRG of 1 ppb TCDD would require remediation of only 9% of the sediment area from RM 0 to RM 8—a small fraction of the area to be addressed by the Proposed Plan and one that demonstrates that Region 2's compounded conservatism, not actual risk, is the real driver for the extent of remedial action Region 2 proposes. Region 2 should incorporate the results of these analyses into its decision-making process before selection of any remedial action, authorize implementation of the proposed additional biota sampling, and consider the results of that additional sampling in its remedy selection.

---

[199]ARCADIS, Attachment 3, *Development of Correction Factors for Split Samples Using the Approach Developed by CSC Analytical -- Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons.*

[200]ARCADIS, Attachment 4, *Evaluation of Potential Ecological Risks for the Lower Passaic River Study Area*.

[201]*Id.*

[202]ARCADIS, Attachment 2, *Conceptual Fish and Crab Sampling Plan for Lower Passaic River Study Area*.

[203]The dioxin-like congeners include TCDD, PCB-118, and PCB-126.

VI. The Proposed Plan is not implementable and will not result in environmental benefits.

While the sections above demonstrate that the interim remedy described in Region 2's Proposed Plan will not accomplish its intended goals, and that there is no risk-based justification for proceeding with it at this time, there is another reason why Region 2 should not select the proposed interim remedy for LPRSA sediments. Even if there were unacceptable risks from the COCs evaluated in the FFS, which is disputed, and even if a bank-to-bank cap would reduce those risks to acceptable levels, which is also disputed, the Proposed Plan simply cannot be implemented as a practical matter. This hurdle cannot be relegated to the remedial design phase. Region 2 is required to consider the implementability of a remedy at the remedy selection stage,[204] and both CERCLA and the NCP require selection of a remedy that can actually be implemented.

Further, Region 2's inadequate evaluation of this issue places its cost estimates well outside the -30%/+50% range required by EPA guidance.[205] While this requirement is not a bright-line rule that is universally enforced, the FFS cost estimates are such a gross deviation from this standard that Region 2's analysis must be significantly refined before it can serve as the basis for a CERCLA remedy selection decision.[206]

---

[204] EPA, *Development and Screening of Alternatives*, at http://www.epa.gov/superfund/cleanup/alter.htm ("The development of alternatives phase of the Remedial Investigation/Feasibility Study (RI/FS) process usually begins during scoping when likely response scenarios may first be identified. The development of alternatives requires:... screening the technologies based on their effectiveness, implementability, and cost"; *see also* B. OSWER Directive 9355.3-01, (October 1988) at 7.

[205] OSWER Directive 9355.3-01, (October 1988) at 6-12 ("Accuracy of Cost Estimates. Site characterization and treatability investigation information should permit the user to refine cost estimates for remedial action alternatives. It is important to consider the accuracy of costs developed for alternatives in the FS. Typically, these "study estimate" costs made during the FS are expected to provide an accuracy of + 50 percent to -30 percent and are prepared using data available from the RI. It should be indicated when it is not realistic to achieve this level of accuracy.").

[206] EPA, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA 540-R-00-02, (July 2000) at 2-6 ("Remedial action alternative cost estimates for the detailed analysis are intended to provide a measure of total resource costs over time (i.e., 'life cycle costs') associated with any given alternative. As such, these estimates generally are based on more detailed information and should achieve a greater level of accuracy than screening-level estimates. The detailed analysis level accuracy range of -30 to +50 percent means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $70,000 and %150,000.").

A. The interim remedy described in the Proposed Plan is not practically implementable.

The many considerations that undermine the implementability of the Proposed Plan are explained in the detailed reports provided with these comments. To summarize, however, major practical problems exist that cannot be overcome. First, the Proposed Plan will take far longer to construct than the FFS acknowledges.[207] The duration of construction is an important consideration in Region 2's evaluation of the risks and benefits of the Proposed Plan for an interim remedy,[208] and Region 2 has radically underestimated the time needed to implement an interim remedy of this magnitude. Region 2 has, for instance, ignored the challenges associated with bank stabilization measures, which not only will add construction time for the physical work, it will add delay and costs associated with access agreements, permitting requirements, and other complications.[209] The five-year duration for the Proposed Plan is materially understated; a realistic estimate would involve a more than 10-year construction period occurring after what is likely to be a 3-5 year remedial design phase.[210] The deep dredging alternative would likely take even longer, on the order of 15-20 years, creating far more environmental disruption and risk than Region 2 acknowledges.

Further, the USACE routinely overdredges by two feet as a standard practice to ensure navigational depth is achieved. Region 2 failed to account for the substantial additional volume of dredging that will be needed to address this issue. Region 2's approach introduces significant error and makes it impossible to reliably evaluate the likely dredging volume, a critical factor in remedy selection as it significantly impacts the cost, duration, and risks associated with the interim remedy.

Given the resuspension into the water column inherent in dredging, as well as the unavoidable exposure and redistribution of contaminants during the period of construction, the projected risk reductions simply cannot be achieved by the Proposed Plan. The risks of exposing highly contaminated material during the deep dredging proposed in Alternatives 2 and

---

[207] Tierra Solutions, Inc., Comment 11.

[208] Proposed Plan at 42 ("While both Alternatives 2 and 3 meet the threshold criterion of protectiveness, Alternative 3 does so in half the construction duration of Alternative 2 and a smaller volume dredged than Alternative 2. This means that there would be significantly less short-term impact on the community, workers and the environment.").

[209] Tierra Solutions, Inc., Comment 12.

[210] Tierra Solutions, Inc., Comment 11.

3 are high, but cannot be quantitatively predicted, because the hydrologic cycle and storms cannot be predicted 10-40 years in advance.[211] What is clear is that dredging will inevitably expose layers of highly contaminated material now buried far below the sediment bed surface. A major flood or combined flood-surge event during the dredging process, such as Hurricane Irene in 2011, could easily result in broad redistribution of pollutants, increasing contaminant concentrations throughout the LPR and Newark Bay. To evaluate this issue, a modeling process is needed that: (a) considers the impacts of extreme events takes during construction; and (b) takes into account the stochastic nature of extreme events. The interim action described in the Proposed Plan simply cannot be implemented in an environmentally responsible way, given the uncertain consequences of this implementation.

Region 2 has also failed to develop the estimates of operation, maintenance, and monitoring costs required by the NCP. Because the modeling was unable to show when the PRGs would be achieved, the operation and maintenance costs cannot be accurately predicted because the FFS does not provide a reliable assessment of when the goals would be met.[212] This is also a material deviation from EPA guidance.[213]

In addition, unsolvable physical constraints exist in the vicinity of the FFS Study Area and render the Proposed Plan impractical, if not impossible. For example, the upland processing facility required for off-site disposal is likely not feasible due to siting issues—there is simply no place available to site a facility of the size likely needed to handle the extraordinary volume of dredged material associated with the Proposed Plan.[214] Region 2 estimates the need for 26 acres to accommodate the construction of an upland processing facility ("UPF") to support the processing of dredged material under Alternative 3: Dredged Material Management ("DMM") Scenario B (Off-Site Disposal). Any UPF must allocate space to barge unloading,

---

[211] Jay/Talke, Comment 1.3, Appendix B.

[212] FFS at 5-31.

[213] EPA, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA 540-R-00-02, (July 2000) at 4-2 ("The project duration generally begins with the planning, design, and construction of the remedial alternative, continues through short- and long-term O&M, and ends with project completion and closeout...Site-specific justification should be provided for the period of analysis selected, especially when the project duration (i.e., time required for design, construction, O&M, and closeout) exceeds the selected period of analysis. "); EPA, *The Role of Cost in the Superfund Remedy Selection Process*, EPA 540/F-96/018, PB96-963245 (September 1996), at 2 ("During the first step of the FS, a range of remedial alternatives is developed and then screened in order to identify those alternatives that should be considered in more detail. Cost estimates developed for each option comprise the short- and long-term cost of remediation, including capital costs (e.g., the costs to put remedial technology in place, including those for equipment, labor, materials, and services), and the annual costs of operations and maintenance (O & M) for the entire period during which such activities will be required.").

[214] Tierra Solutions, Inc., Comment 7.

mechanical dewatering, wastewater treatment, processed material storage, reclaimed sand storage, debris processing, water storage, roadways, loading of rail cars, rail spur(s), and ancillary support areas. The size of these work areas would be consistent with GE's Hudson River processing facility which operates at a daily throughput of processed material consistent with Region 2's assumed daily throughput in the FFS (4,000 cy per day). To achieve this throughput, GE's Hudson River processing facility is constructed on more than 100 acres of land.[215] The size of GE's Hudson River processing facility stands in stark contrast to Region 2's estimate of 26 acres. The acreage assumed by Region 2 to support a viable UPF is grossly underestimated; considering the siting studies Region 2 references in the FFS, it is highly improbable that siting a UPF is technically feasible in the region.

Similarly, degraded public infrastructure (i.e., bridges that are no longer reliably operable to allow dredging vessels to pass) makes it impractical, and potentially a source of safety concerns, to implement the interim remedy described in Proposed Plan. The public reaction to any attempt to site the very large facility needed to handle the dredged material was also not taken into account. If Region 2 discarded the selection of a CAD simply because the Governor of New Jersey did not favor it, how can it select a remedy that will require a treatment facility for which no land if available and which would almost certainly be the subject of public outrage were it somehow to be actually constructed. Any absence of community objections to the construction of a large treatment plant is the result of Region 2's lack of transparency in failing to inform the public that its Proposed Plan would require the construction and operation of such a massive plant. Simply put, the general public does not know what Region 2's Proposed Plan will involve and how they will be affected. They should be told.

Another area of concern related to remedy implementation is the substantial volume of generated water that will need to be treated. Region 2 has publicly stated that the volume of dredged sediments will fill the Giants Stadium two times.[216] Region 2 does not, however, provide similar detail to explain the volume of water generated from the dredging that will need to be treated. Experience from the Phase 1 Removal Action suggests that the volume of untreated water generated by the Proposed Plan remedy would fill the Giants Stadium approximately eighteen times.

---

[215] http://www.hudsondredging.com/hudson-pcb-cleanup-how-dredging-is-performed.

[216] EPA, Fact Sheet: Cleaning up the Lower Passaic River- An Overview of EPA's Proposal for the Lower 8 Miles (April 2014).

Finally, the costs of the interim remedy render the Proposed Plan unimplementable. While cost is only one criterion relevant to CERCLA remedy selection, it must be considered, not disregarded, as part of any NCP-compliant analysis.[217] This consideration was not properly addressed by Region 2. Region 2 ignored many substantial costs and understated many others, including the costs associated with bank stabilization measures, fish windows, as well as the costs that would need to be incurred by public entities outside of the CERCLA process, such as for repair of public infrastructure (e.g., bridges).[218] Region 2 has further underestimated the costs associated with the proposed armored cap.[219] These likely costs are so significant that they call into question the implementability of the remedy. EPA guidance recognizes the principle that exorbitant cost can render a remedy not implementable[220] and explains that under the NCP "[a]lternatives may be screened out if they have costs that are "'grossly excessive compared to [their] overall effectiveness' (40 C.F.R. 300.430(e)(7)(iii))."[221] This guidance further provides that "[c]ost is a critical factor in the process of identifying a preferred remedy."[222]

Region 2 itself has extensive experience in remediating contaminated sediment sites, including on the Hudson River and two separate removal actions in the LPRSA, one of which was conducted in the FFS Study Area itself. Inexplicably, the FFS does not appear to incorporate this experience, as the estimated unit cost of the FFS proposed dredging is substantially below the actual costs of those earlier actions, with no disclosure of this fact or explanation of the differences provided. The FFS estimates a unit cost of $555 per cubic yard,[223] which is implausible based on the real world experience from past dredging projects in Region 2, where the unit costs for Phase I of the Tierra removal action were $2000 per cubic yard, and it is Maxus and Tierra's understanding that the unit costs for the RM 10.9 removal

---

[217] EPA, *Development and Screening of Alternatives*, http://www.epa.gov/superfund/cleanup/alter.htm ("The development of alternatives phase of the Remedial Investigation/Feasibility Study (RI/FS) process usually begins during scoping when likely response scenarios may first be identified. The development of alternatives requires:... screening the technologies based on their effectiveness, implementability, and cost"; *see also* OSWER Directive 9355.3-01 (October 1988), at 7.

[218] *See generally,* Tierra Solutions, Inc. Comments.

[219] *See generally* FFS Appendix H: Cost Estimates.

[220] EPA, The Role of Cost in the Superfund Remedy Selection Process, EPA 540/F-96/018, PB96-963245, September 1996).

[221] *Id.* at 4.

[222] *Id.* at 5 (emphasis added).

[223] Appendix H: Cost Estimates, Table 1-6 Cost Estimate: Alternative 3 with DMM Scenario B Capping with Dredging for Flooding and Navigation, Off-site Disposal.

action were approximately $1300 per cubic yard. Failure to take into account such real world experience is inconsistent with EPA guidance.[224]

CERCLA and the NCP require that every remedy selected must be cost-effective. CERCLA requires selection of remedies that provide for cost-effective response taking into account the total short-term and long-term costs of such actions, including the costs of operation and maintenance for the entire period during which such activities will be required.[225] Remedies that permanently and significantly reduce the volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants are to be preferred.[226] Moreover, the offsite transport and disposal of hazardous substances or contaminated materials without such treatment should be the least favored alternative remedial action where practicable treatment technologies are available.[227]

A remedy shall be deemed cost-effective if its costs are proportional to its overall effectiveness.[228]In the preamble to the NCP, EPA explains its use of the term "proportional" in determining cost effectiveness:

> EPA uses the term "proportional" because it intends that in determining whether a remedy is cost-effective, the decision-maker should both compare the cost effectiveness of each alternative individually and compare the cost and effectiveness of alternatives in relation to one another (*see* 53 Fed. Reg. 51427-28). In analyzing an individual alternative, the decision-maker should compare, using best professional judgment, the relative magnitude of cost to effectiveness of that alternative. In comparing alternatives to one another, the decision-maker should examine incremental cost differences in relation to incremental differences in effectiveness. Thus, for example, if the difference in effectiveness is small but the difference in cost is very large, a proportional relationship between the alternatives does not exist . . .. Using such an analysis should enable the decision-maker to determine whether an alternative represents a reasonable value for the money; more than one alternative may be considered cost-effective.[229]

---

[224]Sediment Guidance at 3-25, Highlight 3-4 ("Accurate cost estimates, including long-term O&M costs and, where appropriate, materials handling, transport, and disposal costs, are very important to a good comparison of alternatives; and actual costs from pilot projects at a site and at similar, completed sediment sites are among the best cost resources.").

[225]42 U.S.C. § 9621(a).

[226]*Id.* at § 9621(b)(1).

[227]*Id.*

[228]40 C.F.R. § 300.430(f)(1)(ii)(D).

[229]55 Fed. Reg. 8666, 8728 (Mar. 8, 1990).

Region 2's estimated cost of the interim remedy described in the Proposed Plan is so high, Region 2's underlying scientific analysis so questionable, the implementability so suspect, and the potential for disrupting the community and permanently damaging the environment so likely, that the interim remedy described in Proposed Plan cannot be justified under this "proportional" test or any other measure.

There have been excellent analyses of cost effectiveness in some past Superfund RODs. One such example is the Tar Creek OU4 ROD.[230] By comparison, the cost effectiveness analysis in the LPR Proposed Plan is so sparse and elementary that an accurate analysis of the cost benefits of various remedial alternatives is not possible. Acknowledging that the Proposed Plan is not yet at the ROD stage, a review of Region 2's recently issued Gowanus Canal ROD likewise shows a cost-effectiveness analysis that is just as sparse and unhelpful in making a remedial action decision. Region 2 should perform a more robust cost effectiveness analysis (such as was done at Tar Creek OU4) before making any remedy decision. The costs are simply too high and the lack of transparency too great to base a remedy selection decision on such a superficial analysis of this issue, which is one of CERCLA's remedy selection criteria.

B. The FFS overstates the future benefits and understates the potential risks associated with the Proposed Plan.

The extensive dredging, materials handling, and trucking called for in the Proposed Plan will impose quality-of-life impacts on affected communities, but Region 2 did not evaluate the net environmental benefits of the remedy. While this is not expressly required by the NCP, the results of such an analysis are relevant to a number of remedy selection criteria, including the threshold criterion of environmental protectiveness and the balancing criteria of effectiveness and cost—which, properly understood, should include the non-monetary ecological costs of the remedial action—and, if publicized as it should be to provide transparency, the community acceptance criterion.[231]

EPA has identified net environmental benefits analysis ("NEBA") as an important decision-making tool to assess these issues, and it has been applied to guide remedial

---

[230] EPA Region 6, *Tar Creek OU4 ROD* (February 20, 2008) at 56-59, available at http://www.epa.gov/region6/6sf/oklahoma/tar_creek/ok_tar_creek_ou4_rod_200802.pdf.

[231] *See* 40 C.F.R. § 300.430(e)(9)(iii) (setting forth the nine criteria for evaluation); 40 C.F.R. § 300.430(f)(1)(i) (defining threshold, primary balancing, and modifying criteria).

decision-making, including recent remediation work addressing contaminant releases on the Kalamazoo River and remedy selection at the New Jersey Woodlands Superfund Site. Indeed, EPA's own website emphasizes the importance of this issue: "EPA is continuing to develop methods for understanding and reducing the environmental footprints of projects and policies. In particular, EPA's footprint evaluation methodology is used to support green remediation and reduce negative environmental effects that might occur during the assessment and cleanup of contaminated sites."[232] Federal policies and other regulatory guidance and executive orders mandate that the evaluation process demonstrate the degree to which remedies manage ecological and human health risks during and after implementation, provide a "net benefit" to the public, implement sustainable solutions, minimize impacts to water quality and water resources, reduce air emissions and greenhouse gas production, minimize material use and waste production, and conserve natural resources and energy.[233] None of these considerations has been addressed in the FFS.

Appended hereto is a partial analysis of net environmental benefits that demonstrates the potential negative consequences of the remedy proposed by Region 2.[234] A full analysis of these issues would identify additional such shortcomings. This analysis identifies the short- and long-term environmental and social factors/risks that were not considered by EPA for the remedial options, such as the significant and undisclosed air emissions impacts of the project, which will effectively create a new major source of greenhouse gas and fine particulate matter ($PM_{2.5}$) emissions, with attendant impacts on the community and the environment. The provided analysis also demonstrates the potential benefits of alternative remedial approaches. This information should be considered by Region 2, EPA Headquarters, and affected community stakeholders evaluating a potential remedy for the FFS Study Area. Because the FFS did not evaluate these considerations, the FFS is incomplete. Region 2 should withdraw the FFS and evaluate remedial alternatives consistent with EPA policy and guidance.

---

[232] http://epa.gov./sustainability/analytics/environmental-footprint.htm.

[233] *See, e.g.,* EPA, *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA 542-R-08-002)(2008), available at http://epa.gov/tio/download/remed/green-remediation-primer.pdf. These policies are discussed in more detail in Environ, *Technical Comments on EPA's Focused Feasibility Study for the Lower Passaic River; Focus on Net Environmental Benefits Analysis*.

[234] *Id.*

VII. The Proposed Plan should not include navigational dredging, which is unwarranted for commercial reasons and increases the risk, environmental and community impact, and cost of the proposed remedy.

An important and not clearly disclosed aspect of the Proposed Plan is that a major driver for the massive dredging volume required is the navigation channel in the lower two miles of the FFS Study Area. Navigational dredging constitutes approximately 40% of the total volume of dredging,[235] and if Region 2 were to include USACE's standard two feet of over-dredge, this percentage would be even greater.

There is no justification for Region 2 to make navigational dredging such a significant component of its Proposed Plan. The authorized depth of a navigational channel is not, and has never been treated as, an ARAR with which a CERCLA remedy must comply. Indeed, Region 2's Proposed Plan itself allows for capping at levels shallower than the authorized navigational depth as part of the preferred alternative.[236] While Region 2 is allowed to consider reasonably foreseeable future use in determining the scope of a CERCLA remedy, and it must avoid obstructing navigation pursuant to § 10 of the Rivers and Harbors Act,[237] which has been treated as an ARAR at CERCLA sites, Region 2's decisions must be reasonable.[238] Here, the future navigational uses posited by the FFS are anything but. Navigational dredging was discontinued in the LPR over three decades past for economic reasons,[239] and a deepened navigation channel in the FFS Study Area will not be competitive with alternative navigation investments.[240] The increasing use of deep-draft container vessels for commercial navigation generally, and the substantial investment the Port Authority of New York and New Jersey made

---

[235] Dr. James J. Opaluch, University of Rhode Island, *Comments on Navigational Dredging in Louis Berger Group, Inc. FFS Report* (hereinafter "Opaluch"), Comment 1.1.

[236] Proposed Plan at 40.

[237] 33 U.S.C. § 403.

[238] EPA, *Considering Reasonably Anticipated Future Land Use and Reducing Barriers to Reuse at EPA-lead Superfund Remedial Sites*, OSWER Directive 9355.7-19 (March 17, 2010), at 4 ("Regions should consider reasonably anticipated future land use when determining remedial action objectives, and during the evaluation of alternatives leading to the selection of the remedy. Consistent with one of the objectives of the 1995 Land Use Directive, Regions should use information related to reasonably anticipated future land use 'to formulate realistic assumptions regarding future land use and clarif[y] how these assumptions fit in and influence the baseline risk assessment, the development of alternatives, and the CERCLA remedy selection process.' Regions should also ensure that the Agency's consideration of reasonably anticipated future land use is thoroughly documented in the administrative record prepare for each site."), available at http://www.epa.gov/superfund/programs/recycle/pdf/reusedirective.pdf.

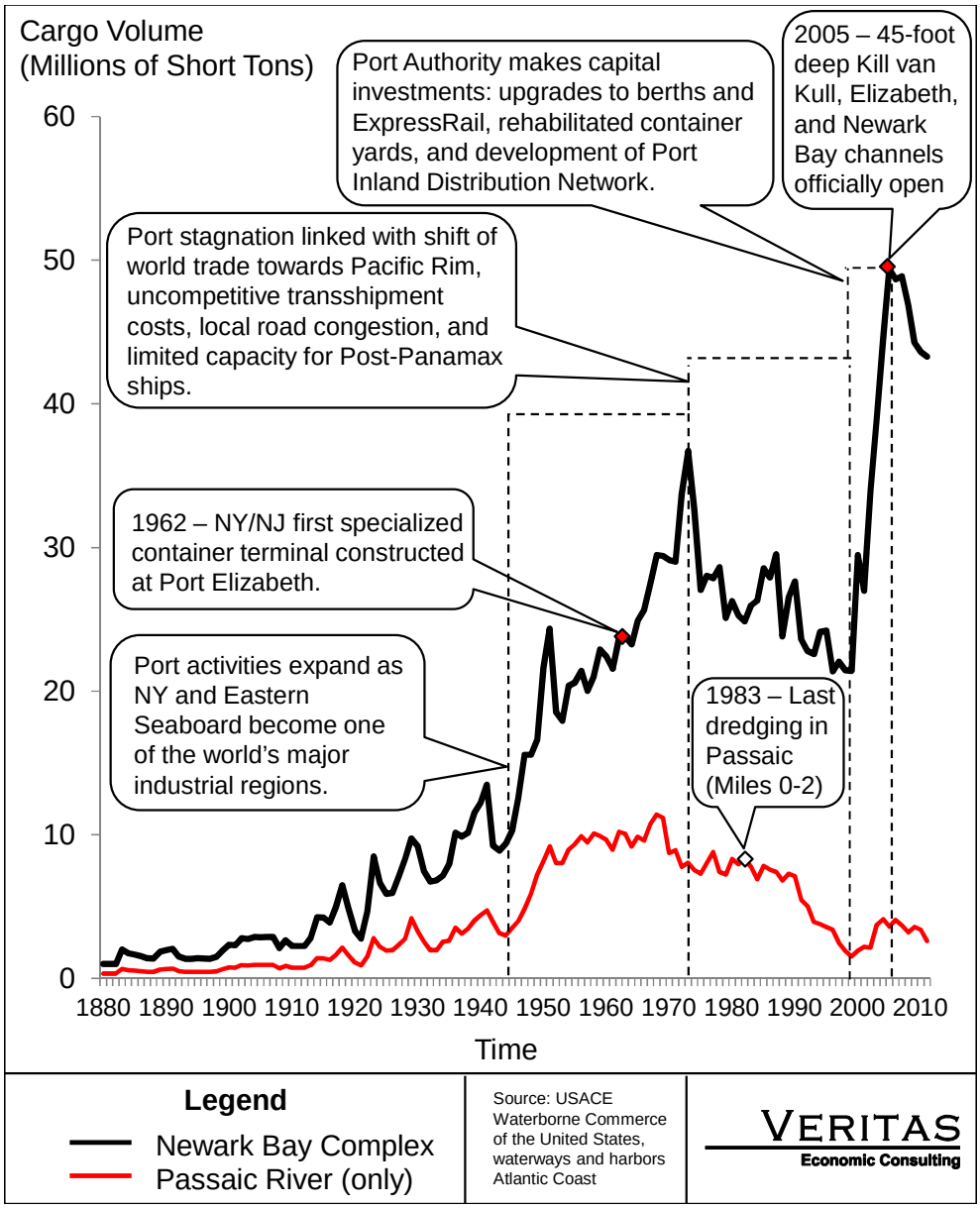
[239] Veritas, Comment 6.2.

[240] Veritas, Comment 6.3.

to accommodate such vessels in Port Elizabeth and Newark Bay, undermines the need and largely eliminates the economic justification for navigational dredging of the Lower Passaic River.[241] Such containerized shipping relies on off-loading containers for shipment by truck and rail, for which—unlike for facilities inside the FFS Study Area—the ports in Newark Bay have been substantially upgraded, rendering competing navigational uses of the sort contemplated by the FFS uneconomic.[242] If the channel were deepened under the Proposed Plan, the LPR is not wide enough to accommodate deep-draft container vessels or to justify investment in the necessary surface facilities, so the deeper channel would simply refill with sediment. That was true in 2007 when Region 2 proposed its misconceived draft FFS, where many alternatives under consideration were incorrectly focused on restoration of the navigation channel,[243] and it is even truer today. Indeed, commercial navigation has declined since that time.[244] A recent analysis of shipping data for the Lower Passaic River and the Newark Bay Complex as a whole demonstrates this fact.[245]

---

[241]Veritas, Comment 6.3.
[242]Veritas, Comment 6.3.
[243]2007 Draft FFS, Executive Summary at vii.
[244]Veritas, Comment 6.3.
[245]Veritas, Comment 6.3.



Such considerations also make it uneconomic for facility owners in the FFS Study Area to invest in the necessary upgrades to make use of an expanded navigation channel. The uneconomic nature of such investments is exacerbated by the need to accelerate those investments before the remedial construction begins and the protracted nature of the construction process itself. Further, depth is not the only, or even the primary, constraint on

LPRSA navigation; the width of the channel is also a significant constraint.[246] Thus, deepening the channel will prompt little, if any, increased commercial navigation.

The USACE study cited to justify deeper navigation depth in the Lower Passaic River was conducted improperly. It relies upon a hypothetical survey methodology that is known to overstate the likely future use of the River, a shortcoming that Region 2 did not correct or take into account.[247] Contrary to the conclusions of this study, future navigational uses requiring a 20-30-foot channel depth are not reasonably foreseeable and should not be included as part of a CERCLA remedy. Even if Region 2 were to require portions of the LPRSA to be dredged to full navigational depth, the channel will not continue to exist in the future because the necessary maintenance dredging could never be justified under applicable USACE cost-benefit principles that govern the allocation of maintenance dredging funds.[248] Additionally, if a deeper channel were to be created, it would require regular maintenance. The material that would accumulate in this deeper channel would be contaminated by deposition of new contaminants from ongoing surface or marine activities and redeposition of dredged materials, making disposal unnecessarily expensive.[249] The cost-benefit ratio of channel deepening is highly unfavorable, and the costs of maintenance dredging have simply been ignored in cost estimates of the remedial alternatives that involve dredging.[250] Future navigational dredging in the Lower Passaic River cannot be justified under applicable federal guidelines or budget processes, and it will never occur in any other context. Because there will be no maintenance dredging, such future navigation uses are not reasonably foreseeable.

Finally, while the USACE principles requiring evaluation of the costs and benefits of navigational dredging[251] are not an ARAR, where—as here—Region 2 frames its analysis expressly in terms of the need and future use of navigational dredging, those principles are "to be considered" matters that Region 2 must evaluate in making its remedy selection decision.[252]

---

[246]USACE, *Lower Passaic River Commercial Navigation Analysis* (Rev. 2 2010) at 27, available at http://passaic.sharepointspace.com/Public%20Documents/2010-07-29%20USACE%20Lower%20Passaic%20River%20Commercial%20Navigation%20Analysis.pdf.

[247]Veritas, Comment 6.5; Opaluch, Comment 1.3.

[248]Opaluch, Comment 1.1.

[249]Jay/Talke, Comment 1.5.

[250]Veritas, Comment 7.

[251]Council on Environmental Quality, *Principles and Requirements for Federal Investments in Water Resources* (March 2013); USACE, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (March 10, 1983).

[252]40 C.F.R. § 300.400(g)(3).

If Region 2 intends to make navigational considerations such an important aspect of the remedy selection decision in the FFS Study Area, it also must consider the well-established principles governing navigational dredging, which should explicitly be incorporated into the FFS analysis of navigational issues before Region 2 selects a navigation-driven remedy, where 40% or more of the dredging volume is actually intended to address perceived navigation needs.

Because these issues significantly call into question the need for navigational dredging, the requirement of the interim remedy in the Proposed Plan for navigational dredging should be deferred to the full 17-mile RI/FS, so that these issues can be resolved consistently throughout the watershed and in accordance with USACE principles governing navigation and maintenance dredging.

VIII. A CAD would be environmentally protective, implementable, and efficient.

If Region 2 proceeds with a dredging remedy, it should select a CAD for dredged materials management. Indeed, EPA's own National Remedy Review Board/Contaminated Sediments Technical Advisory Group endorsed consideration of a CAD: ". . . [T]he Boards recommend that the Region reconsider the less costly CAD scenario."[253] In fact, Region 2 has already determined that a CDF shall be used for disposal of sediments dredged during Phase 2 of the Non-Time-Critical Removal Action for sediments near 80 Lister Avenue,[254] both including this approach in the relevant administrative order and explaining in the supporting action memorandum that "Phase II involves the excavation of 160,000 cubic yards as shown in Figure 1, behind sheet piling, with the dredged materials sent to a modular confined disposal facility (CDF) within the areal extent of contamination of the Diamond Alkali Superfund Site."[255] Region 2 was correct to endorse this approach in 2008, and its deviation from that sound decision in the FFS is inexplicable and unjustified.

---

[253] EPA, *National Remedy Review Board and Contaminated Sediments Technical Advisory Group Recommendations for the Diamond Alkali Superfund Site, Lower Eight Miles of the Lower Passaic River (Focused Feasibility Study Area)* (April 11, 2014) at 7.

[254] *In the Matter of Lower Passaic Study Area of the Diamond Alkali Superfund Site, Administrative Order on Consent,* CERCLA Docket No. 02-2008-2020 (June 23, 2008) ¶¶ 9.o., p.

[255] EPA Region 2, *Documentation of Concurrence with the preparation of an Engineering Evaluation/Cost Analysis in Support of a CERCLA Non-Time Critical Removal Action at the Diamond Alkali Superfund Site in New Jersey* (June 12, 2008) at page 1-2.

Confined aquatic disposal consists of placement of dredged material inside a confining depression or excavation in a body of water, followed by engineered capping.[256] The CAD technology, as well as the closely related nearshore CDF technology, has been used extensively and successfully in Superfund and other settings throughout the United States and the world for over 30 years.[257] It has even been successfully used in Newark Bay to manage contaminated sediments.[258] There is no official tally of the number of sites or total volume currently placed in CAD or CDF sites, but many are currently in use and substantial quantities of dredged materials, including contaminated sediments, have been safely and efficiently disposed of using a CAD.[259] Of all the CAD and CDF sites in use today, none has failed. A CAD would provide robust and stable physical isolation of sediments, leading to reliable and secure chemical isolation from the environment and sensitive receptors. Another great advantage is that the CAD technology is not sensitive to contaminant concentration in sediment, rendering implementation of a remedy easier to manage and therefore more quickly achievable.

A CAD is a far better approach to securing FFS Study Area sediments than off-site disposal for a number of reasons. It is a proven and reliable technology, which is more easily implemented and has fewer capacity limits and bottlenecks than other approaches.[260] A number of good sites are available within the boundaries of this Superfund site, a great advantage over off-site disposal, given that there is likely nowhere to locate the necessary upland processing facility. A CAD would be relatively simple to design, build, and operate, and it will eliminate on-land transport of contaminated sediments through densely-populated urban areas to landfill sites hundreds or even thousands of miles away. A CAD will decrease the exposure of workers and the community to contaminated sediments. It will also provide environmental and safety advantages, including a smaller carbon footprint and better worker safety than for dewatering and off-site disposal, with no risk of highway accidents and related injuries or fatalities.[261]

---

[256]Tierra Solutions, Inc., Comment 13.

[257]Tierra Solutions, Inc., Comment 14.

[258]*Id.*

[259]Presentation of Philip A. Spadaro, *A Public Forum on the Proposed U.S. Environmental Protection Agency Plan for the Lower 8 Miles of the Lower Passaic River* (July 22, 2014).

[260]Tierra Solutions, Inc., Comment 14.

[261]Tierra Solutions, Inc., Comment 15.

For Lower Passaic River sediments, a CAD would work because the sediment will remain wet and anoxic, which binds the contamination to the mineral and organic particles comprising the sediment.[262] Control of the particles, which is straightforward in a CAD, necessarily controls the contamination. Indeed, this is demonstrated in the Lower Passaic River by the presence of elevated levels of contamination at depth, which occurs only because the contaminants at issue have remained bound to the sediment. The potential losses during placement can be reduced through good site design, control of disposal events, and the possible use of barriers; the dredged material in the CAD will remain immobilized and isolated from the environment so long as well-understood principles of site selection, site design, and engineered cap design are implemented.

Indeed, Region 2 implicitly accepts the principle of aquatic entombment of contaminants. The proposed remedy for the FFS Study Area is just such an action—contaminated sediments will be left in place and buried beneath a cap.[263]There is no analysis in the FFS that purports to compare the relative benefits or disadvantages to capping sediments distributed throughout a river as compared to an engineered and monitored underwater cell.

While Region 2 dismissed the CAD option as "administratively infeasible" due to New Jersey's objections,[264] this decision is incorrect. EPA has the authority to mandate a CAD over state and local objections[265] and need not accede to the state's view on this issue, especially where, as here, use of a CAD will greatly aid the implementability and accelerate the completion of a CERCLA remedy. Region 2 should have entered into substantive dialogue with New Jersey to highlight the benefits of a CAD, including the superior protectiveness of an engineered CAD and the potential social benefits of such a facility for the State of New Jersey and its residents.

IX. Conclusion

Given the number and magnitude of the errors and shortcomings in the FFS, Region 2 should devote its attention to completion of the RI/FS process for the LPRSA and the Newark

---

[262]Presentation of Philip A. Spadaro, *A Public Forum on the Proposed U.S. Environmental Protection Agency Plan for the Lower 8 Miles of the Lower Passaic River* (July 22, 2014).

[263]Tierra Solutions, Inc., Comment 16.

[264]Proposed Plan at 39.

[265]*See* 40 C.F.R. § 300.515(e)(2)(ii) (state concurrence not required); 40 C.F.R. § 300.515(e)(2)(ii) (EPA right of entry to construct or maintain remedial action).

Bay Study Area, following which it should develop an informed Proposed Plan that addresses the many shortcomings highlighted in these comments. This is the only way for Region 2 to select a remedy for the FFS Study Area that complies with CERCLA, the NCP, and EPA guidance. Region 2 has not been transparent to ensure meaningful public participation; its analysis does not allow decision makers to understand or evaluate the technical underpinnings of the FFS or the Proposed Plan; and its deviation from the sound adaptive management approach established by EPA guidance is both inexplicable and unjustifiable. Not surprisingly given these procedural failings, the substance of the FFS and the Proposed Plan is misguided and will create more risk and environmental harm than it is intended to cure. Any remedy selected on the basis of the FFS will fail, cannot be technically justified, may create increased risk due to inadequately analyzed uncertainties, and cannot be implemented as a practical matter. Ultimately, the Proposed Plan is a wasteful and risky exercise that will accomplish little or nothing in terms of risk reduction, subjecting the environment of the Lower Passaic River and the residents of nearby communities to considerable disruption, while wasting both public and private resources and funds.

While few EPA remedies have been held to be arbitrary, capricious, or contrary to law in past cases,[266] it is a matter of black-letter law that such Agency actions may not be enforced, whether through use of a CERCLA § 106 order or otherwise.[267] Past cases have deferred to EPA remedial decisions in many circumstances, but these cases are likely inapposite to the potential enforceability of a future Record of Decision based on the FFS or the Proposed Plan. The cases that have upheld EPA remedies did not address circumstances where an EPA Region selected a multi-billion dollar interim remedy while the RI/FS process for the site had not yet been completed, nor have they dealt with a remedy selected through a process that is not in accordance with CERCLA, the NCP, and EPA guidance and policies, lacking the technical basis to support a conclusion that the selected remedy would be effective, and where there are ample reasons to believe the remedy may be worse than no action at all. Region 2's rush to prematurely select a remedy that will cost billions of dollars on the basis of a manifestly inadequate technical analysis will leave little choice for affected private parties other than to resist Region 2's invitations to participate and even enforcement efforts, likely delaying the

---

[266] *See generally In re Bell Petroleum*, 3 F.3d 889 (5th Cir. 1993).

[267] 5 U.S.C. § 706 ("[T]he reviewing court shall . . . hold unlawful and set aside agency action, findings, and conclusions found to be . . . arbitrary, capricious, and abuse of discretion, or otherwise not in accordance with law . . . .").

implementation of a remedy. Given the substantial shortcomings in the FFS and Region 2's attempt to circumvent the RI/FS process and relevant EPA guidance and policies by using the FFS to preordain a multibillion-dollar, decade-long *interim* remedy, a ROD based on the FFS is likely to be unenforceable under CERCLA due to the arbitrary and capricious nature of Region 2's action.

COMMENTS

Key Lower Passaic River Focused Feasibility Study Issues and Uncertainties

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
David A. Jay, Ph.D.
Stefan A. Talke, Ph.D.
Portland State University, Portland, OR

KEY LOWER PASSAIC RIVER FOCUSED FEASIBILITY STUDY ISSUES AND UNCERTAINTIES

David A. Jay, Ph.D. and Stefan A. Talke, Ph.D.

Executive Summary

The Remedial Investigation Report for the Focused Feasibility Study (FFS) of the Lower Passaic River (LPR) issued by Region 2 of the Environmental Protection Agency (EPA) is the culmination of two decades of work and presents an exhaustive and seemingly complete plan for remediating the lower 8 miles of the LPR. However, misappraisal of key conceptual issues and lack of physical process knowledge combine with an outdated and inadequate modeling framework to invalidate key portions of the analysis presented in the FFS and to raise serious questions about the proposed remediation. As presently formulated, the proposed remediation likely will not deliver its purported benefits. There are multiple reasons why the FFS analysis of alternatives is inadequate:

- The Conceptual Site Model (CSM) guiding the proposed remediation is incomplete and contains significant “blind spots;” this has led to inadequate model formulations (section 1.2).

- The estuary turbidity maximum (ETM) and its potential role in re-contaminating the LPR was only superficially analyzed and remains poorly understood (section 1.4).

- Many unanswered questions exist regarding the distribution of contaminant concentrations, and the possibility that significant additional contaminant sources remain unidentified should be investigated more thoroughly, particularly for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), which figures so prominently in the modeling and discussions.

- Available environmental data are inadequate to calibrate and verify the models (Sections 1.2 and 1.3).

- Extreme events were under-estimated, particularly the erosive potential of combined river flow/storm surge events; the capping analysis and long-term predictions need to more realistically incorporate extreme events (section 1.6; Appendix B).

- Future climate change, sea-level rise, engineering projects in New York harbor, deepening the LPR (remediation option 2 & 3), and natural variability may significantly alter LPR dynamics and outcomes, but these factors are not realistically considered (Section 2.10).

- The magnitude and error bounds of key parameters and boundary conditions are poorly known and/or incorrectly modeled. In particular, water and particulate inputs to the LPR need to be determined using a carefully calibrated watershed model. The inaccuracy and uncertainty of the sediment load estimates used in the FFS Report call into question the utility of FFS model results (Sections 1.3 and 2.3-2.6; Appendix A).

- Model resolution is too coarse to properly characterize relevant circulation and erosion/ deposition processes (Sections 1.3 and 2.3 -2.4).

- Model skill assessment is inadequate, and an appropriate and comprehensive analysis of uncertainty that propagates bias and error through models should be conducted (Section 1.3).

- A deterministic prediction of outcomes 45 years into the future (i.e., to 2059) was made for each proposed alternative. Given the stochastic nature of hydrologic and storm-surge forcing, this is inappropriate—an ensemble forecasting approach that yields realistic uncertainty bounds should have been used (Section 1.3).

- The uncertainty analysis for ECOMSED in FFS Report Appendix BII [*EPA*, 2014], shows that an uncertainty of ±20% in the sediment load at Dundee Dam was sufficient to change estimates of net deposition/erosion by ±25 to 125% in many model reaches. Analysis of FFS sediment load models suggests that long-term average sediment load to the LPR from the Upper Passaic River is uncertain by 25-50%, and that the load from other tributaries is uncertain by 50-100% on a long-term average basis. Moreover, the sediment for large events like Hurricane Irene is uncertain by up to a factor of two. Given this uncertainty (which interacts with other uncertainties in ECOMSED and in the Fate and Transport modeling and is only one of many), deposition and erosion cannot be credibly modeled with the FFS Report model suite, and modeling that integrates these uncertain (and possibly biased) estimates over decades simply is n0't credible.

- There are other errors and inconsistencies, too numerous to list here, that invalidate model results.

In summary, a large structure of inference has been erected based on fragmentary system knowledge, and an inadequate modeling framework has been used to evaluate remedial alternatives. The FFS modeling procedure should be thoroughly overhauled and brought up to the standard of best scientific and engineering practices. To determine whether statistically significant and scientifically defensible differences exist among the four remedial alternatives and/or to design better alternatives, we recommend that: (a) more measurements be made, particularly of the critical exchange of contaminated sediment between Newark Bay and the LPR, and also of the sediment input to the LPR; (b) numerical model resolution be increased to characterize relevant physical processes; (c) a watershed model be used to specify LPR inputs of water and particulates; (d) retrospective modeling be used to verify the hypothesis that upstream transport produced the observed upstream contamination pattern, rather than additional, unidentified contaminant sources; (e) a stochastic modeling approach be implemented that more realistically incorporates uncertainties in future sea-level rise, extreme events, climate variability, and anthropogenic development; (f) a multi-modeling approach be used, such that the bias in any individual model can be assessed and reduced; (g) error, bias, and uncertainty be propagated realistically through the suite of linked hydrodynamic, sediment, and contaminant models; and (h) that a realistic, observationally based understanding of the ETM be incorporated into the CSM and FFS modeling suite. Though labor intensive, each of these recommendations is feasible and in line with current "best practice." This approach will help Region 2 to realistically evaluate the risk to human and environmental health posed by LPR contamination and design a defensible preferred remedial alternative.

1. Themes and General Comments

1.1 Review Approach

The Focused Feasibility Study (FFS) Report [EPA, 2014] is a vital public document. Its intent is to protect human health and promote environmental recovery, at a cost of billions of dollars. As such, it is incumbent upon Region 2 to use the best scientific and engineering practices in reaching its conclusions. The following comments are intended to help Region 2 attain that standard.

1.2 The Conceptual Model is Incomplete

The Environmental Protection Agency (EPA) conceptual site model (CSM) of the Lower Passaic River (LPR), used implicitly to justify alternatives that lead to massive system alteration, is inadequate and incomplete. The LPR Conceptual Model (EPA, 2007)[1] fails to correctly characterize the LPR in that it: (a) under-emphasizes the role of extreme events; (b) does not contain the understanding of LPR circulation, sediment transport processes and the sediment budget needed to guide decision making; (c) incorrectly suggests that an approach to equilibrium conditions is occurring; and (d) fails to address impacts of climate change (e.g., rising mean sea level, altered hydrology and increasingly severe or more frequent storms) that will cause the system to evolve in the future. When these factors are considered, it is clear that Region 2 needs to reconsider the design of remedial alternatives, based on a relevant CSM. Our argument is as follows:

a. *What is a "conceptual site model"?*: To properly design, model and evaluate remedial alternatives, we argue that improving the process-level understanding of the LPR ecosystem and its boundary conditions is imperative. Similarly, the remedial investigation report (RI-FFS, 2014) suggests that "a good CSM is a valuable tool for evaluating the potential effectiveness of remedial alternatives". The Region 2 CSM (*EPA*, 2007) is, therefore, a philosophical basis of the FFS Report, yet contains little specific process information regarding circulation and sediment transport issues. Supporting documents (e.g., *Sea Engineering & HDR* [2011]) and later documents (RI-FFS Ch. 6, 2014) are also incomplete (see Section 2.2). One focus in these comments is to identify issues and factors that need to be included in the CSM, so that they can be adequately modeled and, thus, considered in the evaluation of the remedial alternatives analyzed in the FFS. We also point out those areas in which the CSM is inadequate for the purpose of evaluating the remedial alternatives. Finally, the material in this section suggests an alternative way to think about an LPR conceptual model. This approach, in turn, leads us to conclude that the FFS Report evaluation of remedial alternatives has major shortcomings, preventing realistic evaluation of the remedial alternatives.

[1] While *EPA* [2007] does not appear to be referenced explicitly in the FFS documents we have examined, it is the CSM upon which the FFS Report modeling framework was based; as stated on p. 1-3 of the CSM: "*This CSM is intended to support the overall remedial investigation and feasibility study for the Lower Passaic River as well as to assist in the development of other tasks*". It is, therefore, treated as part of the FFS for purposes of this review. It is vital that *EPA* [2007] does not even mention the estuarine turbidity maximum or ETM that is central to the sediment and contaminant transport dynamics of the system. We note that minor changes were recently made to the CSM [Remedial Investigation Report, 2014, Ch. 6]; e.g., the estuarine turbidity maximum (ETM) is mentioned. However, reflecting the original CSM, ETM dynamics were only superficially incorporated into FFS models.

b. *The Qualitative understanding of LPR processes is inadequate*: Understanding the transport and fate of contaminants is not simply a modeling task. In complex estuarine environments like the LPR, successful and accurate modeling implies having a complete and accurate process-level CSM and quantitative understanding of processes. Achieving this understanding is typically an iterative exercise based on collection and analyses of data; application of physical, chemical, geological and ecological theory (and perhaps development of new theoretical understanding); interpretation of numerical models in light of data and theory; and presentation of results in the peer-reviewed literature. This iterative exercise allows key system properties and boundary conditions to be quantified via rigorous and transparent comparison of data and model results, so that a widely accepted qualitative understanding can be achieved. This has only been started here. Basic system properties are unknown or poorly characterized, for example, how tidal properties vary with river flow[2], or how the salinity distribution and density stratification respond to river flow, MSL, and tidal range variations.[3,4]

c. *The LPR is a complex river basin*: Because of the 'flashiness' of its flooding, its complex flood hydraulics, and its diverse sub-basins, the Passaic River basin is complicated, and the limited hydrologic data available raises obstacles for numerical modeling. This hydrology needs to be properly understood to define the 100 and 500-year floods in the LPR, which have been underestimated in the FFS Report (Appendix BI of *EPA* [2014]), as we discuss below. The northern parts of the basin drained by the Pompton River and its tributaries (the "Highlands") are steeper than the mainstem. They supply much of the flood waters that enter above Dundee Dam and produce high flows before mainstem flows entering from the south [*US Army Engineers New York District*, 1948]. There is a hydraulic control at Little Falls during floods that controls the timing of flood water delivery and backwaters the mainstem Passaic River. The severity of flooding for any given event also depends on the previous history of soil saturation and discharge. For these and other reasons, flows measured at Little Falls, the site of the longest gauge record, are not directly proportional to flows at Dundee Dam, the upstream boundary for the models used in the FFS Report.[5] Lower River tributaries can also rise very quickly, sometimes leading to a pulse in flow that leads the peak at Little Falls by a day or two. These factors have

[2]Typically, tidal amplitudes are decreased and phases increased (high water delayed) as flow increases, and this effect increases in the upriver direction [e.g., Jay and Flinchem, 1997], though more complex patterns may also occur.

[3]Tools for analysis of non-stationary tidal processes have been in the literature for more than a decade (e.g., *Jay and Flinchem* [1997], *Flinchem & Jay* [2000], and *Kukulka et al.* [2003]) and continue to evolve (e.g., *Jay et al*. [2011]; *Matte et al*. [2013]). They should be applied here to analyses of tides, currents, salinity, suspended particulate matter, and other properties that vary tidally.

[4]Our point is illustrated by Figure 9 of *Sea Engineering & HDR* [2011]. The position of the high tide salt front is considered only as a function of flow, whereas flow, tidal range and mean water level are all likely to be influential. The result is that, for flows of 20 to 80 cfs, the salt front position is uncertain by about four river miles. Also, the figure was constructed from model results, not data, and it has not been demonstrated that the model actually produces the correct salinity intrusion.

[5]We show in Appendix A that sediment transport estimates based on Little Falls data are not likely to be a good representation of the actual sediment input at the upstream boundary of the system. Differences between Passaic River flow at Little Falls and at Dundee Dam also need to be considered in estimating flood recurrence intervals. Unfortunately, there are only about 7 years of modern flow data available at Dundee Dam and no sediment load observations.

important consequences for sediment and contaminant transport and need to be analyzed (Appendix A).

d. *A gradualist conceptual model is inadequate*: Generic, gradualist conceptual models [e.g., *Meade*, 1972] based on regional generalizations are not appropriate for the LPR. In particular, the idea of a slow approach to equilibrium is likely incorrect. We suggest that important system variables have irregular trajectories in time and are affected by oscillations, non-stationarity, and disruptive change, as shown schematically in Figure 1. In a hypothetical world without human alterations and other perturbations like floods and extreme events, the system might approach equilibrium, as suggested in Figure 1a. The effects of decadal scale variations in flow and storm surge activity (as suggested by Fig. 1b) plus secular rise in MSL (Fig. 1c) mean that equilibrium is not achieved in practice. Large human alterations (e.g., dams, filling of wetlands, deep dredging of the LPR beginning about 1930, and the more recent dredging in Newark Bay) impose discontinuities in the trajectory of system variables, making equilibrium even more elusive. In concrete terms, sediment deposition and erosion patterns respond strongly to flood and surge events and are sensitive to depth changes caused by rising mean sea level (MSL) or dredging. Because the magnitude of extreme events has been underestimated, none of these factors have been correctly considered in the CSM and FFS Report analyses, and MSL rise has been completely ignored. Given the number and complexity of alterations to the LPR, it is challenging to separate the impacts of engineering modifications from those associated with climate change and other larger-scale processes. Either of the two more intrusive remedial alternatives (Alternatives 2 and 3) amount to another major, human-imposed discontinuity in system trajectory. To evaluate the consequences of such a large alteration using the FFS Report suite of numerical models (some of which are not fully mechanistic), it is first necessary to demonstrate that the models can actually reproduce the historic trajectory of the system through one or more major alterations. Because of the importance of extreme events (major floods and storm surges) to evaluating remedial alternatives, it is also important that the models employed be able to accurately model extreme events. This has not been done. As discussed below, the FFS Report models demonstrate only a rather modest ability to predict bathymetric change between 1994 to 2010, a period that included no major human alterations. The FFS Report does not, therefore, make a convincing case for its ability to evaluate and distinguish the remedial alternatives. Even if the models' predictive skills levels were improved, the stochastic and non-stationary nature of the system (below) requires a different modeling strategy. The timing and nature of extreme events and man-made interventions cannot be predicted decades in advance. Thus, the deterministic modeling approach used in the FFS report, which assumes a single condition in 2059 for each alternative, is quite likely to be inaccurate or biased. We suggest instead that a scenario-based approach that includes an ensemble of likely events and outcomes (a so-called 'spaghetti-plot' approach) is needed to encompass the possible range of final states for each remedial alternative and to accurately convey the differences in outcome (if any) among the four remedial alternatives.

e. *The LPR as a highly non-stationary river-estuary*: The LPR is a small, highly altered river-estuary, rather than a partially mixed, coastal-plain system (as

suggested by *Sea Engineering & HDR* [2011]), and needs to be understood and modeled as such. In particular, river flow fluctuations play a larger role than in most coastal plain estuaries and are highly non-stationary on daily, monthly, annual, and even decadal time scales. Stationarity is a precondition for morphodynamic equilibrium, but there is no time scale over which forcing and boundary conditions (river flow, storm surge, tides) have been constant, as discussed in our Appendix B. For these reasons, circulation, sediment transport, contaminant transport processes and morphodynamic evolution are also stochastic and non-stationary. As such, they should be modeled using an approach that accounts for stochastic behavior.

There are other implications of the river-estuary nature of the LPR. As discussed in *Jay and Smith* [1988] and *Jay et al.* [2000], two important characteristics of a partially mixed estuary are that: (a) stratification is intermediate between weakly and highly stratified; and (b) the river outflow is small relative to the two-layer mean circulation. Both are likely to be true for the more seaward parts of the system during low-flow periods (cf. Figs. 6 and 8a of *Chant et al.* [2011]) when sediment is retained. During high-flow periods, stratification is high up to the salinity intrusion limit, and the freshwater flux is large relative to the mean flow (cf. Figures 6 and 8b of *Chant et al.* [2011]), as is typical in a river-estuary. Sediment is exported toward Newark Bay during these periods, which *Chant et al*. identify with flows >30-40 m^3/s.[6] In fact, many river estuaries change from partially mixed to highly stratified seasonally, as river flow varies. As such, they have extremely high variability with transitions between residual flow modes and density types on seasonal and even tidal monthly time scales (*Jay and Smith* [1990]; *Jay and Musiak* [1994]). Similarly, the LPR salinity distribution and estuarine turbidity maximum (ETM) characteristics are highly variable, depending on river flow [*Chant et al.,* 2011]). Also, the tidal characteristics of a tidal river vary with flow, often quite strongly (*Godin* [1999]; *Jay and Flinchem* [1997]), and this aspect of the system has not yet been defined. The large degree of system variability imposes a need for extensive data collection to define the scope of system processes that need to be modeled, and to allow proper model calibration. As we discuss below, adequate data are not available for model calibration (particularly long-term monitoring data), and some data that should have been used have been overlooked.

f. *The along-channel gradient of dominant forcing processes*: An improved conceptual understanding of the spatial and temporal variability of forcing is required to understand the effects of extreme events and improve LPR model validation and skill. As is typical of river estuaries, the LPR exhibits a strong gradient in system energetics and forcing processes, the distribution of which varies seasonally with river flow and (to a lesser degree) as tidal range varies over the tidal month [*Giese and Jay*, 1989; *Jay et al.*, 1990]. We summarize these forcing factors in Figure 2a: the dominant sources of mechanical energy in the system are tides, surge, river inflow, and wind waves. Wind waves are important in Newark Bay and probably also over tidal flats near the mouth of the LPR; wind wave erosion of mudflats can occur even with 10-20 cm wind waves [*Talke et al*., 2008]. Tidal forcing is important throughout the system, but its

[6]Their mooring was at about RM-3, and the value of 30-40 m^3/s for export pertains to the Harrison Reach. Likely, higher flows are needed to actually export material to Newark Bay.

importance relative to fluvial forcing decreases upriver. The importance of fluvial energy increases in the landward direction and is reflected in elevated water levels upriver during periods of high flows. Storm surges are episodic, but can be highly energetic on rare occasions. As is typical of US East Coast river-estuaries (cf. *Ralston et al*. [2013]), the largest floods and surges likely play a large role in shaping sedimentary features of the system. Estuarine responses are, however, system-specific, and we know little about how the LPR responds. Loss of wetlands and channelization have removed buffering of extreme events, and a narrower, deeper and more hydraulically efficient channel has likely increased tidal ranges relative to the early 20th Century. Energy is dissipated by turbulence, which is produced primarily in two places: (a) at the bed throughout the system, and (b) in the density interface in stratified parts of the system. Upstream of salinity intrusion, interfacial mixing is absent. Based on measurements in other river estuaries, energy loss at the bed is likely to be larger than interfacial mixing in the mesohaline part of the system except perhaps during neap tides (*Kay and Jay* [2003a,b]; *Ralston & Stacey* [2005]). Two-layer estuarine circulation is not an independent source of energy. It is driven by the density differences between fresh and salt water (gravitational circulation [*Hansen and Rattray*, 1965]) and indirectly by the tides (internal tidal asymmetry [*Jay and Musiak*, 1994, 1996] and tidal nonlinear circulation [*Ianniello*, 1977]). While gravitational circulation is likely to be dominant in Newark Bay and the deeper parts of the LPR below RM-2, *Chant et al*. [2011] point out the role of internal asymmetry further landward. Variations in the distribution of the gravitation circulation and internal asymmetry contributions to two layer flow typically vary in a complicated manner with river, tidal range, and along-channel position, and will change as depths change (e.g., due to dredging or MSL rise). These processes have not been sufficiently analyzed in the LPR to determine whether the FFS Report models function correctly. A comprehensive analysis of water level, salinity and current variance is needed to quantify the spatial variability described schematically in Figure 2a (cf. *Geise & Jay* [1989]; *Jay et al*. [1991]; *Geyer et al.* [2000]; *Ralston et al.* [2008]).

g. *Factors producing erosion*: The strong spatial gradients in tides, surge, waves, and river flow result in space and time variability in factors driving erosion (Fig. 2b). This should be recognized correctly within the CSM and quantified via data analysis to help define an appropriate model scope (for example, wind waves are discounted without recourse to actual data from tidal flats, and storm surge/river floods are incorrectly considered to be uncorrelated). Tides, storm surge and waves are likely dominant in Newark Bay (the latter primarily in shallow areas), but the influence of wind waves probably decreases and becomes more localized in the seaward few miles of the LPR (again, however, this supposition should be verified with data). In the middle stretches of the LPR, surge, tides and river flow are all likely important. Further landward, the influence of surge and tides decreases, leaving river flow as the dominant factor. As with the variability in forcing factors shown in Figure 2a, the factors driving erosion in Figure 2b vary strongly with the strength of river flow and with tidal range, so that the conceptual boundaries shown change position as external forcing changes. While surge and wind waves are episodic, there is a significant (and heretofor unrecognized) correlation between storm surges and river flow (below and Appendix B). Moreover, bed shear stress varies with the square of total velocity due to all factors (tides, flow, surge and waves), and dissipation varies with the cube of

velocity. Hence, fine sediment transport (which varies with a power >1 of bed shear stress; cf. Table 4-10 of *Mehta & McAnally*, 2008) is highly nonlinear, and extreme events can have an inordinate influence on sediment transport in a strongly non-stationary system like the LPR. An analysis of bed shear stress or dissipation based on data is needed to quantify the variability that is shown schematically in Figure 2b.

The strong spatial variability of the dominant forcing factors interacts with extreme events to produce spatially variable risk. In river dominated areas, peak stress is closely related to peak flow (and hence peak water levels) during a flood. This is no longer true in the mid and outer estuary. As the river flow velocity decreases in the downstream direction, maximum bed stress is forced primarily by how fast water level H changes with time t (see Appendix B). Fast moving storms with surges of short duration have larger maximum dH/dt values. Thus, a storm like Hurricane Gloria in 1985 may actually cause as much, or more, erosion than slower-moving storms like Hurricanes Sandy (2012) or Donna (1960), despite a lack of catastrophic flooding (see Appendix B). Particularly erosive conditions occur when a large ebb tide coincides with an ebbing storm surge and significant river flow, as occurred during Hurricane Irene (2011). When storm surge coincides with stratified or partially mixed conditions, the water column velocity profile—and also bed stress and mixing—will be different between ebb and flood, and careful analysis is required to assess sediment concentrations and transport. Thus, the 100-year bed shear stress-event is not the same as the 100-year flood or storm surge event (measured in terms of inundation), and multiple design events should be modeled to account for various combinations of erosion and flooding, spatial variability, and variations in the relative timing of the surge and the flood peak. Defining the 100-year or 500-year event also requires considering the joint probability of storm surge, tides, and river flow at various points along the length of the system. Different methods of modeling multivariate probability distributions (such as the Copula-based methods; see Nelson [1999]; Schölzel [2008]; Salvadori et al. [2011], and Gräler et al. [2013]) have been developed and are increasingly used in hydrologic and climate sciences [e.g., Gräler et al., 2013]. These approaches address the basic question: what is the probability of x, y, and z occurring together jointly? In coastal regions, the copula method has been applied to erosion problems in which multiple variables influence erosion risk [Corbella & Stretch, 2012]. A simple methodology for assessing the combined influence of river flow, storm surge, and tides is discussed in appendix B, and can be used to define the return period of stress events.

h. *The importance of historic changes*: The CSM should recognize that estuarine systems typically follow a trajectory that results from a combination of direct human engineering alterations to the system and larger scale factors like the effects of climate variability on system hydrology, and MSL change. In the LPR, an overwhelming degree of engineering alteration (e.g., channel dredging and loss of the floodplain) has probably accentuated river-flood water level variations and likely produced greater landward sediment fluxes (by changing tides and increasing depths) over time. Because the LPR has few remaining wetlands, its hydrodynamic processes are different from classical coastal plain systems, and different from their historic functioning. Determining an ensemble of likely future states of the system without major intervention (Alternative 1) is necessary as a

benchmark against which to compare the three active remedial alternatives (Alternatives 2-4). Understanding where the system is headed (in terms of trajectory) implies knowing where the system has come from, but this system history is only partially understood. The system was likely more retentive of sediment from ca. 1910 to 1970, when channels were maintained to a deeper depth than at present, and dredging removal was an important part of the sediment budget. Tidal amplitudes in both New York Harbor [*Talke et al.*, 2014) and the LPR have changed due to non-astronomic factors and continue to change in ways that have not been defined.[7] System hydrology is evolving due to climate change, will continue to evolve, and may be influenced by the North Atlantic Oscillation or NAO (see discussion below). Clearly, sediment transport patterns have changed and will continue to do so in the future. The diverse effects of non-stationarity on the four remedial alternatives need to be defined, yet it has not been shown that the FFS Report models can adequately model the (non-stationary) past or even the present. Predictive skill should be proven by demonstrating that the FFS models: (a) can reproduce historic shoaling and contaminant distribution patterns from 1930 to the present; and (b) can statistically reproduce processes such as measured salinity intrusion, tidal currents, non-linear river-tide interaction, river slope, and sediment patterns under a variety of forcing conditions (river flow, tides, storm surge). Once it is confirmed that the model can reproduce the relevant historic patterns and processes, it can be used in a prognostic mode.

i. *Future LPR evolution*: As MSL rises, further sediment deposition will occur due to ongoing natural processes, but the possible processes involved are stochastic. Depths will likely continue to decrease, unless this trend is altered by dredging, because the shoaling rate exceeds the rate of MSL rise. This will contribute to burial of contaminants without resorting to extensive dredging operations that have considerable potential for redistributing contaminants. At the same time, it is necessary to understand the impact of likely future extreme events (in a stochastic sense) on the four remedial alternatives. Finally, LPR dynamics are complicated by the complex patterns of rivers and channels in Newark Bay and New York Harbor that influence the system from the marine side. These systems continue to be altered by dredging and MSL rise. An example of the impact of changes in Newark Bay on the LPR is shown in Figure 4.2 of FFS Report Data Evaluation Report No. 2, “Boundary Conditions”. Modeled salinity intrusion and residual currents are shown for 1949, 1966, 1976, 1995 and 2008, and considerable changes are suggested. There is no demonstration, however, that the model results are correct, they are not fully interpreted, and the changes in currents near the bed do not appear to be consistent with standard estuarine scaling (e.g., *Burchard & Hetlan*d, 2010; *Geyer & MacCready* [2014]). This apparent inconsistency does not mean that the model is necessarily wrong, but it does suggest that validation and interpretation are needed.

j. *Impacts of the rapid rise of MSL on future LPR evolution* : Predicted MSL rise will tend to cause the system to remain net depositional. Our calculations are based on National Oceanic and Atmospheric Administration (NOAA) data

[7]Other factors being equal, Green’s law says that a narrower, deeper channel will have larger tides. While Green’s law is strictly applicable only to frictional waves, it is still qualitatively correct in narrow, convergent channels with friction [J*ay*, 1991].

for Bergen Point (NOAA station 8519483, http://tidesandcurrents.noaa.gov/waterlevels.html?id=8519483). They suggest a rate of MSL rise of ~4.7mm/year (Fig. 3a), about 10-15% of the system-wide, long-term average sedimentation rate determined by radioisotope analyses of cores [*Erickson et al.*, 2007]. The regional MSL rise for New York Harbor exceeds the global rate due to about 1mm/year (Fig. 3b) of land subsidence. It is unrealistic to simulate the period out to 2060 without recognizing MSL rise for several reasons:

i. MSL rise will tend to prevent achievement of morphodynamic equilibrium, and the LPR will continue to evolve. Over 45 years out to 2059, MSL will rise >0.2m, even if the MSL rise rate does not further increase. There are strong indications, however, that MSL rise is accelerating (*Jevrejeva et al*., [2008]) and that MSL rise will likely be considerably more than 0.2m by 2060. Rising MSL tends to prevent achievement of morphodynamic equilibrium, and the CSM should recognize that this substantial change in system depth will likely be compensated by additional sediment deposition. Because the shoaling rate currently exceeds the rate of MSL rise, further sediment deposition beyond MSL rise will also likely occur. In turn, this will cause channel depths to further decrease, unless this trend is altered by dredging. These two factors—MSL rise and natural shoaling— contribute to burial of contaminants, without resorting to extensive dredging operations that have considerable potential for redistributing contaminants. Hence, if the combined, on-going deposition from MSL rise and natural processes are properly modeled, simulated near-surface contaminant levels in Alternative 1 and 4 will likely be lower in 2059 than present model results show. In turn, the modeled contamination differences between different FFS options may diminish, changing the relative benefits of different options.[8]

ii. Regional storm-surge threat is increasing: This increase should be considered, along with rising MSL, in formulating and modeling the remedial alternatives. Specifically, the 10-year storm-tide level for New York Harbor has increased by ~0.7m (including MSL rise) or 0.3m (excluding MSL rise) since the 1850s (*Talke et al*. [2014] and Fig. 4). In addition to the secular increase, there are multi-decadal changes in surge threat that are related to the North Atlantic Oscillation or NAO, which is calculated from the atmospheric pressure gradient between the Azores and Iceland (Figs. 4 and 5). Negative NAO phases are correlated with higher than normal storm surge and storm tides [Talke et al., 2014]. By contrast, positive NAO phases are associated with higher East Coast precipitation (*Hurrell* [1995]; *Durkee et al*. [2007]), and hence affect Passaic River flood incidence. Such teleconnections do not provide precise predictions of the future, but do inform the likely range of events. Combined, secular trends and long-term fluctuations should be considered for assessment of risk during the (long) construction time predicted for the remedial action. As we note below, the construction period brings with it an enhanced risk of accidents that will spread

[8]We also argue below that the benefits in the form of reduced concentrations predicted by the more intrusive remedial alternatives are highly uncertain.

contaminants. The longer this period lasts, the greater the threat of an accident that causes serious contamination.

iii. Other Engineering alterations: Engineering changes may also alter local MSL and/or the water level forcing. The FFS Report does not consider the implications of possible large-scale human interventions into the New York Harbor system over the next 50 years or their effects on the fate and transport of contaminants in different scenarios. A flood tunnel for the Passaic River, now under consideration by the US Army Engineers [*US Army Engineers New York District and State of New Jersey Department of Environmental Protection*, 2013] would greatly reduce flooding and alter LPR sediment transport. The New York region will likely implement plans to ameliorate storm-surge threats over the time horizon of the FFS report (to 2059). If a storm surge barrier is built, the experience in the Rhine River delta [*Vellinga et al.,* 2014] suggests that: (a) tidal heights and currents could decrease significantly (by 10% or more); (b) mixing and turbulence will decrease, as a result; (c) extreme surge events will be reduced in magnitude, reducing erosion and sediment export; and (d) local MSL will be altered. Decreased mixing would likely cause the salt wedge and ETMs to move upstream (e.g., *Jay & Smith*, [1990]; *Talke et al.*, [2009a]; and *Chant et al.* [2011]), perturb system morphodynamics, and alter the morphodynamic equilibrium state. As explained below, increased upstream transport will likely result in the recontamination of the LPR by Newark Bay sediments. Future human-induced alterations should be taken into account in some way, since the present assumption—no change—is implausible based on historic precedent.

k. The FFS Report considers the effect of storm surge and river floods separately, and it implicitly assumes that the 100-year flood event includes no significant storm surge component: The LPR is shaped in part by periodic large floods and storm surges, often in connection with one another, but the FFS Report does not consider long-term trends and non-stationary patterns in storm surge and river flow, and incorrectly assumes that the two will not interact. The differences between the FFS alternatives may diminish when extreme events are correctly modeled and uncertainties in model outcomes are considered. See Appendix B for a definition of extreme events and for a discussion that shows how surge and floods interact.

l. *ETM processes are not well understood*: The ETM works to focus both contaminants and ecosystem activity, and provides a pathway for contaminant uptake into the ecosystem. However, the CSM [EPA, 2007] does not mention the ETM, though it is briefly mentioned in the 2014 CSM (RI report, 2014, Ch. 6). Hence, models used in the FFS (designed based on the original CSM) were not designed or calibrated with ETM dynamics in mind; in fact, the Fate and Transport model still fails to consider ETM processes [FFS Report Appendix B-III, 2014]. Thus, data collection and analysis was not optimized to monitor and understand ETM dynamics and related phenomenon such as salinity intrusion, lateral circulation and exchange with Newark Bay over long time-scales[9]. The

[9]Chant et al., [2011] recognized that ETM processes are crucial to LPR contaminant dynamics, but this realization appears to have been too late to be incorporated in a substantial manner into FFS analyses.

belated recognition of ETM processes means that the resulting assessments (e.g., FFS Report Appendix BII [2014]; *Sea Engineering & HDR* [2011]) are *ex-post-facto* rather than by design, and available data cannot adequately verify models or provide a proper conceptual understanding. Key ETM properties (e.g., centroid position and concentration, aggregate properties, horizontal length scale, and vertical distribution of sediment) have not been described (from observations) as a function of tidal range and river flow; nor have models been analyzed in such a way as to describe and explain them, and only qualitative comparisons of models and data are possible. The FFS reports provide only a rough idea of how ETM position corresponds to salinity intrusion. Is the ETM always at the salt front (defined by the 0.5 or 2 PSU contour), or does it become attached to terrain features, so that it is less mobile than the salinity distribution over the tidal month, or with river flow variations? Given that LPR contaminant transport is closely connected to the ETM, and that salinity distribution is widely used as a surrogate for the ETM position, these are crucial knowledge gaps. Once ETM processes and properties are better understood, the implications of ETM processes for remediation and system management should be considered more fully. For example, how will changes to system depth affect trapping of sediments (some contaminated) and recontamination after remediation? A first step is to both qualitatively and quantitatively understand ETM processes; this is currently incomplete for the LPR (see Theme 4 below). Next, modeling tools must demonstrate a clear ability to reproduce the measured ETM processes under a variety of conditions. This ability has emphatically not been demonstrated, which renders FFS Report conclusions speculative, not predictive.

m. *There may be multiple ETM in the system*: The CSM should recognize that there may be other types of turbidity maxima in the system in addition to the classical one at the upstream limit of salinity intrusion [Festa & Hansen, 1978]. Diverse types of ETMs exist, each corresponding to a different kind of “turbidity trap” or trapping process (e.g., *Allen et al*. [1980], *Fain et al.* [2001], *de Jonge* [1995], North et al., [2004]; *Huijts et al.*, [2006, 2009], *Kessarkar et al.* [2009]; and *Chernetsky et al*. [2010] , [Winterwerp, 2011]), and many systems have multiple ETMs (e.g., *Allen et al*. [1980], *Fain et al.* [2001], *Chernetsky et al.* [2010]). Amongst the relevant processes are: two-layer mean circulation (gravitational circulation plus internal asymmetry); tidal pumping; settling lag and scour lag; tidally variable flocculation; barotropic tidal-wave distortion by overtides that can trap material landward of salinity intrusion; wind and wind waves; and lateral effects (e.g., erosion from point bars and tidal flats). Lateral effects are likely to be quite prominent in a sinuous river estuary like the LPR, but have not been discussed in the CSM. FFS model results suggest that the LPR sometimes has multiple ETM, but no analysis or discussion is available to explain the occurrence of multiple ETMs or the mechanisms involved. Thus, for example, Figure 4-7 of Appendix BII [*EPA*, 2014] shows two maxima for a situation with a decreasing river flow of 40-50 m^3/s. One extends from RM-3 to RM-8, while the salt front (1 PSU) is at about RM-3.7. Most of this ETM is landward of salinity intrusion. There is a second smaller ETM at RM-13 to 15, well upstream of salinity intrusion; this ETM could be caused by localized erosion, lateral effects and/or barotropic wave distortion. Also, the data available for this date suggest higher sediment concentrations at about RM-6.8 than modeled. Another example of multiple predicted ETM is provided by Figure 12 in *Sea Engineering & HDR* [2011], for very low flows. In this case, the strongest ETM is at about RM-11 to 13, with the

salt front (0.5 PSU) at about RM-13. There is a second, somewhat weaker, ETM extending from RM-2 to 6. In this case, both ETM are seaward of the limit of the salt water intrusion, whereas they were mostly landward of salinity intrusion in the higher flow example; the processes causing this distribution of suspended particulates remain unanalyzed. These differences clearly illustrate that an adequate conceptual understanding of LPR ETM dynamics has yet to be developed. Finally, modeled sediment concentrations are generally higher in Newark Bay than in the LPR (at least seaward of RM-10) in Figure 12 of *Sea Engineering & HDR* [2011]. If the lower two miles of the LPR are deepened, these higher concentrations (with their contaminant load) will likely be transported into the LPR. As noted elsewhere, it is unclear whether FFS Report models correctly reproduce horizontal sediment fluxes at the Newark Bay-LPR boundary.

n. *Contaminant dynamics and transport*: The only type of erosion considered by the FFS models is uniform, shallow erosion distributed over large grid cells; however, the CSM should consider other, more localized, and smaller scale processes. Contaminant levels throughout the lower 11 miles remain elevated above statutory levels, despite system-wide sedimentation rates of 3.8 (average) and 3.7 (median) cm/year as determined by radioisotope analyses of 107 cores [*Erickson et al*., 2007]. The reasons for this situation are not adequately explained in the CSM. As noted in *Chant et al*. [2011], a flow event in April 2005 with a peak flow at Little Falls of 330m^3/s resulted in water column sediment concentrations of ~250mg/l. This concentration implies no more than about 2 cm erosion from the bed, if uniform erosion were supplying the material. However, that upper limit does not (as *Chant et al*. note) consider supply from upriver. The sediment rating curve for Little Falls developed in Appendix A suggests that an average of about 1000 metric tons/day of sediment was supplied to the system over a 12 day period, with a maximum load of >2000 metric tons/day at the time of the *Chant et al*. [2011] survey.[10] If we assume an ETM that is 5km long with an average cross-sectional area of 500m^2 (a rough estimate based on Figure 1 of *Chant et al.* [2011]), and temporary retention of 1000 metric tons of the upriver supply of sediment in the water column, then all of the observed 250 mg/l could derive from upstream supply.[11] Obviously, an exchange of sediments occurs at the bed, and at least some localized erosion to deeper depths likely occurred, so that part of the sediments in the water-column were likely derived from the bed. Still, a large amount of the sediment in suspension in April 2005 probably originated from upriver, and less than 2 cm was eroded on average from the bed. Even the farthest upstream reaches considered by *Erickson et al*. [2007] have average sedimentation rates of 2.0 to 3.8 cm/year and median rates of 2.8-2.9 cm/year. Thus, it is likely that less than a year of sediment accumulation was eroded by the 2005 event, and uniform, large-scale erosion from the bed cannot be invoked as the cause of persistent contaminant levels in the water column and near-surface sediments (top 15 cm). The CSM suggests that bioturbation and

[10] As discussed in Appendix A, the loads estimated from the rating curve in FFS Report Appendix BII, Figure 3-1 [*EPA*, 2014] are ~20% higher than those from the CARP Report rating curve [*HydroQual*, *Inc*. 2007] ~30% lower. While the actual sediment load during storms remains highly uncertain, the point remains – whichever estimate of sediment load is used, much of the material in the water column during the storm event came from upriver.

[11] This estimate can be qualified in various ways, e.g., by assuming some fraction of the supply is sand. Nonetheless, suspended sediment is likely retained in the ETM for more than one day, and there are various downriver sources of particulates (e.g., lower-river tributaries, CSOs and WSOs) that have not been included.

sediment reworking accounts for high surface concentrations, and model this with a constant vertical diffusivity in the upper part of the bed (see section 2.6). A constant bed-diffusion coefficient does not adequately model the processes bringing contaminants to the surface, which are likely to be very patchy and dependent on sediment texture. There are a number of other factors that might cause elevated contaminant levels that should also be considered. These include scour behind bridge piers and other flow obstructions; scour pits in fine sediment areas (cf. comments by J. Best and M. H. Garcia); inputs from CSOs (combined sewer outfall s) and SWOs (storm water outfalls); release of material from wetlands during periods of elevated water levels; thalweg migration; and exchange with Newark Bay. Subtle adjustments of channel alignment during periods of high flows are a normal fluvial process, and a large adjustment would not be needed to release contaminants. The flip-side of unrealistically modeled erosion is that model deposition processes are also unrealistic (e.g., due to thalweg migration); this most likely prevents the model from adequately simulating contaminant burial and recontamination after remedial action. Unfortunately, information is not available to distinguish between these mechanisms as the primary source of contaminants in the water column and in near-surface sediments. It is vital to know this, because there are strong implications for sediment and contaminant transport modeling, and for the choice of remedial alternative. As discussed below, the grid resolution of the models used by the FFS Report [described in *EPA*, 2008, and Appendices BII and BIII of *EPA*, 2014] is quite coarse relative to the scale of sediment and contaminant transport processes, and CSO and SWO inputs are not realistic. Accordingly, the only process potentially relevant to the spread of contaminants described by FFS models is relatively uniform, shallow erosion, yet the observations of *Chant et al*. [2011] noted above do not suggest that this is the primary process moving contaminants for flows <330m^3/s.

In summary, the FFS Report model has implicitly chosen a dominant mechanism (uniform scour at a scale at least as large as the rather coarse grid cells) as the major source of contemporary movement of LPR contaminants and made use of models that cannot or do not represent other relevant mechanisms. Yet uniform, large-scale scour is unlikely to be the major reason why contaminant levels remain in excess of statutory limits. The reasons for persistently high contaminant levels in the upper 15cm of the bed should be carefully reconsidered in the CSM and should be used to evaluate whether models are including the most relevant processes. Moreover, the correctness of assuming a constant contaminant diffusivity in the bed should be reevaluated.

o. *The LPR sediment mass budget is poorly defined*: The CSM should more rigorously quantify and describe the sediment mass budget in the LPR, as a way of identifying key sources of uncertainty, identifying historical changes, and defining the system trajectory. As shown conceptually in Figure 6a,b, the LPR system sediment mass budget consists of terms representing inputs and outputs of cohesive material and sand/gravel at system boundaries (both fluvial and at Newark Bay). In addition to fluvial loads, boundary inputs presently include those from CSOs and SWOs, and from atmospheric deposition; historically, dredging removed large amounts of sediment and LPR industrial operations produced particulate inputs. While the fluvial inputs at the upstream boundaries (from the Passaic River and its tributaries) would seem to be the easiest terms to define,

we argue below (Appendix A) that, when the large differences among the various rating curves are considered, the sediment input to the LPR from the mainstem Passaic River at Dundee Dam is known only within a factor of 1.5 to 2× during high flow events, though the uncertainty in long-term averages appears to be about 25-50%. Results of the Sediment Transport model (and therefore, the Contaminant Fate and Transport model) are very sensitive to fluvial sediment input, and this key uncertainty impairs the ability of FFS models to evaluate and distinguish the remedial alternatives. Moreover, the two-way exchange of sediment with Newark Bay (also highly contaminated) is poorly known. There is export from the LPR to Newark Bay during high-flow events, but there is also import during low-flow periods. Knowing these fluxes and how they will change is vital to determining the degree of recontamination that will occur in the deeper channel envisioned in Alternatives 2 and 3. To illustrate just how uncertain the net flux to Newark Bay is, we reproduce Table 1 from *Shresti et al.* [2014] as our Table 1. Note that estimates of the annual net export of sediment from the LPR to Newark Bay vary by a factor of ~6.4×. Yet without a quantitative understanding of this key process, it is not possible to evaluate remedial alternatives, because the degree of recontamination cannot be realistically determined except from models that have not been demonstrated to accurately model this process.

Table 1: Estimates of Sediment Export from the LPR to Newark Bay

Table 1. Passaic River sediment loading rates.

Source	Load (MT/year)	Analysis
Table 4-7 in [46]	7440	Solids balance [1] (0.6 MT/yard^3)
page 1 in [22]	17,000	Sediment flux data [2]
Table 10 in [18]	18,100	Sediment flux data [2]
Table 4-7 in [46]	21,360	Chemical balance [3] (0.6 MT/yard^3)
page 1 in [47]	22,700	Sediment flux data [2]
page 35 in [16]	30,000	Sediment flux data [2]
Table 5-3 in [30]	30,790	Sediment flux data [2]
Table 3-5 in [15]	36,109	Sediment runoff data [4]
Table 3 in [31]	47,456	Sediment flux data [5]

[1] Based on measured sediment flux data; [2] Based on a solids balance of sediment loads through the Dundee Dam from Lowe *et al.* [31] with deposition of 2.54 cm/year (1 in./year) along the Passaic River; [3] Based on the chemical mass balances of 2,3,7,8-tetrachlorinated-*p*-dibenzodioxin (TCDD) and total TCDD of the solids mass balance in note 1; [4] Based on a sediment yield of 39 MT/km^2/year for the Passaic River watershed; [5] Based on measured sediment flux data; however, it is not clear if these are tons/year or MT/year.

p. <u>*Long-term changes in the sediment budget*</u>: The CSM should describe how long-term changes to ETM processes and sediment trapping lead to a changing (non-stationary) sediment budget over time, and how this affects the system trajectory. Our preliminary representations of the historic (1913 to 1983) and contemporary (1984 to 2013) LPR sediment mass balances (Figs, 6a,b) are based on existing literature and Appendix A, but are not intended to be authoritative. They show, rather, that though the sediment mass balance has evolved greatly over time, significant uncertainties of 50-80% are found even for fluxes calculated over

decades. The large range of possible values has important consequences, since the actual values (much smaller? much larger?) have implications for the pathways and sources of recontamination that may occur after remediation. Historically, import from Newark Bay and dredging removal were the dominant factors with import from fluvial sources and export to Newark Bay distinctly secondary (Fig. 6a). At present, imports and exports to Newark Bay are smaller, but material imported from Newark Bay is necessary to provide the observed rate of shoaling (Fig. 6b). Annual export from the LPR to Newark Bay is equivalent to about half the supply from fluvial sources, though much of this is deposited landward of Newark Bay, and the material exported in any given year is not necessarily the same as the material supplied by the river. These multi-decadal average pictures disguise considerable inter-annual variability that is even less-well understood. One lesson from comparison of Figures 6a and b is that deepening of the LPR (in remedial Alternatives 2 and 3) will result in a return to a sediment mass balance more like the historic situation (Figure 6a); hence, more sediment will be imported from Newark Bay, along with its load of contaminants. Further conclusions require a more thorough analysis, which is urgently needed to facilitate a comprehensive analysis of the remedial alternatives.

q. *The CSM should explain the variability of sediment fluxes with position, river flow, tidal range, and perhaps atmospheric forcing*: Chant et al. [2011] (their Fig. 13) and Sea Engineering & HDR [2011][12] have made an initial attempt to quantify along-channel sediment fluxes (their Fig. 18), but only for a limited stretch of the LPR between about RM-2 and RM-4. This analysis is a very good starting point, but not the desired endpoint, for several reasons. First, fluxes are a strong function of position, but Engineering & HDR combined data from multiple different along-channel positions without accounting for along-channel variations. Also, the only independent variable in their analysis is flow, though *Sea Engineering & HDR* [2011] reproduce Figure 12 of Chant et al. [2011], which shows that tidal range also contributes to variability; this may account for part of the considerable scatter at the low-flow end of Figure 18 of *Sea Engineering & HDR* [2011]. Few data are available for elevated flows; for example, flows higher than 100 m^3/s are represented by only two data points. These isolated points emphasize that large fluxes occur during high flow events but are not sufficient to characterize these fluxes – for example, does tidal range matter during high flow periods, and is there hysteresis in the fluxes in the estuary, as there is at Little Falls (cf. Appendix A)? A primary attempt to compare observed vs. modeled fluxes is provided in Figure 4-15 of the FFS Appendix BII [EPA, 2014]. While results suggest there is a qualitative resemblance between the two, no direct statistical comparison is made to quantify the resemblance. The sediment fluxes predicted by ECOM and ECOMSED should be thoroughly vetted against data before these models are used to evaluate the remedial alternatives.

1.3 The FFS Report Model Framework is Inadequate and Inappropriate:

The FFS uses inadequate models to evaluate the alternatives. The combined Hydrodynamics, Sediment Transport, and Fate and Transport models are imprecise as

[12] Like the CSM [*EPA*, 2007], we consider the *Sea Engineering & HDR* [2011] analysis to be an implicit part of the FFS Report. This report should also include a full accounting of flux calculation methods, as the results are highly dependent on the methods used [cf. *Jay et al*, 1997].

implemented and lack an appropriate framework for analysis of uncertainty and bias. Thus, a very large structure of inference (i.e., evaluation of alternatives) has been erected on a fragile modeling framework that is unable to demonstrate statistically significant differences among the four remedial alternatives that have very different costs and collateral impacts, as described in the FFS Report. An overview of the modeling efforts suggests that:

a. The modeling approach and architecture are outdated: *Box and Draper* [1987] famously said: "*all models are wrong, but some are useful.*" The question implicit in this statement ("does this model work well enough to be useful in answering the questions at hand?") is even more crucial when the "model" is actually a system of models that build sequentially upon one another, with an inevitable accumulation of uncertainty and bias. We visualize the accumulation of errors in chained models schematically in Figure 7a. Environmental inputs and parameters are uncertain at every step, but errors also accumulate during a simulation, such that the uncertainty of outputs is greater than the uncertainty of inputs.[13] To correctly estimate errors for each model in the hierarchy, the uncertainty and bias associated with outputs from prior models must be considered at each step in the modeling process (Fig. 7a).

Thus, a key aspect of determining whether a modeling system is useful lies in the way in which these biases and uncertainties are quantified and minimized. It has been recognized for more than a decade that it is necessary to treat propagation of bias/uncertainty through the chained models to the final predictions as an integral part of the modeling architecture, not as an *a posteriori* addition thereto [e.g., *Reckhow*, 1999; *Reckhow and Chopra*, 1999; *Malve et al.*, 2005; *Arhonditsis and Brett*; 2004; *Borsuk et al.*, 2004]. Thus: "*Uncertainty analysis of mathematical models has been a central topic in aquatic ecosystem research, and there have been several attempts to rigorously assess model error associated with model structure and parameter uncertainty [Omlin and Reichert, 1999; Brun et al., 2001; Reichert et al., 2002; Chen et al., 2007]*" (from *Zhang and Arhonditsis* [2009]).[14] This is particularly important in the modeling of ecosystem and biogeochemical processes for which exact equations cannot be formulated, so that any model is, by necessity, statistical or heuristic [*Kawamiya*, 2002]. *Aguilera et al*. [2011] recently reviewed the field, described a variety of Bayesian approaches, and provide 76 references to applications in water and water resources. *Chen and Pollino* [2012] provide additional references and define the current practices that make up the state of the art.

To demonstrate the current state-of-the-art, we quote a meta-review of mechanistic aquatic biogeochemical modeling. With respect to the need for rigorous error analysis of linked models, *Arhonditsis et al*. [2006] state:

[13]Model uncertainty and bias also accumulate over time, but that is not our point here. Here we refer to factors such as algorithmic and parameter uncertainty, finite grid resolution, and simplification of the ecosystem represented. All of these take a toll on the accuracy of model results at each model step. The uncertainties that accumulate in each model need to be considered in analysis of errors for subsequent models.

[14]The models employed here begin with a hydrodynamic model that forces a sediment transport model. Thus, considerable uncertainty accumulation (which begins with the boundary forcing for the first model) has already occurred before the ecosystem and contaminant transport models are reached. This sharpens rather than ameliorates the central dilemma – are the final predictions precise and accurate enough to be useful?

> *"However, robust modeling tools to address impaired conditions of water bodies are needed now more than ever before; e.g., the costly implementation of total maximum daily loads for pollutants during the next 10-15 years has raised the bar for innovative model developments that can accommodate rigorous error analysis (36). Conceptual weaknesses, methodological omissions, failure to incorporate residual variability, and parameter uncertainty in predictions are more critical when addressing practical management problems (10). In oceanography, the use of models as heuristic tools to elicit conceptual paradigms, to provide semiquantitative (or even qualitative) descriptions and understanding of ecological patterns is still a fundamental objective, while the policy-making process that guides costly management decisions requires predictive tools able to support deterministic statements (and associated errors)."* From Arhonditsis et al. [2006].

With respect to the importance uncertainty analyses, *Arhonditsis et al.* [2006] state:

> "*The importance of investigating the effects of uncertainty on model predictions has been extensively highlighted in the modeling literature (12, 41, 43)…. (M)odelers should understand the necessity for explicitly reporting the uncertainty contributed by both model structure and parameters. There is also an urgent research need for novel uncertainty analysis methods that can accommodate complete error analysis and the Bayesian calibration is one of the most promising prospects (38). Bayesian calibration can be used to refine our knowledge of model input parameters, obtain insight into the degree of information the data contain about model inputs (i.e., parameter estimates with measures of uncertainty and correlation among the parameters), and obtain predictions and uncertainty bounds for modeled output variables (44, 45). Technically, this method is a proof of the concept that there are better ways to parameterize mechanistic models, other than simply tuning (adjusting) model parameters until the modeler obtains a satisfactory fit."* From Arhonditsis et al. [2006].

While a Bayesian approach is not the only way in which to analyze and reduce model uncertainties, it is one of the most commonly used. Regarding use of a Bayesian approach to model calibration, *Arhonditsis et al*. [2006] continue:

> *"For the purpose of prediction, the Bayesian approach generates a posterior predictive distribution that represents the current estimate of the value of the response variable, taking into account both the uncertainty about the parameters and the uncertainty that remains when the parameters are known (38). Therefore, estimates of the uncertainty of Bayesian model predictions are more realistic (usually larger) than those based on the classical procedures. Predictions are expressed as probability distributions,*

> *thereby conveying significantly more information than point estimates in regards to uncertainty (46). The—often deceptive—deterministic statements are avoided and the water quality goals are set by explicitly acknowledging an inevitable risk of non-attainment, the level of which is subject to decisions that reflect different socioeconomic values and environmental concerns."* From Arhonditsis et al. [2006].

The above statement provides a roadmap of how the FFS Report should have been structured. Rather than providing a deterministic prediction for 2059 for each scenario, a broad range of outcomes should be provided that recognize not only accumulated modeling errors and biases, but also uncertainties in future environmental conditions.

Finally, *Arhonditsis et al*. [2006] recognize the great structural difficulties of multi-level modeling. Given these structural difficulties, it is even more important to provide a thorough calibration and analysis of uncertainty:

> *"In essence, modelers believe that if they can "get the processes right" in the mathematical equations, then the model truly is a mimic of the real system. However, if we inspect the theory behind process description, we will realize that all models are drastic simplifications of reality that approximate the actual processes…and all parameters are effective (e.g., spatially and temporally averaged processes) values unlikely to be represented by a fixed constant …. Causal explanations and mechanistic descriptions are scale-dependent and many practical applications are based on simple aggregated summaries. Furthermore, poorly understood ecology, determination of the optimal aggregation level of biotic entities, and understanding the entire suite of direct and interactive effects between system components impose barriers to the potential of success of these reductionistic views on aquatic ecosystem modeling (12). While the increase of the articulation level is certainly an effective means for improving our models, we should not neglect that the increasing complexity also reduces our ability to properly constrain the model parameters from observations, i.e., the number of parameters that must be specified from the data is approximately proportional to the square of the number of compartments (34).* ***In this case, the application of mechanistic models for extrapolative tasks gradually becomes "an exercise in prophecy" rather than scientific action based on robust prognostic tools (41). Our current experience indicates that the forecasting of ecosystem behavior is extremely difficult and even in well-studied, data-rich systems using very sophisticated models, accurate predictions were not feasible (3, 42).****"* From: Arhonditsis et al. [2006]; (**emphasis** added).

b. <u>*Model error assessments*</u>: The hydrodynamic (ECOM) and sediment transport (ECOMSED) calibration and error assessment efforts are limited by a lack of data; in particular, long-term, multi-year installations to measure physical (e.g.,

tide) and sediment transport processes under different conditions are lacking. This magnifies the difficulties in obtaining quantitative predictions regarding contaminant transport, in calibrating/validating modeling efforts, and assessing the effect of changing conditions. Compared to other estuaries, the LPR lacks data. We note that many systems—for example the Columbia River, San Francisco Bay, and European estuaries such as the Elbe and the Ems—have long-term monitoring records of turbidity of a decade or more, typically at many locations (see for example, http://www.portaltideelbe.de/ for the Elbe River in Germany; and http://www.stccmop.org/ for the Columbia River). Given the multi-billion dollar ramifications of correctly modeling the system and the comparatively modest cost of monitoring, this lack of data could and should be remedied.

c. *The need for multi-modeling*: The FFS modeling process places undue confidence in one model at each modeling step (e.g., circulation modeling). The current best-practice is to use multiple models, apply agreed-upon benchmark tests, assess their errors and bias under a variety of conditions, and produce a composite result with reduced uncertainty and bias. An outdated reliance on one realization of one model runs the risk that predictions are actually outliers, viewed from the perspective of multiple models used in ensemble mode (Fig. 7b). Multi-modeling has been used in the estuarine context, and given the complexity of the LPR system, the use of multi-modeling at least up through the hydrologic, hydrodynamic and sediment transport modeling levels is highly desirable.[15] For example, *Najar et al.* [2009] employed a multi-modeling approach to predicting climate impacts in the Hudson River, Delaware Bay and Chesapeake Bay estuaries, in a study funded by EPA. In that study, outputs from seven global climate models were analyzed, with the outputs from the four being averaged to forecast future climate conditions and hydrological forcing for the three systems. Closer to the scale of this study, *Monte et al.* [2006] used a multi-modeling approach to assess radioactive contaminant behavior in the Dnieper-Bug Estuary. This study also required multiple levels of modeling, including: circulation, sediment transport, radioactive transfer from the basin to the estuary, and radioactive movement through the abiotic and biotic components of the estuarine system. Both 2D and 3D models were employed. In another example, *Exbrayat et al*. [2011] employed four models of fluvial nutrient dynamics to predict future nitrogen concentrations in a Western Australian River.

Closer to home, the Chesapeake Bay Scientific and Technical Advisory Committee (STAC) describe use of a multi-modeling approach in Chesapeake Bay [*Friedrichs et al.* 2012]. The objective of the study is to: "*improve Bay shallow water simulations of dissolved oxygen and water clarity in order to better understand the impacts of alternative management strategies on living resources in the tidal Chesapeake Bay.*" Amongst the reasons for a multi-modeling approach: "*STAC believes that the routine comparison of output from several other models with the EPA regulatory model output will (1) help determine whether the regulatory model is as skillful as other models of the Bay, (2) enable effective adaptive management and accountability, and (3) build scientist,*

[15]We recognize the importance of computational efficiency for long, predictive model runs. However, given the potential costs of the various alternatives under consideration, it is imperative that state-of-the-art modeling technology be use. In this case, we suggest using multi-year (but not multi-decadal) runs of multiple models for purposes of understanding uncertainties and error propagation.

management, and stakeholder confidence in the model." Amongst the limitations cited for the regulatory model was the fact that it was a curvilinear finite difference model that had proved unable to represent shallow water processes, because it lacked enough grid cells in peripheral areas. This is also an issue with LPR, as discussed below.

d. *Uncertainty of future environmental conditions*: Natural variability and the fundamental unpredictability of the future are not considered in the FFS modeling approach. Inputs from a 15-year period, 1995-2010, are used cyclically to produce the final model state in 2059. This is only one out of an infinite number of possible future scenarios. An ensemble of scenarios combines to produce an inherent uncertainty that is a function of both natural variability and model errors and bias (Fig. 7b). Weather and hydrologic systems are both stochastic, and climate change is ongoing. The next 50 years may be less or more stormy than 1995-2010; two 100-year storm events may occur, or none at all. As a real-world example, Figure 7c shows ensemble predictions for Hurricane Sandy, four days before landfall. A deterministic forecast based on a single model run would likely have been disastrously wrong.

The FFS Report situation is analogous. Even if all model error were to be eliminated, the stochastic nature of future natural events would produce uncertainty in a prediction (e.g., Fig. 7b); this source of uncertainty has not been considered in the FFS Report at all. If this uncertainty were considered, the error bars of the forecasts for the four remedial alternatives would be much broader. An ensemble approach with many forcing scenarios and appropriate extreme events (variable magnitudes and timing between scenarios) should be used for each remedial alternative. Otherwise, it cannot be demonstrated that the predicted results do not depart considerably (like the purple line in Fig. 7b) from the "true" ensemble mean (red line) and even the modeled ensemble mean. Again, these observations are demonstrated by real-world ensemble predictions (Fig. 7c). In summary, use of an ensemble approach is important, if forecasts out to 2059 are to be made.

e. *FFS sensitivity analyses*: The FFS sensitivity analyses were added or augmented in response to peer review [EPA, 2013] in an *ad-hoc* fashion, rather than being built into the modeling architecture from the start to finish. The current best-practice in ecosystem modeling requires employing a rigorous approach to quantify the accumulation of bias and uncertainty in chained models. As discussed below, the FFS Report uncertainty analyses are not rigorous for any single model and fail to account for accumulation of bias and uncertainty when models are chained together sequentially (see e.g. Fig. 7a). In order to make present modeling results useful, it is necessary to carry out a thorough and defensible analysis of uncertainty and bias, from the forcing data through the various modeling steps to final model predictions and alternative evaluations (as per *Arhonditsis et al.* [2006]). Were such an analysis to be carried out, meaningful distinctions among the four alternatives (in terms of outcome) may well disappear. As a result, a useful evaluation of the alternatives will likely require acquisition of new data and use of a revised modeling strategy. In summary, given that the estimated cost of remedial alternatives is as high as $3.2 billion, the use of best-practice methods to evaluate remedial alternatives is necessary.

f. *Model grid resolution is too low and does not reflect current best-practice*: The coarse grid resolution employed in all models limits the ability of the combined models to accurately evaluate and differentiate the outcomes of the proposed alternatives. The ECOM grid used here has changed little since 2006 [*HydroQual*, 2006], when computation time was a more limiting factor than is the case today. Since the resolution of ECOM limits the resolution of all models linked to it, the entire modeling system reflects technological limitations that no longer exist. More specifically, the ECOM and ECOMSED grid: "*consists of 74×268 segments in the horizontal plane and 10 equally spaced σ-layers in the vertical plane*" [*HydroQual*, 2008]. Thus, the total number of grid cells is a quite modest 198,320. Presently, 3D hydrodynamic models with an order of magnitude more cells (10-20× larger) can be run manageably without using a super-computer. Multiple ensembles of long runs needed for this project would likely require a super-computer, but are also feasible. Given the importance of issues at hand and the costs of the remedial alternatives, the necessary computational resources should be devoted to the project to allow a more detailed grid to be run.

g. *Consequences of Low resolution grid*: It is axiomatic that grid resolution (horizontal and vertical) must be sufficient to resolve the processes of interest, if a model is to be useful. Grid resolution issues are most severe in the Sediment Transport and Fate and Transport models (the latter of which has even lower resolution than the Hydrodynamics and Sediment Transport models), because:

i. Scale of processes: The transport of sediment and contaminants is closely related to bed properties and topography (e.g., channel migration over time); the latter vary on spatial scales much smaller than the grid resolution. These vital properties cannot be properly represented by the modeling tools employed in the FFS analysis of alternatives.

ii. Representing and differentiating alternatives: Differentiating outcomes for the various remediation alternatives requires that the model grid employed be able to accurately represent the alternatives, in terms of their footprint on the bed. The coarse grid resolution does not allow this for Alternative 4 (focused capping), especially in the Fate and Transport model, where grid resolution is reduced relative to ECOMSED. The representation of Alternative 4 in terms of this grid will inevitably be inaccurate.

iii. Effect of bridges and other obstructions: Bridge abutments from the numerous bridges in the system cannot be represented with the low grid resolution employed in the coupled FFS modeling suite (ECOM, ECOMSED and Fate and Transport modeling). Yet these are vital parts of the total resistance to flow in the system and certainly impact system response to variations in river flow. Other structures along the river bank may similarly affect sidewall turbulence. Because these aspects of the system are not explicitly represented, the bed roughness parameter Z_0 must be artificially adjusted (likely increased) to compensate for the missing roughness. However, this adjustment will adversely affect the accuracy of modeled sediment transport.

h. *Poorly known boundary conditions*: Crucial boundary conditions are poorly known and/or inaccurately represented, especially for sediment and contaminants. This limits the ability of the models to accurately represent the sediment and biogeochemical dynamics of the system. For example:

i. Importance of fluvial sediment input – inappropriate use of rating curves: The sediment transport model ECOMSED is very sensitive to the amount of sediment input from the fluvial side. More specifically, a ±20% uncertainty in sediment load causes a ±25% to >125% uncertainty in the modeled deposition/erosion balance throughout most of the LPR. However, fluvial sediment input to ECOMSED is determined from rating curves based on very sparse data (see section 2.5 and Appendix A). The modeled ±20% accuracy is therefore overly optimistic. A review of sediment rating curves in the American Society of Civil Engineers (ASCE) Sedimentation Engineering Manual [*Gray & Simões*, 2008] cites several sources that provide an evaluation of the accuracy of sediment load rating curves. For example, *NCASI (National Council for Air and Stream Improvement)* [1999] considers a rating curve that is accurate within 30% as being "relatively good." *Meade et al*. [1990] indicate that a sediment rating curve will typically generate a 50% error in annual-average discharge. Errors for individual events will be larger. Overall, these considerations suggest that the annual average sediment load to the LPR is uncertain by ±50%, which is twice the amount of uncertainty that causes serious divergence of in ECOMSED results (cf. Fig. 5-3 of FFS Appendix BII). *Gray & Simões* [2008] go on to say: "*Although a well-defined, carefully constructed, and judiciously applied rating curve can be a useful tool for estimating sediment loads, load estimates derived from rating curves should not be considered a substitute for daily-sediment records*…." The following discussion and Appendix A show that the rating curves used here are neither well-defined (due to insufficient data) nor carefully constructed (due to conceptual limitations and errors). Realistic estimates of sediment load rating curve uncertainty (±50%) should be considered in estimating uncertainty of ECOMSED and Fate and Transport model results.

ii. Inaccurate rating curves: In addition to the general unreliability of rating curves, there are specific difficulties with those used in the FFS models. Because the rating curves used for LPR tributaries do not take into account the hysteresis in sediment loading that is a very strong feature of the system, sediment load is not input at the correct time during high flow events (i.e., before the peak of the flow). Also, the load input from estuary tributaries appears to be greatly in error, and there is no provision for sand input from the Passaic River (which may be up to 50% of the load during storms and appears to average ~20%). These difficulties have a major impact on the ability of the FFS Report modeling system to represent the effects of storms and floods and even long-term average conditions. Given that most sediment and contaminant transport occurs during high flow periods when large (but uncertain) amounts of sediment are input, and that model results are very sensitive to this input, problems in quantifying sediment load call into question the utility of FFS Model results. See Appendix A for details.

iii. Incorrect or inconsistent treatment of the Saddle River: There appears to be a mistake in the rating curve for the Saddle River (as represented in Fig. 3-1 of FFS Report Appendix BII). With this rating curve, the sediment load for the Saddle River is overestimated by about 1.5x for the two-year return period flow and by more than an order of magnitude for the highest flows. This rating curve was then used for other ungauged tributaries (Third River, Second River, and MacDonald Brook), overestimating the load from these tributaries as well and compounding the error. Figure 3-3 (FFS Report Appendix BII; *EPA* [2014]) shows that the loads used for the Saddle River are indeed excessive, e.g., greatly exceedingly the loads for the mainstem Passaic River during the 2007 flood (compare Figs. 3-2 and 3-3 of Appendix BII). In contradiction to this, more reasonable average loads for the Saddle River are given elsewhere (FFS Data Evaluation Report #2, "Boundary Conditions," Section 5.0; *EPA* [2014]). These must derive from an undisclosed rating curve which appears not to have been used for the modeling. This contradiction should be resolved. Given the high sensitivity of ECOMSED results to sediment load, if the rating curve in Fig. 3-1 of Appendix BII was used, this single factor (not considering other difficulties with the model) suffices to completely discredit FFS Report modeling results. See Appendix A for details.

i. *Calibration and validation data are very limited*: The available suspended sediment, velocity, water level, contaminant and salinity data are not in proportion to the needs of such an elaborate set of modeling tools as employed here. Amongst the consequences of this lack of data are:

i. Lack of skill statistics: Quite aside from recognizing error propagation (as discussed above; see Fig. 7), conventional model skill statistics should be provided for each model. Moreover, each model should attain minimum levels of skill using benchmarks that are agreed-upon *a-priori*, using current best-practice. While some statistics have been provided, the absence of a systematic approach makes it difficult to evaluate how well the models perform, individually and in combination. Several skill assessment approaches are available for hydrodynamic models; e.g., *Warner et al.* [2005]. Also, the National Oceanic and Atmospheric Administration (NOAA) has a standard set of metrics that are used with its nowcast/forecast models, meaning that they can be calculated rapidly (http://www.nauticalcharts.noaa.gov/csdl/skillassess.html, accessed 9 July 2014). *Stow et al*. [2009] and *Lynch et al.* [2009] provide skill assessment approaches for ecosystem models, and *Joliff et al.* [2009] provide a conceptual overview and recommend a series of graphic tools that facilitate visual comparison. Thus, skill assessment should be carried out on a systematic basis, so that readers of the FFS can understand how well the models perform in reproducing the rather limited data. Standard benchmarks of performance should be defined based on best-practice within the scientific literature, and the models should demonstrate that the standard has been achieved.

ii. The Newark Bay boundary: A lack of hydrodynamic and suspended sediment data at the estuary mouth means that the crucial exchange of sediment between Newark Bay and the LPR is unmeasured, such that

the accuracy of the modeled horizontal fluxes of suspended sediments and contaminants at this key boundary cannot be validated. There is an extensive, two-way exchange of suspended sediments (with contaminants) between Newark Bay and the LPR [e.g., *Suskowski*, 1978], and the details of this exchange depend on tides, river flow, and channel depths [*Chant et al*., 2011]. Because Newark Bay sediments are also contaminated (see discussion below), recontamination of the LPR from Newark Bay will probably occur after construction of either Alternatives 2 or 3. A deeper channel traps more sediment and will increase import of polluted bottom sediments from Newark Bay, due to increased estuarine circulation. For differentiation of the four alternatives, it is critical that recontamination of the LPR from Newark Bay be correctly modeled. The lack of data to evaluate this process should be corrected by a field program that collects time series of moored acoustic Doppler current profiler (ADCP) data (with acoustic backscatter), temperature and salinity data, optical backscatter data and ground-truth observations of suspended sediment properties (including concentration, sizes, organic content, and floc characteristics). These time series should capture both high and low flow periods, and cover at least a seasonal cycle (one year), and preferably a longer period. The cost of such an undertaking is justified, because the information is so critical to model calibration and determining the ability of the suite of models used in the FFS to distinguish among alternatives.

j. *Sensitivity analysis*: The limited sensitivity analyses that were conducted indicate that model results are highly uncertain. Moreover, absolutely critical grid resolution analyses were either carried out incorrectly (for the Hydrodynamics model) or not at all (for the Sediment Transport, and Fate and Transport models). Specifically:

i. Horizontal grid resolution analysis: The issue of errors associated with the chosen grid resolution was not investigated, but should have been [*Roach*, 1994, 1997]. For example, *Roach* [1997] says: "*Systematic grid-convergence studies are the most common, most straightforward and arguably constitute the most reliable technique for the quantification of numerical uncertainty.*" A standard grid resolution analysis would increase grid resolution incrementally until model results converged, and *Roach* [1997] provides a formalism for determining the convergence rate as the grid is refined.[16] No such test was carried out for the Hydrodynamics model. Instead, a calibrated version of the coarse horizontal-grid model was compared to an uncalibrated version of a refined horizontal-grid model. Results were different in the refined model, but (not surprisingly) no better, because the model was not calibrated and the choice of key parameters depends on the grid size. A standard grid resolution analysis should be carried out.

ii. Vertical grid resolution analysis: Transport properties are critically dependent on vertical density stratification in a model [e.g., *Warner et al.*,

[16]While Roach [1994 and 1997] address specifically the sub-category of numerical codes known as "computational fluid dynamics" models, the methodology defined for grid analysis is also valid in the present context.

2005], which cannot be very well represented by the 10 grid levels employed. No analysis of the effects of refining the vertical grid resolution of the Hydrodynamics model was carried out. The FFS analysis should follow the example of *Warner et al*. [2005] and carry out such an analysis; if analysis shows that refinement changes the results, then a more refined grid should be used.

k. *Sediment Transport and Fate and Transport modeling*: Grid resolution analyses should also have been conducted for the Sediment Transport model and Fate and Transport model, but were not. This test is especially critical for the Fate and Transport model, because it has a lower horizontal resolution than the other models

l. *Propagating errors*: As described above, it is vital to quantify error propagation through linked models and even between components within a single model.[17] Error propagation and the growing uncertainty of linked models were not considered (see Fig. 7a). For example, a sensitivity analysis showed that net deposition in the Sediment Transport model is very sensitive to the poorly known upstream input of sediment at Dundee Dam; a ±20% change in sediment input resulted in ±125% changes in net deposition in some parts of the LPR. Yet the sediment input at Dundee Dam is known only within a factor of ±50% on an annual average basis and with a factor of perhaps 1.5 or 2 during floods (Appendix A). The contribution from LPR tributaries is likely smaller, but very poorly defined, given that RI FFS Appendix BII (Figs. 3-1 and 3-3) suggest that Saddle River loads are actually larger than mainstem loads during large storms. Uncertainties associated with this acute sensitivity were not propagated forward to the Fate and Transport modeling, leaving the uncertainty in the results of this latter model unknown. As stated previously, a rigorous uncertainty analysis is needed.

m. *Errors and omissions occur in individual models*: Each of the FFS models has model-specific issues; three examples are:

i. Errors in contaminant mass-balance modeling: There appear to be errors in the formulation of the Empirical Mass Balance (EMB) model that render the results unreliable, as described in the Specific Comments.

ii. Scour around sheetpile structures: The possible effect of scour around the proposed sheetpile structures to be used during the dredging process was deemed outside the scope of the FFS (FFS p. 4-12) and was not included in evaluation of alternatives, but would appear to be an especially potent way to expose dangerous subsurface contaminants. Material from any of these sources will be re-distributed broadly along the channel by ETM processes. As noted by *Chant et al.* [2011], there is net suspended sediment export from the LPR during periods of flow higher than ~40 m^3/s, so that contaminants lost during dredging operations will

[17] Any single model (e.g., Sediment Transport) is a system of linked computational models; in the case of Sediment Transport, the largest sub-models are ECOMSED and SEDZLJS, but each of these has numerous components. Errors in inputs, parameters, and algorithms will, therefore, propagate through a single model, as well as between models.

be exported. During low flow conditions, contaminants will be fluxed upstream. These issues, including the effects of extreme flows and storm surges, should be analyzed as part of the FFS process.

iii. The effects of propeller wash: Propeller wash or propwash can be considerable in a shallow waterway like the LPR (*Maynard* [2000], *Garcia et al.* [1998, 1999]; see also the comments of J. Best and M. H. Garcia). Propwash impacts of the navigational use in the proposed deeper channel (Alternatives 2 and 3) that will increase traffic, and in the channel with its present depths (Alternatives 1 and 4), should be evaluated. Propwash effects of the construction involved in Alternatives 2 to 4 should also be analyzed.

n. Consistency between models: Results of the Fate and Transport modeling appear to be inconsistent with those of the EMB modeling, and there are significant differences in the predictions of the two models for the four proposed alternatives [Figures 8a-d]. This is important because the EMB modeling is largely independent of the chain of linked models (Hydrodynamics, Sediment Transport, and Fate and Transport) and provides a check of sorts on the linked models, even though the EMB model also appears to be flawed. Figures 8a-d show that there are at least three crucial differences in results between the EMB and Fate and Transport models:

i. Long-term differences between alternatives: The differences in 2059 in contaminant levels for Alternatives 2 and 3 (on one hand) and Alternatives 1 and 4 (on the other) are portrayed quite differently by the two models. Thus, there are order-of-magnitude differences between the pairs of alternatives in the Fate and Transport model, but considerably less than that in the EMB model.

ii. Different Trends: The Fate and Transport model and the EMB model show divergent trends between the pairs of alternatives in 2059. In the Fate and Transport model, Alternatives 2 and 3 continue to improve relative to Alternatives 1 and 4. In contrast, the EMB model suggests that Alternatives 2 and 3 and Alternatives 1 and 4 tend to converge over time, and might be indistinguishable by 2100. Regardless of the time at which the results become indistinguishable in the EMB model, the models are not making consistent predictions.

iii. Response to floods: The Fate and Transport model shows a strong response to floods, which cause contaminant concentrations to increase by a factor of up to 5 after a large flood; these impacts decrease over a period of about five years. Such storm impacts are not seen in the EMB model. Figures 8b and 8d also bring up an important point related to the stochastic nature of system forcing. If the timing of the forcing used in the model runs shown in Figures 8a-d were shifted by a few years or a disturbance the size of Hurricane Irene in 2011 were to occur in the late 2050s, the Fate and Transport modeling would show much smaller (if any) differences among remedial alternatives. This observation demonstrates again that a stochastic modeling approach is needed to assess the results of natural variability.

The FFS contends that differences in model outcomes which do not change the order of the Alternatives (in terms of contaminant concentrations after construction) are immaterial. This argument is incorrect: taken at face value, the two models suggest fundamentally different long-term outcomes. If the outcomes of the two models are valued equivalently, then a high degree of uncertainty of modeled outcomes must be acknowledged. If they are fundamentally different, then alternatives can only be evaluated by first proving that one model is deficient, and then rejecting it. In either case, it is clear that the biases, uncertainties, and algorithmic formulations of both models need to be examined more closely.

These issues are discussed in more detail below; see Specific Comments.

1.4 **The Estuary Turbidity Maximum is Poorly Understood:**

Understanding and correctly modeling ETM processes and phenomena: This is vital to determining how to remediate the LPR, because ETM processes and sediment transport are at the heart of the LPR contaminant problem. However, the processes involved are poorly understood and the FFS modeling system does not accurately reproduce the physics of ETM sediment and contaminant transport.

a. *Process understanding*: Understanding contemporary ETM concentrations of contaminants and projecting these concentrations into the future requires developing a more sophisticated understanding of ETM processes than is available in FFS documents. Once it is developed, this understanding needs to be incorporated into a model that can demonstrably and quantitatively represent ETM processes. Only then can realistic evaluations of remediation alternatives be made. Among other issues, the role of upstream contaminant transport from Newark Bay and sediment exchange between the Bay and the LPR is vitally important to evaluating alternatives, but has not been realistically quantified. Also, the position and structure of the ETM needs to be quantitatively defined in terms of flow, tides and atmospheric forcing (use of salinity as a proxy may lead to inaccuracies, as discussed below).

b. *Contemporary contaminant concentrations*: In order to evaluate remedial alternatives, it is necessary to understand the contemporary contaminant distribution—why are contaminants so widely distributed at the surface of the bed, and why have their concentrations not decreased more quickly over time? Contaminants likely occur in the water column and near-surface sediments (top 0.15m) for a variety of reasons. These may include: localized re-working of older, contaminated sediments by biota or erosion/deposition processes; localized erosion of older sediments associated with specific scour points (e.g., downstream from bridges or as channel alignment adjusts); upstream inputs; wave scour; translation of dunes or ripples; thalweg movement; CSO and SWO inputs; transport from Newark Bay; and inputs of contaminants from contaminated wetlands (possibly during floods). The above erosion processes often occur over small length scales. It is unclear that broad-scale reworking of sediments (over grid-scales of >50 to 100 m), the only process that the FFS models can realistically evaluate, is particularly relevant. The system understanding does not exist to distinguish between different sources of contamination, and the FFS models do not represent the relevant processes or

distinguish different sources of contamination at the necessary scale to be useful. It is important that these issues be correctly understood, so that remedial alternatives can be properly evaluated.

c. *Trapping of sediment, time scales and mechanisms*: The direction of net suspended sediment transport in the LPR (and even the existence of an ETM in the LPR channel) is a function of river flow, tidal processes (mixing, flow), settling velocity, and water depth (*Festa & Hansen*, 1978; *Geyer*, 1993; *Burchard and Bolding*, 1998; *Fain et al*., 2001; *Talke et al.*, 2009a, *Chant et al.*, 2011). An ETM occurs because tidal and subtidal trapping mechanisms exist that bring material to the ETM against the mean suspended sediment concentration gradient and enhance that gradient (Fig. 9; *Jay et al*. [2007a,b]; *Talke et al*. [2009a]). These typically involve both gravitational circulation [*Hansen & Rattray*, 1965] and internal asymmetry; i.e., correlations between depth variations in currents and sediment concentrations on both tidal and subtidal time scales (*Jay & Musiak* [1994, 1996]; *Burchard & Bolding* [1998]). Other factors being equal, a greater depth and settling velocity moves the ETM upstream; conversely, larger river discharge and increased turbulent mixing move the ETM downstream [*Talke et al.*, 2009a,b]. The salinity structure and how it reacts to river and tidal forcing determines subtidal circulation patterns and mixing (e.g., *MacCready* [2004]; *MacCready & Geyer* [2010]). In turn, the salinity structure helps determines the horizontal length-scale of the turbid zone, and the magnitude of sediment concentrations at the maximum (*Talke et al.* [2008], *Talke et al.,* [2009a]). Because river flow, tides, the salinity structure, and depths change on daily, monthly, seasonal, and longer time scales, the system never reaches equilibrium; it is continually adjusting to (but lags behind) external forcing [*MacCready*, 2007]. The implications of this non-stationarity, and their impact on the evolution of system morphology, have not been considered. For example, the existence of an ETM in one location (due to convergent sediment fluxes) may coincide with a turbidity minimum elsewhere, i.e., an area marked by sediment flux divergence and enhanced erosion [*Talke et al*., 2009a]. Moreover, multiple trapping mechanisms exist and may produce multiple maxima. As noted elsewhere, ECOMSED produces evidence of multiple ETM, though this has not been confirmed by observations. As a result of these complex factors, transport direction cannot be inferred simply from the direction of an observed gradient. Rather, the detailed transport mechanisms involved on different times scales must be considered in some depth, an exercise that *Chant et al.* [2011] began for the LPR, but which was not completed in the FFS. If these processes are not understood and modeled correctly (using a modeling suite verified against appropriate field data), then model predictions will likely be invalid.

d. *Spatial Patterns*: The spatial patterns of erodible sediment in the LPR, and their connection to the fluctuations in the turbidity and contaminant distributions around the ETM, remain poorly characterized. ETM dynamics may transport material landward during low-flow periods to any point to which salinity is also transported; if tidal asymmetry is strong enough, ETM transport may actually extend landward of salinity intrusion. On the other hand, the ETM may remain trapped at a topographic feature and remain largely seaward of the salt front. Further, turbidity is typically distributed within a zone of 5-10km around the ETM centroid, further increasing the upstream and downstream footprint. The size of this footprint in the LPR is unknown and not considered in the FFS Report. *EPA*

[2007] (see Fig. 1.11), *Israelsson et al*. [2014] and the more detailed analysis contained in the Arcadis comments on the FFS report agree that, in general, 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) levels increase in surface sediment from Newark Bay landward to a maximum between about RM-10 and 12 (mouth of Third River; see Figs. 2.1.18 and 2-19 of the Arcadis comments, reproduced here as Fig. 10a-b). A similar pattern is seen for total PCB (polychlorinated biphenyl) congeners (see Figs. 2-20 and 2-21 of the Arcadis comments, reproduced here as Figs. 10c,d). In fact, contaminants may accumulate in local "traps" (e.g., tidal flats or the inside of a channel bend) anywhere within the ETM excursion. A number of studies have examined how transverse circulation patterns can lead to sediment trapping on one side of an estuary (e.g., *Huijts et al.* [2006]). However, there is no obvious reason why typical ETM transport processes should cause contaminant concentrations to be maximal at the upstream limit of the ETM reach, as seen in Figures 10a-d. On the contrary, one might hypothesize that flood events would periodically move the contaminated material farther downstream, where sediment retention is stronger. *Israelsson et al.*, [2014] suggest an inverse dependence of surface concentration on burial rate (i.e., slower burial equates to higher surface concentrations). This argument fails, however, to account for several factors, and the mechanism for an ETM-mediated upstream focusing of contaminant concentrations remains, along with the contaminant distributions themselves, to be satisfactorily explained. Specifically:

i. <u>Sedimentation rates are relatively uniform along-channel.</u> If *Israelsson et al.*, [2014] were correct that different surface concentrations correspond to different sedimentation rates, this would produce only minor variability in median contaminant concentrations, smaller than those observed.Sedimentation rates show similar magnitudes and variability in all reaches. This is documented in Table 4 and Figure 2 of *Erickson et al*. [2007], reproduced here as Figures 11 and 12. Median sedimentation rates are essentially the same from the Newark to Arlington reaches (2.8 to 2.9 cm/year); moreover, and all sections and reaches (except the Kearney reach) have some individual cores which show no detectable post-1950s sedimentation. The median rates for all reaches are within a range of 75 to 125% (2.8 to 4.6 cm/year) of the overall median for all reaches (3.7 cm/year). In terms of averages, all reaches are within a range of 52 to 131% (2.0 to 5.0 cm/year) of the overall mean (3.8 cm/year). The variations between river sections are smaller by all measures (mean, mean, maximum minimum and standard deviation) than those between reaches. Variations by geomorphic type are much more important (Fig. 13), with averages varying by a factor of ~5x between types. The medians range from 0 cm/year for outer bends to 5.6 cm/year for point bars. Hence, rates are highly variable in all environments—all geomorphic areas have some cores without measurable sedimentation, which by the *Israelsson et al.*, [2014] hypothesis, should result in an equal distribution and magnitude of hotspots. Maximum sedimentation rates vary by geomorphic type from 5.2 cm/year (river bend channels) to 12 cm/year (point bars). These statistics do not support the idea that higher surface 2,3,7,8-TCDD concentrations upriver can be explained by a lack of sedimentation. For example, even though the average carbon normalized 2,3,7,8-TCDD

concentration is larger by only a factor of 2 or 3X at RM-10.9 , there is a cluster of points where concentrations of both 2,3,7,8-TCDD and PCBs are an order of magnitude higher. This hot spot is on a point-bar tidal flat where sedimentation is likely on-going at an above-average rate, contrary to the Isrealsson et al, [2014] hypothesis, and as noted, hot spots exist in various locations. Like the one at RM-10.9, many of them likely experience continued ongoing sedimentation. There has been ample sedimentation in all reaches in the geomorphic area types inclined to accumulate sediment to cover contaminants deposited in the 1940s to 1960s. More complex physical processes and/or the existence of additional contaminant sources are needed to explain the distribution of contaminants, but have not heretofore been developed.

ii. River flow is increasingly dominant upstream: A further issue to be resolved in the *Israelsson et al.,* [2014] hypothesis is that it does not consider spatial variability in physical forcing and also apparently contradicts FFS modeling results. An increasing dominance of riverine processes occurs in the upstream direction in a convergent channel such as the LPR. Accordingly, the dominant seaward transport mechanisms would transport this material downriver during floods more strongly than is the case closer to Newark Bay. In fact, the fate and transport model (RI-FFS Appendix BIII, 2014) seems to show this: downstream transport from above RM8 apparently recontaminates the FFS Study Area during episodic storms, but takes several years to be exported out of the FFS Study Area or buried (see other sections for flaws in the model, however). ETM processes may bring contaminated sediments upstream past RM8; but it remains to be established by Region 2 to what extent this occurs and whether contaminants will stay upriver when brought there. A related question is how the observed distribution of contaminants (with concentrations increasing upstream) was produced. The model as currently implemented does not preferentially trap recontaminated sediments in the upstream portion of the FFS (otherwise, results would show recontamination over time). Moreover, the FFS models do not demonstrate a 'focusing mechanism', i.e., a method by which concentrations are increased while being transported upstream. Thus, the FFS cannot explain the observed surface 2,3,7,8-TCDD concentration patterns without invoking either: (a) additional sources, or (b) a complex (and apparently inconsistent with model results) series of historical events that explain why there are hot-spots in some locations and not others. Retrospective modeling should be done to determine whether a plausible series of events can reproduce the *Israelsson et al.,* [2014] hypothesis and the observed historical contaminant patterns starting from a downstream source. We argue elsewhere that ETM movements combined with small-scale erosion/deposition patterns (e.g., thalweg migration) could contribute to exposure and subsequent reburial of contaminated sediments. This could perhaps explain the observed spatial concentration patterns, but has the implication that the current FFS models do not model recontamination correctly after remediation. Another possibility, however, is that additional unidentified and

unmodeled sources (e.g., from SWO and CSOs) still exist.[18] The problem is complicated by non-stationary ETM processes, which were likely different in the historically deeper estuary. Determining the source of dioxin contaminants is perhaps less important for the FFS than understanding the mechanisms of its transport. Nonetheless, identification of historic and/or current sources, and demonstrating that historical patterns can be reproduced without additional sources, is particularly vital to evaluating the proposed remediation alternatives and to evaluating the degree of recontamination that will occur after construction.[19]

iii. Total PCB and 2,3,7,8-TCDD concentrations have a similar spatial pattern: Comparing Figures 10a,b with 10c,d shows that these sediment-attached contaminants have a maximum around RM-11 that is most pronounced when normalized by organic carbon, yet the Fate and Transport assumes and EMB model argues for the existence of one or more upstream sources for total PCBs above Dundee Dam and other tributaries.[20] Neither the *Isrealsson et al*. [2014] argument nor the FFS Report explain why different boundary conditions do not lead to different contaminant distributions. It is, moreover, not tenable to maintain that ETM trapping processes wipe out all traces of contaminant history and source. Figures 4-1 to 4-52 of the Remedial Investigation Report [*EPA*, 2014] demonstrate that not all sediment-attached, hydrophobic contaminants have the same along-channel distributions, despite the assumed similarity in ETM processes for all such contaminants. These distributions should be analyzed rigorously and fit with appropriate spline curves, as carried out in the Arcadis comments for selected contaminants (cf. Figures 10a-d).

e. *Interaction of ETM processes with proposed bank-to-bank dredging*: The position of the ETM fluctuates with tides and river flow [*Chant et al.*, 2011], but statistics on its centroid and limits are not available. If we associate the most upstream position of the ETM centroid with the salt front, use the relationship between X2 position (position of the 2 PSU contour) and river flow in Figure 9 of *Chant et al*. (taking into account that his River km-0 is offset from RM-0), and consider the river flow histogram for Little Falls, we can estimate approximate ETM positions. More than 95% of the time, the X2 position is seaward of RM-8, as river flow and tides vary. Also, there is an average tidal excursion of about 7 km for an average tide and an average ETM length of 5-10 km [*Chant et al.*, 2011]. Thus, ETM

[18]The FFS also does not consider that other sources may have existed historically, but that their possible existence does not necessarily explain existing near-surface contamination.

[19]We note that *Israelsson et al.* [2014] engage in a lengthy attempt [starting from their eq. (1)] to use a relationship from *Jay et al.* [1997] to support the idea that there is only one significant (downriver) source of 2,3,7,8-TCDD in the LPR. Given the lack of quantification of the relevant fluxes, the arguments based on their (1) could just as easily be used to argue for multiple sources distributed between about RM-2 and 12. In other words, the argument is inconclusive.

[20]For example, Figure 4-3a of the EMB Model Report (FFS Report Appendix C, *EPA* [2014]) suggests that only 0.1% of the source concentration for 2,3,7,8-TCDD in the Lower 8 miles comes from above Dundee Dam, with insignificant contributions from other tributaries. The rest of the 2,3,7,8-TCDD comes either from Newark Bay (3%) or resuspension (~97%). For total PCBs, the picture is different; the Upper Passaic contributes 11%, other tributaries 1.8%, Newark Bay 7%, and resuspension 81%. Note that this analysis applies to the lower 8 miles. Presumably, the influence of upstream sources for total PCBs would be larger, if the lower 12 miles were considered.

erosion and deposition will occur both upstream and downstream of any given dredging site between RM-0 and RM-8. The proposed bank-to-bank dredging from RM-0 and RM-8 in Alternatives 2 and 3 will move from upstream to downstream. During the proposed decade-long dredging, the ETM (and contaminated sediment from downstream areas) will move upstream past the dredges, likely resulting in contaminated sediment deposits further upstream. Hence, 'cleaned' areas will be continually re-contaminated by deposition of contaminants from downstream, carried upstream with the ETM, at least under low to moderated flow conditions, as illustrated conceptually in Figure 14. One could argue that these contaminated sediments will eventually be re-eroded, and moved downstream (in fact, the FFS model implies this). However, if the system is net depositional, some permanent reburial of contaminants will occur. Even if there is no net deposition within a reach, multiple other mechanisms exist for burying contaminated sediment. For example, contaminated sediment may settle in a scour hole or on the depositional side of a migrating channel. Note that the FFS model cannot adequately model these fine scale processes because of course grid resolution. If the contaminated sediments are buried deeply (e,g., in scour holes not represented in the coarse ECOMSED grid), then they may not be resuspended, and recontamination occurs. In the same way, contaminants from upstream of RM-8 will be brought in during high-flow periods. After an extreme event produces localized scour and erosion (e.g., around bridge piles or sheet piles), the low flow period that follows would produce the deposition of contaminated sediments.

f. *Implications for Evaluation of FFS remedial alternatives*: In summary, it is not possible to correctly model complex ETM sediment and contaminant transport processes unless these processes are actually understood, sufficient data are available to verify the accuracy of the models, and the models are correctly implemented, calibrated and verified. With respect to ETM processes, none of these conditions has been met. Our present conceptual understanding of the system suggests that recontamination of areas already dredged will be extensive as dredging moves from upstream to downstream. It also suggests that unidentified sources of contaminants may exist or may have existed.

1.5 Impacts of channel deepening for navigation*:*

The hydrodynamic and morphological effects of deepening and maintaining the lower 2.2 miles for navigation have not been realistically considered. If this reach is deepened, contaminants from Newark Bay will likely re-deposit in this reach and diffuse upstream, an effect that will be more pronounced in Alternatives 2 and 3, which deepen the dredged channel for navigation. This will, in part, negate the predicted benefits of large-scale capping. The actual benefit would likely be closer to those for focused capping (Alternative 4). Our argument is as follows:

a. *Relative contaminant levels*: Excluding outliers and hotspots, contaminant levels in Newark Bay are nearly as high as in the LPR.For example, the 2,3,7,8-TCDD concentration downstream of RM-0 is a median of ~50-100 ng/kg in the top 6 inches of sediment, vs. a median of ~200-300 ng/kg within the estuary (Fig. 4.1, FFS Report Appendix BIII). Similarly, total PCB concentrations are a median of ~400-600 µg/kg in Newark Bay below RM-0, and ~800-1000 µg/kg in RM 0-8 (Fig. 4.11, RI FFS Report Appendix BIII). If these concentration levels are

transported back into the estuary, the median concentration of TCDD and PCBs may only decrease by as little as 25-50%, even by the more intrusive alternatives (Alternatives 2 and 3). Over time, some dilution with river sediment and natural attenuation may be expected, probably at about the same rate as pre-dredging (25-40 year attenuation half-time, depending on contaminant; FFS Appendix C). Nonetheless, as explained below, these sediment concentrations are significantly higher than the projected two orders-of-magnitude decrease in contamination.

b. *Transport processes*: On a process level, sediment from Newark Bay is being pumped into the LPR during low flow, depositional conditions, with export from the LPR only during high-flow periods (*Chant et al.*, 2011). Deepening a tidal channel—as proposed for the lower 2 miles—will increase the upstream flux of sediments and salinity, for a variety of hydrodynamic reasons (see e.g., *Talke et al.*, [2009a]; *Chernetsky et al.*, [2010]; *Winterwerp* [2011]).[21] This upstream flux of bottom sediments would return Newark Bay pollution to the LPR. Other consequences of deepening will likely be observed: sediment contaminant concentrations will likely increase, and increased oxygen depletion may occur (*Talke et al.*, [2009b]). This issue is illustrated schematically in Figures 15 and 16. Figure 15 shows a vertical section along the channel. The deeper the bed depths after dredging, the stronger the upstream near-bed flow will be (e.g., *Hansen & Rattray* [1965]; *Jay & Musiak* [1996]; *MacCready* [2004]), and the more recontamination will move back into the LPR. Figure 16 illustrates the time sequence. The net result is likely to be considerable recontamination of the LPR due to ETM processes (just as ETM processes spread out contaminants in the first place). A deeper channel, as in Alternatives 2 and 3, will likely enhance recontamination from Newark Bay.

c. *Unrealistic expectations*: Because of the likelihood of sediment input from Newark Bay and contamination from outside sources, the following statement is unrealistic:

> *"Post-remediation, the suspended sediment from the Upper Passaic River will mix with suspended sediment from other sources entering the FFS Study Area (e.g., Newark Bay, Saddle River, Third River, and Second River), with the cleaner solids in the water column resulting from a remediated FFS Study Area and with any clean material placed on the river bed as part of the remediation. As a result, contaminant concentrations in the top six inches (bioactive zone evaluated in the risk assessment) can end up being much less than background concentrations coming over Dundee Dam."* (FFS study, p. ES-4).

The background concentrations of 2,3,7,8 TCDD coming in over Dundee Dam are ~ 0.1 ng/kg, or nearly *3* orders-of-magnitude less than Newark Bay. To obtain a dilution factor of nearly 1000, the top 6 inches of Newark Bay sediment that returns to the LPR will need to be mixed with 1000 parts of background (clean) sediment from the Passaic River. The FFS gives no guidance on how this

[21] Indeed the FFS cites the *Chant et al*. [2011] argument that a deeper channel facilitated the historic contamination of the system by providing an effective sediment trap. If this process occurred historically, it will happen if the channel is deepened again.

(unrealistic) dilution will be achieved, and implicitly assumes (models) that all sediment input after capping will be sourced from upstream. Clearly, sediment is being mixed and fluxed both landward and seaward (Fig. 6), and the remediation effort will result in the LPR taking on Newark Bay characteristics. This line of argument again emphasizes the need to correctly model the exchanges of sediment and contaminants between the LPR and Newark Bay, an aspect of the model that has not been verified, and for which adequate calibration/validation data do not appear to exist.

d. *Maintenance dredging impacts*: Deepening of the lower two miles of the LPR for navigation is not a one-time effort. Maintenance of this channel will be required, or there is no point in the channel deepening. Past dredging records for 1957 up to 1983 (the last date of dredging) suggest an annual maintenance dredging amount of about 98,000 cu yd/year to maintain a 30 ft channel in the lower 2 miles *[Iannuzzi et al.*, 2002]. If the entire period after construction to 30 ft in 1932 is considered, maintenance dredging (from 1933 to 1983) was about 138,000 cu yd/year, though up to 1946, dredging to Rm-2.5 or 2.6 occurred. This dredging will require removal of contaminated material at each maintenance operation, because the dredged material to be removed will resemble the polluted sediments of Newark Bay, as already noted (and may also contain polluted sediments eroded from upstream of RM-8, or brought in by CSOs). Thus, there is a very real possibility of spreading contamination during each maintenance dredging operation. Further, each time the area is dredged, there is a risk that the cap will be accidentally breached, causing further contamination (at least in Alternative 3). Finally, assuming the sediment is contaminated, it would have to be disposed of in the same manner as during construction, requiring truck or rail shipment of the material over long distances. Realistic maintenance dredging costs and associated impacts should be considered in the remedial alternatives where they would occur.

1.6 **Extreme Events have been Underestimated:**

The FFS study underestimates the effect of extreme events in the Passaic, with implications for dredging and remediation scenarios.

a. *Passaic River flood events*: Our preliminary estimates suggest that the magnitude of the 100-year flood at Little Falls is ~20% larger than the one considered in the FFS analysis.[22] This is in part because large flood events in 2007, 2010, and 2011 were not used in the analysis, leading to an under-prediction in risk and uncertainty. The Passaic hydrologic system is also non-stationary over decadal scales, for reasons that need to be explored but are not considered in the FFS. As a result the 95% confidence intervals in any flood return period analysis are quite large. These considerations suggest that the full range of possible floods has not been considered, with implications for dredging and capping structures, and for recontamination from polluted areas after floods. See Appendix B of this document for more details on defining realistic 100 and 500-year floods.

[22]For reasons discussed in Appendixes A and B (e.g., the flow at Dundee dam is flashier than that at Little Falls), the 100 and 500-year floods at Dundee Dam are probably more severely underestimated. Watershed modeling is needed to better understand inputs of water and sediment from the basin.

b. *Non-stationarity*: Storm surge and storm tide risks are also non-stationary in New York harbor [*Talke et al*., 2014 and Appendix B], and the height of the 10-year event has increased by ~0.7m since the mid-19th century due to a combination of sea-level rise and increasing storm tides (Fig. B-10). Further, storm surge risk fluctuates with the NAO. The effects of changing risk should be considered in the Capping Analysis and in evaluation of remedial alternatives.

c. *Outdated Analyses*: The extreme events used to estimate flooding and bed stress are outdated and too small. Analyses focused on two events: Hurricane Donna in 1960, and the 1984 river flood event on the Passaic. Though these were large storms, recent flooding from Hurricane Irene (2011) exceeded the 1984 event, and Hurricane Sandy exceeded the Donna storm-tide by a very large margin, about 1m (Talke et al., 2014). Historically, 1984 is the 6th largest Passaic River flood event since 1878, or approximately the once-in-20-year event. Similarly, Donna water levels have been exceeded twice in the last 200 years—by the 1821 event (Scilleppi and Donnelly, 2007; Kussman 1957) and by Hurricane Sandy. A more realistic 100-year event should be modelled to adequately assess flood and storm surge risk. As shown by Hurricane Sandy, the FEMA 100-year and 500 year floodplains underestimated the potential for flooding.[23] To fully understand the consequences of different remedial actions, and their interaction with proposed dredging, the flood analysis should be updated to include new information.

d. *Coupled storm and surge events*: Focusing on a hurricane with little river flow (Hurricane Donna) and a river flood without a significant storm surge (the 1984 event) misses an important fact: river floods and storm surge often act together in the LPR and in concert with tides, to produce an overall flood risk that is larger than from flood or surge alone. Three examples are shown in Figures 17, B4, and B-6. The most severe flood on record—in 1903—was apparently a slow moving storm, such that the peak storm surge coincided nearly exactly with the peak river flow (Fig. 17), undoubtedly increasing the severity of the flood damage. Therefore, a more realistic view of extreme events and flood risks should include the joint probability of elevated surge, tides, and river flow occurring simultaneously, rather than treating surge and flood events separately (as in the FFS Report).

e. *Bed shear stress spatial patterns*: Because storm surge, tides, and river discharge all affect water levels and currents, and there is a spatial pattern to bed shear stress (and flood risk) that is not considered in the FFS (Fig. 2b). Upstream at Dundee Dam, river flow is clearly the most important factor. As the estuary widens, river flood heights diminish and storm tides (surge + tides) become more important. In between, a combination of surge and flooding is important. For these reasons, an ensemble of different events should be run to determine the effective 100 and 500-year flood along the estuary-fluvial continuum. The important point is that erosion risk is larger when floods and surge events are considered together, rather than separately.

[23]This can be seen by comparing Figure 6-12 of the Capping Analysis (FFS Report Appendix BI, EPA [2014]) with the actual inundation for Hurricane Sandy shown by the USGS Hurricane Sandy Storm Tide Mapper (http://54.243.149.253/home/webmap/viewer.html?webmap=c07fae08c20c4117bdb8e92e3239_837e, accessed 16 July 2014).

f. *Flood vs. erosion risks*: The FFS Report fails to distinguish between flood risk—which is caused by elevated water levels—and erosion risk, which is caused by elevated velocities. The latter (and bed shear stress) are forced primarily by how quickly water levels are changing, rather than the absolute water depth. Therefore, fast moving storms such as Hurricane Gloria in 1985 may be more erosive than slow-moving storms such as Hurricane Sandy, even though their flooding was less severe (see Appendix B). Realistic analysis of such factors may considerably (and differentially) alter the costs and collateral impacts of the various alternatives

g. *Erosion risk interacts with dredging in several ways*: First, as shown by *Chant et al*. [2011], any river flow greater than ~35-40 m^3/s results in sediment export to Newark Bay. Flow rates greater than 40 m^3/s occur ~ 28% of the time (66% of the time between October 1st and April 1st). Hence, buried contaminants exposed during dredging have a substantial chance of being resuspended (by tidal, surge, and/or flow processes) and exported, particularly during higher-flow winter months. Tropical storm surges bring a similar risk. Conversely, sediment transport is upstream during low flow periods, 72% of the time. This may move contaminated sediment back to previously dredged and capped locations, maintaining high contamination levels in the bed throughout the system. The FFS should consider whether there are any times in which dredging should not occur, either due to risk of storm surge or risk from flooding. Such an evaluation would inevitably result in an increase in estimated construction time and cost, especially for the more intrusive alternatives with large dredging volumes. This would decrease their attractiveness relative to the less instrusive alternatives. Failure to consider these issues means that EPA has not realistically evaluated the remedial alternatives.

h. *Flood occurrence during construction*: The impact of a large flood during construction has not been considered at all. Given that construction times for Alternatives 2 and 3 have been considerably underestimated (see Specific Comments), this is not a trivial issue. A 100-year flood or surge event has a non-trivial chance of occurrence (about 9%) in the projected 10-year construction time for Alternative 2. If estimated construction times are unduly optimistic, this will increase this risk. Because a large storm or flood event during construction risks a major contamination event, and the longer the construction time the larger the risk, this is a fundamental problem that needs to be considered in the FFS. As discussed below under Specific Comments, scour may occur around the sheetpile structures to be used during dredging, especially during flood and/or surge events.

i. Summary: Overall, the effect of extreme events on the proposed remedy has been only superficially investigated; however, these considerations are critical to ensuring that contaminated sediments are not exported during dredging, or moved upstream to 'cleaned' areas.In particular, the longer the construction time, the more likely that an extreme event will occur during the dredging. This increases the risk of exposing deeper, more contaminated sediment to erosion and export to Newark Bay, and of an accident occurring that releases considerable amounts of contaminated material. Because the four remedial alternatives involve very different risks in this regard, these issues need to be considered in the FFS.

1.7 **Carbon Footprint/Collateral effects not considered**

No consideration has been given to the very different carbon footprints of the four alternatives. Alternatives 2 and 3, which propose to remove 4.3 to 9.7 million yd^3 of sediment, will fill a large fraction (or perhaps all) of the presently available disposal site volume in the Eastern United States (FFS Report Appendix F and Fig. 18), requiring truck or rail shipment of waste across much of the continent. It does not appear that the very large carbon footprint of such an operation has been considered. Such long distance shipment is also undesirable from the standpoint of potential rail accidents that could distribute contaminants far from the Passaic River, as the recent spate of accidents associated with increased rail shipment of oil demonstrates.

2. Specific Comments

2.1 The Conceptual Site Model

An appropriate Conceptual Site Model (CSM) is vital to any successful remedial action. It summarizes basic system properties and process understanding, thus providing a firm basis for formulating and evaluating a range of remedial actions. In the FFS Report, much of the process understanding (particularly for physical and geological processes) and factual basis needed to evaluate remedial alternatives is missing, and the CSM does not correctly convey the degree of uncertainty that surrounds the information that is available. The system trajectory over time has also not been adequately considered. Overall, the CSM does not provide an accurate or complete basis for evaluating the remedial alternatives.

a. *Scope*: The beginnings of an alternative conceptual site model were presented above in Section I.2. The purpose of these comments is to respond to the specific content of the CSM [*EPA*, 2007] as revised by Remedial Investigation Report (Chapter 6; *EPA* [2014]) and point out omissions. The most important omission is that the ETM is not mentioned at any point in the 2007 document and only superficially in the 2014 revision.[24] This illustrates a discrepancy between the CSM discussions and system reality. It is not reasonable to attempt to explain the LPR contaminant distribution without understanding the ETM and its role in contaminant transport.

b. *System classification*: Sometimes names matter. On p. 1-8 of the CSM, the LPR is described as a "partially stratified estuary." While the LPR is sometimes partially stratified or partially mixed, it is actually a highly channelized and altered river-estuary. As such it is more non-stationary than most partially mixed estuaries and has a rather broader process repertoire. This point needs to be considered with respect to sediment and contaminant transport, model verification, and cap stability, among other issues.

c. *System trajectory*: The history of human modification of the LPR and the system's subsequent trajectory is treated in a qualitative manner in the CSM. This is inadequate. A quantitative understanding of changes in bathymetry, circulation processes and sediment fluxes on multiple time scales is needed to realistically evaluate remedial alternatives. A good test of model efficacy would be to determine whether it can simulate the past history of contamination (e.g., follow contaminants from discharge sites to their present-day distributions).

d. *Erosional and depositional areas*: the present division of the system into fine and coarse grained areas is partially (as stated pp 1-9 to 1-10 of the CSM) a response to changes in width and, therefore, in currents. However, currents are highly variable with river flow, tidal range and intermittent wind/surge events. The history of dredging and the observation that the ETM is often centered just below RM-8 and are also likely important factors in morphological evolution. Most

[24] We also note that the 2007 CSM is the document that actually guided the modeling studies, given that: ECOM has not been revised since 2008; the EMB and Fate and Transport models do not realistically deal with the ETM; and the FFS Report contains no unified analysis of whether the combined models from ECOM and ECOMSED through to the EMB and Fate and Transport models actually reproduce ETM phenomena.

dredging since 1932 has occurred seaward of Rm-8.1 [*Iannuzzi et al*., 2002], and this area was the most "over-deepened" relative to its natural depth. Also, although about 25% of the sediment load from the Passaic River is coarse material, essentially no export of sand to Newark Bay has been observed. Thus, even though the bed below RM-8 is predominantly fine, slow deposition of the coarse material is likely ongoing. Also, the reach above RM-8 required occasional maintenance dredging after it was deepened to 10 ft in 1931 [*Iannuzzi et al*., 2002], even if the dredging amounts were modest relative to those further seaward. Thus, there are multiple factors leading to the present distribution of bed properties, and these will change if the system is altered.

e. *Erosional areas*: The concentration of scour in limited areas and the connection of scour to fluvial processes associated with channel curvature is mentioned on p. 1-10 of the CSM. Scour in channel bends is intimately related to lateral (secondary) circulations in both estuarine and fluvial environments, though the presence of stratification makes these processes very complicated. While recognizing their importance, Region 2 has used a model incapable of representing these processes because (as noted above) the horizontal and vertical resolutions of the ECOM and ECOMSED grids are too low; the Fate and Transport grid is even coarser. The implications of this pathway to the cost/benefit analysis of various alternatives should be investigated. In particular, full capping (with or without dredging) proposed in Alternatives 2 and 3 is not an appropriate response to a localized "hotspot" problem.

f. *Source(s) of 2,3,7,8-TCDD:* The assertion on p. 1-13 of the CSM (EPA [2007]) is contradictory and unproven: *"Moreover, the presence or absence of an interval of high concentration within the sediments at a given location is a function of the depositional history and is not controlled by proximity to source. Thus, thick sequences of contaminated sediments will tend to have similar inventories of contaminants throughout the Brackish River Section and even into the Transitional River Section (refer to Section 6.2.1 "Surface Sediment Concentrations and Gradients")."* It is first stated that the somewhat uniform along-channel distribution is evidence for the efficacy of tidal circulation in transporting contaminants, presumably in the ETM (which is not mentioned). Then this efficacy of transport is implicitly used to justify the assertion that depositional histories control lateral distributions and the formation of hotspots. Neither this assertion nor the following discussion of the 2,3,7,8-TCDD/Total TCDD proves that there are not multiple sources. Moreover, as we noted in Section I, the presence of the highest average 2,3,7,8-TCDD concentrations well landward of the usual ETM position has not been explained. The section referred to in the above quote (Section 6.2.1, with the argument continued in Section 6.2.2) contains no further information and merely repeats the same assertion that there are no other sources, but there is no quantitative analysis of fluxes. The statement on p. 2-6: *"While the source of the Lower Passaic River 2,3,7,8-TCDD contamination has not been quantitatively identified, the primary candidate is the upland area at RM3.2 and the associated chemical manufacturing facility and Superfund sites* (USEPA, 2007)" (emphasis added) is rather more frank. One source has been identified, but the hard work of identifying or eliminating alternative sources has not been done.

g. *Exchanges with Newark Bay:* The text on p. 4-7 of the CSM fails to provide a clear explanation of sediment exchanges with Newark Bay: "*While this analysis precludes substantive contaminant transport from Newark Bay to the Lower Passaic River, it does not entirely rule out the transport of some Newark Bay solids to the Lower Passaic River."* A substantial flux of material into the LPR still occurs today (e.g., as discussed by Chant et al. [2011] and shown in Table 1 of Shresti et al. [2014], reproduced as Table 1 herein) and is the inevitable result of the estuarine circulation processes. To the rather considerable extent that this material is contaminated, contaminants are transported into the LPR along with the sediment. That historical fluxes of sediment into the LPR were larger than the present values of these fluxes is suggested in Figures 6a,b (see also Appendix C) and acknowledged in the discussion on p. 4-8 of the CSM. What is not acknowledged is that deepening the LPR in Alternatives 2 and 3 will increase the landward flux of polluted material from Newark Bay into the LPR.

h. *Small-scale nature of deposition and erosion:* p. 5-7 of the CSM says: *"One striking feature of Figure 5-1 is the complexity of the Lower Passaic River as denoted by the intertwining of net depositional and net erosional area, not only along the river but also across the river from bank-to-bank."* Given this statement, it is clear that the grid used in ECOM and ECOMSED (and the yet coarser grid used for Fate and Transport Modeling) is unable to represent the relevant processes, which occur on scales smaller than the grid. This grid is not, therefore, a useful tool for evaluating the remedial alternatives.

i. *Revisions to the CSM:* On p 1-4, the CSM (EPA [2007]) states that: *"In addition, the geochemical evaluations presented in this CSM should be further refined to integrate the remaining historical data and the data collected during recent and future field investigations that have not been included here."* As noted above, the need for further refinement of the CSM is broad and not confined to "geochemical evaluations."

2.2 Lower Passaic River System Understanding of Sediment Transport

This document [Sea Engineering & HDR, 2011] supplements the CSM in contributing to the understanding of system sediment transport. It is incomplete in several respects, substitutes analyses of model results for analyses of data to draw conclusions that cannot be substantiated due to lack of full calibration of ECOM and ECOMSED, and falls short of providing a proper conceptual model of sediment transport in the system.

a. *Status of document:* On p. 5, *Sea Engineering & HDR*, [2011] says: *"The objective of this document is to outline a basic System Understanding for Sediment Transport (SUST) which provides a description of the sediment transport processes governing the fate and transport of contaminants in the LPR. Although a Conceptual Site Model (CSM) has been developed as part of a Focused Feasibility Study of the Lower 8 Miles of the LPR, the system understanding will be used as a tool for synthesizing and linking existing data sets and sediment transport modeling analysis for answering site management questions. Additionally, the understanding will be used to develop a strategy to guide future data and sediment transport modeling analysis efforts in addressing the site management questions. The conceptual understanding presented here is primarily qualitative in nature and is not intended to present a complete analysis*

of all data available for the system." Thus, it is fully appropriate to review Sea Engineering & HDR, [2011] as part of the LPR FFS report. However, the understanding, described here as "qualitative" and not complete, should have been made quantitative and complete before issuance of the FFS Report.

b. *System overview*: The SUST fails to recognize the importance of MSL rise, calculates 100-year and 500-year flows that are too low, does not consider storm surges as a major disturbing factor in the system, and does not consider that the effects of the floods are enhanced by storm surges (see Appendix B).

c. *Discussion of tides and tidal currents*: The SUST contains no quantitative discussion of the tidal properties of the system, or of how those vary with river flow, or of the ECOM's success in modeling them. Since it is argued that tides are one of the factors driving sediment landward, these are crucial omissions.

d. *Analysis of salinity intrusion:* SUST argues that the salt front is important as a locator of the ETM, among other things (pp. 7-8), and a plot is provided of the position of the high-tide salt front as a function of river flow (Figure 9 of SUST). While such an analysis is important, this plot is based entirely on model results with no attempt to verify their correctness, and no account is given on the effect of tidal range and mean water level (e.g., as influenced by storm surges).

e. *ETM location in relation to the salt front*: The discussion of the salinity front location on pp. 7-8 is motivated by an assumed coincidence of the ETM with the salt front (as in Figure 10 of the SUST), yet model results do not locate the ETM centroid at the salt front and Figure 8 of Chant et al. [2011] suggests a variable relationship of the ETM to the salt front. Obviously, salinity intrusion is vital to the transport convergence that creates an ETM, but tidal processes are also important, and ETM position is often also strongly related to lateral processes and bed features, as noted in Section 1.4. Actual ETM properties (e.g., centroid position, length, concentrations, relationship to salinity intrusion) need to be defined from a combination of data analyses and the use of verified models. This has not occurred as part of the FFS Report process, and ETM processes remain poorly understood.

f. *Role of tidal transport*: The rather offhand comment on p. 8 of SUST that: "The upper river generally behaves as a normal river with advective transport of sediments downstream" is indicative of the problems with the SUST and the FFS Report – process understanding is lacking, leading to incorrect conclusions. Upriver of salinity intrusion, the LPR is still a tidal river. That model results show at least the occasional presence of an ETM in this reach suggests that seaward fluvial transport is not the entire story (or that the model results are in error). An ETM can occur upstream of salinity intrusion, for example, due to tidal distortion (e.g., *Allen et al*. [1981]; *Chernetsky et al*. [2010]). This again demonstrates a lack of understanding of the ETM processes active in the LPR, in the FFS Report and more generally.

g. *Water column sediment fluxes*: Figure 21 of SUST shows modeled sediment fluxes. Models are needed to provide an integrated picture of processes, and this would be an appropriate exercise if ECOMSED were properly verified, and if

sufficient comparison to observations were to be performed. Much more data analysis and comparison with model results needs to be carried out.

h. *Importance of detritus*: The text (p. 16) and Figure 37 of SUST suggest that organic macro-detritus (in this case sticks and leaves) play an important role in sediment accumulation. This is an important observation, as sticks and leaves will also modify sediment erosion. The overall importance of macro-detritus in the system needs to be understood, and possibly modeled, if it is a major component of the bed surface even seasonally.

i. *Summary:* Two points stand out in the Summary on pp. 18-19 of SUST. The first is the statement (p. 18): *"The LPR typically has tidal delivery of sediment from the direction of Newark Bay into the LPR during low flow conditions due to estuarine circulation."* This is followed by a bullet that states: *"The delivery of sediment is generally limited to the lower 8 miles."* This statement emphasizes that recontamination will occur after dredging. It is at also at odds with the FFS Report's theory that tidal movement of the ETM has delivered contaminated sediments containing dioxins as far landward as RM-12. Clearly, the transport dynamics of the system need to be better understood, particularly historical ETM processes, and the possibility of multiple sources of dioxins needs to be considered more seriously.

2.3 The Present Understanding of the Contaminant Distribution

Mechanisms for contaminant dispersion and concentration: The reasons for the present contaminant distribution have not been thoroughly analyzed. The FFS hypothesis for the mechanism of contaminant spread in the LPR is that ETM processes have distributed dioxins, PCBs, and other contaminants from their sources over the entire lower 14 miles (e.g., Chant et al [2011]; Isrealsson et al. [2014]). While ETM processes may spread contaminants over this region, this hypothesis does not by itself explain the observed spatial patterns or finer scale variability of contamination. Considerably more analysis is needed.

a. Modeling the observed contaminant distribution: We argue elsewhere that retrospective modeling to reproduce contaminant patterns should be used to calibrate and verify the FFS numerical models. The process knowledge gained by such an exercise would help the FFS determine why, where, and to what extent future recontamination will occur. Retrospective modeling would also provide insights into whether all the relevant contaminant sources have been discovered. Can modeled historical upstream transport reproduce known hotspots? Or must another explanation be invoked; e.g., another source of contamination? This is particularly important for interpreting the 2,3,7,8-TCDD contaminant hotspot located near RM 10.9, since considerable controversy remains concerning its origin (see references in *Isrealsson et al*. [2014]).

The FFS Report CSM [EPA, 2014] has no process-based explanation for the two-orders of magnitude variation in contaminant concentrations in the lower 8 miles, or for the formation of non-source-related hotspots. It argues, essentially, that: (a) all sediment-attached contaminants are transported by the ETM in a similar manner; (b) the ETM homogenizes contaminant concentrations over the entire excursion of the ETM, producing no significant variation in median

concentrations between RM2 and RM 12; and (c) the highest surface concentrations are found in areas of silt. By contrast, *Isrealsson et al*. [2014] attempt to explain the pattern of 2,3,7,8-TCDD concentration in the LPR by showing that the largest mass of area-averaged dioxins remains buried near the site of known contamination near RM-3. Both upstream and downstream of RM-3, the mass of buried contaminants decreases, consistent with dilution/diffusion of contaminants with other sediments sourced from both Newark Bay and the upper Passaic River. As acknowledged by *Isrealsson et al*. [2014], the unknown removal of contaminant mass by dredging complicates the picture. Similarly, the spatial pattern of dilution due to mixing from upstream and downstream is unknown. Such unanswered issues demonstrate the difficulty in definitively reducing spatial patterns to simple explanations. Nonetheless, it is worthwhile to further examine the *Israelsson et al*. [2014] analysis, since it produces additional questions that should be investigated in the FFS process.

b. *The Isrealsson et al. [2014] argument*: The explanation that dioxin contaminant mass is largest near RM-3 seemingly contradicts another observation: median and peak 2,3,7,8-TCDD levels increase in surface sediment from Newark Bay landward to a maximum between about RM-10 and Rm-12 (*Isrealsson et al.*, [2014]; see also Fig. 10a-b). A similar pattern is seen for total PCB congeners (Figs. 10c,d). The FFS has not, however, rigorously tested whether this pattern holds for other types of hydrophobic contaminants. *Isrealsson et al*. [2014] attempt to explain the2,3,7,8-TCDD pattern by hypothesizing an inverse relationship between sedimentation rate and surface contaminant concentration (i.e., slower burial equates to higher surface concentrations). This theory, while simple, is overly reductive, not supported by statistical analyses, and does not adequately explain the observed contaminant concentration patterns. There are multiple issues in the data analysis, presentation and conclusions in *Isrealsson et al.*, [2014], which are discussed below.

c. The 2,3,7,8-TCDD concentration vs. sedimentation-rate hypothesis is statistically untested: The *Isrealsson et al*. [2014] hypothesis that high surface 2,3,7,8-TCDD concentrations are associated with low sedimentation rates (the "inverse relationship" hypothesis) is presented in their Figure 13b, which shows a scatter plot of surface dioxin concentration vs. sedimentation rate. Figure 13b is absolutely vital to their analysis but is presented without a trend line, R^2 value, p-value, or other statistical apparatus. The number of 'high sedimentation rate' samples above 5 cm/year is small, and may not yield a statistically significant variance. No analysis by river mile is given, which may hide spatial variability (for example, some of the high sedimentation rate samples are likely from dredging-affected areas). A variety of curves could also be drawn through the data, leading (in the absence of statistical analysis) to diverse conclusions. The hypothesis cannot be regarded as proven without consideration of statistical issues. An alternate, more parsimonious interpretation might be that there is no significant trend in these results.

d. Small-scale advective processes are important for surface hotspot formation, not just depositional history and large scale ETM processes. The scatter observed in Figure 13b may occur because some areas were never depositional, as discussed by *Isrealsson et al*. [2014]. In other areas, contaminants were presumably first deposited and then eroded, resulting in a lower net

sedimentation rate. On the other hand, Figure 12b of *Isrealsson et al*. [2014] suggests an increase in dioxin concentration between 1995-2002 in core 29A taken at the RM-10.9 to RM-11 hotspot. This Increase in contaminant concentration could have occurred for reasons as diverse as the existence of a local source, fluvial secondary circulation, and/or recent exposure (e.g., by a slight thalweg shift) of heavily contaminated material at some nearby point. Whatever the physical mechanism, the uptick is likely produced by advection from nearby, as suggested also by *Isrealsson et al*. [2014]. This observation does not support the idea that high surface concentrations are produced solely by a vertical sedimentation process, i.e., a process in which a low deposition rate results in elevated surface concentrations. Other cores also show evidence of upticks at various times. Since the *Isrealsson et al*. [2014] "inverse relationship" does not account for recent advection, it is no more than a partial explanation (even if it were shown to be statistically robust).

e. *The Isrealsson et al*. [2014] explanation of surface concentrations is not predictive: A necessary condition for the validity of the *Isrealsson et al*. [2014] "inverse relationship" hypothesis is that median sedimentation rates in the LPR should decrease, on average, in the upstream direction, in order to explain observed median surface concentrations. However, this is not observed: the median and the lower limits of the sedimentation rate show similar magnitudes and variability in all reaches, as we have discussed in Section 1.4. Hence, the observed contaminant patterns cannot be simply explained by the "inverse relationship". *Isrealsson et al*. [2014] suggest that the depositional history is important; in other words, areas in which contaminants never settled will contradict the simple inverse relationship between sedimentation rate and high surface concentrations (Footnote 30, *Isrealsson et al*. [2014]). Hence, only areas that are mixed 'depositional-erosional', or where deposition ceased after initial contamination ('morphodynamically stable'), would show elevated surface contaminant concentrations. This assertion should be tested with further investigation since it is critical to the *Isrealsson et al*. [2014] hypothesis and also to future patterns of recontamination.

f. Depth of burial: The *Isrealsson et al*. [2014] "inverse relationship" hypothesis rests on an observed linear relationship between sedimentation rate and depth of maximum dioxin concentration (i.e., burial depth; Fig. 13c). This is a reasonable, but unsurprising, result if the maximum contamination event occurred (on average) at the same time. The average sedimentation rate is defined by the depth of maximum sedimentation (Smax), divided by the time T of Smax as determined by Ce-137 concentration.[25] Hence, the graph shows Smax/T vs. Smax; a line fit to this graph would show that the median time of contamination occurred around 50 years ago, a result that would also have been conveyed by plotting a distribution of estimated T. Other contaminants should be used to verify this relationship in the FFS analysis, and the FFS should consider using independent definitions of sedimentation rate (e.g., using bathymetric surveys, if of sufficient quality). A different slope would suggest a different time of contamination.

[25]Some rate estimates also used the initial appearance of concentration or Pb-210 decay rate [*Erickson et al*., 2007], but all are determined assuming constant deposition.

g. Missing data: *Isrealsson et al*. [2014] have not used all available data in supporting their "inverse relationship" between dioxin concentrations and sedimentation rate. Specifically, the data used in Figure 13d from RM 10.9 were not used in Figures 13a,b, and c, for reasons that are not explained. *Isrealsson et al*. [2014] state that cores with Ce-137 dating of poor quality were not used (p. 7); this assertion is unproven, however for RM 10.9 data from 2011, and it is unclear why dating from all 54 cores would be unilaterally poor. This omission should be addressed by analyzing the stored cores and/or by estimating sedimentation rates from bathymetric surveys.

h. Consequences of missing RM-10.9 data: The implication of the missing data in *Isrealsson et al*. [2014] in Figure 13c is that the "inverse relationship" hypothesis cannot be applied at RM-10.9, even if proper statistical analyses were applied to data from other locations. In particular, if RM-10.9 data show a different relationship between sedimentation rate and burial depth, that might suggest a different time of deposition. If multiple cores near RM-10.9 show a different timing of deposition, this would contravene the current ETM contamination hypothesis and would: (a) either suggest a different contaminant source, and/or (b) suggest that the time line of ETM-induced contamination would need to be modified and the physical mechanisms explained.

As *Isrealsson et al*. [2014] note, areas above RM 8 are more affected by river flow and have not been subject to the same dredging history. Because the physical processes and dredging history are different for areas above RM-8, a single, simple explanation of contaminant history cannot necessarily be applied over the entire LPR. The discussion on p. 16 of *Isrealsson et al*. [2014] notes that increasing scour is observed in the navigation channel upstream of RM 8, such that fines are removed during periodic river floods. Based on particle sizes, the scour is assumed to be less on shoals, which suggests that sedimentation rates should be larger on the shoals than within the channel. Indeed, the hot spot at RM 10.9 is on a point-bar tidal flat where sedimentation may be occurring at an above-average rate.

i. Conclusion: We established above that the "inverse relationship" hypothesis was accepted in *Isrealsson et al*. [2014] without adequate statistical validation. In itself, that point does not mean that the hypothesis has been falsified, only that it cannot be accepted. However, if a high shoaling rate is verified for the highly contaminated RM 10-9 sediments, then the "inverse relationship" hypothesis would be falsified at this location, and explanations for the source and timing of the surface contamination should be found. More generally, further data collection and analyses are needed to clarify the mechanisms leading to hotspots, and other hotspots and shoals should also be carefully examined from a process point of view.

j. Other considerations: The importance of physical processes in interpreting the RM 10.9 core data and analyzing *Isrealsson et al*. [2014] is highlighted by a simple fact: the cores in question at RM 10.9 were taken in 2011, shortly *after* 3 of the top 10 floods to impact the Passaic since 1897 occurred (see Appendix Figure B-11); i.e., in April 2007, March 2010, and March 2011). Hurricane Irene (Aug. 2011) represents another large event. Knowing the extent to which these floods caused erosion and/or deposition is critical to interpreting the 2008 to 2012

contaminant samples and core profiles. For example, perhaps bank areas were scoured by the combination of flood waters (nearly 600m^3/s at Little Falls) and surge from Hurricane Irene (Aug. 2011), likely exposing contaminants or bringing them closer to the surface. Comparison of the 2008 to 2011 results with 1995 and 2005 survey results (with their different spatial distributions) may not be valid, as suggested by the Arcadis comments. These storms seem to have changed (at least temporarily) the surface 2,3,7,8-TCDD distributions, and this may particularly impact interpretation of areas in which elevated surface contaminants of recent origin have been measured. Knowledge of the storm effects is also critical to evaluating the FFS Report models and the transport of contaminants to the lower 8 miles from upstream, after remediation. A post-mortem analysis of the 2007-2012 storm effects (also including Hurricane Sandy) would be a first step in this direction.

k. Contaminant mobility: The possibility that contaminants may move is made in Figure 12b of *Isrealsson et al*. [2014], which shows an interesting uptick in RM 11 contaminant 2,3,7,8-TCDD concentrations between 1995 and 2002, from about 10% to about 40% of its peak value in 1970. This observation in one core is ascribed to local movement of contaminants from nearby. Comparison with nearby cores is missing, however, and we cannot evaluate this assertion. Another equally plausible hypothesis is that the uptick after 1995 may result from a recent contamination event.

l. Can other sources be excluded?: An alternative explanation of elevated RM-10.9 contaminant levels is that PCBs and 2,3,7,8-TCDD have been input into the LPR near or landward of RM-11, producing contamination in the top 15cm at this location.[26] This interpretation is speculative, but no more so than the *Isrealsson et al.* [2014] analysis. As the uncertainties discussed here show, the *Isrealsson et al*. 2014 article has raised additional questions, rather than provided a definitive conclusion.

m. Application to the FFS Report: The FFS does not explain how contaminants are trapped due to ETM and other processes. Sediments may accumulate in local "traps" (e.g., tidal flats or the inside of a channel bend) anywhere within the ETM excursion. A number of studies have examined how transverse circulation patterns can lead to sediment trapping on one side of an estuary (e.g., *Huijts et al.* [2006]). However, there is no obvious reason why typical ETM transport processes should cause surface contaminant concentrations to be maximal near the upstream limit of the ETM reach, as seen in Figures 10a-d, and in Figure 10a,b or *Israelsson et al.* [2014]. On the contrary, one might hypothesize that flood events would periodically move the contaminated material farther downstream, where sediment retention is stronger. Elevated concentrations near the upstream limits would then need to be explained by one of the other hypotheses that we have mentioned. The presence of multiple hypotheses regarding the RM-10.9 hotspot (none of which can be conclusively falsified or validated) means that more analysis is needed. A careful combination of data collection, data analyses and numerical modeling will likely be required to determine how hotspots work. Given that the Phase 2 removal is eliminating the

[26] A source further seaward is not excluded, but seems less likely, given the number of floods since 2007 and reduced intrusion of the ETM. Also, PCBs are known to be input from the upper Passaic and Saddle Rivers.

RM-10.9 hotspot, analyses will need to be carried out elsewhere. This site should, however, continue to be monitored, to see if further contaminants accumulate. Interpreting such further contamination would still require, however, considerable analysis. Also, a rigorous evaluation of the along-channel and lateral distributions of all major LPR contaminants is needed, and these should be interpreted with respect to their variances (as a function of location and contaminant). An objective curve fitting process should be used (as the Arcadis comments, and their figures, reproduced here as Fig. 10a-d), along with appropriate descriptive statistics.

2.4 Hydrodynamics Model (ECOM):

A number of flaws and shortcomings exist in the implementation of the ECOM hydrodynamic model. Issues include lack of calibration data; low horizontal and vertical grid resolution; a relatively poor reproduction of water levels, tides and currents; a lack of verification of modeled density stratification; a high sensitivity to key but poorly known parameters; a failure to include wind waves; no analysis of whether the combined Hydrodynamic, Sediment Transport, and Fate and Transport models actually represent key ETM processes; and no analysis of Newark Bay sewage treatment plant inputs on the LPR. Together, these problems suggest that ECOM (as implemented here) does not provide a sound foundation for the further modeling and analyses based on it. More specifically:

a. *Available data*: the more detailed a model, the more calibration and validation data are needed. Water column data (including but not limited to water levels, currents, and wave information) are very inadequate for the purposes of verifying a 3D Circulation model. Accordingly, the model is not very well calibrated and verified, and no model skill assessment has been provided, or compared against agreed-upon minimum standards of skill/efficacy. In addition, model outputs have not been evaluated in terms of their sensitivity to uncertainties or biases in boundary conditions and forcing data.

b. *Relevant data have not been used*: Even though the LPR is a rather data-poor system, some of the fundamental physical data that are available have not been used. For example, none of the historic tide data listed in Table 2 appear to have been used to calibrate ECOM or determine historic system changes. Given that the LPR is highly variable and non-stationary, it is essential to use all available data – the variability of the system is invariably greater than captured in any limited segment of the data.[27]

c. *ECOM horizontal grid resolution is too low*: In most areas of the LPR, the ECOM grid has only three or four grid cells across the channel. This does not suffice to resolve laterally variable estuarine and fluvial processes, or lateral trapping processes. Furthermore, grid statistics (e.g., orthogonality, smoothness, aspect ratio and resolution) should be reported. While there are always trade-offs between model resolution and execution time, the model domain is not especially large by contemporary standards, and it does not (as discussed below)

[27] While all available tide data should be considered, not all are necessarily suitable for calibration of model of contemporary conditions. Thus, there have been considerable changes in depths in the LPR and Newark Bay since the 1970s, making the 1976 to 1982 data of uncertain utility for calibration. These data should still be used to analyze historic changes in tidal properties, as depths have changed.

adequately resolve the relevant sediment and contaminant transport processes. In comparison to the ECOM grid, we note that the *Tierra Solutions* [2010] grid had 12 cells cross-channel, with a much more detailed sub-model near the sheetpile structure used for the Phase 1 Removal Action.

Table 2: National Oceanic and Atmospheric Administration (NOAA) and US Geological (USGS) Survey Water Level Data collected, 1976-2014

Location	Station ID	LPR River Mile	Dates	Duration	Comments
USGS Stations	USGS ID				
Newark	01392590	4.6	1993-2005	12 yr	Some gaps
Newark PVSC	01392650	0	2005-2014	10 yr	Some gaps; active
Hackensack, Hackensack River	01378570	NA	2000-2007	7 yr	Some gaps
NOAA stations	*NOAA ID*				
Hackensack, Hackensack River	8530278	NA	1994	3.5 mo	
Amtrak Swing Bridge, Hackensack	8530345	NA	1976-1977	13 mo	
Carlstadt	8530528	NA	1994	3.5 mo	
Kearney Point, Hackensack River	8530772	NA	1994	3.5 mo	
Port Elizabeth, Newark Bay	8530882	NA	1979-1982	2.8 yr	Some gaps
Point No Point	8530743	1.8	1976-1977	1 yr	
Belleville	8530591	8.9	1994	3.5 mo	
East Rutherford	8530403	13.8	1994	3.5 mo	
Garfield	8530345	16.5	1976	3.5 mo	

d. *ECOM horizontal grid resolution sensitivity analyses were not correctly conducted*: An uncalibrated, higher (2×) resolution model was compared to a calibrated, lower-resolution model, leading to the conclusion that grid refinement was not useful. Instead, the influence of grid resolution should have been assessed by increasing resolution until the model no longer showed significant changes in results [cf. *Roach* 1994; 1997].

e. *ECOM vertical grid resolution is too low*: Mixing and stratification patterns, vital to correct modeling of ETM processes, cannot be accurately represented with the existing grid. There are only 10 grid cells in the vertical. In a system that is 4 to 10m deep, this means a vertical resolution of 0.4 to 1m. Vertical gradients in salinity, velocity, shear and suspended sediment concentration frequently exist in the LPR on smaller scales than this; e.g., see Figure 10 of *Chant et al.* [2011], reproduced here as Figure 19.

f. *Water levels are not well reproduced by the model*: Modeled tides appear not to respond correctly to changing river flow, especially at upriver stations (e.g., Table

4-9 of the Final Hydrodynamics report [*HydroQual*, 2008]). This affects the representation of the ETM response to flow and the system response to storms and surge. Also, low-passed water levels at upstream locations depart significantly from observations (e.g., Table 4-8 in *HydroQual* [2008]), sometimes even during low flow periods (Fig. 4-7 in *HydroQual* [2008]).

g. *Currents and salinity are not well reproduced by the model*: Comparisons with the limited available calibration/validation data suggest that ECOM's representation of currents (e.g., near bottom currents in Figure 4-9 in *HydroQual* [2008]) and salinity (e.g., near bottom currents in Fig. 4-13 in *HydroQual* [2008]) are often incorrect. The systematic response of these variables to tidal range and Passaic River flow has not been assessed. Similarly, it is unknown whether the crucial "internal" salinity boundary condition between Newark Bay and the LPR (i.e., the model's representation of Upper Newark Bay salinities) is correctly represented; i.e., does ECOM correctly solve salinities and salt transport here?

h. *Model stratification patterns have not been verified*: It is well-known that tidal and sub-tidal variations in water column density stratification (due mostly to vertical variations in salinity) are absolutely critical to ETM processes (e.g., *Geyer* [1993] and *Jay and Musiak* [1994, 1996]). However, no attempt has been made to validate the model's representation of stratification. This is a vital step in calibrating and validating the FFS models.

i. *Treatment of bed roughness*: A single value of the bed roughness parameter Z_0 has been used for the entire grid domain despite the existence of a variety of fine and coarse grained environments with very different skin friction and form drag. Bed roughness should more closely correspond to bed characteristics. Also, structures like bridge piers are not represented by the coarse grid, so the value of Z_0 must have been altered to account for these missing features. Because only one value of Z_0 is used, the realism of the model is reduced, and the confidence to realistically represent and distinguish the various intrusive alternatives is diminished.

j. *Parameter sensitivity studies*: These analyses indicate that ECOM is very sensitive to the choice of the roughness parameter Z_O and horizontal mixing parameter Cs, the only two parameters examined (Figures 5-3 to 5-5 of HydroQual [2008]). Cs is, moreover, a function of grid resolution, and except for a particular range of Cs, the model crashed. Obviously, Cs must be kept within the range of model stability, but this leaves open the question of whether this range of Cs is physically reasonable. For example, an unrealistically large Cs will cause both the salinity distribution and the turbidity distribution to be incorrect. Failure to examine sensitivity to other parameters may be an important omission.[28] Moreover, no analyses of model sensitivity to the combined manipulation of multiple parameters were considered. In this sense, the model remains poorly calibrated. More specifically:

[28]Thus, *Blumberg et al.* [1999], working with an earlier version of ECOM, calibrated an additional parameter that quantified the sensitivity of water levels to atmospheric forcing, though the *Blumberg et al.* analysis falls short of being a comprehensive skill assessment.

i. Parameter sensitivity: This was analyzed only in the FFS Study Area (RM-0 to 8), not globally.

ii. Joint analyses: Bottom velocities (that set the bed shear stress) are particularly sensitive to choice of Cs and Z_0 and strongly influence sediment transport. This suggests that a joint analysis of varying grid cell size, Cs and Z_0 (and perhaps other parameters) are needed, if ECOM is to provide accurate results when used in combination with ECOMSED.

iii. Bottom salinity: Bottom-layer salinities are very sensitive to Cs and more sensitive than surface salinities. Thus, two key ETM parameters (salinity intrusion and density stratification) are very sensitive to parameters that are poorly known. These problems are likely connected to the inadequate grid resolution.

iv. Turbulence model issues: The performance of the turbulence closure model needs to be examined, due to known problems with the Mellor-Yamada level 2.5 turbulence closure (*Stacey et al.*, 1999). In particular, Mellor-Yamada type schemes have difficulty in correctly modeling variably stratified estuarine systems. This difficulty interacts with the relatively low vertical resolution, such that stratification and thus, erosion, deposition and sediment transport processes (which are related to stratification) are likely not well-represented in ECOM and ECOMSED.

k. *Wind waves are not represented*: There are no wind waves in this implementation of ECOM; they are known to be important in Newark Bay and may affect re-suspension of sediment over tidal flats in the LPR, including some that are "hot spots" for contaminants. That is, wind waves of only 0.1 to 0.2m may re-suspend significant amounts of sediment when they occur over tide flats [*Talke and Stacey*, 2008]. Re-suspension of sediment in Newark Bay tidal flats may be important as well, since this (contaminated) sediment can be transported into the LPR during the flood tide or by tidally averaged estuarine circulation.[29]

l. *A lack of integrated analysis of the ETM*: ETM processes are critical to LPR sediment and contaminant transport. They are not analyzed in an integrated manner, and it is impossible to determine whether they are correctly represented by the combination of ECOM, ECOMSED and SED-ZLJS, and the Fate and Transport models. The ETM is created and maintained by a combination of circulation, salinity intrusion, and suspended sediment patterns. The ETM governs contaminant fate and transport. There is no analysis that actually evaluates the behavior of the model in producing/maintaining the ETM. The longitudinal distribution of suspended sediment is not analyzed as a function of river flow and tidal conditions, even though this distribution helps determine which areas are depositional and which are erosional. The behavior of the ETM under non-equilibrium conditions (changing river flow and tides) is also largely unknown, as is the model suite's representation of these processes. Because of the importance of these processes, this is a major omission.

[29]We note that wind waves are included as an important factor in sediment transport in Figure 2 of the *Sea Engineering & HDR* [2011] system understanding of sediment transport. As such, they should have been included in the modeling.

m. *Summary*: The existing implementation of ECOM, with its coarse grid, omission of wind waves, and lack of skill assessment does not provide a sound basis for the sediment and contaminant transport modeling which it drives.

2.5 Sediment Transport and Bed Models

(ECOMSED and SEDZLJS): A number of flaws and shortcomings have been identified in the sediment transport (ECOMSED) and bed structure (SEDZLJS) models. These include: a lack of data for calibration and validation; poorly known and/or inaccurate characterization of upstream and downstream boundary sediment inputs; inadequate grid resolution; use of only one class of fine sediment; inaccurate reproduction of suspended sediment concentrations and sedimentation rates; no demonstration that ETM processes and properties have been correctly modeled, a high sensitivity to poorly known parameters; and a susceptibility to errors inherited from ECOM that is not considered. More specifically:

a. *Available data*: As noted above for ECOM, water column data (including in this, case currents, suspended sediment concentration, and grain size data) are inadequate for the purposes of verifying a 3D sediment transport model. Thus, the ECOMSED model cannot be considered properly verified, nor have comprehensive skill statistics been provided.

b. *Upstream boundary conditions (Passaic River)*: ECOMSED results are very sensitive to uncertain boundary conditions (both upstream and downstream). The upstream boundary condition for ECOMSED (at Dundee Dam) is based on limited data, and is uncertain or inaccurate. A more complete sediment rating curve analysis (Appendix A) based on a larger data set shows that the input of sediment from upstream is highly uncertain, and that the sediment is input at the wrong time during a storm event. Due to sediment transport hysteresis (a common phenomenon in rivers), sediment inputs (especially of fines) are "front loaded" at the beginning of a flood event, a factor not represented in ECOMSED. Also, FFS Report Appendix BII [*EPA*, 2014] does not distinguish between input of fines and sand at Dundee Dam, but the latter can be up to half of the total load during high flow events; it is unclear what assumption ECOMSED makes about the size distribution of the particulates input at Dundee Dam.[30] Because the system is supply limited for fines, the sources of sediment and types of events that lead to fine sediment supply need to be understood and modeled. Overall, the uncertainty in the Passaic River (at Dundee Dam) sediment input from upstream is a factor of ~1.5 to 2 for annual average load, but much more than that during the events that actually move large amounts of sediment. Uncertainty in sediment input is important, because ECOMSED sediment transport results are very sensitive to the upstream boundary condition. Thus, ECOMSED uncertainty analyses show that a ±20% change in sediment input at Dundee Dam can cause a >100% change in net deposition in some parts of the LPR; see Figure 5-3 of FFS Report Appendix BII [*EPA*, 2014], reproduced here as Figure 20. If actual sediment input errors are ±50% at the boundary (see discussion in

[30]The Dundee Sediment load provided by the model in Figure 3.1 off FFS Report Appendix BII [*EPA*, 2014] appears to be about 35% higher on average than the load provided by the model in Appendix 1 of *HydroQual* [2007]. This change is not revealed in the FFS, which says only that: "Freshwater solids boundary conditions used in this modeling effort are based on relationships between suspended sediment loading and river flow developed as part of the CARP project." See Appendix A for details of uncertainties in sediment rating curves.

section 1.3h), then uncertainty limits are much broader than suggested by Figure 5-3 of FFS Report Appendix BII.

c. *Upstream sediment boundary conditions on the Saddle River are wrong*: No high-flow sediment load data for the Saddle River were used in determination of the Saddle River rating curve; see Figure 3-1 of FFS Report Appendix BII [*EPA*, 2014], reproduced here as Figure A-2. The sediment loading approach used for ECOMSED arbitrarily separates high and low-flow conditions; the division is at twice the mean flow [FFS Report Appendix BII; *EPA*, 2014]. Because no high-flow sediment load data for the Saddle River were used, a "generic" regional (Eastern US) rating curve line is used for all flows above twice the mean flow. This causes an arbitrary ~1.5-fold increase in sediment load when the flow rises to twice the annual mean flow. For higher flows, this generic line suggests a much steeper increase in sediment input (above an already inflated estimate at twice the annual mean flow) than was measured for the mainstem Passaic River (Fig. 3-1 of Appendix BII). The highly urbanized Saddle River bears little relationship to most Eastern US river basins, and the estimated sediment input for flood flows (from the rating curve in Fig. 3-1) is greater than that for the Passaic River by a large margin; this is wrong, as demonstrated in Appendix A. This already arbitrary sediment input scheme was extended, because of an absence of data, to other small LPR tributaries. The result is that small tributary sediment loads are, in ECOMSED, treated in an arbitrary manner that greatly exaggerates their inputs. Given the strong response (above) of model results to external inputs, this is a significant modeling error that compromises all results based on it, including those from fate and transport modeling.

d. *Upstream boundary conditions (General)*: The difficulties in prescribing LPR sediment inputs based on rating curves emphasizes the need for a more sophisticated boundary condition approach. Given the importance of understanding LPR sediment dynamics, water and particulate inputs should be specified through use of an appropriate watershed model. This is necessary, for example, to understand whether hurricanes, winter/spring storms without snowmelt, and winter storms with snowmelt have fundamentally different effects on the basin, in terms of timing of flow and quantity and quality of sediment input. Watershed models have been reviewed recently by *Migliaccio and Srivastava* [2007], *Daniel et al.* [2011], and *Parajuli and Ouyang* [2013]. There are several alternatives to choose from for the purpose at hand.

e. *Downstream boundary conditions (Kill van Kull and Arthur Kill)*: Sediment concentrations at the model boundaries to the remainder of New York Harbor are based on acoustic backscatter from ADCPs. But the calibration of the backscatter is uncertain at both boundaries, and no analysis of particle sizes at the boundaries has been attempted. Thus, these boundary conditions must be judged to be poorly known.

f. *Conditions at the boundary between Newark Bay and the LPR*: Conditions at the downstream LPR boundary (Newark Bay, RM-0) are not well known, and model results have not been meaningfully compared to actual data. There is no way to determine the fidelity of model performance at this key location. This is a significant problem, because there is a complicated two-way exchange of sediment at this boundary that will change if the LPR channel is deepened for

navigation. Re-contamination of the LPR from Newark Bay is a crucial issue that has not been properly evaluated, and cannot be evaluated with the FFS Report models until they are known to correctly reproduce this important exchange.

g. *ECOMSED horizontal grid resolution*: The cross-channel grid resolution used (with no more than four grid cells across the LPR) is not adequate to represent the typical river-estuary sediment transport processes that occur in the LPR. These include strong lateral variations and secondary (lateral) circulations and ETM particle trapping that cannot be represented with only four cells. Bed composition, currents, bed properties (including erosion and deposition), and water column sediment concentrations and fluxes all vary strongly in the across-channel direction, and these patterns cannot be represented with the existing horizontal resolution. Sediment and contaminant transports are inherently related to bed properties that vary on scales considerably smaller than the grid used for ECOM and ECOMSED. A higher resolution model is needed in order to make valid predictions about future contaminant conditions or realistically evaluate the four remedial alternatives.

h. *ECOMSED vertical grid resolution*: The ECOMSED vertical grid resolution is inadequate to accurately represent turbulent mixing and stratification, both of which are vital to correctlymodel LPR sediment transport and ETM dynamics.

i. *Modeled suspended sediment properties*: To reduce computation time, ECOMSED represents only one class of suspended sediment, even though the hydrophobic contaminants in question are mostly carried by fine particulates, and modeling of their transport is vital. Appendix BII acknowledges that the particle population is a mix of faster-settling aggregates and slowly settling disaggregated fine particles. In order to represent fine sediment transport using only one settling-velocity class of particles, the fines settling velocity W_S is made an arbitrary function of concentration. This represents very crudely the well-known dependence of flocculation and settling velocity on turbulence conditions [e.g., *Winterwerp*, 2002]. The modeled dependence in the FFS models causes fines to dominate for very low and high river flows, while faster settling particles dominate at intermediate flow levels. Because of the arbitrary concentration-dependence of W_S (beyond the standard corrections for concentration), the W_S of particle populations will vary as they are transported horizontally, or settle/mix vertically. This may lead to completely unrealistic behavior in the ETM as tidal currents, bed shear stress, and the supply of erodible sediment vary over time. ETM concentrations can be an order of magnitude larger than upstream/down-stream conditions. Therefore, the same particle will have a different W_S in the ETM than if it were located in nearly identical tidal conditions 5km upstream or downstream, due to the greater amount of erodible sediment. Since there is feedback between W_S and the ETM position and distribution [*Talke et al*., 2008 & 2009], incorrectly estimating W_S introduces non-physical elements and feedback into the model, unrealistically affecting transport patterns and sediment trapping/erosion throughout the estuary. Moreover, the model for W_S is implicitly a system-specific function of material on the bed. Fine sediment behavior would inevitably change a coarse sediment environment, i.e., after capping. Therefore, the approach used for representing Ws cannot be applied when evaluating the active alternatives (Alternative 2 to 4). Realistic modeling of ETM processes will require

that multiple cohesive sediment classes be used with a finer grid than is the case at present.

j. *Modeled suspended sediment concentrations*: are generally higher than those inferred from ADCP backscatter (Figs. 4-8 to 4-12 of FFS Report Appendix BII), but may sometimes be lower than suggested by ADCP data (Figs. 4-13 and 4-14 of FFS Report Appendix BII). The reasons for these problems are unclear, but they may be the result of: a) the single particle class approach used to model the suspended load, and/or b) the use of an artificial (1 mm thick) bed-surface "fluff" layer with arbitrary behavior. This non-physical fluff layer facilitates numerical stability, but severely limits the realism of model results. The fluff layer should either be represented in a physically realistic manner (to the extent that it exists), or be eliminated by some combination of changes in algorithm and increased grid resolution (both vertical and horizontal). Another possible problem is that ETM position and distribution of sediment around the ETM may also be incorrect. Other factors being equal, an ETM that is unrealistically far upstream will typically result in greater sediment concentrations [*Talke et al.*, 2009]. If the modeled turbid zone is too small (for example, because of problems with the salinity structure, diffusion, or settling velocity), concentrations can become too large in some areas.

k. *Modeled bed shear stresses*: are generally lower than those inferred from ADCP velocities, even when modeled near-bed sediment concentrations are too high, as in most of the panels of Figures 4-8 to 4-14 in FFS Report Appendix BII. This suggests systematic problems in ECOM and ECOMSED that should be resolved before analyses of remedial alternatives are carried out.

l. *Modeled sedimentation rates*: Figure 5.5 of FFS Report Appendix BII emphasizes that modeled deposition rates are locally too high for all time periods considered (1996-2004, 2007-2010 and 2010-2011). That is, the number of areas showing too much accumulation exceeds those showing too little. These periods contain a wide variety of flow conditions and events and are representative of recent decades. Overall, the first period (with the longest integration time) exhibits the largest deviations between modeled and observed conditions. Thus, long averaging times do not eliminate model problems. Furthermore, the lateral distribution of shoaling is often wrong, as emphasized by the results shown in Figure 4-44 of Appendix BII (*EPA*, 2014), which compares modeled and observed shoaling 1996 to 2004. The model is unable to capture the details (lateral and along-channel) associated with flow in a curved estuarine channel. One factor leading to unrealistic sedimentation rates may be the uncertainty in boundary inputs of sediment from the landward side (Appendix A). The low grid resolution and inaccurate representation of the salinity field are also likely factors. A denser grid would deal more effectively with complex river-estuary secondary (lateral) circulation and better represent the salinity field. These difficulties raise major concerns with respect to using the models to infer changes on 30 to 50-year time scales, as the FFS does. If ECOMSED is to be used to evaluate remedial alternatives, then sedimentation rates need to be more realistic.

m. *ETM processes*: The spatial and temporal pattern of ETM processes and erosion remain poorly known. Modeling suggests the existence of multiple ETMs, but

there is no conceptual understanding in the FFS document that explains this observation, , nor do we know whether data confirm their existence. The position of the ETM centroid relative to the salt front appears to be highly variable, but the position of the salt front is widely (and potentially incorrectly) used as a surrogate for ETM centroid position. The dependence of ETM concentrations, fluxes, and horizontal and vertical length scales have not been characterized relative to relevant physical forcing factors (e.g., flow, tidal range, sediment supply and atmospheric forcing). ETM processes, represented by the combined models from Hydrodynamics to Fate and Transport, are not well understood, and model results have not been analyzed to evaluate fidelity of the results to LPR observations.

n. *Uncertainty analyses*: Model sensitivity to ±20% changes in upstream and downstream boundary conditions, the critical bed shear stress, settling velocity and erosion rate of cohesive particles, and the effective grain size of model size classes were considered, but these parameters were examined only for the lower eight miles of the LPR, rather than for the model domain globally. As noted, net deposition is very sensitive to upstream boundary conditions, particularly between RM-16.6 and 7.4 and between RM-5.2 and 2.8 (see Fig. 5-3 of Appendix BII of the FFS report; *EPA* 2014; reproduced here as Fig. 20). The W_S for fines strongly influences net deposition in some reaches. Conditions between RM-9.7 and 7.4 (typically encompassing the upstream end of the ETM) were sensitive to all parameters tested, with deposition responses of >±125% to ±20% changes in some parameters. The usual downstream end of the ETM (RM-5.2 to 2.8) exhibited responses up to ±75% for the various parameter manipulations. More reaches exhibited strong parameter sensitivity in terms of gross erosion and gross deposition, but these seem to have compensated one another to some extent, so that net erosion was less sensitive overall. Given that all the parameters tested are likely uncertain to more than ±20%, the sensitivity of model outputs to model parameters is quite high, limiting the predictive ability of the ECOMSED for evaluating remedial alternatives.

o. *Coupled uncertainties*: The effects of uncertainties in ECOM on ECOMSED are not acknowledged or evaluated. Moreover, the joint ECOMSED/SEDZLJS sensitivity to variations in multiple parameters has not been considered, because sensitivity tests varied only one parameter at a time. These omissions have the effect of underestimating the uncertainties in ECOMSED and SEDZLJS. As noted above, a thorough analysis of biases and uncertainties from the boundary conditions though the various linked models is needed.

2.6 The Fate and Transport Models

Fate and transport modeling, carried out by the combination of a carbon model (ST-SWEM) and a toxics transport model (RCATOX) also has a number of serious flaws. These include lower grid resolution than ECOM and ECOMSED; unclear formulations for cohesive particle settling velocities; possible inconsistencies with ECOMSED; incorrect evaluations of extreme events; poorly known and possibly incorrect contaminant boundary conditions; a high sensitivity to poorly known parameters and boundary conditions; errors cascading from the Hydrodynamics and Sediment Transport models; and an uncertainty as to which contaminants actually limit the effectiveness of the alternatives. Specific comments are:

a. *Grid resolution*: The grid resolution for Fate and Transport modeling is reduced in the along-channel direction by a factor of 2 or 3 relative to ECOM and ECOMSED. This severely limits the ability of the Fate and Transport modeling to reproduce the detailed processes that actually re-suspend and transport contaminants. Moreover, the models cannot realistically represent limited capping (Alternative 4) because the areas capped cannot be accurately mapped onto the large grid cells used.

b. *Non-algal particle settling velocity, W_S*: In a manner that is not clearly explained, vertical settling, erosion and burial processes for non-algal particles were calculated separately in ST-SWEM, rather than being taken from ECOMSED. A concentration and salinity-dependent value of W_S was used in ST-SWEM, instead of the concentration-dependent value used in ECOMSED. While the ST-SWEM W_S values might be more realistic, ST-SWEM still represents only one class of suspended material (with properties that vary in time and space), rather than more realistically modeling multiple classes of fines (including both aggregated and dis-aggregated particles). This approach becomes increasingly unrealistic when the bed material is changed (in Alternatives 2 to 4).

c. *Consistency between ECOMSED and ST-SWEM*: Given the grid aggregation in ST-SWEM and the differences between STWEM and ECOMSED in their treatment of particle settling velocity W_S, it is not clear that the two models are consistent in terms of horizontal and vertical fluxes, and erosion and burial of fine particulates. This problem has not been analyzed; it should be.

d. *Unknown and uncertain boundary conditions for contaminants*: Contaminant inputs are poorly defined, even at Dundee Dam; therefore, arbitrary assumptions were used. Due to a lack of measurements, Hackensack and Mohawk River values were used for the Saddle River and other smaller tributaries. CSO and SWO inputs are also poorly known, but may be very important in maintaining contaminant levels in the lower eight miles, in a way not represented in RCATOX.

e. *Contaminant bed model*: The contaminant distribution in the upper 6 inches of the bed is modeled with a diffusion coefficient. This is used in the FFS as an arbitrary 'tuning coefficient', and is not based on LPR measurements. In fact, the first value used was taken from the CARP model and resulted in all contaminated sediments being removed from the system between the model years 1995 and 1998 (page 4-6, FFS Report Appendix BIII). Because this was clearly incorrect, the diffusion coefficient was lowered (eventually to 10 cm^2/year) until model results fit the 'rate of decline' of contaminant concentrations in the data since 1995. While the report shows that the 10 cm^2/year is (barely) within the range shown by Boudreau [1994] (Fig. 4.9, FFS Report Appendix BIII), the use of bed diffusion as a tuning coefficient is highly questionable. Another hypothesis might be that the initial contaminant diffusion coefficient was correct, but that the sediment exchange with Newark Bay was modelled incorrectly (allowing all the contamination to escape). In other words, changing the diffusion parameter may cause the model to get the right answer for the wrong reasons. This can be empirically tested by retrospective modeling of historical conditions. If, for example, the problem is that the modeled exchange is incorrect, the model will

be unable to reproducepre-1995 historical contaminant patterns (rate of decline) without further adjustment of the diffusion parameter.

f. *Incorrect Saddle River load*: Table 3.3 (p. 3-11) of the FFS Report Appendix BIII gives Saddle River particulate dioxin contaminant inputs that are 1/1000 the level of Hackensack inputs, even though the text states they are the same. If this is not just a typographic error, it presents a major challenge to the correctness of FFS Report conclusions.

g. *Representation of extreme events*: Repeating a 15-year cycle of river inflow from which major flow events have been excluded is not a valid way to analyze the remediation alternatives. Model predictions for 2014 to 2059 should include events appropriate to the time span, and multiple scenarios should be run, representative of the stochastic nature of floods and storm surges. The effects of large floods and surges during the construction period should also be considered. Otherwise, the predicted history of contaminant concentrations is unrealistic. Definition of appropriate extreme events is discussed in Appendix B.

h. *Response to storms:* Figures 8b and d emphasize that moderately severe floods (e.g., repeats of the 2007 and 2010 events in 2024 and 2027) cause an order of magnitude increase of 2,3,7,8 TCDD concentrations in surface sediments for Alternatives 2 and 3, and somewhat smaller increases of other contaminants. These elevated concentrations decrease over a period of five to seven years. The mechanism of the initial increase is not clearly delineated, nor is the reason for the subsequent decline. Broadly distributed shallow scour is not, per *Chant et al*. [2011], a likely mechanism – and average of <2cm of sediment was apparently eroded in a 2005 event. While a flood can result in re-working to deeper depths, this has not been verified in the model or with data; see other sections for why localized erosion/deposition processes are probably important.[31] The FFS Report [*EPA*, 2014] holds that the ETM distributes contaminated sediment throughout the Passaic up to RM-12, with generally upstream transport except during periods of elevated flows. However, the Fate and Transport model appears to suggest downstream transport of contaminants over time after storm events. For example, Figures 6-5 to 6-7 of Appendix BIII [*EPA*, 2014] show elevated concentrations in Newark Bay surface sediments, before, during, and after a storm event in about 2024, presumably indicating net downstream transport for a range of conditions. The increase is greatest in the deep-dredging alternative (Alternative 2). The Fate and Transport modeling results therefore seem to contradict the conceptual understanding of ETM processes in the FFS. Either the combination of ECOMSED and RCA-TOX are not correctly representing sediment and contaminant transport, or the CSM is wrong with respect to the nature of contaminant transport. In any event, recontamination from either upstream or from Newark Bay is not realistically assessed.

i. *Summary of storm effects*: A major storm "resets" the system, disrupts system recovery, and results in much higher levels of contaminants in surface sediments for long periods. Especially if the strength and/or frequency of storms and floods

[31]While the FFS Report documents higher concentrations after floods, e.g., the conclusion that the source is re-working of sediments, either broadly or locally, is an assumption that has not been verified. The possibility of external sources cannot be excluded, even for dioxin contaminants.

have been underestimated the distinction between the alternatives is blurred–it becomes unclear (given broad confidence limits) if the more intrusive and expensive alternatives are actually more effective in remediation. The arbitrary timing of the storm event relative to the end period of the modeling period also becomes very important. Had the simulation stopped after the uptick in contaminants, the differences between FFS scenarios would be quite small. This illustrates the need for an ensemble approach, as approach to the incorrect use of deterministic predictions (see Fig. 7).

Sensitivity Analyses: Sensitivities of model results in the lower eight miles of the LPR were carried out with respect to: upstream (Dundee Dam) boundary concentrations of two contaminants, the partitioning coefficient between the fluid and particulate phases, the assumed depth and rate of sediment mixing in the bed, and the sensitivity to a 100-year storm. There are several problematic aspects, specifically:

i. Upstream boundary inputs: It is argued that the weak response to changing the boundary input of TCDD and octachlorodibenzo-*p*-dioxin (OCDD) means that detailed knowledge of upstream contaminant concentration is unimportant. Because there is considerable internal recycling of TCDD and OCDD[32], sensitivity analysis results for dioxins should not be assumed to apply to contaminants, like polycyclic aromatic hydrocarbons (PAHs), PCBs and mercury (Hg), that have substantial external sources that are represented in the model. Sensitivity of PAHs, PDBs, and heavy metals to their boundary inputs should, therefore, be examined. While changing boundary concentrations might not change the relative order of concentrations modeled between scenarios, the ability to determine non-overlapping error bounds for the various alternatives may well be compromised by uncertain pollutant inputs.

ii. Bed parameters: The model response to changes in the depth of mixing in the bed (to 0.05 and 0.2cm instead of 0.1m) is important. Either change slowed the modeled recovery, for different reasons. The rate of bed mixing affected recovery times directly; slower or faster mixing slowed or sped up recovery, respectively. If the recovery times are modeled incorrectly, the relative cost/benefit of the alternatives is affected. These two parameters may also interact with each other, but no joint manipulations were attempted. The considerable uncertainty in their values clearly affects the ability of the models to distinguish between alternatives.

iii. Effects of storms: As noted, any major storm “resets” the system, disrupts the recovery, and results in much higher levels of contaminants in surface sediments. The uncertainty in extreme events and the effects thereof blur the distinction between the alternatives in a manner that is not considered.

[32]As discussed above, it is possible, even likely, that there are other sources besides re-suspension. Since these are not represented in the model, they have no effect on the point we are trying to make – that model sensitivity to uncertainty or bias in boundary conditions has not been correctly represented.

iv. Storms and construction: The occurrence of a major storm during construction was not considered. Given that construction of the Alternatives 2 and 3 would likely take 10 to 15 years, impacts of such storms should be considered.

v. Uncertain CSO and SWO inputs: CSO and SWO inputs of contaminants are poorly known and may not be correctly treated – actual CSO data have been neglected in favor of past modeling practice with an uncertain foundation. CSO and SWO contaminant boundary conditions are assigned a concentration that does not vary in time, based on the median for the CARP model. The sensitivity of model results to this assumption should be tested, and a more reasonable suite of boundary conditions used, based on actual measurements. Uncertainty in CSO and SWO inputs could have a strong impact on projected outcomes, and these inputs should be better characterized in fate and transport modeling.

j. Cascading errors: Fate and Transport model results are critically dependent on the flaws and uncertainties in the Hydrodynamic and Sediment Transport models (ECOM and ECOMSED), including their boundary conditions and representation of extreme events. Were these cascading uncertainties considered, confidence limits would be much broader than stated. Even though large uncertainties in the data are acknowledged, the methodology used apparently does not actually include data uncertainties in the error bars on model results.[33] Thus, Appendix BIII acknowledge that: "*The uncertainty values computed represent a lower bound on the uncertainty in the RM 0 to 8.3 averages passed to the risk assessment*" [p. 4-18 of Appendix BIII, *EPA*, 2014]. Further, Appendix BIII [*EPA*, 2014] acknowledges that uncertainty modeling for computationally intensive models is a challenge (pp. 4-17 and 4-18). Citing an estimated 6-9mo time to perform a more thorough analysis of uncertainties (comparable to that used for the Duwamish Estuary), the FFS Report selects an approach to uncertainty estimation that is based on a comparison between residuals and data [*Connolly and Tonelli*, 1985]. This reliance on an almost 30-year old approach to error propagation, one that is now known to be incomplete and insufficient (see the reviews cited above, e.g., *Arhonditsis et al.*, [2006]) is inappropriate. In summary, it is unlikely that results for the four Alternatives can be distinguished with any reasonable level of confidence, using the methods employed by the FFS Report. A far more thorough error analysis is needed.

k. Limiting contaminants: While there has been a focus on remediation of dioxin contamination, it is not necessarily the case that dioxin is the most limiting contaminant in terms of ongoing, future contamination. This point needs to be carefully examined. At present, the rather contradictory results of the Fate and Transport model vs. the EMB model suggest that this issue has not been resolved; however, it greatly affects the choice of alternatives. Intrusive alternatives that are costly, require a long time to construct, and have major impacts in their own right are much less attractive if contaminants (like PCBs and Hg) from sources outside the lower eight miles of the LPR actually limit the effectiveness of recovery. If the LPR will remain highly polluted at the end of

[33]The text on pp. 4-17 and 4-18 is not entirely clear as to what was done. The text needs to be expanded in this area to make the methodology used clearer.

2059 due to non-dioxin contaminants, it is not justified under EPA guidance to spend billions of dollars on aggressive remediation efforts.

l. In summary, Hegel's *Preface to the Phenomenology* of the Spirit calls German romantic philosophy "a night in which all cows are black" [from https://ndpr.nd.edu/news/24815-hegel-s-preface-to-the-phenomenology-of-spirit/, accessed 13 July 2014], meaning that it failed to make vital distinctions. The results of the FFS Report Fate and Transport modeling are similar – when realistic uncertainty levels are considered, we assert that the outcomes for the four remediation alternatives, with their very different costs and collateral impacts, are probably not distinguishable.

2.7 The Environmental Mass Balance model

The EMB model is flawed: Issues include: consistency with the Fate and Transport model; an incorrect conceptual approach; underestimation of flood and surge events; a failure to extend the prediction period beyond 2059 even though this is clearly important; a dominance of systematic errors over the random errors that can be assessed by a Monte Carlo analysis; and overall uncertain results with unrealistic error bars. More specifically:

a. *Consistency between models*: The EMB model appears to be inconsistent with the Fate and Transport Model, in terms of system trajectory and projected contaminant concentrations for the various alternatives (see Figs. 8a-d). Also, the EMB model uses an observed contaminant decay rate (e.g., a half-time of 25 years for 2,3,7,8-TCDD; Table 5-2, Appendix C, of the FFS), while the need for remediation is argued on the basis that contaminant levels are not decreasing.

b. *Incorrect model formulation*: the EMB model formulation is inconsistent with system dynamics when applied to all three action Alternatives. That is, the assumed internal source of contaminants is removed in proportion to the area capped and/or dredged. This is incorrect. Only a shallow surface layer of sediment is assumed active, and this layer will be re-established by contaminated sediments to a degree that varies with the contaminant and the alternative. Thus, contrary to the assumptions used, the internal source will not decrease in proportion to the area remediated. Also not considered in the EMB model is the fact that recontamination from outside the system will be enhanced by the channel deepening that would occur in Alternatives 2 and 3. The EMB model is incapable of representing this enhanced contaminant trapping. Therefore, it cannot realistically portray the outcome of these alternatives.

c. *The EMB model does not credibly represent the ETM*: For reasons that are not explained, the EMB model domain covers only the lower 8 miles, even though this is illogical from a process point of view. It does not explicitly consider the existence of the ETM and does not represent the full excursion of the ETM, which extends beyond RM-8. In fact, it is crucial to the reasoning of the FFS Report that the ETM routinely transport contaminant landward of RM-8. Even after remediation, the ETM will continue to move suspended sediment (with contaminants) upstream beyond RM-8, and this pattern would be enhanced if the channel is deepened. Contaminants from further upstream, which are and will continue to be trapped landward of RM-8, will move seaward. Without

representing the full spatial extent of the ETM (which the FFS argues to be the primary transporter of most contaminants), the EMB model is simply not capable of modeling future system states.[34] If the EMB is to be credible, defensible boundaries should be used.

d. *Effect of extreme events*: The EMB does not show a response to storms. This factor is vital in that, according to the Fate and Transport model, storms cause a large increase in surface contaminant levels that endures for some years. In this case, we suspect that the Fate and Transport model is qualitatively correct, but we do not understand why the EMB model does not show the same result. This contradiction needs to be resolved. If it does not show a response to storms, then it is not a useful model and should be discarded.

e. *Time period*: The EMB model results are not projected beyond 2059 (30 years after project completion). If they were, it appears that the differences between Alternatives 1 and 4 (on the one hand) and Alternatives 2 and 3 (on the other), would become small, probably within the uncertainty limits of the model.

f. *Error analysis*: The statistical accuracy of the EMB model was tested via a Monte Carlo approach, which is appropriate for evaluation of random errors within the EMB model itself. The sensitivity of the EMB model to storm water composition was also examined, as was the effect of one internal constraint in the model. However, the largest errors and uncertainties in the EMB model are likely systematic (see above), and not assessed by either the Monte Carlo approach or the sensitivity analysis. Results are quite sensitive to storm events (and thus to assumptions made about river inflow). Also, as noted above, there is a systematic error in failing to account for recontamination of the LPR during and after the remediation process. Further, re-contamination due to re-suspension during dredging and due to enhanced sediment trapping in a deeper channel (Alternatives 2 and 3) cannot readily be included in the model formulation and appear to have been ignored. Finally, an ensemble of predictions should be produced for each alternative, recognizing the uncertainty in boundary conditions. These ensembles should be used in estimating model uncertainty.

g. *Overall results*: Given that systematic, rather than random, errors are the dominant concern with this model, the error bars shown in Appendix C, Figures 5-11 to 5-17 are inaccurate and misleading. Without addressing systematic errors, the EMB model cannot demonstrate statistically different outcomes for the four alternatives, even for 2,3,7,8 TCDD. This would especially be the case if the simulations were extended out to 2100. If, as we contend below, construction times have been underestimated, then the convergence of the models later in the century is highly relevant. If the outcomes of the various alternatives cannot be reliably distinguished, then a costly remediation alternative cannot be justified using the EMB model.

[34] It is not relevant that the worst hotspot upriver of RM-8 will be cleaned up before project construction. The ETM will continue to move material landward to this point, even after remediation.

2.8 Dredging and Construction Analyses

Dredging and Construction Analyses (Appendices F and G): There are also several issues with the dredging and construction analyses that strongly affect the relative attractiveness of the four alternatives. These include: underestimated losses of contaminants to re-suspension and other factors; a failure to assess the adverse effects of possible extreme events during construction; unrealistic estimates of construction time; miscellaneous threats to dredging productivity; and possibly extensive propwash re-suspension of contaminated material during construction of the more intrusive alternatives. More specifically:

a. *Dredging losses and re-suspension during construction*: Appendix F, Section 4.2.1 assumes a 3% (of dredged volume) re-suspension rate, which may be an underestimate, given a dredging operation complicated by debris of all sizes on the bed and the possibility of accidents and/or extreme events. Undisturbed and generated residuals are also likely to be a problem with the more intrusive alternatives; they also need further consideration. Because Alternative 2 dredges more deeply into old sediments, and contamination increases with depth, this alternative runs larger risks. Finally, no allowance has been made for re-contamination of the bed by boundary inputs of contaminants, ETM trapping processes, and extreme events.

b. *Effect of extreme events during construction*: Model simulations include no extreme surges or floods during the construction period. After construction, RCATOX and ST-SWEM suggest up to 5× increases in bed-surface contaminant levels after major storms, even for events that do not reach the level of a 50-year storm. Results of such a storm during construction need to be considered, particularly the effects of and on physical barriers (sheet-pile enclosures) used to protect the dredging operation. Scour may occur adjacent to such barriers, or the barriers themselves might be compromised, leading to a large contamination event.

c. *Unrealistic construction time estimates*: Project construction time has been under-estimated. According to Appendix F, dredging of 2000yd^3/day is "conservative," even though pilot dredging achieved only 830 yd^3/day. Even if 2000yd^3/day is taken as a realistic daily dredging volume per dredging unit, then the 9.37×10^6 yd^3 of dredging needed for Alternative 2 would require 4685 days of dredging work. The FFS assumes a 40 week dredge season (i.e., 240 days/year) for two dredging plant units, which yields construction periods of about 10 and about 5 years for alternatives 2 and 3, respectively. As indicated by the Tierra Engineering comments, these estimates are unrealistic. A 180d dredging season is more realistic, given a 4-month fishery closure (1 March to 30 June; FFS Report, Appendix F, Section 4.3.3), inclement winter weather and other storms. This more realistic estimate of the length of the dredging season increases construction times to about 13 and 6 years, respectively for Alternatives 2 and 3, respectively.[35] Delays associated with the need to extensively reconstruct or

[35]As noted in the Tierra Engineering Comments, increasing the number of units of dredging equipment in use could reduce these long construction times to some extent, but given the very narrow channel in the LPR and the numerous bridges, there would appear to be limits on the feasibility of increasing the number of dredging units. In any event, construction time appears to have been underestimated.

strengthen bank protection would further lengthen the construction period The FFS report's under-estimation of construction times overestimates the attractiveness of the more intrusive alternatives (Alternatives 2 and 3) that have long construction times for at several reasons:

i. A longer construction period brings a longer disruption of the community and the system (with the attendant risks of contaminant dispersal) than assumed in the FFS.

ii. The longer construction lasts, the lower the contaminant concentrations will be at the end of the construction period for the less intrusive alternatives (Alternatives 1 and 4). This reduces the relative benefits of the more intrusive alternatives (Alternatives 2 and 3), with their much larger costs and enhanced risks of contaminant release.

iii. A longer construction period increases the risk of the occurrence of a major flood or storm surge during the construction period. Such an event could result in a substantial release of contaminants.

d. *Propwash effects during dredging*: A large number of roundtrips by tugs and barges will be required. This will inevitably result in erosion of contaminated bed material. Thus, the more intrusive remedial alternatives would likely cause dispersal of material throughout the LPR and Newark Bay that could be avoided by use of less extensive dredging operations.

2.9 The Capping Analysis and Extreme Events

The capping analysis does not correctly consider the effects of extreme events and has other flaws: A number of issues have been identified in Appendix BI. These include an under-estimation of severity of extreme surge and flood events; a lack of consideration of the coupled nature of surges and floods in the system; and a failure to consider the effect of normal fluvial evolution on any cap installed. More specifically:

a. *Under-estimation of extreme events*: The 100 and 500-year flood and storm surge events have been under-estimated, as explained in our Appendix B. Our analysis suggests that the 100 and 500-year flood levels at Little Falls are about 680m^3/s and 1030 m^3/s, respectively, rather than 560-633 and 917 m^3/s. Hurricane Sandy resulted in flooding similar to the 500-year scenario in FFS Report Appendix BI, but it was not a 500-year event. Our analysis suggests that Hurricane Sandy was about a once-in 300-year event. Non-stationarity is also evident, and flood and surge risks exhibit variability on multi-decadal scales. This occurs because climate patterns such as the North Atlantic Oscillation (NAO) cause rainfall and storm surge to change over time (see also Section 1.2). The implication for the FFS is that approaches to risk analysis that assume stationarity (as used here) underestimate true risk during some climate periods. *Talke et al.* [2014] show, for example, that the 10-year storm-tide hazard in New York Harbor has increased by nearly 0.3m over the past 150 years, even neglecting the effects of MSL rise. Clearly, a non-stationary approach should be used to assess extreme events and their impact on the long-term viability of different capping options. Finally, no analysis of the character and effects of winter storms and nor'easters vs. hurricanes has been carried out to determine

whether their impacts on the LPR are similar or different – different storms likely have different effects, and this needs to be considered in the capping analysis. In particular, the rate at which water levels rise and fall affects the amount of erosion that occurs, and not all storm surges of the same magnitude will have the same rates of rise and fall. See Appendix B for details.

b. *Flood and surge interactions*: The assumption that storm surge and river floods can be modeled separately is flawed.As shown by Hurricane Irene, a significant storm surge can occur during the leading edge of a flood. Tide data back to the 19th century [data described in *Talke et al.*, 2013] show that extreme flood events in the Passaic are typically accompanied by a significant surge. In fact, a 0.8m surge occurred at the peak of the largest Passaic River flood on record (in fall 1903; Fig. 17); see our Appendix B. Appendix BI of the FFS Report argues that the likelihood of the 100-year surge occurring at the same time as the 100-year flood is small, but this statement misses a key point. Bed shear stress is nonlinear; it is quadratic in velocity, and sediment transport occurs only when a threshold (critical bed shear stress) is exceeded. Thus, sediment erosion increases very rapidly as the critical shear stress is exceeded; even a 25% increase in peak flow can result in a large amplification in entrained sediment. System depth is also changed, and non-linear interactions between the river flow, salinity, and tides occur. For this reason, the actual impact of even a moderate surge during a 100-year flood (or a moderate flood during a 100-year surge) can be much greater than the sum of the two events alone. Thus, the possible joint occurrence and impacts of the two processes should be assessed using joint probability methods; see Appendix B for further details. Further, the interactions of surge and flood varies along channel, so that the risk associated with a particular combination of conditions needs to be assessed as a function of position. Other risk factors have also been ignored. For example, multiple sequential storms could cause a river flood to peak at the crest of the next surge. Finally, tributaries below Little Falls have flashy hydrographs and can bring a flood peak into correspondence with a surge peak. Thus, flows at Little Falls (the gauging station with the longest record) are not entirely representative of flows into the LPR; see Appendix A for a discussion of the differences between Little Falls and Dundee Dam flows.

c. *Normal evolution of a fluvial system*: The analysis of storm and surge impacts on an artificial cap is conducted as if the cap would abolish normal fluvial processes, and no allowance is made for changes in thalweg orientation, scour and other natural processes before and between storm and surge events. These natural processes may well thin the cap in some places. While it might be argued that the cap will be maintained over time, this does not reckon with the occurrence of multiple events over a short period of time. The 1903 flood occurred about one month after a major hurricane, for example, and one of the reasons for the extremely severe flooding that occurred was the fact that the soil was saturated from a summer of high precipitation, including the hurricane before the flood. Thus, there were multiple periods of elevated flow over a period of months. Cap repairs during such a period would be quite difficult. This point suggests that the projected benefits of the more intrusive alternatives may be rather less than projected—the cap may not be robust against a series of severe events, even if none of them rise to the level of a 100-year flood or surge.

d. *Scour around sheetpiles during dredging*: The FFS report mentions that "sheetpile wall" technology can be used to reduce/eliminate dredging loss, but it is unclear whether it will be used all the time and how effective it is against extreme events. Stated side-effects include possible scouring around the sheetpile, and greater flood risk due to partial damming of the flow (FFS, p. 3-10). The risks are stated in the FFS, but do not appear to have been investigated in the hydrodynamic model. In particular, the interaction of monthly, yearly, and decadal flood/surge return period events with such dredging structures should be considered. We note that *Tierra Solutions* [2010] found that up to 2.4 m of abutment scour could occur around a sheetpile structure in the LPR (Harrison Reach), though proper streamlining could reduce this scour by up to a factor of four. However, the conditions used for this calculation did not correspond to a severe flow event, and much deeper scour would likely occur during a severe flood or surge event. For the limited area of the Phase 1 removal modeled by *Tierra Solutions* [2010], it was found useful to install bed armoring around the structure. Whether this would be feasible in a situation where the sheetpile structure had to be continuously moved is unclear. Further, *Tierra Solutions* [2010] examines impacts for an intertidal flat in which flow velocities were not particularly large. Sheetpile structures within the main channel may distrurb the flow regime much more, producing more scour. Also as already noted, the physical source of erosion risk changes with river mile (e.g., river floods, tides, and surge), and may necessitate different containment strategies in different locations.

e. *Interaction with the ETM*: The location of the ETM and the mobile pool of sediment relative to sheetpiles should also be considered. The ETM zone itself is depositional; however, as conditions change and the mobile pool of sediment moves away, the area around a dredge or around sheetpile walls may become more prone to erosion. In particular, if a large flood occurs during construction, then the use of sheet pile walls may greatly increase the risk of release of large amounts of contaminants. Vortex shedding, enhanced turbulence, enhanced bed shear stress, and therefore enhanced sediment/contaminant resuspension may occcur upstream or downstream of sheetpile structures (depending on flow direction). The literature on the dynamics of flow past sharp objects is informatative. Flow obstructions such as large dunes and engineering structures typically result in flow separation and the formation of coherent structures and boils with enhanced turbulent kinetic energy (e.g., *Simpson* [1989]; *Best* [2005]; *Talke et al.* [2010], *Talke et al.*, [2013]). See Figure 21 for a conceptual view of this process. The lengthscale over which flow is perturbed is large: in flow over a backward-facing step (a prototype for flow past sharp geometry) that protrudes a horizontal distance *H* into the flow, the flow in the accelerated 'separated flow' region reattaches to the bed (or wall, depending on orientation) only after a length-scale of ~5H [*Simpson*, 1989]. The enhanced turbulence is observed even 10 or 15H downstream. This scaling suggests that the effects of a hypothetical sheetpile structure that protudes 50m laterally into the flow may be felt more than 500m downstream. These issues should be considered in the FFS, because the four remedial alternatives are quite different in the degree to which this issue arises – the more dredging required, the larger the hazard of a large erosion event occuring.

2.10 Effects of future system changes not considered

<u>Large-scale future systems changes have been ignored</u>: The ramifications of possible future changes to the system have not been considered. These include: (a) a possible Passaic River flood diversion tunnel; (b) climate change and sea-level rise; (c) a storm surge barrier in New York Harbor; and (d) abandonment of the shipping channel above RM-0. These should be amongst the scenarios that make up the ensemble analysis of outcomes for each alternative.

3. Detailed Analyses

Appendix A: Analyses of Fluvial Sediment Input, Passaic River and Tributaries

Rationale

Purpose: This appendix has three purposes: (a) to demonstrate that fluvial input of sediment to the LPR is very uncertain; (b) to show that sediment load hysteresis is very important and needs to be included in the sediment load functions for the Passaic River and its tributaries; and (c) to provide more realistic sediment load rating curves that incorporate hysteresis. Figure 20 of the main text emphasizes the sensitivity of the combined sediment transport (ECOMSED) and bed (SED-ZLJS) models to sediment input at the Passaic River upstream boundary at Dundee Dam. Changes of ±20% in sediment load are amplified by the models, resulting in changes in the deposition/erosion balance of ±25 to >125% in most parts of the system. The deposition/erosion balance is critical to correct representation of system bathymetric evolution, and to contaminant transport in the Fate and Transport modeling, though the FFS Report did not explore the latter issue as it should have. This appendix reviews the FFS Report approach to rating curves, reproduces these rating curves, and then develops an alternative approach. The existence and importance of hysteresis effects and the uncertainty of the sediment load are then demonstrated.

FFS Report approach: The sediment input at Dundee Dam (US Geological Survey [USGS] station #01389890) was determined from a rating curve for Little Falls, USGS station #0138950036, the closest location for which sediment concentration and load data are available. A rating curve expresses sediment load (sediment concentration in mass/volume × river flow in volume/time). The resulting units for sediment load are mass/time. In this case, results are expressed in metric tons/day (mtons/day). The FFS rating curve methodology (the Normalized Sediment Load or NSL approach) is described in FFS Report Appendix BII, with most of the details provided in *HydroQual* [2007].[37] Appendix BII describes the NSL method as follows:

> *"Freshwater solids boundary conditions used in this modeling effort are based on relationships between suspended sediment loading and river flow developed as part of the CARP project (HydroQual, 2007b). Relationships for the Upper Passaic and the Saddle Rivers were reevaluated using mean flows that include flow records for the period after completion of the CARP analysis. The methodology used to develop relationships between suspended sediment loadings and river flow is based on the Normalized Sediment Loading analysis (HydroQual, 2007b), in which suspended sediment data are segregated into two subsets based on river flow conditions at the time of data collection. The boundary between the two flow regimes is defined by a flow equal to two times the annual average flow. The suspended sediment*

[36]The sediment input at Dundee Dam was apparently estimated from the Little Falls rating curve, but scaled up by the ratio of basin areas above the two gauges, 762sq. mi for Little Falls and 805 mi. sq. for Dundee Dam. Regardless of the exact procedure, the loading at Dundee Dam is based on Little Falls load data.

[37]The NSL approach non-dimensionalizes or normalizes the flow by the mean flow and the sediment load by its mean. Thus, the rating curve is a relationship between non-dimensional variables, and the constants derived by regression are dimensionless. Practical use of the model requires, however, that the predicted load be expressed in dimensional variables.

> *loading relationships were derived from log-log regressions of loading vs. flow corrected to eliminate the low-bias introduced by performing the regression of log-transformed values (Ferguson, 1986). The loading function for the Saddle River was used for the Second and Third Rivers and MacDonald Brook."* (Appendix BII, p. 3-1)

As we show below, the rating curves developed for the CARP Report are quite different from those used in the FFS, even though they were developed using the same method. This is a first indication that sediment load to the LPR is quite uncertain.

The CARP Model Report (*HydroQual* 2007) emphasizes the regional validity of this analysis approach, and its applicability to many river basins. This might be an advantage for a comparative regional study, but is irrelevant here. In fact, this generic rating curve approach is ill-suited to the Passaic River and its tributaries for several reasons:

1. Prominence of hysteresis: sediment load hysteresis[38] is very prominent in the Passaic River and other regional rivers. An example of this hysteresis is shown in Figure A-1. This factor is excluded by definition from the HydroQual NSL approach, which always produces the same load for a given flow, regardless of timing relative to the peak of an event. As demonstrated below, a rating curve that ignores hysteresis substantially underestimates sediment input early in a flood event and overestimates it after the peak flow. As noted in Appendix BII, FFS Report analyses were unable to determine whether hysteresis was important, perhaps because not all available data were used and/or because no method except the NSL approach was attempted.

2. General inapplicability of NSL to flashy rivers: The apparent reason for segregating the load relationship into two components at the level of twice the mean flow is that different load laws may pertain below and above bankfull; i.e., that the rating curve might be nonlinear in log-space. Dividing the load data into two groups (above and below twice the mean flow) might be useful if ample data (many years) are available, but results in a very uncertain rating if few data (with insufficient dynamic range of flow) are available, as is the case here for the high-flow data set. A flashy river like the Passaic has only a few high-flow days per year, but these few days transport most of the sediment load. These days are likely to be under-sampled, for logistical reasons and due to their infrequent occurrence. The rating curve provided by *HydroQual* [2007] for the Passaic River at Little Falls has about 16 points for high flow periods. The resulting log-log high-flow regression analysis reports an R^2 of -0.082, which means that the regression contains no information. While a larger data set was used to prepare the load rating curve employed in the FFS [Fig. A-2], the difficulty remains.[39] There are few high-flow data, and the dynamic range in flow is only a factor of 3, i.e., the highest flow represented is only three

[38] Sediment load hysteresis refers to the fact that the sediment load during periods of rising flow may be very different than the load during periods of falling flow. Typically, as in the Passaic River, the rising arm of the hydrograph carries much more sediment than the falling arm of the hydrograph, sometimes by an order of magnitude. The quality of the load (in terms of sediment size and or contaminant input) may also be quite different during rising and falling flows.

[39] We have repeated the NSL analysis for high flow data using all available Little Falls data from 1963 to 2014. The result is an adjusted R^2 of 0.134. Parameter confidence limits are so broad as to make the analysis meaningless. Appendix BII does not state what data were used in their analysis. Our result may, therefore, be slightly different from theirs, but the statistical problems in the NSL method are largely independent of the exact choice of data.

times the lowest for the high flow data set.[40] The resulting R^2 and model parameter confidence intervals are not stated, but certainly leave the load during high-flow periods as highly uncertain.

3. Missing data: There were apparently no high-flow data (more than twice the annual mean flow) available for the Saddle River at Lodi, according to Fig. 3-1 of Appendix BII; a generic curve for a typical Eastern US river was used instead. This approach causes an arbitrary jump in load of ~1.5× at the boundary between high and low flows. The rating curve then rises with a slope that is much steeper than that seen for the Passaic River. This assumed curve leads to very implausible load predictions. For example, for the peak Saddle River flow levels 107 m^3/s in 2007 and 110 m^3/s in 2011, the predicted Saddle River load from the curve in Figure A-2, would have been ~18,400 and 20,000 mtons/day. As shown below, these loads are several times larger than those delivered by the mainstem Passaic River. The same inaccurate rating curve chosen for the Saddle River is then applied to the Second and Third Rivers and MacDonald Brook, because no data are available for these streams. Because the net deposition shown by the sediment transport model is very sensitive to fluvial sediment input (see main text), these incorrect inputs may lead to highly erroneous model predictions during floods and affect estimates of long-term deposition and erosion. Inaccurate estimates of deposition/erosion will likely affect predicted contaminant distribution, compromising the evaluation of the remedial alternatives[41]

4. Sand load vs. fines load: The NSL rating curve approach does not allow inputs of sands and fines to be distinguished. This is a crucial omission for the Passaic River, as sand may make up as much as half the total load during high-flow events.

Also, as discussed below, the FFS Report sediment loads are quite different from those derived in the CARP Report (*HydroQual*, 2007).

Methods for Load Estimation:

A. Load estimation for a river with strong hysteresis

Approach: Ultimately, the suspended sediment load to the LPR needs to be estimated by an appropriate watershed model. Given that no such model is available, it is important to optimize a loading curve to take into account the specific characteristics of the Passaic River, i.e., that it is flashy (the flow and load both change rapidly) and hysteresis is strong. Therefore, we have developed an alternative rating curve analysis for the load data for the Passaic River at Little Falls and for the Saddle River at Lodi. To implement this analysis, we assembled all relevant data for each station and developed a rating curve that includes the effects of hysteresis; it specifies total suspended load at Little Falls in terms of flow and the rate of change of flow. In addition, available data specifying the fine fraction of the total load were used to model inputs of fines and sands, several methods of extending the calculation downstream from Little Falls to Dundee Dam were explored, and the applicability of the Saddle River loading curve to the Second River and Third River was examined.

[40] In contrast the ratio of maximum to minimum historical flow in the Passaic at Little Falls is 28,000.

[41] It is important to note that FFS Report gives another account of sediment loading for the Saddle River and other tributaries (Section 5.0 of the Data Evaluation Report No. 2 "Boundary Conditions" [*EPA*, 2014]) that does not agree with the rating curves shown in Figure 3.1 and is less unrealistic. It is unclear which approach was used, so both are examined below.

Data: The data used include the following:

1. Passaic River at Little Falls (USGS station #01389500) daily river flow (1897-2014), downloaded from: http://nwis.waterdata.usgs.gov/nj/nwis/dv/?site_no=01389500&agency_cd=USGS&referred_module=sw. The basin area above this gauge is 762 mi^2.

2. Passaic River at Little Falls (USGS station #01389500) hourly river flow (2007-2014), downloaded from: http://nwis.waterdata.usgs.gov/nj/nwis/uv/?site_no=01389500&agency_cd=USGS.

3. Passaic River at Dundee Dam (USGS station # 01389890) hourly river flow (2007-2014), downloaded from: http://waterdata.usgs.gov/nj/nwis/uv/?site_no=01389890&agency_cd=USGS. The basin area above this gauge is 805 mi^2.

4. Passaic River at Little Falls (USGS station #01389500) daily suspended sediment concentration and load data for 1963/10/7 to 1965/7/12 (645 daily values), downloaded from: http://nwis.waterdata.usgs.gov/nj/nwis/dv/?site_no=01389500&agency_cd=USGS&referred_module=sw. While these data are 50 years old and come from a generally very low-flow period, they have the strong benefit of being daily, so that the importance of hysteresis can be evaluated, and they do contain several significant flow events. No metadata are available, but USGS practice at the time would have been to use a single vertically integrated sample per day and multiply this by the daily average discharge. Multiple samples were collected on some days, but the data set as we have it indicates only one such occurrence – several concentration and flow observations are available for a high flow event on 1965/2/8.

5. A USGS National Water Information System (NWIS) sediment data set for Passaic River at Little Falls (USGS station #01389500) with multiple parameters and scattered instantaneous values from 1978 to 2014; these were downloaded from: http://nwis.waterdata.usgs.gov/nj/nwis/_qwdata/?site_no=01389500&agency_cd=USGS. This data set includes 436 values of flow, concentration and/or load, 115 determinations of percent fine fraction (reported as percent finer than 62.5 microns), and 146 values of turbidity.

6. Saddle River at Lodi (USGS station #01391500) for 1923-2014, downloaded from http://water-data.usgs.gov/nj/nwis/dv/?site_no=01391500&agency_cd=USGS&referred_module=sw. The basin area above this gauge is 54.4 mi^2.

7. Second River at Belleville (USGS station #01392500) for 1937-2014 (missing 1964 to early 2011) downloaded from http://waterdata.usgs.gov/nj/nwis/dv/?site_no=01392500&agency_cd=USGS&referred_module=sw. The basin area above this gauge is 11.6 mi^2.

8. Third River at Passaic (USGS station #01392210) for 1977 to 1997, downloaded from http://waterdata.usgs.gov/nj/nwis/dv/?site_no=01392210&agency_cd=USGS&referred_module=sw. The basin area above this gauge is 11.8 mi^2.

9. A USGS National Water Information System (NWIS) sediment data set for Saddle River at Lodi (USGS station #01391500) with multiple parameters and scattered instantaneous

values from 1978 to 2008, downloaded from http://nwis.waterdata.usgs.gov/nj/nwis/qwdata/?site_no=01391500&agency_cd=USGS. There are 149 values from 1978 to 2008.

Passaic River at Little Falls load model: As evident from Figure A-4a,b, sediment load hysteresis is prominent in the Passaic River. Flows rise more rapidly than they fall (as shown by the flow ratio shown in Fig. A-3), and the rising freshet limb brings much more sediment than the falling limb, presumably because sediment transport is supply limited, especially for fines. There can be a variety of reasons for the initial, enhanced load. These may be anthropogenically induced (e.g., flushing of dirt and debris from streets and storm sewers), or climate related (e.g., rain on snow events often erode fine sediments as the snow melts), or reflect the underlying geology of the basin and river channel (e.g., supply limitation). For present purposes, the source of the hysteresis is perhaps less important than its existence. However, there is an additional factor that accompanies the hysteresis that increases its importance: the percent fine fraction decreases as the flow increases (Fig. A-5). Because of this decrease, the fine fraction is even more "front loaded" in a flood event than the total load. This is an important factor in representing the sediment transport dynamics of flood events in the LPR.[42]

To form a suspended sediment rating curve function $LF[Q_W]$, we choose perhaps the simplest approach that is capable of representing hysteresis:

$$LF[Q_W] = Q_S = aQ_W{}^b R^C$$

$$Log[10, Q_S] = Log[10, a] + bLog[Q_W] \quad + cLog[R]$$

$$R = \frac{Q_{W,n}}{Q_{W,n-1}}$$

(A-1)

Where: LF stands for "Load Function", Q_S is suspended load (mtons/day), Q_W is river flow (m^3/s), R is unitless flow ratio, and a, b, and c are parameters specific to the data set. Specifically, R is the ratio of flow on the day of the load observation, $Q_{W,n}$, to the flow on the previous day, $Q_{W,n-1}$. The parameters a, b, and c are determined by robust regression [*Leffler & Jay*, 2009]. Robust regression is useful in that it: a) reduces the influence of outliers without *a priori* rejecting any data points, and b) provides more certain parameter estimates with small confidence intervals. It is particularly useful with sediment load data, because these data are typically quite scattered.

Separate analysis of the 1963-1965 (645 data points) and the 1978-2014 (436 data points) data sets and comparison to the analysis of the entire data set led to the conclusion that the combined analysis was better, because of the larger total number of points and dynamic range of flows. Combining the two data sets runs two risks:

- Sediment transport patterns may have changed as land use has evolved. However, neither individual data set had enough points to convincingly demonstrate that it had different properties from the combined data set. Combining the two data sets also

[42]The fit shown in Figure A-4 is not definitive – there are too few data. Nonetheless, the curve properly describes the phenomenology of the situation. As noisy as the data are, percent fine fraction generally increases with increasing flow.

provides tighter confidence limits and reduces uncertainties in the loads calculated with (A-1).

- There are methodological differences between the 1963-to-1965 and later data sets, in that the first data set represents daily concentrations and transports (i.e., loads) while the second provides instantaneous concentrations and transports. However, the daily loads of the first data set were, in almost all cases, based on a single sediment sample, and it is only on a few days when flow changes rapidly that flow varies strongly over the course of a day. Thus, the actual differences between the two data sets are likely small or insignificant in this regard.

Therefore, it was deemed advantageous to form a rating based on the combined data set of 1081 points.

One more detail of the regression is important: the weighting of the data points. High flow days with high sediment loads are rare in a flashy river, and a much longer record than the 1081 available points (equivalent to only 3 years of daily data) is needed to capture a representative sample of the high flows that transport most of the sediment. This situation is dealt with by using a flexible weighting approach that sets the weight wt[j] of each of j data points according to:

$$wt(j) \sim Log[10, Q_S(j)]^n \quad 0 \leq n \leq 10 \tag{A-2}$$

Parameter *n* can be set in a variety of ways, depending on the character of the data. In the case of the Passaic River at Little Falls, a log-log plot of load vs. flow suggests an upward tendency at higher flows; i.e., the exponent *b* in (A-1) increases as the high flow data are more heavily weighted. This fact is also evident in the FFS load model in Figure A-2: the exponent of Q_W is higher for the high flow data set than for the low-flow data set. Also, the available data do not have any representations of really high flow events, e.g., a 50-year to 100-year flood. The highest flow included in the sediment load data set is 189m^3/s, a quarter of the 100-year flow level of 680-720 m^3/s (Appendix B). Accordingly, the available data likely underestimate the load. Thus, *n*=8 was chosen to overestimate the average observed load by ~25% (Fig. A-5; Table A-1); *n*=5.7 would produces approximately 100% of the observed load. Choosing *n*=8 has, however, the benefit of more closely reproducing loads during high flow events than *n*=5.7; it also brings the average load predicted by eq. A-1 closer to that predicted by the model shown in Figure 2-1 of the FFS Report Appendix BII [*EPA*, 2014]. It is also evident from Figure A-6 that parameter uncertainty is less important than hysteresis (driven by extremal values of *R*), and that the skewed distribution of *R* means that on days of rapidly rising flow, the sediment load is much higher than the mean for that flow. The comparison of the hindcast vs. observed sediment loads (Figure A-7) emphasizes that the loads associated with some relatively high flows are still underestimated, though others are overestimated.

Table A-1: Suspended Sediment Model Parameters from (A-1) and (A-2), with 95% Confidence Limits

Station	a	b	c	n	Adjusted R^2
Passaic R. at Little Falls	-0.174±0.112	1.340±0.0607	0.815±0.0556	8	0.714
Saddle R. at Lodi	-0.0240±0.0625	1.675±0.0674	0.3289±0.154	3.8	0.934

The use of the weights defined in eq (A-2) has another advantage – it avoids the need to implement "smearing corrections" as used in *HydroQual* [2007]. The need for smearing corrections arises from the nature of a log-log model with flow weights. Load data exhibit a scatter that causes a conventional log-log regression model to underestimate load in proportion to the scatter in the data. If we imagine that, for some given flow, loads of 1, 10 and 100 are observed (in arbitrary units), averaging the logs (base 10) of these three values (0, 1, 2) yields a log-average of 1 and an average value of 10 (when converted to real-world units), whereas the actual average is (100+10+1)/3 =37 in real world units. Clearly, the load is underestimated when a line is fit in a log-log analysis to scattered load data. Conventional smearing corrections (as used in *HydroQual* [2007]) effectively increase the constant *a* in (A-1) without regard for the fact that the slope of the log-log load vs. flow relationship varies with flow[43]. We prefer to use weights that represent the slope b in (A-1) in a way that preferentially weights high-flow data. This is useful because over-estimates of load for low flows have little influence on the mean load and process analyses, whereas underestimates of loads on rare, high-flow days have a much more significant impact. With the approach embodied in (A-1) and (A-2), there is no need for a smearing correction.

Little Falls fine fraction model: The fines (<62.5-micron diameter) and sand loads (>62.5-micron diameter) were estimated by multiplying the modeled suspended load by the fine fraction (*Fr*) and by the sand fraction (1-*Fr*), respectively. *Fr* was determined from the post 1978 data represented in Figure A-5 using a robust regression equation for percent sands of the form:

$$(1 - 100Fr) = aQ_W + bQ_W{}^{0.5} \tag{A-3}$$

Where: parameters *a* and *b* were chosen by a robust regression of the 115 available data points. The form of (A-3) was chosen to fulfill three physically sensible criteria:

- The sand fraction (1-*Fr*) should be zero for Q_W=0.
- The fine fraction should decrease with flow without ever becoming negative, even for the 100-year flow.
- The model should have the minimum possible number of parameters, as befits the relatively small number of data points (115).

[43]HydroQual [2007] deals with this issue by deriving separate load laws for high and low flows, but this works poorly for the limited data set available for the Passaic River at Little Falls.

A variety of forms could satisfy these criteria, and (A-3) is not unique. Still, it provides physically sensible results and leads to useful insights. Model parameters are provided in Table A-2. It is also evident from Table A-2 that, despite an adjusted R^2 =0.792, model parameters are quite uncertain. Therefore, predicted variations in fines and sand loads should be regarded as qualitative only.[44] Even so, these predictions of fines and sand load provide important information.

Table A-2: Fine Fraction Model from (A-3), with 95% Confidence Limits

Parameter	a	b	Adjusted R^2
Value	0.317±2.8	1.352±6.49	0.792

Passaic River at Dundee Dam load model: The flow and sediment boundary conditions for ECOM and ECOMSED are applied at Dundee Dam, not Little Falls. After 2007, hourly flows are available at both locations and were used in FFS modeling, rather than the daily data used for earlier periods. There are, however, no sediment load data for Dundee Dam. The flow data suggest that there is a problem in projecting the sediment load downstream from Little Falls to Dundee, because flow characteristics at Dundee Dam are different from those at Little Falls. Specifically, flows at Dundee Dam are even flashier than those at Little Falls (for example, in Fig. A-8). The ratio of flows at Little Falls to those at Dundee Dam does not follow in strict proportion to the basin area above the two gauges, which is ~1.056, and the flows at Dundee Dam tend to rise more quickly than those at Little Falls. For the 2007/10/1 to 2014/6/21 period, the median of the flow ratio is 1.11, and the 25th and 75th percentiles of this ratio are 1.052 and 1.247. The distribution of the ratio is highly skewed with extremal (minimum and maximum) values of 0.29 and 17.9, respectively. The likely reason for this pattern is that a hydraulic control slows the rise of the flow at Little Falls, while the lower part of the Passaic River basin below Little Falls responds very quickly to rainfall because the terrain contributing this flow is close to the estuary.

There are at least two ways to use the Little Falls rating curve to estimate sediment loads at Dundee Dam. The simplest is to scale up the sediment load at Little Falls by the ratio (1.056) of drainage basin area at Dundee Dam (805 mi^2) to that at Little Falls (762 mi^2), and this is likely the approach that was used in the FFS Report Appendix BII, though the text is unclear. This approach suffers from the fact that, as noted, the flow at Dundee Dam is flashy and the ratio of flows is not necessarily represented by the ratio of areas. Also, a flood wave will take some hours to travel from Little Falls to Dundee Dam, so the timing of the load is not the same at the two locations. Finally the composition of the load (e.g., fine fraction) may change.

There is a second way to project the sediment transport downstream from Little Falls to Dundee Dam that preserves the difference in flow timing and recognizes that the ratio of flows between the two locations is variable:

$$LF_{Dundee_t}[Q_{WDundee}] = const * LF_{LittleFalls}\left[\frac{Q_{WDundee,t}}{const}\right] \tag{A-4}$$

[44]In calculation of the fines and sand loads from modeled total load, the uncertainty in the fines and sand loads is affected by the uncertainty in the estimated total load, as well as the uncertainty of the fine fraction value.

Where: *const* is a factor that allows the Dundee Dam flows to be used with the Little Falls rating curve. If the factor *const* is taken as 1.0, this would mean that additional no flow or load is added between Little Falls and Dundee Dam, but this is unrealistic. Alternatively, *const* could be the ratio of areas (1.056) or the median of the flow ratio (1.11); we choose the latter, because this minimizes the increase in estimated load at Dundee Dam in Figure A-11 and appears to be more realistic.

Saddle River Load model: A sediment load model was developed for the Saddle River using eq (A-1) with n =3.8 in (A-2). The model and its fit to the data are shown in Figure A-9a,b, and model coefficient are listed in Table A-1. With this value of n, the mean of the observed transports is over-estimated by ~4%, but the few high flow observations are represented quite well. In this case, the highest observed flow of 83 m^3/s is ~80% of the 100-year flow of 103 m^3/s, though all but 5 values are for flows <10 m^3/s. Also, as noted in Appendix B, flows in the Saddle River appear to have increased in recent decades. Thus, the load cannot be considered to be well characterized. Comparing the values in Table A-1 for the Saddle River at Lodi with those for the Passaic River at Little Falls, it is evident that the exponent b in eq (A-1) at Lodi (1.675) is considerably larger than that at Little Falls (1.340); thus, the load increases more rapidly with flow at Lodi. On the other hand effect of hysteresis is larger at Little Falls (c =0.815) than at Lodi (c =0.329). The constant a is sometimes taken to represent sediment supply, and it usually countervaries with b, which is considered to represent (in an approximate way) stream power [*Syvitski et al*., 2000]. Accordingly, a is slightly larger at Little Falls (where b is smaller), but the values of a are not statistically different at the two locations.

Load Models for other tributaries: Because the FFS Report Appendix BII applies the Saddle River load model to Second and Third Rivers and MacDonald Brook, it is important to determine whether this procedure is appropriate. The Saddle River is a right-bank tributary (looking landward) flowing into urban terrain from somewhat higher elevation, whereas the Second and Third Rivers are left-bank tributaries originating in highly urbanized areas. While synoptic weather systems are typically large relative to the areas of these tributaries, the same cannot be said for convective systems. Thus, they may be exposed to different precipitation regimes produce flow in response to precipitation with a different timing. Thus, it is not obvious that the flows in the Saddle River are representative of those in the other two tributaries. The FFS Report assumes (in the "Boundary Conditions" Report, *EPA* [2014]) that the solids yield per unit area would be the same for the Second and Third Rivers as for the Saddle River, so that the Saddle river sediment load could be scaled up to account for the other tributaries.[45] This presupposes that the flow regimes are, in fact, similar. A very simple means to test this assumption is to examine the mean, median and 75th percentile flows per unit area for the various relevant basins, as in Table A-4. Several points are evident. First, the 2011 to 2014 time period exhibits higher than typical mean flows/area in all basins for which a comparison can be made. The median flows/area are considerably lower than the means for all basins, which suggests flashy systems with relatively few high flow days. Because sediment transport increases more than linearly with flow, sediment transport is typically dominated by relatively scarce high flow periods. In this sense, the 75th percentile flows per unit area are perhaps the best measure. By this measure, the Passaic River at Little Falls and the Saddle River at Lodi are fairly similar, while the Second and Third Rivers have substantially lower flow/area values. This is a first indication that the Saddle River is not an adequate surrogate for the Second and Third Rivers, in terms of sediment load.

[45]When Saddle River loads are scaled up using ratios of basin areas, there are actually two assumptions, that: (a) the flow/area is the same; and (b) sediment rating curves have the same parameters.

The question of whether Saddle River flows are a good surrogate for Second and Third River flows can be further examined plotting the ratio of Saddle River flow to Second River flow as a function of Saddle River flow (Fig. A-10a) and as a function of Second River flow (Fig. A-10b). Regardless of how the two are plotted, they bear little relationship to each other. Examination of a time series for the two stations (Fig. A-11a) suggests that, when both rivers show a peak: (a) the timing of flow peaks is sometimes different; (b) the relative magnitude of peaks is highly variable; and (c) Second River is flashier than the Saddle River—this may reflect the highly urban nature of the Second River basin. Also, not all peaks occur in both systems. In other words, the systems are not well matched, and it is not appropriate to use the Saddle River load model for Second River.

Table A-4: Mean and Median Flows per Unit Area for Selected river Basins and Time Periods

Basin	USGS #	Time Period	Mean Flow/Area $m^3/(s\ ha^*)$	Median Flow/Area $m^3/(s\ ha)$	75% Flow/Area $m^3/(s\ ha)$
Passaic R. at Little Falls	01389500	1897-2014	1.736	0.976	2.346
Passaic R. at Little Falls	01389500	2011-2014	2.102	0.932	2.647
Saddle R. at Lodi	01391500	1923-2014	2.170	1.496	2.465
Saddle R. at Lodi	01391500	2011-2014	2.600	1.933	2.749
Second R. at Belleville	01392500	1937-1964	1.802	0.978	1.581
Second R. at Belleville	01392500	2011-2014	2.016	0.932	1.456
Third R. at Passaic	01392210	1997-2007	2.028	1.068	1.845

* ha =hectare

The ratio of Saddle River flow to Third River flow is plotted as a function of Saddle River flow (Fig. A-10c) and as a function of Third River flow (Fig. A-10d). As with the Second River, Third River flows are different from Saddle River flows. However, time series for the two stations (Fig. A-11b) suggests that, when both rivers show a peak, the peaks coincide well in timing, but that the ratio of flows is variable. Also, while the Second River produced more flow/area during the 2011 flood (Fig. A-11a) than the Saddle River, the Third River produced less flow/area than the Saddle River during the 1984 flood (Fig. A-11b). It is unclear how general these patterns are, but scaling Saddle River sediment load up using the areas of the various tributaries will clearly produce sediment load estimates that are very uncertain and perhaps biased.

Given that Saddle River and Second River flows are rather dissimilar, a means of modeling the Second river sediment load is needed. In the absence of sediment concentration data to derive a rating curve for Second River, we elect to use the Saddle River load model with Second River flows (for periods when these are available) following the approach suggested by eq (A-4). This

approach has the advantage of recognizing the very flashy nature of Second River, and the fact that the ratio of Second to Saddle River flows is variable. A similar approach is used for Third River flows (for periods when these are available).[46] While the use of the Saddle River rating curve for these two tributaries is sufficient to provide qualitative understanding and to form a critique off the FFS Report to load estimation, the results are no more than first estimate and are not a substitute for the use of watershed model verified with observations.

B. FFS load models

It is difficult to determine exactly what was done to estimate sediment loads for the ECOMSED model results reported in the FFS Report Appendix BII, because the description of the methods used to determine rating curves is vague, and the rating curves are not the same as in the CARP Report [*HydroQual*, 2007]. As we will see, the model for the Passaic River at Little Falls is quite different from the corresponding CARP model, and the FFS Report is internally inconsistent with respect to what model was used for the Saddle River at Lodi. We present, therefore, two models each for the Passaic River at Little Falls and for the Saddle River at Lodi.

FFS load models for the Passaic River at Little Falls: The CARP model (*HydroQual*, 2007) is defined in Appendix 1 of that report and is reproduced here as Figure A-12. This model is introduced here to demonstrate that a large departure was made from the CARP model with respect to the Passaic River load, and to indicate the dependence of the estimated rating curve on the data employed. We refer to the model in Figure A-12 as the "CARP model" for Little Falls. A second model for the Passaic River at Little Falls is derived from Figure 3-1 of the FFS Report, reproduced as Figure A-2. While model parameters can be derived (approximately) from Figure A-2 for comparative purposes, the FFS report does not explain what data it is based on, or provide statistics of the resulting fit; this omission should be remedied. We refer to this model as the "FFS model" for Little Falls. The FFS model equations can be approximately written as:[47]

FFS model for Little Falls flows <65m^3/s:

$$Log_{10}\left[Q_{S,lower}\right] \cong -1. + 1.272\, Log_{10}[Q_R + 0.745]$$

$$= -0.0524 + 1.272 Log_{10}[Q_R] \qquad \text{(A-5a)}$$

FFS model for Little Falls flows ≥65m^3/s:

$$Log_{10}\left[Q_{S,upper}\right] \cong 2.255 + 1.588\, Log_{10}[Q_R - 1.815]$$

$$= -0.627 + 1.588 Log_{10}[Q_R] \qquad \text{(A-5b)}$$

[46] In terms of the two assumptions mentioned above, this approach avoids the assumption that the flows in the two systems are similar, while still assuming that the load curves are the same.

[47] Eq. (A-5a) and (A-5b) are sufficiently accurate to allow graphic reproduction of the Little Falls rating curve in Figure 3-1 of Appendix BII and for comparison of models. They are not intended to provide an exact representation of the rating curve used in the FFS Report, and, without knowing on what data set the FFS model based, there is no way to exactly reproduce this model or provide confidence limits.

Note that the flow coefficient *b* in eq. (A-5b) is larger than it is in the hysteresis model based on eq (A-1), but that the intercept *a* is smaller; this is typical.

We also provide two models for the Saddle River at Lodi, because the FFS report has internal contradictions that appear to derive from use of two different rating curves. One model, which we refer to as the "FFS Model" for Lodi, is derived graphically from Figure 3-1 of Appendix BII (our Fig. A-2), in the same way that eq (A-5a,b) were determined. Thus:

FFS model for Saddle River flows <5.84m^3/s:

$$Log_{10}[Q_{S,lower}] \cong -1. + 1.266\, Log_{10}[Q_R + 0.638]$$

$$= -0.192 + 1.266\, Log_{10}[Q_R]$$

(A-6a)

FFS model for Saddle River flows ≥5.84m^3/s:

$$Log_{10}[Q_{S,upper}] \cong 2.255 + 2.618\ Log_{10}[Q_R - 0.766]$$

$$= 0.250 + 2.618\, Log_{10}[Q_R]$$

(A-6b)

Note the high value of exponent *b* for Q_R, without a corresponding low value of *a* in eq (A-6b); this means that the load will increase very rapidly with flow. As we have already noted, this high flow model is derived from a generic representation for an East Coast river basin; it will prove to be very unrealistic.

A second model can be derived by applying the NSL approach described in Appendix BII of the FFS Report and in the CARP Report to the 1978-2008 flow and sediment concentration data available for the Saddle River; coefficients are chosen by robust regression. We call this the "NSL model" for the Saddle River. The resulting equations are (with 95% confidence limits on parameters):

NSL model for Saddle River flows <5.84m^3/s:

$$Log_{10}[Q_{S,lower}] = (0.196 \pm 0.134) + (0.993 \pm 0.334)\, Log_{10}[Q_R]$$

Adjusted R^2 =0.209

(A-7a)

NSL model for Saddle River flows ≥5.84m^3/s:

$$Log_{10}[Q_{S,upper}] = (0.294 \pm 0.136) + (2.074 \pm 0.388)\, Log_{10}[Q_R]$$

Adjusted R^2 =0.674

(A-7b)

The smearing corrections described in *HydroQual* [2007] are included in the constant term. Note that the exponent of Q_R (*b*) in eq (A-7b) is smaller than in eq (A-6b), but still much higher than for the Little Falls models.

The confidence limits are also considerably broader than those in Table A-1.This uncertainty reflect the relatively low R^2 values and the sparse data. The effect of the highly uncertain determination of model coefficients is shown in Figure A-13. Division of the NSL model into high and low-flow models has detrimental effects on both. The NSL high-flow model has very broad confidence limits (a factor of 30 or more for highest flows), because it is derived from a small number of data points, while the NSL low-flow model has insufficient dynamic range in flow to closely constrain the parameters.[48]

The FFS Report Appendix BII also extends the Saddle River load model to Second and Third Rivers and MacDonald Brook; the first two have total surface areas (including ungauged portions) of ~14.6 and 12.5 mi^2, respectively, compared to 54.4 mi^2 for the Saddle River at Lodi. Also, the load for the Saddle River at Lodi is amplified by 10% to account for the difference in drainage area between Lodi and the Saddle River mouth (basin area =60.4 mi^2). Thus, the total load for the Saddle River plus the Second River and the Third River is ~1.61 times the load given in eqs. (A-6a,b) and (A-7a,b) for the FFS and NSL models of Saddle River load, respectively, assuming that load scales by surface area drained.

C. Estuarine sediment fluxes

Chant et al. [2011] used ADCP observations of alongchannel velocity and acoustic backscatter (ABS) to model net (non-tidal) fluxes at mooring M2 (selected months, 2004 to 2005), at RM-3. Fluxes were then regressed against river flow to provide a simple model of transport through the cross-section at RM-3. This model (the "Chant model") is reproduced in Figure A-14. The fit to the flux data shown in Figure A-14 has the equation:[49]

$$Q_{nontidal}[Q_R] = -41. + 0.052\, Q_R + 0.031\, Q_R^2 \tag{A-8}$$

Net fluxes are negative (i.e., landward) for flows <35.6 m^3/s; about 68% of Little Falls flows are in this category. For higher flows, accounting for about 32% of all measured flows, the net flux is seaward (positive). This relationship, eq. (A-8), is presented here, not because it models sediment input to the LPR, but because it provides perspective on sediment load models. Presumably, the sediment load provided by Passaic River and its tributaries is larger than export at low flows and smaller than the export at high flows. Eq. (A-8) can also be used in estimation of a sediment budget for the LPR.

Results: Modeled Sediment Loads

The suspended sediment load and fine fraction models described by (A-1) to (A-3) and Tables A-1 and A-2 facilitate important conclusions regarding the sediment load entering the LPR and modeling of this load with a rating curve.

[48]The CARP Report [*HydroQual, 2007*] and FFS Report Appendix BII both indicate that the offset at the boundary between the low and high-flow regimes has been suppressed by an undisclosed means. While there a number of ways that this can be done, it is evident from Figure A-13 that, if the high flow model is forced to match the low-flow model, then the high-flow data will be poorly modeled. If the low-flow model is forced to match the high-flow model, then the low-flow data will be poorly modeled. This is an artifact of the sparse data and indicates that the CARP Report is not appropriate to the present environment.

[49]The coefficient for the Q_R^2 term in (A-8) is given as 0.0031 in *Chant et al.* [2011], but this does not reproduce the data and has been corrected here to 0.031.

Hysteresis: Hysteresis has strong effects on sediment load in the Passaic River and its tributaries. This can be seen in Table A-5, which details the distribution of the flow ratio R as defined in eq. (A-1) and the effect of hysteresis on the sediment load, which is given by R^c, where c is the constant defined in eq (A-1). The median of R is <1 for the Passaic River and its tributaries, but the distribution is skewed toward high values, so the mean of R is >1. For the Passaic river at Little Falls with c =0.815, 98% of the values of R^c are between 0.58 and 2.7, though there isolated values as high as 68.3. Loads for the Saddle River at Lodi, with c =0.329, are somewhat less affected by hysteresis than those in the Passaic River, and 98% of the values of R^c are between 0.70 and 1.75. The flow for Second River at Belleville is flashier than that for Saddle River, and hysteresis is generally stronger; however, the value c is assumed to be the same as for the Saddle River, as discussed above, and cannot be independently verified. The Third River is less flashy than the Second River, and more comparable to the Saddle River, in terms of hysteresis effects.

Figure A-4b suggests that the Little Falls hysteresis model adequately hindcasts loads for the largest flow event for which multiple days of data are available. It also suggests that the FFS Little Falls and CARP model approaches do not correctly hindcast load for this high flow period, because both the magnitude and timing of the sediment input are incorrect. This is in large part because they cannot represent the hysteresis that plays such a prominent part of Passaic River sediment dynamics.

Magnitude and variability of load, Passaic River at Little Falls: Figure A-15 shows predicted suspended sediment loads at Little Falls as a function of Little Falls flow for four models: (a) the hysteresis model based on eq. (A-1); (b) the FFS Little Falls load model based on eq (A-5a,b); (c) the CARP model as shown in Figure A-12; and (d) the Chant model from eq. (A-8). It is evident from Figure A-15 that, for high flows, the CARP predicts a lower load and the FFS model a higher load than the hysteresis model. For low flows, the hysteresis model predicts the lowest load, however, little sediment is supplied under these conditions. Note that the hysteresis model is plotted for the median value of R =0.944 (Table A-5). As suggested by Table A-5, the predicted load value will be between 0.332 and 5.492 times the value shown 98% of the time. Thus, the hysteresis model has the flexibility to represent a variety conditions and has much tighter confidence limits than the CARP model. The *Chant et al*. [2011] analysis provides a useful comparison to the two load estimates. The estuarine fluxes modeled by *Chant et al*. are estimated from acoustic Doppler current profiler (ADCP) velocity and backscatter observations. They should not be the same as the input fluxes, because they are influenced by estuarine processes. They do confirm that, for low-flows, the LPR exports more sediment than is supplied to it from upstream. But for high flows, more sediment is exported than is supplied, regardless of the model used to estimate sediment input at Little Falls.

Table A-5: Hysteresis Effects on Sediment Load for the Passaic and Saddle Rivers

	Passaic R. at Little Falls	1897-2014	Saddle River	1923-2014	Second River	1937-1964, 2010-2014	Third River	1977-1997
Ratio R, %	Ratio R	Hysteresis* Factor, R^c	Ratio R	Hysteresis** Factor, R^c	Ratio R	Hysteresis Factor, R^c	Ratio R	Hysteresis Factor, R^c
Min	0.00847	0.020	0.110	0.484	0	0	0.0497	0.372
1%	0.516	0.583	0.332	0.696	0.1833	0.572	0.286	0.662
25%	0.869	0.892	0.869	0.954	0.814	0.935	0.842	0.945
Median	0.944	0.954	0.958	0.986	0.952	0.984	0.957	0.986
Mean	1.080	1.065	1.15	1.047	1.590	1.164	1.474	1.136
75%	1.066	1.053	1.056	1.0179	1.111	1.035	1.067	1.021
99%	3.378	2.70	5.492	1.751	8.00	1.981	4.681	1.661
Max	178.	68.31	46.03	3.523	91.71	4.419	52.72	3.683

* For the Passaic R. at Little Falls, c = 0.815.
** For the Saddle River at Lodi, Second River at Belleville and Third River at Passaic, c =0.329.

Magnitude and variability of load, Saddle River at Lodi: Figure A-16 shows the load functions for the Saddle River as predicted by the hysteresis, NSL and FFS models. The FFS model (based on Figure 3-1 of Appendix BII) clearly diverges from the data for flow >~30 m^3/s. It predicts a load that is ~30× higher than the hysteresis model and ~8× higher than the NSL model for the 100-year flow of 110 m^3/s. As we show below, it also predicts a maximum daily load that is much higher than for the maximum load from the mainstem Passaic River during Hurricane Irene. It is clear that this load model is unrealistic. On the other hand, the NSL model predicts average loads that are smaller than the hysteresis model and does not account for hysteresis effects.

Average yearly Load, Passaic River at Little Falls: The long-term average sediment loads predicted by the hysteresis, CARP and FFS models are shown in Figure A-17a. The results for the hysteresis and FFS models are reasonably similar except for high-flow years, but the CARP model predictions (which closely follow the USGS calculations of *Wilson & Bonin* [2007]) are considerably lower. In very high flow years, the FFS model is somewhat higher than the hysteresis model, as reflected by the totals in Table A-6. Still, the major difference is between the CARP model and the other two[50]; the hysteresis and FFS models predict 29.5% and 35.9% more transport than the CARP model for 1980-2013; the ratios for longer periods are similar. Of the three models, the hysteresis model likely has the tightest confidence limits and the highest adjust R^2 value. Thus, it is the best of the three, but this does not obviate the point that it is still based on an inadequate data set equivalent to about three years of data. Overall, these differences suggest a considerable degree of uncertainty in the sediment load for the Passaic River at Little Falls. Given that a change of ±20% in Passaic River load produced differences in net deposition/erosion in ECOMSED of up to 125% in some reaches, the uncertainty in sediment load is certainly large enough to be significant. It is also important to note that ~20%

[50]The large difference between the CARP and FFS models should have been disclosed, as it illustrates the point that the sediment load is quite uncertain.

of the long-term average total load is sand, for all time periods, but the ECOMSED boundary conditions apparently do not distinguish between sand and fines. This is also an important omission in the FFS Report analyses.

Average load, Saddle River at Lodi: The long-term average sediment loads predicted by the hysteresis, NSL and FFS models are shown in Figure A-17a and listed in Table A-6. In this case, the NSL model predicts lower loads than the other two, but the FFS model prediction (based on Figure 3-1 of Appendix BII) is much higher, especially in years with floods. As indicated by Table A-6, the hysteresis model predicts ~35 to 42% more sediment input than the NSL model, whereas the FFS model predictions are 240 to 265% higher than the NSL model. The inconsistency of the two FFS Report estimates is a reflection of the disagreement between Figure 3-1 of Appendix BII and the text of the "Boundary Conditions" Data Report [*EPA*, 2014]. The latter gives the sediment load of the Saddle River at Lodi as 2,100 mtons/year, which agrees with the 1923-2013 estimate of mean load by the NSL model, but is far lower than the estimate from the FFS model. These two very contradictory estimates emphasize again the uncertainty in the sediment load delivered to the LPR.

Average load, LPR tributaries: It is not possible to give an authoritative estimate of total load from the Saddle, Second and Third Rivers together, because there are not enough sediment load data for the Third River (6 values) and none for Second River. A rough estimate can be provided by combining the load model shown in Table A-1 with the daily flows for the Third River (1977 to 1997) and for the Second River (1937-1964 and after May 2011). The Saddle River at Lodi estimates are scaled up to account for the difference in total Saddle River surface area (60.4 mi^2) relative to the gauged area of 54.6 mi^2, and to account for the ungauged areas in Second and Third Rivers, whenever data are missing for those sources. Results are given in Table A-6. Obviously, this is not an ideal procedure, given the differences between the tributaries noted above, but it suffices to obtain a rough idea of the importance of the three LPR tributaries in the sediment budget. Overall, taking into account the diversity of estimates from the three models, the total tributary load is uncertain by a factor of ~2 for 1980 to 2013 and by a factor of about 1.8 over the 1923 to 2013 period. The hysteresis model estimate is that the three tributaries supplied an average of 5,400 mtons/year for 1980 to 2013, which is about 15% of the Passaic River load at Little Falls for the same period.

Table A-6: Hindcast Long-Term Average Sediment Load Estimates for the Passaic River at Little Falls, for the Saddle River at Lodi, and for the Sum of Loads for the Saddle, Second and Third Rivers

Station	Model	Load, 10^3 mtons/year	Load, 10^3 mtons/year	Load, 10^3 mtons/year
Passaic River at Little Falls		1980-2013	1913-2013	1897-2013
	Hysteresis total load	34.6	34.1	35.9
	Hysteresis sand	7.2	6.7	7.4
	Hysteresis fines	27.5	27.5	28.5
	FFS	36.3	35.3	37.1
	CARP	26.7	26.5	27.5
Saddle River at Lodi		1980-2013	1923-2013	
	Hysteresis	3.65	3.0	
	FFS	7.16	5.1	
	NSL	2.67	2.1	
Sum of tributary loads*		1980-2013	1923-2013	
	Hysteresis	5.4	4.5	
	FFS	11.6	8.3	
	NSL	4.3	3.4	
Total load to LPR**				
	Hysteresis	45.2	43.7	
	FFS	50.0	47.5	
	NSL+CARP	32.5	32.4	

* The sum of tributary loads is for the Saddle, Second and Third Rivers together.

** The total load to the LPR is the sum of the load at Dundee Dam plus the load for the Saddle, Second and Third Rivers. For the hysteresis method, the load at Dundee Dam is scaled up from the load at Little Falls 1.11^b =1.15; where 1.11 is median of the Dundee Dam:Little Falls flow ratio.

Average load, lower river tributaries plus mainstem Passaic River at Dundee Dam: Assuming that the Passaic River total load at Dundee Dam is 1.11^b to 1.15 times that at Little Falls, an estimate can be given for suspended sediment input to the LPR from all fluvial sources. For 1980 to 2013, this estimate varies from 32.5 to 50 mtons/year, depending on the choice of models, an uncertainty of about a factor or 1.5; the uncertainty is slightly lower for 1923 to 2013.

The preferred hysteresis model estimates a total load of 45.2 mtons/year for 1980 to 2013 and a long-term load of 43.7 mtons/year. The same caveats apply as for the tributary loads – these rough estimates serve to illustrate the differences among the load models and the overall uncertainty in sediment loads. None is good enough to be used in a model intended to make quantitative predictions regarding LPR sediment dynamics. These estimates do suffice, however, to give a qualitative understanding of processes.

Time History of Hurricane Irene: The averaging that occurs in preparation of the annual average sediment loads discussed in the previous section disguises a very large uncertainty in timing and amount of sediment load input to the LPR during high-flow events. To illustrate this point, we examine the time history of Hurricane Irene (August 2011), which also illustrates important features of LPR sediment dynamics. For perspective, daily flows at Little Falls associated with Hurricane Irene reached 580 m^3/s, or about 85% of the 100-year flood flow. Figure A-18a shows the hysteresis model estimated loads and observed river flows for the Passaic, Saddle and Second Rivers. It is evident that the peak sediment inputs occur 1 to 2d before the peak flow at Little Falls. For the Passaic River, this occurs because hysteresis is strong. For the Saddle and Second Rivers, the peak flows and sediment loads occur on the same day, but (due to hysteresis) the sediment loads rise faster than the flows, and these tributaries respond much more rapidly to precipitation than the mainstem Passaic River. While their input of sediment is brief, the Saddle River actually has the highest daily load in Figure 18a by a small margin. This is in part because a flow greater than the 100-year flow occurred in the Saddle River, whereas the peak mainstem Passaic River flow was less than the 100-year flow level, but again, uncertainties in the rating curves may also play a role. In this storm at least, the load from the Second River appears to have been more than an order of magnitude lower than that for the Saddle River, even though the same load function was used for both tributaries. It is likely, however, that the flows in the Second River did not reach the level of the 100-year flood.

FFS model estimates are compared to the hysteresis model predictions in Figure A-18b. It is evident that the maximum Saddle River FFS model predictions are much higher than hysteresis model predictions for the Passaic River at Little Falls (19,800 vs. 4500 mtons/day) and also much higher than the peak Little Falls FFS model predicted load (5800 mtons/day). The Saddle River FFS model (from Figure 3-1 of Appendix BII) is not based in data and is clearly unrealistic. However, there are also significant differences between the FFS and hysteresis model predictions for the Passaic River at Little Falls. Taking into account the sharply rising flow allows the hysteresis model to predict a peak load one day before the peak in flow, after which the predicted load drops. The FFS model, without a hysteresis correction, predicts a load that peaks at the time of the peak flow; Figures A-1 and A-4a,b emphasize that this is not realistic.

Figure A-19a shows the timing of flow and sediment load (total load, fines load and sand load) at Little Falls, along with the storm surge at the Bergen Pt tide gauge;[51] in this case, the hourly flow data have been used. The hourly data bring out a feature not evident in Figure 18a, that there was a small initial flow pulse at Little Falls more than one day in advance of the main flow peak. The rapid rise of the flow at this time results in a small peak in the total load and the maximum fines load. After this peak and as the flow continues to rise, the fines load falls and the sand load increases. The peak total load appears about half a day in advance of the peak flow, while the peak sand load coincides with the peak flow. These predictions derive from the fact that the fines load decreases with flow, as per eq. (A-3). Significantly, the fines load is relatively well synchronized with the storm surge. Thus, large quantities of fines were provided

[51]Unfortunately, the only tide gauge in the LPR, the Newark gauge at Rm-0, was out of commission at the critical time, and did not document the surge in the LPR.

while water levels were fluctuating strongly whereas the largest sand load followed the surge by a day or more. Further, significant sand load is provided during high flow events, and the maximum sand load will typically coincide with or follow the peak in flow. Figure 19b emphasizes that the FFS model is likely wrong in terms of both magnitude and timing of the sediment load. During the initial peak of flow and sediment input, the hysteresis model predicted sand input is nearly as large as the FFS model total load, and the hysteresis model fines input exceeds the FFS model load.[52]

Implications for surge-flood interactions: The timing of the surge relative to peak flows and sediment inputs will vary with the event, but Hurricane Irene is likely typical of hurricane-associated flood events, and the general pattern is clear. As per Appendix B, the storm surge peak will usually (but not always) precede the freshet peak; the peak total load and peak fine sediment input will occur on the rising arm of the hydrograph; and the peak sand input will follow somewhat later. The details of these events are significant, because the net erosion/deposition balance predicted by the FFS Report sediment model is very sensitive to sediment input. If deposition and erosion are not predicted correctly, then contaminant transport will also be incorrect.

Differences between the Dundee Dam and Little Falls sediment loads: The flow and sediment boundary conditions for ECOM and ECOMSED are applied at Dundee Dam, not Little Falls. After 2007, hourly flows are available at both locations, and have been used in FFS modeling, rather than the daily data used for earlier periods. There are, however, no sediment load data for Dundee Dam. The flow data suggest that there is a problem in projecting the sediment load downstream from Little Falls to Dundee, because flow characteristics at Dundee Dam are different from those at Little Falls. Specifically, flows at Dundee Dam are even flashier than those at Little Falls (Figure A-10), and the ratio of flows at Little Falls to those at Dundee Dam do not follow the ratio (1.056) of the basin areas above the two gauges. Flows at Dundee Dam tend to rise more quickly than those at Little Falls. For the 2007/10/1 to 2014/6/21 period, the median of the Dundee Dam:Little Falls flow ratio is 1.11; the 25th and 75th percentiles are 1.052 and 1.247. The distribution of this ratio is, however, highly skewed with extremal (minimum and maximum) values of 0.29 and 17.9, respectively. There are likely two reasons for this pattern. First, there is a hydraulic control at Little Falls that limits the rise of the flow. Further, the lower part of the Passaic River basin below Little Falls responds very quickly to rainfall, because the distances along the tributary channels to the mainstem channel are small; urbanization effects may also be important.

Estimated Dundee Dam sediment load: Examination of the time period around Hurricane Irene in August 2011 (Fig. A-20) shows that the early flow peak at Dundee Dam (on 28 August) was stronger than that at Little Falls, and the flow peaks at Dundee Dam followed those at Little Falls by 2-3 hours. Moreover, the very rapid rise of the flow at Dundee Dam causes a considerable boost in sediment transport on the rising limb of the freshet, such that the estimated peak Dundee Dam transport is 390 mtons/hr (equivalent to 9350 mtons/day), which is twice the hourly load at Little Falls on the same day. The highest load at Dundee Dam coincides with the first flow peak and with the peak of the storm surge, rather than with the higher, second flow peak. The modeled peak Dundee Dam sediment load in Figure A-20 was scaled up relative to the Little Falls load using eq. (A-4), rather than by multiplying the Little Falls load by the ratio of areas, 1.056, which is physically correct for a transport-capacity limited flow. However, the load

[52]Again, the hysteresis model estimates of sediment load are first estimates. They provide process-level understanding and are statistically superior to the load models used in the FFS Report. They are not a substitute for proper load estimates from a validated watershed model.

may actually be supply limited, in which case the load estimates for Dundee Dam in Figure A-20 could be too high – there may not be enough sediment in the reach below Little Falls to actually deliver the load shown in Figure A-11. In any event, the two approaches for estimating Dundee Dam sediment load from Little Falls load [i.e., use of eq (A-4) vs. multiplication by the geometric factor 1.056) disagree by a factor of nearly 2×. Thus, the load estimates in Figure A-20 emphasize that projecting the suspended sediment load at Little Falls (estimated via a rating curve) downstream to Dundee Dam is not trivial. The only real way to remedy this problem using a rating curve approach would be to measure sediment load at Dundee Dam. Even if a basin-scale watershed model were implemented to estimate sediment loads, verification data at Dundee Dam would still be needed, so these data should be collected.

Table A-7 summarizes the modeled loads for the Passaic and Saddle Rivers for the 1-day Hurricane Irene event and scales these up to include the area below Little Falls and the three tributaries (the Saddle, Second and Third Rivers). The results suggest that the total Passaic River sediment load at Dundee Dam is uncertain by a factor of at least 2× for this event. The tributary load is uncertain by a factor of about 5×, though the hysteresis and NSL models nearly agree with respect to the total tributary load, if not the timing of the load. The grand total sediment loads integrated over a 10-day event period (mainstem plus tributaries) are: 19.7 $\times 10^3$ mtons (CARP + NSL models), 31.0 $\times 10^3$ mtons (hysteresis models), and 67.5 $\times 10^3$ mtons (FFS models). Thus, the hysteresis and CARP + NSL models disagree by a factor of ~1.6×, while the FFS model total is more than twice that of the hysteresis model and ~3.4× the CARP + NSL estimate.

Table A-7: Estimated Sediment Loads during Hurricane Irene, 20-29 August 2011

River	Model	Load, 10^3 mtons[i]	
Passaic River		Little Falls	Dundee Dam[ii]
	Hysteresis total load	19.8	24.0
	Hysteresis sand	8.8	
	Hysteresis fines	11.0	
	FFS	24.9	26.3
	CARP	11.7	12.4
Saddle River		at Lodi	At mouth[iii]
	Hysteresis	4.8	6.0
	FFS	23.6	29.5
	NSL	4.8	5.7
Sum of tributary loads			Sum of Saddle, Second & Third R.
	Hysteresis[iv]		7.0
	FFS		38.0
	NSL		7.3
Total load to LPR			Dundee Dam + tributary loads
	Hysteresis		31.0
	FFS		67.5
	NSL+CARP		19.7

[i] All load estimates except Dundee Dam are based on daily loads; Dundee dam loads are based on hourly data.

[ii] FFS and CARP loads for Little Falls are multiplied by 1.056,as per the procedure used in FFS modeling.

[iii] Saddle River and other tributary loads are scaled to the mouths of the respective streams using area ratios.

[iv] The hysteresis model load for the sum all tributaries is based on application of the Saddle River at Lodi rating curve to the flows for Saddle and Second Rivers; Saddle River were scaled up geometrically to account for the Third River

Summary:

Estimating the sediment load to the LPR is a difficult problem because of the flashy nature of the system and the very sparse sediment load data base. Table A-6 suggests that even the long-term averaged Passaic River suspended sediment load at Little Falls is uncertain by 25 to 50%. While we believe that the hysteresis model is more reliable than the CARP or FFS models because it includes the effects of hysteresis, the hysteresis model predicts about 25% higher sediment loads than USGS model of *Wilson & Bonin* [2007]. The CARP and FFS models predict, respectively, 20% to 25% lower and higher loads than the hysteresis model, even though they were developed using the same approach with largely overlapping data. Even if it is argued that either the CARP or FFS models is superior to the hysteresis model based on (A-1), it must nonetheless be acknowledged that a physically appropriate and statistically superior model gives very different results from the other two, which also do not agree with each other. Further, the load at Dundee Dam is different from that at Little Falls because the flow at Dundee Dam is flashier, and the actual load amplitude is highly uncertain – a factor that was not considered at all in error analyses for ECOMSED. As discussed in conjunction with Figure A-20, two different methods of scaling up the load at Little Falls to Dundee Dam give divergent results. Moreover, the differences between model predictions (Table A-6) of the long-term average sediment load from LPR tributaries (the Saddle, Second and Third Rivers) emphasizes that this load is uncertain by 50-100%. As per Table A-7, the total Little Falls sediment load delivered during Hurricane Irene can be estimated to no better than a factor of 2×, and the load at Dundee Dam is even less certain. Tributary loads during floods are uncertain by an order of magnitude. Finally, ECOMSED boundary conditions do not appear to distinguish sand and fines, even though sand can make up half of the total load during high-flow periods. Overall, the sediment load to the LPR is highly uncertain, and this fact vitally affects the validity of the evaluation of the remedial alternatives using the FFS Report model suite. Referring back to the uncertainty analysis for ECOMSED in FFS Report Appendix BII [*EPA*, 2014], an uncertainty of ±20% in the sediment load at Dundee Dam was sufficient to change estimates of net deposition/erosion by ±25 to 125% in many model reaches. Given this uncertainty (which interacts with other uncertainties in ECOMSED and in the Fate and Transport modeling and is only one of many), present deposition and erosion cannot be credibly modeled with the FFS Report model suite, and modeling that integrates these uncertain (and possibly biased) estimates over decades simply is not credible. Thus, it is doubtful that the various remedial alternatives can be meaningfully distinguished (in terms of their predicted contaminant concentrations) with the present model boundary conditions.

Appendix B: Analyses of Extreme Flood and Surge Events and their Joint Occurrence

The FFS Report Capping Analysis (Appendix BI) of return period has a number of flaws:

1. *Preliminary Evaluation of extreme flows and return intervals for the Passaic River*: We evaluated annual extremes from 1897 to 2013 for the Passaic River at Little Falls using the Generalized Extreme Value (GEV) method, a commonly used approach to estimate the likelihood of rare events (e.g., *Sweet et al.* [2013]); it is considered more generally applicable than traditional tools used to evaluate extremes. Using GEV, the estimated 100-year return flow is approximately 20% larger (683 m^3/s, vs. 19,808 cfs = 560 m^3s); compare Table 5.1 from the FFS Report Appendix B1 (*EPA* [2014], reproduced below as Table B-1) with Figure B-1. This difference is at least partly because large flood events in 2007, 2010, and 2011 were not used in the FFS analysis, leading to an under-prediction in risk and uncertainty. However, differences in methodology may also cause divergent results. Thus, both for methodological reasons and because of new data, more realistic extreme floods should be defined, and confidence intervals in the estimates defined. The peak-over-threshold method should also be employed to obtain a second estimate of return period magnitudes.

Table B-1: FFS Extreme Flow Return Intervals from Appendix BIII

Table 5-1. Lower Passaic River Return Flows for Cap Stability and Erosion Analysis

Return Period	*Flow (cfs)*	
	Little Falls	*River Mouth*
1-month	3,900	5,060
6-month	4,500	5,840
1-year	6,200	8,050
2-year	6,751	8,767
5-year	9,968	12,945
10-year	12,219	15,869
25-year	15,280	19,844
50-year	17,465	22,681
100-year	19,808	25,725

2. *Evaluation of extreme flows and return intervals for the Saddle River*: Saddle River flows should be considered when defining the design flood. As shown in Fig. B-2, the 100 year flood level is >100 m^3/s, and even the once-in-10 year event is large enough to export sediment out of the LPR, according to Chant et al. [2011]. Saddle River extreme flows have also increased over time (Fig. B-3). Combining flow from Little Falls and the Saddle River increases the magnitude of the 100 year and 500 year event, but not additively; this is because flood peaks on the Saddle River typically precede those of the mainstem Passaic (Fig. B-4).[53] As such, Saddle River flows are more likely to be elevated during a large storm surge event (see below).

[53]We note that the sum of flows in Figure 4 is not the total inflow to the LPR, because there are other tributaries and because the Dundee Dam flow is larger, on average, by about 11% than Little Falls flow.

3. *Non-stationary hydrology*: The Passaic River hydrologic system is non-stationary on decadal scales, for reasons that need to be explored but are not considered in the FFS Report (see Fig. 4 of the main text). The 10-year flood risk at Little Falls decreased from 1900 until about 1920, but has increased since then and is currently close to 400 m^3/s (Fig. B-5), or approximately 10% higher than the value listed in Table 5.1 of FFS Report Appendix BI (see Fig. B-5). While human development may have changed the hydrological system since the 19th century, another possibility is that the floods in the late 19th century represent natural system variability that will recur. Natural fluctuations in flood risk are likely related to the atmospheric pressure difference between the Azores and Iceland; during periods of a positive NAO (roughly around 1900 and 1980), elevated river flow is observed. A similar fluctuation with the NAO is observed in the Saddle River; during the positive NAO phase from 1970-1985, floods are markedly larger and 6 of the largest 10 recorded events since 1923 occurred during this time period (Fig. B-3). This teleconnection has previously been observed in the literature (e.g., *Rogers* [1990]). Given the long time range of the FFS scenarios, fluctuations in flood risk should be considered. These considerations are unexplored in the FFS Report, leading to possible systematic bias and under-engineering of capping structures. Note that storm-surge risk has the opposite behavior from river flow; it is largest during periods of negative NAO [Talke et al., 2014].

4. *Return intervals are highly uncertain*: The 95% confidence intervals on any flood return period analysis is quite large. This means, for example, that the actual 100-year or 500-year event may be much larger (or smaller) than one might expect based on the data that has been collected. From Figure B-1, the chance of the 100 year flood at Little Falls being larger than 933 m^3/s is about 16%, or one in six (assuming a Gaussian distribution in which 68% of values fall within one standard deviation of the mean). Hence, the full range of possible floods has not been considered. To avoid being 'surprised' by an unexpectedly large event like Hurricane Sandy, it would be advisable to stress test the FFS models with both larger and smaller 100-year and 500-year floods than either Table B1 or Figure B1 suggests. This would show whether the model results are sensitive to the imprecision in the return period estimate. However, the FFS does not consider error bounds in its design flood definitions.

5. *Uncertain Dundee Dam flows*: Dundee Dam flows need further consideration, because (as shown in our Appendix A) the ratio of Dundee Dam to Little Fall flows is highly variable, and there is often a peak at Dundee Dam before the peak at Little Falls. This will influence the return interval of the flows shown in Figure B-4 in the direction of higher flows.

6. The FFS study uses an inadequate approach in modeling the effect of extreme events in the Passaic. The following issues are evident: More specifically:

   a. The extreme events used to estimate flooding and bed shear stress are outdated. Analysis focused on two events: Hurricane Donna, in 1960, and the 1984 river flood event on the Passaic. Though these were large storms, recent flooding from Hurricane Irene (2011) exceeded the 1984 event, and Hurricane Sandy exceeded the Hurricane Donna storm-tide by ~1m (*Talke et al.*, 2014). Historically, 1984 is the 6th largest Passaic River flood event since 1878, or approximately the once-in-20-year event. Similarly, Hurricane Donna water levels have been exceeded twice in the last 200 years—by the 1821 event (*Scilleppi & Donnelly* [2007]; *Kussman* [1957]) and by Hurricane Sandy. More

realistic 100-year and 500-year event should be modelled to adequately assess flood and storm surge risk. As shown by Hurricane Sandy, the FEMA 100-year and 500-year floodplains greatly underestimated the effect of flooding. To fully understand the consequences of different remedial actions and their interaction with proposed dredging, the flood analysis should be updated to include new information and checked to make sure that flood plain definitions are adequate.

b. Focusing on a hurricane with little river flow (Hurricane Donna) and a river flood event with little storm surge (the 1984 flood) misses an important fact: river floods and storm surge often act in concert with LPR tides to produce enhanced flood and erosion risks. Three examples are shown in Fig. B6 to B-8 (out of many possible). Figures B-6 and B-7 show that significant storm surge often occurs at the leading edge of a flood, such that both contribute to flood risk. The most extreme flood on record—in 1903—was apparently a slow-moving storm, such that the peak storm surge coincided nearly exactly with the peak river flow (Fig. B-8) and undoubtedly increased the severity of the flood damage. Therefore, a more realistic view of extreme events should include the joint probability of elevated surge, tides, and river flow occurring simultaneously, rather than treating surge and flood events separately (as in the FFS Report).

c. Because both storm surge, tides, and river discharge affect water levels and currents, there is a spatial pattern to bedstress (and flood risk) that is not considered in the FFS; see Figure 2b. Upstream at Dundee Dam, river flow is clearly the most important factor. Near the estuary mouth where the system is wider, river flood heights diminish and storm tides (surge + tides) are dominant. In between, a combination of tides, surge and flooding is important. For these reasons, an ensemble of different events should be run to determine the effective 100-year and 500-year flood along the estuary/fluvial continuum, and the impact of engineering structures such as sheetpile walls for dredging and the cap.

d. The FFS Report fails to distinguish between flood risk, which is caused by elevated water levels, and erosion risk, which is caused by elevated velocities (which may also be brought to unexpected places by high water levels). Erosion risk (and bed shear stress) are forced primarily by how quickly water levels are dropping, rather than the absolute water depth. Therefore, fast-moving storms, such as Hurricane Gloria in 1985, may be more erosive in the LPR than slow-moving storms like Hurricane Sandy, even though their flood elevations and extent may be lower. This important distinction is explored in Figure B-9, in which the depth averaged flow velocity at Mooring M2 (Harrison Reach) is shown to be linearly related to *dH/dt*, the fall rate of water. Figure B-9 provides, therefore, a means to evaluate different storms through history (provided tide data are available), and determine the most erosive storms at this location (~RM 3).

e. Figure B-10 shows the top 20 most erosive events in the LPR from 1897 to 2013. The most erosive events occurred in 1903 and 2011, and both combined large surges with floods. Some events—like 1917 and 1985—are primarily forced by tides and storm surge, while others—like those in 2007 and 1903—are primarily forced by tides and river flow. Some events, such as the 1938 hurricane, are a combination of all three. The peak velocity during Hurricane Irene in 2011 occurred due to only river flow and tides; this is somewhat misleading because this rapidly moving hurricane created a substantial storm-tide velocity that nearly

equaled the tide plus river-flow induced velocity at this location. Given the hysteresis of sediment input (Appendix A), the hydrodynamic conditions in the estuary during peak sediment input become more important.

f. Conceptually, the results in Figure B-10 suggest that the estuary can be divided into several sections based on the mechanism of erosion. The implications of this division for the proposed dredging and capping solutions have not been adequately considered. Upstream, river flow likely dominates and sets the monthly, yearly, and decadal erosion risk. In a middle section, which likely includes RM-3 to RM-5 (e.g., Fig. B10), the joint risk posed by storm surge events and river flow are important. Downstream of RM-3, storm surge becomes increasingly important and may become, in combination with tides, the primary driver of extreme events. Further analysis of mooring data may help elucidate these divisions. The important observation is that erosion risk is larger when floods and surge events are considered together, rather than separately.

g. Erosion risk interacts with dredging in several ways. First, as shown by Chant et al. [2011], any river flow greater than ~35-40 m^3/s results in sediment export to Newark Bay.Flow rates greater than 40 m^3/s occur ~28% of the time (though 66% of the time between October 1st and April 1st). Hence, toxic, buried contaminants exposed during dredging have a substantial chance of being resuspended (by tidal, surge, and/or flow processes) and exported, particularly during higher flow winter months or by tropical storm surge. Conversely, 72% of the year sediment transport is upstream (on average), and may move contaminated sediment back to previously dredged and capped locations. The FFS should consider whether there are any times in which dredging should not occur, either due to risk of storm surge or risk from flooding. Such an evaluation would inevitably increase the construction time for the more intrusive alternatives with large dredging volumes.

h. The FFS report mentions that sheetpile wall technology can be used to reduce/eliminate dredging loss, but it is unclear whether it will be used all the time and how effective it is against extreme events. Side-effects, including possible scouring around the sheetpile and greater flood risk due to partial damming of the flow are stated in the FFS (FFS, pp. 3-10), but do not appear to have been investigated using FFS models. In particular, the interaction of monthly, yearly, and decadal flood/surge return flow events with such dredging structures should be considered. As shown in Figure B-11, storm surge and substantial river flow typically coincide. More than 500 events of river flow >80 m^3/s have occurred since 1897. Most exhibited a storm surge of >0.3m (1 foot), and many had a surge >0.6m (2 feet). Thus, the source of risk changes with river mile, and may necessitate different containment strategies. In addition, the location of the estuary turbidity maximum (ETM) and the mobile pool of sediment relative to sheetpiles should be considered. The ETM zone itself is depositional, and may tend to protect sheetpile walls; however, as conditions change and the mobile pool of sediment moves away, the area around a dredge or around sheetpile walls may become more prone to erosion. The timing of peak surge is generally 1-2 days before the peak river flow measured at Little Falls (Figure B-12). This means that storm surge typically occurs during the rising limb of the flood hydrograph, which may coincide with the timing of flow input from LPR tributaries like the Saddle River. However, sometimes the largest surge event

occurs after the peak river flow, during the falling limb of the hydrograph (Figure B-12). While more research is necessary, we hypothesize that this may occur when multiple storms occur sequentially. In other words, river flow remains elevated until the next storm surge occurs.

i. Overall, the effect of extreme events on the remedial dredging plan has been only superficially investigated. However, these considerations are critical to ensuring that contaminated sediments are not exported during dredging. In particular, the longer the construction time, the more likely that an extreme event will occur during the dredging. This increases the risk of exposing deeper, more contaminated sediment to erosion and export to Newark Bay, and of an accident occurring that releases considerable amounts of contaminated material.

7. *Non-stationary risks*: Storm-tide risk is non-stationary in New York Harbor (*Talke et al.*, 2014) and has increased by nearly a foot since the mid-19th century (Fig. B-13). The surge risk also fluctuates with the NAO, but the effects of changing risk have not been considered.

8. *Summary:* The 100-year and 500-year floods and storm surges have been underestimated, and the design events for the capping analysis do not reflect recent events. Storm surge and flood risks are also non-stationary, and the analysis of flooding (in FFS Report Appendix BI) neglects the basic fact that storm surge and river flow can—and do—occur at the same time in the Passaic. As an example of the consequences of neglecting this point, consider the following. The calibration of water levels (FFS Report Appendix BI, p. 3-2) attributes the increased elevation measured at two mooring sites (M3 and M5) between 26 and 30 September 2004 to a vertical shift (settling) in the mooring. However, an analysis of tide data at the Battery (Fig. B-11) shows that water levels rose nearly 0.5m between the 26 and 30 September 2004, due to a storm surge. The storm surge contributed to the observed water level anomalies in the Passaic, and probably explains them. This demonstrated lack of system understanding in the report undermines the conclusions.

Appendix C: A Century-Scale Analysis of the LPR Sediment Mass Balance

The importance of the sediment mass balance: It is important to understand the sediment mass balance for a system, because this provides vital clues regarding the fate and transport of contaminants. It can also reveal important changes in system status and processes. Thus, we estimate the LPR mass balance for two periods, 1913 to 1983, and 1984 to 2013 (see Fig. 6). The first period encompasses the years during which large-scale dredging occurred and for which there are records available documenting the amount of material removed. No dredging occurred during the years 1984 to 2013. Separating these two periods is important, because it is likely that large landward sediment fluxes into the LPR from Newark Bay accompanied dredging; as we shall see, there is no other obvious source of the material. The boundaries of the space for which the sediment mass balance is estimated are Dundee Dam, tributary river mouths, RM-0 (the Newark Bay boundary), the LPR water surface, and surface of the bed beneath the water column.

Methods

Imports and Exports 1913 to 1983: Fluxes for the 1913 to 1983 period are listed in Table C-1. All quantities are calculated as integrals over the period and on a yearly basis, averaged over 1913 to 1983. The imports of sediment from the mainstem Passaic River at Dundee Dam and from LPR tributaries (the Saddle, Second and Third Rivers) and uncertainty limits thereon are taken from hysteresis model hindcasts described in Appendix A. CSO, SWO and industrial inputs are a very rough estimate scaled from the *Lowe et al*. [2005] analysis for Newark bay. This estimate is, however, for the modern period, and industrial outputs were likely much larger historically. Though some have been routed into sewage treatment plants, many have ceased. Atmospheric inputs are also scaled from those in *Lowe et al*. [2005]. The dredging export term is the sum of dredged amounts listed by *Iannuzzi et al*. [2002], assuming that there was no in-water disposal in the LPR. If some material was disposed of in Newark Bay and returned, this would be part of the flux to the LPR from Newark Bay. The export to Newark Bay reflects the range of estimates listed in *Shresti et al.* [2014]. The methods and time periods for these estimates are diverse, and some represent net export, others are gross export, and some estimates do not recognize two-way transport. The result is a high level of uncertainty. The most uncertain term is, however, the net deepening that occurred between the onset of major documented dredging (1913) and the cessation of dredging in 1983. A rough estimate of this term from historic documents has been used, with appropriate error bounds. Import from Newark Bay in this time period can only be estimated by difference as the discrepancy in the balance of the terms estimated. Limits are large, reflecting uncertain knowledge of important factors. Absent more specific knowledge, imports and exports are considered uncertain by ±50%. Dredging amounts were considered uncertain by ±20%. Net particulate organic carbon transfer to the bed is ignored, and the cohesive and sand balances are not separated. As per Appendix A, the sand input at Dundee Dam is likely ~20% of the total. Little or no sand is exported to Newark Bay, but an unknown amount of sand has been lost to dredging since 1913.

Table C-1: LPR Mass Balance for the 1913 to 1983 Period*

	Low	Medium	High		Low	Medium	High
	10^6 mtons	10^6 mtons	10^6 mtons		10^3 mtons/yr	10^3 mton/yrs	10^3 mtons/yr
Imports		Sum for period				Yearly	
Passaic River at Dundee Dam	1.86	2.78	4.18		18.4	27.6	41.4
LPR tributaries	0.22	0.32	0.48		2.1	3.2	4.7
Channel deepening	2	7.2	12.4		19.8	71.3	123
CSO, SWO, industrial	0.11	0.163	0.245		1.53	2.3	2.45
Atmospheric	0.001	0.002	0.003		0.01	0.02	0.03
Import from Newark Bay	?	?	?		?	?	?
Exports							
Dredging	-26.0	-21.7	-17.4		-258	-215	-172
Export to Newark Bay	-3.37	-1.52	-0.53		-33.4	-15	-5.2
Import from Newark Bay as discrepancy	25.2	12.75	0.59		249	126	4.8

* See text for analysis details.

Table C-2: LPR Mass Balance for the 1984 to 2013 Period*

	Low	Medium	High		Low	Medium	High
	10^6 mtons	10^6 mtons	10^6 mtons		10^3 mtons/yr	10^3 mton/yrs	10^3 mtons/yr
Imports		Sum for Period				Yearly	
Passaic River at Dundee Dam	0.80	1.19	1.79		26.5	39.8	59.7
LPR tributaries	0.11	0.16	0.24		3.6	5.4	8.1
CSO, SWO, industrial	0.046	0.069	0.104		1.5	2.3	3.5
Atmospheric	5×10^{-4}	7.4×10^{-4}	11×10^{-4}		0.016	0.025	0.037
Import from Newark Bay 2X(Chant et al., 2014)	0.32	0.486	0.73		10.8	16.2	24.3
Exports							
Net sedimentation	-3.62	-2.41	-1.61		-121	-80.4	-53.6
Export (Shresti et al., 2014)	-1.42	-0.64	-0.22		-47.5	-21.3	-7.4
Export to Newark Bay ½X(Chant et al., 2014)	-0.55	-0.36	-0.24		-18.2	-12.1	-8.1
Discrepancy**	-3.779 to -2.9	-1.14 to -0.9	1 to 1.04		-126 to -96	-38 to -28.8	33.9 to 34.6

* See text for analysis details.
** The two values of the discrepancy reflect use of the two different estimates for export to Newark Bay.

Imports and Exports 1984 to 2013: Fluxes for the 1984 to 2013 period are listed in Table C-2. All quantities are calculated as integrals over the period and on a yearly basis, averaged over 1984 to 2013. The imports of sediment from the mainstem Passaic River at Dundee Dam and from LPR tributaries are estimated from the results described in Appendix B, as for Table C-1. CSO, SWO and industrial inputs and the atmospheric inputs are scaled from the *Lowe et al*. [2005] estimates for Newark Bay. Imports from Newark Bay are estimated as twice those specified by the *Chant et al.* [2011] model. Given ongoing sedimentation that exceeds fluvial inputs, the flux from Newark Bay must contribute to sedimentation. Since considerable sedimentation is occurring seaward of the mooring used in formulating the Chant et al. [2011] model, the model estimate has been scaled up by 2×, an arbitrary factor based on professional judgment (again, this demonstrates the need for more measurements). The result is somewhat lower than that obtained by *Suszkowski* [1978], but that is appropriate, in that shoaling has

reduced imports since the 1970s. There was no dredging in the 1983 to 2013 period. Sedimentation was calculated using the average rate (0.038m/yr) estimated from 107 radioisotope cores by *Erickson et al*. [2007]. This rate was applied to an area assumed to be 15 km long and 100 m wide. Given that sand contributes about 20% pf the average sediment load from the Passaic River, the density of the material is estimated at 1.41 mton/m^3. Two estimates of export to Newark Bay were used: (a) the range of estimates from *Shresti et al.* [2014], as for Table C-1; and (b) half the export calculated from the flux model in *Chant et al.* [2014]. This flux for RM-3 is greater than the actual export to Newark Bay, because considerable shoaling occurs between RM-0 and RM-3.

Interpretation of the Sediment Mass Balance:

Figures C-1 and C-2 summarize the information presented in Tables C-1 and C-2; they are repeated from Figures 6a,b of the main text for convenience.

Imports and Exports 1913 to 1983: The 1913 to 1983 balance is dominated by dredging and the response of the system (inferred from the discrepancy in the balance), which is to import material from Newark Bay. The next largest term is the volume of sediment generated by net deepening; this is thought be small relative to dredging, but is highly uncertain. The uncertainty in the Newark Bay input term is nearly as large as that input, and dwarfs the fluvial inputs. The amount of material input from industrial sources is essentially unknown and its omission may account for part of the discrepancy, assigned here to import from Newark Bay.

Imports and Exports 1984 to 2013: The post-dredging balance is very different from the balance that prevailed in previous decades. The largest physical term in the 1984 to 2013 balance is shoaling, which is almost twice the input from fluvial sources and much larger than input from Newark Bay. In contrast to the period or active dredging (1913 to 1983), the cessation of dredging has allowed accretion and has greatly decreased input from Newark Bay. Export to Newark Bay is about half the material input each year at Dundee Dam, if the medium estimate based on *Shresti et al.* [2014] is accepted. If a lower estimate based on modifying the Chant et al. [2011] flux at RM-3 is used, then the export volume is only 30% of the supply. The uncertainty in the imbalance is larger than any of the physical terms.

Summary: The LPR sediment mass balance has changed dramatically since dredging has ceased. In particular, the import of sediment from Newark Bay is now much smaller than when dredging was active, a conclusion very relevant to interpreting FFS alternatives. If the system is deepened, as contemplated in Alternatives 2 and 3, the sediment mass balance suggests that imports of sediments (and the pollutants that they carry) will increase dramatically. This conclusion is statistically robust, even though the mass balances for the 1913-1983 period of active dredging and the 1984-2013 post-dredging period are both highly uncertain in most respects. The uncertainty in even this very basic aspect of LPR system knowledge emphasizes that the system and its trajectory (in terms of sediment budget) are poorly understood. In order to define and evaluate useful remedial alternatives, it is vital to know the system trajectory and how the various alternatives will interact with this trajectory. Without a better understanding of the sediment dynamics of the system, these alternatives cannot be credibly evaluated.

List of Acronyms

ABS	acoustic backscatter
ADCP	acoustic Doppler current profiler
ASCE	American Society of Civil Engineers
CSM	Conceptual site model
CSO	Combined sewer overflow
EMB	Empirical Mass Balance
EPA	Environmental Protection Agency
FFS	Focused Feasibility Study
LPR	Lower Passaic River
NAO	North Atlantic Oscillation
NCASI	National Council for Air and Stream Improvement
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
STAC	Scientific and Technical Advisory Committee
SUST	System Understanding for Sediment Transport
SWO	Storm water outfalls

References

Allen G. P. J.C. Salomon, P. Bassoullet, Y. Du Penhoat, C. de Grandpré, 1980. Effects of tides on mixing and suspended sediment transport in macrotidal estuaries**,** *Sedimen. Geol.*, 26, 69-90.

Aguilera, P.A., Fernández, R., Fernández, A., Rumi, R., Salmerón, A., 2011. Bayesian networks in environmental modelling. *Environ. Model. Softw*. 26., 1376e1388.

Arhonditsis, G.B., Adams-VanHarn, B.A., Nielsen, L., Stow, C.A., Reckhow, K.H., 2006. Evaluation of the current state of mechanistic aquatic biogeochemical modeling: citation analysis and future perspectives. *Environ. Sci. Technol.* 40, 6547–6554.

Arhonditsis. G.B.. Brett, M.T.. 2004. Evaluation of the current state of mechanistic aquatic biogcochemical modeling. Marine Ecology Progress Series 271. 13-26.

Best, J., 2005, The fluid dynamics of river dunes: A review and some future research directions, *J. Geophys. Res*., 110, F04S02, doi:10.1029/2004JF000218.

Borsuk, M. A., C. A. Stow, and K. H. Reckhow. 2004. A Bayesian network of eutrophication models for synthesis, prediction, and uncertainty analysis. *Ecolog. Model.* 173:219–239.

Boudreau, B.P., 1994. Is burial velocity a master parameter for bioturbation? *Geochimica et Cosmochimica Acta*, 58, 1243-1249.

Blumberg, A. F., L. A. Khan, and J. P. St John, 1999. Three dimensional hydrodynamic model of New York Habor Region, *J. Hydraul. Engin*. 125, 799-816.

Box, George E. P.; Norman R. Draper (1987). *Empirical Model-Building and Response Surfaces*, p. 424, Wiley. ISBN 0-471-81033-9.

Burchard, H., Baumert, H., 1998. The formation of estuarine turbidity maxima due to density effects in the salt wedge. A hydrodynamic process study. Journal of Physical Oceanography 28, 309–321.

Burchard, H. and R. D. Hetland (2010),Quantifying the contributions of tidal straining and gravitational circulation to residual circulation in periodically stratified tidal estuaries, *J. Phys. Oceanogr*, 40, 1243-1262, doi:10.1175/2010JPO4270.1

Chant, R.J., D. Fugate, and E. Garvey. 2011. The shaping of an estuarine superfund site: Roles of evolving dynamics and geomorphology. *Estuar. Coasts* 34: 90–105.

Chen, C.F., Ma, H.W., Reckhow, K.H., 2007. Assessment of water quality management with a systematic qualitative uncertainty analysis. *Sci. Total Environ*. 374, 13–25.

Chen, S. H. C. A. Pollino, 2012. Good practice in Bayesian network modelling, *Environ. Model. Softw*., 37, 134-145.

Chernetsky, A.S., H.M.Schuttelaars, & S.A. Talke, 2010. The effect of tidal asymmetry and temporal settling lag on sediment trapping in tidal estuaries*. Ocean Dynamics* 60, 1219-1241, doi: 10.1007/s10236-010-0329-8.

Connolly, J.P., and R. Tonelli, 1985. Modeling Kepone in the Striped Bass Food Chain of the James River Estuary. Estuarine Coastal and Shelf Science (20), pp 349-366, 1988.

Corbella, S., and D.D. Stretch, 2012. Multivariate return periods of sea storms for coastal erosion risk assessment. *Nat. Hazards Earth Syst. Sci.,* 12, 2699–2708.

Daniel, E. B., J. V. Camp, E. J. LeBoeuf, J. R. Penrod, J. P. Dobbins and M. D. Abkowitz, 2011. Watershed modeling and its applications: a state-of-the-art review, *Open Hydrol J.* 5, 26-50.

de Jonge, V. N. and J. E. E. van Beusekom, 1995. Wind- and tide-induced resuspension of sediment and microphytobenthos from tidal flats in the Ems estuary. *Limnol. Oceanogr.*. 40(4), 1995, 766-778

Durkee, J.D., J.D. Frye, C.M. Fuhrnamm, M.C. Lacke, H.G. Jeong, T.L. Mote, 2007. Effects of the North Atlantic Oscillation on precipitation-type frequency and distribution in the eastern United States, *Theor. Appl. Climatol.* DOI 10.1007/s00704-007-0345-x.

EPA, 2007., *Lower Passaic River Restoration Project Conceptual Site Model,* Malcolm Pirnie, White Plains, NY.

EPA, 2013. *Lower Passaic River Lower Eight Miles Focused Feasibility Study Report of the Peer review of Sediment Transport, Organic Carbon and Contaminant Fate and Transport Model*, HydroQual, New York.

Exbrayat, J.-F., Neil R. Viney, H.-G. Frede and L. Breuer, 2011, Probabilistic multi-model ensemble predictions of nitrogen concentrations in river systems, *Geophys. Res. Lett.* DOI: 10.1029/ 2011GL047522.

Fain, A.M.V., D. A. Jay, D. J. Wilson, P. M. Orton, and A. M. Baptista, 2001, Seasonal, monthly and tidal patterns of particulate matter dynamics in the Columbia River estuary, *Estuaries* 24: 770-786.

Festa, J.F., Hansen, D.V., 1978. Turbidity maxima in partially mixedestuaries: a two dimensional numerical model. Estuarine and Coastal Marine Science 7, 347–359.

Flinchem, E. P. and D. A. Jay, 2000, An introduction to wavelet transform tidal analysis methods, *Estuar. Coast. Shelf Sci.* **51**: 177-200.

Friedrichs, M., K.G. Sellner, and M.A. Johnston, 2012. "*Using multiple models for management in the Chesapeake Bay: A shallow water pilog project*." Chesapeake Bay Program Scientific and Technical Advisory Committee Report. No. 12-003, Edgewater, MD. 2012 09.

Garcıa, M. H., Admiraal, D. M., Rodriguez, J. F., and Lopez, F. (1998) Navigation-induced bed shear stresses: Laboratory measurements, data analysis and field applications. *Civil Engineering Studies, Hydraulic Engineering Series No. 56*, Univ. of Illinois at Urbana-Champaign, Ill.

García, M.H., Admiraal, D.M., and Rodriguez, J.F. (1999) Laboratory Experiments on Navigation-Induced Bed Shear Stresses and Sediment Resusupension, 14(2), 303-317, *International Journal of Sediment Research*.

Geyer, W.R., 1993. The importance of the suppression of turbulence bystratification on the estuarine turbidity maximum. Estuaries 16,113–125.

Geyer, W. R., John H Trowbridge, Melissa M Bowen, 2000, The Dynamics of a Partially Mixed Estuary, *J Phys. Oceanogr*. 30, 2035-2048.

Geyer, W. R., and P. MacCready (2014) The Estuarine Circulation. *Annu. Rev. Fluid Mech.* 2014. 46:175–97, 10.1146/annurev-fluid-010313-141302.

Giese, B. S. and D. A. Jay, 1989. Modeling tidal energetics of the Columbia River Estuary, *Estuar. Coast. Shelf Sci*. **29**: 549-571.

Godin, G., 1999. The Propagation of Tides up Rivers With Special Considerations on the Upper Saint Lawrence River, *Estuar. Coast. Shelf Sci.*, 48, 307–324.

Gray, J.R., and Simoes, F.J.M., 2008, Estimating sediment discharge, Appendix D in Garcia, M.H., ed., *Sedimentation engineering—processes, measurements, modeling, and practice*: American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 110, p. 1067–1088.

Gräler, B., M. J. van den Berg,S. Vandenberghe, A. Petroselli, S. Grimaldi, B. De Baets, N.E.C. Verhoest, 2013. Multivariate return periods in hydrology: a critical and practical review focusing on synthetic design hydrograph estimation. *Hydrol. Earth Syst. Sci.* 17, p. 1281

Hansen, D. V. and M. Rattray, Jr. 1965. Gravitational circulation in straits and estuaries. *J. Mar. Res.* 23, 104-122.

Huijts K. M. H., Schuttelaars H. M., de Swart H. E., Valle-Levinson, A., 2006, Lateral trapping of sediment in tidal estuaries: an idealized model. *J Geophys Res Oceans* 111: C12016.doi:10.1029/ 2006JC003615.

Huijts, K.M.H. , H.M. Schuttelaars & H. E. de Swart, 2006. Lateral entrapment of sediment in tidal estuaries: An idealized model study. *J. Geophys. Res*., 111, F02013, doi:10.1029/2005JF000312.

Huijts K. M. H., Schuttelaars H. M., de Swart H. E., Friedrichs C. T., 2009, Analytical study of the transversive distribution of along-channel and transversive residual flows in tidal estuaries. *Contin Shelf Res.* 29:89–100. doi:10.1016/j.csr.2007.09.00.

Hurrel, JW, 1995. Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269: p.276-279

HydroQual, Inc., 2006. *Lower Passaic River Restoration Project Draft Hydrodynamic Modeling Report, April 2006*, HydroQual, Mahwah, N.J.

HydroQual, Inc. 2007. *A model for the evaluation and management of contaminants of concern in water, sediment, and biota in the NY/NJ Harbor Estuary. Sediment Transport/Organic Carbon Production Sub-model.* Report prepared for the Hudson River Foundation on behalf of the Contamination Assessment and Reduction Project (CARP).

HydroQual, Inc. 2008. *Final Hydrodynamic Modeling Report of the Lower Passaic River Restoration Project and Newark Bay Study*, January 2008.

Iannuzzi T. J., Ludwig D. F., Wallin J. M., Kinnell J. C., Dunford R. W., Desvousges W. H, 2002. *A common tragedy: History of an urban waterway*, Amherst (MA): AmherstPress. 200 pp.

Ianniello, J. P., 1977: Tidally induced residual currents in estuaries of constant breadth and depth. *J. Mar. Res*. 35, 755- 774.

Israelsson, P. H., J. D. Quadrini, and J. P. Connolly, 2014, Fate and Transport of Hydrophobic Organic Chemicals in the Lower Passaic River: Insights from 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin, *Estuar. Coasts*, DOI 10.1007/s12237-013-9761-6.

Jay, D. A., 1991, Green's law revisited: tidal long wave propagation in channels with strong topography. *J. Geophys. Res.* **96**: 20,585-20,598.

Jay, D. A., B. S. Giese, and C. R. Sherwood, 1990, Energetics and sedimentary processes in the Columbia River Estuary. *Prog. Oceanogr.*, **25**: 157-174.

Jay, D. A. and Flinchem, E. P., 1997, Interaction of fluctuating river flow with a barotropic tide: A test of wavelet tidal analysis methods, *J. Geophys. Res.* **102**: 5705-5720.

Jay, D. A., K. Leffler and S. Degens, 2011, Long-term evolution of Columbia River tides, *ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering*, 137: 182-191; DOI: 10.1061/(ASCE)WW.1943- 5460.0000082.

Jay, D. A., W. R. Geyer and D. R. Montgomery, 2000. "An ecological perspective on estuarine classification," in *Estuarine Science, A Synthetic Approach to Research and Practice,* J. E. Hobbie (ed.), Island Press, pp. 149-175.

Jay, D. A. and J. D. Musiak, 1994, Particle trapping in estuarine turbidity maxima, *J. Geophys. Res.* 99: 20,446-61.

Jay, D. A. and J. D. Musiak, 1996, Internal Tidal Asymmetry in Channel Flows: Origins and Consequences. C. Pattiaratchi (ed.), *Mixing Processes in Estuaries and Coastal Seas,* an American Geophysical Union *Coastal and Estuarine Sciences Monograph,* pp. 219-258.

Jay, D. A., P. M. Orton, T. Chisholm, D. J. Wilson, and A. M. V. Fain, 2007a, Particle trapping in stratified estuaries – I Consequences of Mass Conservation and explorations of a parameter space, *Estuar. Coast.* 30: 1095-1105.

Jay, D. A., P. M. Orton, T. Chisholm, D. J. Wilson, and A. M. V. Fain, 2007b, Particle trapping in stratified estuaries – II Application to Observations, *Estuar. Coast.* 30: 1106-1125.

Jay, D. A. and J. D. Smith, 1988. Circulation in and classification of shallow, stratified estuaries. In: *Physical Processes in Estuaries*, J. Dronkers and W. van Leussen, pp. 21-41.

Jay, D. A. and J. D. Smith, 1990, Circulation, density distribution and neap-spring transitions in the Columbia River Estuary. *Prog. Oceanogr.* **25**: 81-112.

Jay, D. A., R. J. Uncles, J. Largier, W. R. Geyer, J. Vallino and W. R. Boynton (LMER Scalar Transport Working Group), 1997, A review of recent developments in estuarine scalar flux estimation, *Estuaries* **20**: 262-280.

Jevrejeva S., J. C. Moore, A. Grinsted, P. L. Woodworth (2008), Recent global sea level acceleration started over 200 years ago?, *Geophys. Res. Lett.*, 35, L08715, doi:10.1029/ 2008GL033611.

Jolliff, J.K., Kindle, J.C., Shulman, I., Penta, B., Friedrichs, M.A.M., Helber, R., and R.A. Arnone, 2009. Summary diagrams for coupled hydrodynamic-ecosystem model skill assessment, J. Mar. Syst. 17, 4-15.

Kawamiya, M., 2002, Numerical model approaches to address recent problems on pelagic ecosystems. *J. Oceanogr.* 58, 365- 378.

Kay, D. J. and D. A. Jay, 2003a, Interfacial mixing in a highly-stratified estuary. 1. characteristics of Mixing, *J. Geophys. Res*. 108, 3072 doi 10.1029/2002 JC000252.

Kay, D. J. and D. A. Jay, 2003b, Interfacial mixing in a highly-stratified estuary. 2. a "method of constrained differences" approach for the determination of the momentum and mass balances and the energy of mixing, *J. Geophys. Res*. 108, 3073 doi 10.1029/2002 JC000253.

Kessarkar, P. M., V. P. Rao, R. Shynu, I. M. Ahmad, P. Mehre, G. S. Michael, D. Sundar, 2009. Wind-driven estuarine turbidity maxima in Mandovi Estuary, central west coast of India. *J. Earth Sys. Sci.*, 118, pp 369-377

Kukulka, T., and D. A. Jay, 2003a, Impacts of Columbia River discharge on salmonid habitat I. a non-stationary fluvial tide model, *J. Geophys. Res*. 108, 3293 doi 10.1029/2002JC001382.

Kussman, A.S., (1957), Report on the Hurricane of September 3, 1821. *Weather Bureau Office*, New York, N.Y. 53 pp.

MacCready, P., et al., (2004), Dynamics of Willapa Bay, Wasington: A highly unsteady, partially mixed estuary, *J. Geophys. Res.,* 34, 2413-2427, doi: 10.1175/JPO2637.1.

MacCready, P., 2007. Estuarine adjustment, *J. Phys. Oceanogr,* 27: 2133-45.

MacCready, P., Geyer, R., (2010), Advances in estuarine physics, *Ann. Review Mar. Sci*, 2, doi: 10,1146/annurev-marine-120308-081015.

Leffler, K. and D. A. Jay, 2009, enhancing tidal harmonic analysis: Robust (hybrid L1/L2) solutions, *Contin. Shelf Res.* 29, 78-88.

Lynch, D. R., D. J. McGillicuddy Jr, and F. E. Werner, 2009. Skill assessment for coupled biological/physical models of marine systems, *J. Mar. Syst* 76.1, 1-3.

Malve, O., M. Laine, H. Haario, 2005. Estimation of winter respiration rates and prediction of oxygen regime in a lake using Bayesian inference, *Ecolog. Model*. 182, 183–197.

Matte, P, D. A. Jay and E. Zaron, 2013, Adaptation of Classical Tidal Harmonic Analysis to Non-Stationary Tides, with Application to river tides, *J. Ocean. Atmos. Technol*. 30: 569-589, doi 10.1175/ JTECH-D-12-00016.1.

Maynord, S. T., 2000, P*hysical Forces Near Commercial Tows, Upper Mississippi River-Illinois Waterway System Navigation Study*, ENV Report 19, Vicksburg, MS, 73 pp., Appendices.

Meade, R. H., 1972, Transport and deposition of sediment in estuaries, Geol. Soc. Am Mem 133, 91-120.

Meade, R. H., T. R. Yuzyk, and T. J. Day. 1990. Movement and storage of sediment in rivers of the United States and Canada. Pages 255–280. in Wolman, M. G. and H. C. Riggs, editors. eds. Surface Water Hydrology, vol. 0–1: The Geology of North America. Boulder (CO) Geological Society of America.

Mehta, A. J., and W. H. McAnally, Fine-grained sediment transport, Chapter 4 in Garcia, M.H., ed., *Sedimentation engineering—processes, measurements, modeling, and practice*: American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 110, pp. 253-306.

Migliaccio, K. W., and P. Srivastava, 2007. Hydrologic components of watershed-scale models, *Trans. Am. Soc. Agri. And Biolog. Engin*., 50, 1695-1703.

Monte L., Hakanson L., Perianez R., Laptev G., Zheleznyak M., Maderich V., Angeli G,. 2006. Experiences from a case study of multi model application to assess the behaviour of pollutants in the Dnieper-Bug Estuary. Ecological Modelling, Vol. 195, p. 247-263.

Najjar, R, L. Patterson, S. Graham, 2009. Climate simulations of major estuarine watersheds in the Mid-Atlantic region of the US *Climat. Change* 95:139–168 DOI 10.1007/s10584-008-9521-y.

NCASI (National Council for Air and Stream Improvement), 1999. *Technical Bulletin No. 0776: Scale Considerations and the Detectability of Sedimentary Cumulative Watershed Effects*, National Council for Air and Stream Improvement, Research Triangle, NC.

Nelsen, Roger B., 1999). *An Introduction to Copulas*, New York: Springer, ISBN 0-387-98623-5.

North, E. W., S. Y.Caho, L. P. Sanford, R. R. Hood, 2004. The influence of wind and river pulses on an estuarine turbidity maximum: Numerical studies and field observations in Chesapeake Bay. *Estuar.*, 27, 132-146.

Omlin, M., Reichert, P., 1999. A comparison of techniques for the estimation of model prediction uncertainty. Ecol. Model. 115, 45–59.

Parajuli, P. B. and Y. Ouyang, 2013. "Watershed-Scale Hydrologic Modeling Methods and Applications," Chapter 3 in Bradley, P. M. (Ed.), *Current Perspectives in Contaminant Hydrology and Water Resources Sustainability*, INTECH, http://dx.doi.org/10.5772/53596.

Ralston, DK, WR Geyer, and JA Lerczak, 2008. Subtidal salinity and velocity in the Hudson River estuary: observations and modeling. *J. Physical Oceanogr*., 38(4), 753-770.

Ralston, D. K., J. C. Warner, W. R. Geyer, and G. R. Wall, 2013. Sediment transport due to extreme events: The Hudson River estuary after tropical storms Irene and Lee, *Geophys. Res. Lett*., 40, 5451–5455, doi:10.1002/2013GL057906.

Reichert, P., Omlin, M., 1997. On the usefulness of overparameterized ecological models. *Ecol. Model.* 95, 289–299.

Reckhow K. H., 1999. Water quality prediction and probability network models. *Can. J. Fish. Aquat. Sci.* 56, 1150–1158.

Reckhow K. H., and Chapra S. C., 1999. Modeling excessive nutrient loading in the environment, *Environ. Pollut.* 100 197-207.

Roach, P. J., 1994. Perspective: a method for uniform reporting of grid refinement studies, *J. Fluids Engin.* 1994: 405-413.

Roach, P. J., 1997. Quantification of uncertainty in computational fluid dynamics, *Annu. Rev. Fluid. Mech.* 29, 123–60.

Rogers, G.C., 1990, Patterns of Low-Frequency Monthly Sea Level Pressure Variability (1899-1986) and Associated Wave Cyclone Frequencies. *Journal of Climate* 3, 1364-1379.

Salvadori, G., De Michele, C., and Durante, F, 2011. On the return period and design in a multivariateframework, *Hydrol. Earth Syst. Sci*., 15, 3293–3305, doi:10.5194/hess-15-3293-2011

Scileppi, E., and Donnelly, J. P. 2007, Sedimentary evidence of hurricane strikes in western Long Island, New York, *Geochem., Geophys., Geosyst*. 8**,** Q06011, doi:10.1029/2006GC001463.

Schölzel, C.; Friederichs, P., 2008. "Multivariate non-normally distributed random variables in climate research – introduction to the copula approach". *Nonlinear Proc. Geophys.* 15, 761.

Sea Engineering & HDR, 2011. *Lower Passaic River System Understanding of Sediment Transport May 2011*, 66 pp.

Shrestha P. L., S. H. Su, S. C. James, P. J. Shaller, M. Doroudian, C. E. Firstenberg, and C. T. Thompson, 2014. Conceptual Site Model for Newark Bay—Hydrodynamics and Sediment Transport, *J. Mar. Sci. Eng.* 2014, 123-139; doi:10.3390/jmse2010123.

Stow, C. A., J. Jolliff, D. J. McGillicuddy, S. C. Doney, J. I. Allen, M. A.M. Friedrichs, K. A. Rose, and P. Wallhead, 2009. Skill assessment for coupled biological/physical models of marine systems, *J. Mari. Syst.*, Volume 76, 4-15.

Stacey, MT, S. Monismith, J. Burau, 1999. Observations of Turbulence in a partially stratified estuary. *J. Phys. Oceanogr.*, 29, p. 1950-1971.

Simpson, R. L., 1989, Turbulent boundary-layer separation, *Ann. Rev. Fluid Mech*., 21, 205–234, doi:10.1146/annurev.fl.21.010189.001225.

Suszkowski, D. J., 1978. *Sedimentology of Newark Bay, New Jersey: An urban Estuarine Bay*; University of Delaware: Newark, DE, USA, 1978.

Syvitski, J. P., M. D. Morehead, D. B. Bahr, and T. Mulder, 2000. Estimating fluvial sediment transport: The rating parameters, *Water Resour. Res.,* 36, 2747–2760, doi:10.1029/2000WR900133.

Sweet, W, Zervas, C., Gill, S. and Park, J., 2013, Hurricane Sandy inundation probabilities today and tomorrow, *Bull. Amer. Meteor. Soc.* 94, S17-S20.

Talke, S.A., A.R. Horner-Devine, C.C. Chickadel, 2010. Mixing layer dynamics in separated flow over an estuarine sill with variable stratification, *J. Geophys. Res*. 115, C09004, doi:10.1029/2009JC005467.

Talke, S. A. and David A. Jay, 2013**.**, Nineteenth Century North American and Pacific Tidal Data: Lost or Just Forgotten?. J. Coastal Res., doi: http://dx.doi.org/10.2112/ JCOASTRES-D-12-00181.1.

Talke, S. A., P. Orton, *and* D. A. Jay (2014), Increasing storm tides in New York Harbor, 1844–2013, *Geophys. Res. Lett.,* 41, 3149–3155, doi:10.1002/2014GL059574.

Talke, S.A., H.E. de Swart, & H.M. Schuttelaars, 2008. An analytical model of the equilibrium distribution of suspended sediment in an estuary. In *Dohmen-Janssen and Hulscher, eds: River, Coastal and Estuarine Morphodynamics 2008*, p. 403-411, London, Taylor & Francis. Talke,

S.A., and M.T. Stacey, 2008. Suspended Sediment Fluxes at an intertidal flat: Shifting Influence of wave, wind, tidal, and freshwater forcing. *Contin. Shelf Res*., 710-725, doi:10.1016/ j.csr.2007.12.003.

Talke, S.A, H.E. De Swart and H.M.Schuttelaars, 2009a. Feedback between residual circulation and sediment distribution in highly turbid estuaries: an analytical model. *Continental Shelf Research*, 29(1) p. 119-135. doi:10.1016/j.csr.2007.09.002

Talke, S.A., H.E. de Swart, and V.N. de Jonge, 2009b. An idealized model and systematic process study of oxygen depletion in highly turbid estuaries. *Estuaries and Coasts*, 32 (4) p. 602-620. DOI 10.1007/s12237-009-9171-y.

Tierra Solutions, 2010. *Hydrodynamic Model report Phase 1 Removal Action CERCLA Non-Time-Critical Removal Action Lower Passaic River Study Area*, Tierra Solutions, Inc., East Brunswick, NJ.

US Army Engineers New York District, 1948. *Survey report for Flood Control, Volume 1 Main Report*, New York Preliminary Alternative Reevaluation Report Phase 11.

US Army Engineers New York District and State of New Jersey Department of Environmental Protection, 2013. *Passaic River Mainstem Flood Risk Management New Jersey/New York*, 202 pp.

Vellinga, NE, A.J.F. Hoitink, M. Van der Vegt, W. Zhang, 2014. Human impacts on tides overwhelm the effect of sea level rise on extreme water levels in the Rhine-Meuse delta. Coastal Engineering, 90, p. 40-50.

Warner, J. C., W. R. Geyer, and J. A. Lerczak, 2005, Numerical modeling of an estuary: A comprehensive skill assessment, J. Geophys. Res., 110, C05001, doi:10.1029/2004JC002691.

Wilson, T.P. and Bonin, J.L., 2007. *Concentrations and Loads of Organic Compounds and Trace Elements in Tributaries to Newark and Raritan Bays, New Jersey*. U.S. Geological Survey Scientific Investigations Report 2007-5059, 176 p.

Winterwerp, J.C., 2002. On the flocculation and settling velocity of estuarine mud. *Contin. Shelf Res*. 22, 1339–1360.

Winterwerp, J.C. 2011. Fine sediment transport by tidal asymmetry in the high-concentrated Ems River: indications for a regime shift in response to channel deepening. *Ocean Dynam.* 61: 203–215.

Zhang, W., G.B. Arhonditsis, 2009. A Bayesian hierarchical framework for calibrating aquatic biogeochemical models *Ecological Modelling* 220, 2142–2161.

FIGURES

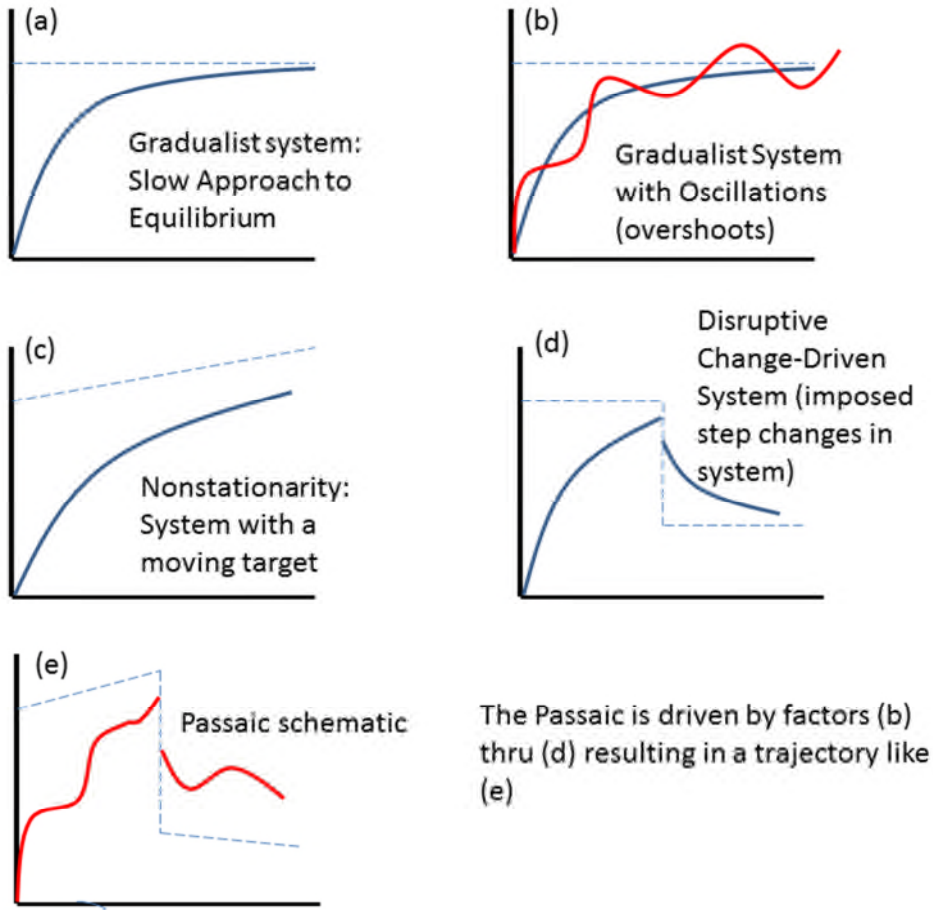


Figure 1: Conceptual view of the trajectory of the LPR over the last century. The x-axis is time, and the y-axis is a system variable. The system is not approaching equilibrium in a simple manner, as suggested by (a). Rather, the hypothetical approach to equilibrium is perturbed (b) by oscillations (e.g., related to the decadal-scale variations due to the North Atlantic Oscillation or NAO), (c) secular changes like MSL rise, and (d) disruptive system changes (e.g., channel deepening early in the 20th century). The result is a complex, discontinuous system trajectory that needs to be explored using historical data and modeling.

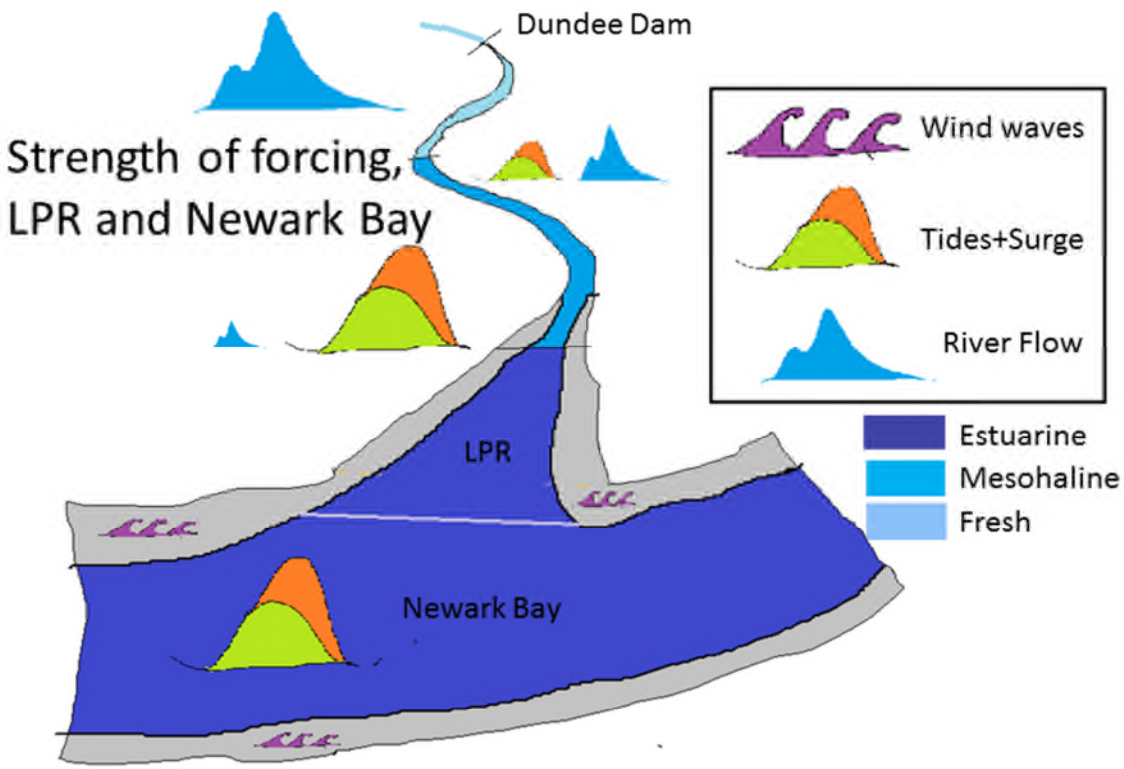


Figure 2a: Schematic view of the dominant forcing factors and their distribution in the LPR and Newark Bay. Spatial boundaries are approximate; they vary with river flow and (to a lesser extent) with tidal range. Tides and surge are absent upstream of Dundee Dam.

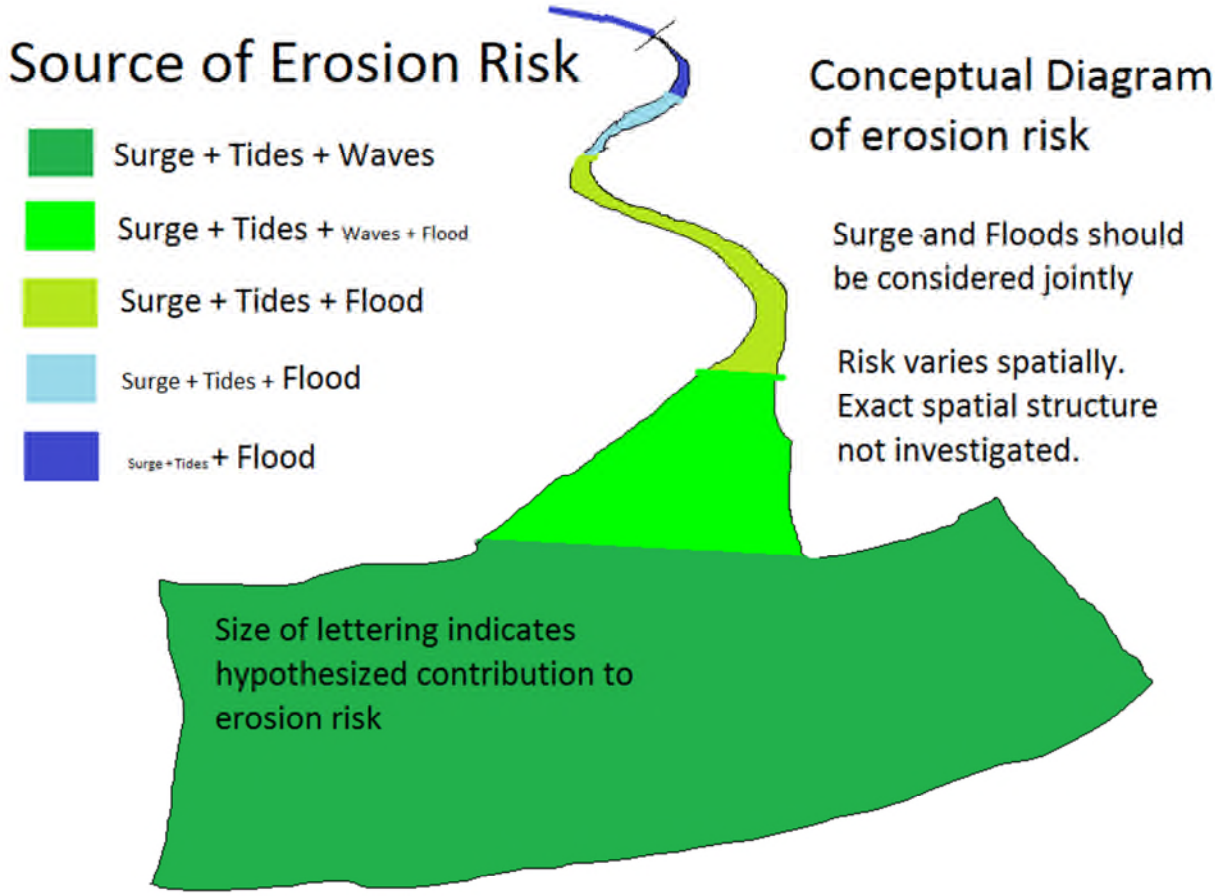


Figure 2b: Schematic view of spatial variations in factors leading to erosion; boundaries are approximate; they vary with river flow and tidal range. Tides and surge are absent upstream of Dundee Dam. The size of the text letters in the legend at left indicate the importance of each process in each area.

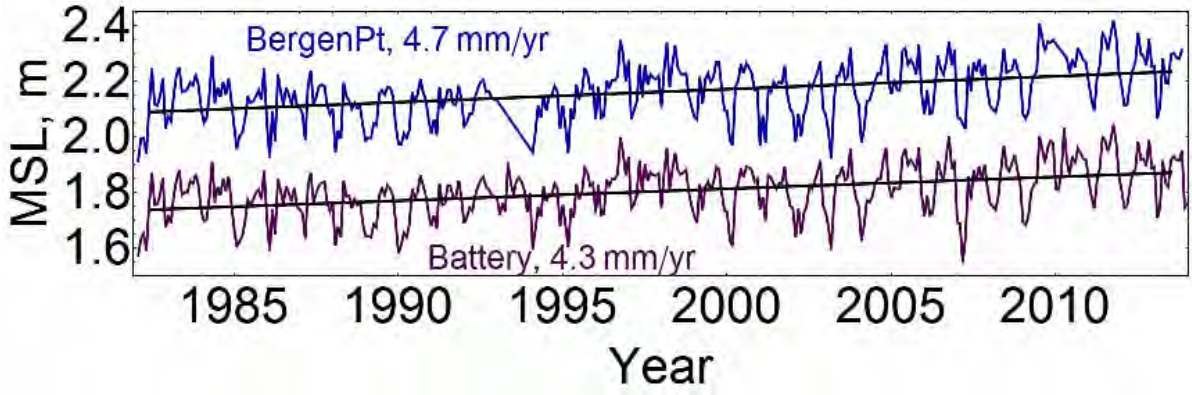


Figure 3a: Monthly mean sea level (MSL) rise since 1981 estimated from NOAA data for Bergen Point (Newark Bay; station 8519483, http://tidesandcurrents.noaa.gov/ waterlevels.html?id=8519483) and for The Battery (New York Harbor; station 8518750, http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750). These are the closest long-term tide stations to the LPR. Of the two, Bergen Point is more likely to be characteristic of the LPR because it is closer.

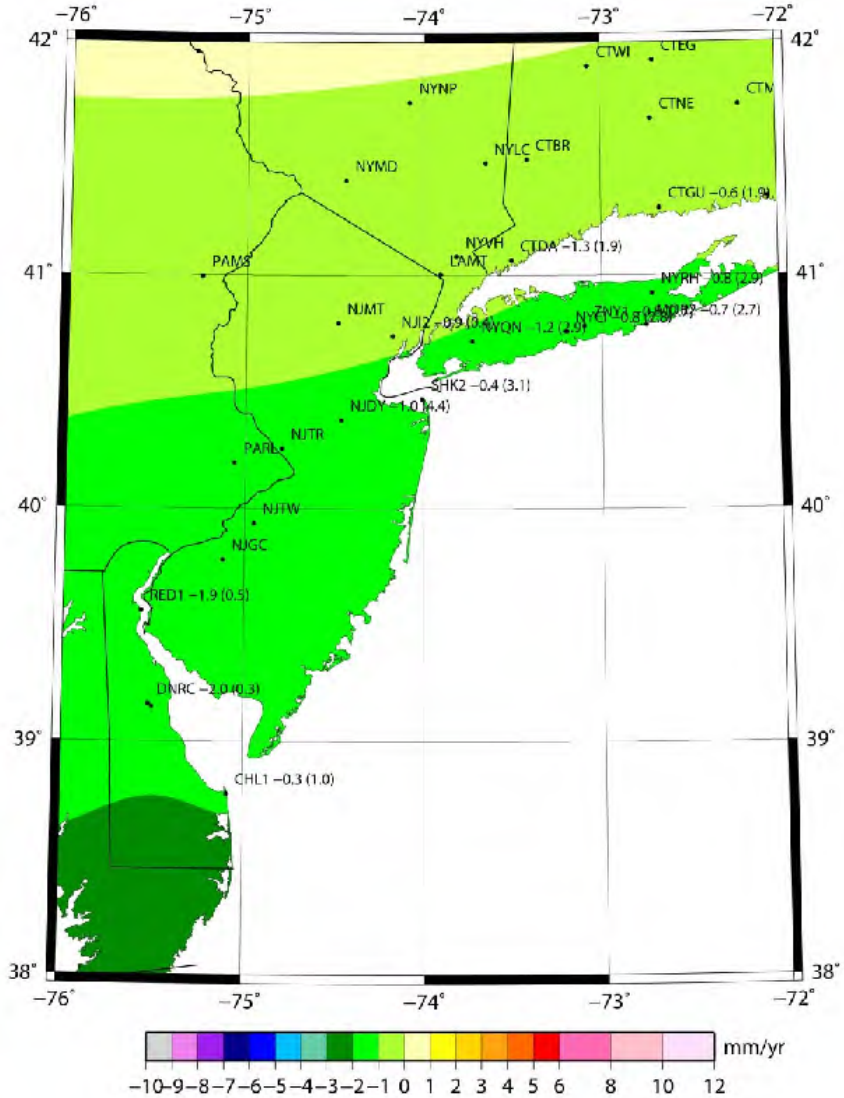


Figure 3b: Regional rates of vertical land movement from GPS data (personal communication R. S. Snay); The numbers immediately following station names are estimated ITRF2008 vertical velocities (in mm/yr) at these stations. The numbers in parentheses are standard deviations for these estimated velocities. Contours represent a highly smoothed model for the ITRF2008 vertical velocity field.

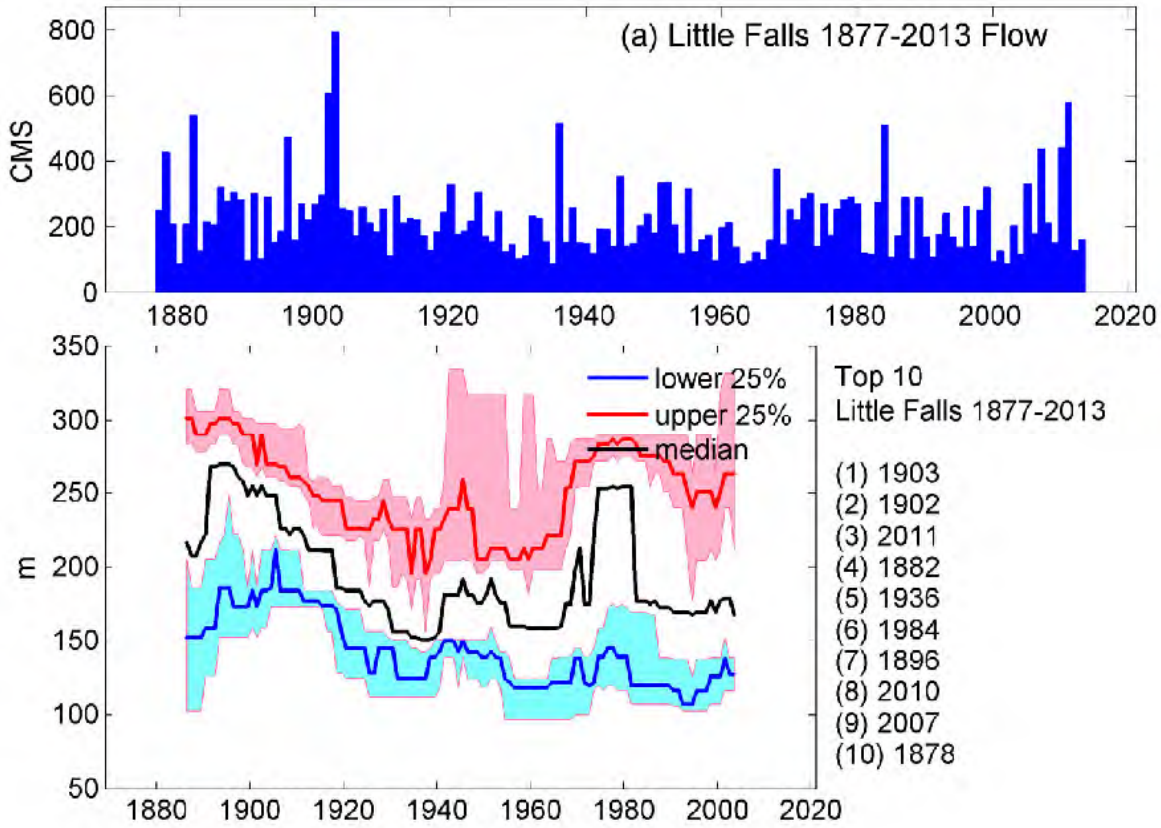


Figure 4: Annual maximum Passaic River flow at Little Falls based on daily flows (a), with quartiles based on a 25-year moving window (b). Flows pre-1897 are from listed Dundee Dam values listed in *Vermeule* [1894], and are reduced by 10% to adjust for the difference between Little Falls and Dundee Dam (see Appendix A). Pre-1897 values below 200 m^3/s were unavailable and were therefore bootstrapped from post-1897 data (7 values) to allow for estimation of statistics. The periods of high flood threat appear to be correlated with the North Atlantic Oscillation.

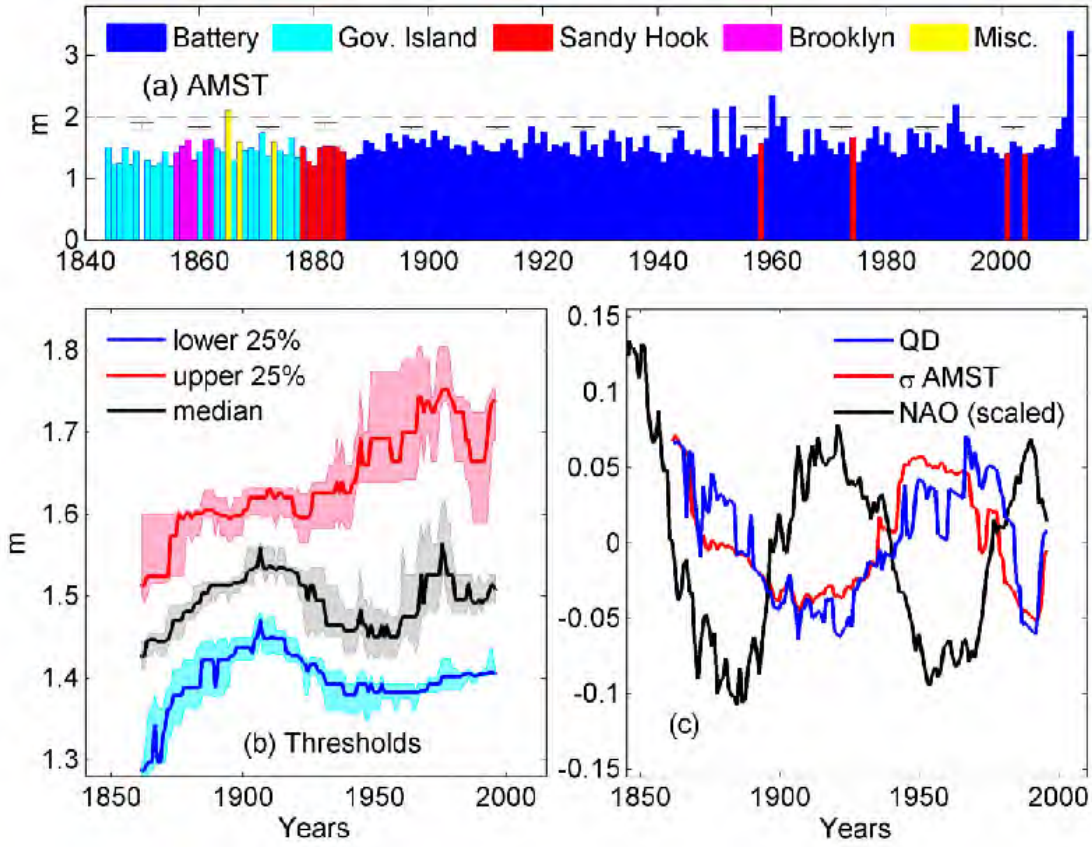


Figure 5: Annual maximum storm tide (AMST) in New York Harbor since 1844 (a); time variations in median and quartile values of AMST from a 37-year moving window; and the relationship of AMST standard deviation and quartiles (QD) with the North Atlantic Oscillation or NAO [*Talke et al.*, 2014].

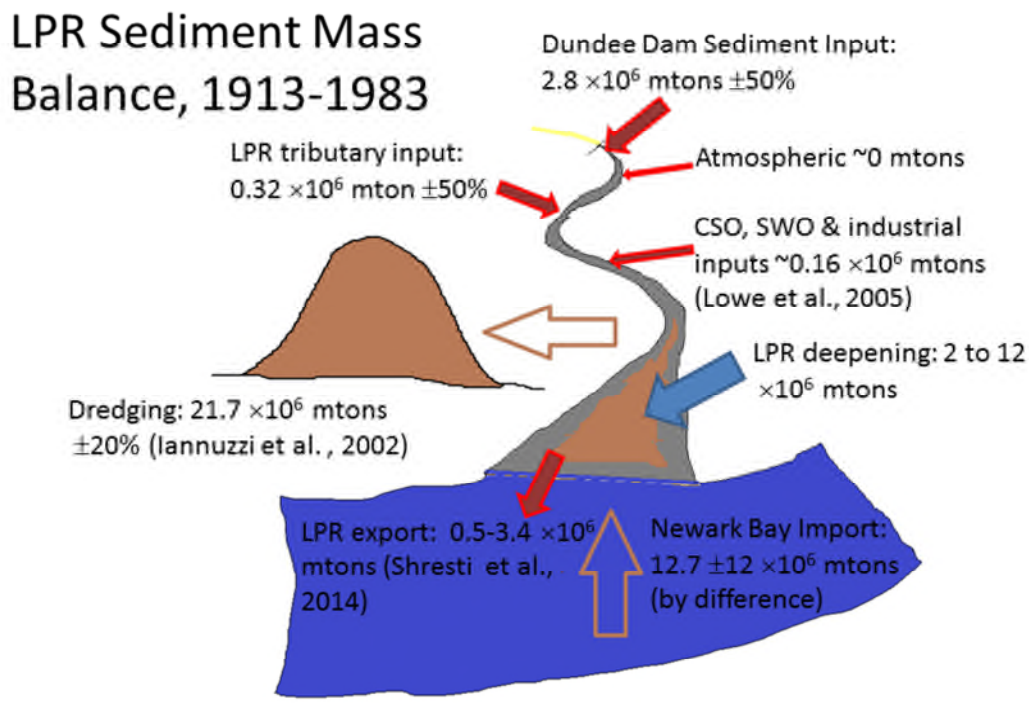


Figure 6a: A preliminary estimate of the LPR sediment total mass balance 1913 to 1983; see Appendix C for details. Net particulate organic carbon transfer to the bed is ignored, and the cohesive and sand balances are not separated. As per Appendix A, the sand input at Dundee Dam is likely ~20% of the total. Little or no sand is exported to Newark Bay, but some sand was lost to dredging, though part of that was material already on the bed before 1913. The Newark Bay input to the LPR is the discrepancy between the remaining terms, with the broad range reflecting the uncertainty of the other estimates. The range of uncertainty on the discrepancy is larger than all terms except dredging loss and input from Newark Bay.

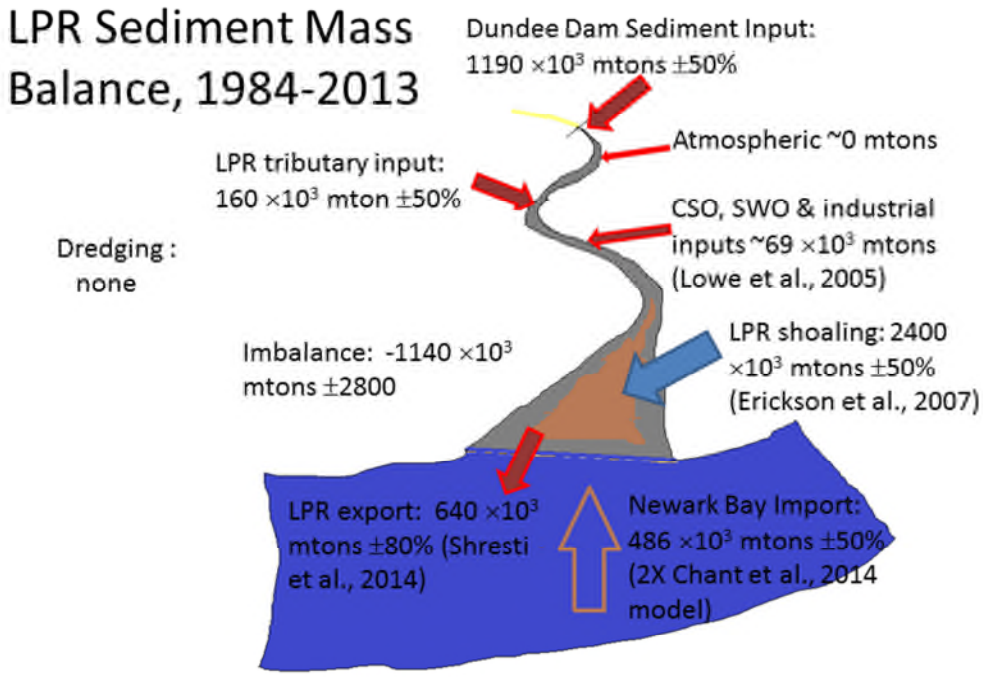


Figure 6b: A preliminary estimate of the LPR sediment total mass balance for 1984 to 2013; see Appendix C for details. The imbalance is the difference between the terms estimated. The uncertainty in the net encompasses zero, so that for some values within the ranges of the estimates, balance is achieved. However, the uncertainty in the imbalance is larger than any individual term.

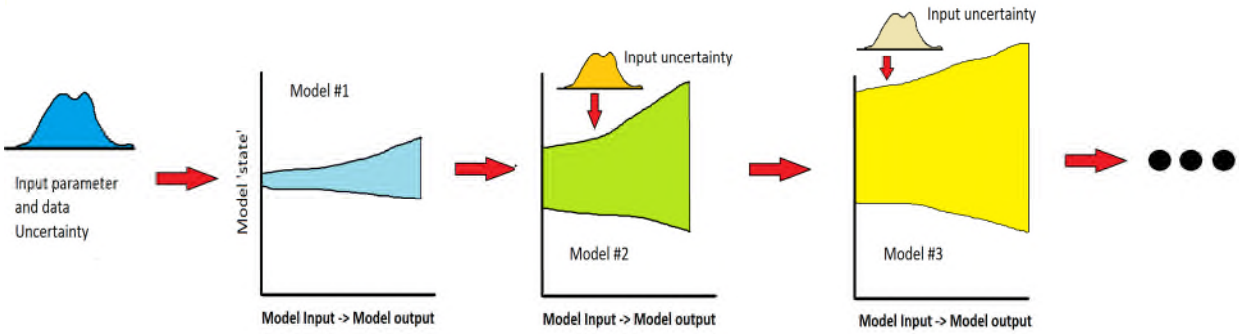


Figure 7a: Model uncertainty increases as models are chained. Environmental input data to the first model and to all subsequent models are uncertain and possibly biased. Also, models are put together in sequence, the uncertainty in the prior model(s) must be considered in estimating the uncertainty at any level in the modeling hierarchy. Results from a nonlinear model also become more uncertain over time as errors accumulate (which is why weather can only be predicted a short time in advance), but that is not illustrated here.

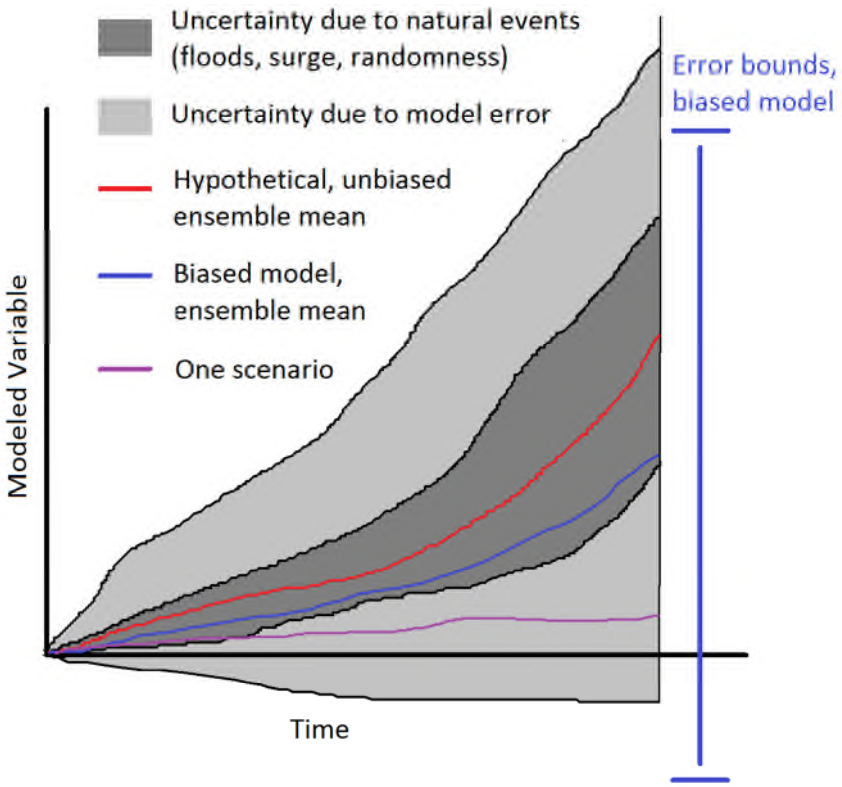


Figure 7b: A conceptual argument for ensemble modeling. Because future environmental conditions are uncertain and models are imperfect, the hypothetical, unbiased ensemble mean (red; which represents the output that is the best way to evaluate alternatives) is an unreachable goal. It can be approximated by forming an ensemble of outputs that vary model parameters and environmental forcing and produce a biased mean (the blue line). A multi-modeling approach can be used to reduce bias (not shown). Use of only one simulation is likely to lead to a prediction (purple) that departs considerably from the ensemble mean.

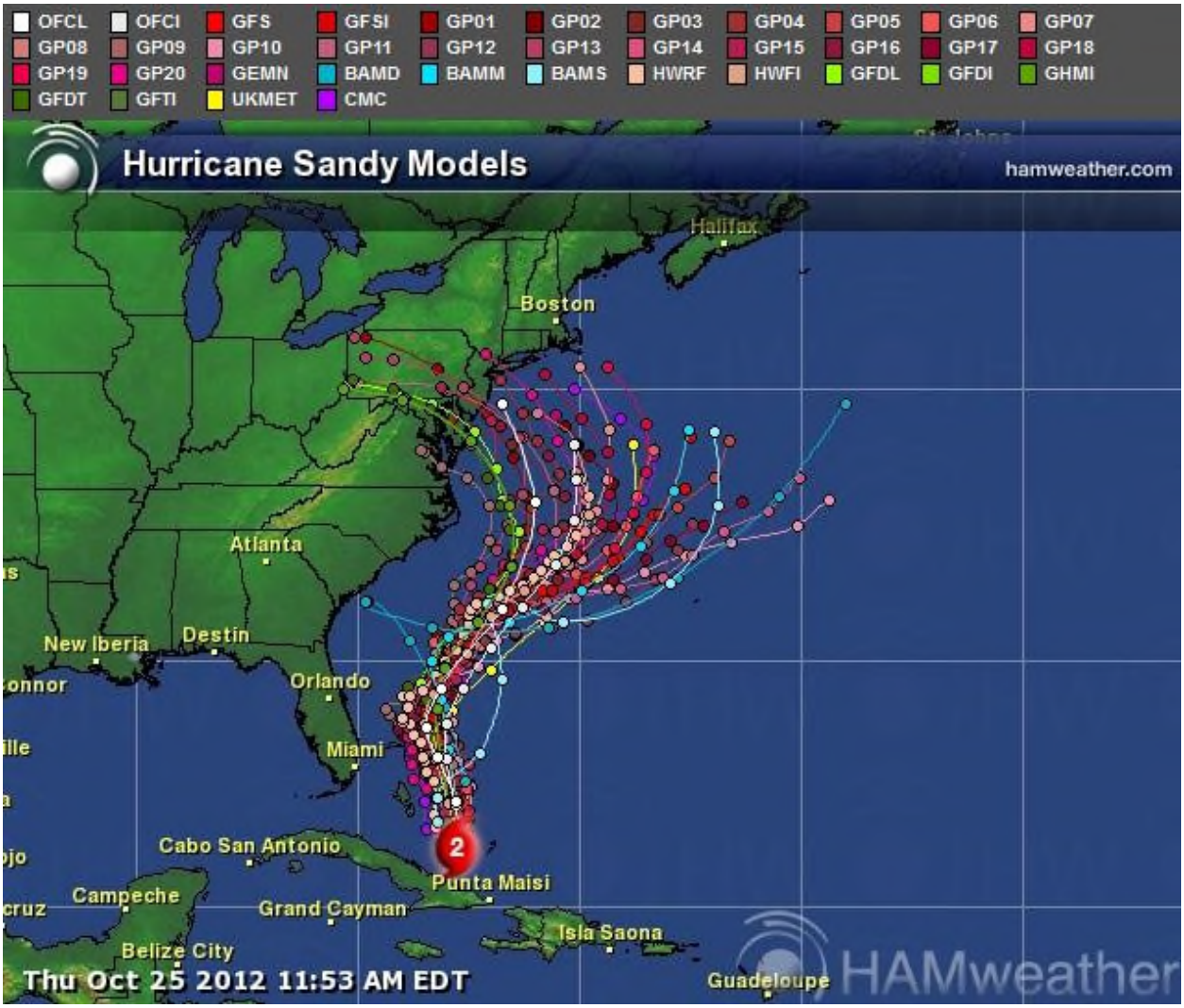


Figure 7c: An example of ensemble forecasting, for Hurricane Sandy. With minor changes in boundary conditions and/or parameters, a wide range of outcomes were possible 4 days before the storm hit New Jersey coast. Forecasting future conditions in the LPR is similar – boundary conditions are uncertain, model parameters are imperfectly known, and models accumulate error over time. In both weather forecasting and estuarine modeling, the basic equations are approximately integrated, and both systems are chaotic. For these reasons, it is not reasonable to carry out a 45 to 50-year forecast for future LPR conditions based on a single realization.

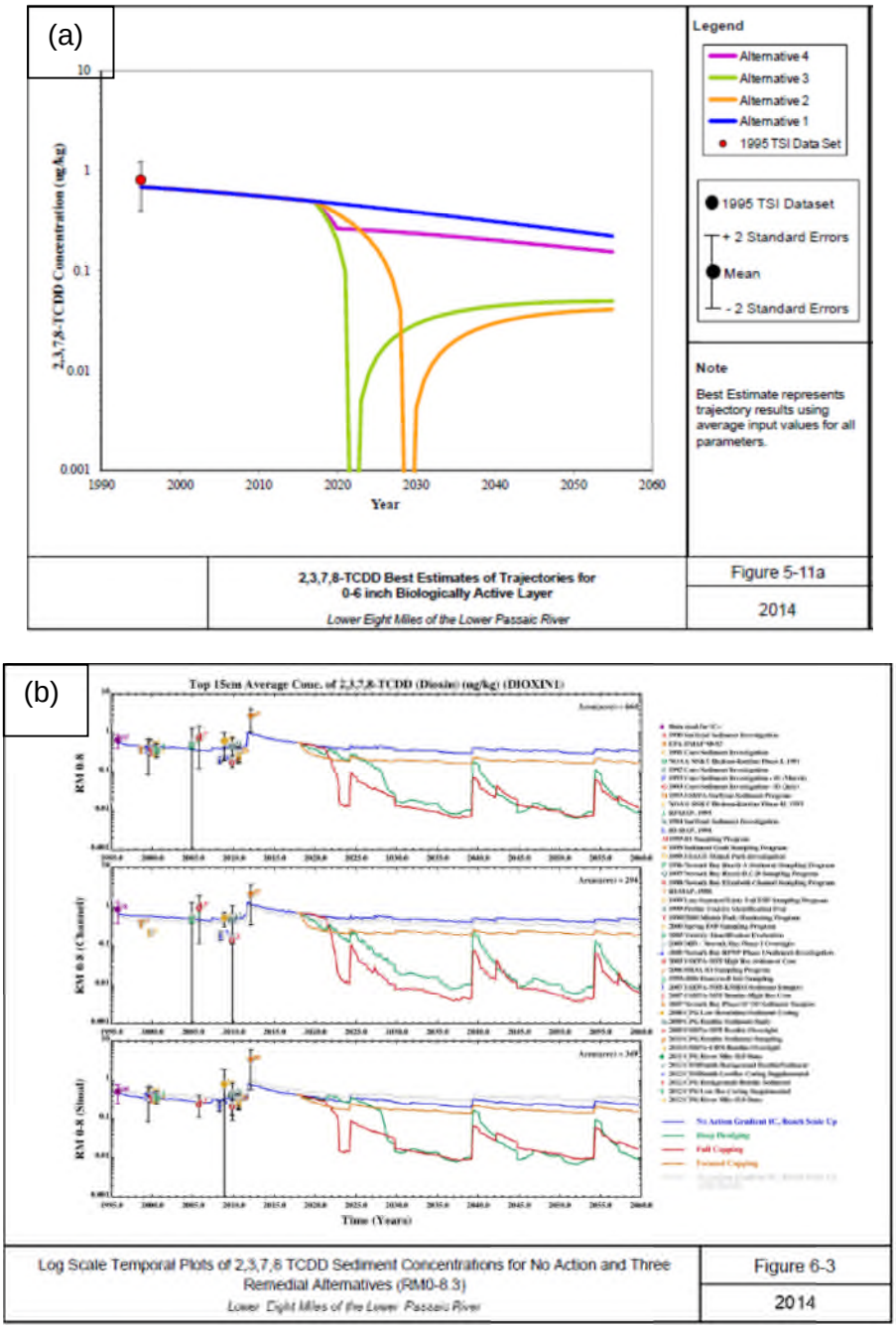
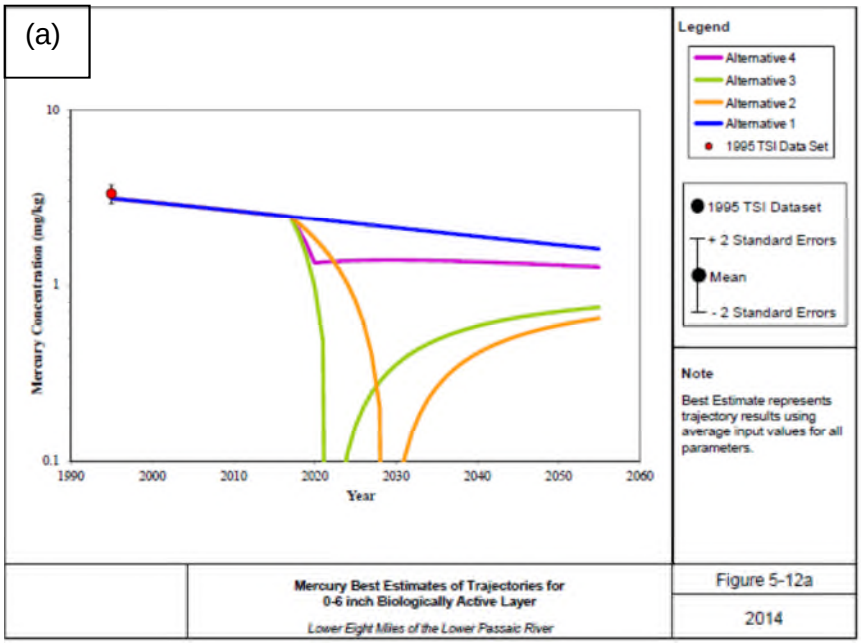


Figure 8: (a) EMB model estimates and (b) Fate and Transport model estimates of the future trajectory of 2,3,7,8-TCDD in the top 0.15m of sediments in the LPR, Rm-0 to Rm-8. The top panel of (b), which includes both channel and shoal areas, is the most relevant for comparison to (a).



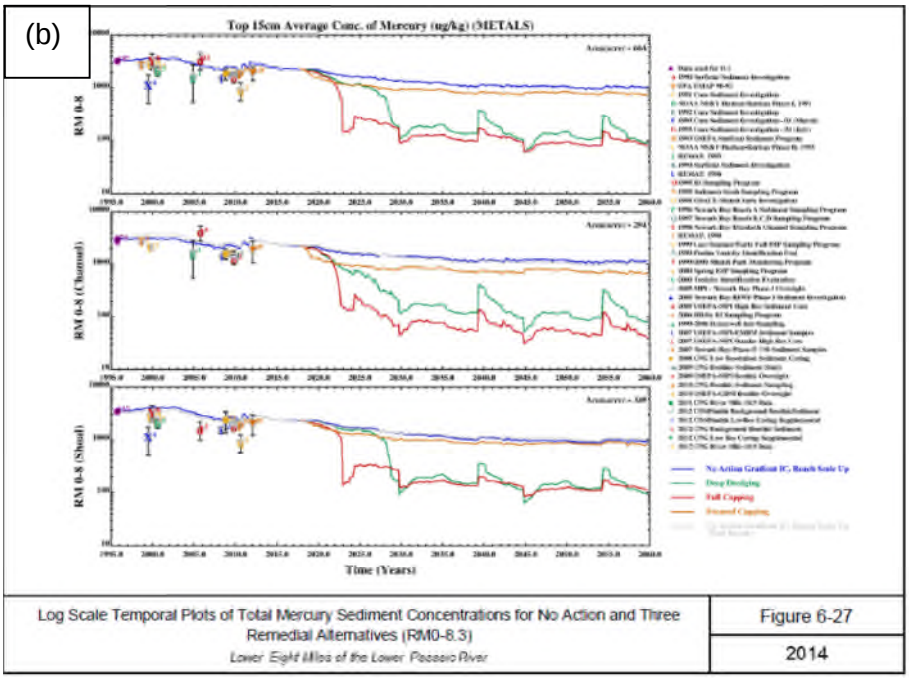


Figure 8: (c) EMB model estimates and (d) Fate and Transport model estimates of the future trajectory of Hg in the top 0.15m of sediments in the LPR, Rm-0 to Rm-8. The top panel of (c), which includes both channel and shoal areas, is the most relevant for comparison to (d).

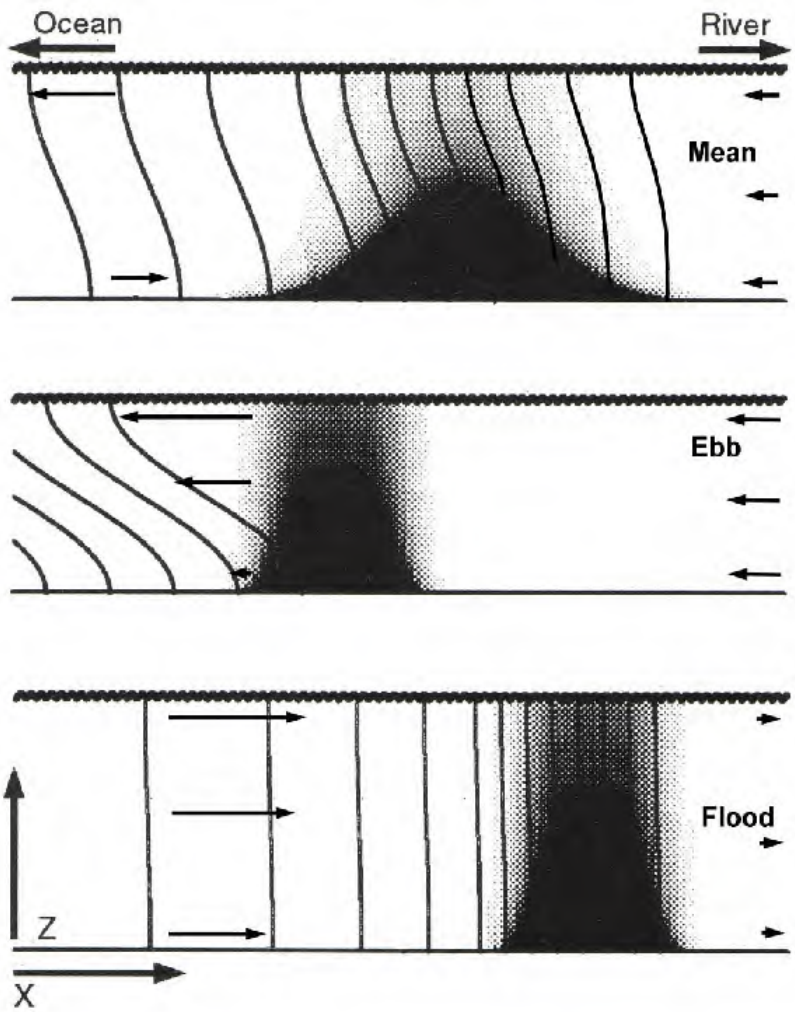
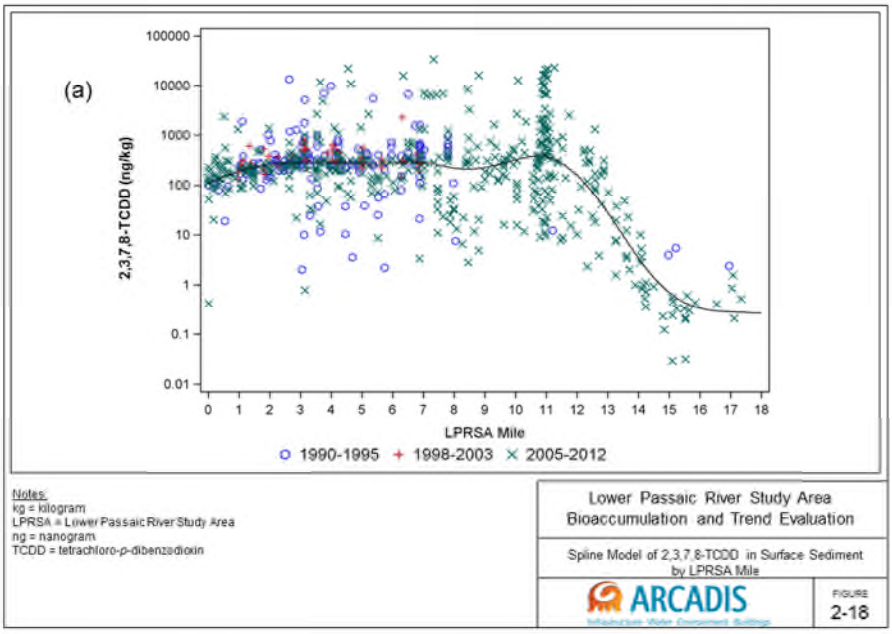


Figure 9: A conceptual view of fluxes and concentrations for (top to bottom) the tidal cycle average, end of ebb, and end of flood for an ETM near the upstream limit of salinity intrusion. Salinity is shown as contours and suspended particulate matter (SPM) by shading; fluxes are indicated by arrows. An ETM is created by convergent horizontal fluxes near the bed that move sediment countergradient against the mean gradient on at least one side of the ETM, often both. Tidal variations are strong, and the mean picture is typically quite different from either ebb or flood. Landward near-bed fluxes are driven by both the mean flow (gravitational circulation and internal tidal asymmetry) and tidal transport of tidal variations in SPM concentration. Settling during periods of low currents and erosion during periods of high currents contribution to the tidal variations. Lags in settling and erosion relative to the velocity field also contributes to particle trapping in some estuaries.



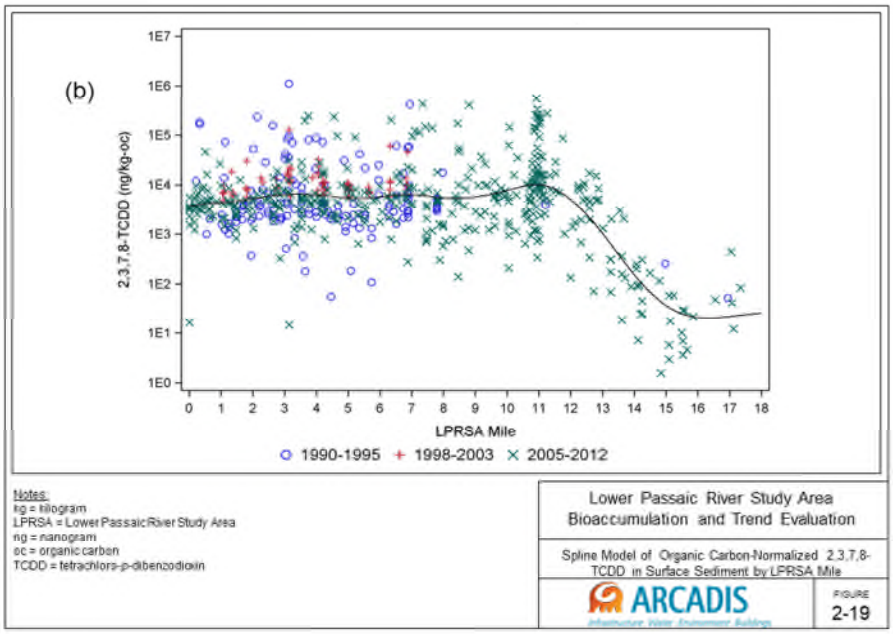
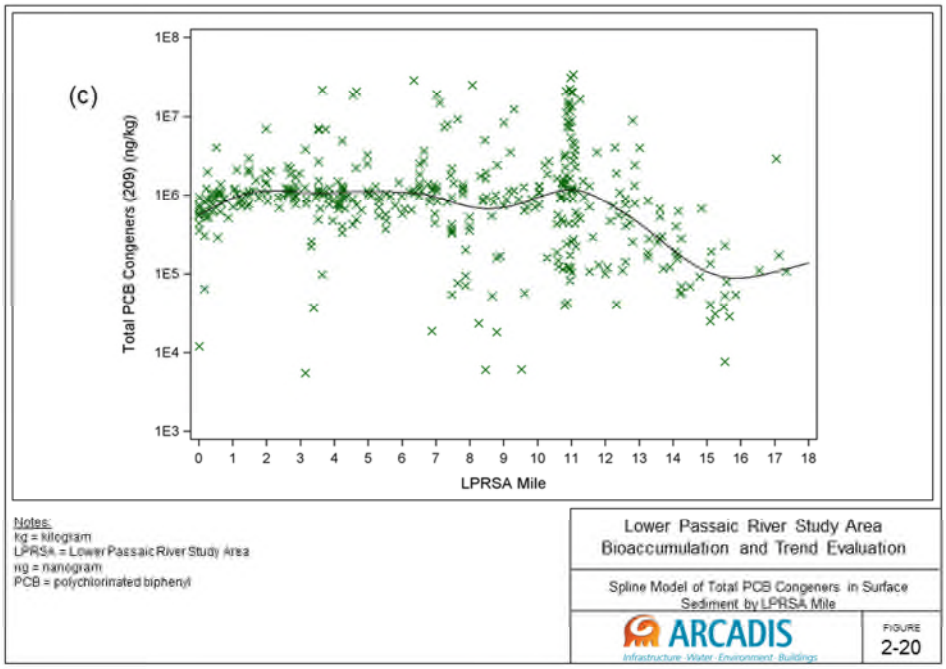


Figure 10a,b: Longitudinal distributions of (a) near-surface concentration of 2,3,7,8 TCDD and (b) near-surface concentration of 2,3,7,8 TCDD normalized by organic carbon concentration; from *Arcadis* comments on the FFS. Note the upstream concentration maximum, which is especially evident in the organic carbon normalized concentrations.



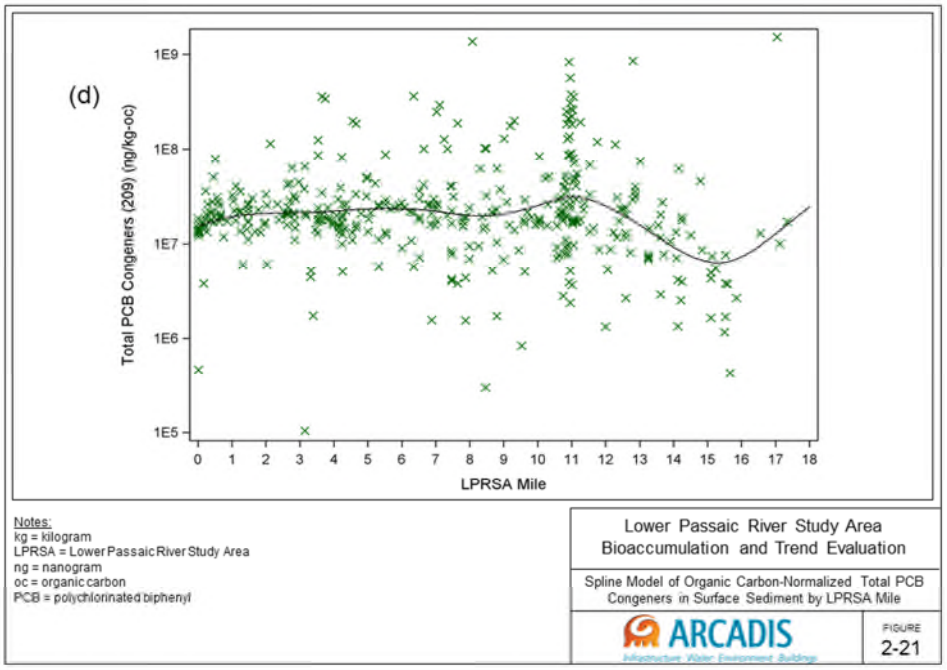


Figure 10c,d: Longitudinal distributions of (a) near-surface of total PCB congeners and (b) near-surface concentration of total PCB congeners normalized by organic carbon concentration; from Arcadis comments on the FFS. Note the upstream concentration maximum, which is especially evident in the organic carbon normalized concentrations. Up to about RM-15, the pattern strongly resembles the 2,3,7,8-TCDD distribution.

Table 4. Statistical summary of calculated sedimentation rates[a]

	Count	Sedimentation rate (cm/y)					
		Average	Median	Maximum	Minimum	SD[b]	*CV* (%)[c]
Reach							
Arlington	3	2.0	2.9	3.0	0.0	1.7	87
Kearny	12	3.8	2.9	8.8	2.0	2.0	53
Newark	23	2.6	2.8	7.0	0.0	2.4	91
Harrison	51	4.1	3.7	12	0.0	3.0	74
Point–No-Point	18	5.0	4.6	9.4	0.0	2.8	56
Total	107	3.8	3.7	12	0.0	2.8	73
Section							
3	27	3.0	2.9	8.8	0.0	2.3	76
2	66	4.0	3.8	12	0.0	2.9	74
1	14	4.9	4.1	9.4	0.0	2.8	58
Total	107	3.8	3.7	12	0.0	2.8	73

[a] Cores assigned a value of 0 exhibited no ^{137}Cs or excess ^{210}Pb. Presented in order from upstream to downstream.
[b] SD = standard deviation.
[c] *CV* = coefficient of variation = (SD/average) × 100.

Figure 11: Table 4 from *Erickson et al.* [2007], showing average, median, maximum, and minimum sedimentation rates by reach and by section. See Figure 8b for reach and section locations (section and reach locations defined in Fig. 12). Note that all sections and all reaches except the Kearney reach have areas of zero sedimentation, and that median rates are essentially the same from Newark to Arlington. Maximum rates vary spatially by a factor of 4× (for reaches) but <50% by section. The median rates for all reaches are within a range of 75 to 125% of the overall median for all reaches. In terms of averages, all reaches are within a range of 52 to 131% of the overall mean. The variations between sections are smaller.

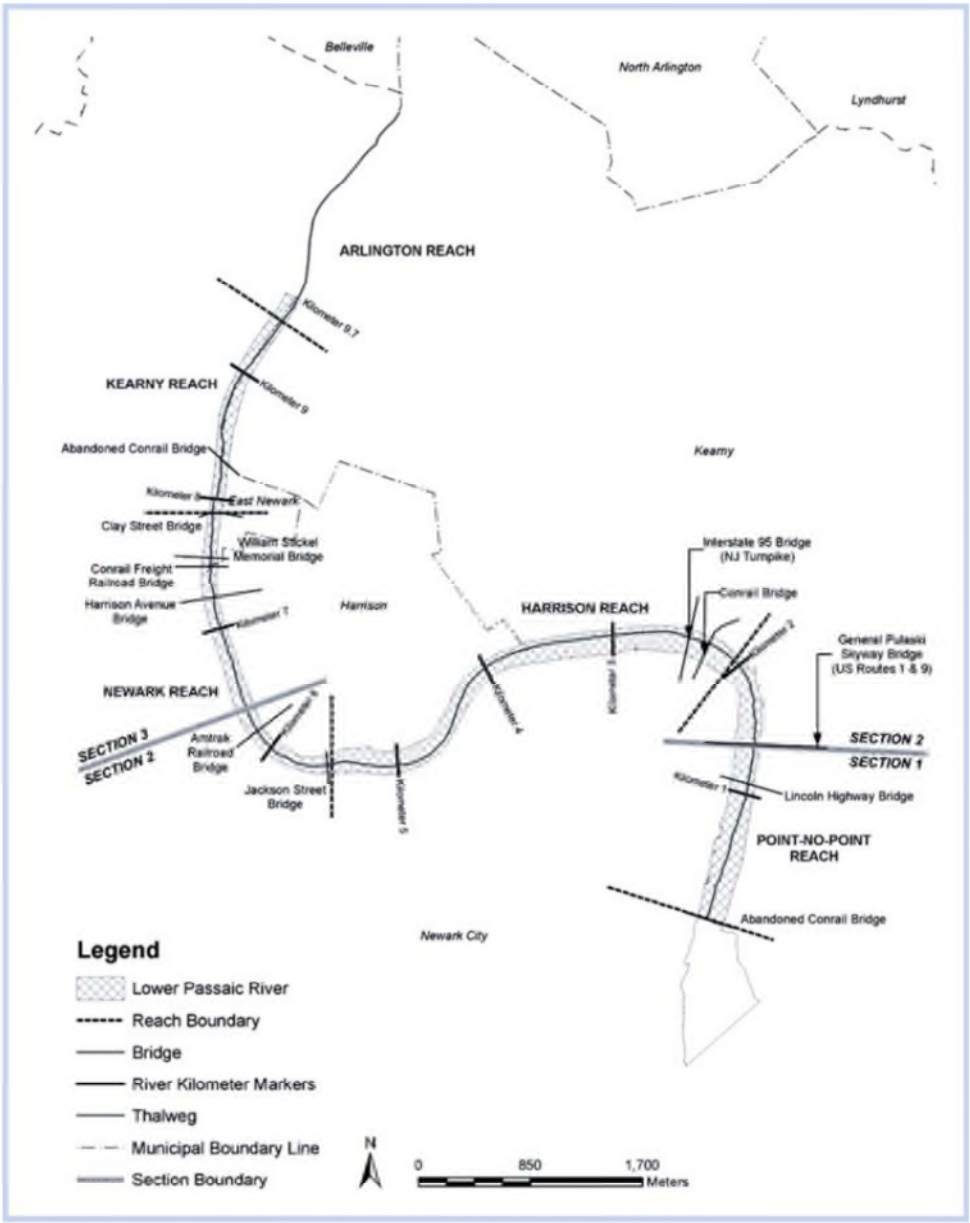


Figure 2. Lower Passaic River site map.

Figure 12: Section boundaries for reaches in Erickson et al. Table 4, from *Erickson et al.* [2007].

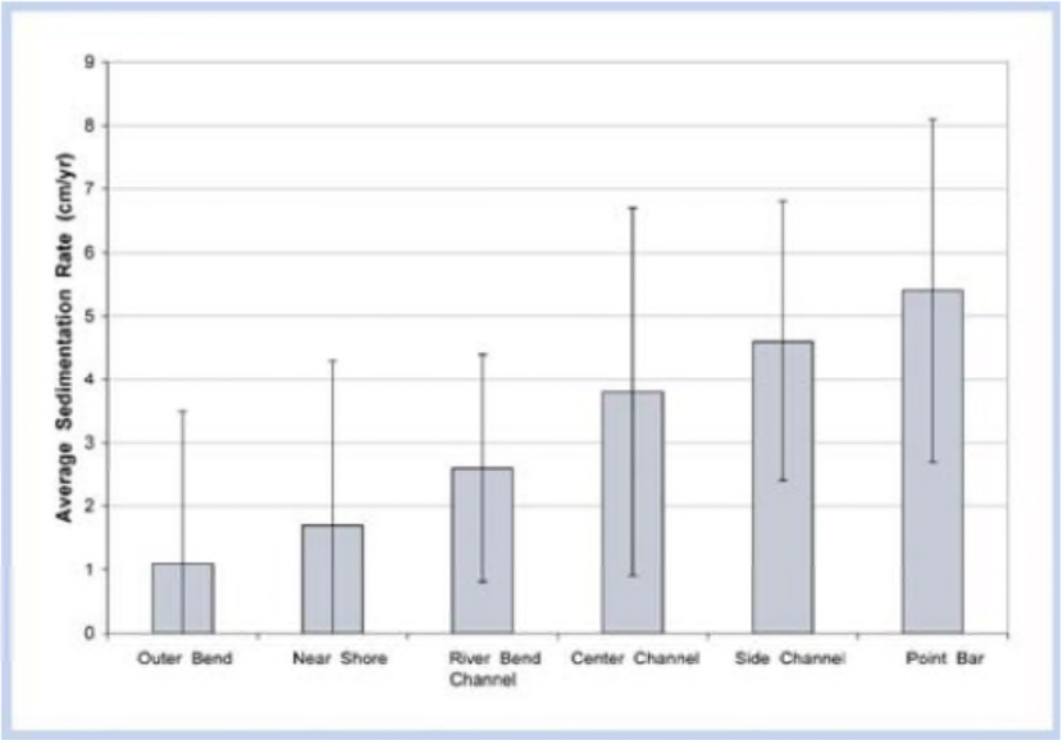


Figure 13: Average sedimentation rates by geomorphic area, reproduced from Figure 12 of Erickson et al. [2007]. Note that variations between geomorphic environments are stronger than variations between reaches.

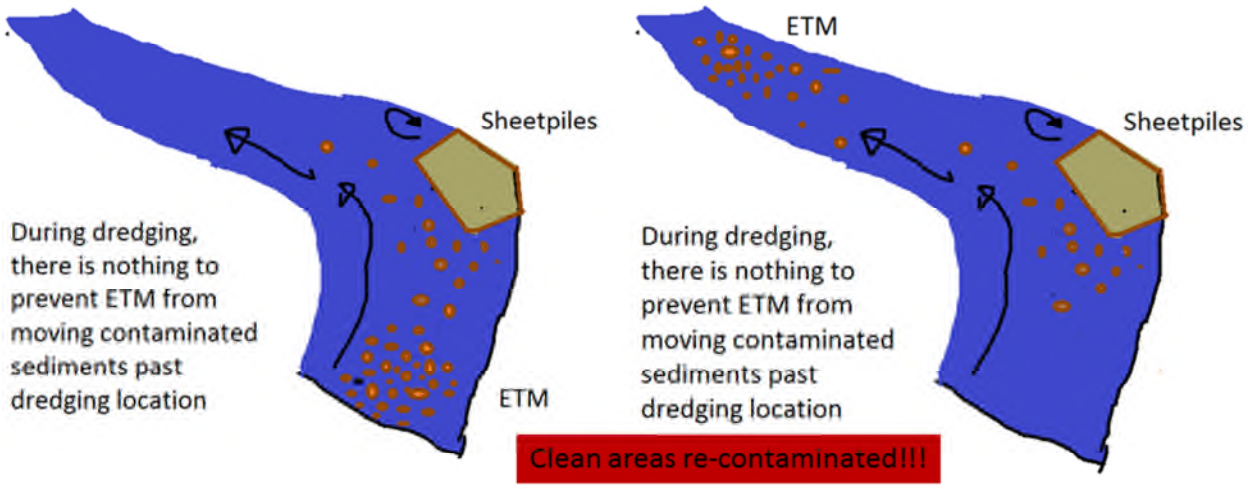


Figure 14: Dredging considerations: conceptual view of ETM transport of contaminated materials upstream past a site of active dredging to points upstream, already dredged. Because of this transport, Dredged and capped areas will likely be recontaminated.

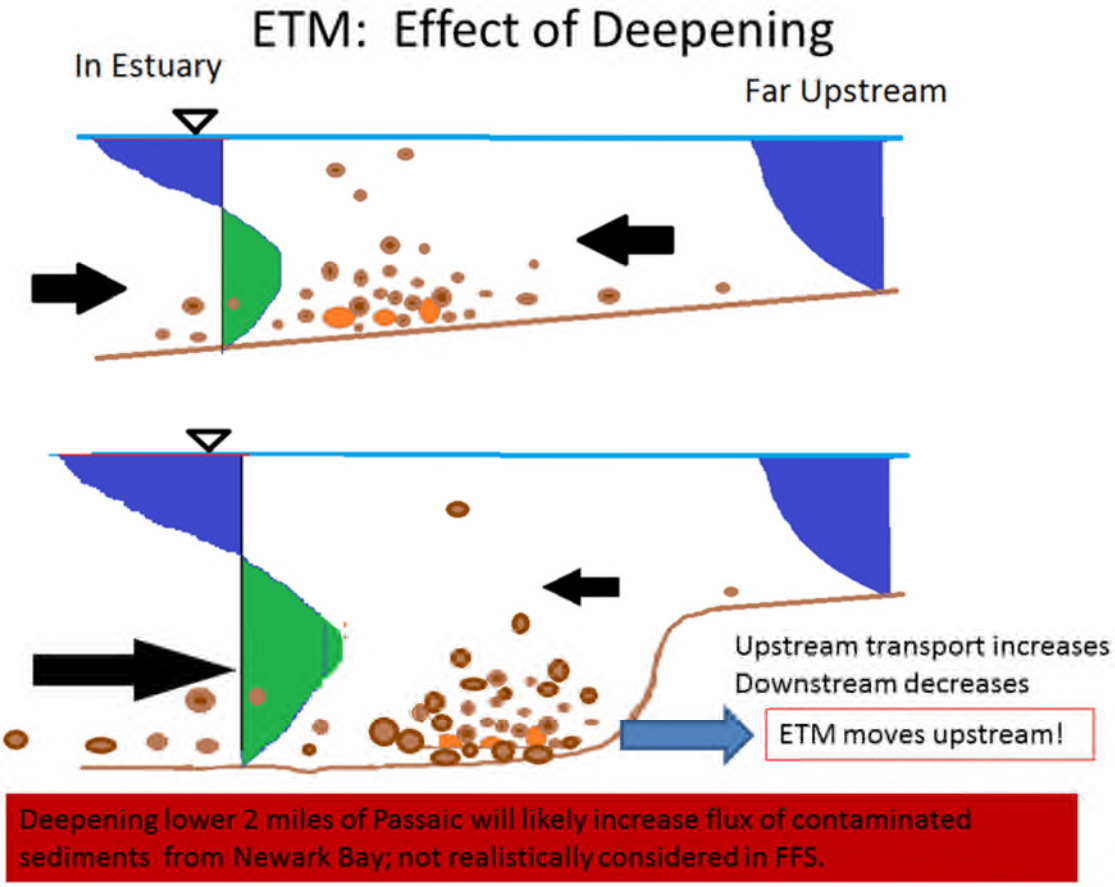


Figure 15: Conceptual view of the effects of channel deepening on ETM transport. A deeper channel, as proposed in Alternatives 2 and 3, will increase near-bed circulation and estuarine exchange flows, and hence facilitate the transport of contaminated from Newark Bay into the LPR.

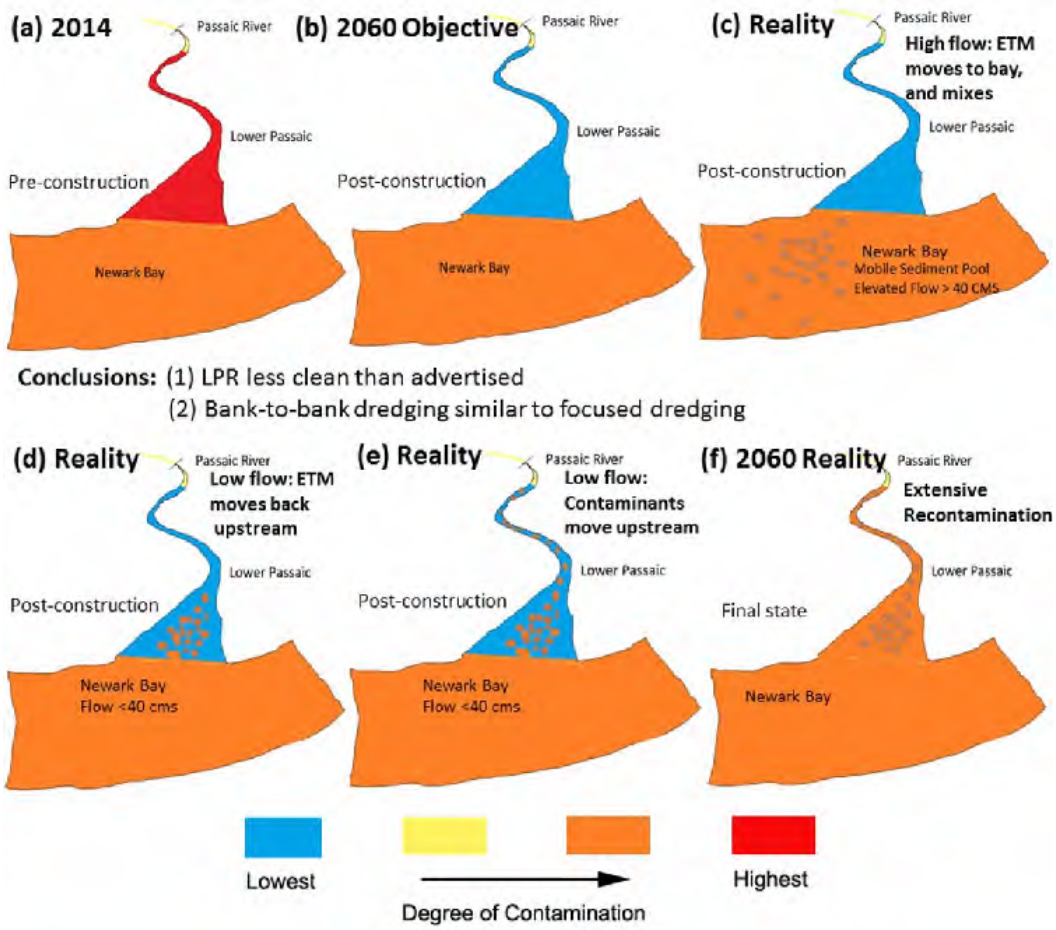


Figure 16: Schematic view of the results of dredging and capping in the LPR. Because Newark Bay is contaminated and there is a considerable upstream transport from Newark Bay, contamination will return to the LPR from downstream sources, regardless of which of the active alternatives is chosen (Alternatives 2-4). As per Figure 15, the deeper the final channel depth, the stronger the upstream transport of contaminants is likely to be

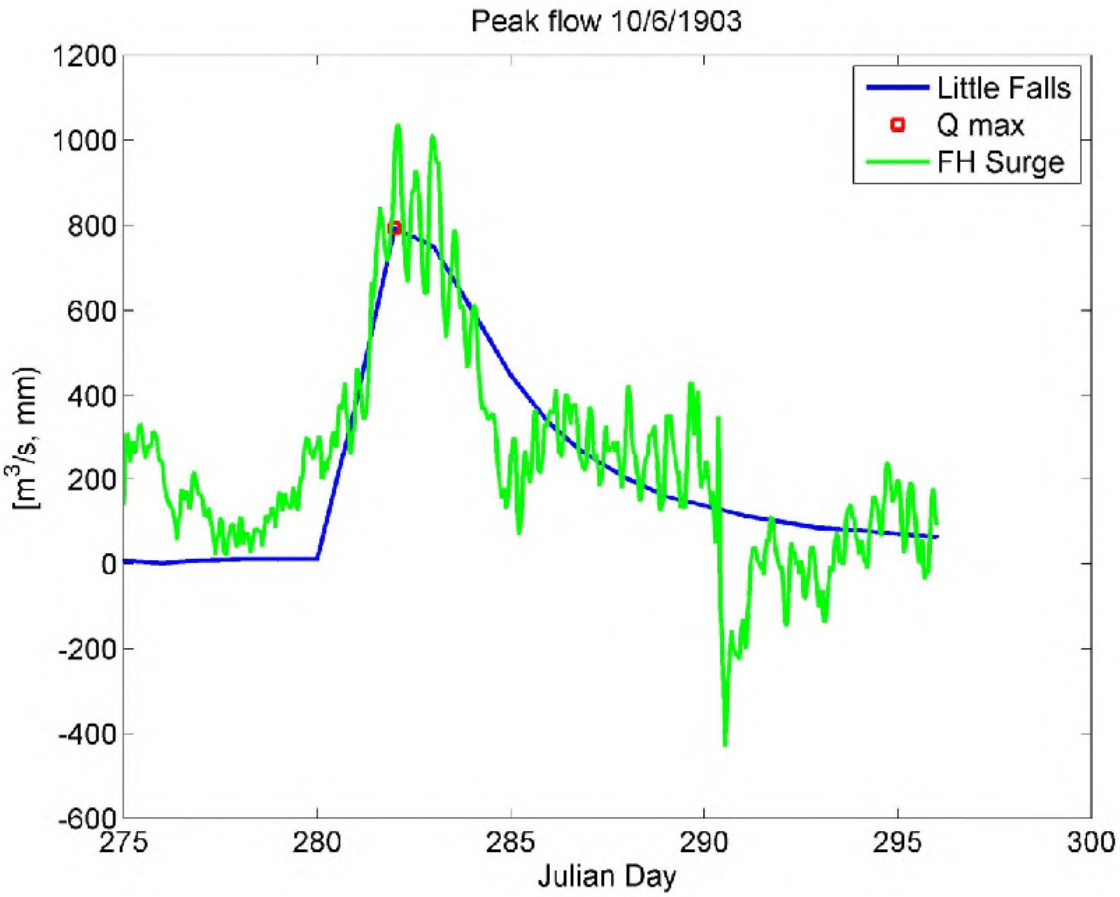


Figure 17: Storm surge measured at Fort Hamilton (Verrazano Narrows) in New York harbor during the largest river flood ever measured at Little Falls. The storm was apparently slow moving and the Passaic River basin responded rapidly due to saturated soil. Thus, the peak in storm surge coincides nearly perfectly with peak flow. Clearly storm surge played a role in the physics of that event in the Passaic estuary.

Figure 18: Subtitle C landfills in the US (excluding California). Alternatives 2 and 3 require use of landfills west of the Mississippi River (figure courtesy of B. Beal, US Geological Survey).

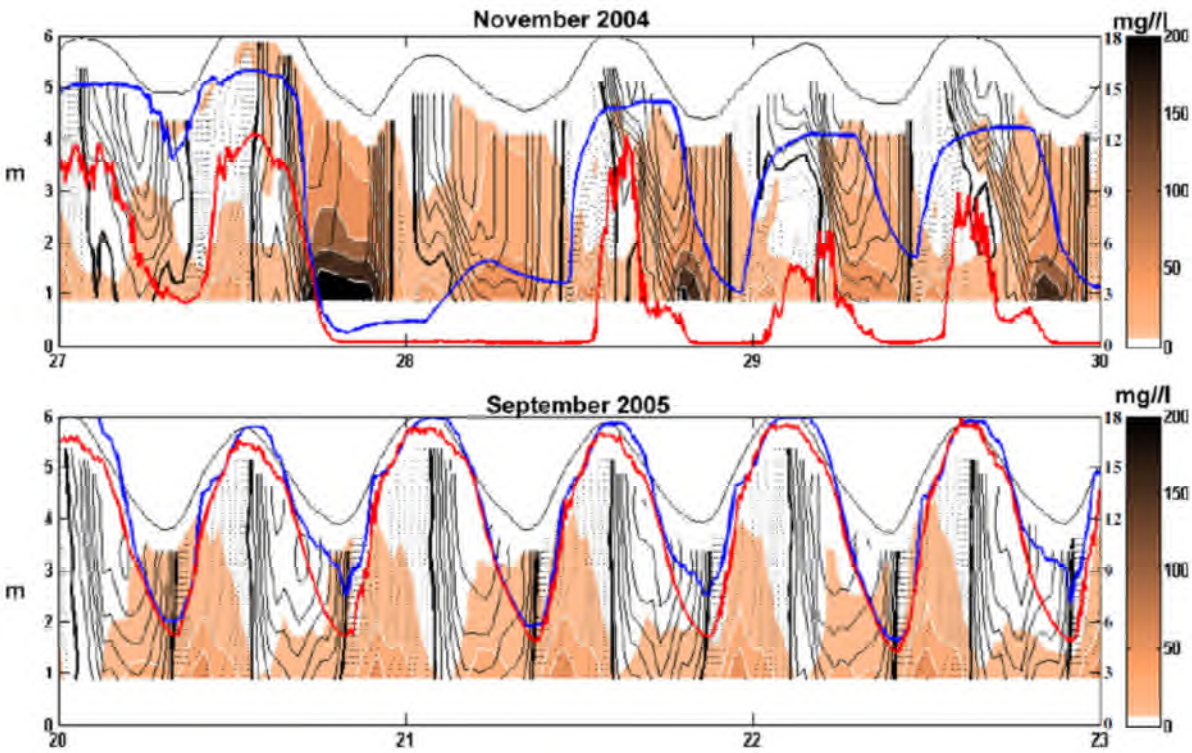
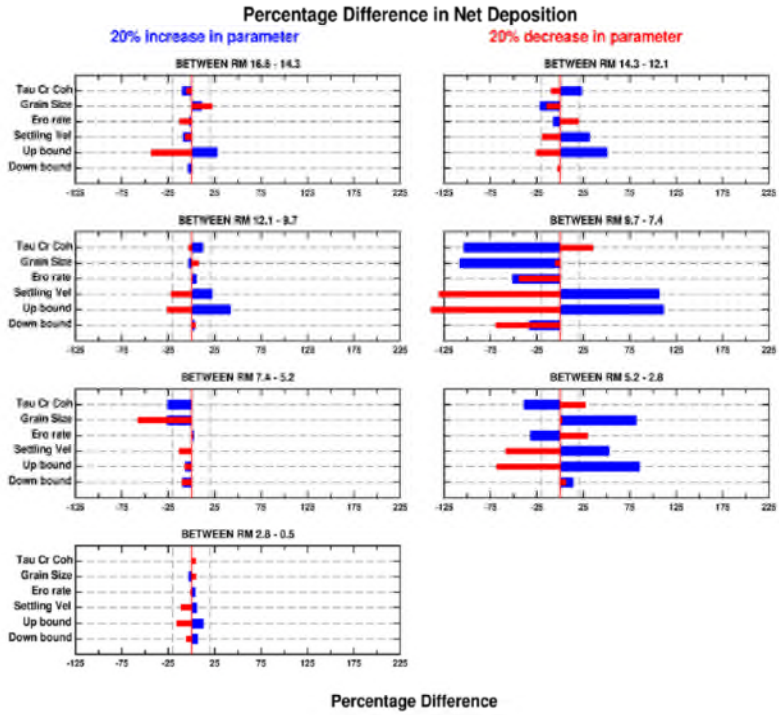


Fig. 10 Times series from mooring M2 during high flow ($Q \sim 100$ m^3/s) and low flow $Q \sim 2$ m^3/s) from November 2004 to September 2005, respectively. *Color* and *white contours* are total suspended sediment from ADCP backscatter calibrated against TSS measurements. *Black contours* are along channel velocity at 10 cm/s intervals. *Thick black contour* is the zero isotach, *dashed lines* indicate flooding currents, and *solid lines* are ebbing currents. *Red* and *blue lines* are surface and bottom salinity with salinity values indicated on *right axis*

Figure 19: LPR velocity (contours) and suspended concentrations (colors), from *Chant et al*. [2011]; note the close spacing of contours (horizontally and vertically) at certain phases of the tide.



Sensitivity of Net Deposition to Parameter Changes	Figure 5-3
Lower Eight Miles of the Lower Passaic River	2014

Figure 20: Sensitivity of net deposition, as predicted by ECOMSED and SED-ZLJS, to changes in selected parameters by ±20%. Note very high sensitivity of some segments of the LPR down to Rm-2.8 to upstream boundary sediment input (changes in results of up to >125%)

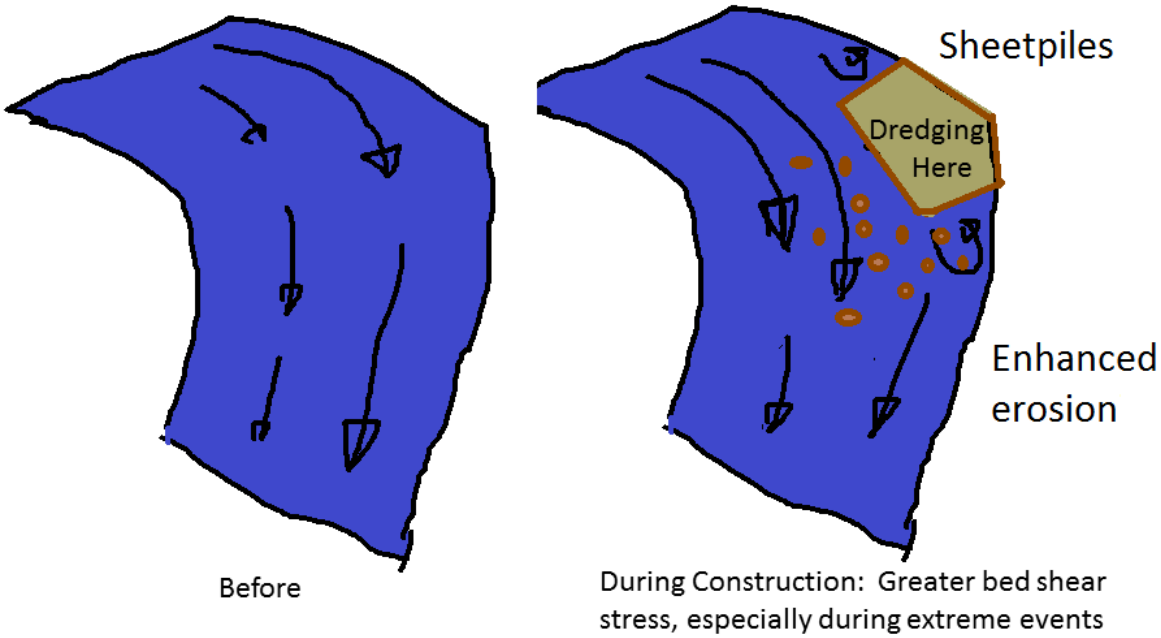


Figure 21: Dredging considerations: the presence of sharp obstructions in the flow (like sheet-pile walls) can disturb the flow a distance of more than 10x the distance from the bank to the edge of the enclosure, e.g., as shown here for ebb. This disturbance can cause considerable erosion downstream from the structures, especially in areas of strong flow like the outside of a bend, and during floods. Reversing flow may cause disturbance upstream of the enclosure. This might occur, for example, during the rising phase of a storm surge.

Appendix A Figures

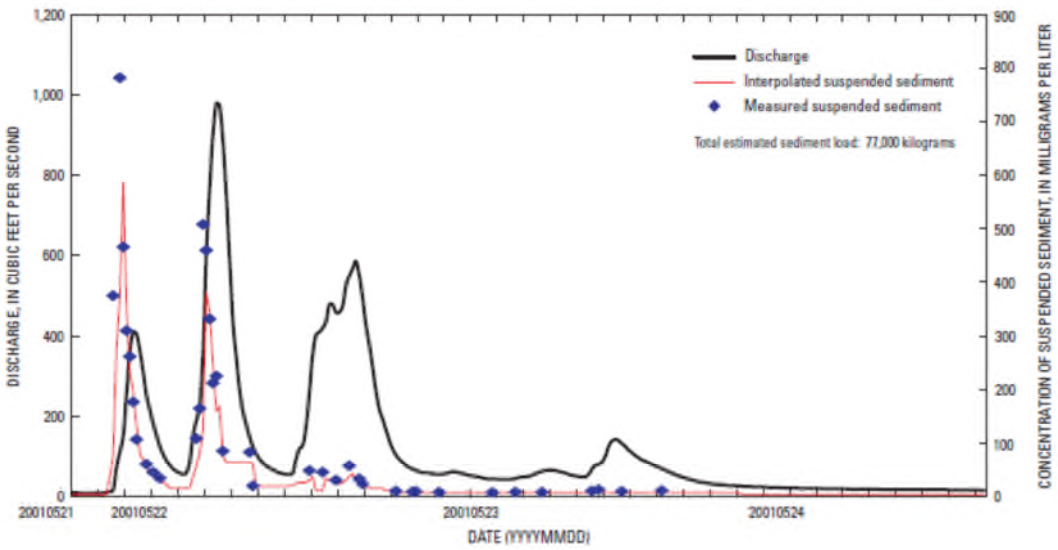


Figure 50. Discharge and the concentration of suspended sediment in samples collected from the Elizabeth River at Hillside, NJ, May 21 to 24, 2001.

Figure A-1: An example of sediment load hysteresis, for the Elizabeth River for 21 to 24 May 2001, based on high resolution (in time) sediment data; from Wilson and Bonin [2007]. Note that the sediment load is highest on the rising part of the hydrograph during the first two events, before the peak flow in each case. The highest sediment concentrations occur at the onset of the first event, and the two successive events have lower concentrations, though not necessarily lower loads (at least for the second event). The sediment supply appears to have been exhausted by the beginning of the third flow event, and there is only a small increase in concentration during the third period of elevated flows. As shown below, hysteresis is strong in the Passaic River at Little Falls, but the degree of supply limitation appears to be lower.

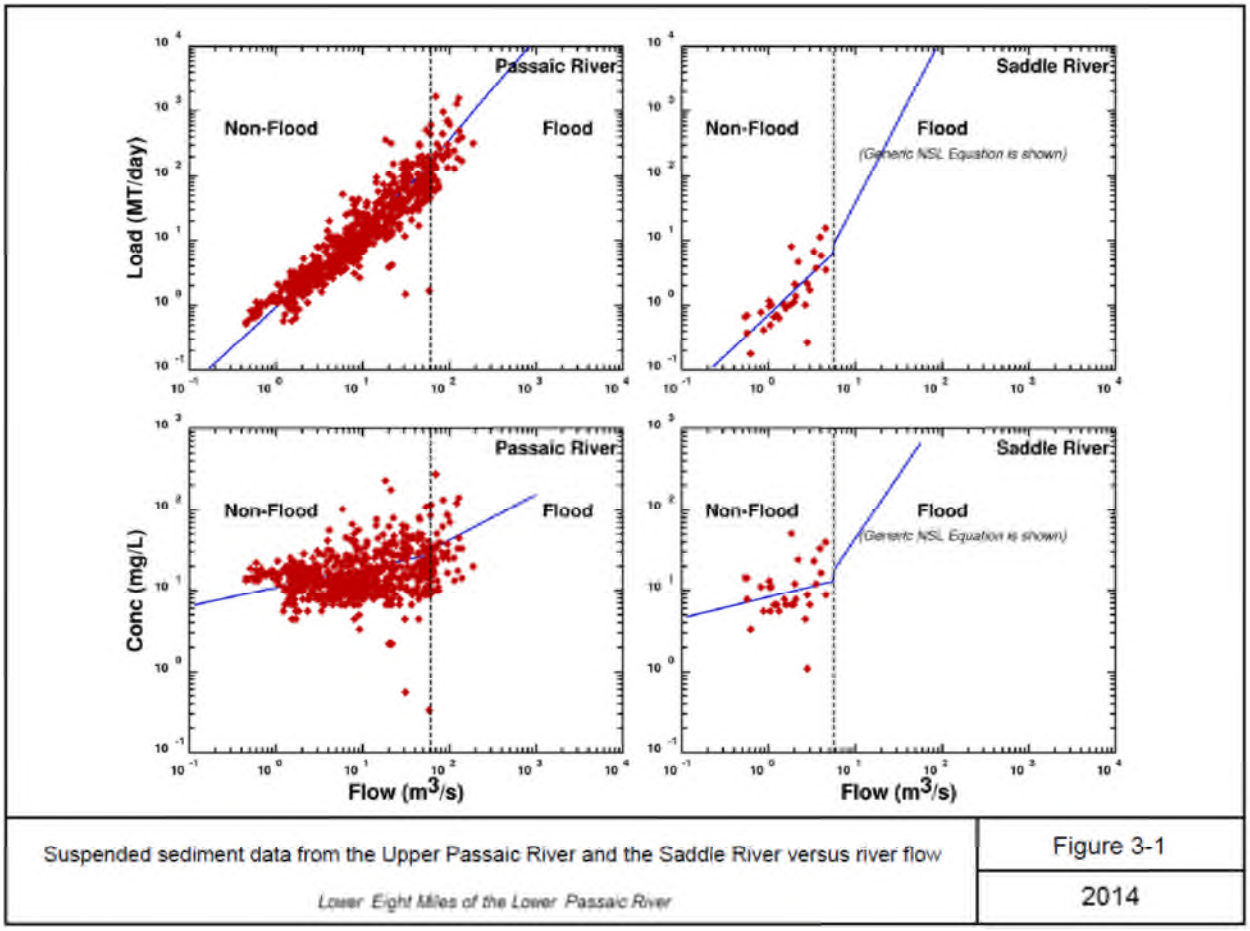


Figure A-2: FFS rating curve models of suspended sediment load for the Passaic River and the Saddle River; Figure 3-1 from FFS Appendix BII.

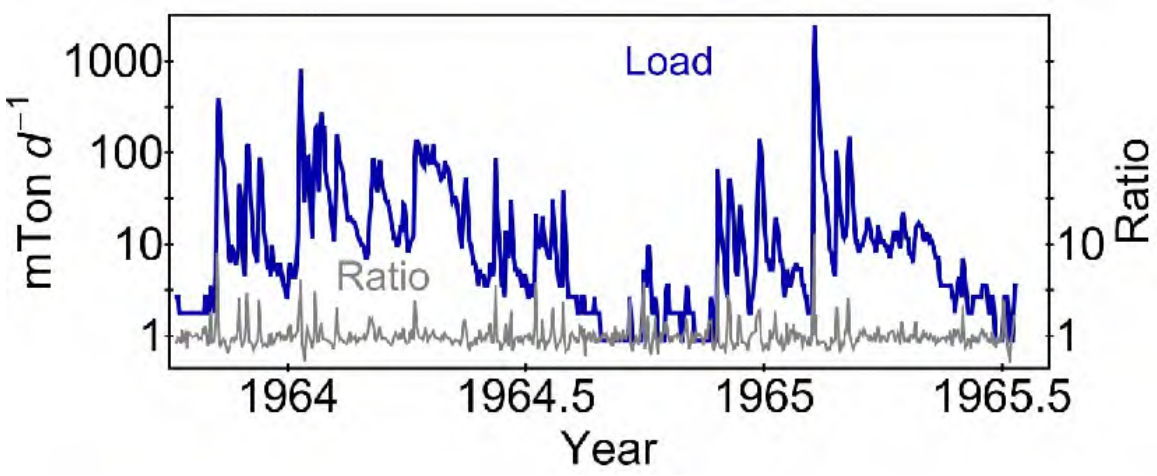


Figure A-3: USGS estimated suspended sediment load and Little Falls daily flow ratio for 1963 to 1965. The flow ratio is the ratio of the flow on the day of the sediment load observation to the flow of the previous day. Note that the ratio is skewed toward positive values; i.e., the flow tends to rise more rapidly than it falls. This means that a load rating curve that does not consider hysteresis will underestimate load.

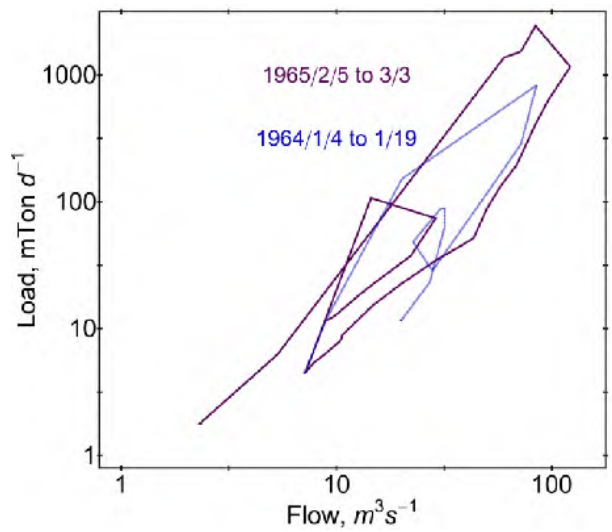


Figure A-4a: Two examples of suspended sediment load hysteresis during high flow events in 1964 and 1965. The peak sediment transport on the rising limit of February 1965 flood event is a factor of at least 5× higher than the transport on the falling limb for the same flow. The peak difference is >10×. Multiple samples are available for 1965/2/8, leading to a slight deflection the rising arm of the load curve.

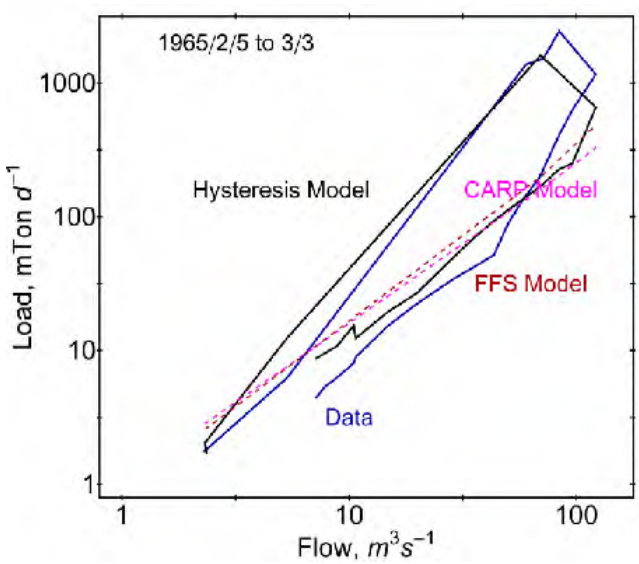


Figure A-4b: For 1965/2/5 to 1965/3/3, the USGS daily observed sediment load (blue) at Little Falls as a function of flow. Also shown are the predicted loads from the FFS and CARP models (red and magenta dotted lines, respectively) and the model described by (A-1) and (A-2) (purple). The FFS and CARP approaches underestimate the load and predicts the same load for both the rising and falling arms of the hydrograph. Our approach comes much closer to reproducing the observed load.

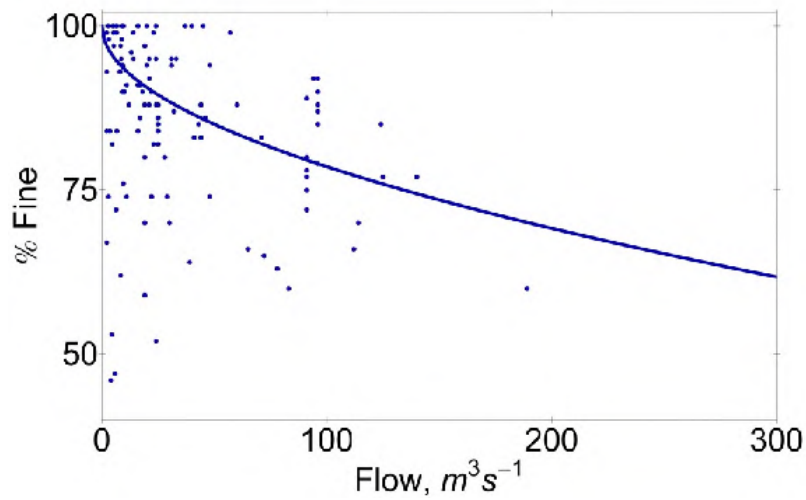


Figure A-5: USGS observed percent fine fraction and a three-parameter fit to these data.

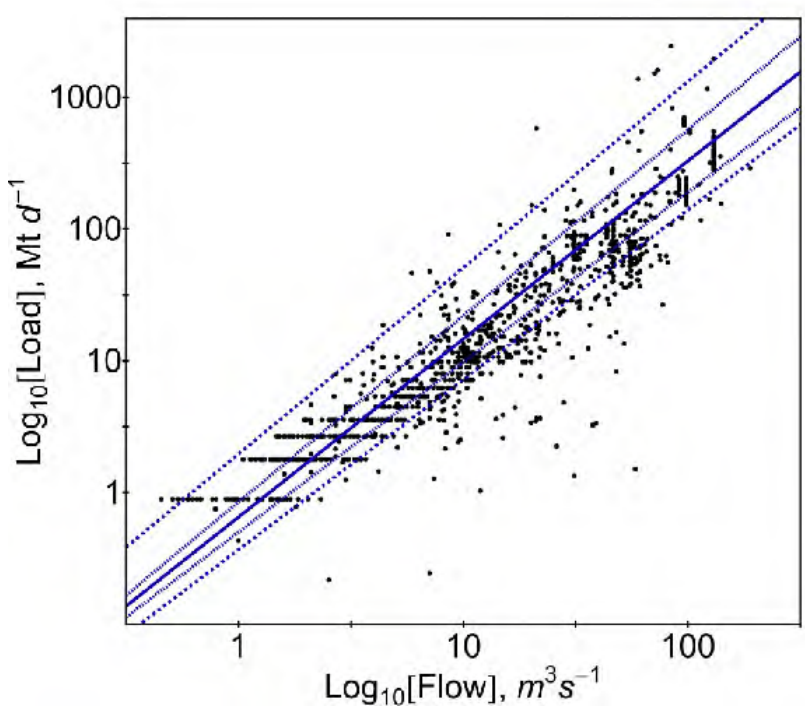


Figure A-6: The suspended sediment rating curve (solid line) produced by robust regression analysis of (A-1) using (A-2). The plot assumes that *R* = its median value. The fine dotted lines assume the upper and lower 95% confidence limits for all parameters. The coarse dotted lines represent the effect of the model with the 1 and 99% occurrence values for *R*; i.e., the extremes of rising and falling flow.

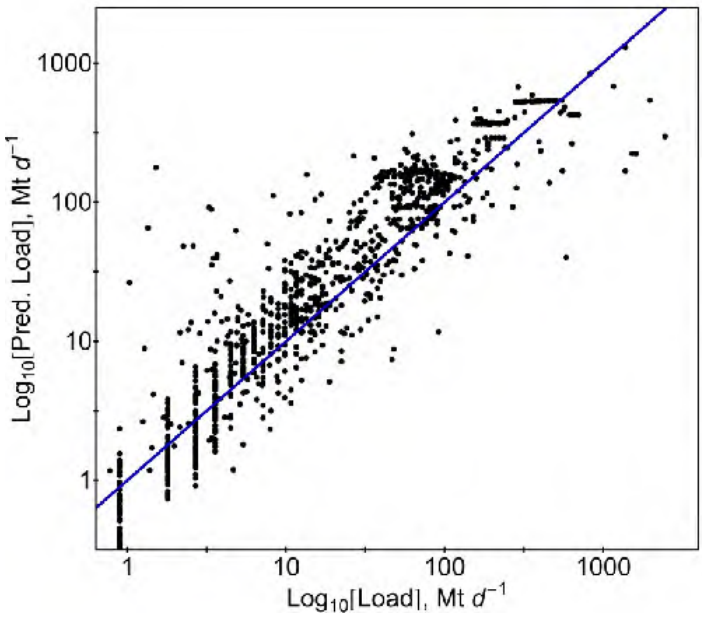


Figure A-7: Comparison of suspended sediment loads predicted by (A-1) with estimated suspended sediment loads for the Passaic River at Little Falls for the full 1963-2014 data set.

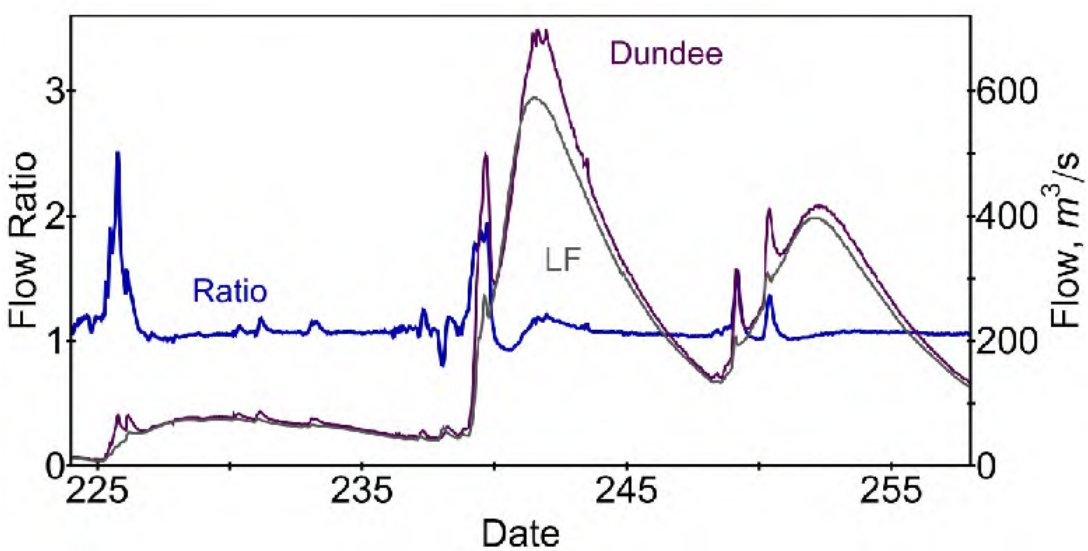


Figure A-8: Hourly river flows at Dundee Dam (purple) and Little Falls (Gray), and the Dundee Dam to Little Falls flow ratio for the Hurricane Irene period in 2011.

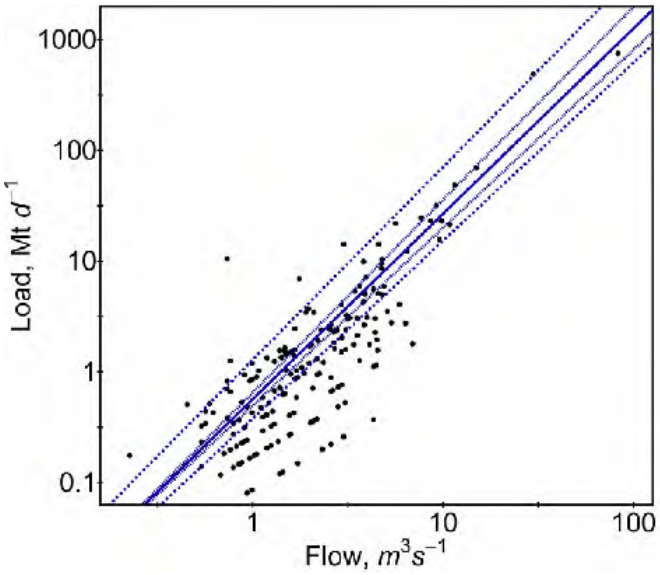


Figure A-9a: The Saddle River suspended sediment load rating curve (solid line) produced by robust regression analysis of (A-1) using (A-2), assuming *R* = its median value. The fine dotted lines assume the upper and lower 95% confidence limits for all parameters. The coarse dotted lines represent the effect of the model with the 1 and 99% occurrence values for *R*; i.e., the extremes of rising and falling flow.

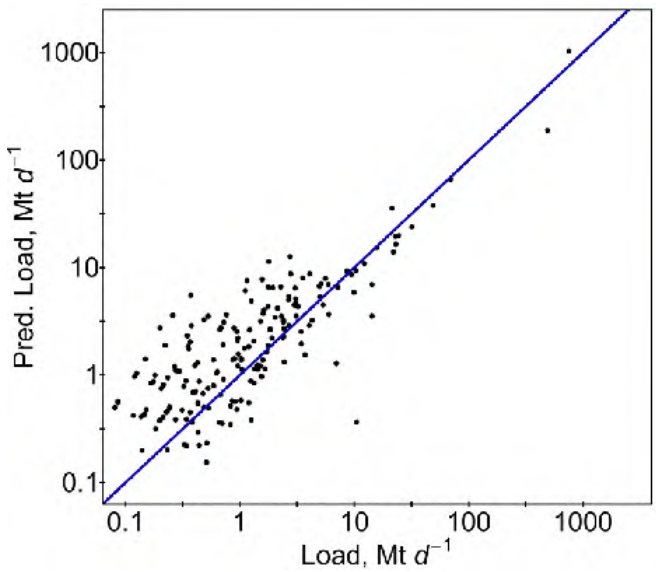


Figure A-9b: Comparison of suspended sediment loads predicted by (A-1) with estimated suspended sediment loads for the Saddle River at Lodi for 1978 to 2008.

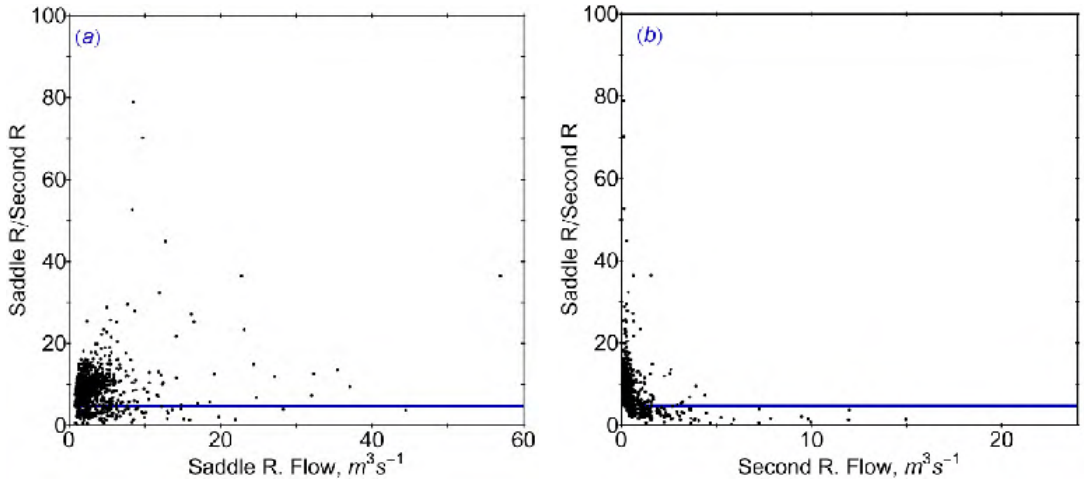


Figure A-10: The non-dimensional ratio of Saddle River to Second River flow as a function (a) of Saddle River flow, and (b) as a function of Second River Flow. The blue line indicates the ratio Saddle River area to Second river area.

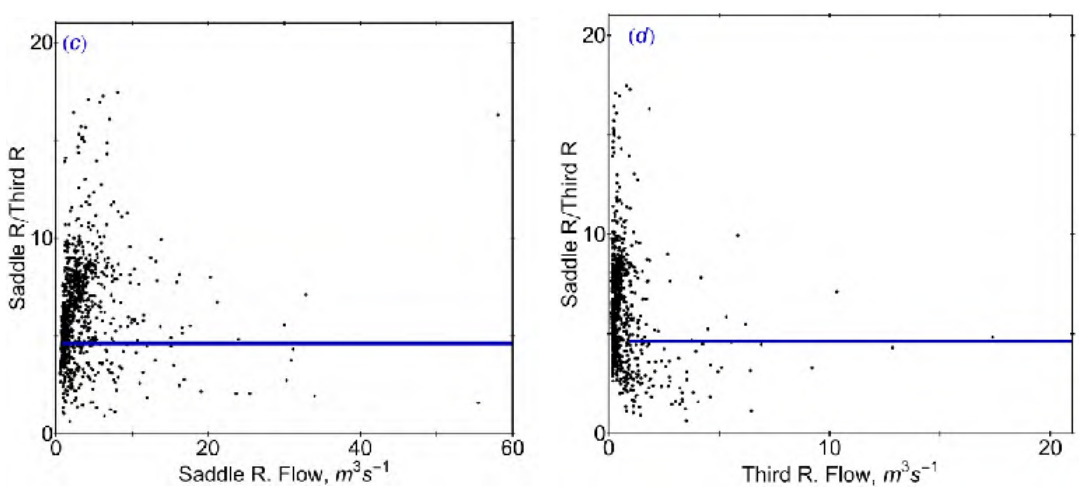


Figure A-10: The non-dimensional ratio of Saddle River to Third River flow as a function (c) of Saddle River flow, and (d) as a function of Third River Flow. The blue line indicates the ratio Saddle River area to Third river area.

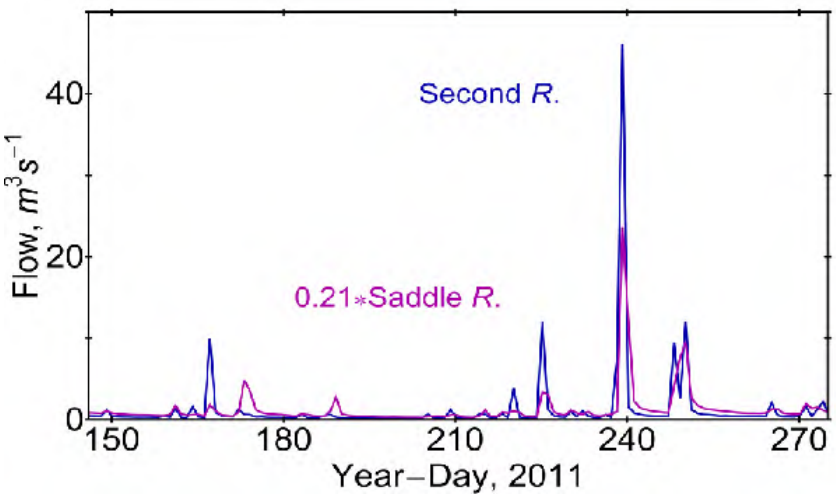


Figure A-11a: Times series of flow in the Second River and in the Saddle River for a period in 2011 that includes Hurricane Irene. Saddle River flows have been multiplied by the ratio of areas, such that the two lines would coincide, if Saddle River were a good representation of flows in the Second River. The records are clearly dissimilar. In particular, the response of Second River was much stronger than that in the Saddle River, even though the latter was approximately at the level of the 100-year flow.

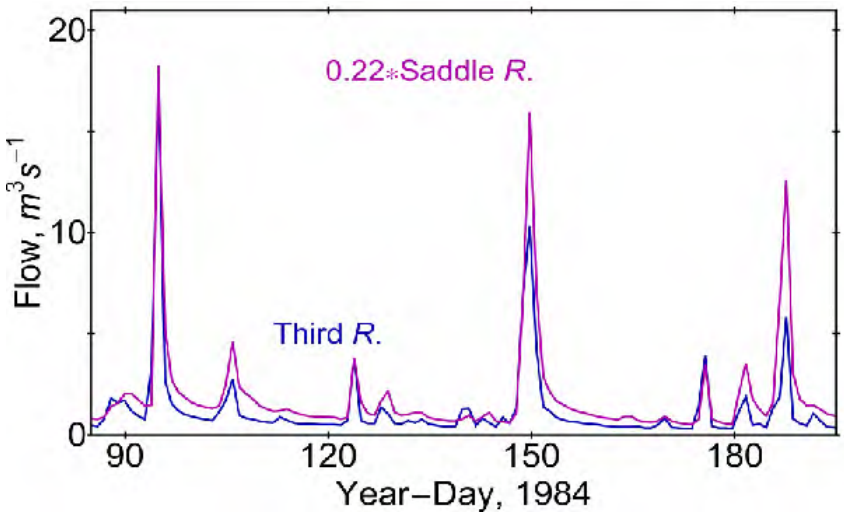


Figure A-11b: Times series of flow in the Third River and in the Saddle River for a period in 1984 that includes the 1984 flood and several other high flow events. Saddle River flows have been multiplied by the ratio of areas, such that the two lines would coincide, if Saddle River were a good representation of flows in the Second River. The ratio of flows is quite variable, but the timing of flow events is similar.

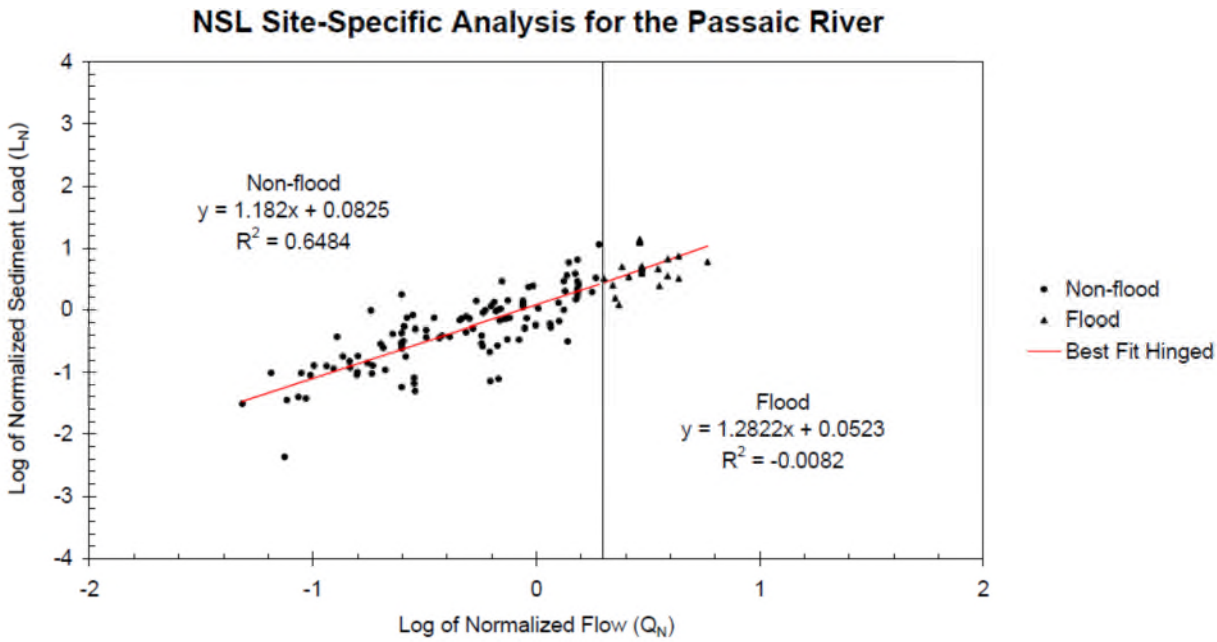


Figure A-12: The CARP model rating curve for the Passaic River at Little Falls. Note the poor, statistically insignificant R^2 value for the "Flood" model.

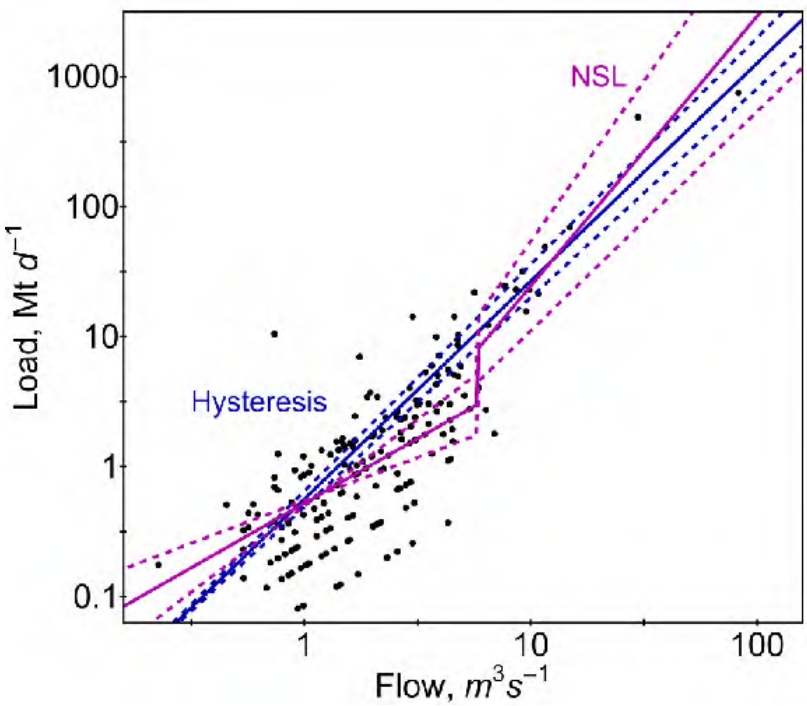


Figure A-13: The NSL model (magenta) and the hysteresis model based on eq (A-1) (blue) for the Saddle River at Lodi. Shown are rating curves (solid) and high and low curves derived using the upper and lower 95% values of the model parameters.

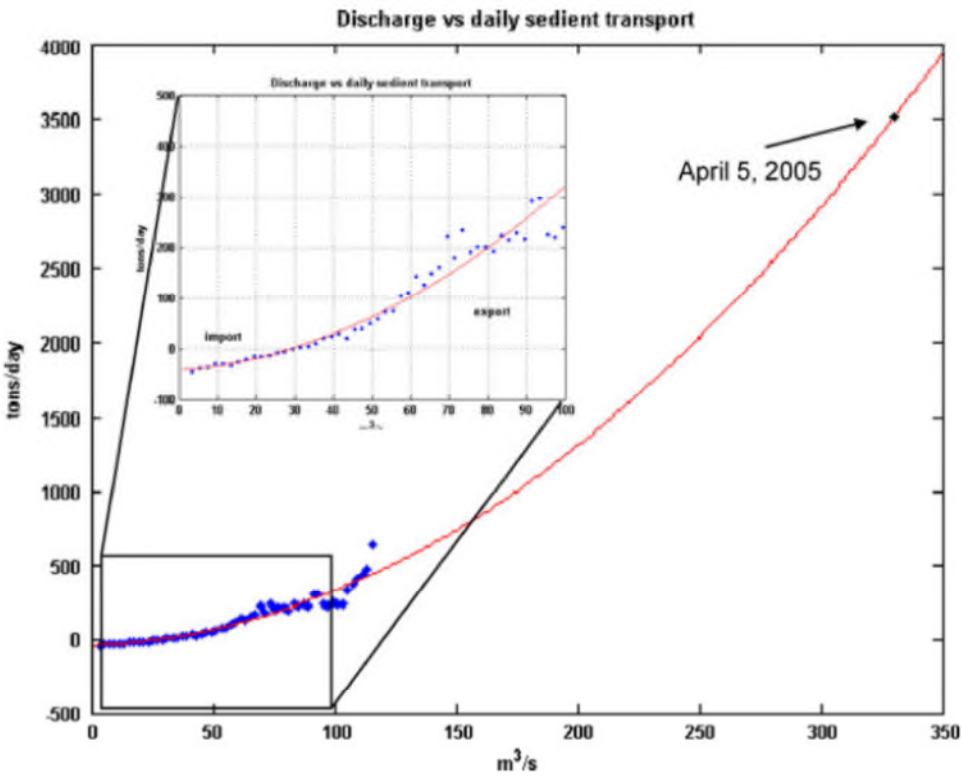


Figure A-14: The *Chant et al.* [2011] model of LPR estuarine net (non-tidal) fluxes at RM-3, with flux expressed as a function of discharge at Little Falls. Net fluxes are negative (i.e., landward) for flows <35.6 m^3/s. For higher flows, the net flux is seaward (positive).

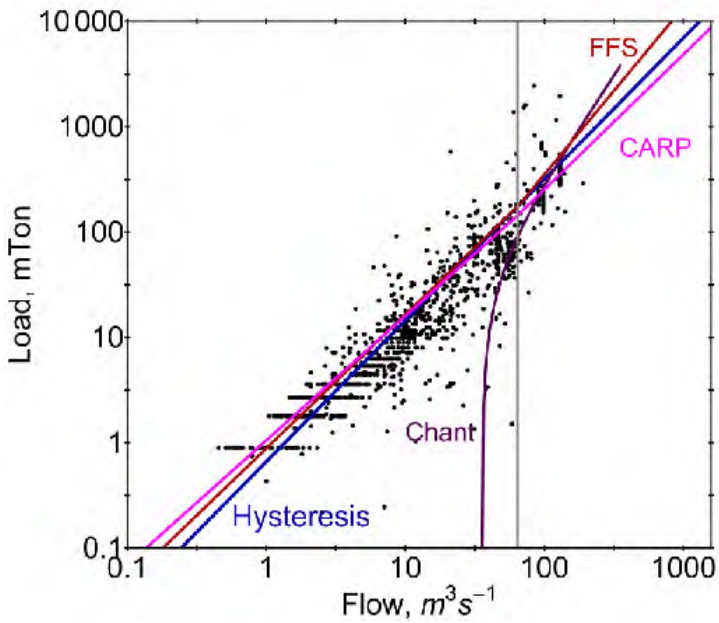


Figure A-15: The suspended load for the Passaic River at Little Falls as predicted by (A-1) (blue); by the CARP model (magenta), and by the FFS model (red). Also shown are the predicted estuarine suspended sediment fluxes as a function of flow, from Chant et al. [2011]. The line for the hysteresis model is plotted for the median value of *R* =0.944 (Table A-5). The details of the Chant et al. model are given in the caption to their Figure 13; however, the coefficient to the quadratic term should be 0.031 (not 0.0031 as given in their caption). For flows less than ~35.5m^3/s, the Chant model predicts landward (nagative fluxes) that cannot be represented on this log-log plot. The vertical gray line is at twice the mean flow, which the boundary between the low and flows components of the CARP and FFS models.

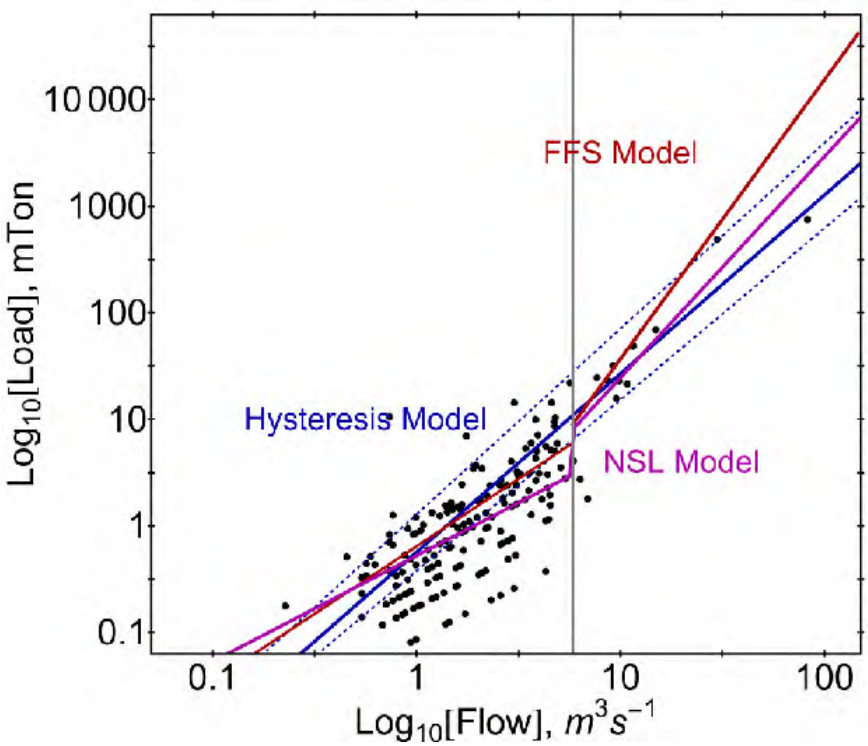


Figure A-16: The suspended load for the Saddle River at Lodi, as predicted by (A-1) (solid blue line; by the NSL model [eq. (A-7a,b), magenta] and by the FFS model eq. (A-6a,b), red] The solid blue line for the hysteresis model is plotted for the median value of *R*, while the dotted blue lines represent the 1% and 99% values of hystesesis, respectively. The vertical gray line is at twice the mean flow, which is the boundary between the low and flows components for the NSL and FFS models.

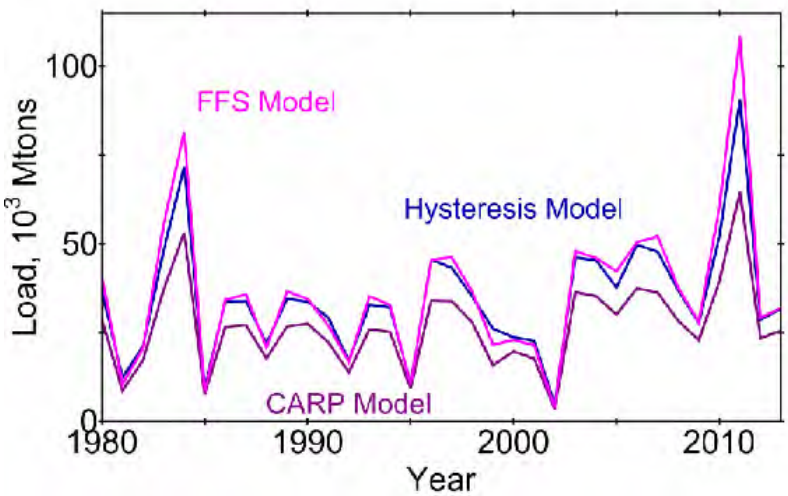


Figure A-17a: Total annual suspended sediment loads predicted by the hysteresis, CARP and FFFs models for the Passaic River at Little Falls, 1980-2013.

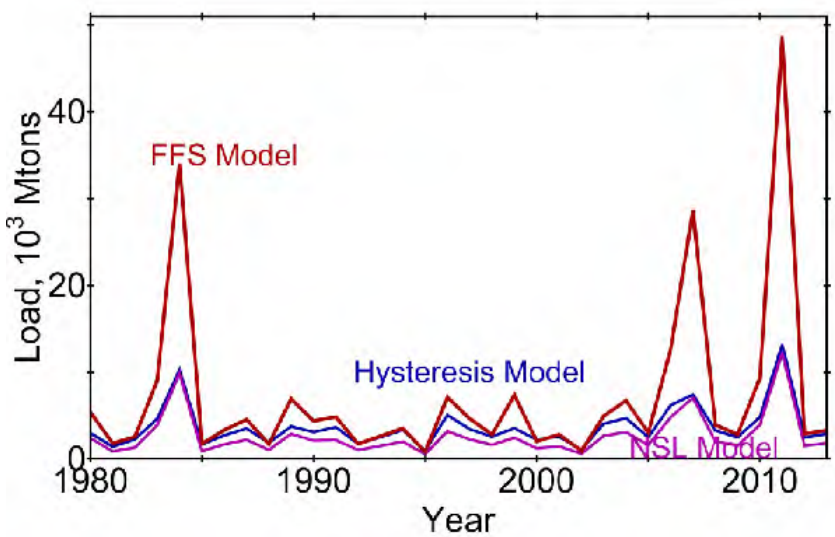


Figure A-17b: Total annual suspended sediment loads predicted by the hysteresis, NSL and FFFs models for the Saddle River at Lodi, 1980-2013.

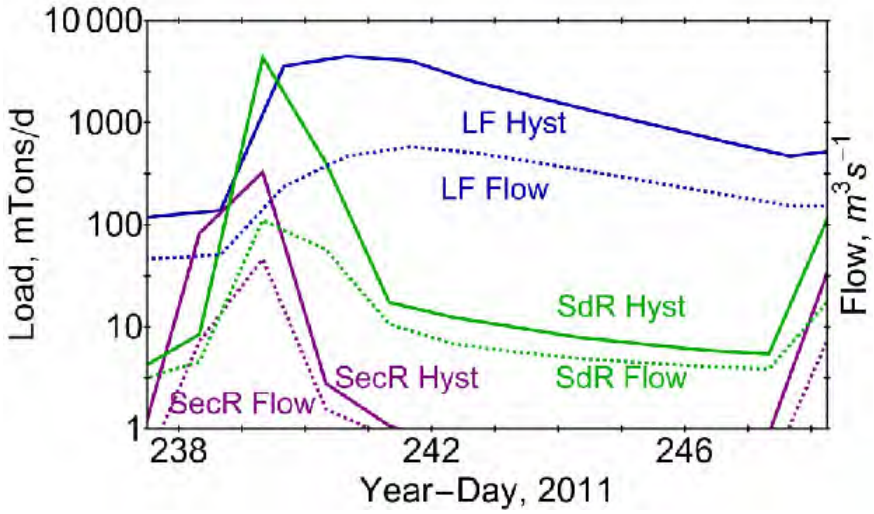


Figure A-18a: Hysteresis model estimated loads (solid lines) and observed flows (dotted lines) during the Hurricane Irene period in 2011 for the Passaic River at Little Falls (blue), the Saddle River (green) and the Second River (purple); all estimates based on daily flow data for consistency. Note that the peak sediment inputs occur 1 to 2d before the peak flow at Little Falls.

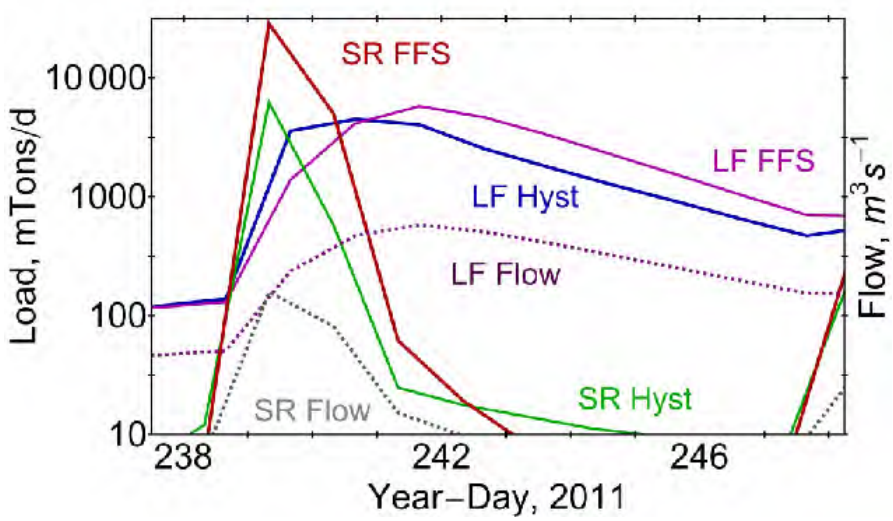


Figure A-18b: Estimated sediment load (solid lines) and observed flows (dotted lines) during the Hurricane Irene period in 2011 for the Passaic River at Little Falls and the Saddle River at Lodi; all estimates based on daily flow data for consistency; note the different vertical axis relative to the previous figure. Shown are load estimates for the Little Falls hysteresis model (blue), the Little Falls FFS model (purple), the Saddle River hysteresis model (green), and the Saddle River FFS model (red). The Saddle River NSL model prediction is similar to that of the Saddle River hystersis model and is not shown.

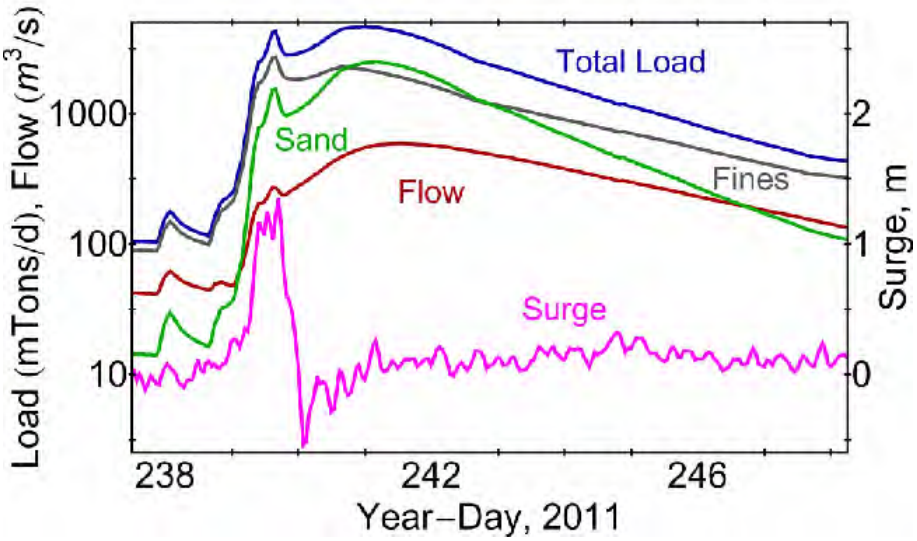


Figure A-19a: Time histories during Hurricane Irene (August 2011) of hourly Little Falls sediment load predicted by the hysteresis model (blue), with the fines load (gray), sand load (green), flow at Little Falls (red), and Bergen Point (NOAA gauge 8519483) surge (difference between observed and predicted tides). The coincidence between the surge and the first pulse of flow and sediment is coincidental but typical (see Appendix B).

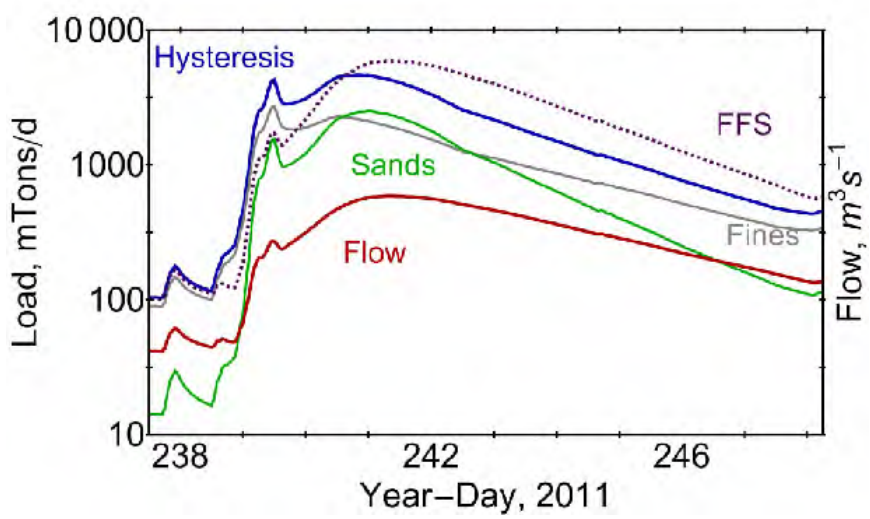


Figure A-19b: Time histories during Hurricane Irene (August 2011) of hourly Little Falls sediment load predicted by the hysteresis model (blue), with the fines load (gray), sand load (green), flow at Little Falls (red), and the FFS model predicted load (purple).

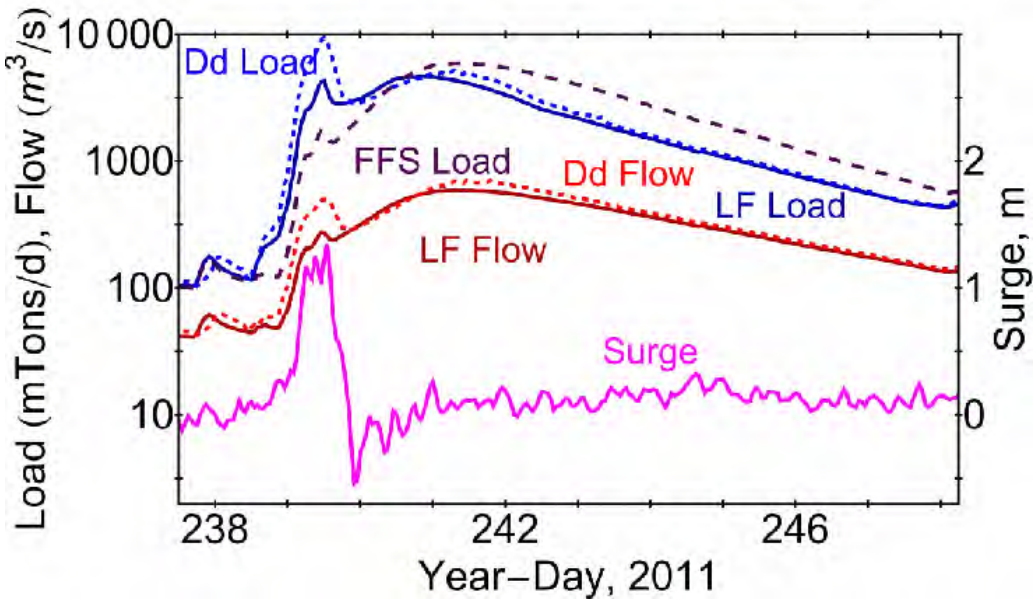


Figure A-20: Hourly observed flows and hysteresis model predictions of Passaic River sediment loads during Hurricane Irene at Dundee Dam (Dd) and at Little Falls (LF), along with the measured storm surge at Bergen Point.

Appendix B Figures

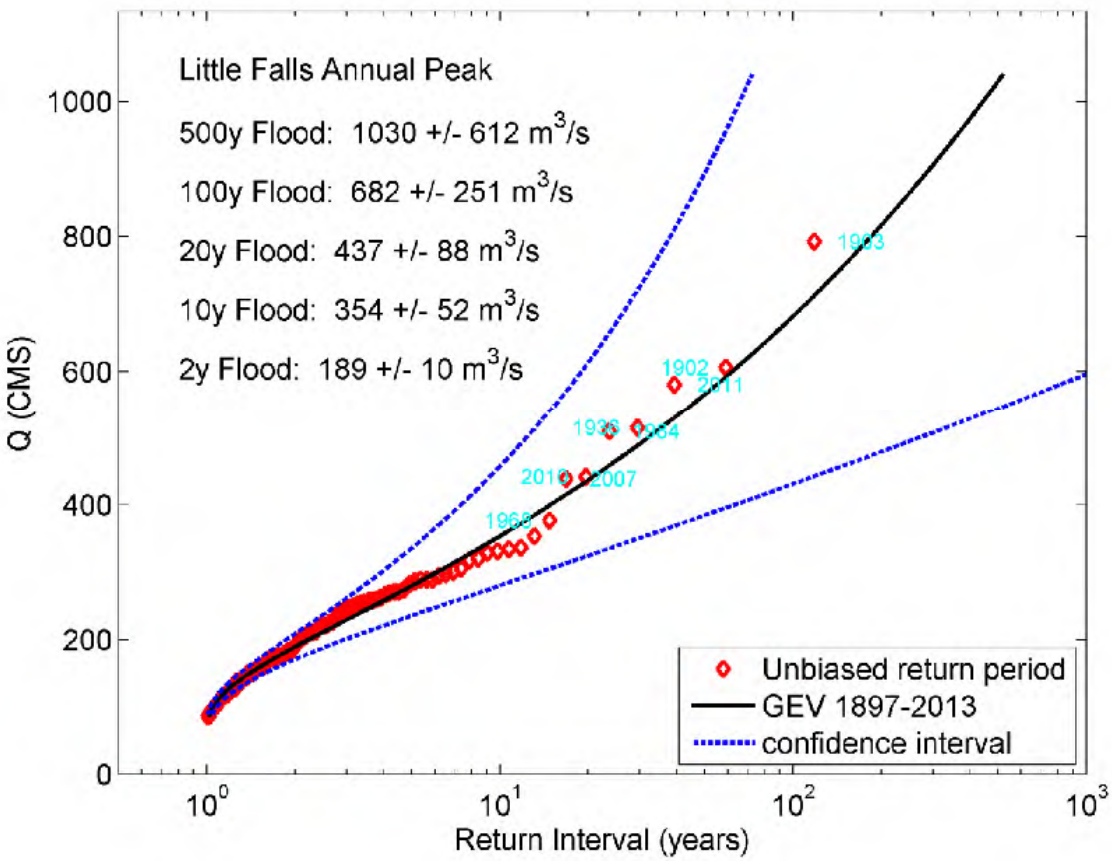


Figure B-1: Return period at Little Falls, estimated using annual extremes between 1897 and 2013 and modeled using the Generalized Extreme Value (GEV) theorem. The 95% confidence interval and unbiased return period based on data are shown (see Talke et al. [2014] for discussion and definition of this method). The 100-year and 500-year flood events are estimated to be 20% larger than those used in the FFS study (see Appendix BI Capping, Section 5). The listed errors for various flood magnitudes are +/- 1σ. As can be seen, three of largest 10 annual extreme events occurred within the last 10 years (2007, 2010, and 2011).

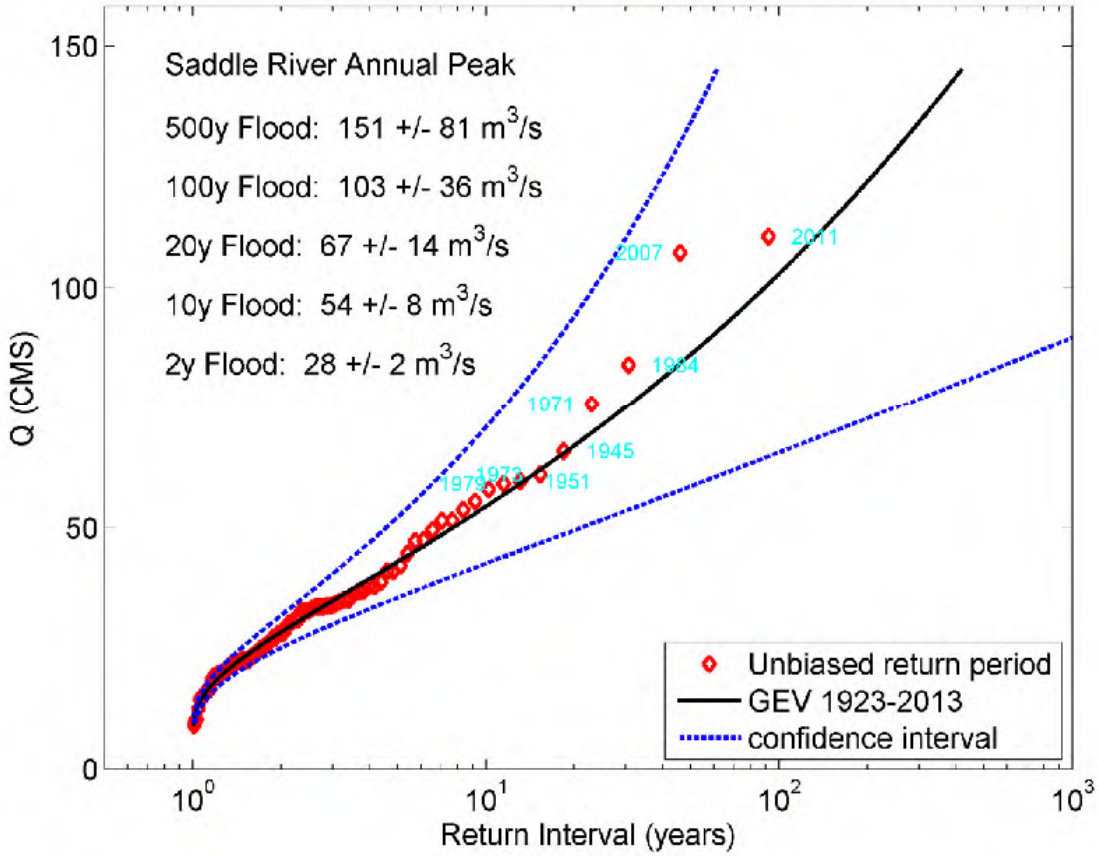


Figure B-2: GEV analysis of Saddle River annual peaks, 1923-2013. A 100-year flood of >100 m^3 is predicted.

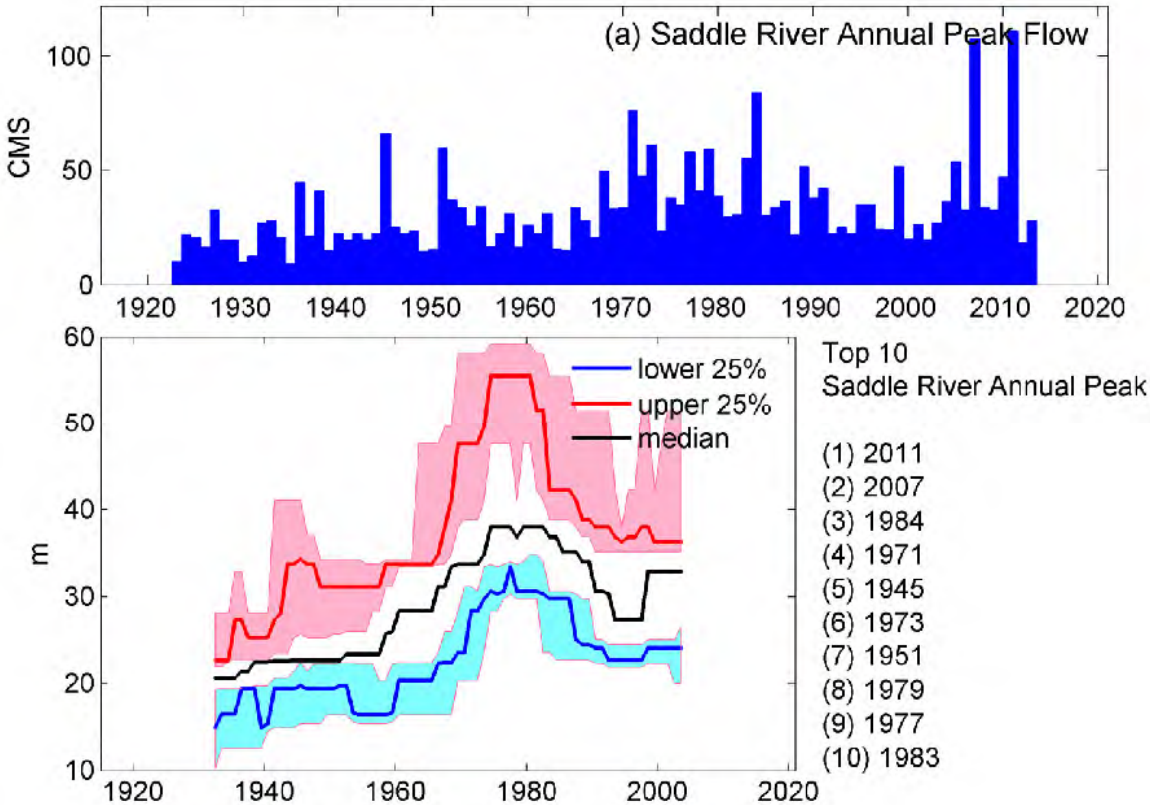


Figure B-3: (a) Saddle River Annual Peaks and (b) variability in quartile statistics, based on a 20-year moving window. There is a long-term trend toward larger flows since 1923, as well as large fluctuations related to the North Atlantic Oscillation (NAO). Extreme flood magnitudes increased during the positive phase of the NAO between 1970-1985, and 6 of the largest 10 events were measured during this period.

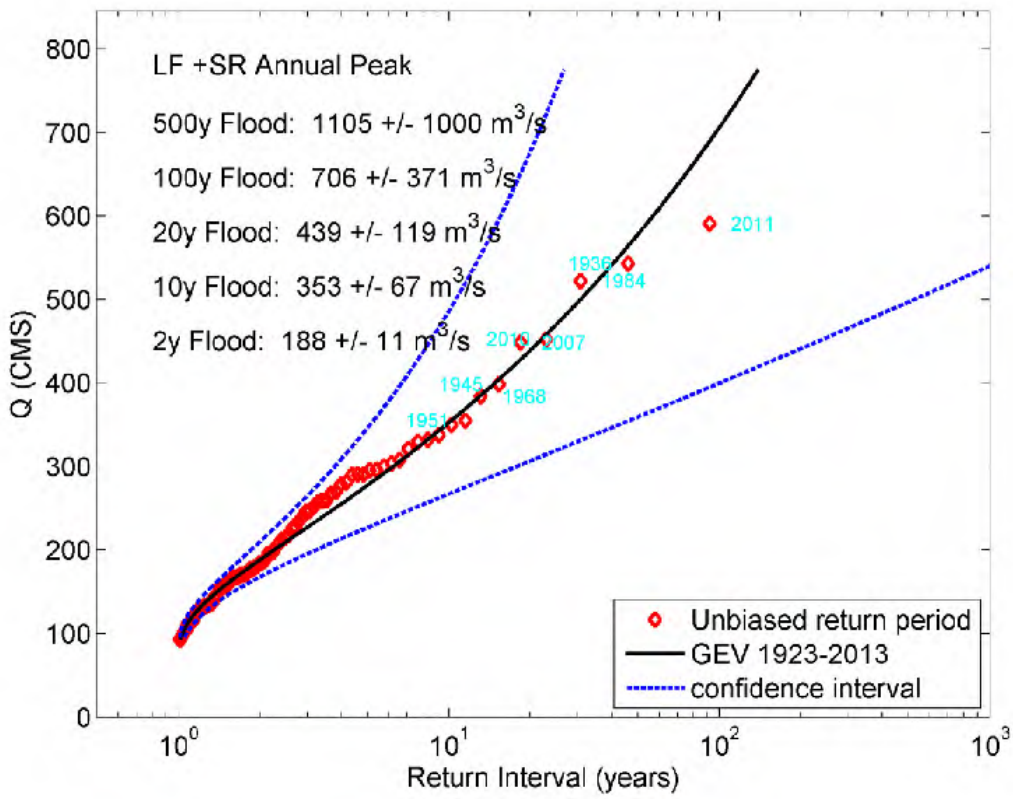


Figure B-4: Return period combined flood estimated by adding Little Falls flow to the Saddle River, 1923-2013, determined using GEV theory applied to peaks. Because the timing is different, the 100-year flood from the two locations cannot simply be added.

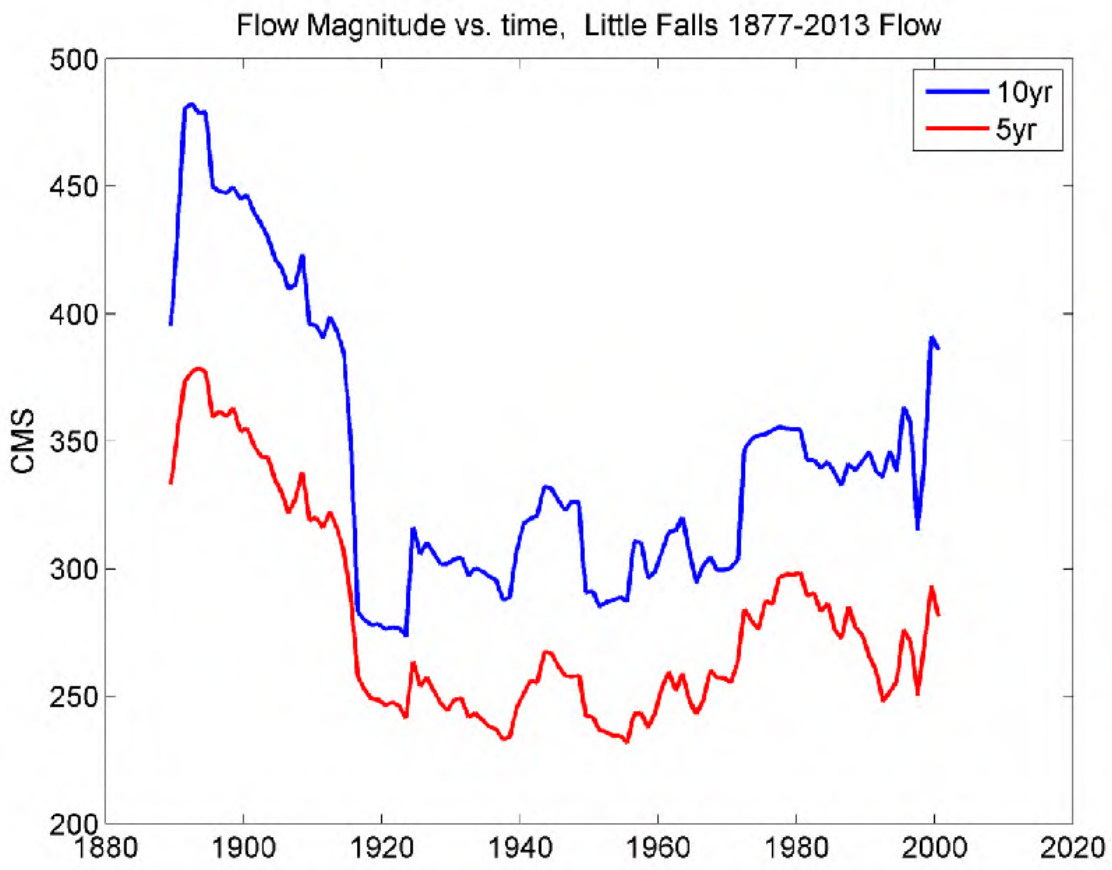


Figure B-5: The evolution of the 5-year and the 10-year flood risk measured at Little Falls. A series of annually incremented 25 year blocks are evaluated using GEV analysis. Long term (decadal) fluctuations and trends in flood risk are noticeable. Additional values from 1877-1896 were found in an 1894 report by the New Jersey State Geology Department [Vermeule, 1894] and are also listed in part at http://nwis.waterdata.usgs.gov/nj/nwis/peak?site_no=01389500&agency_cd=USGS&format=html. Seven annual peak values before 1897 were below 8000 cfs, and therefore unlisted in Vermeule (1894). These were infilled by randomly bootstrapping these values from the set of post 1897 events below a threshold of 8000 cfs.

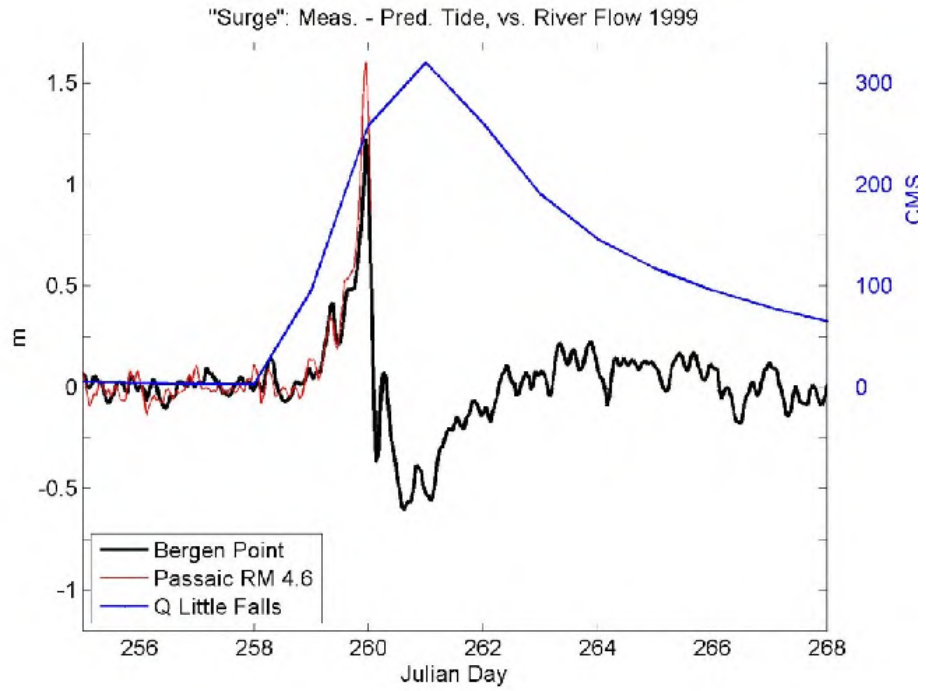


Figure B-6: Storm surge in the LPR often occurs during the leading edge of a flood event. This 1999 flood event, with about a 5-year return period, combined with the ebb of the surge event to knock out the USGS tide gauge near Newark (red line). Of the 5 events of flow > 150m^3/s that were measured on the USGS RM-4.6 gauge in Newark between 1993 and 2003, four of them coincided with signficant storm surge of >0.5m. Interaction between floods and storm surge is clearly important in the Passaic.

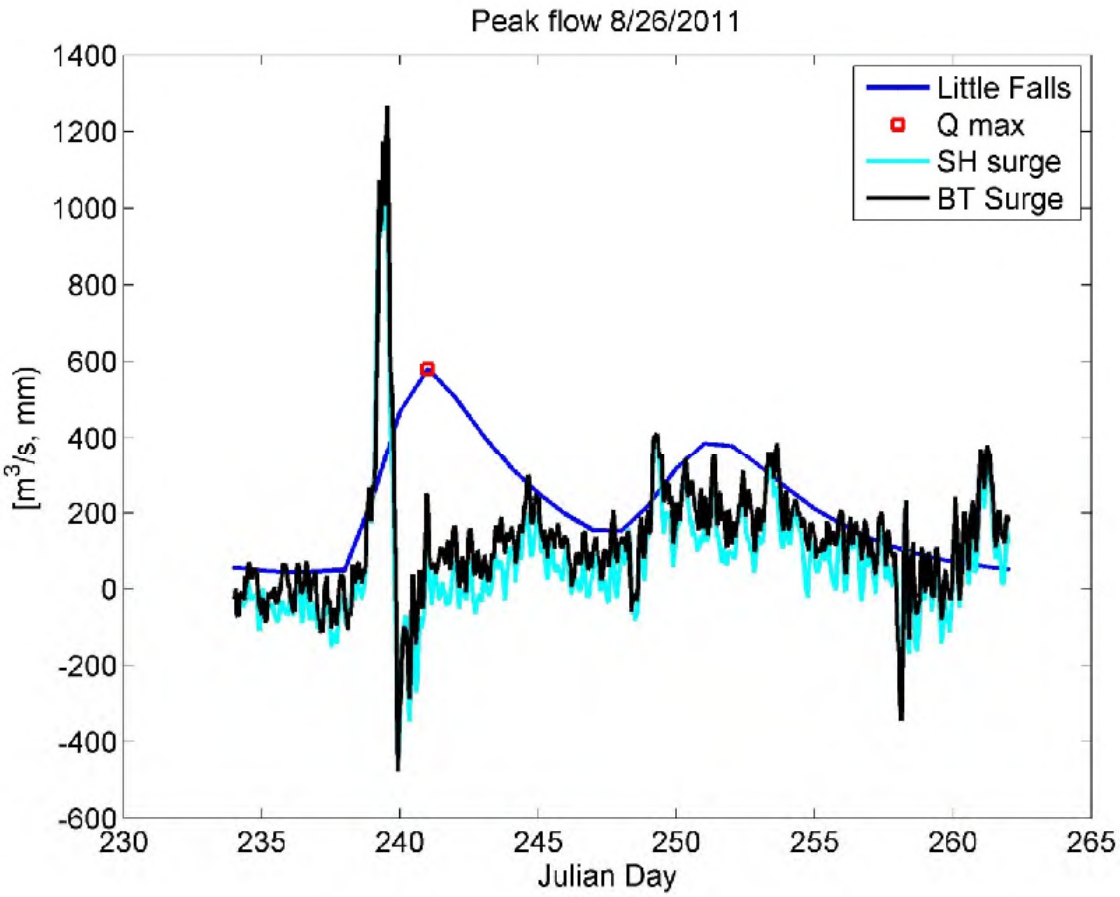


Figure B-7: Storm surge (in mm) measured at Sandy Hook (SH) and the Battery (BT) during hurricane Irene in August 2011, compared to river flow at Little Falls. In this case, the surge occurred during the leading edge of the storm, at substantial flow rates of 200-400 m^3/s. Because there is little spatial variation in storm surge and tides throughout New York harbor, the storm surge in Newark was likely similar to the surge depicted here.

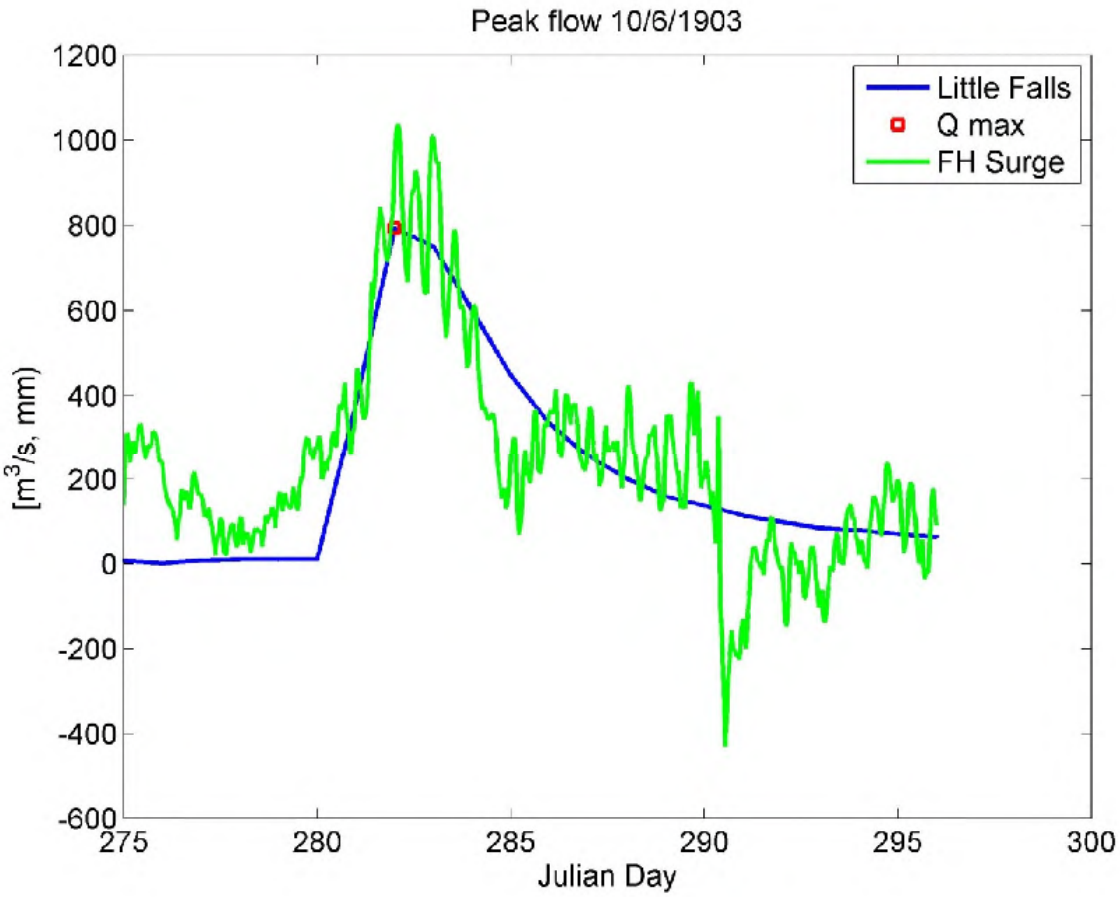


Figure B-8: Storm surge measured at Fort Hamilton (Verrazano Narrows) in New York harbor during the largest river flood ever measured at Little Falls. The storm was apparently slow moving, and the peak in storm surge coincides with peak flow. Clearly storm surge played a role in the physics of that event in the LPR. Any possible delay of the surge between Fort Hamilton and the LPR is insignificant on the time scale of the plot.

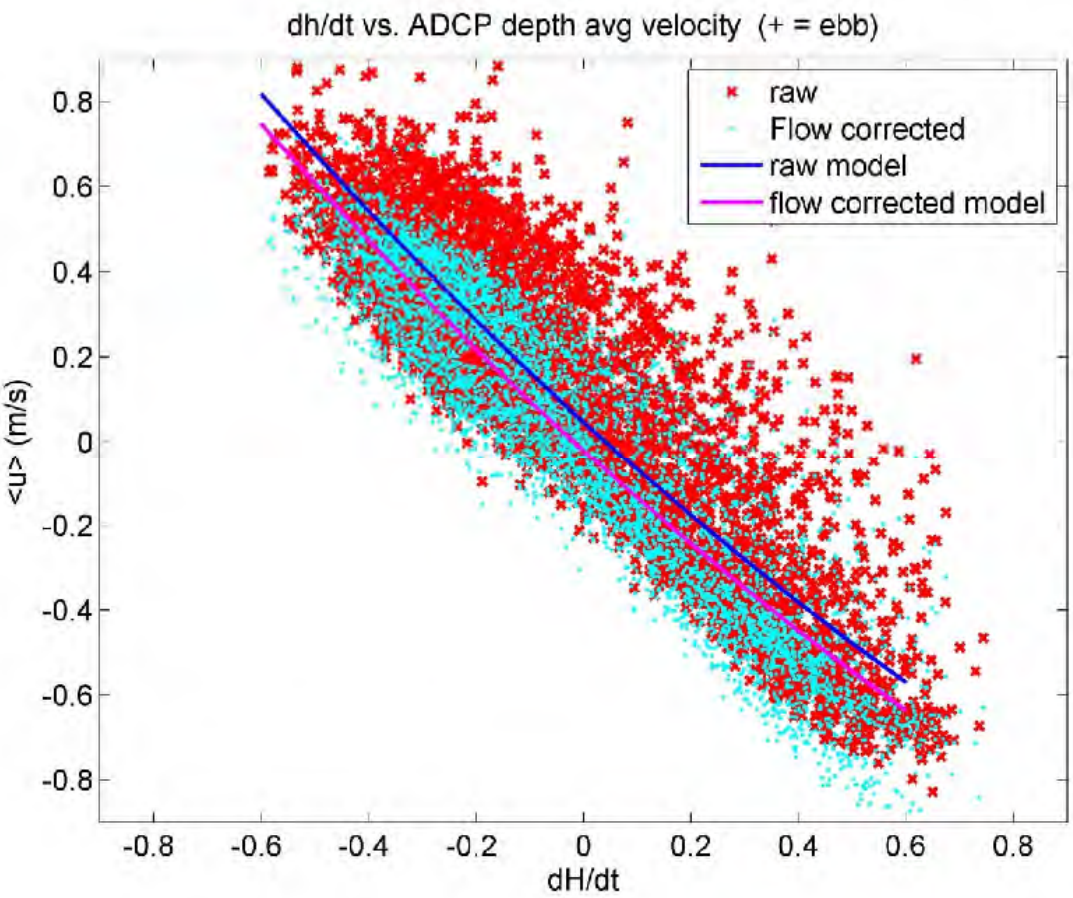


Figure B-9: First-order relationship between the fall rate of water depth (dH/dt) and depth-averaged velocity at approximately RM-3 in the Passaic. Data were collected in 2004 and 2005, and reused with permission of R. Chant, Rutgers University. Raw data were corrected by subtracting out Q/A, where Q is the river flow at Little Falls and A=500 m^3 was the cross-sectional area at the mooring site (M2). A parabola was fit to the data.

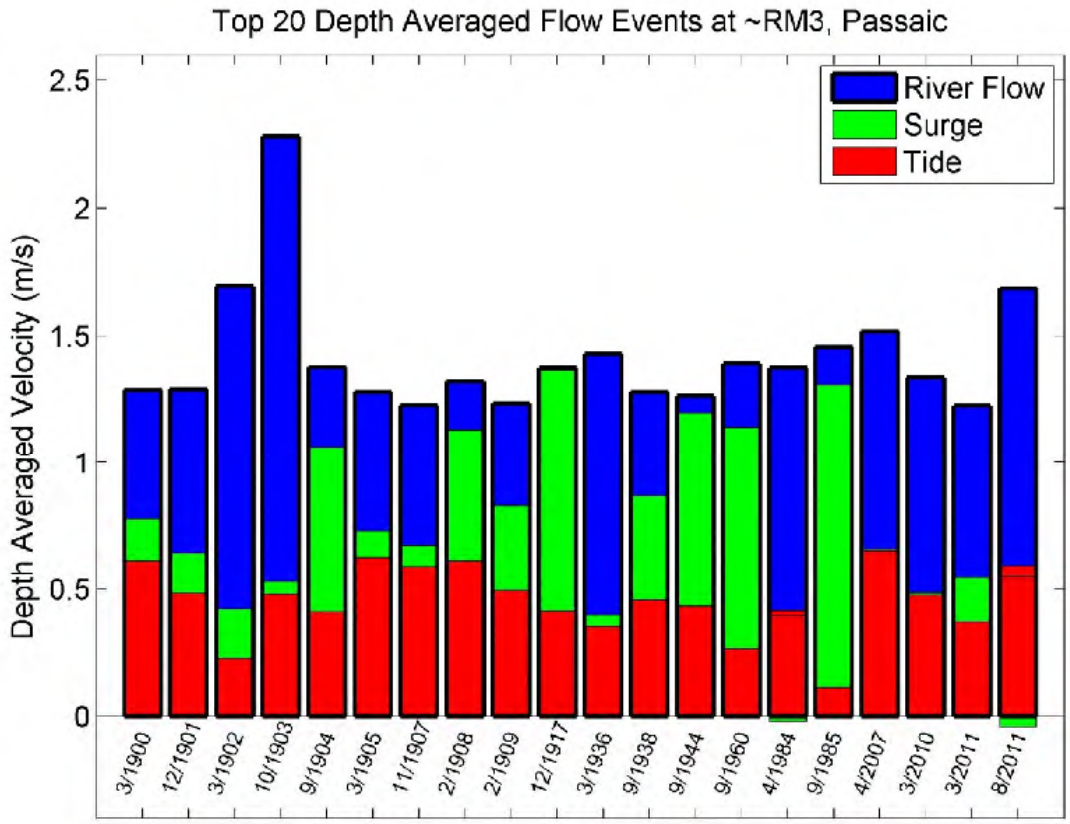


Figure B-10: The top 20 erosive events in the Passaic since 1897, using tide data from Fort Hamilton and the Battery (see *Talke et al.* [2014]), and river flow from Little Falls (1897-2013) and the Saddle River (1923-2013). Velocities were estimated via the relationship in Figure B-8. The largest erosive events occurred in 1903 and 2011. Note that some events—1917 and 1985—are primarily forced by tides and storm surge, while others—2007 and 1903—are primarily forced by tides and river flow. Other events, such as the 1904 storm and the 1938 hurricane, are a combination of all three. The peak velocity during Hurricane Irene occurred due to river flow and tides; this is somewhat misleading, since this 'fast-pulse' hurricane created a substantial velocity that nearly equaled the later flow (see Fig. B7). Lower in the estuary, the Irene storm-surge probably dominated over river flow.

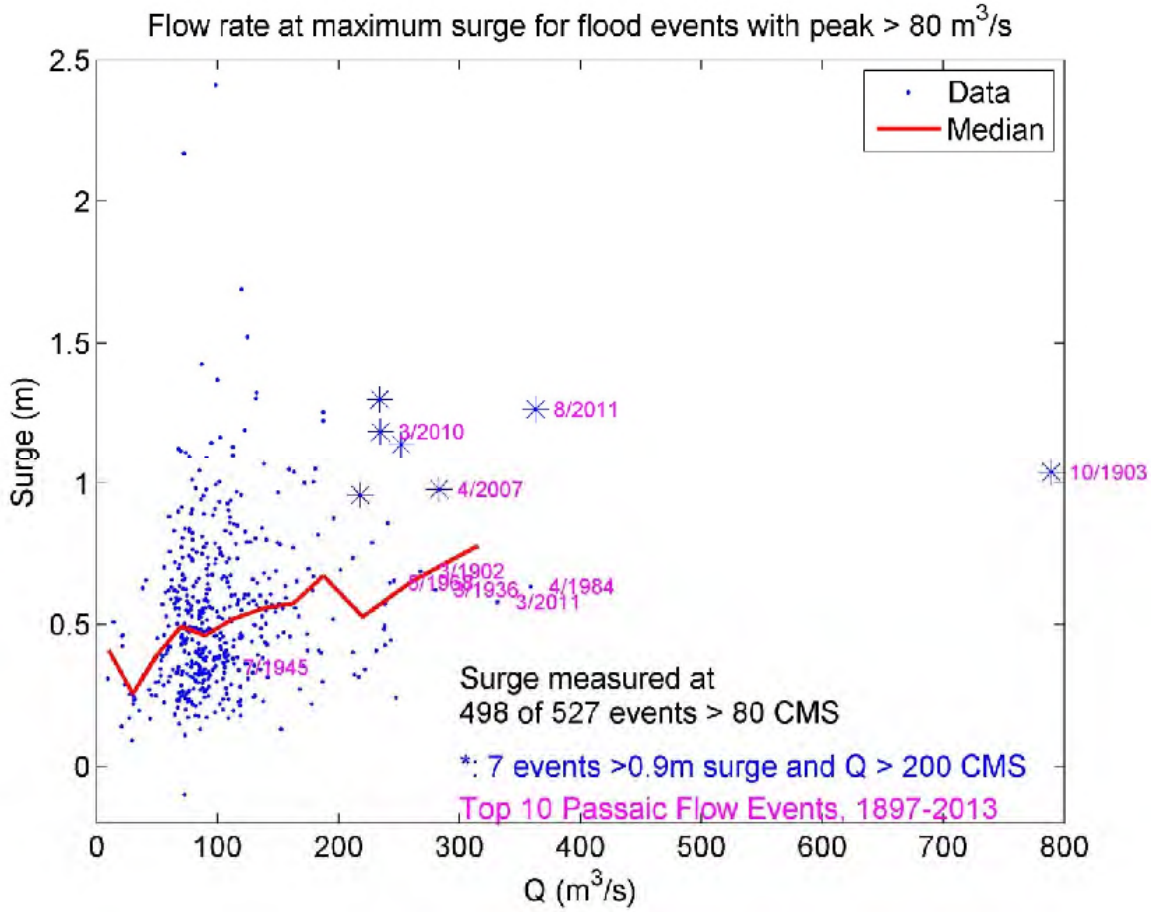


Figure B-11: A scatter plot of the river flow rate measured at Little Falls at time of large peak surge events in New York Harbor. First, 527 events were identified in the Little Falls record with a flow rate >80 m^3/s. Next, a window of time was defined which spanned from 5 days before the peak flow to the end of the event, defined as the time when flow dropped below 80 m^3/s. Within this time window, the peak surge and time of peak surge was defined. The figure shows the peak surge vs. the river flow measured at this time. Of these 527 events, tide data were available for 498. In nine out of 10 of the top 10 flood events, significant surge of >0.5m coincided with flow grater than 250 CMS. Only one of the top-10 flood events at Little Falls coincided with a peak surge < 0.5m. Significant river discharge coincided with all peak surge events. The median surge increases with river discharge, indicating a statistical correlation.

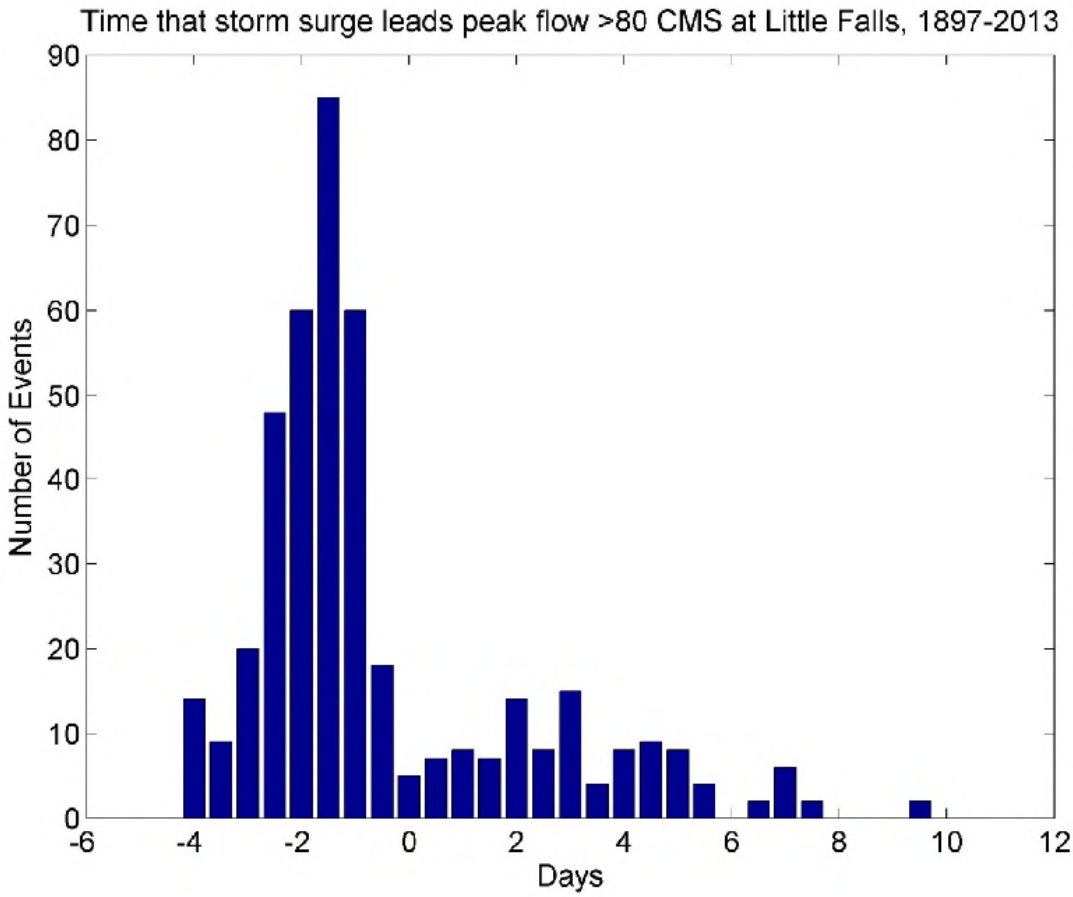


Figure B-12: The difference in timing between peak surge measured in New York harbor and the maximum flow rate measured at Little Falls. Nearly 500 events with a peak flow of >80 m^3/s were identified (see Figure B-12) that coincided with available tide data from New York harbor (1897-2013). Nearly half of peak surge occurs within 2 days of the peak flow, and ~60% precedes the peak flow by between 0-3 days. Surge occurring after the peak flood may be linked to a subsequent wind event, i.e., the next storm surge occurs before the previous high-flow event has ended.

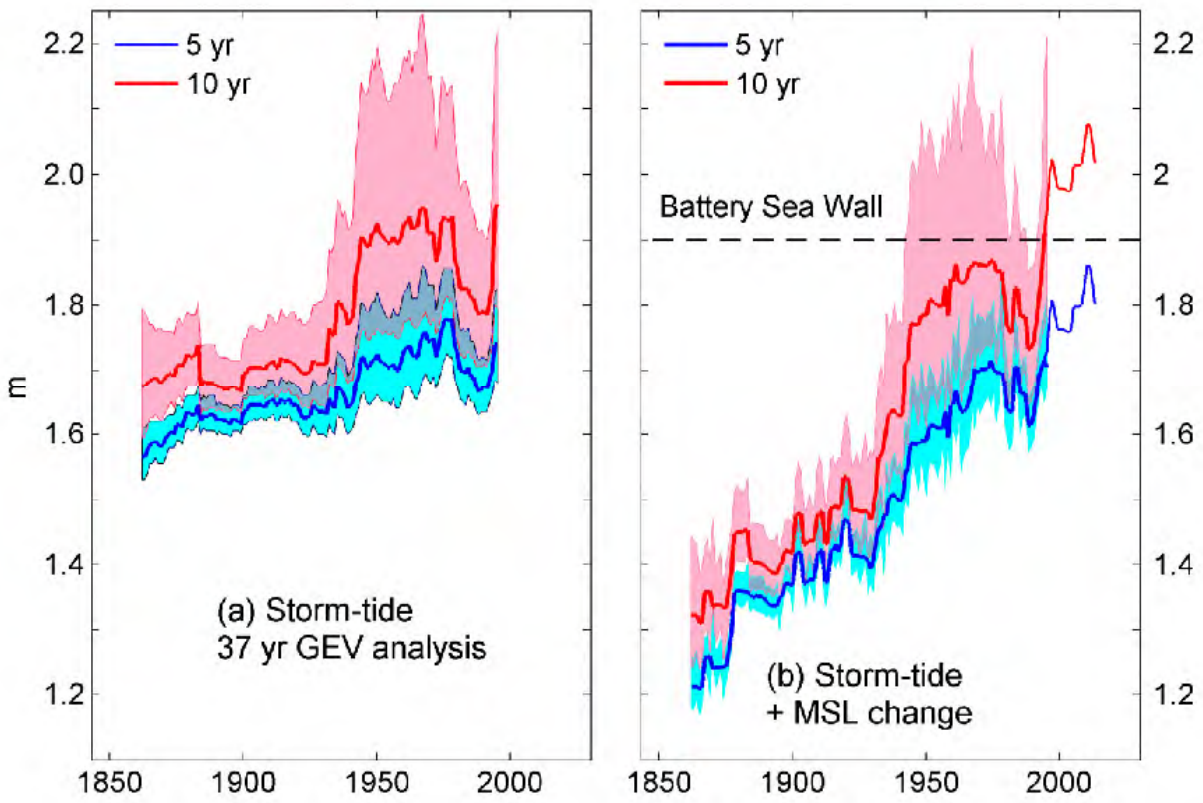


Figure B-13: Long term increase in extreme water levels, from *Talke et al.* [2014]. An increase in storm tides should be considered in long-range planning. Note the decrease in storm tide risk between 1970-1985 during the positive NAO phase, and increased risk between 1950-1970, during negative NAO.

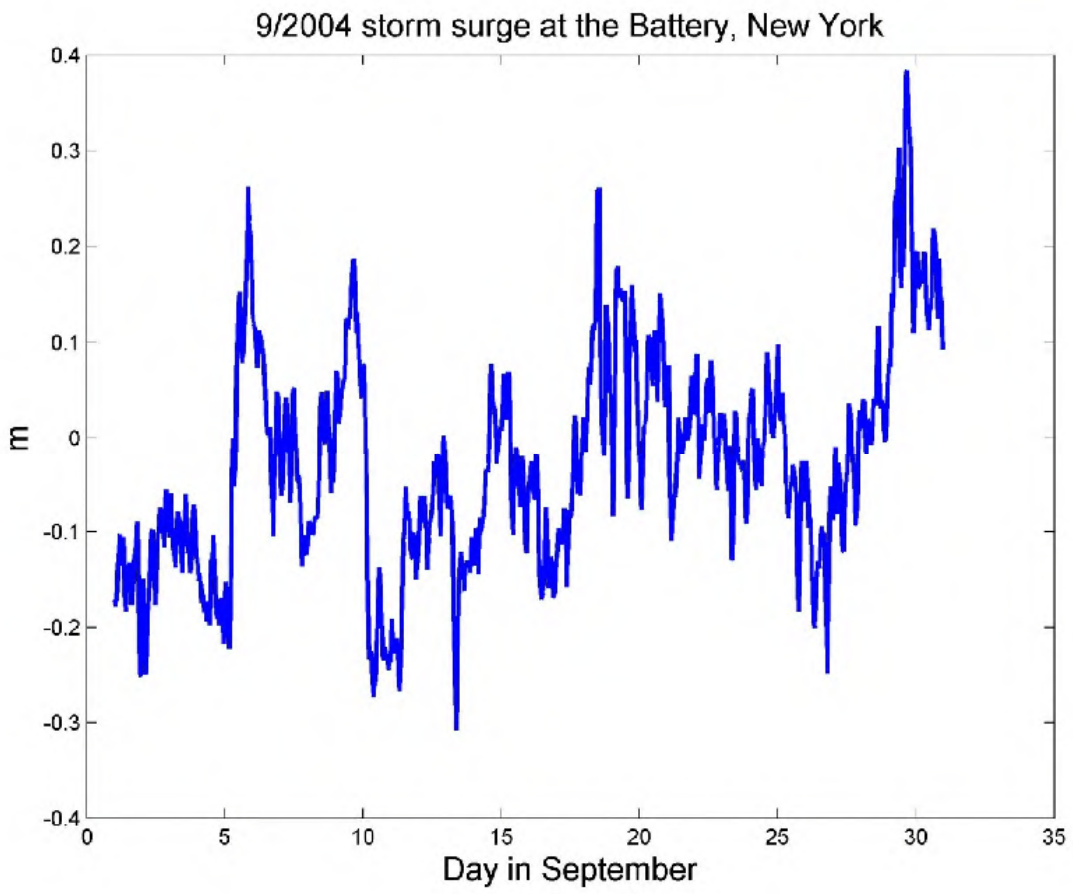


Figure B-14: The storm surge measured at the Battery (Manhattan Island) during September 2004. Since storm surge in New York harbor is fairly homogenous, the water levels in the Passaic were likely similar. The peak in water level at the end of September likely explains the water level anomalies discussed in appendix B1, page 3-2, and incorrectly attributed to the settling of two sensors.

Appendix C Figures

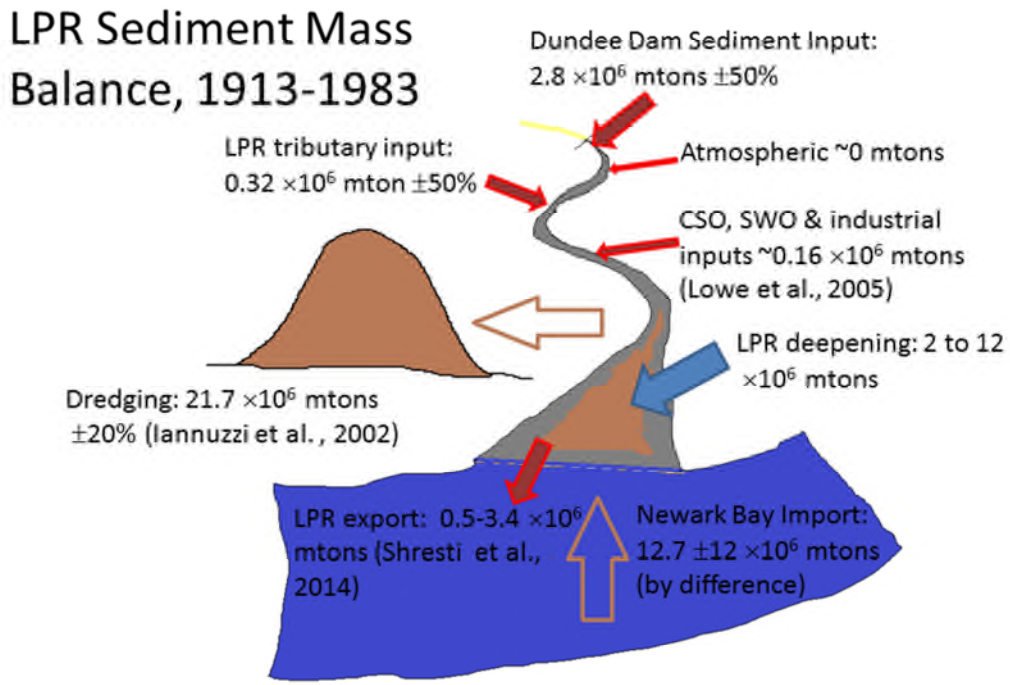


Figure C-1: A preliminary estimate of the LPR sediment total mass balance for 1913 to 1983; See Table C-1 for details. Net particulate organic carbon transfer to the bed is ignored, and the cohesive and sand balances are not separated.

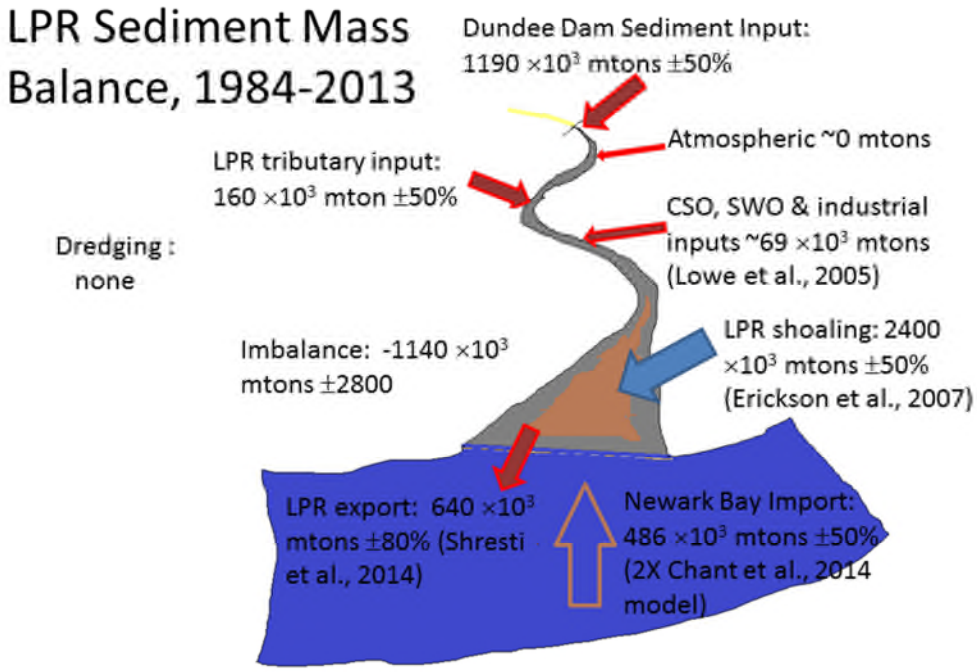


Figure C-2: A preliminary estimate of the LPR sediment total mass balance for 1984 to 2013; see Table C-2 for details. The imbalance is the difference between the terms estimated. The uncertainty in the net encompasses zero, so that for some values within the ranges of the estimates, balance is achieved. However, the uncertainty in the imbalance is larger than any individual term. The Newark Bay input to the LPR is the discrepancy between the remaining terms, with the broad range reflecting the uncertainty of the other estimates. The range of uncertainty on the descrepancy is larger than all terms except dredging loss and input from Newark Bay.

David A. Jay, Ph.D.

Professor
Department of Civil and Environmental Engineering
Portland State University, PO Box 751, Portland, OR 97207-0751
djay@cecs.pdx.edu
Home page: www/cee.pdx.edu /~jaylab/

INTERESTS

Dr. Jay earned his Ph.D. in physical oceanography at the University of Washington in 1987. He has been a process scientist and has participated in the science and management of coastal systems for 38 years. His research interests span a range of topics and scales including estuarine circulation and sediment transport, estuarine turbidity maxima, stratified flows and turbulent mixing, basin-scale hydrology, buoyant plumes, local and basin-scale tides, tidal analysis methods, sea level rise, coastal system comparison, climate and human impacts on coastal ecosystems, and coastal ecosystem science. Management issues he has been involved in include: New York Harbor pollution, San Francisco Bay salinity intrusion, Pacific Northwest salmonid recovery, Columbia River navigational impacts and safety, Lower Columbia River sediment budget, and hydropower impacts and management in several system. His experience in crossing disciplines and bridging the divide between basin hydrology and coastal processes in both science and management brings an important perspective to the Focused Feasibility Study process.

EDUCATION

University of Washington, Seattle	Physical Oceanography	Ph.D.	1987
SUNY at Stony Brook, NY	Marine Environmental Studies	M.S.	1974
Pomona College, Claremont, CA	Chemical Physics	B.A.	1970

APPOINTMENTS

2008-date	Professor, Department of Civil and Environmental Engineering, Portland State University.
2005-2007	Associate Professor; Department of Civil and Environmental Engineering, Portland State University.
1999-date	Adjunct Faculty, Oregon State University, College of Ocean and Atmospheric Sciences.
1995-2005	Associate Professor; Oregon Health & Science University, OGI School of Science & Engineering, Department of Environmental and Biomolecular Systems.
1993-1999	Adjunct Research Associate Professor; Physics Department, University of Washington.
1993-1995	Research Associate Professor; Geophysics Program, University of Washington.
1987-1993	Research Assistant Professor; Geophysics Program, University of Washington.

PUBLICATIONS

Publications Most Closely Related to Project

- Talke, S. A., P. Orton, and **D. A. Jay** (2014). Increasing storm tides in New York Harbor, 1844-2013, *Geophys. Res. Lett.*, 41, doi:10.1002/2014GL059574.
- **Jay, D. A**., Leffler, K., Diefenderfer, H., Borde, A. (2014). Tidal-fluvial and estuarine processes in the Lower Columbia River: I: along-channel water level variations, Pacific Ocean to Bonneville Lock and Dam. *Coasts and Estuaries*, DOI 10.1007/s12237-014-9819-0.
- **Jay, D. A.**, P. M. Orton, T. Chisholm, D. J. Wilson, and A. M. V. Fain (2007). Particle trapping in stratified estuaries – I Consequences of Mass Conservation and explorations of a parameter space. *Estuaries and Coasts* 30: 1095-1105.
- **Jay, D. A**., P. M. Orton, T. Chisholm, D. J. Wilson, and A. M. V. Fain (2007). Particle trapping in stratified estuaries – II Application to Observations. *Estuaries and Coasts* 30: 1106-1125.
- Fain, A. M. V., **D. A. Jay**, D. J. Wilson, P. M. Orton, and A. M. Baptista (2001). Seasonal, monthly and tidal patterns of particulate matter dynamics in the Columbia River estuary. *Estuaries* 24: 770-786.
- **Jay, D. A**. and J. D. Musiak (1996). Internal Tidal Asymmetry in Channel Flows: Origins and Consequences. C. Pattiaratchi (ed.). *Mixing Processes in Estuaries and Coastal Seas,* pp. 219-258.

- **Jay, D. A**. and J. D. Musiak (1994). Particle trapping in estuarine turbidity maxima. *J. Geophys. Res.* 99: 20,446-20,461.

Other Selected Recent Publications

- Devlin, A. T., **D. A. Jay**, S. A. Talke, and E. Zaron (2013). Tidal trends associated with anomalous sea level rise in the western Pacific Ocean. *Ocean Dynamics*, DOI 10.1007/s10236-014-0741-6.
- Zaron, E. and **D. A. Jay** (2014). An analysis of secular change in tides at open-ocean sites in the Pacific. *Journal of Physical Oceanography*: 44, 1704-1726.
- Moftakhari, H. R., **D. A. Jay**, S. A. Talke, T. Kukulka, and P. D. Bromirski (2013). A Novel Approach to Flow Estimation in Tidal Rivers. *Water Resour. Res.*, 49, doi:10.1002/wrcr.20363.
- Templeton, W. and **D. A. Jay** (2013). Lower Columbia River sand supply and removal: estimates of two sand budget components. *ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering*, doi:10.1061/(ASCE)WW.1943-5460.0000188.
- **Jay, D. A.** and P. Naik (2011). Distinguishing human and climate influences on hydrological disturbance processes in the Columbia River, USA. *Hydrological Sciences Journal,* 56, 1186-1209.
- Naik, P. and **D. A. Jay** (2011). Distinguishing human and climate impacts on Columbia River: changes in mean flow and sediment transport. *J. Hydrol.* 404, 259-277.
- **Jay, D. A**., Leffler, K., and Degens, S. (2011). Long-term evolution of Columbia River tides. *ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering* 137:182-191.

SYNERGISTIC ACTIVITIES

- Member, National Oceanic and Atmospheric Administration, Hydrographic Services Review Panel, 2011-date.
- Program Chair, Physics of Estuaries and Coastal Seas (PECS2006), September 2006, Astoria, OR.
- Distinguished reviewer, *Journal of Geophysical Research – Oceans*, 2004.
- Member, National Science Foundation, Physical Oceanography Program Review Panel, May 2002 and Long-Term Ecological Research Program Review Panel, Dec. 1999 and May 2006.

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators and Co-Editors: D. Bottom (NOAA-Fisheries), P. Bromirski (UCSD-Scripps), E. Casillas (NOAA-Fisheries), H. Diefenderfer (PNNL), B. M. Hickey (UW), A. Horner-Devine (UW), T. Kukulka (U Delaware), W. Lang (PSU), E. Lessard (UW), J. Liu (PSU), H. Moradkhani (PSU), J. Pan (PSU), W. Peterson (NOAA-Fisheries), C. A. Simenstad (UW), A. Strecker (PSU), S. Talke (PSU), H. Yeh (OSU), E. Zaron (PSU).

Graduate Advisor: J. D. Smith (USGS).

Thesis Advisor and Postgraduate-Scholar Sponsor:

Graduate Students (13): S. Boyd, C. N. Cudaback, (Assistant Professor, North Carolina State); A. Devlin (PSU), A. Fain, E. P. Flinchem, A. Gupta, D. J. Kay, T. Kukulka (Assistant Professor of Oceanography, University of Delaware), K. Leffler (PSU), J. D. Musiak, L. Meachem (PSU), T. Kordich (PSU), A. Devlin (PSU), C. McNeil (PSU), H. Moftakhari-Rostamkhani (PSU).

Postdoctoral Associates (6): T. Chisholm (Bonneville Power administration), T. Hibiya (Professor, Department of Earth and Planetary Science, University of Tokyo), D. J. Wilson (Imagenex Technology, Canada), J. Pan (Associate Professor, Institute of Space and Earth Information Science, The Chinese University of Hong Kong), E. Zaron (Research Assistant Professor, Portland State University), S. Talke (Assistant Professor, Portland State University).

Stefan A. Talke, Ph.D.

Assistant Professor
Department of Civil and Environmental Engineering
Portland State University,
PO Box 751, Portland, OR 97207-0751
Phone: 503-725-2870; Fax: 503-725-5950
talke@pdx.edu

BIOGRAPHICAL SKETCH

Dr. Talke's research focuses on tidal processes, storm surge, mixing and sediment transport in estuaries. His publications include studies which (a) measure and model estuary turbidity maxima; (b) elucidate mixing, erosion, and turbulence on intertidal flats and estuarine channels; and (c) investigate historical changes to estuary tides, transport, water quality, and storm surge. A recent publication on the nearly 1 foot increase in New York storm tides since 1844 garnered extensive media coverage (see https://www.google.com/search?q=talke+storm+tides+AGU).

PROFESSIONAL PREPARATION

University of California, Berkeley	Civil and Environmental Engr.	Ph.D.	2005
University of California, Berkeley	Civil and Environmental Engr.	M.S.	2001
University of California, Berkeley	Mechanical Engineering	B.S.	1996

APPOINTMENTS

2012-date	Assistant Professor, Portland State University
2010-2012	Senior Research Associate, Portland State University
2007-2010	Research Associate, University of Washington
2005-2007	Post Doctoral scholar, University of Utrecht, The Netherlands
2000-2004	Graduate Research Associate, University of California, Berkeley

PROFESSIONAL EXPERIENCE

2014	Expert Witness Consultant, Maxus International
2008-2010	Expert Witness Consultant, Brown & Winters Environmental Law (Carlsbad, CA)
2000	Intern, Montgomery Watson (Walnut Creek, CA)
1997-1999	Software Quality Assurance Engineer, Parametric Tech. Corp. (San Jose, CA)
1996	Intern, Phase Metrics (San Diego, CA)
1994	Intern, Bodensee Geraete Technik (Ueberlingen, Germany)

PUBLICATIONS

Five publications most relevant to the Lower Passaic River FFS:

- **Talke, S. A.**, P. Orton, D. A. Jay (2014). Increasing Storm Tides in New York Harbor, 1844-2013. *Geophysical Research Letters* 41(9), p3149-3155, DOI: 10.1002/2014GL059574.
- **Talke, S. A.** and M. T. Stacey (2008). Suspended Sediment Fluxes at an intertidal flat: Shifting Influence of wave, wind, tidal, and freshwater forcing. *Continental Shelf Research* 28(6), p. 710-725, doi:10.1016/j.csr.2007.12.003.
- Chernetsky, A. S., H. M. Schuttelaars, and **S. A. Talke** (2010). The effect of tidal asymmetry and temporal settling lag on sediment trapping in tidal estuaries. *Ocean Dynamics* 60, p. 1219-1241.
- Jonge, V. N. de, H. M. Schuttelaars, J. M. M. van Beusekom, **S. A.Talke**, H. E. de Swart (2014). The influence of channel deepening on estuarine turbidity dynamics, as exemplified by the Ems estuary. *Estuary, Coastal and Shelf Science* 139, p. 46-59.
- **Talke, S. A.**, H. E. de Swart, and H. M. Schuttelaars (2009). Feedback between residual circulation and sediment distribution in highly turbid estuaries: an analytical model. *Continental Shelf Research*, 29(1) p. 119-135. doi:10.1016/j.csr.2007.09.002.

Five Other Significant Publications:

- **Talke, S. A.** and D. A. Jay (2013). Nineteenth Century North American and Pacific Tides: Lost or just forgotten? *Journal of Coastal Research* 29(6a), p. 118- 127.
- **Talke, S. A.**, A. R. Horner-Devine, C. C. Chickadel, and A. T. Jessup (2013). Turbulent kinetic energy and coherent structures in a tidal river. *Journal of Geophysical Research*. 118(12), p. 6965-6981, DOI: 10.1002/2012JC008103.
- Moftakahri, H. R., D. A. Jay, **S. A. Talke**, T. Kulkulka, P. D. Bromirski (2013). A novel approach to flow estimation in tidal rivers. *Water Resources Research*. 49, 1-16, doi:10.1002/wrcr.20363.
- **Talke, S. A.**, A. R. Horner-Devine, C. C. Chickadel (2010). Mixing layer dynamics in separated flow over an estuarine sill with variable stratification. *Journal of Geophysical Research* Vol.. 115, C09004, doi:10.1029/2009JC005467.
- **Talke, S. A.**, H. E. de Swart, and V. N. de Jonge (2009). An idealized model and systematic process study of oxygen depletion in highly turbid estuaries. *Estuaries and Coasts*, 32 (4) p. 602-620. DOI 10.1007/s12237-009-9171-y.

RECENT AWARDS

- Young Investigator Award, 2012 (Office of Naval Research)
- Outstanding Reviewer Reward, 2013 (Coastal and Estuarine Research Federation)
- Outstanding Researcher Award, 2014 (Sigma Xi, Portland Chapter)

COMMENTS

Lower Passaic River Focused Feasibility Study: Analysis and Issues

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
James L. Best, Ph.D.
Marcelo H. García, Ph.D. Dist.M.ASCE F.EWRI

LOWER PASSAIC RIVER FOCUSED FEASIBILITY STUDY: ANALYSIS AND ISSUES

James L. Best, Ph.D. and Marcelo H. García, Ph.D. Dist.M.ASCE F.EWRI

General Comments

General Comment 1: ***The spatial resolution of the numerical grid used in the existing hydrodynamic model is insufficient to resolve details on the physics of flow and sedimentation patterns that may be of key local influence on sediment transport and bed scour. These deficiencies in the hydrodynamic and sediment transport models make it impossible to develop an informed decision regarding the correct remedial action for the Lower Passaic River.***

With the computational grid used in the hydrodynamic model, the width of the river is approximated with four cells. In most rivers, including the Lower Passaic, there are large differences in erosion between the deeper and shallower parts along a cross-section of a channel. In particular, erosion/deposition in the deeper parts may not be the same as the erosion/deposition averaged across the river. Predicting the dissimilar amounts of erosion in the deeper areas and erosion/deposition in the shallower areas is crucial in predicting the long-term exposure of COC by erosion of the bottom sediments and/or natural recovery by deposition. As it stands, the spatial scale of the hydrodynamic model is inadequate to even approximately describe the variability of erosion/deposition across the river, and hence the effectiveness of any of the remediation alternatives presented in the FFS (Reible et al., 2003).

The reduced ability of the model to predict erosion/deposition at the appropriate spatial scale has a direct impact on the choice of remedial action. Small or no erosion at high shear stresses indicates that contaminants are probably being buried over the long term and natural recovery (Alternative 1 in the FFS) is the best choice of action. Large amounts of erosion indicate that buried sediments may be uncovered, be resuspended, and hence will contaminate surface waters; dredging and capping are therefore necessary (Alternative 4 in the FFS). However, the deficiencies in the hydrodynamic and sediment transport models make it impossible to develop an informed decision regarding the correct remedial action for the Lower Passaic River.

The spatial resolution of any numerical model is always a trade-off between the details required and the computational resources (number of processors and time to run the model) available. As such, it is realized that choices must be made to allow the most efficient grid size for the study that reaches this compromise between resolution and resource.

This issue of grid resolution is reported within the FFS, for instance in discussions of bathymetric change where it is acknowledged that "….bed elevation changes estimated from the bathymetry data show spatial variations of erosion or deposition on spatial scales smaller than a model grid cell" (Appendix BII, page 4-13).

In addition, the testing of grid size sensitivity and grid independence has not been correctly conducted. It is normal for two linked approaches to be taken:

a. The grid cell size is progressively changed until a range of parameters can be shown not to change, and thus any finer resolution grid is unwarranted; and

b. A grid independence statistic is calculated to quantitatively address this issue.

Another important issue related to the size of the computational grid relates to the approach used to determine the erosive properties of the bed material in the LPR. The sediment cores used in the SEDFLUME tests are only a few square inches in size. Total suspended solids (TSS) for a given flow discharge is a function of erosion, which depends on bottom shear stress to a power n. Bottom shear stress predicted by the hydrodynamic model, in turn, depends on the local flow velocity squared, making erosion dependent on velocity raised to the power 2n. Because ECOMSED uses four grid cells per channel width, it can only output one mean velocity and bottom shear stress per cell. However, the erosive properties determined with the SEDFLUME test cores (i.e., critical shear stress for erosion) are assigned to a much larger area than that given by the average computational grid cell size (605 ft by 418 ft). This procedure introduces a large amount of error when computing potential erosion and scour with a numerical hydrodynamic model that has a spatial resolution that is much larger than the surface area of the sediment sample used to estimate the value of the critical shear stress for erosion. This value of the critical shear stress for erosion corresponds to the grain (skin) friction, whereas the computational grid cell used for the FFS also includes form drag associated with bedforms and scour features, which are incorrectly accounted for in the FFS sediment transport model as described below. Furthermore, the effectiveness of the remediation alternatives proposed in the FFS cannot be assessed, since velocity extremes (and boundary shear stress) associated with lateral variations in channel depth and meandering are not captured by the hydrodynamic and sediment transport models.

<u>General Comment 2:</u> The quantification of bed roughness within the numerical model does not realistically account for the real nature of the river bed and the likely effect of bed roughness on flow mixing and the shear stresses exerted on the sediment bed. Implementation of some of the proposed remedies, such as dredging and capping, without a good understanding of the dynamics of river channel morphology, could result in a larger risk of erosion and resuspension of contaminated sediments during floods, as well as an increase in flood stages. All these issues fundamentally call into question the implementability of the proposed remedies.

The one-way coupling from hydrodynamics to sediment transport of ECOM-SEDZLJS does not allow for hydrodynamic feedback on the total bed roughness (i.e., bedform drag plus grain friction), so the model keeps the total roughness constant everywhere and at all times (Appendix BII, Page 2-8). This is a major drawback given that there are models in the literature, such as the EPA-supported Environmental Fluid Dynamics Code (EFDC) used for remediation of PCB contamination in the Housatonic River, which allow for coupling between hydrodynamics and sediment transport, thus capturing the effect of morphological changes along the river (http://www.epa.gov/athens/wwqtsc/EFDC.pdf). In nature, the formation and decay of bedforms (e.g., ripples, dunes) results in a continuously changing bottom roughness as the bed morphology dynamically adjusts to changes in flow conditions induced by river currents and tidal action. It is clear that a model such as ECOM-SEDZLJS, which can only reproduce flow and sediment transport patterns associated with a “static river bed morphology,” cannot be used to assess the effectiveness of potential remedial actions requiring a dynamic representation of the river morphology and, hence bed roughness, as submitted in the FFS.

Bed roughness is a key parameter to account for when assessing flow modelling and sediment transport in any natural system, since it influences the velocity gradients near the bed surface, the mixing of near-bed flow and generation of turbulent shear stresses exerted on the bed that entrain sediment. Parameterization of bed roughness within any model is thus critical and must

be based on an assessment of the likely roughness, of many different scales, in the field prototype. As such it is critical in the FFS hydrodynamic model to correctly model sediment transport. However, in the FFS model, bed roughness is highly simplified in that it is assumed spatially and temporally constant over a given computational grid cell (about 400 ft by 600 ft on average), and the one-way coupling between hydrodynamics and sediment transport does not allow for hydrodynamic feedback to the total bed roughness (Appendix BII, Page 2-8). The FFS makes it clear that the hydrodynamic calculations use a "spatially and temporally constant total bottom roughness parameter to generate time and space varying total stress distributions based on changing water depth and bottom layer velocity (Appendix BII, footnote Page 2-7)" but with an incorporation of bed roughness using the van Rijn formulation (1983).

It is important to point out that van Rijn's (1983) bedform predictor was developed with data obtained mainly from unidirectional flows corresponding to laboratory experiments and sand-bedded rivers (Garcia, 2008) making it unsuitable for a river like the LPR where the interaction of tidal flows, riverine flows, and the salt wedge over a bottom covered with both sand as well as fine-grained cohesive sediment, result in hydrodynamic and sediment transport conditions that are very different from those addressed by the FFS models.

Examination of the MBES dataset for 2012 collected for the LPR (Figure C2A-D) illustrates the complexity of the LPR bed roughness and its high degree of spatial variability that is not represented in the model and questions its parameterization, and thus its effects on estimates of bed shear stress. Several issues are apparent:

a. That bed roughness is far more complex than assumed where roughness is divided into grain roughness and then simply bedforms represented by a van Rijn (1983) formulation.

b. Even the bedforms that are present and [are?] not typical of those represented by the van Rijn (1983) formulation. This is evident in: i) unidirectional bedforms that appear to be very low and flat compared to those ripples and dunes characterized in van Rijn's formulation; and ii) bedforms that show the influence of upstream flow and thus flow reversals that will therefore possess a different geometry (and hence roughness value) to those assumed in adoption of van Rijn's formulation that addresses bedforms in unidirectional flows. A proper characterization of bed roughness should examine the spatial variation in bedform type and geometry within the LPR.

c. Some types of bed roughness, and in particular that formed as erosive features within a cohesive bed, or roughness from man-made structures such as cables, pipes and sunken boats are not accounted for in the FFS model. Examination of the MBES imagery shows that much of the LPR river bed is characterized by erosive bedforms cut into what appear to be cohesive substrates. These areas of channel are typically assumed as smooth in the hydrodynamic and sediment transport model and yet will have roughness values that exceed the sand bedforms that are present in sediment patches at different places in the river. The size, shape, and amplitude of these erosive forms require quantification, together with mapping of their spatial distribution, in order to properly examine roughness variations within the LPR.

d. The spatial variations in bed roughness have not been assessed but show a complex arrangement, suggesting spatially–variable roughness should be

assigned within the numerical model at a resolution higher than that adopted. The hydrodynamic model cannot capture the effects of such roughness when the size of the computational grid is far greater than the roughness and where the type of roughness is not quantified.

e. Additionally, analysis of bed elevations at different survey periods (2011 and 2012) clearly show that the bed roughness at a site can vary in time, with this example showing the post Hurricane Irene survey in 2011 and the same areas in 2012. It is apparent that the bed roughness characteristics have changed markedly, largely in response to mobile sediment, presumably sand, moving through the channel.

f. All the images analyzed indicate that across a transverse cross-section of the river, the bottom boundary could be hydrodynamically smooth, transitional or fully rough (Garcia, 2008, Chapter 2), depending on which one of the four computational grid cells employed to characterize the flow distribution in the FFS hydrodynamic and sediment transport models is considered. This will create an uneven flow distribution and bottom shear stress across the channel that will most likely not be representative of the flow conditions in the LPR. Such oversimplification of the bed morphology with this limited cell size results in considerable complexity in roughness being averaged out, and therefore not accounted for, by the current coarse numerical grid.

These points all suggest that a more realistic parameterization of roughness in the LPR is required that should: i) better define the actual roughness and its spatial distribution; ii) assess the temporal variation of bed roughness between survey periods, and iii) examine the influence of these spatial and temporal variations in roughness on the model output, and hence the implications of this for sensitivity analyses and assessment of stability of the sediment bed and any remedial action cap as proposed in the FFS. Even more critical is the fact that none of these goals can be accomplished without the use of a model allowing for two-way coupling between hydrodynamics and sediment transport, hence accounting for the spatial and temporal variability in bed morphology and roughness. Implementing some of the proposed remedies, such as dredging and capping, without having a good understanding of the dynamics of river channel morphology (e.g., meander bend flow), and bed roughness induced by bedforms and scour features, could result in a larger risk of erosion and resuspension of contaminated sediments during floods, as well as an increase in flood stages due to underestimation of flow resistance due to bedforms. All these issues fundamentally call into question the implementability of the proposed remedies.

<u>General Comment 3:</u> Apart from bed roughness, in the hydrodynamic and sediment transport models no attention is given to the type, scale and effect of changing bank roughness and how this may influence flow and sediment transport. The type of bank roughness, and any possible bank roughness improvements, will influence the stress exerted on the bed, sediment erosion, and deposition and thus influence the required dredging depths.

Improvement of river banks along the Lower Passaic River has not been taken into account as an important element in the restoration alternatives proposed in the FFS. However, bank improvements could provide better access to the river, decrease resistance to flow and increase the conveyance capacity of the river during floods. This would require a completely new feasibility study that considers, and prepares cost- and implementability- estimates, for the

entire bankline of the LPR. As explained below, it is quite clear that existing river bank conditions most likely raise flood stages in the river during extreme hydrologic events. If the flow discharge capacity could be augmented with the improvement of the banks (i.e., roughness reduction), the amount of sediment that needs to be dredged could be less than that outlined in the current FFS, since the resistance to flow will decrease and the bottom shear stress exerted by the flow on the river bed will diminish accordingly, thus reducing the risk of sediment erosion and contaminant resuspension during floods.

No attention is given whatsoever to the roughness characteristics of the LPR banks, which show a high degree of heterogeneity, ranging from natural river banks covered with vegetation, metal sheet piling, construction debris, to family backyards. Roughness heterogeneity is mentioned in the FFS (page 36): "The banks of the FFS Study Area between RM1 and RM7 consists of bulkheads and riprap (70 to 80 percent), bulkheads or bulkhead with overhanging vegetation (10 to 30 percent) and aquatic vegetation (5 percent)." However, roughness variation along the banks, which varies with water stage, has not been taken into account in the hydrodynamic and sediment transport modeling. Bank roughness affects the hydraulic radius of the channel (i.e. cross-sectional area over wetted perimeter) and reduces its flow conveyance capacity. During extreme floods, bank roughness can play a large role in flow resistance and flooding extent, and any capping analysis and design should account for the form drag and increased stage potentially induced by bank roughness. Thus the roughness of the river margins needs to be included in the FFS hydrodynamic model. Past work (e.g. Meile et al., 2013) has shown the potential significant effects of bank roughness on influencing the celerity of flood surge waves in a channel, and how roughness may both reduce flood surge propagation velocities and increase water levels. Quantification of such bank roughness could be obtained using LiDAR technology to survey the banks at low tide, possibly combined with MBES surveys of the channel sidewalls in deeper sections of the channel where the banks are not exposed at low flow. Input from this field data needs to be incorporated into the numerical model in order to account for the effects of changing roughness, both spatially along channel and also temporally in response to changing water level within the LPR. The implications of this possible effect are that it could change flow velocities and the turbulence characteristics of flow near the banks, which can affect sediment erosion, and can also change prediction of flood wave height and celerity, with implications for changing water levels and flooding extent. Scour around prominent roughness elements (e.g. piers, sheet piling, caissons) as flow velocity increases could also be a source of contaminants, once a rapid flow erodes deeper into bottom sediments and turbulence increases around, and along, the wake of an object (Liu and Garcia, 2008). Bank roughness is also known to have an effect on the lateral mixing of sediments and contaminants in rivers (Fisher et al., 1979), which is also a factor that has been neglected in the FFS studies. None of these potentially detrimental effects have been taken into account as they should for a remediation project of this magnitude.

General Comment 4: ***The morphological zonation and classification of the LPR bears little resemblance to the features that are present in the bed of the river, with the result that the geomorphological zonation and classification of the river are largely incorrect. This zonation underestimates the considerable roughness present, the extent and complexity of surface roughness and the degree of erosion shown into fine cohesive substrates on the river bed. Bedform morphology is incorrectly described and the grain size analysis is often at odds with the morphological features present. As such, the model thus cannot be trusted to evaluate the response of the LPR to any remedial actions if the river morphology is not initially well-characterized.***

The present morphological characterization of the LPR is extremely deficient and does not reflect the complexity observed in the field based on the MBES surveys. When the morphological features are parameterized (i.e., roughness) for model predictions of the future response of the river system to remedial alternatives, as proposed in the FFS, this translates into a hydrodynamic and sediment transport model that provides, at best, a very crude approximation of the river behavior under different flow conditions and remedial actions. As such, the model cannot be trusted to evaluate the response of the LPR if the river morphology is not initially well-characterized.

The Sediment Transport Model divides and classifies the channel into seven broad categories intended to "help understand the general lateral and longitudinal features in the river" (Appendix BIII, p 3-13). These regions are i) abutments, ii) abutment scour, iii) broad shoals with mudflat and/or point bars on the inside of bends, iv) islands that are above water level, v) margins that are broad shoal areas at the channel edge, vi) smooth channel that is reported to be present throughout much of the river, and vii) deep scoured channel typically at the outside of bends. Examination of the MBES imagery from the LPR shows, however, that these are considerable oversimplifications and that the bed is spatially far more complex than stated. For instance, examination of the lower five miles of the LPR illustrates that much of the channel bed that is labelled as 'smooth' in fact contains a range of erosive sedimentary bedforms, of amplitude between 0.1 and 0.5m, that are presumably eroded into sediment with some cohesive strength. Similarly, MBES images show a range of anthropogenic and natural roughness (Figs C4A-C) that produces a complex geomorphology that is not captured in the present 7-fold scheme. Such simplifications in the present geomorphic zonation conceptual geomorphological model of the LPR thus underestimate and misrepresent the bed conditions present, and undermine the need to better represent such complexity within the LPR model. Such zonation is also important since this feeds the allocation of contaminants within the CARP model (page 4-23, FFS Report), where "individual data points were averaged locally and spatially using geomorphic zones. The geomorphic make-up of each model grid cell was used to assign its concentration."

General Comment 5: ***The bathymetry reported within the FFS reveals that the agreement between the measured bed changes and the modelled predictions are poor and do not show a good correspondence between models and field. Good agreement does, however, underpin successful application of the model to any remediation schemes proposed in the FFS.***

Comparison of field data against numerical modeling output is central to validation and verification of any numerical modeling scheme, in order to show the robustness of the model. This is critical to reveal how well the model can predict channel change and the volume, and spatial distribution, of erosion and deposition. This underpins successful application of the model to any remediation schemes proposed in the FFS. Such a comparison has been conducted in the FFS and displayed for a number of differing years in Chapter 4 'Model Calibration', where the volumetric change in sediment deposition and erosion is calculated for each river mile. However, although in the summary to Chapter 4 in Appendix BII (page 4-30), it is concluded that "The general agreement between the multibeam bathymetric data sets provides a degree of confidence that the model is producing results consistent with a system that is reaching or has reached a quasi-equilibrium bathymetric condition", this statement is not borne out by comparison of the model and field data.

If the longest difference period of high resolution bathymetric coverage is examined (2007-2010; Figure 4-41, Appendix BII), the distribution of erosion and deposition volumes predicted by the model and measured in the field can be examined. Replotting these data on a cross-plot (Fig.

C5) allows direct comparison of the two data sets, with the line of perfect agreement (1:1) and various percentage difference lines being superimposed (i.e. 50% line shows a 50% over- or under-prediction by the model). This plot reveals that the conclusion in the FFS that "The comparison of simulated areas of erosion and that are derived from the data are in reasonable agreement for the vast majority of the 1-mile reaches" (page 4-18) cannot be supported. If the percentage in the volume of erosion calculated when compared to the field measured values is measured, this shows a range between an underestimation of 3900% (Mile 0-1) and an overestimation by 50% (Mile 13-14). Similarly, for volumes of deposition, the agreement ranges from an underestimation in the model of up to 75% (Mile 8-9) and an overestimation by up to 5200% (Mile 14-15). This data questions how well the model simulates the erosion and deposition measured in the LPR from the longest records of high resolution, and highlights that the model is incapable of achieving a good representation of the field processes and erosion and deposition volumes.

Furthermore, the field results presented in MBES bed elevation difference maps (Figs 4-23-4.28) show fine details of erosion and deposition that are not captured in the coarse model grid results (Fig 4-29-4-30), again demonstrating the inadequacy of the model in terms of both spatial resolution and accuracy of prediction of erosion and deposition.

General Comment 6: ***The influence of navigation traffic on enhanced sediment transport and bed scour has been completely ignored within the numerical model and thus sediment transport and bed scour, which influence both fine grained sediment, sand and the engineered cap, may currently be substantially underestimated. Ignoring the possible effects of navigation, especially around RM0 and Newark Bay, renders the analyses done so far, ranging from natural attenuation to dredging and/or capping, practically useless for any meaningful modeling study, since mass balance in the LPR cannot be satisfied. Navigation impacts cannot be ignored as has been done in the FFS.***

The numerical model employed in the FFS makes the explicit statement (Appendix BII LPR Sediment Transport Model, page 2-2) that "Given the added complexity of incorporating ship effects on suspension into the model, and the limited ship traffic in Northern Newark Bay and the LPR, it was concluded that ship-driven resuspension was not necessary for the FFS." Although the ship traffic into the Passaic River is smaller in size and volume than in the adjacent Newark Bay, USACE (2010) provided an analysis of past and future likely use of the LPR for navigation and concluded that "Despite formidable challenges, the Lower Passaic River has established a niche for the transportation of petroleum products to or from major facilities, including those of Motiva Enterprises, Amerada Hess, Sunoco Logistics Partners, L.P., Apex Oil Company at Center Point Terminal Newark LLC, and Getty Petroleum (among others), which are all located below RM 1.7." Additionally, analysis of the *Waterborne Vessel Statistics* (accessed June 2014) shows that 10,676 vessel journeys were made in the Passaic River over the 5 years 2008-2012 in the reach from the river mouth upstream to Gregory Avenue. Here, the controlling depth for ship traffic is 15 feet from the junction of Hackensack and Passaic Rivers to C. R. R. of NJ Bridge, with the balance of waterway ranges being between 6 and 14 feet (*Waterborne Vessel Statistics*). Of these 10,676 journeys, 42% had a draft of 0-5ft (Fig. C6), 13% a draft of 6- ft and 2% a draft of 18-20ft. Whilst the exact details of these journeys are not reported in this database, it is evident that ship traffic does access the lower 1-2 miles of the Passaic River. Furthermore, USACE (2010) assumes that the greatest size vessel to reach or pass RM 2.5 (the upper limit of the thirty foot dredge channel) would be of a size to draw 27 feet or less, assuming three feet of underkeel clearance, and would have a beam of 45 feet or less. In the Point no Point reach (RM 1.2 – 2.5), the constructed channel depth is 30ft but with average depth in the reach being 15ft, with a range of depths from +0.5 to -27ft. USACE (2010)

indicates vessels with drafts of up to 25ft, but with many in the 16-18ft range. In the Kearny reach/ Clay Street Bridge – Congoleum Nairn Company reach (RM 6.1 – 7.1), the authorized constructed channel depth was 20ft but only constructed to 16ft, with average depth in the reach being 13ft, with a range of depths from +1.5 to -21ft. USACE (2010) indicates vessels with drafts of 14-18ft. A summary of drafts and tonnages on vessels accessing the lower 2.2 miles of the Passaic River is given in Table 5 of USACE (2010).

Given these statistics and uses, it is evident that commercial ship traffic has used the lower Passaic River in 2008-2012. Additionally, during recent dredging and remedial action at RM 10.9, and also planned during remedial action under this FFS, dredging vessels and barges would have to access and exit the Passaic River during operations. Consequently, vessel traffic and its characteristics, as well as its possible influence on the natural fine sediment resuspension and engineered cap, must be included in the numerical model. Thus, there is an impact of navigation on sediment erosion and entrainment that is not accounted for in the FFS. This is surprising given that the environmental impact of navigation has been long recognized worldwide (Wuebben et al., 1984; Admiraal and Garcia, 2002).Enhanced near-bed velocities generated by propeller wash has been documented in many previous studies (Hamill et al., 1996) with the magnitude of the propeller-induced velocities and near-bottom velocities (and bed shear stresses) depending of the propeller number, size, power and shaft angle, draft of the vessel relative to the flow depth, vessel speed and current velocity, whether the vessel is transiting upstream or downstream, the vessel length and beam, vessel hull shape and the interaction of the propeller flow with the boat rudder (Wuebben et al., 1984; Liou and Herbich, 1977; Garcia et al., 1998; Hong et al., 2012).

In order to assess the impact of navigation-induced erosion and entrainment into suspension, the forces exerted on the bottom of the LPR need to be characterized. In particular, the spatial and temporal variations experienced by bed shear stresses caused by the passage of a barge tow or ship, must be evaluated (Admiraal and Garcia, 2000; Rodriguez et al., 2002).

As an example, if we adopt the USACE assumption for the Upper Mississippi and Illinois rivers of an up-bound vessel having a length of 1280 ft (barges + tow boat), a boat width of 105 ft, a flow depth of 14 ft, and a draft of 9 ft, and adopt a downstream flow velocity of 3.28 fts^{-1} and upstream boat velocity of 4.92 fts^{-1}, these values can be used to calculate the estimated near-bed flow velocities and bed shear stresses. These figures reveal that the flow velocities and bed shear stresses exerted under this vessel may be as large as 13.1 fts^{-1} and 46 Pa respectively, thus representing a 4 and 46 times increase in flow velocity and bed shear stress, respectively, to the case when the ship traffic is not considered (Garcia et al., 1998).

The total amount of sediment entrained and resuspended by the boat considered above can be estimated with the methodology proposed by Garcia et al. (1999), which makes use of the Garcia-Parker sediment entrainment function adapted to the case of unsteady, rapidly varying flows (Garcia et al., 1999). This approach makes it possible to estimate the total amount of sediment entrained by the front, hull, propeller and wake of the boat. If we assume that the bed is covered with non-cohesive sediment having a mean diameter of 0.5 mm (approximately 0.02 inches) and a settling velocity of 0.25 fts^{-1}, the rate of sediment entrainment by the front and hull is estimated as 4.41 ft^3s^{-1} while the boat propellers and its wake resuspend bed sediment at a rate of 161,528 ft^3s^{-1}. The total amount entrained by the barges (barges + tow boat) is thus 161,533 ft^3s^{-1}. Although these results are approximate, they give an indication of the huge amount of sediment that is resuspended during barge passages, in particular the impact that the propeller wash has on resuspension. The results can be even more dramatic if we consider a smaller sediment size that is more characteristic of most of the LPR, not only because of the

larger volume expected to be entrained into suspension, but also due to the fact that the finer material can remain suspended for a longer time in the water column, unlike the 0.5 mm considered herein that re-deposits almost immediately. The order of magnitude of the computed values of resuspended sediment agrees with that reported by Sutton et al. (1996) and corresponding ship maneuvering.

The amount of scour induced by the boat propellers can also be estimated. In the case of 0.5 mm sand, the scour would reach a maximum value of about 0.3 ft but if the bed material is finer and has a mean diameter of 0.1 mm (0.004 inches), the maximum scour depth could be as much as 33 cm (about 1 foot) for a smooth bed, and about 40 cm (1.3 ft) deep if a rough boundary is considered (Garcia et al., 1999). Once again, these results highlight the importance of correctly assessing the river bed roughness. It should thus be clear that the impact of navigation on sediment erosion, entrainment into suspension, and transport cannot be neglected as it has been done in the FFS since its impact could be huge, in particular for the different alternatives that are being considered for remediation of the LPR.

Further evidence for the likely influence of ship propeller resuspension is given the Appendix BII of the FFS (Sediment Transport Model) in relation to the calibration of acoustic instruments for TSS concentrations. Data collected for this procedure from the Kill van Kull and used in the TSS calibration (page 3-10 and Figure 3-15 (middle panel, bottom row)) show evidence of some elevated TSS concentrations in the upper water column. Appendix BII (page 3-10) states that these elevated values were "…suspected to be caused by boat wake interference and screened out of the analysis if the concentration was more than two times greater than the next deeper vertical bin'. Figure 3-15 (middle panel, bottom row) of Appendix BII shows values in the upper water column (13.5m above bottom) of up to c. 170 mgL^{-1}, with values near bed (within 2m of the bed) being <50 mgL^{-1}. This data and explanation within the FFS thus suggest that boat-generated suspension is likely. Additionally, papers by Clarke et al. (2007a,b) highlight the resuspension of sediment in the Newark Bay area can be produced by both dredging and ship traffic. Clarke et al. (2007b) conclude that "The passage of several tugs in tandem with barges, while disturbing the upper portion of the water column, did not appear to measurably affect the bottom…. However, acoustic signatures clearly depicted large areas of bottom and water column disturbance for maneuvering container ships, with evidence for significant movement and resettlement of sediment…….The frequency of deep draft vessel arrivals and departures on a daily basis suggests that vessel movements probably represent a significant contribution to the net sediment suspension budget in the Newark Bay system." Although this study was not conducted in the LPR, it further highlights the potential suspension of sediment by ship traffic, as explained earlier, especially when maneuvering vessels and barges in the narrow, constrained, LPR, and such effects will depend on the list of controlling variables listed above, including boat size, draft and the depth and velocity characteristics of the LPR. It also suggests a navigation-induced flux of fine sediment in Newark Bay that may be transported into the LPR, and that the downstream boundary condition for the river must include this flux.

The possible importance of ship-driven re-suspension was raised in the Peer Review of the Sediment Transport Model (2013) that stated "The authors mention in the BII report that they did not include wind-driven or ship traffic-driven re-suspension in NB in the model. I would suspect that these are the most likely drivers of re-suspension in the Bay and resulting contaminant concentration at the boundary between the Bay and RM 0 of the Lower Passaic River. Therefore, these processes need to either be included in the model formulation or an analysis needs to be presented that convinces the user that they are indeed not important." However, the reply to this point states "Ship generated resuspension was not included in the FFS modeling. An inspection of ship traffic information from several months indicated that the vast majority of

ship traffic occurs south of the Port Newark Channel, and most of that occurs into and south of the Port Elizabeth Channel. Ship-driven resuspension is being evaluated for the Newark Bay Study Area, but was judged to be too limited in the Passaic River and northern portion of Newark Bay to warrant inclusion in the FFS modeling. Additional information on both of these topics will be included in the final modeling report." However, this statement directly contradicts both the data presented above on ship traffic in the LPR and also with the statement in the FFS Report that "Despite various constraints described in Chapter 3 of the RI Report (*e.g.*, shallow depths, low vertical clearance bridges), the lower two miles of the river are used for commercial navigation by a number of companies. A berth-by-berth analysis for 1997-2006 done by United States Army Corps of Engineers (USACE) established current waterway use and a survey of commercial users showed clear future waterway use objectives in the lower 2.2 miles of the river (USACE, 2010)." (FFS Study Report page ES-3). This highlights possible increasing navigation traffic in the future in the LPR. Both of these suggest a clear need for such an analysis of navigation and dredge-induced resuspension in the LPR. No further details of assessment of this source of resuspension were provided in the final modeling report.

Additionally, it is worthy of note that other investigations into contaminant remediation in the region, such as that at the Gowanus Canal (Gowanus Canal FFS, Appendix D) include an analysis of navigation-induced resuspension. This analysis was conducted to evaluate the potential effects of propeller wash on sediments in the Gowanus Canal in Brooklyn, New York, to support the development and evaluation of remedial alternatives in the Gowanus Canal feasibility study. This involved an analysis of boat and canal properties, with the canal depths ranging from 11 to 23 feet. The report indicates the potentially significant effects of propeller wash and that this had to be included in order to estimate the correct size of capping material in the Gowanus canal (which was recommended as 0.76 feet diameter). It is evident that such analyses should also be conducted for the LPR and included in the modeling in order to assess sediment entrainment and the possible effects of selection of capping materials and their stability.

In summary, the likely extent and magnitude of barge- and ship-induced bed erosion through enhanced near-bed flow velocities and shear stresses are not modelled or considered within the FFS, but the likely effects of such erosion within different regions of the river requires assessment. This modeling should examine both the commercial traffic that uses the river as well as the tugs, barges and boats that would be used in the remedial action dredging and fill operations (see YouTube, 2014), to assess the magnitude of these effects and the modification of the remedy selection to account for these increased bed shear stresses. Of particular importance to the remedy selection is that by ignoring the effect of navigation around RM0 and Newark Bay, the downstream boundary condition for TSS used in the model is basically unknown; this therefore renders all the analyses done so far, ranging from natural attenuation to dredging and/or capping, practically useless for any meaningful modeling study, since mass balance in the LPR cannot be satisfied. Navigation impacts cannot be ignored as has been done in the FFS.

General Comment 7: ***The presence of ice on the Passaic River in winter months, and the possible influence of ice cover and ice jams upon sediment transport and bed scour have been ignored within the numerical model. Thus predictions of sediment transport and bed scour, that may entrain both fine grained sediment and the engineered cap, may currently be erroneous under these conditions.***

Ice effects on sediment transport may be noticeable over varying scales of time and channel length. On the scales of months and of miles of channel, for instance, ice alters the relationships

between flow rate, flow depth, and sediment transport rates. As it forms, an ice cover usually increases and redistributes a channel's resistance to flow and reduces its overall capacity to move water and sediment (Ettema, 2008). An ice cover imposes an additional resistant boundary that decreases the flow capacity of a channel and vertically redistributes streamwise velocity of flow in the channel. If the cover is free-floating, it may reduce the erosive force of flow in the channel and thereby reduce rates of sediment transport. However, the presence of ice cover may also laterally re-distribute flow, usually concentrating it along a thalweg or navigation channel. If the thalweg lies close to one side of a channel, flow concentration may locally increase bank erosion and channel shifting. On the other hand, if the thalweg is more-or-less centrally located in a channel, the cover may reduce bank erosion and channel shifting. Additionally, if the full cover were fixed to the riverbank, it may increase locally flow velocities and rates of sediment transport. The variability of flow response to ice-cover presence makes it difficult to draw simple overall conclusions about ice-cover effects on the bed and banks of a river and the net effects will vary from site to site. At the local scale, an ice cover over a short reach may re-distribute flow laterally across the reach, accentuating erosion in one place and deposition in another place. Such local changes of the bed may develop during the entire cycle of ice formation, presence, and release. They may develop briefly, lasting slightly longer than the ice cover and disappear shortly after the cover breaks up, or may trigger a change that persists for some time. In any event, they should be verifiable from a site investigation.

Ice may dampen or amplify erosion processes locally. Obvious dampening effects of ice are reduced water runoff from a watershed, cementing of bank material by frozen water, and ice armoring of bars and shorelines by ice-cover set-down with reduction in flow rates. Yet, ice may amplify erosion and sediment-transport rates, notably during the surge of water and ice consequent to the collapse of a large ice jam.

The direct effect of imposing a level ice cover on a two-dimensional open-water flow is to increase substantially the wetted perimeter of flow. For a wide channel, the wetted perimeter is almost twice that for the open channel flow. The usual consequence is increased water depth, for a constant discharge and bed slope. As roughness characteristics of the ice-cover and the bed will likely differ, the influences on velocity distribution and flow resistance of the roughness of bed and ice-cover underside must be taken into account.

Although ice on the Passaic River is relatively rare, with one hour of ice conditions (2014-1-7 at 0200-0300) reported at the Newark USGS tide gauge (at RM-5 in 1993-2003) and ~RM-0 for the entire 1993-2003 record, ice can occur and have significant effects. For instance, in February 2014 ice formation on the LPR forced temporary cessation of dredging operation at RM10.9. Ice conditions on the river in 2014 raised some concerns about ice jams within the river and culverts (http://www.northjersey.com/news/potential-in-passaic-valley-for-snow-ice-to-jam-up-rivers-culverts-1.657285). Reports of tug and barge traffic transiting the river show the extent and thickness of the ice present in 2014 (YouTube, 2014). This state of awareness in January 2014 alerted the public to potential ice jam and flood risk events along the Passaic River (http://www.tredyffrin.org/home/showdocument?id=3025).

Past work (e.g. Ettema et al., 2000; Kellerhals and Church, 1980; Lau and Krishnappan, 1985) has indicated the appreciable influence that ice may have on sediment transport and erosion through acceleration of flow under ice jams, and that additional scour may be produced by such a process. Formation of such ice jams has been found to be capable of scouring engineered caps (i.e. the Grasse River, Northern New York State; http://www.thegrasseriver.com/ice_mgmt.html). Although the formation of ice on the LPR may be rare, the potential effect of such build ups should be assessed to indicate if any appreciable

scour generated by ice could affect the bed or the engineered remedial cap, and if modifications to the remedial strategy are required to account for this. Sections of the LPR prone to ice formation should be treated differently from other areas that do not experience any ice formation. While one section of the river could be left alone (natural attenuation), another section of the river could undergo dredging and capping. This scenario is better than just dredging the whole 8.5 miles of river from bank to bank without taking into account the impact of ice formation.

General Comment 8: ***Assessment of erosion of the capping material provides estimates of the entrainment of the coarsest particle sizes within the UBS (Upland Borrow Sand) but does not detail the entrainment of the finer grain sizes within the sediment size distribution. It is thus unclear as to how much of the size distribution will be entrained and how effective the UBS will be as a capping material. Additionally, the influence of bedform generation in causing scour depths in excess of those predicted has not been assessed. Use of a coarse armor layer of 0.5ft diameter stone also is likely to cause infiltration of sediment into the interstices of the gravel. The loss of this sediment and any preferential accumulation of fines within the armored cap have also not been assessed. These issues all question whether the analysis of sediment entrainment from the engineered cap using the UBS and presented in the FFS is reasonable. Implementation of capping as a remedial action thus needs to be re-considered, since the material to be used, as well as the cost and construction of the cap, could result in a remedial action that is not truly viable from a technical and economic point of view.***

Analysis of the cap stability under a range of flow conditions is assessed (Appendix BII) using two different sand size distributions, with the UBS being the one that is recommended for adoption as the capping material, with armor blocks being placed in some areas where high bed shear stresses are present. Entrainment of the capping sand is modelled for a series of differing return period floods over a ten-day period and using several size classes for each layer of sand. The results show that 'in most locations bottom shear stresses do not exceed the critical threshold for erosion of the largest grain size (12,500μm < τ_{ce} = 111.2 dynes cm^{-2}) of the USB capping material" (Appendix BI, page 5-16). However, this size range only accounts for 5% of the size distribution of the UBS, with the UBS possessing grain sizes from 150-12,500 μm (Table 5-2, Appendix BI, page 5-10). Consequently, the rest of the sediment size distribution will be more mobile than the 12,500 μm diameter size fraction, but this is not analyzed in the FFS. For instance, if the plot presented in Figure 5-8 of FFS Appendix BI is examined, the critical entrainment thresholds of all the sediment size classes given in Table 5-2 can be overlain on the plots. As an example of a site where the modelled bed shear stresses are high (RM 3.11: Figure C8-1), it is evident that the critical shear stresses for most of the size fractions are below the modelled shear stresses for much of the time. This implies that the erosion risk of such material is fairly high (Lopez and Garcia, 2001). The risk of non-cohesive sediment resuspension is known to increase with the ratio between shear velocity and fall velocity (Figure C8-2), and thus it is important to estimate both the total bottom shear stress and the fall velocity of the sediment in order to correctly predict sediment resuspension (Lopez and Garcia, 2001).

Additionally, the progressive winnowing of the finer grains is argued to produce an armor layer that would be more immobile, but the amount of erosion of the UBS that would be required to produce this armor layer, and of sufficient thickness, is not investigated. Furthermore, the effect of having mixed sizes on the threshold for sediment erosion is also not taken into account (Nino et al., 2003). If such hiding and armoring effects are not taken into account, rates of sediment entrainment can be overestimated. In areas where the coarsest size fraction is required to produce the armor layer, then presumably 95% of the UBS sediment would have to be eroded

to produce this armor. In a cap thickness of 2ft, this would imply an erosion of *c.* 1.9 ft is needed to yield a stable armor layer only of this grain size. Additionally, no analysis is given of possible bedform generation in the UBS that may produce a bed morphology whose amplitude may allow scour into the UBS and result in additional form-related roughness, turbulence generation, and higher bed shear stresses. It is clear that the implementation of capping as a remedial action needs to be re-considered, since the material to be used, as well as the cost and construction of the cap, could result in a remedial action that is not truly viable from a technical and economic point of view.

General Comment 9: ***The sediment transport model uses a conceptualization of the near-bed sediment distribution, consisting of the uneroded bed, a transitional layer, an active layer and a "fluff" layer. The justification for this flow structure and sediment bed properties, and its parameterization in the model, which play a large part in the estimation and prediction of sediment transport rate, is unjustified and lacks any rigorous scientific rationale.***

The sediment transport model cannot be used to predict "bed armoring" resulting from the action of a turbulent flow over an erodible sediment mixture. The model uses a 1 mm thick "fluff layer" and "transitional layer" which serves the purpose of ensuring numerical stability, but has no physical meaning other than allowing the sedimentation model to compute bed erosion. The current model cannot reproduce sorting of sediments with depth and therefore cannot be used to assess remedial actions such as dredging and capping.

The Exner equation of sediment conservation is the basis upon which river morphodynamics stands. In the case of mixtures of different sediment sizes, it is customary to formulate sediment conservation in terms of multiple discrete layers stacked in the vertical (Parker, 2008). In the simplest of these formulations, the bed is divided into two layers; an "active" ("surface," "exchange") layer, which directly exchanges sediment with the water column, and a "storage," ("substrate") layer below which sediment exchanges with the active layer by means of aggradation and degradation (Hirano, 1971; Parker, 2008). The discrete layers of such active layer formulations, however, are a gross simplification of the vertical structure of a bed deposit, which should show a continuous variation in the vertical when averaged over area. The discrete active layer formulation should be replaced by a fully continuous probabilistic formulation. However, the FFS sediment transport model ignores all the literature on transport of sediment mixtures and falls short of what is required (e.g. Paola and Seal, 1995; Wilcock, 1988) to fully assess bed armoring and cap stability in the LPR. Hence, the remedy selection is based on the wrong arguments and assumptions. If armoring is desired for bed protection, why not introduce sediment downstream of Dundee Dam so that the river itself builds over time its own armor and prevents resuspension of contaminated sediments? This remedial alternative should be considered and assessed.

General Comment 10: ***Assessment of erosion of the capping material is provided for a ten-day simulation using the 100-year return flow. No assessment is given of the total erosion expected for a sequence of differing flows over a design period to include the effects of flow turbulence, and likely between cap maintenance works, and thus there is no evidence presented as to the total potential erosion of the cap over a design period, or in the long-run, that would be yielded by an expected sequence of events rather than one flood of a certain size. As such, the likely prediction of sediment entrainment from the cap over a period of time, and accounting for the turbulent flows present in the LPR, is uncertain.***

Analysis of the cap stability for the UBS (Appendix BI, page 5-15) is modeled for a ten-day period of the 100-year return flow event. However, the analysis does not seem to take into account the role of turbulence and armoring on the cap stability (Egashira and Ashida, 1990).

The dimensions of the lower Passaic River make it necessary to take into account large fluctuations in bottom shear stress due to the high turbulent flow intensities that can be expected during high Reynolds number flows associated with riverine floods and extreme events (e.g. Sandy, Irene). Santa Cruz and Garcia (2014) have recently modified a method based on the ideas of Grass (1970) and first proposed by Gessler (1971) to estimate armoring of stream bottoms having a wide range of sizes. A schematic of the method is shown in the Figure C10. This method can be used to estimate the stability of a cap and the potential for armoring. Given a bed shear stress and sediment size distribution, the method will determine the stability of the cap as well as the size distribution of the material forming the armor layer. Preliminary computations suggest that the cap material proposed in the FFS will not be stable under all possible flow conditions (i.e. wide range of bottom shear stresses). However, the method needs to be extended to include the presence of cohesive sediments before any conclusions can be reached. Recent work by Mier and Garcia (2011) on the erosion of glacial till in the St. Clair River provides a good starting point, since the empirical relation obtained for the erosion of fine-grained cohesive material (Figure C11) collapses rather well data from several rivers with contaminated sediments similar to the LPR. It is clear from this figure that viscous effects do play an important role in providing a “natural cap” for sediments, suggesting that water temperature is an important parameter for consideration. Some sediment could be more easily erodible than other at certain times of the year, depending on their location in the river bottom and local water temperature. Hence it is relevant to consider a proper thermal/hydraulic model for the river, besides a hydrodynamic model, to analyze stability of river beds, armoring and capping (Liu et al. 2012).

<u>General Comment 11:</u> In the CARP model, the sediment bed is split into six layers that are presumably horizontally stratified. However, natural sedimentary environments sort and deposit their sediment according to the processes operative within the environment, with the result that the internal sedimentary architecture of many fluvial and fluvial-tidal deposits is complex, with stratigraphic surfaces, and grain size differentiation, commonly being non-horizontal. A representative subsurface sedimentary structure should thus be constructed to allow proper simulation of subsurface contaminant movement. The remedy selection does not take into account the stratigraphy of the riverine sediments, and by proposing to dredge from bank to bank, could be causing more harm than good since most contaminants may be more deeply buried in the sediments.

Natural fluvial sedimentary successions are constructed by the movement of topographic forms, of various scales, within rivers. As such, the sedimentary sequences that are produced are rarely flat and horizontal, but rather reflect the topographic forms that have produced them. An example of this is deposition on point bars on the inside of meander bends that generate depositional surfaces that dip across channel, mirroring the original point bar surface. This suggests that a realistic layering of sediment in the subsurface is not horizontal but rather reflects the sedimentary evolution of the area. This non-horizontal layering may thus complicate layering adopted within the CARP model and suggests such layering may be different spatially within the channel and that depth below surface may have different grain size and strength characteristics depending on location within the channel. A more realistic CARP model of the subsurface should thus seek to quantify this sedimentary structure and its variability within the LPR in order to more correctly model the sedimentary layering and its spatial distribution. The

FFS remedy selection may thus be based on an erroneous representation of the subsurface sedimentary structure, and its grain size characteristics. Since the remedy selection does not take into account the stratigraphy of the river sediments, proposals to dredge from bank-to-bank could be causing more harm than good since most contaminants may be both more deeply buried in the sediments, and vary spatially according to the subsurface sedimentary structure.

Furthermore, existing guidelines provided in Transportation Research Board Special Report No. 262 (National Research Council, "Process for Setting, Managing, and Monitoring Environmental Windows for Dredging Projects") that is commonly used as a management tool for reducing the potentially harmful impacts of dredging activities on aquatic resources, have been completely ignored, suggesting that the true environmental impact and risks associated with the proposed bank-to-bank dredging of the LPR are both poorly understood and marginally quantified in the FFS. The bank-to-bank remedial action could be causing more harm than good (Transportation Research Board, 2001).

General Comment 12: ***Recontamination. No account is given whatsoever of the recontamination of sediment in the LPR due to input from areas both upstream of RM 8 and downstream of RM0 both during and after any remedial dredging and capping. Consequently, the remediation scheme proposes clean-up for the lower 8 miles of the LPR but does not assess the long-term accumulation of contaminants in the newly engineered cap.***

The FFS acknowledges flux of a range of contaminants into the reach from both upstream and downstream boundaries, as well as from resuspension from within the LPR. As such, fine sediment and contaminant transport will occur into the reach both during and after any remedial dredging and capping. As such, the remediated capping and channel will be subject to recontamination, starting immediately after the capping is completed in each section of river. In fact, contamination of the engineering works may be amplified through the suspension of fine sediment that is caused by remedial dredging up and downstream of any completed cap, that may be transported there by the ETM, and/or river floods. No account of recontamination is presented within the FFS, including the rate of recontamination and the effect of any coarse cap (whether UBS or 6inch armor) on the infiltration of fines into the bed. An assessment of this recontamination is required during both the period of dredging and cap emplacement, together with the longer term input of contaminants from up and downstream and their longer term retention within the engineered cap. By depositing sediment on top of a cap, these sediments may be more easily resuspended, thus increasing bioaccumulation and risk to humans that use the river for recreational purposes.

General Comment 13: ***The hydrodynamic and sediment transport model has very poorly constrained boundary conditions, including specification and quantification of the sediment load (both suspended sediment and bedload) coming over Dundee Dam, and the suspended sediment concentration at Newark Bay (RM 0). These values strongly influence how much material will be transported upstream via tidal action and within the ETM, as well as the characteristics of the material being deposited. Without better constrained boundary conditions, the flux of sediment coming into and exiting the LPR is very uncertain, leading to great uncertainty in the reliability of the sedimentation estimates used in the remediation scenarios.***

If the amount of sediment and attached contaminants entering the LPR cannot be quantified, the present selection of remedial actions would be based on the premise that by dredging and/or capping a portion of the river, the risk to humans and biota will be reduced. However,

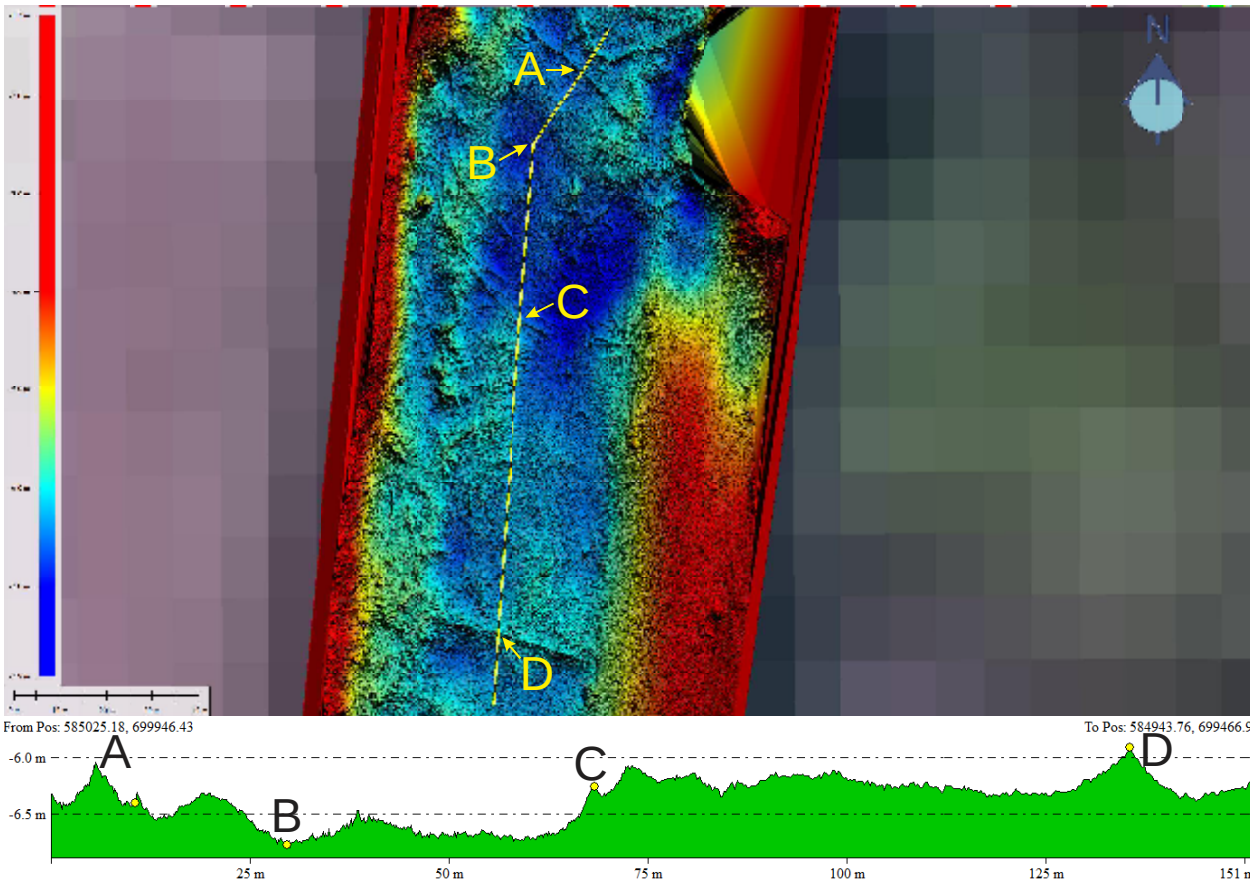
potentially the greatest risk does not come from the sediments along the 8.5 miles of the LPR, but rather from the contaminated sediments that continue to enter the river from upstream of Dundee Dam, all the tributaries, the combined sewer overflows (CSO) and, most importantly from Newark Bay that is likely the most important source of sediments to the LPR.

The amount of sediment in suspension in Newark Bay depends strongly on navigation-induced resuspension, which has been completely neglected in the hydrodynamic and sediment transport modeling. The amount of suspended sediment in the water column determines how much material can be transported upstream by tides and residual currents. Ignoring such important boundary condition renders the analysis of any potential remedial actions useless.

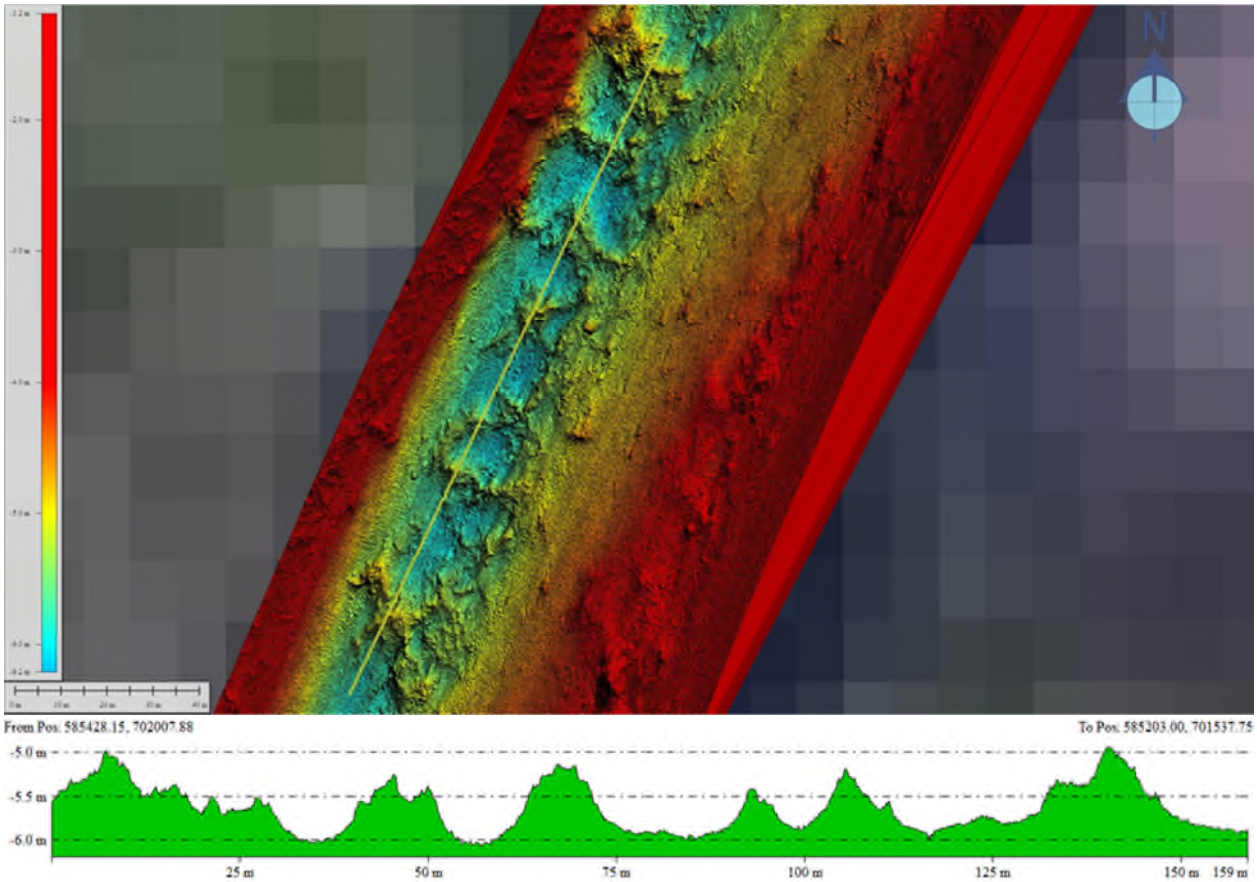
Figures

(Note: the Figures refer to the relevant specific general comment; e.g. Fig. **C2** for General **C**omment **2** and Figure **C5** for General **C**omment **5** etc. Also note that not all General Comments have associated Figures).

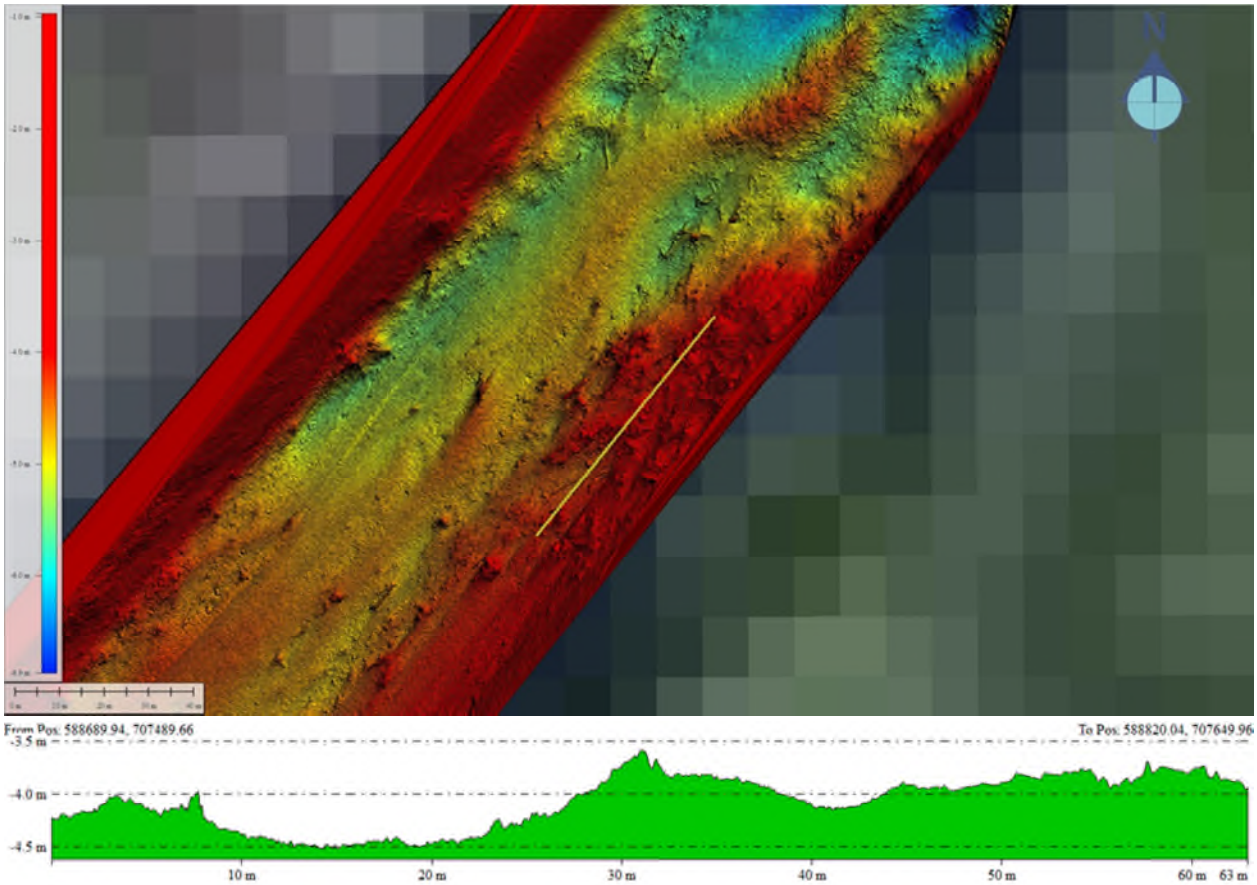
Figure C2: Examples of geomorphic complexity and variable bed roughness revealed by the 2012 multibeam echo sounder survey. Each figure shows a morphological map of an area of the LPR, with the section below each panel illustrating the bed morphology along the yellow line shown in each plot (upstream to downstream in A, B, C, and E and left to right on 2D).



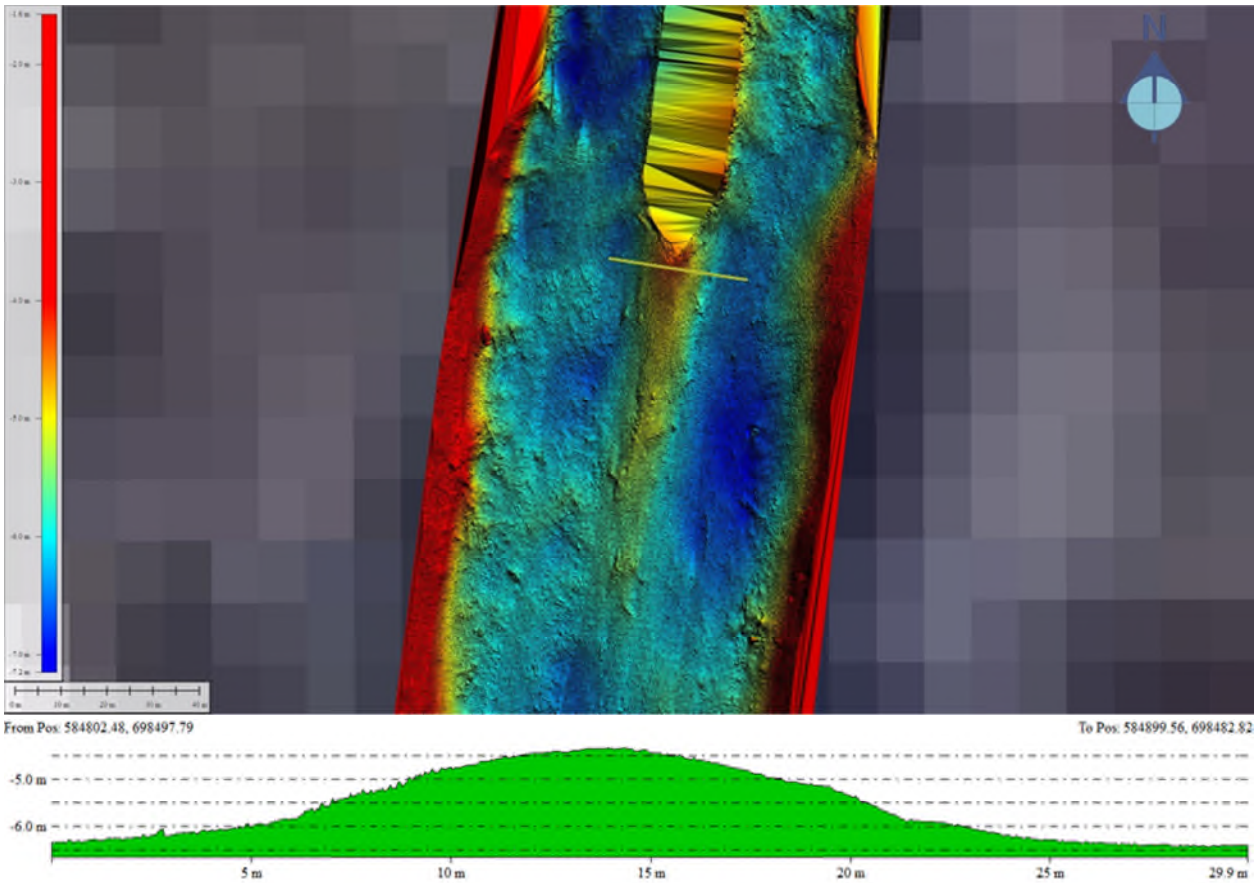
A: Roughness created by man-made objects, such as cables and unidentified debris (labelled A, C and D).



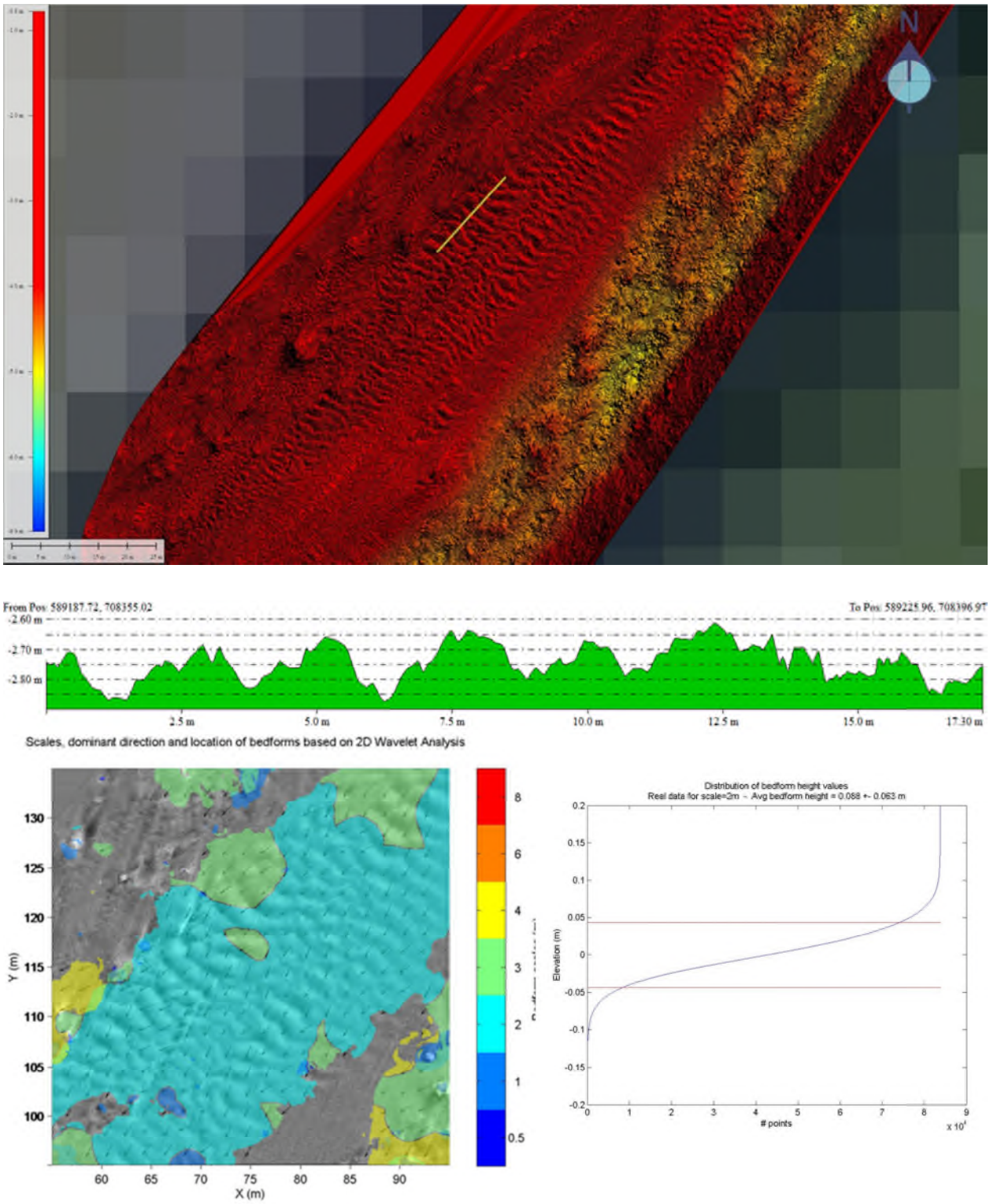
B: Roughness created by erosion into cohesive sediment, which is typical of much of the LPR, illustrating very irregular topography with an amplitude of *c.* 0.6 - 1m.



C: Roughness created by erosion into cohesive sediment, which is typical of much of the LPR, illustrating very irregular topography with amplitude of *c.* 0.2 – 0.5m. Note eroded irregular smaller higher areas of bed in this plot, which represent erosional remnants within a cohesive bed.



D: Roughness created by sediment deposition generated downstream of a pier abutment**.**



E: Roughness created by mobile bedforms in cohesionless sediment. The lower plots show a wavelet decomposition of a bedform field (left) in an adjacent area of channel, yielding a quantitative representation of this roughness and the bedform height (mean height = 0.088m +/- 0.068m).

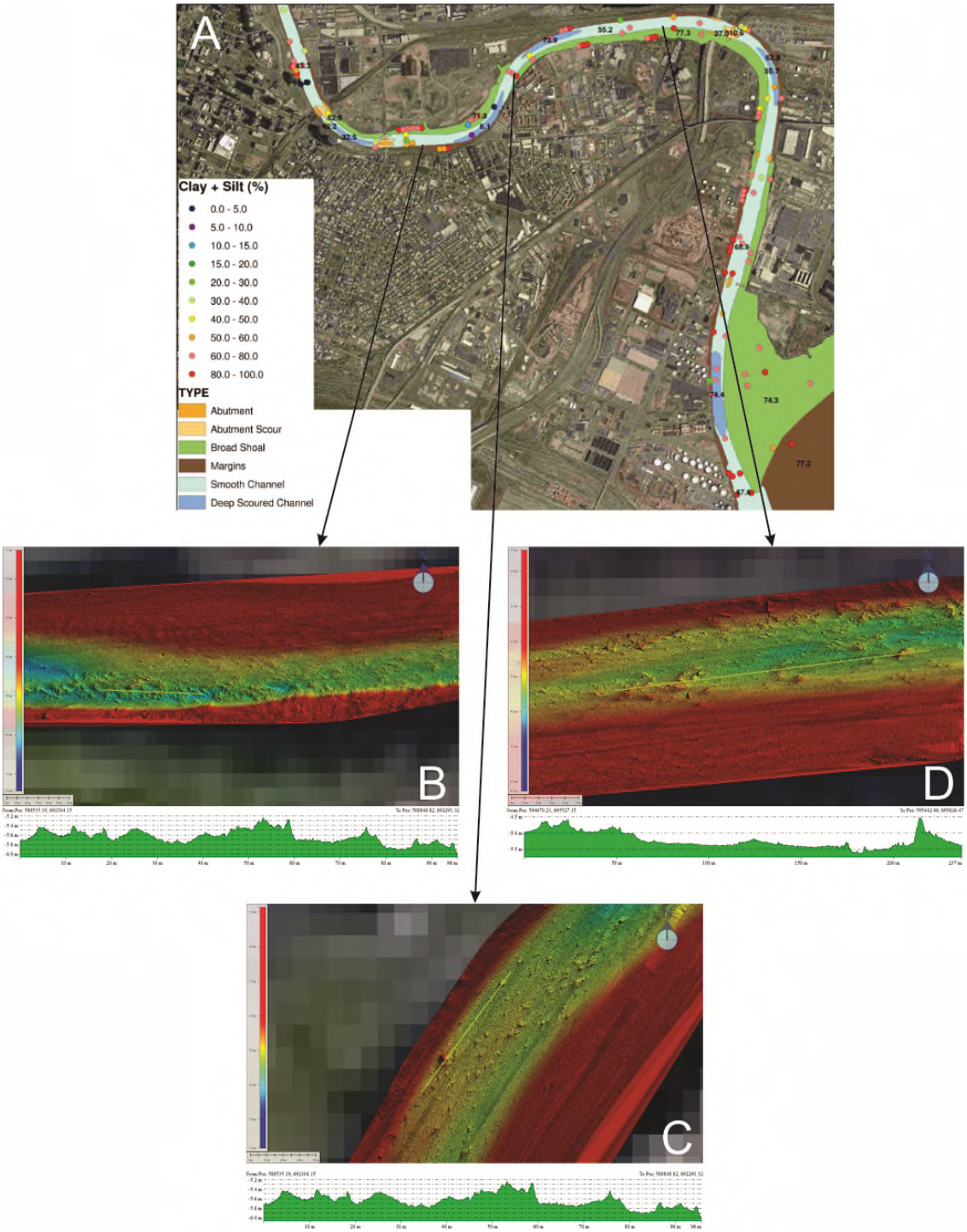


Figure C4: Example illustrating the geomorphic complexity of erosional forms (B, C, D) in areas of channel classified as 'smooth' (A) in the FFS (from Attachment A, Fig. 4 with clay and silt % marked on geomorphic classification).

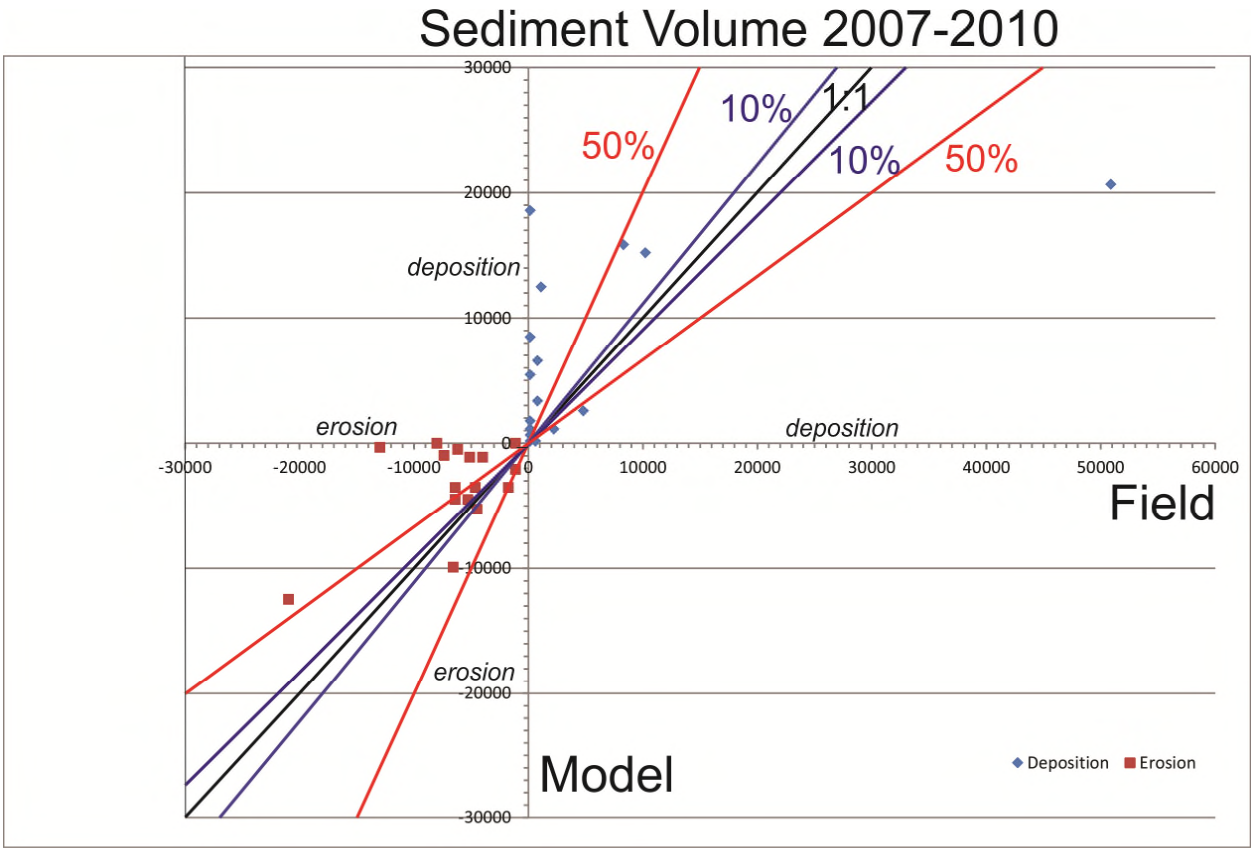


Figure C5: Plot of the volume of sediment change (in m^3) measured in the field versus that modeled in the FFS. Negative values indicate erosion whilst positive values denote deposition. A 1:1 line indicates the line of perfect agreement between model and field, whilst the percentage values indicate the deviation from the field case for the modeled values. Note the values that lie outside 50% of the field case, especially where the volume of erosion or deposition is large.

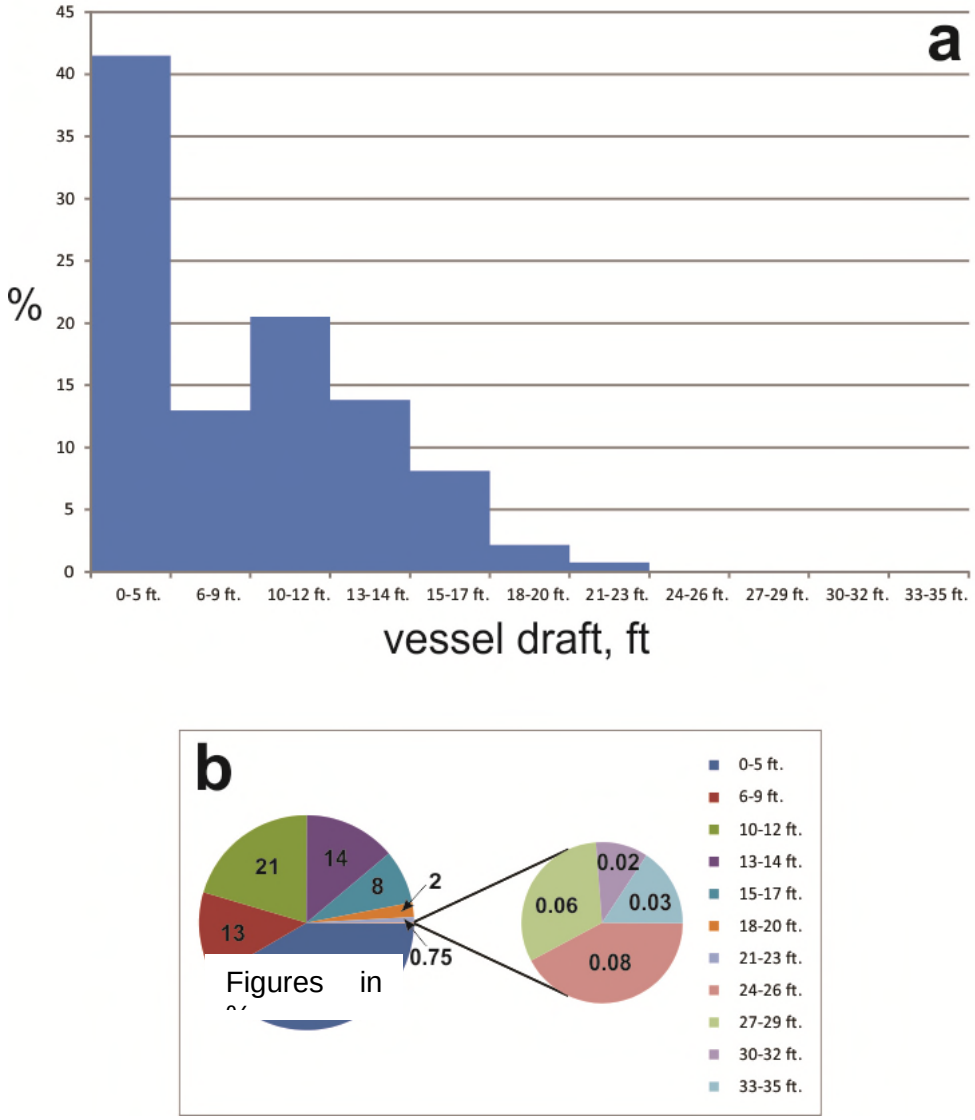


Figure C6. Ship traffic in the LPR, 2008-2012. This data is drawn from the *Waterborne Vessel Statistics* and shows 10,676 vessels accessed the LPR in its lower 14 miles for inward and outward journeys. a) Distribution of vessels of differing draft; b) Pie-diagram of percentage occurrence of vessels of differing draft, with detail shown for larger vessels with > 21ft draft (that are difficult to discern in the left pie diagram).

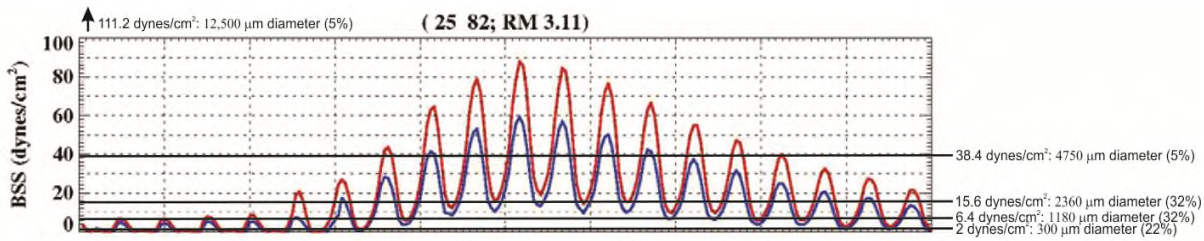


Figure C8-1: Plot of bed shear stress at location 25 82, RM 3.11 for a modelled time period of 10days, showing the fluctuation in bed shear stress for two scenarios (Red - Capping with armor area, pre-dredging; Blue - Capping with dredging for flooding, exposed armor areas) (Fig. 5-8 Cont'd; third panel), but with the critical entrainment thresholds for various grain sizes superimposed. The entrainment threshold shear stress and grain size are shown at the end of each line, with the percentage values indicating the percentage of sediment with that median grain size within the UBS sediment.

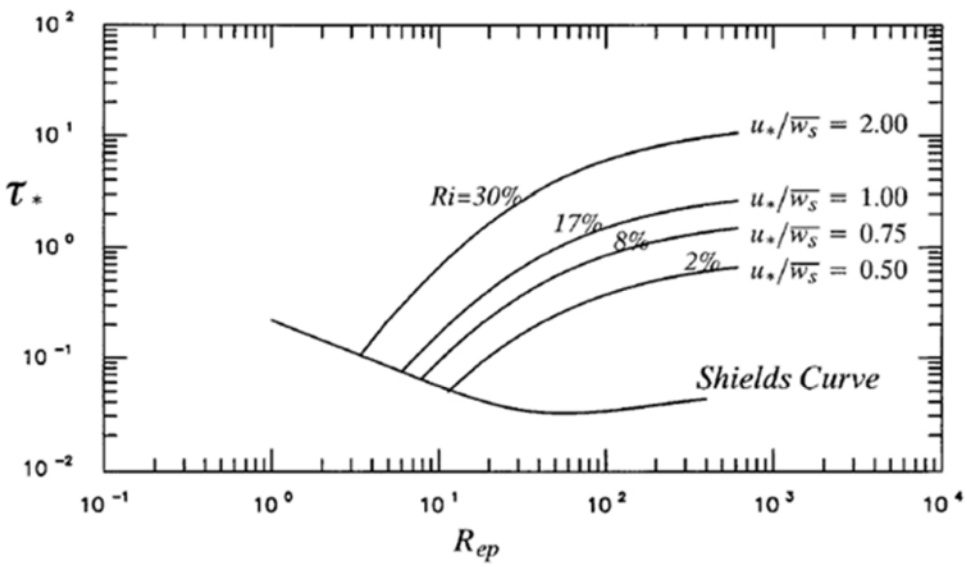


Figure C8-2: Plot of dimensionless shear stress against particle Reynolds number, showing the sediment erosion threshold, and illustrating the control on entrainment by the ratio of bed shear stress to the settling velocity of the sediment (from Lopez and Garcia, 2001).

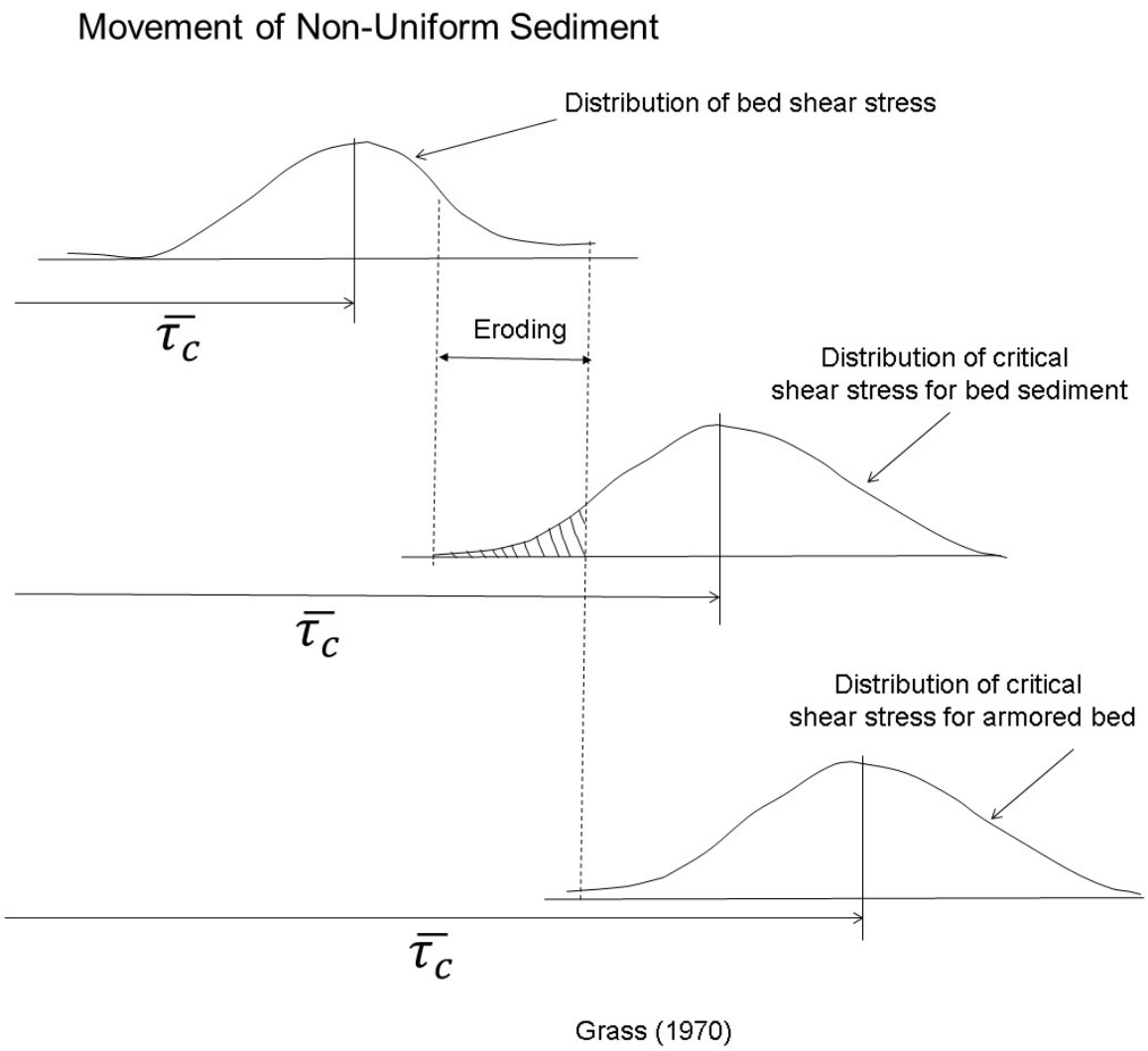


Figure C10. Schematic diagram of probabilistic method of Grass-Gessler adapted to predict the development of an armor layer in a channel revetment under the action of a highly turbulent flow like in the case of the LPR during an extreme flow event.

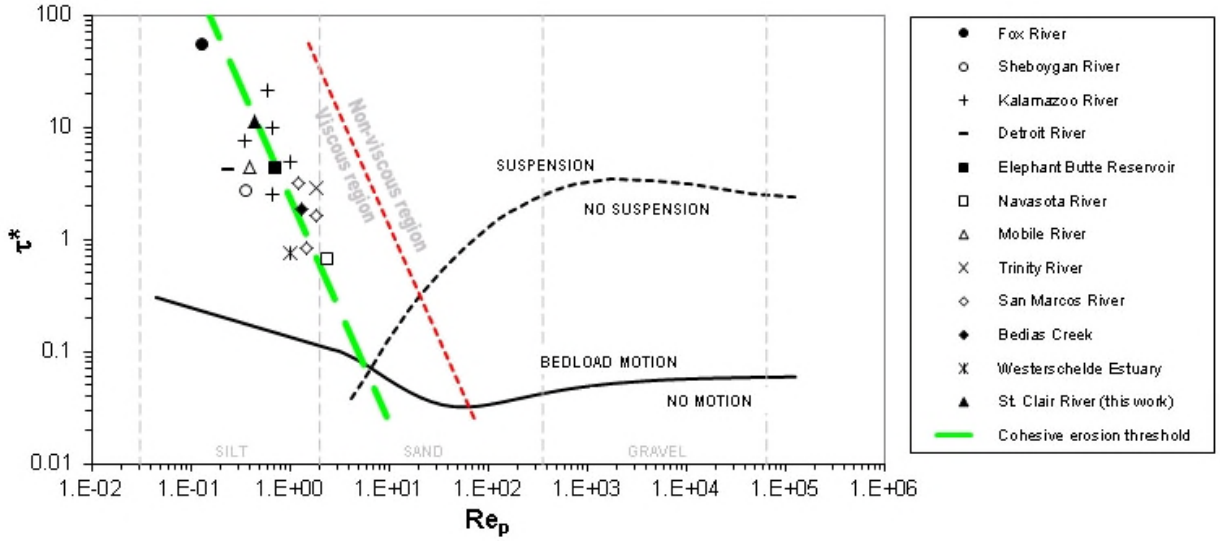


Figure C11. Values of critical shear stress for erosion of fine-grained cohesive sediments plotted on a modified Shields diagram. Reynolds particle number (Rep= (RgD)0.5 D/v) against Shields number ($\tau^*=\tau_b/(\rho RgD)$), both dimensionless (from Mier and Garcia, 2011).

Specific Comments

Appendix BI: Hydrodynamic and Sediment Transport Evaluation

Comment BI-1: p.5-1: No analysis of the transport of fine-grained sediments was conducted in this study, and yet fine-grained material will continue to be transported into the LPR during and after remedial capping, and these fines can be expected to infiltrate into, and be deposited on, the coarser grained cap. An analysis is needed of this transport and its effect on the cap and any accumulation of capping material and its recontamination over time.

Comment BI-2: p.5-5: The total bed shear stress is computed using a 'log-law' profile according to Eq. 5-11. However, this law assumes a logarithmic variation in velocity away from the bed that may not be the case in flows with appreciable bed topography and secondary flows. There is no assessment of the veracity of using such a log-law approach with data collected in the LPR. An analysis of the suitability of the log-law is required with available data to assess its validity and its accuracy in deriving bed shear stresses.

Comment BI-3: p.5-5: No form roughness to account for bedform development in the capping material is considered in this analysis. What range of bedforms may be generated and how will this affect both erosion depths and stability of the cap?

Comment BI-4: p.5-7: The text states that no boat wake effects or propeller wash effects were accounted for within the model, and that these would largely act to mix the capping material, since it is 'unlikely that a boat (or boats) would follow the exact same path within the river time after time'. First, the effects of boat wakes and propeller wash must be accounted for to estimate bed shear stresses that could erode the capping material. Secondly, boats, especially those entering mooring berths or following navigation routes and dredged channels, and using GPS navigation, frequently do adopt exactly the same path, due to the narrow channel, and thus this rationale is conceptually flawed.

Comment BI-5: p.5-9: 6-inch diameter stone will be used as an armor when required, but no analysis is presented of the stability of this coarse cap overlying finer materials and whether liquefaction may be induced to cause any cap instability.

Comment BI-6: p.5-16: Although the model results indicate that shear stresses in most locations do not exceed the erosion threshold for the coarsest fraction of the UBS, they do exceed the entrainment thresholds for grains finer than this size and that constitute the majority of the grain size distribution. What quantity of sediment thus needs to be eroded to leave a coarser immobile cap consisting of the coarsest fractions of the grain size distribution, and what is the fate of this transported sediment load within the River and where does it lead to later deposition and by how much?

Comment BI-7: p.6-21: Bedform formation in the UBS is accounted for in a sensitivity analysis by using a modified bottom roughness length of half that of the 6-inch cobble armor layer. This selected roughness value is not justified in terms of the bedforms that may be generated, especially larger dunes that would have a height in excess of 3 inches and thus a different roughness. A roughness value appropriate to the bedform roughness generated in this sand is required to accurately simulate water level rise under these conditions.

Appendix BII: LPR Sediment Transport Model

Comment BII-1: p.1-6: No details are given as to how these periods for consolidation tests were chosen, and how they relate to longer periods of consolidation time that influence the LPR bottom sediments

Comment BII-2: p1-9: It is stated that the grid resolution of the numerical model was evaluated with grid convergence tests but no results nor details of these convergence tests are presented, and thus it is not possible to assess the effects of grid size on the results obtained

Comment BII-3: p2-1: It is stated the model does not account for wind-waves, yet these waves could be important in shallow water depths over the bar-tops, even in a fetch-limited system. Additionally, it is stated that sensitivity analysis allowed the conclusion that "the added complication of specifying wave regimes and scenarios and calculating wave-current boundary shear stresses was not deemed warranted" but no sensitivity analyses are presented of the details of the wave-current regimes that could be expected in the LPR, especially in RM0 – RM2.

Comment BII-4: p2-2: It is stated the model does not account for ship-driven resuspension, yet boat traffic is present now, and planned in the future, and boat-driven resuspension may be significant. Additionally, it is stated that only a fraction of the ship traffic entering Newark Bay comes into the LPR. This may be true, but statistics show that a large number of boats, of varying draft, still enter the LPR, and the USACE (2010) suggested that there is future potential for navigation traffic in the LPR. As discussed above in General Comment 6, ship-induced sediment suspension may greatly increase the quantity of sediment entrained into the water column. As such, an analysis of ship-driven resuspension seems vital to predict its effects on the quantity of sediment transport and the stability of any remedial engineered capping.

Comment BII-5: p2-5: What is the basis for the 400 □m grain size to fractionate sediment into bedload and suspended load in the model, and how does this vary with water column density as affected by salinity and stratification within the ETM? A justification is required for this grain size and its possible variation with water column structure.

Comment BII-6: p2-6: The total bed shear stress is computed using a 'log-law' profile according to Eq. 2-5. However, this law assumes a logarithmic variation in velocity away from the bed that may not be the case in flows with appreciable bed topography and secondary flows. There is no assessment of the veracity of using such a log-law approach with data collected in the LPR. An analysis of the suitability of the log-law is required with available data to assess its validity and its accuracy in deriving bed shear stresses.

Comment BII-7: p2-7: A spatially and temporally constant bottom roughness parameter is used within ECOM-SEDZLJS, yet the bottom roughness of the LPR shows considerable variation in both space and time. A full analysis of the bottom roughness and its variation is required to better verify the bed shear stresses predicted, and such an analysis should seek to represent the spatial and temporal changes in bed roughness within the LPR.

Comment BII-8: p2-7: The text states that in some case, especially over cohesive beds with moderate flows, the shear velocity estimation requires changes because the bed is actually 'smoothed or transitional'. This statement applies to a flat bed but examination of the LPR bathymetry shows many of the cohesive bed sediments to contain appreciable roughness (erosional features) that result in the bed not being smooth whatsoever. Thus use of any new grain roughness parameter without considering this erosional form roughness will lead to errors in estimation of bed shear stresses.

Comment BII-9: p2-8: The text acknowledges that the current model is only one-way coupled and this cannot account for hydrodynamic feedback due to changing roughness. This is achieved through the van Rijn (1993) formulation, but no justification is given as to whether the roughness and bedforms are appropriate to the types of bedform dealt with by van Rijn (1993) and thus whether this approach is valid.

Comment BII-10: p2-10: What are "large bedform conditions" and where and when do they occur in the LPR? This statement requires full explanation.

Comment BII-11: p2-10: No data is presented to compare the bedforms predicated with those present in the LPR as stated in the text, and thus it is not possible to evaluate the success in implementation of this formulation that "significantly reduced excess erosion of the sandy regions of the upper LPR during storms."

Comment BII-12: p2-11: What is the justification for not including the effects of bioturbation within ECOMSED used herein?

Comment BII-13: p2-13 – 2-14: There is no scientific rationale for use of a "fluff layer" in the model. A scientific rationale and physical basis must be provided for these fluff and transitional layers and for their thickness being assigned a value of 1mm. How does the thickness of this layer change with bed shear stress and sediment concentration, as well as in saline stratified flows within the ETM. A full explanation and parameterization of any such flow structure should be provided to justify the physical rationale for this flow structure adopted in the model (Mehta and McAnally, 2008).

Comment BII-14: p2-14: A single size class for cohesive sediment is used in the model and is justified as being based on 'site-specific observations'. No evidence is presented to support this statement nor is there a sensitivity analysis to show the effect of several particle sizes, or size variations through time. Additionally, the text states that flocculation and floc break-up are not modelled explicitly within ECOM-SEDZLJS. Flocculation is a key process within fine-grained sediments, especially when the water may be saline, and it can drastically alter sedimentation rates within the ETM. The text is contradictory here in that it both states that site-specific observations show that a single size-class can be used, but then states that "In the absence of direct measurements of suspended particle settling characteristics for the LPR…" that a semi-empirical approach was used. Flocculation processes are well known to be vital in these types of environments and a full characterization of fine-grained particle size and flocculation characteristics within the LPR is essential to accurate modeling of the fate of fine-grained sediment. For instance, in the San Jacinto estuary near Houston, Texas, flocculation of estuarine mud has been found to play an important role in the transport and fate of contaminants such as PCBs and Dioxin (Kumar et al., 2010). However, such analyses in field and laboratory have not been conducted for the LPR sediments, which introduce considerable uncertainty into the behavior of this sediment and prediction of sediment transport within the LPR. Laboratory tests on flocculation and settling with sediments from the LPR should be conducted, including the effect of salt-induced stratification (Mehta and McAnally, 2008).

Comment BII-15: p2-14: What is a "reasonable concentration-dependent functional form" and what uncertainties are associated with this formulation?

Comment BII-16: p2-15: The report should provide a justification for the assumption of a quasi-steady Rouse profile of suspended solids at maximum tidal flow, in terms of a full error analysis involved in this process, especially regarding the calibration of suspended sediment with acoustic backscatter.

Comment BII-17: p3-3: It is stated that particle size information is not available to describe the distribution of particle sizes for the TSS estimates. Since the acoustic response of sediment depends, amongst other factors, on the particle size distribution and the acoustic frequency (Pedocchi and Garcia, 2006); Sontek, 2007; Chanson et al., 2008), it is vital to: i) quantify the particle size distribution and assess how much of the size range may be acoustically monitored, and ii) obtain calibration data from different sites when the size distribution of the suspended sediment may be different. This is essential to quantify the veracity of the calibrations across the survey area. Additionally, analysis should be conducted of the calibration of acoustic instruments within the moving ETM if salinity and sediment concentration vary in time and space.

Comment BII-18: p3-3: It is assumed that all suspended solids entering the model domain through the open boundary were silt-sized but no justification whatsoever for this assumption is provided. A full field quantification of the particulate size distribution at both upstream and downstream boundaries must be conducted to inform the model assumptions and assess whether the size and mineralogy of the fine sediment are suitable for flocculation processes to change the size distribution both spatially and temporally.

Comment BII-19: p3-5: The regressions of estimated TSS vs current speed are stated to be ”reasonably robust” throughout the water column and coefficients of determination are given. However, the level of confidence at which these correlations are significant should be presented. Such statistical testing, and accompanying error analysis, is essential in this type of calibration.

Comment BII-20: p3-9: Two different frequency ADCP instruments were employed in the study and TSS calibrations obtained for each. However, no assessment is given of the grain sizes that can be detected by these different instruments and how these correspond to the grain size distributions of the sediment in the LPR at the various sites. Such analysis is essential to allow confidence in the sediment transport estimates derived from these instruments.

Comment BII-21: p3-13: Examination of the MBES data reveals that the classification of morphological features is oversimplified in representing the bottom type and roughness, and that the ‘Smooth Channel’ is commonly typified by erosive bed features that produce a non-uniform and very irregular rough bed. Such zonation presented in the FFS does not capture the true nature of the LPR, and these aspects are thus misrepresented in the LPR model (for instance parameterization of bed roughness).

Comment BII-22: p3-15: Grain size data based on side scan sonar are purported to show a ‘dramatic shift’ at RM8.3 from sand/gravel upstream to silt and sand downstream. Whilst a downstream fining of bed sediment is apparent, the % Clay and Silts plots illustrate that clays and silts are present all the way up the River, and MBES data show erosive bed features in the upper Passaic River, suggesting that cohesive clays may be present along much of the river channels, but are in places covered with a veneer of sand and clay. Hence the contention that this is a dramatic transition that is associated with the bed morphology, position of the salt front, and estuarine circulation is not substantiated by the grain size data. In addition, no calibration or images are given to detail the calibration of the sidescan sonar imagery with the grab samples from the bed.

Comment BII-23: p3-16: The simple contention that particle size correlates strongly to morphologic regions in the River is not borne out by examination of the data in many places. Principally, the River contains a high percentage of fine grained, apparently cohesive, bed sediment in both shallow and deeper areas. Hence, these sediments show erosion into cohesive substrates where fine-grained sediment has a higher erosion threshold. It is also untrue to generalize that the deepest channels and higher velocity channels also have a higher sand content since the distribution of sediment is also a function of both the sediment transport pathways and sediment availability. In areas of erosive features in cohesive sediments, the link between velocity and grain size is evidently more complex and shows this simple zonation, and inferences based on this, are erroneous. This point is important since the morphology is used to assess the distribution of grain sizes.

Comment BII-24: p3-17: How was grain size estimated in Newark Bay and how does this variability compare to that within the LPR? Since the input of sediment into the LPR will be strongly influenced by Newark Bay, a full grain size and morphological characterization of this area is required.

Comment BII-25: p3-17: “Sufficient data are not available to describe or explain small-scale variability in erosion properties and, as a result, the model parameterization attempts to describe the average characteristics of the erosion data for the fine-grained sediment areas.” This data omission is critical given the abundance of fine-grained, cohesive sediment within the LPR. The result of the current approach is acknowledged in “the model is expected to generate results with less variability than the data, but approximate the central tendency of the data.” However, it is often the extremes of the data that are important in assessing the limits and maximum amounts of erosion resuspension and deposition. The data collected thus appear insufficient to fully characterize the sediment in the area, and thus for correctly estimating the temporal and spatial distribution of erosion and deposition.

Comment BII-26: p3-18: Replicate cores show an order of magnitude difference in erosion rates. How do these link to the points of data collection as regards sedimentary history and also how is this variation accounted for in the spatial distribution of sediment properties in the model?

Comment BII-27: p3-19: Why is 28 days chosen as the upper time limit for consolidation experiments since sediments in the field will presumably consolidate for longer than this?

Comment BII-28: p3-25: What median grain size is used as the threshold for cohesive or non-cohesive sediment classification and how was composition also used in this classification.

Comment BII-29: p3-25: Why is 60% sand chosen as the value for defining if a grid cell is non-cohesive and what is the physical rationale for this classification? A detailed analysis is required as to the percentage composition of sediments and their cohesive/non-cohesive behaviors. This value is critical in that it spatially distributes sediment type in the model. For instance, Deltares (2012) states that clay content and clay mineral type are critical in determining the cohesionless – cohesive boundary and that clay percentages of 5-15% have been shown for this transition. Additionally, Deltares quotes van Ledden et al. (2004) as stating a clay fraction of 7.5% results in a transition between non-cohesive and cohesive properties. A full analysis and justification of this threshold limit is thus required in the FFS.

Comment BII-30: p4-4: In the data and plots presented, the agreements between model and data are often qualitatively stated, for instance as 'generally good' for data in Fig. 4.3. However, a statistical comparison of all this data and its significance at different confidence levels is required for all model-data comparisons in order to quantitatively demonstrate their robustness and applicability. If this is not conducted, it is impossible to assess how well the model does perform.

Comment BII-31: p4-5: If the procedure to estimate sediment loads coming over Dundee Dam does not account for flow history, some analysis is required of the magnitude of this affect [effect?]. This suggests the need for a linked watershed model that can predict temporal changes in sediment flux into the upper LPR.

Comment BII-32: p4-5: Although the model captures the phase of the TSS, a quantitative comparison of the magnitude of the modeled output is required to ascertain how well the model is reproducing the field data.

Comment BII-33: p4-8: A quantitative statistical analysis is required to verify if the statement that the overall range of the predicted tidal TSS fluctuation was similar to the field case.

Comment BII-34: p4-9: Differences in the magnitude of the model predictions are attributed to "difficulties in predicting the delicate balance between erosion and deposition of the thin floc layer at the sediment surface." Two central issues are apparent here. First, this questions the conceptual flow structure model adopted and in particular the use of a fluff and transitional layer. Second, no flocculation is accounted for in the model and so how can this possibly account for such a "fluff layer"? These issues point to significant deficiencies in the model that should be examined to justify and explain the differences in the magnitude of the model predictions, which are central to estimates of erosion and deposition, contaminant fate, and long-term behavior of the LPR and its remedial capping strategies.

Comment BII-35: p4-9: What is meant in the comparison between the PWCM derived fluxes and model results being considered “acceptable?” What is the statistical analysis to back this up and how does this relate to the errors and uncertainties in the methods and model?

Comment BII-36: p4-10: Is a 20-year event extreme?

Comment BII-37: p4-10: What are the statistical relations for the TSS predictions and what is their significance at different confidence levels?

Comment BII-38: p4-12: The report stresses that the solids loading from the watershed is of “considerable importance” but is not accounted for in the model. If the importance of modeling this influx is considerable, why has a linked watershed model not been developed for the Passaic basin, which would enable such issues to be addressed and also allow better estimation of the upstream boundary conditions?

Comment BII-39: p4-12: The report alludes to the importance of “event specific calibration of the TSS-OBS relationship”. If this calibration is critical, together with fuller calibrations of TSS with acoustic records at different locations, a field campaign(s) should seek to collect this critical data for calibration and estimation of sediment transport.

Comment BII-40: p4-12: It is stated that "Non-cohesive solids in suspension could alter the TSS v OBS relationship derived at lower flow conditions.” If this is the case, why has this effect not been quantified in the laboratory? (e.g. Admiraal and Garcia, 2000).

Comment BII-41: p4-13: The field data is stated to show "spatial variations of erosion or deposition on scales smaller than a grid cell,” and attributed to non-linear sediment transport processes and sediment heterogeneity on a sub-grid scale. This acknowledgment suggests that a finer scale grid is required to resolve these processes and rates and allow assessment of whether the large-scale grid captures the dynamics, and predicts the rates of sediment movement, with the LPR.

Comment BII-42: p4-15 - 4-16: The presentation of the bathymetric data provides bar graphs of the erosion/deposition modeled and measured in each river mile but gives no quantitative comparison and crossplot of the data, which yet is required to assess the performance of the model. Analysis of some of these data (Fig. C5 herein) shows that the model both considerably over- and under- predicts erosion and deposition in some regions, and thus the statement that the data agree ”quite well” (p. 4-15) is questionable. Agreement between the model and field data must be statistically tested so it can be assessed how well the two are matched. This is central to proper examination of how well the model is performing and cannot be left to qualitative comparison of maps and qualitative bar graphs: statistics are needed to examine the strength of these relationships between modeled and measured bed change.

Comment BII-43: p4-16: What are the causes of these longitudinal strips of net change and are these either real, suggesting a process is required for their formation and effect on the flow or an artifact of the MBES data and its processing?

Comment BII-44: p4-24: What is the meaning of "…a great deal water column-bed exchanges?"

Comment BII-45: p4-28: The report alludes to the possible importance of hysteresis in the solids concentration during flood hydrographs, but states that the boundary conditions do not permit simulation of this in the model. If such hysteresis is important to estimate sediment flux, why have detailed data not been collected to examine this feature?

Comment BII-46 p4-30: What does the "general agreement between the multibeam bathymetric data sets" mean in terms of a quantitative assessment of the channel bed?

Comment BII-47 p5-8: The report states it is not essential to resolve the interconnections between a wide range of factors to address "the primary factors affecting contaminant transport and fate." However, the magnitude and timing of the changes produced by these interactions are key in assessment of likely change within the LPR, and thus although it can be said that these factors affect the transport, essential knowledge of the magnitude of the processes is surely tied to understanding these links.

References Cited

Admiraal, D. and García, M.H. (2006) Laboratory Measurements of Suspended Sediment Concentration Using an Acoustic concentration Profiler (ACP), *Experiments in Fluids*, 28, 116-227.

Admiraal, D., and Garcia, M.H. (2002) Environmental Impact of Navigation, Article 2.7.5.1 in *Rivers and Streams Encyclopedia of Life Support Systems* (EOLSS), UNESCO.

Admiraal, D. and García, M.H. (2000) Entrainment Response of Bed Sediment to Time-Varying Flows, *Water Resources Research*, 36: 1, 335-348.

Clarke, D., Reine, K., Dickerson, C., Zappala, S., Pinzon, R. and Gallo, J. (2007a) Suspended Sediment Plumes Associated with Navigation Dredging in the Arthur Kill Waterway, New Jersey, *Proceedings of the 18th World Dredging Congress*, 2, 1135-1154.

Clarke, D., Dickerson, C., Reine, K., Zappala, S., Pinzon, R. and Gallo, J. (2007b) Preliminary Assessment of Sediment Resuspension by Ship Traffic in Newark Bay, New Jersey, *Proceedings of the 18th World Dredging Congress*, 2, 1155-1172.

Deltares (2012) *Bed module for sand-mud mixtures*, Ecoshape Draft Report, Project 1200327-000, 111pp.

Egashira, S., and Ashida, K. (1990) Mechanism of armoring phenomena. *International Journal of Sediment Research*, 5(1), 49–55.

Ettema, R., (2008) Ice effects on Sediment Transport in Rivers Chapter 13 in *ASCE Sedimentation Engineering Manual of Practice* 110, Edited by M. H. Garcia, Reston, VA

Ettema, R., Braileanu, F., and Muste, M. (2000) A method for estimating sediment transport in ice-covered channels. *Journal of Cold Regions Engineering,* 14(2), 130–145.

Fischer, H.B., List, J.E., Koh, R.Y.C., Imberger, J. and N.H. Brooks (1979) *Mixing in Inland and Coastal Waters*. Academic Press, San Diego, ISBN: 0-12-258150-4.

Garcia, M.H., (2008) Sediment Transport and Morphodynamics, Chapter 2 in *ASCE Sedimentation Engineering Manual of Practice* 110, Edited by M. H. Garcia.

Garcıa, M.H., Admiraal, D.M., Rodriguez, J.F., and Lopez, F. (1998) Navigation-induced bed shear stresses: Laboratory measurements, data analysis and field applications. *Civil Engineering Studies, Hydraulic Engineering Series No. 56*, Univ. of Illinois at Urbana-Champaign, Ill.

García, M.H., Admiraal, D.M., and Rodriguez, J.F. (1999) Laboratory Experiments on Navigation-Induced Bed Shear Stresses and Sediment Resuspension, 14(2), 303-317, *International Journal of Sediment Research*.

Gessler, J. (1970) Self-Stabilizing Tendencies of Alluvial Channels. *Journal of the Waterways, Harbors and Coastal Engineering Division*, 96(2), 235-249.

Grass, A.J. (1970). The initial instability of fine sand. *Journal of the Hydraulics Division*, ASCE, 96(3), 619-632.

Hamill, G.A., Johnston, H.T., and Stewart, D.P. (1996) Estimating the velocities in a ship's propellers wash, *Bulletin PIANC-AIPCN* No 89, pp. 46-54.

Hirano, M. (1971) On riverbed variation with armoring. *Proceedings, Japan Society of Civil Engineering*, 195, 55–65 (in Japanese).

Hong, J-H., Chiew, Y-M., Susanto, I. and Cheng, N-S. (2012) Evolution of scour induced by propeller wash, *Proceedings Sixth International Conference on Scour and Erosion,* Paris August 27-31, Paper ACSE6-147.

Kellerhals, R., and Church, M. (1980) Comment on 'Effects of channel enlargement by river ice processes on bankfull discharge in Alberta, Canada,' by Smith, D. G. *Water Resources Research*, 16(6), 1131–1134.

Kumar, R.G., Strom, K. B and A. Keyvani (2010) Floc Properties and Settling Velocity of San Jacinto Estuary Mud under Variable Shear and Salinity Conditions. *Continental Shelf Research*, 30, 2067-2081.

Lau, Y.L., and Krishnappan, B.G. (1985) Sediment transport under ice cover. *Journal of Hydraulics Division, ASCE* , 111(6), 934–950.

Liou, YC, and Herbich, J.B. (1977) Velocity Distribution and Sediment Motion Induced by Ship's Propeller in Ship Channels. In: *Hydraulics in the Coastal Zone, Proceedings 28Th Annual Hydraulics Division Specialty Conference*, ASCE, Texas A&M University, Aug. 10-12, pp. 228-235.

Liu, X. and García, M.H. (2008) Coupled Two-Dimensional Model for Scour Based on Shallow Water Equations with Unstructured Mesh. *Coastal Engineering*. 55(10):800-810, 2008.

Liu, X., Parker, G., Czuba, J., Oberg, K., Mier, J.M., Best, J.L., Parsons, D.R., Ashmore, P. and Garcia, M.H. (2011) Sediment Mobility and Bed Armoring in the St. Clair River: Insights from Hydrodynamic Modeling. *Earth Surface Processes and Landform*s, 37(9):957-970

Lopez, F. and García, M.H. (2001) Risk of Sediment Erosion and Suspension in Turbulent Flows, *Journal of Hydraulic Engineering*, ASCE, 127, N3, 231-235.

Mehta, A.J. and McAnally, W.H. (2008) Fine-Grained Sediment Transport, Chapter 4 in *ASCE Sedimentation Engineering Manual of Practice* 110, Edited by M. H. Garcia, Reston, VA.

Mier, J.M. and Garcia, M.H. (2011) Erosion of glacial till from the St. Clair River Great Lakes basin. *Journal of Great Lakes Research*, 37(3), 399-410.

Nino, Y., Lopez, F. and Garcia, M.H. (2003) Threshold for Particle Entrainment into Suspension, *Sedimentology*, 50, 247-263,.

NorthJersey.com (2014) Passaic River capping in Lyndhurst delayed due to ice, NorthJersey.com, http://www.northjersey.com/news/passaic-river-capping-in-lyndhurst-delayed-due-to-ice-1.651007.

Paola, C., and Seal, R. (1995) Grain size patchiness as a cause of selective deposition and downstream fining. *Water Resources Research*, 31(5), 1395–1407.

Parker, G. (2008) Transport of gravel and sediment mixtures Chapter 3 in *ASCE Sedimentation Engineering Manual of Practice* 110, Edited by M. H. Garcia, Reston, VA.

Pedocchi, F., and García M.H. (2006) Evaluation of the LISST-ST instrument for suspended particle size distribution and settling velocities, *Continental Shelf Research*, 26, 943-958.

Reible, D., Bentley, S., Dannel, M.B., DePinto, J.V., Dyer, J.A., Farley, K.J., García, M.H., Glaser, D., Hamrick, J.M., Jensen, R.J., Lick, W., Pastorok, R.A., Schwer, R.F., Ziegler, C.K. (2003) Chapter 2 "The Role of Modeling in Managing Contaminated Sediments," in Contaminated Ground Water and Sediment Modeling for Management and Remediation Edited by Chunmiao Zheng , Danny D. Reible , George F. Pinder , Calvin C. Chien , Brent E. Sleep and Miguel A. Medina, CRC Press, Print ISBN: 978-1-56670-667-4, eBook ISBN: 978-0-203-49415-8, DOI: 10.1201/9780203494158.ch2.

Rodríguez, J. F., Admiraal, D.M., García, M.H. and López, F. (2002) Unsteady bed shear stresses induced by navigation: laboratory observations, *Journal of Hydraulic Engineering*, ASCE, 128(5), 2002.

Sutton, D.W., Richter, K., Cheng, R. and Wang, P.F. (1996) Mass loading and subsequent baywide transport of sediment resuspension during tug assisted ship movements at the Naval Station, San Diego. Part I: Field study and deterministic computer model simulation. *Proceedings AGU Fall Meeting*, San Francisco, California.

Santacruz, S. and Garcia, M.H. (2014) A tool to evaluate the self-stability of alluvial beds. *IAHR Latina American Congress*, Santiago, Chile. (*In Spanish*).

TRB (2001) A process for setting, managing, and monitoring environmental windows for dredging projects / Committee for Environmental Windows for Dredging Projects, *Transportation Research Board Special Report 262,* National Research Council Press, Washington, D.C., ISBN 0-3-9-07244-1

US Army Corps of Engineers (2010) *Lower Passaic River Commercial Navigation Analysis Revision 2*.

van Ledden, M., van Kesteren, W.G.M. and Winterwerp, J.C. (2004) A conceptual framework for the erosion behaviour of sand-mud mixtures. *Cont. Shelf Res.* 24, 1–11.

Wilcock, P.R. (1988) Methods for estimating the critical shear stress of individual fractions in mixed-size sediment. *Water Resources Research*, 24(7), 1127–1135.

Wuebben, J.L., Brown, W.M. and Zabilansky, L.J. (1984) Analysis of physical effects of commercial vessel passage through the Great Lakes connecting channels, *USASCE CRREL Report* AD-A213 913, 198pp.

YouTube (2014) Barge Breaking up Ice on the Passaic River, http://www.youtube.com/watch?v=HFwoo-pOjZ4.

James L. Best, Ph.D.

Professor
Department of Geology, Department of Geography and Geographic Information Science, Department of Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory
University of Illinois

INTERESTS

Dr Best earned his Ph.D. in Geology and Geography from the University of London, UK, in 1985. His interests lie within process sedimentology and geomorphology, sediment transport and fluid dynamics. This research has covered many environments from rivers to estuaries to deltas and deep-sea settings, involving study of modern processes, sediment transport and ancient sedimentary rocks. He has been involved in applied research concerning engineering design of embankments on large rivers, modelling and assessment of environmental change on the Meghna Estuary, sediment flux estimation in large rivers, reservoir characterization in a range of fluvial, estuarine and deltaic hydrocarbon reservoirs, and assessment of channel change and fluid conveyance in the Great Lakes. His interdisciplinary experience in Earth Sciences and Engineering, and in examining fluid dynamics, sediment transport and sediment deposition, forms the background for input to the Focused Feasibility Study process.

EDUCATION

Birkbeck College, University of London, UK (Thesis: '*Flow & Sediment Transport at River Channel Confluences*')	Geology	Ph.D.	1985
University of Leeds, UK	Geology/Geography (*Combined Honours*)	B.Sc.	1979

APPOINTMENTS

- Threet Professor of Sedimentary Geology and Professor of Geography, University of Illinois, USA 2006-present.
- Affiliate Professor in Civil and Environmental Engineering UIUC 2007-present.
- Affiliate Professor in Mechanical Science and Engineering UIUC 2010-present.
- Professor of Process Sedimentology, University of Leeds, UK 2000-2006.
- Reader in Experimental Sedimentology, University of Leeds, UK 1997-2000.
- Lecturer in Earth Sciences, University of Leeds, UK 1988-1997.
- Lecturer in Geology, University of Hull, UK 1983-1988.
- Professor invité, Université de Montréal, Canada 1989-1993.
- Royal Society/National Science & Engineering Research Council (Canada) Sabbatical Fellowship at Université de Montréal, 1990.
- Nuffield Foundation Science Research Scholar, 1994-1995.
- Leverhulme Trust Research Fellowship, 2004-2005.

PUBLICATIONS

Publications Related to the Project

- Baas, J. H., **Best, J. L.**, Peakall, J., and Wang, M. (2009). A phase diagram for turbulent, transitional and laminar clay suspension flows. *Journal of Sedimentary Research*, 79, 162-183.
- **Best, J.** (2005). The fluid dynamics of river dunes: a review and some future research directions. *J. Geophysical Research, Earth Surface*, 110, F04S02, doi:10.1029/2004JF000218.
- Czuba, J. A., **Best, J. L.**, Oberg, K. A., Parsons, D. R., Jackson, P. R., Garcia, M. H., and Ashmore, P. (2011). Bed Morphology, Sediment Transport, and Flow Structure at the Outlet of Lake Huron and in the Upper Saint Clair River: New Observations to an Ongoing Debate. *Journal of Great Lakes Research*, 37, 480-493, DOI: 10.1016/j.jglr.2011.05.011.
- Hardy, R. J., Lane, S. N., Lawless, M. R., **Best, J. L.**, Elliott, L., and Ingham, D. B. (2005). Development and testing of a numerical code for treatment of complex river channel topography in three-dimensional CFD models with structured grids. *J. Hydraulic Research*, 43, 468-480.

- Liu, X., Parker, G., Czuba, J. A., Oberg, K., Mier, J. M., **Best, J. L.**, Parsons, D. R., Ashmore, P., Krishnappan, B. G., Garcia, M. H. (2012). Sediment mobility and bed armoring in the St Clair River: Insights from hydrodynamic modeling. *Earth Surface Processes and Landforms*, 37 (9), 957-970.
- Nittrouer, J. A., **Best, J. L.**, Brantley, C., Cash, R. W., Czapiga, M., Kumar, P., Parker, G. (2012). Mitigating land loss in coastal Louisiana by controlled diversion of Mississippi River sand. *Nature Geoscience*, 5 (8), 534-537.
- Szupiany, R. N., Amsler, M. L., Hernandez, J., Parsons, D. R., **Best, J. L.**, Fornari, E., Trento, A. (2012). Flow fields, bed shear stresses, and suspended bed sediment dynamics in bifurcations of a large river. *Water Resources Research*, 48 (11), art. no. W11515.

Other Selected Related Publications

- **Best, J. L.** and Leeder, M. R. (1993). Drag reduction in turbulent muddy seawater flows and some sedimentary consequences. *Sedimentology*, 40, 1129-1137.
- **Best, J. L.**, Kostaschuk, R. A., Peakall, J., Villard, P. V., and Franklin, M. (2005). Whole flow field dynamics and velocity pulsing within natural sediment-laden underflows. *Geology*, 33, 765-768.
- Gutierrez, R., Abad, J. D., Parsons, D. R., and **Best, J. L.** (2013). Discrimination of bed form scales using robust spline filters and wavelet transforms: Methods and application to synthetic signals and bedforms of the Rio Paraná, Argentina. *Journal of Geophysical Research – Earth Surface*, 118, 1400-1418, DOI: 10.1002/jgrf.20102.
- Lunt, I. A., Ashworth, P. J., **Best, J. L.**, Bridge, J. S., Lane, S. N., Sambrook Smith, G. H., Simpson, C. J., Thomas, R. E. (2013). Deposits of the sandy braided South Saskatchewan river: Implications for the use of modern analogs in reconstructing channel dimensions in reservoir characterization. *Bulletin American Association of Petroleum Geologists*, 97, 553-576.
- Simmons, S. M., Parsons, D. R., **Best, J. L.**, Orfeo, O., Lane, S. N, Kostaschuk, R., Hardy, R. J., West, G., Malzone, C., Marcus, J., and Pocwiardowski, P. (2010). Monitoring Suspended Sediment Dynamics Using MBES. *J. Hydraulic Engineering*, 136, 45-49.
- Zinger, J. A., Rhoads, B. L., and **Best, J. L.** (2013). The morphodynamics of meander bend chute cutoffs: a case study of the Wabash River. USA, *Journal of Geophysical Research – Earth Surface*, 118, 2468-2487.

SYNERGISTIC ACTIVITIES

- Guest Editor for special issues of *Sedimentology* (2011) and *Earth Surface Processes and Landforms* (2011); Principal Editor, *Sedimentology* 1998-2002; Member Editorial Board, *Revista de la Asociación Argentina de Sedimentología*, 2005-2009.
- Bureau Member, *International Association of Sedimentologists* 1998-2002; Chairman, *British Sedimentological Research Group* 1990.
- Member Peer Review College of Natural Environment Research Council (UK) 2000-2004; Member Peer Review College of Engineering and Physical Sciences Research Council (UK) 2000-2002; NSF Earth Sciences ARRA Panel on Instrumentation and Facilities (2009); NSF Geography & Spatial Sciences Panel (2010-2012).

COLLABORATORS

Mario Amsler and Ricardo Szupiany (INALI, Santa Fe, Argentina), Phil Ashworth (University of Brighton, UK), Jaco Baas (University of Bangor, UK), Ken Christensen (Notre Dame), Bruce Fouke (UIUC), Marcelo Garcia (UIUC), Richard Hardy (University of Durham, UK), Ray Kostaschuk (Simon Fraser University, Canada), Stuart Lane (Lausanne), Kevin Oberg (USGS), Oscar Orfeo (Centro de Ecologia Aplicada del Litoral, Corrientes, Argentina), Gary Parker (UIUC), Dan Parsons (University of Hull, UK), Jeff Peakall (University of Leeds, UK), Bruce Rhoads (UIUC), Greg Sambrook Smith (University of Birmingham, UK), Rudy Slingerland (Pennsylvania State University).

Graduate and Postdoctoral Advisors

Prof. Ian Reid (University of Loughborough, UK) and Prof. Lynne Frostick (University of Hull, UK).

Thesis Advisor and Postgraduate-Scholar Sponsor

I currently have seven graduate students (4 Ph.D.; 3 MSc). Between 1987 and 2012 in the USA and UK, I have supervised 38 graduate research students. During my career I have advised 24 postdoctoral fellows, including 2 current fellows at UIUC.

Marcelo H. Garcia, Ph.D. Dist.M.ASCE F.EWRI

M.T. Geoffrey Yeh Chair in Civil Engineering
Professor of Civil and Environmental Engineering & Geology
Director, Ven Te Chow Hydrosystems Laboratory; http://www.vtchl.illinois.edu
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

INTERESTS

Prof. Garcia's research interests are in fluvial and coastal sediment transport and environmental fluid mechanics. He was Editor-in-Chief of the *ASCE Sedimentation Engineering Manual of Practice No. 110*. He has 30 years of experience on river contamination and restoration projects both nationally and internationally. He served on the expert review panel for the Housatonic River PCB Restoration Project (General Electric-USEPA), coauthored the Transportation Research Board Special Report 262 on "Environmental Windows for Dredging," and currently leads a major research effort to model transport and fate of spilled crude oil in the Kalamazoo River, Michigan, and serves as an expert reviewer of the Mississippi River Hydrodynamic and Sediment Transport Modeling conducted by the US Army Corps of Engineers to rebuild the Mississippi Delta. He has been a consultant on river contamination for the Bogota River in Colombia (World Bank) and the "Riachuelo" in Buenos Aires, Argentina (AySA). He became a Distinguished Member of the American Society of Civil Engineers (ASCE) and an inaugural Fellow of ASCE's Environmental and Water Resources Institute both in 2013.

EDUCATION

University of Minnesota	Civil Engineering	Ph.D.	1989
University of Minnesota	Civil Engineering	M.S.	1985
National Litoral University, Argentina	Water Resources	Dipl. Ing.	1982

ACADEMIC EXPERIENCE

2014	M.T. Geoffrey Yeh Endowed Chair in Civil Engineering, UIUC.
2012-2014	Fellow, National Great Rivers Research and Education Center, Illinois.
2001-2014	Chester and Helen Siess Endowed Professor of Civil Eng., UIUC.
2001-present	Director, Centro Internacional de Grandes Rios, FICH, UNL.
2000-present	Professor, Dept. of Civil and Environmental Eng., University of Illinois.
1999 (1 month)	Visiting Assoc. Prof., Ecole Polytech. Federale de Lausanne, Switzerland.
1997 (4 months)	Visiting Associate Professor, California Institute of Technology.
1997-present	Director, Ven Te Chow Hydrosystems Laboratory, University of Illinois.
1996-2000	Associate Professor, Dept. of Civil and Env. Eng., University of Illinois.
1990-1996	Assistant Professor, Department of Civil Eng., University of Illinois.
1993-present	Visiting Professor, Facultad Ing & Ciencias Hidricas., Universidad Nacional del Litoral, Santa Fe, Argentina.
1993 (4 months)	Contract Professor, Istituto di Idraulica, University of Genoa, Italy.
1988-1989	Research Fellow, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota.
1983-1987	Research Assistant, St. Anthony Falls Hydraulic Lab., Univ. of Minnesota.

HONORS

ASCE Hilgard (1996, 1999), Huber (1998), Einstein (2006), Housner (2012), Rouse Award (2012), IAHR Ippen Award (2001), National Academy of Engineering, Argentina (2005).

RELEVANT PUBLICATIONS

(total of 130 archive journal publications)

- Motta, Davide; Abad, Jorge D.; **Garcia, Marcelo H.** (2010). Modeling Framework for Organic Sediment Resuspension and Oxygen Demand: Case of Bubbly Creek in Chicago. *Journal of Hydraulic Engineering* - ASCE, 136(9), 952-964. *Recognized with the ASCE 2012 Wesley Horner Award for best publication*.

- Czuba, J. A.; Best, J. L.; Oberg, K. A.; Parsons, D. R.; Jackson, P. R.; **Garcia, M. H.**; Ashmore, P. (2011). Bed morphology, flow structure, and sediment transport at the outlet of Lake Huron and in the upper St. Clair River. *Journal of Great Lakes Research*, 37(3), 480-493. *Recognized with the IAGLR Chandler-Misener Award for most notable paper published in Journal of Great Lakes Research in 2011*.
- Mier, Jose M.; **Garcia, Marcelo H.** (2011). Erosion of glacial till from the St. Clair River Great Lakes basin. *Journal of Great Lakes Research*, 37(3), 399-410.
- Reible, D., Bentley, S., Dannel, M., DePinto, J. V., Dyer, J. A., Farley, K., **Garcia, M. H.**, Glaser, J., Hamrick, J., Jensen, R. H., Lick, W., Pastorok, R., Schwer, R., Ziegler, C. K. (2003). The Role of Modeling in Managing Contaminated Sediments, Chapter 2 in *Contaminated Ground Water and Sediment Modeling for Management and Remediation*. Edited by Zheng, Reible, Pinder, Chien, Sleep, and Medina, CRC Press.
- Abad, J. D., Buscaglia, G. and **Garcia, M. H.** (2008). 2D Stream Hydrodynamic, sediment transport and bed morphology model for engineering applications. *Hydrological Processes*, 22: 1443-1459.
- **García, M. H.**, Modelling Sediment Entrainment into Suspension, Transport, and Deposition in Rivers, Chapter 15 in *Model Validation: Perspectives in Hydrological Science*. M. G. Anderson and P. D. Bates (Editors), 389-412, Wiley & Sons, England.

SYNERGISTIC ACTIVITIES

- Member, Steering Committee, Community Surface Dynamics Modeling System (CSDMS), 2013-2018.
- Editor-in-Chief, ASCE/EWRI "Sedimentation Engineering," Manual of Practice 110, May 2008.
- Editor-in-Chief, *Journal of Hydraulic Research*, IAHR, 2001-2006.
- Review Panel on "Modeling Study of Contaminated Sediments in the Housatonic River," U.S. Environmental Protection Agency and General Electric, Lennox, MA, 2002-2006.
- Member, National Research Council Panel on "River Science at the US Geological Survey." 2005-2006.
- Team Leader, Sedimentation, St Clair River Study, International Great Lakes Commission, 2007-2010.
- Expert Panel Member, Fargo-Moorhead Metropolitan Flood Risk Management Feasibility Study, North Dakota and Minnesota, Battelle & US Army Corps of Engineers, 2009-2011.
- Expert Panel Member, Mississippi River Hydrodynamic and Sediment Transport Modeling, Battelle & US Army Corps of Engineers, 2013-2016.
- Expert Panel Member, April 2013 Flooding City of Marseilles, Illinois, US Department of Justice.
- International Scientific Committee, ***Firenze 2016***, Florence, Italy, 2014-2016.

Ph.D. Advisees(total: 26): Yarko Niño (Prof., University of Chile); Fabian López, (Under-Secretary for Water Resources, Argentina); Sung-Uk Choi (Prof., Yonsei University, South Korea); Jeffrey Parsons (Consultant, Washington); David Admiraal (Assoc. Prof., University of Nebraska-Lincoln), Xin Huang (Software Engineer, Motorola, Inc.), Fabian Bombardelli (Assoc. Prof., University of California-Davis), Jose Rodriguez (Senior Lecturer University of Newcastle, Australia), Michelle Guala (Ph.D., Univ. of Genoa; Asst. Prof. Minnesota), Robert Holmes, Jr. (National Flood Hazard Coordinator, USGS), Arthur Schmidt (Res. Asst. Prof., University of Illinois), Juan Fedele (Exxon-Mobil), Yovanni Catano (Alden Research Lab), Michael Yang (Consulting., Shaw Group), Octavio Sequeiros (Researcher, Shell Co, The Netherlands, w/ Gary Parker), Carlos M. Garcia (Prof. Universidad Nacional de Cordoba), Mariano Cantero (Asst. Prof., Instituto Balseiro, Argentina), Jorge Abad (Asst. Prof., Univ. of Pittsburgh), Albert Dai (Asst. Prof., National Taiwan University); Xiaofeng Liu (Asst. Prof., Penn State), Arturo Leon (Asst. Prof., Oregon State University), Francisco Pedocchi (Asst. Prof., Universidad de la Republica, Uruguay), J. Ezequiel Martin (Res. Assoc., Univ. of Iowa), Blake Landry (Research Assoc. & Lecturer , UIUC), Sumit Sinha (Res. Assoc., Helmholtz Institute, Germany), Davide Motta (Consultant, PA).
MS Thesis Students Advised: 36.
Current Advisees: 12 graduate students, 2 Post-Doctoral Students, MS Thesis Students Advised: 36.

COMMENTS

Comments on the Passaic River Focused Feasibility Study (FFS) and Related Documents

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
Charles S. Melching, Ph.D., P.E., D.WRE, BCEE

COMMENTS ON THE PASSAIC RIVER FOCUSED FEASIBILITY STUDY (FFS) AND RELATED DOCUMENTS

Charles S. Melching, Ph.D., P.E., D.WRE, BCEE

Executive Summary

Tung et al. (2006, p. 5) note: "the design and operation of engineering systems are always subject to uncertainties and potential failures." Further, Tung et al. (2006) state:

> "engineers always face the dilemma of decision making or design with imperfect information. It is the engineer's responsibility to obtain a solution with limited information, guided by experience and judgment, <u>considering the uncertainties and ranges of variability of the pertinent factors</u>, as well as economic, social, and environmental implications, and assessing a reasonable level of safety." *(emphasis added)*

The remedial actions for the Lower Passaic River Focused Feasibility Study (FFS) certainly comprise a very complex engineering system for which decision making and design must be made with imperfect information. If scientists, economists, lawyers, and decision makers are added to engineers in the foregoing quote, the conditions and characteristics of the Lower Passaic River FFS have been described. Thus, consideration of the uncertainties in the estimates of the concentrations of the Contaminants of Potential Concern (COPCs) and Contaminants of Potential Ecological Concern (COPECs) in the surface sediment of the FFS Study Area and in the human health risk and ecologic risk models is a key aspect of determining the correct remedial action to protect human health and the environment, and, thus, a full uncertainty analysis of the modeling should be done. The comments in this report primarily focus on uncertainties in the hydrodynamic, sediment transport, organic carbon, and contaminant fate and transport models used to estimate the concentrations of COPCs and COPECs in the sediments of the FFS Study Area and how the interaction of these uncertainties could be analyzed. Sensitivity analysis is related to uncertainty analysis in that sensitivity analysis focuses on the effects of one uncertain input or parameter on the output of interest, whereas uncertainty analysis focuses on the effects of all sources of uncertainty acting together. Sensitivity analysis can provide additional useful information as it can show that the uncertainty in just one aspect of the model could substantially affect the reliability of decisions made on the basis of model output.

Water resource and environmental modelers are faced with four principal types of uncertainty: (1) natural randomness, (2) data, (3) model parameters, and (4) model structure (Melching 1995). Plate (1986) noted that even if a perfect model of the hydrologic cycle were available, hydrologists would still be faced with a large random residue caused by natural uncertainties. This same large random residue caused by natural uncertainties also would exist if perfect models were available for river, estuary, and harbor hydrodynamics; sediment transport; organic carbon; and contaminant fate and transport. As discussed in detail in this report, the hydrodynamic, sediment transport, organic carbon, and contaminant fate and transport models used in the Lower Passaic River FFS are far from perfect, with uncertainties far greater than acceptable. In fact, the organic carbon and contaminant fate and transport models have very low predictive ability (and very high uncertainty). Therefore, the large random residue for a "perfect model" is greatly magnified by the "imperfect models" used in the Lower Passaic River FFS. The magnification of the uncertainties is greatly increased because the highly uncertain

output from each “imperfect model” is fed into the next “imperfect model” as input. The flow velocities and depths from the hydrodynamic model are fed into the other models. The estimates of sediment movement from the sediment transport model and organic carbon flux from the organic carbon model are fed into the contaminant fate and transport. The resulting cascade of uncertain output from one model to another yields the possibility for extremely large uncertainty in the final output of COPC and COPEC concentrations in the surface sediments of the FFS Study Area. Thus, a full uncertainty analysis of these models and their interaction must be a part of information considered during selection of the remedial action.

The comments in this report are divided into two groups. The first group is the Uncertainty Comments that are related to the reported accuracy of the models, the assumptions on the model input, the calibration and verification of the models, and uncertainty analysis procedures that could be applied to the models used in the FFS. The second group is General Comments related to aspects of the FFS that are inconsistent with standard engineering practice. The topics of these comments are listed below in this Executive Summary, and the full details of each comment are given in the main body of the report.

Uncertainty Comments

1. The Contaminant Fate and Transport Model (CFTM) calibration is poor. Thus, its use to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remedial alternatives is not reliable. Therefore, in order to properly evaluate whether the various remedial alternatives will achieve the Preliminary Remediation Goals (PRGs), the model calibration and verification must be redone. Failure to do so renders the Focused Feasibility Study (FFS) inconsistent with the National Contingency Plan (NCP) by its inability to demonstrate protection of human health and the environment.

2. The models comprising the Contaminant Fate and Transport Model had known shortcomings that were not corrected in their application to the FFS. Thus, its use to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remediation alternatives cannot demonstrate the protection of human health and the environment. Therefore, in order to properly evaluate whether the various remediation alternatives will achieve the PRGs the model shortcomings must be addressed as proposed in the Final Model Work Plan and other reports. Region 2 should defer remedy selection until it has employed the Uniform Federal Policy (UFP) on Quality Assurance Project Plans (QAPP) process, then adjusted and re-run the models for the 17 mile Lower Passaic River Study Area (LPRSA).

3. Because the Sediment Transport Model calibration is poor, its use to provide input to the Contaminant Fate and Transport model to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remediation alternatives is not reliable. To properly evaluate whether the various remediation alternatives will achieve the PRGs the Sediment Transport Model calibration and verification must be redone. Failure to do so renders the FFS inconsistent with the NCP by its inability to demonstrate protection of human health and the environment.

4. No formal uncertainty analysis was done for the Contaminant Fate and Transport Model alone, and no consideration was given to the propagation of Hydrodynamic Model Uncertainty to Sediment Transport Model Uncertainty to Contaminant Fate and Transport Model Uncertainty. Formal uncertainty analysis was not conducted because it

was argued that such an analysis would be too computationally intensive. However, well-known, well-accepted, and well-tested uncertainty analysis methods are available that are less computationally intensive than the method described in the CFTM report, and, thus, a full uncertainty analysis of the cascade of models used to estimate the contaminant fate and transport can and should be done. This will inform the public of the certainty of the remedial Alternatives in meeting the PRGs and in not being inconsistent with the NCP.

5. The results of the sensitivity analysis with respect to the uncertainty in the inflows from the Upper Passaic River (UPR) have been presented in a way that hides the true sensitivity of the contaminant concentrations in the LPR sediment to these inflows. This incomplete sensitivity evaluation overstates the reliability of the proposed remedial Alternatives in meeting the PRGs. Sensitivity analysis results must be presented for those contaminants with larger loads from the UPR.

6. Approximating the inflow concentrations of various contaminants based on values from the Mohawk River is, by Region 2's own admission, biased low. This will lead to an underestimate of the contaminant concentrations in the FFS Study Area after remediation. Actual field data for the New Jersey tributaries should be collected and used in the contaminant fate and transport modeling, and the data collection should be performed for the full 17 mile RI/FS.

7. The rank-based system used to calibrate the Hydrodynamic Model is flawed, and this may affect the ability of the sequence of models to accurately estimate the spatial distribution of contaminants in the FFS Study Area. The final calibration of the Hydrodynamic Model must be re-evaluated using an objective function that considers the true performance of the model.

8. Dredging can expose more contaminated deeper sediments to the water column, and since these sediments are not in equilibrium with the water column, the contaminants may be released into the water during dredging. The FFS analysis should include an evaluation of the effects of this release of contaminants during dredging.

9. Region 2 contends that "state-of-the-art" methods were employed in the FFS because the SWEM (HydroQual 2002) and CARP (HydroQual 2007) models were extensively Peer-Reviewed. However, the SWEM and CARP model domains are very large, and, thus, the peer reviews could not have considered the model performance in the FFS Study Area in sufficient detail to say with confidence that the models are sufficiently accurate for the current use in the FFS. A detailed peer review of the models as applied to the FFS Study Area must be completed to improve confidence in the models before a remedy is selected.

10. The generation of a long-term inflow time series by repeating the same 15-year time period does not allow for sufficient confidence in the accuracy of the model, and thus, the long-term analysis of sediment movement and contaminant concentrations is flawed. A more reasonable approach to simulating long-term, post-remediation conditions in the FFS Study Area must be applied to improve confidence in the models before a remedy is selected.

11. The approach used to determine the inflow loads of sediment and the various contaminants from the Upper Passaic River and other tributary rivers is unclear.

Because the loads from the Upper Passaic River may substantially affect whether the proposed Alternative remedial actions (Alternatives) can meet the PRGs, the procedure used to estimate the inflows loads must be explained in more detail.

12. The FFS assumes that the probability of a joint occurrence of a flood from the Upper Passaic River and of a high storm surge is small, and thus, it did not evaluate such an event. However, the statistical analysis of flood and storm surge data was insufficient to reach this conclusion. Thus, a more complete analysis of the possible joint occurrence a flood from the UPR and a high storm surge must be done to ensure the safety of the approach to remediation before a remedy is selected.

13. The statistical analyses done in the various reports to determine design flows (100-year flood, 500-year flood) are inconsistent with respect to the data used. Also, no corrections have been made to account for the urbanization of the watershed over time and space. These issues make the design flows highly uncertain. The design flows should be determined, factoring in the effects of urbanization in time and space and should be applied consistently over all the modeling analyses.

14. The assumption that the armor stone is non-erodible is unproven. The uncertainty in the determination of the critical shear stress for particle movement indicates that armor stone has some non-zero probability of movement. The probability of armor stone movement should be evaluated and the armor selection should be modified as appropriate.

General Comments

15. The order in which the remediation projects will be undertaken is inconsistent with standard procedures of cleaning upstream areas first and working downstream so that restored downstream locations are not re-contaminated as a result of later restoration of upstream areas. As proposed, the likelihood for re-contamination of the lower eight miles of the LPR seems high. The remediation of the lower eight miles of the LPR should be delayed until upstream locations have been restored by completing the RI/FS and determining the needed remedial action for the full 17 mile site.

16. The contaminant loads coming from the Upper Passaic River are substantial for many of the Contaminants of Potential Concern (COPCs) and Contaminants of Potential Ecological Concern (COPECs). Thus, it cannot be assumed that the proposed Alternatives can result in achievement of the PRGs without mitigation methods being applied to upstream areas. The chance for re-contamination of the lower eight miles of the LPR is high. The remediation of the lower eight miles of the LPR should be deferred until upstream locations have been remediated by completing the NCP process for the full 17 mile site.

17. The thesis of uniform bank-to-bank contamination of the lower eight miles of the LPR is poorly supported by the data and the discussion in the reports. Thus, advocating cleanup alternatives involving bank-to-bank treatment of the contaminated sediments is unsupportable. A much more detailed study of contaminant heterogeneity within the FFS Study Area must be done to determine the best approach to remediate sediment contamination in the Study Area.

18. The Superfund Proposed Plan (SPP) discusses the Off-Site Sediment Disposal alternative as if it has minor social and environmental effects. This alternative may have very substantial social and environmental effects that <u>must be fully analyzed, documented, and considered</u> before a final sediment remedial alternative is selected.

Detailed Comments

<u>Uncertainty Comments</u>

1. 1. The Contaminant Fate and Transport Model (CFTM) calibration is poor. Thus, its use to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remedial alternatives is not reliable. Therefore, in order to properly evaluate whether the various remedial alternatives will achieve the Preliminary Remediation Goals (PRGs), the model calibration and verification <u>must be redone</u>. Failure to do so renders the Focused Feasibility Study (FFS) inconsistent with the National Contingency Plan (NCP) by its inability to demonstrate protection of human health and the environment.

1.1 HDR|HydroQual (2014c) states "overall the model compares favorably with the data across a wide range of modeled contaminants, locations, and years." This statement greatly exaggerates the accuracy of Region 2's modeling results. The scattergrams show no relation between simulated and measured values, and the percent of samples within a factor of 5 [as presented in Table 4-2 of HDR|HydroQual (2014c)] is an unusual and nearly meaningless assessment of the model's accuracy. Accordingly, the statement that the "model compares favorably" with the data is unrealistic and scientifically unacceptable. Such low targets for declaring an "acceptable calibration" are inconsistent with the large body of hydrologic and water quality model applications that exist (see Paragraph 1.5).

1.2 To be more specific:

- The scales of Figures 4.2 to 4.5 (and many others) render it difficult to truly judge the usefulness of the model. The figures hide the discrepancies between measured values and model results by plotting with too large a scale.
- Figure 4-6 – Water column Particulate Organic Carbon (POC): This shows no relation between simulated and measured values.
- Figure 4-7 – Water column Dissolved Organic Carbon (DOC): Model consistently overestimates measured values.
- Figure 4-8 – Sediment Fraction of Organic Carbon (FOC):
  - Lower Passaic River (LPR) model substantially underestimates measured data;
  - Newark Bay (NB), River Mile (RM) -2 to 0, model substantially overestimates measured values;
  - NB RM -2 to -3, no relation between measured and simulated values; and
  - NB RM -3 to -6 model underestimates measured data.
- Figure 4-10 – For RM 1-7 the original model (black line labeled "No Action Spinup") seems to agree better with the data than the results for the revised initial conditions (dark blue line labeled "No Action Gradient IC, Reach Scale Up") that was used as

the model calibration and the starting point for all projections (HDR|HydroQual 2014c, p. 4-8).

- In Figures 4-11 to 4-26 the model results appear to show reasonable agreement with the measured concentrations of 2,3,7,8-TCDD in the sediments through 2010 in that the simulated values are similar to the mean of the measured values at various RM locations. However, this apparently reasonable agreement does not confirm the usefulness of the model because of (1) the small amount of data available for the various RM locations and years (in fact no data are available for the FFS Study Area (RM 0 to 8.3) for many years); and (2) the wide range in measured concentrations at each RM location that make the mean concentration an inadequate indicator of model accuracy.
- Figure 4-43 – Simulated mercury concentrations appear high (i.e. above the upper 95% confidence limit in the channel and the shoal for many years) in the FFS Study Area (RM 0 to 8.3).
- Figure 4-50 – This shows no relation between simulated and measured 2,3,7,8-TCDD in surface sediments except between RM 8 and RM 17, which is <u>outside</u> of the FFS Study Area.
- Figure 4-51 – The concentration of 2,3,7,8-TCDD in the water column is consistently and substantially overestimated in all reaches of the LPR and Newark Bay (NB).
- Figure 4-52 – This shows no relation between simulated and measured tetrachlorobiphenyl in surface sediments.
- Figure 4-53 – The concentration of tetrachlorobiphenyl in the water column is consistently and substantially overestimated in all reaches of the LPR and NB.
- Figure 4-54 – This shows no relation between simulated and measured mercury concentrations in the surface sediment.
- Figure 4-55 – In the LPR, this shows no relation between measured and simulated mercury concentrations in the water column; the model overestimated mercury concentration in NB.

1.3 In order to understand the poor quality of the modeling results shown in the various scattergrams listed above [as well as others in HDR|HydroQual (2014c)] a brief review of scattergrams is given here. A scattergram is a figure on which pairs of measured and simulated values of discharge, concentration, load, or some other quantity of interest for the same time and location are plotted together. Figure 11.1 from James and Burges (1982) [shown on the next page] illustrates a number of different types of results that might be obtained in a scattergram. Figure 11.1(d) shows the desired result for a model that the model estimates agree with the measured values in a tight range around the "line of perfect agreement" or "1:1 line." Figures 11.1(a-c) show various systematic model errors in the simulation results, such as (a) underestimation of higher magnitudes, (b) consistent underestimation, and (c) higher magnitudes overestimated and lower magnitudes underestimated. If these results or other systematic errors were obtained, the model calibration process should continue so that the model estimates are appropriately adjusted such that a scattergram more like 11.1(d) is obtained. As noted in Paragraph 1.2, Figures 4.8 and 4.55 (among others) in the CFTM report (HDR|HydroQual 2013c) show systematic errors of the type shown in Figure 11.1(b), whereas Figures 4.7, 4.8, 4.51, and 4.53 (among others) in the CFTM report show the opposite problem of consistent overestimation.

The portion of Figure 4-51 of HDR|HydroQual (2014c) showing the concentration of 2,3,7,8-TCDD in the water column in the FFS Study Area is shown on page 9 so that the consistent overestimation can be clearly seen. Also shown on page 9 is the portion of Figure 4-50 of HDR|HydroQual (2014c) showing the concentration of 2,3,7,8-TCDD in the surface sediments of the FFS Study Area. In this figure it can clearly be seen that the model has no ability to predict the measured concentrations as the data points show no correlation to the "line of perfect agreement." The results shown in Figure 11.1 of James and Burges (1982) are representative of the results for hydrologic simulation such as daily mean flows. Simulating water quality constituents generally is much more difficult than simulating daily flows (as discussed in Comment 4). Thus, the tight grouping around the "line of perfect agreement" shown in Figure 11.1(d) of James and Burges (1982) should not be expected for water-quality simulation, but the results should still follow the "line of perfect agreement." For example, also shown on page 9 is the scattergram for hourly measured and simulated dissolved oxygen concentrations at Foster Avenue on the North Shore Channel in Chicago, Illinois for Water Year 2008. The dissolved oxygen comparison shows the high scatter to be expected for water-quality modeling, but it also shows a general correspondence with the "line of perfect agreement" not shown in the figures in the CFTM report (HDR|Hydroqual 2013c). Better correspondence of the results of the organic carbon model and CFTM with the "line of perfect agreement" is needed to increase confidence in the reliability of these models in determining the appropriate remedial action for the FFS.

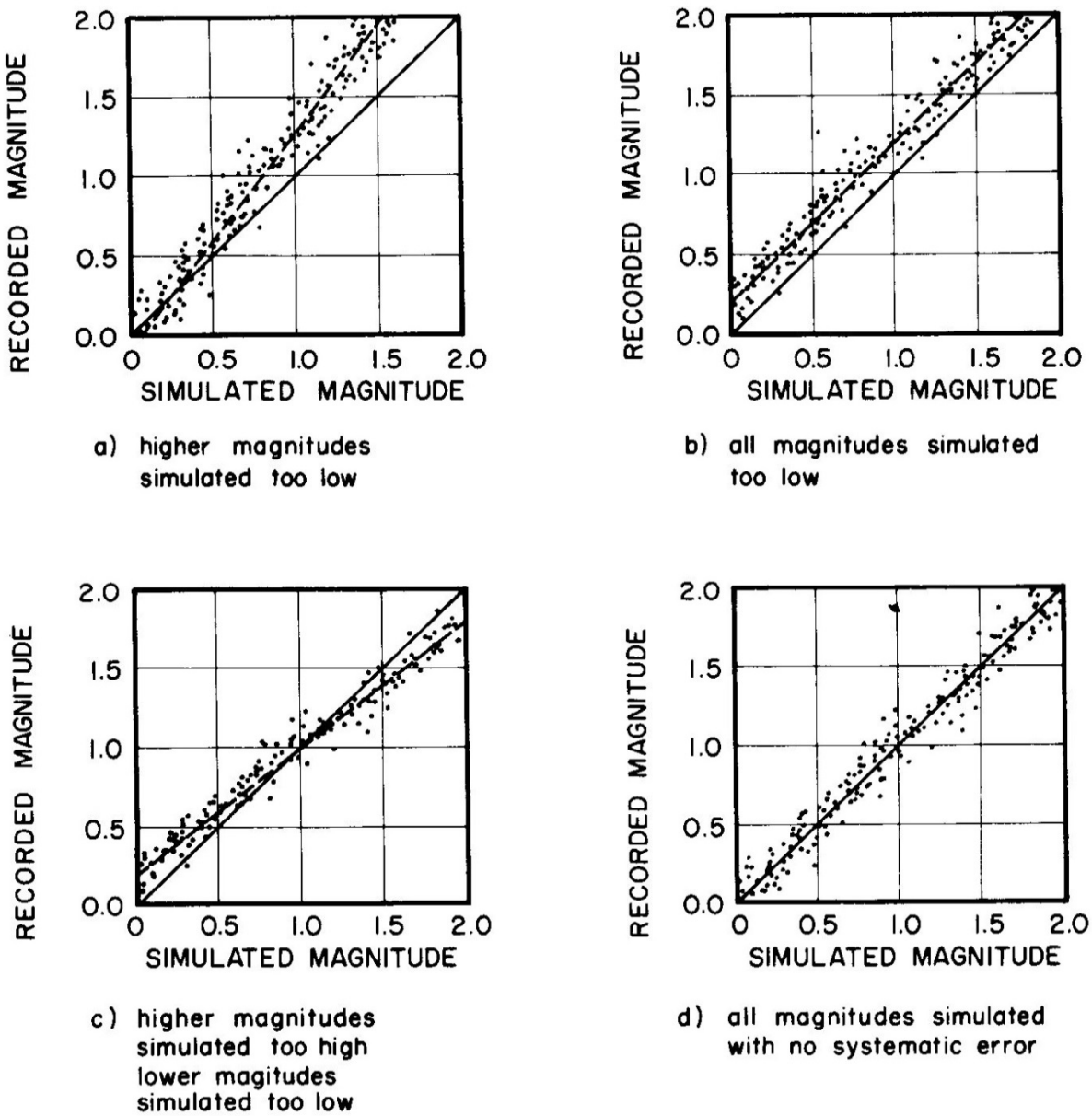
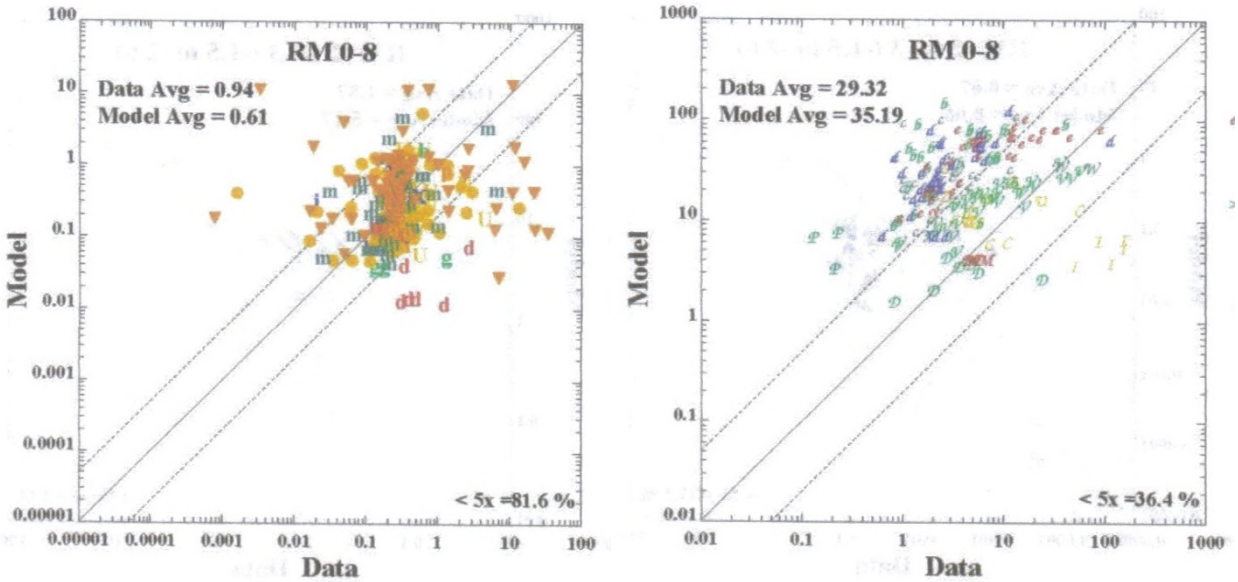
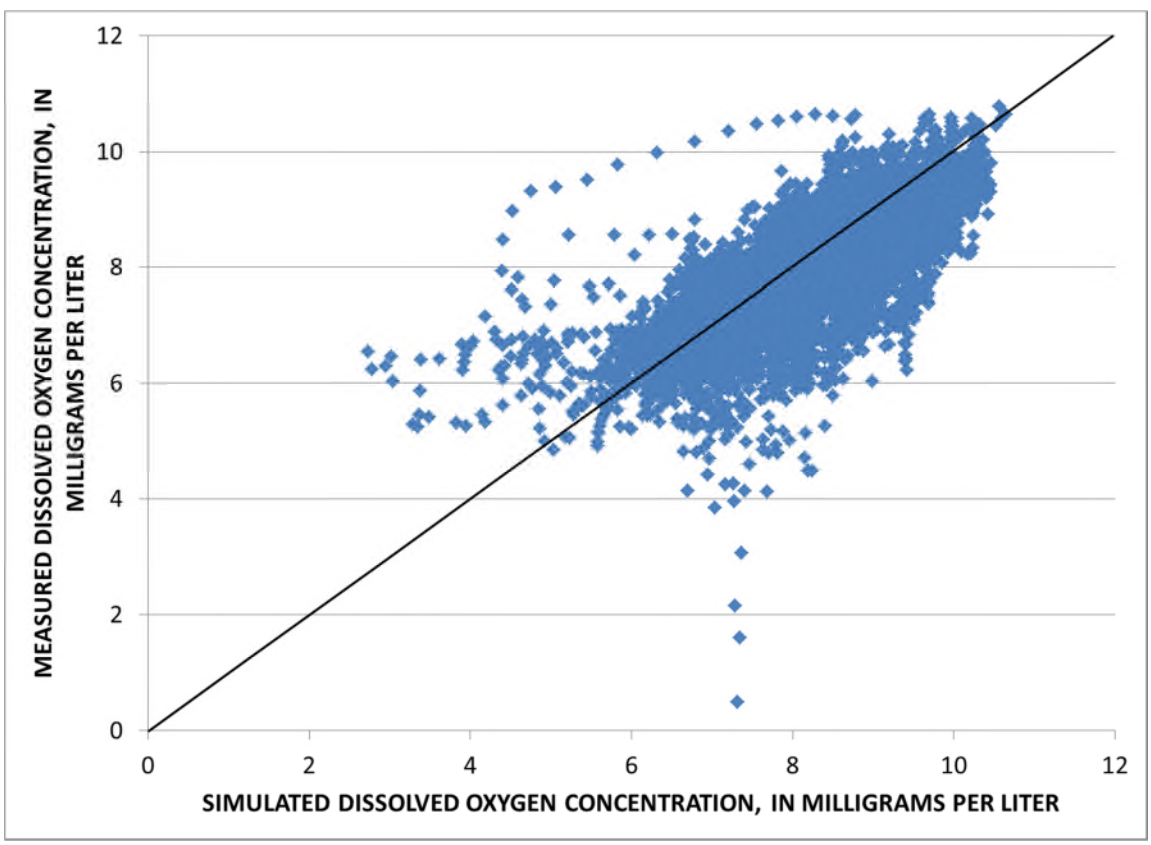


FIG. 11.1 Scattergrams showing presence of systematic errors.

Source: James and Burges (1982)



(left) Scattergram of simulated (model) and measured (data) 2,3,7,8-TCDD concentrations in the sediment of the FFS Study Area from Figure 4-50 of HDR|HydroQual (2014c), and (right) Scattergram of simulated (model) and measured (data) 2,3,7,8-TCDD concentrations in the water column of the FFS Study Area from Figure 4-51 of HDR|HydroQual (2014c).



Scattergram of measured and simulated hourly dissolved oxygen concentration at Foster Avenue on the North Shore Channel in Chicago, Illinois, for Water Year 2008

1.4 Similarly, the Contaminant Assessment and Reduction Project (CARP; HydroQual 2007) report also cited unusual calibration metrics:

> HydroQual (2007, p. ES-2) notes "For hexa-CB, 97% of the water column particulate measurements on an organic carbon normalized basis are within a factor of ten of the CARP model calculations. More significantly, 74% of the water column particulate measurements on an organic carbon normalized basis are within a factor of 3 of the CARP model calculations."

Similar calibration targets are used for 17 dioxin/furan congeners, and the DDx series of pesticides in the CARP (HydroQual 2007) report. Further, HydroQual (2007) notes: "The agreement between model calculations and the limited available methylmercury data is not as good as for other contaminants." Given that the calibration of the other contaminants is poor, it can be concluded that the calibration for methymercury is extremely poor. This discussion of the calibration of the CARP model is important because as discussed in Paragraph 2.1 the CFTM (HDR|HydroQual 2014c) used in the FFS was largely based on the CARP model.

1.5 These calibration criteria problems are <u>not</u> typical of sediment contamination studies, which are not prone to such high modeling inaccuracy and such low quality in fitting model results to measured data. For example, examples of other sediment contamination studies that applied standard criteria to evaluate the quality of the model calibrations include:

- Housatonic River: Calibration target of predictions being within ± 30 % of the data (Weston Solutions Inc. 2004)
- Hudson River: Predictions were compared with 95% confidence interval of the mean of the data (TAMS Consultants Inc. 2000)

1.6 Thus, the contaminant fate and transport model for the LPR should be revised to demonstrate quantitative achievement of "industry-standard" (at a minimum) calibration criteria. Otherwise, there can be no confidence in the model results for the post-remedial action conditions.

1.7 Region 2 should, but failed to, develop a Quality Assurance Project Plan (QAPP) pursuant to the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP). In fact, EPA maintains a Quality Policy, applicable to "all EPA organizations including . . . Regions," that seeks to advance EPA's "philosophy that the quality of environmental data and information supporting the Agency's decisions [is] appropriate for their intended use."[1] Pursuant to EPA's procedures for implementing its Quality Policy, which describe that EPA has adopted "voluntary national and international consensus standards for quality" including the American National Standard Institute/American Society for Quality Control ANSI/ASQC E4-2004. In order to implement the requirements of ANSI/ASQC E4-2004, the Intergovernmental Data Quality Task Force has developed the Uniform Federal Policy for Quality Assurance

[1]EPA, Quality Policy 2 (Oct. 20, 2008), EPA Classification No. CIO 2106.0, CIO Transmittal No. 09-001, *available at* http://www.epa.gov/irmpoli8/policies/21060.pdf.

Project Plans ("UFP-QAPP").[2] Pursuant to EPA guidance, the UFP-QAPP must be used at all federal facility hazardous waste sites.[3] However, in implementing EPA's UFP-QAPP guidance, Region 2, via memorandum dated November 8, 2005, established a policy to apply the UFP-QAPP more broadly. Pursuant to that memorandum, the UFP-QAPP must be applied "to all fund-lead and responsible party lead environmental investigations for CERCLA, RCRA and Brownfields projects in Region 2."[4]

1.8 The QAPP process is designed to ensure that the project can achieve its Project Data-Quality Objectives (PDQOs). The PDQO process includes the following seven steps:

(1) Stating the problem to be studied.
(2) Identifying the decision that will be made using the environmental data from the study and actions that will result to solve the problem.
(3) Identifying the information and measurements needed to make decisions.
(4) Specifying the boundaries (area and time period) to which the decisions apply.
(5) Specifying how the environmental data will be summarized and used to make the decision.
(6) Specifying acceptable error rates considering the consequences of making an incorrect decision.
(7) Selecting the most resource-efficient study design that will achieve all of the PDQOs.

1.9 The QAPP process is designed to obtain data of sufficient quality to ensure that the best possible decisions are made. For example, in 1997-1998, the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA), Region 5, developed a Hydrological Simulation Program-Fortran (HSPF) model for application to the rivers, lakes, and wetlands potentially impacted by the Proposed Crandon Mine in Wisconsin. For this project the USGS and Aqua Terra Consultants developed a QAPP for the model development and application. In the case of the Crandon Mine, a QAPP was developed for the HSPF modeling (the first QAPP developed for a modeling project for EPA) because the Crandon Mine was a highly contentious project (see O'Brien, 2008), and Region 5 wanted to document *a priori* the acceptable calibration and verification criteria on the basis of published experience with HSPF. Setting the calibration criteria *a priori* sought to minimize complaints that the model was not adequate for its intended uses to determine the proposed mine's impact on stream flow, wetland and lake water levels, and on critical ecological resources such as wild rice. This entailed review of dozens of published HSPF applications and the subsequent proposal of general statistical criteria that defined an acceptable calibration and graphical support information. These criteria and information then were revised on the basis of comments from Aqua Terra Consultants and HSPF experts within the USGS and published in February 1998 (U.S. Geological Survey and Aqua Terra Consultants, 1998). Through this process EPA could document that the HSPF model was objectively calibrated to meet industry standards, and, thus, the results of the model and any decisions made on the basis of model results also would not be arbitrary. In the case of the Lower Passaic River FFS not developing

[2]Intergovernmental Data Quality Task Force, Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual (Mar. 2005), *available at* http://www2.epa.gov/sites/production/files/documents/ufp_qapp_v1_0305.pdf.

[3]EPA, OSWER Guidance 9272.0-17: Implementation of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) at Federal Facility Hazardous Waste Sites (Jun. 7, 2005), *available at* http://www2.epa.gov/sites/production/files/documents/oswer_qapp_directive.pdf.

[4]EPA Region 2, Quality Management Plan (April 14, 2011), http://www.epa.gov/region2/science/qmp/qmp.html.

a QAPP as per the UFP-QAPP requirements has resulted in models that have been calibrated to arbitrary standards and, thus, the remedy decisions are not founded on rigorously proved models.

1.10 Region 2 should have followed a similar procedure for the models applied to the LPR. Despite the availability of more rigorous, systematic approaches to evaluating model performance, the FFS Study Area Final Modeling Work Plan (FMWP; HydroQual 2006) essentially defers the question of what constitutes acceptable model performance to be evaluated after the fact (HydroQual 2006, p. 2-19):

> "Although no consensus on the model performance criteria has been established in the past or present literature, a number of "basic truths" can be established for the Passaic River study. …
>
> - There is no single, accepted statistic or test that determines whether or not a model is validated. Both graphical comparisons and statistical tests are required in model calibration and validation. …
>
> Thus, numerous graphical comparisons and statistical tests will be adopted to provide sufficient evidence upon which to base a decision of model acceptance or rejection."

1.11 Even if it is true that there is "no consensus on model performance criteria," that does not mean that Region 2 can arbitrarily choose unusual statistics and characterize figures showing poor agreement between simulated and measured values as constituting a favorable comparison with the data across a wide range of modeled contaminants, locations, and years. On the current record there is simply no evidence that the model is yielding good results.

1.12 The poor results shown in the scattergrams suggest that it is not useful to perform a comparison over the entire FFS Study Area.

2. The models comprising the Contaminant Fate and Transport Model had known shortcomings that were not corrected in their application to the FFS. Thus, its use to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remediation alternatives cannot demonstrate the protection of human health and the environment. Therefore, in order to properly evaluate whether the various remediation alternatives will achieve the PRGs the model shortcomings <u>must be addressed</u> as proposed in the Final Model Work Plan and other reports. Region 2 should defer remedy selection until it has employed the UFP-QAPP process, then adjusted and re-run the models for the 17 mile Lower Passaic River Study Area (LPRSA).

2.1 EPA maintains a Quality Policy, applicable to "all EPA organizations including . . . Regions," that seeks to advance EPA's "philosophy that the quality of environmental data and information supporting the Agency's decisions [is] appropriate for their intended use."[5] Pursuant to EPA's procedures for implementing its Quality Policy, which describe

[5]EPA, Quality Policy 2 (Oct. 20, 2008), EPA Classification No. CIO 2106.0, CIO Transmittal No. 09-001, *available at* http://www.epa.gov/irmpoli8/policies/21060.pdf.

that EPA has adopted "voluntary national and international consensus standards for quality" including the American National Standard Institute/American Society for Quality Control ANSI/ASQC E4-2004, EPA organizations, including EPA Regions, may adopt and promote various "tools, processes, and requirements" to ensure the quality of EPA "products and services."[6]

In order to implement the requirements of ANSI/ASQC E4-2004, the Intergovernmental Data Quality Task Force has developed the Uniform Federal Policy for Quality Assurance Project Plans ("UFP-QAPP").[7] Pursuant to EPA guidance, the UFP-QAPP must be used at all federal facility hazardous waste sites.[8] However, in implementing EPA's UFP-QAPP guidance, Region 2, via memorandum dated November 8, 2005, established a policy to apply the UFP-QAPP more broadly. Pursuant to that memorandum, the UFP-QAPP applies "to all fund-lead and responsible party lead environmental investigations for CERCLA, RCRA and Brownfields projects in Region 2."[9]

2.2 HDR|HydroQual (2014c, p. 1-1) states: "The contaminant fate and transport model used for these analyses was based largely on the peer reviewed model developed for the NY/NJ Harbor Contaminant Assessment and Reduction Project (CARP)." (HydroQual 2007). HDR|HydroQual (2014c, p. 1-2) also states: "For the carbon production sub-model all model input rates and constants were used directly from the CARP model without adjustment. For the contaminant sub-model all model input rates and constants were used directly from the CARP model with the exception of rate of mixing within the biologically active surface sediments." HDR|HydroQual (2014c, p. 2-1) states: ". . . [P]rior application of organic carbon production modeling originate from the calibrated, validated and peer-reviewed eutrophication model developed by HydroQual as part of SWEM." (HydroQual 2002). Finally, HDR|HydroQual (2014c, p. 2-2) states: "SWEM was calibrated and validated against observed water and sediment nutrient flux and quality data collected during two full annual cycles, the 12-month periods from October 1, 1994 to September 30, 1995 and from October 1, 1988 to September 30, 1989." However, HDR|HydroQual (2014c) fails to note that the data from 1988-1989 were not sufficient to validate SWEM. In particular, HydroQual (2002, p. 1-2) notes: ". . . [I]t is appropriate to say that SWEM has been validated in Harbor and Sound waters, but not in the New Jersey tributaries." Further, HydroQual (2002, p. 3-1) notes no changes in grid resolution were made in the Passaic and Hackensack Rivers, only bathymetry changes were made, and HydroQual (2002, p. 3-6) notes no change in bottom friction was made for the Passaic River. Thus, the SWEM (HydroQual 2002) and CARP (HydroQual 2007) models form the heart of the CFTM used for the FFS. Further, as described in Paragraph 1.4 the CARP model calibration relied on highly unusual and imprecise measures of goodness of fit that were not substantially improved in the CFTM model (see all of Comment 1) and as noted above the SWEM model was never validated for the Lower Passaic River. Therefore, Region 2's failure to collect the data needed to improve the models as described below is unacceptable.

---

[6]EPA, Procedure for Quality Policy 2-3 (Oct. 20, 2008), EPA Classification No. CIO 2106-P-01.0, CIO Transmittal No. 09-001, *available at* http://www.epa.gov/irmpoli8/policies/2106p01.pdf.

[7]Intergovernmental Data Quality Task Force, Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual (Mar. 2005), *available at* http://www2.epa.gov/sites/production/files/documents/ufp_qapp_v1_0305.pdf.

[8]EPA, OSWER Guidance 9272.0-17: Implementation of the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) at Federal Facility Hazardous Waste Sites (Jun. 7, 2005), *available at* http://www2.epa.gov/sites/production/files/documents/oswer_qapp_directive.pdf.

[9]EPA Region 2, Quality Management Plan (April 14, 2011), http://www.epa.gov/region2/science/qmp/qmp.html.

2.3 The CARP report (HydroQual 2007) and the FMWP (HydroQual 2006) make several recommendations for the improvement of the CARP model in order for it to be used in future projects such as the FFS. The Preface of the CARP report (HydroQual 2007) states: "CARP products, particularly the modeling results, will no doubt provide important new information for these programs to consider, but further data collection and model refinement may be necessary to suit the scale and requirements of any particular program." The domain of the CARP model is quite large, including the entire New York/New Jersey Hudson-Raritan Estuary. Thus, it is reasonable to expect, based on HydroQual (2007), model refinements would be necessary to focus on the FFS Study Area. Specifically, HydroQual (2007, p. C-1) states

> "Detailed analyses of specific sections of the Harbor will require further model refinement and data collection. In this regard, the data collected to support the development of the CARP models, although unprecedented, were somewhat marginal and would not be fully sufficient for sub-regional evaluations."

Application of the CARP model to the Lower Passaic River is exactly one of the sub-regional evaluations for which more data are needed.

2.4 HydroQual (2007) listed the following specific needs for further research or data collection:

- (p. C-4) "Additional monitoring of storm water and runoff is recommended."
- (p. C-4-5) "Additional sampling at the Dundee Dam should be conducted for both dissolved and particulate contaminant phases with coincident measurements of suspended sediment, particulate organic carbon, and dissolved organic carbon."
- (p. C-5) "Additional dissolved phase measurements would be helpful is assessing the bioavailability of dioxin/furan congeners."
- (p. C-5) "Although the final CARP model calibration results for PAHs are reasonable, further improvement on this calibration would require collection of additional site-specific PAH data to test field-derived partition coefficients."
- (p. C-6) an effort should be undertaken to perform a post-audit assessment of the CARP mercury model relative to all the new research on mercury being done. "It is possible that refinements and enhancements to the CARP mercury model, based on the latest research, would benefit the utility of the model in assessing mercury contamination."
- (p. C-7) "additional measurements of methymercury in the NY/NJ Harbor would be useful for additional model verification."

2.5 None of these tasks was performed in a systematic way focused on model calibration or verification along the lines proposed in the FMWP (HydroQual 2006). Instead, the results of the CFTM model (HDR|HydroQual 2014c) were compared to other data available outside of the original calibration and verification periods for the CARP model (HydroQual 2007). These data sets were limited in their spatial and temporal extent and were not collected for the purpose of refining the CARP CFTM model applied to the FFS Study Area. Further, HydroQual (2006, p. 5-18) recommended that a hindcast verification should be done for the CFTM. HydroQual (2006, p. 5-18) stated: "For the hindcast, the Lower Passaic River Restoration Project contaminant fate and transport model will be run for a thirty or forty year time period to determine if the model correctly calculates current conditions." This hindcast verification was not done. All of the

aforementioned refinements should be accomplished for the CFTM before final alternatives are selected. Absent these refinements, there is no basis to conclude that the model is sufficiently accurate to support reasoned decision-making about a remedy for the FFS Study Area.

2.6 HydroQual (2006, p. 4-21) made several recommendations to solve the inadequacies of the SWEM verification in the New Jersey tributaries as follows:

- "It is proposed to conduct 4 to 8 spatial surveys of this region with a total of 15 to 20 stations distributed between the Passaic River, Hackensack River, Newark Bay, the Arthur Kill and Kill van Kull."
- "The surveys would be conducted concurrently with the sampling for the chemicals of potential concern."
- "The eutrophication model will be calibrated against chlorophyll-a, organic carbon (soluble and particulate), the nitrogen series (organic, ammonia, and nitrite plus nitrate), phosphorus (organic and phosphate), silica (dissolved and biogenic), BOD, and dissolved oxygen."

2.7 These aspects of the Final Modeling Work Plan (HydroQual 2006) were not accomplished. Further, these refinements to the SWEM model should be undertaken before final alternatives are selected because in their absence, there can be no confidence that the model is sufficiently accurate to support a remedy selection decision.

3. Because the Sediment Transport Model calibration is poor, its use to provide input to the Contaminant Fate and Transport model to evaluate the improvements in contaminant concentrations in the sediment resulting from the various remediation alternatives is not reliable. To properly evaluate whether the various remediation alternatives will achieve the PRGs the Sediment Transport Model calibration and verification <u>must be redone</u>. Failure to do so renders the FFS inconsistent with the NCP by its inability to demonstrate protection of human health and the environment.

3.1 The quality of the sediment transport model calibration also is expressed and explained in unusual terms that raise doubt about the reliability of the Sediment Transport Model (STM). For example, when discussing the results for the March 16, 2010 high flow period, HydroQual (2014b, p. 4-11) states "The model results tend to be lower than the data; however, the majority of the points lie within the factor of 2 variation line indicating that the model in general doesn't over represent or under represent the data by more than a factor of 2 in most cases." A "factor of 2" fit quality is better than the "factor of 10" or "factor of 3" fit qualities for the CARP CFTM (HydroQual 2007) or the "factor of 5" fit quality reported for the FFS CFTM (HDR|HydroQual 2014c), but it is still a far cruder fit quality compared to the percentage error tolerances commonly applied for sediment transport modeling in, for example, HSPF of less than 20% is very good, 20-30% is good, and 30-45% is fair (Donigian et al., 1984). This crude fit to the available sediment concentration data indicates that the STM has substantial uncertainty that propagates into the CFTM increasing the overall uncertainty of the predicted natural recovery due to sedimentation and of the general sediment and attached contaminants of concern movement into and within the FFS Study Area.

3.2 The STM report (HDR|HydroQual 2014b) also includes a number of confusing or irrelevant statements. For example, for low flow periods HDR|HydroQual (2014b, p. 4-8) states

> ". . . [T]he model often over-predicts peak tidal TSS levels near the bottom, though there were times when the predictions were very similar to the data and times when observed TSS levels were higher than the prediction. More importantly, the phase of the predictions usually agreed well with the phase of the observations."

The importance of matching the phase is not explained here, and given the dominance of the hydrodynamic tidal signal, the mere fact that the simulation matches the phase says little or nothing about its actual predictive ability. It does not confirm the reliability of the STM.

3.3 Further, the undersimulation of sediment concentrations for March 16, 2010, (HDR|HydroQual 2014b, p. 4-12) and the oversimulation of the peak sediment concentrations in early April 2010 (HDR|HydroQual 2014, p. 4-5), which, being blamed on errors in boundary inflow loads from the Upper Passaic River (UPR), actually demonstrate the failure of the model input to consider hysteresis in the sediment loading curve from the UPR. This failure is an important shortcoming of the STM because hysteresis in the sediment loading affects the proper estimation of the total load and timing of the loads coming from upstream during storms, which result in the bulk of the sediment load coming from the UPR to the FFS Study Area. Thus, if the storm loads are improperly estimated the natural recovery of the surface sediments in the FFS Study Area will be uncertain.

3.4 Finally, in Figure 4.15 of the STM report (HDR|HydroQual, 2014b) the model results and data should be presented on the same figure to allow for a more direct comparison of the model and data. Also the scale of this figure distorts the comparison between the model and data because only the flux data for RM 4.2 span the range of the figure, all other locations have far lower ranges of flux data and model results. Thus, for RMs 13.5, 6.7, and 1.4 smaller ranges of flux should be displayed so that the agreement between the measured and simulated values can be more clearly seen. One thing that is clear from the figure, is that the model substantially underestimates the solids flux during high flows at RMs 4.2 and 6.7, which implies the scour of surface sediments during storms is underestimated adding to the uncertainty in the estimated natural recovery.

3.5 In order for the public to evaluate and comment upon the acceptability of the calibration and the reliability of the boundary conditions, information on the calibration curves and accuracy of the acoustic backscatter measurements should be described in the STM report. This is important information (as described below) that is not discussed or made transparent in the report. For example, HDR|HydroQual (2014b, p. 4-9) notes: "Given the variability in the relationship between acoustic backscattering and suspended solids, and the limited range of suspended solids data available to develop the relationship, the comparisons between the PWCM *[physical water column monitoring program]* derived fluxes and model results are considered acceptable." (note: explanation in italics added). Further, HDR|HydroQual (2014b, p. 1-6) notes that for 2000-2002 Acoustic Doppler Current Profiler (ADCP) and acoustical backscatter measurements in the Kill van Kull and Arthur Kill were used to develop boundary conditions for the sediment transport

model. The failure to provide this information undermines the ability of the public to meaningfully comment on the STM and FFS reports.

4. No formal uncertainty analysis was done for the Contaminant Fate and Transport Model alone, and no consideration was given to the propagation of Hydrodynamic Model Uncertainty to Sediment Transport Model Uncertainty to Contaminant Fate and Transport Model Uncertainty. Formal uncertainty analysis was not conducted because it was argued that such an analysis would be too computationally intensive. However, well-known, well-accepted, and well-tested uncertainty analysis methods are available that are less computationally intensive than the method described in the CFTM report, and, thus, a full uncertainty analysis of the cascade of models used to estimate the contaminant fate and transport can and should be done. This will inform the public of the certainty of the remedial Alternatives in meeting the PRGs and in not being inconsistent with the NCP.

4.1 As noted in the Executive Summary, the design and selection of remedial actions to protect human health and the environment in the FFS Study Area is a case of design and decision making with imperfect information (i.e. under uncertainty). Under these conditions Tung et al. (2006, Preface) note:

> "Due to the presence of numerous uncertainties, the ability of the system to achieve the goals of design and management decisions cannot be assessed definitely. It is almost mandatory for an engineer involved in major hydrosystem infrastructural design or hazardous waste management to quantify the potential risk of failure and associated consequences."

Again for the case of the Lower Passaic River FFS, scientists, economists, lawyers, and decision makers can be added to engineers in the foregoing quote. Therefore, a thorough uncertainty analysis of the various models applied needs to be done for the Lower Passaic River FFS to ensure the selected remedial action has a high probability of meeting the PRGs and in being consistent with the NCP. Also, the thorough uncertainty analysis can determine if the performance of the selected alternative in lowering surface sediment concentrations of COPCs and COPECs is significantly better than that of the No Action alternative.

4.2 For water-quality modeling Beck (1987) noted that uncertainties affect primarily four problem areas that engineers and scientists must address:

(1) uncertainty about model structure, i.e., what basic processes are involved, how they interact, and how these processes and interactions can be mathematically characterized in an efficient and parsimonious manner;
(2) uncertainty in the model parameters, i.e., parameter identification and calibration problems;
(3) uncertainty associated with estimates of the future behavior of the system, i.e., aggregation of uncertainties in model structure, model parameters, and in the definition of the design or decision scenario into overall estimation uncertainty; and

(4) reduction of critical modeling uncertainties via carefully designed experiments and/or monitoring programs.

The four problem areas are strongly interrelated. For example, evaluation of estimation uncertainty (area 3) assumes that the model structure (area 1) has been reasonably identified, and examines the propagation of model parameters (area 2) and data uncertainties through the model and the resulting forecast or estimation reliability. For the case of the Lower Passaic River FFS, area 3—estimation of the uncertainty in the simulated concentrations of the COPCs and COPECs in the FFS Study Area—is the ultimate goal of the uncertainty analysis.

4.3 Because the estimated concentrations COPCs and COPECs in the surface sediments of the FFS Study Area are the result of a cascade of model results—i.e. the output from the Hydrodynamic model is input to all the other models and the output from the Sediment Transport and Organic Carbon models is input to the Contaminant Fate and Transport model—the potential for the uncertainty in the contaminant concentrations in the surface sediments to be very large is high. Figure 9.4 from Novotny and Olem (1994) [shown on the next page] illustrates the increase in possible error (i.e. possible uncertainty) in estimates of various outputs from watershed models. For example, the simulation of sediment transport is dependent on accurate estimates of flow rates and velocities. Thus, the accuracy of the sediment simulation cannot be better than that of the hydrologic simulation, and the sediment simulation experiences larger errors than the hydrologic simulation. Similarly, substantial fractions of the phosphates and metals transported in a watershed are attached to sediment particles, and, thus, the accuracy of the simulation of the phosphates and metals is limited by the accuracy of the sediment transport simulation. This magnification of errors and uncertainties continues as organic chemicals and contaminants are simulated. Novotny and Olem (1994) indicate that the errors increase on a logarithmic scale from one output to the next suggesting that the compounding of errors and uncertainties typically is multiplicative rather than additive. Further, because, as described in Comments 1 and 3, the levels of error in the Sediment Transport, Organic Carbon, and Contaminant Fate and Transport models are unusually high, the expected multiplicative increase in errors and uncertainties in the model outputs could result in uncertainties in the concentrations of the COPCs and COPECs in the surface sediments in the FFS Study Area that are so high that it may be impossible to distinguish among the Remedial Action and the No Action alternatives.

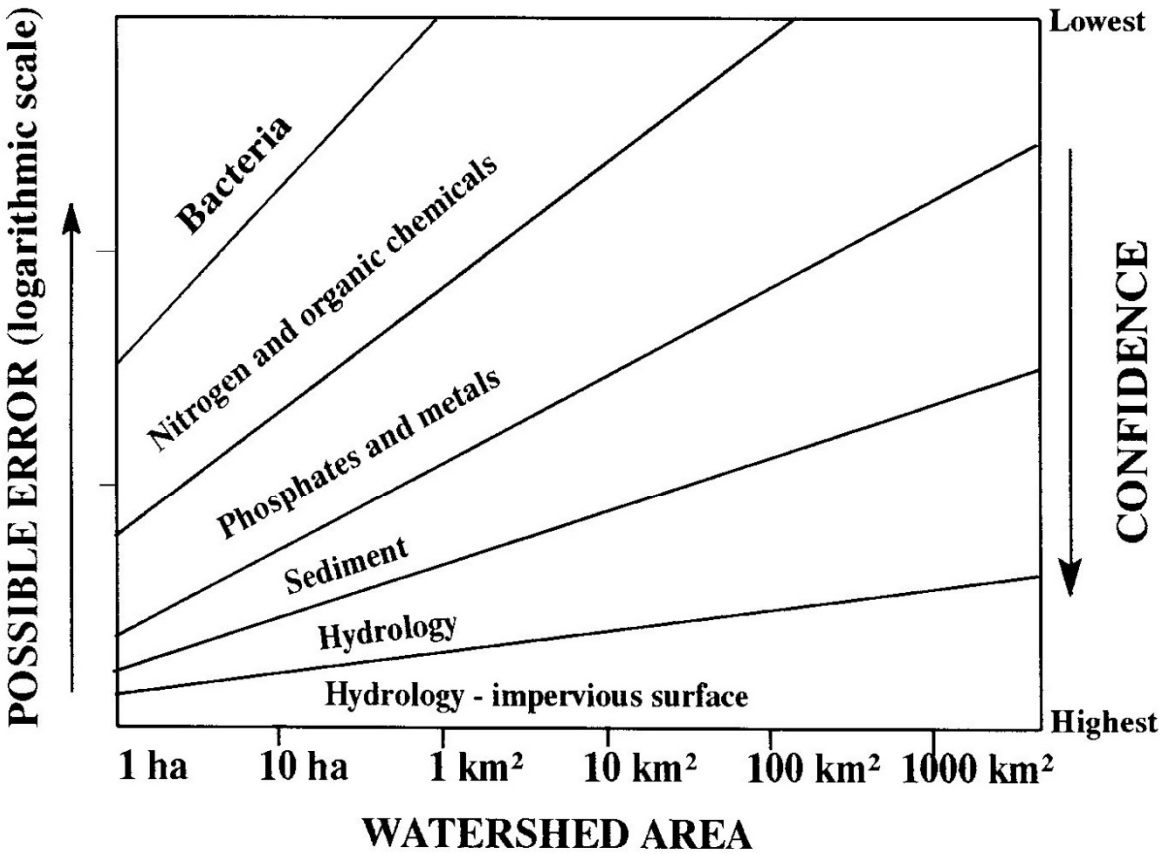


FIGURE 9.4. Relative accuracy and reliability of hydrologic models of diffuse pollution. Accuracy and reliability decreases with the increased complexity and size of the modelled system.

Source: Novotny and Olem (1994)

4.4 The first, most basic assumption of conducting a model uncertainty analysis is that the calibrated model has been proven through validation to be capable of simulating the key behavior for the water body of interest. Once such a model is available, then uncertainty analysis methods can be used to evaluate how uncertainties in the input data, model parameters, and model performance propagate through the model to determine the likely range over which model results may vary and to estimate key statistics of model output (i.e. standard deviation, confidence intervals, probability distributions, etc.). In this case, as discussed in Comments 1-3, the contaminant fate and transport model and sediment transport model have not been proven to be capable of simulating the key behavior for the Lower Passaic River. This makes it nearly impossible to rigorously evaluate the modeling uncertainty, illustrating another reason that the modeling is not adequate to support remedy selection decisions.

4.5 No formal uncertainty analysis was performed for the Contaminant Fate and Transport Model alone, and no consideration was given to the propagation of Hydrodynamic Model uncertainty to Sediment Transport Model uncertainty to Organic Carbon Model uncertainty to Contaminant Fate and Transport Model uncertainty, let alone any continuation of the compounded uncertainty of these models into the ecological and human health risk models. This apparently was not done because of a mistaken belief

that such analysis was too computationally intensive to be practical. HDR|HydroQual (2014c, p. 4-17) refers to the uncertainty analyses done for the sediment transport model for the Lower Duwamish Waterway, suggesting that the analysis there demonstrates the computational intractability of the needed uncertainty analysis:

> "These involved developing upper and lower bound estimates for selected model inputs and running 6-years with permutations of the upper and lower bound values for the selected parameters, requiring 2n *[really 2^n, reviewer correction]* simulations, where n is the number of parameters included in the analysis (i.e. 32 simulations for 5 parameters). Results from the simulations were then compared to the calibration results to identify upper and lower bound sets of parameters which were then used in long-term simulations (21 years). This approach was considered for the FFS modeling, which includes hydrodynamics and sediment transport, a eutrophication model, and a contaminant fate and transport model. The time required to implement a similar approach and include each of these components was estimated 6 to 9 months, even with a dedicated bank of computers." [sic]

4.6 While it is not clear precisely what type of analysis was under consideration, the discussion implies the use of some sort of Rosenblueth (1975) uncertainty analysis procedure in the first part, and then possibly a Hornberger and Spear (1981) type analysis in the second part. If each model had 5 uncertain parameters/inputs (15 total uncertain variables), 32,768 ($=2^{15}$) simulations would be needed and the problem would be computationally intractable as indicated in the CFTM report (HDR|HydroQual 2014c).

4.7 However, there are several uncertainty analysis methods that have a long history of successful application to water quality models that require far fewer model runs to obtain estimates of output uncertainty, but which were not considered in the CFTM report (HDR|HydroQual 2014c). For example, first-order uncertainty analysis (FOUA) was first applied in water-quality modeling by Burges and Lettenmaier (1975) for a Streeter-Phelps model of dissolved oxygen (DO) in a hypothetical stream. Its use quickly expanded to applications to much more complex water quality models; for example, Scavia et al. (1981) used it to identify the key uncertainty sources in the Saginaw Bay eutrophication model. By the late 1980s, EPA recognized it as a useful technique with its inclusion in the uncertainty analysis routines (UNCAS) designed to work with QUAL2E (Brown and Barnwell 1987). Melching and Bauwens (2000, 2001) showed that FOUA could identify key sources of uncertainty and measures of output uncertainty for a cascade of models used to compute DO in the Zenne River in Brussels, Belgium. The DO simulation involved the coupling of a nonpoint pollution load model (to estimate combined sewer flows and loads to treatment plants and directly to the river as overflows), a constant treatment efficiency model, and a river water-quality model (unsteady flow on an hourly time step) applied over a one-year modeling period. The combination of models involved 53 uncertain parameters/inputs. The use of FOUA requires n+1 simulations.

4.8 Another method that yields useful uncertainty analysis information with a relatively small computational burden is the Latin Hypercube Sampling (LHS) technique.LHS (McKay et al. 1979; McKay 1988) is a stratified sampling approach that allows efficient estimation of the statistical characteristics of the output. McKay (1988) suggested that the use of twice the number of uncertain variables for sample size ($M \geq 2n$) would be sufficient to yield accurate estimation of the statistics model output. Iman and Helton (1985)

indicated that a choice of M equal to 4/3n usually gives satisfactory results. For a dynamic stream water-quality model over a 1-year simulation period, Manache and Melching (2007) compared results from LHS using M = 4/3n and M = 3n and found reasonable convergence in the identification of the most sensitive parameters but not in the calculation of the standard deviation of model output. Thus, if it is computationally feasible, the generation of larger numbers of samples would further enhance the accuracy of the estimation. In water-resources engineering, the LHS technique has been widely applied to sediment transport (Yeh and Tung, 1993; Chang et al., 1993), water quality modeling (Jaffe and Ferrara, 1984; Melching and Bauwens, 2001; Sohrabi et al., 2003; Manache and Melching, 2004), and rainfall-runoff modeling (Melching, 1995; Yu et al., 2001; Christiaens and Feyen, 2002; Lu and Tung, 2003). Therefore, the LHS technique is now a standard practice applied to many modeling studies, and software to generate Latin hypercube samples are included in standard commercial software such as Palisade's @Risk: Risk Analysis software.

4.9 Another means to simplify an uncertainty analysis is to view spatially varying parameters as standardized variables as proposed by Melching and Bauwens (2000, 2001). In their study, eight of the parameters of the watershed pollutant-load model varied among the different sub-basins. If each of these eight parameters was considered independent in the uncertainty analysis, >200 variables would need to be considered and the uncertainty analysis would have become computationally prohibitive. Therefore, these eight parameters were considered as standardized variables in the uncertainty analysis. A standardized variable, Z_i, is computed as

$$Z_i = \frac{x_i - \overline{x_i}}{\sigma_i}$$

where x_i is the original variable value in sub-basin i, $\overline{x_i}$ is the mean of variable x_i, and σ_i is the standard deviation of variable x_i. In this way, the parameters for each sub-basin can have a mean and variance characteristic of that sub-basin in the uncertainty analysis.

4.10 In summary, the conclusion that a full uncertainty analysis of the interactions among the hydrodynamic, sediment transport, eutrophication (organic carbon), and contaminant fate and transport models is computationally intractable is not correct. Thus, a meaningful uncertainty analysis should be performed as discussed in the following paragraphs.

4.11 The "uncertainty analysis" method applied in HDR|HydroQual (2014c, p. 4-18) was "an approach discussed in EPA's 2005 Contaminated Sediment Remediation Guidance for Hazardous Waste Sites *(EPA 2005)*, which relies on consideration of residuals between model results and data (Connolly and Tonelli, 1985)." [information in italics added]. HDR|HydroQual (2014c, p. 4-18) notes: "The uncertainty values computed represent a lower bound on the uncertainty in the RM 0 to 8.3 averages passed to the risk assessment." This discussion greatly understates the problem because residual-based methods are not good at estimating the uncertainty in projected future conditions after the system has changed due to remedial action. This is because the residuals are dependent on the current state of the river system to which the model is applied, once the river system is dramatically changed via dredging, capping, or both the combination of model structure, input data (boundary and initial conditions), and model parameter

uncertainties will be greatly changed from the calibration period, and, far different total uncertainty (and residuals) would result. For example, consider the hitting statistics of baseball players before and after they took steroids and the resulting dramatic changes in their bodies. Further, Garen and Burges (1981) note that residual-based methods only are valid if the historical record used to determine the residuals is representative of a wide range of system responses and is of sufficient length to constitute a statistically significant sample. In the case of the Lower Passaic River, the amount of the data used to determine the residuals is sparse and sporadic and is not representative of a wide range of system responses (including, notably, the post-remediation case) and does not constitute a statistically significant sample.

4.12 Melching et al. (1990, 1991) proposed the use of a model correction factor that would reflect the uncertainty in model output in addition to the uncertainty from inputs and model parameters propagating through the model(s). This model correction factor would partially account for model structure uncertainty. Melching et al. (1991) stated

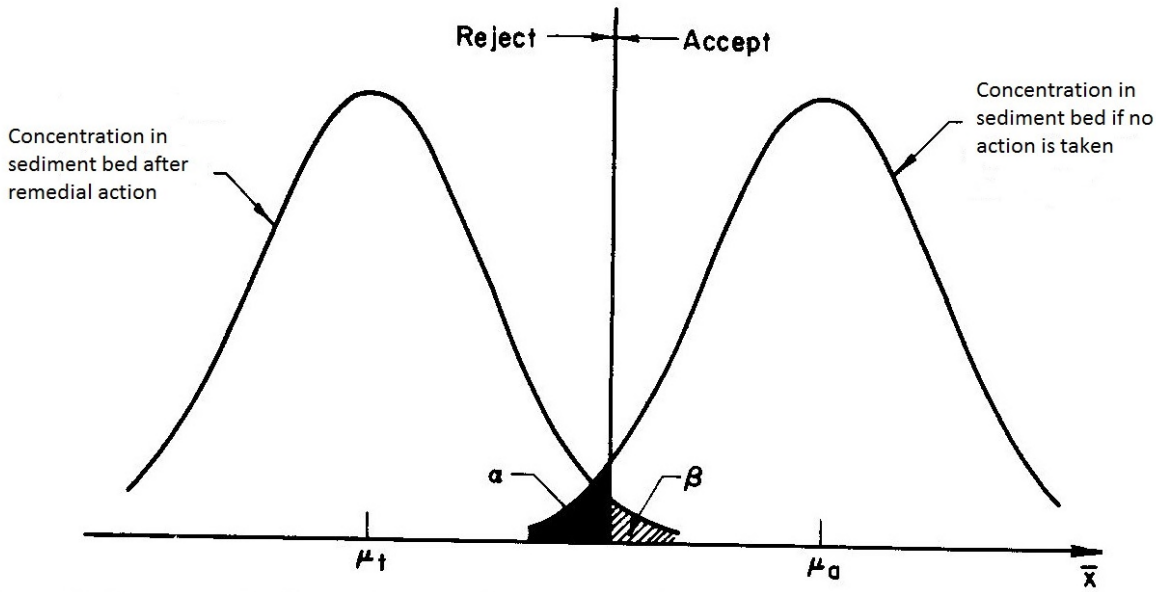
> "The model correction factor λ_m is not strictly a fitting parameter. Its purpose is to reflect any bias or modeling inadequacies in the best-fit model.It may be estimated from physical considerations, previous verification experience with the model for similar problems, or as a byproduct of calibration."

4.13 Thus, for the CFTM the residual-based results could define the model correction factor and its statistical properties. For example, if the CFTM was unbiased in its prediction of a contaminant, the mean value of λ_m would be 1, its standard deviation could be derived from the mean or median error, and, if LHS is applied, a probability distribution for λ_m must be proposed [note: the selection of this distribution is much less important than the determination of the mean and standard deviation, see e.g., Melching (1994)]. Similarly, the mean, standard deviation, and, if necessary, probability distribution for each uncertain input or model parameter must be determined. Usually, the mean is the best-fit value of the parameter or input. The standard deviation can be determined from (a) the reasonable range of values for this parameter, (b) variation in measured values of an input or parameter, (c) guidance from the literature, or (d) professional judgment. A lot of this information is compiled in the calibration process as a modeler seeks to be sure that the model is reasonable because the calibrated parameter values fall in the range of values expected for that parameter based on past experience.

4.14 The principal problem with the uncertainty analysis of the cascade of model results from the Hydrodynamic Model to the Sediment Transport Model to the Organic Carbon Model to the Contaminant Fate and Transport Model is that combining the propagation of parameter and input uncertainties with the model structure uncertainties from the residual analysis will result in a high level of total uncertainty in the simulation of the results for the different Alternatives. Considering the propagation of uncertainties from one model to another, it is possible that the results of the different Alternatives will be indistinguishable when the uncertainty is properly considered and quantified for each model, and then propagated from the first model (hydrodynamic) through the last models (ecologic and human health risk).

4.15 To understand the concept of statistically indistinguishable results consider the hypothetical distribution of contaminant concentrations in the sediment bed shown below. In this figure, μ_t and μ_a represent the expected value of the contaminant concentration yielded by a computer model for the cases of application of a remedial

action and no remedial action applied, respectively. The two curves in the figure represent the probability density functions of the contaminant concentration for the two cases considering the modeling uncertainty. For a given concentration indicated by the "Reject-Accept" line in the figure, α represents the probability that the result for the no action case would be less than this concentration and β represents the probability that the result for the remedial action case would be higher than this concentration. From this figure, it is clear that there could be a substantial probability that the concentration for the no action case could be similar to that for the remedial action case especially if the modeling uncertainty is high as is likely to be the case for the cascade of models used to estimate the concentrations of the COPCs and COPECs in the surface sediments in the FFS Study Area (as previously discussed in this Comment). Numerous statistical tests are available to determine whether results of two models (or two data samples) are significantly different, but a full uncertainty analysis must be done in order to apply these tests.



5. The results of the sensitivity analysis with respect to the uncertainty in the inflows from the Upper Passaic River have been presented in a way that hides the true sensitivity of the contaminant concentrations in the LPR sediment to these inflows. This incomplete sensitivity evaluation overstates the reliability of the proposed remedial Alternatives in meeting the PRGs. Sensitivity analysis results <u>must be presented</u> for those contaminants with larger loads from the UPR.

5.1 Because HDR|HydroQual (2014d, Table 3-2) concludes that the Upper Passaic River is a "Minimal contributor" of 2,3,7,8-TCDD to the LPR, the sensitivity results reported for 2,3,7,8-TCDD in HDR|HydroQual (2014c) were as expected. These results are summarized on Page 5-2 of HDR|HydroQual (2014c) as follows: "Because the 2,3,7,8-TCDD boundary concentrations are so low relative to the ambient concentrations in the river, the change in concentration is too small to see a difference between the response across the range of boundary conditions simulated." Specifically, Figure 5-1 of

HDR|HydroQual (2014c) indicates that the measured 2,3,7,8-TCDD concentrations in the sediments of the FFS Study Area range between 0.1 and 1 µg/kg (ppb) whereas Figure 3-7 indicates that the 2,3,7,8 TCDD concentrations at the Upper Passaic River boundary are less than one ten thousandth of a ng/L (ppt). Thus, the concentrations of 2,3,7,8-TCDD coming in from the Upper Passaic River are on the order of a million times smaller than the ambient concentrations in the sediment of the FFS Study Area. Obviously, doubling the concentration of 2,3,7,8 TCDD coming from the Upper Passaic River as was done in the Sensitivity Analysis in HDR|HydroQual (2014c) represents a negligible change relative to the difference between the ambient and upstream boundary concentrations.

5.2 HDR|HydroQual (2014d, Table 3-2 and text) notes that for PCBs, cadmium, chromium, copper, lead, mercury, DDD, DDE, and DDT the Upper Passaic River is an "Important contributor" to the LPR; for dieldrin and aldrin the Upper Passic River is a "Major contributor," and for PAHs the Upper Passaic River is a "Dominant contributor." If the sensitivity analysis was done for PCBs, mercury, and DDT, which have a higher concentration relative to the sediment concentrations in the FFS Study Area relative to 2,3,7,8-TCDD, compliance with the PRGs for the various Alternatives would not be possible for the case of increased loads from the Upper Passaic River. That is, if the input of these contaminants from the Upper Passaic River was doubled as was done for the concentration of 2,3,7,8-TCDD in the sensitivity analysis, concentrations of PCBs, mercury, and DDT would certainly exceed the PRGs. Thus, a sensitivity analysis applied for PCBs, mercury, and DDT would raise substantial doubt that the evaluated Alternatives can meet the PRGs without remedial measures to reduce the contaminant loads from the Upper Passaic River. Such sensitivity analyses would clearly show the large effect of uncertainty on the evaluation of the performance of the proposed remedial Alternatives simply because of one source of uncertainty (the contaminant loads entering the FFS Study Area from the Upper Passaic River). The sensitivity analysis presented in HDR|HydroQual (2013c) must be extended to more constituents of concern to provide a clearer picture of the performance of the proposed remedial Alternatives in the face of uncertainty in the inflow loads from the Upper Passaic River.

5.3 If all the uncertainties in all the inputs and models were considered, it is likely that the proposed remedial Alternatives would have a high probability if not achieving the PRGs and the protection of human health and the environment.

6. Approximating the inflow concentrations of various contaminants based on values from the Mohawk River is, by Region 2's own admission, biased low. This will lead to an underestimate of the contaminant concentrations in the FFS Study Area after remediation. Actual field data for the New Jersey tributaries <u>should be collected and used</u> in the contaminant fate and transport modeling and the data collection should be performed for the full 17 mile RI/FS.

6.1 Regarding the twelve PCB congeners that display dioxin-like toxicity (TEF-PCBs) the CFTM report (HDR|HydroQual 2014c, p. 3-9) states:

> "Total dissolved (free + DOC-complexed) concentrations were not reported for the New Jersey heads of tide for dioxins and furans as part of CARP. Values from the Mohawk River were used for the dissolved phase for the tributaries.

The Mohawk was chosen during the development of the CARP model because it had the lowest concentrations out of the tributaries that were measured for that study.

The Saddle River was not measured during the CARP sampling program. When available, data from the Hackensack (the New Jersey tributary with the lowest concentrations) were used for the Saddle River. If data were unavailable for the Hackensack River, then data from the Mohawk River were used."

These are not valid assumptions given that the Upper Passaic River has been defined as an "Important contributor" of PCBs to the FFS Study Area in HDR|HydroQual (2014d). This is a prime example of Region 2's arbitrarily prioritizing the legacy contamination of LPR sediments as the most important source of contamination by minimizing the significant impact of external sources. Similarly, it is not reasonable for the values in Table 3.3 of HDR|HydroQual (2014c) to be massively smaller than the concentrations in the Passaic River upstream of Dundee Dam reported in HDR|HydroQual (2014d). These assumptions move beyond adding uncertainty to the analysis of contaminant concentrations in the FFS Study Area to biasing the results of the analysis.

6.2 On a related subject, it is not clear how the time series of contaminant loads in Figures 3-7 to 3-9 of HDR|HydroQual (2014c) were obtained, nor whether they are based on measured concentrations. The report should provide additional detail and justification regarding the approach taken to develop the time series of inflow loads to the LPR.

7. The rank-based system used to calibrate the Hydrodynamic Model is flawed, and this may affect the ability of the sequence of models to accurately estimate the spatial distribution of contaminants in the FFS Study Area. The final calibration of the Hydrodynamic Model <u>must be re-evaluated</u> using an objective function that considers the true performance of the model.

7.1 Chapter 5 of the Final Hydrodynamic Modeling Report (FHMR; HydroQual 2008) discussed a system where various model fit statistics were ranked from best to worst and then the ranks were summed to determine the best fit values of the Smagorinsky coefficient (C_s) for horizontal mixing and the bottom roughness length (Z_0). This rank-based system for picking C_s and Z_0 is seriously flawed because the statistics in Tables 5-2 to 5-4 clearly show the differences are small among the statistics for runs using various values of C_s and Z_0. Thus, Rank 1 output is not clearly superior to Rank 2 output. A better approach should have been applied, such as a weighted sum of the various fit statistics. Using such an approach would increase the confidence that the model had been properly calibrated to the available data.

8. Dredging can expose more contaminated deeper sediments to the water column, and since these sediments are not in equilibrium with the water column, the contaminants may be released into the water during dredging. The FFS analysis <u>should include</u> an evaluation of the effects of this release of contaminants during dredging.

8.1 The independent review panel convened to propose an Ecosystem-Based Rehabilitation Plan for the PCB contamination in the Lower Fox River and Green Bay in Wisconsin noted the following issues regarding release of contaminants during dredging (The Johnson Company, 2002, p. 36):

> "PCB concentrations are higher at greater sediment depths than at the surface in many areas of the River. Thus, dredging will generally result in the interim exposure of sediments with higher PCB concentrations that are not in equilibrium with the water column. PCB flux from these newly exposed sediments could significantly increase water column PCB concentrations for the duration of the dredging project, as the exposed sediments attempt to reach equilibrium."

8.2 For many COPCs and COPECs in the LPR the concentrations also are higher at greater sediment depths. Thus, the potential for these contaminants to release to the water column during dredging also is possible. This process is not considered in the models for the FFS but it is a critical issue that must be fully understood before a remedy is selected for LPR sediments. Ignoring the potential release of contaminants to the water column during dredging in the modeling increases the uncertainty in the model results and the likelihood that the state of contamination in the LPR and Newark Bay after remediation will be substantially different from that estimated by the CFTM.

9. Region 2 contends that "state-of-the-art" methods were employed in the FFS because the SWEM (HydroQual 2002) and CARP (HydroQual 2007) models were extensively Peer-Reviewed. However, the SWEM and CARP model domains are very large, and, thus, the peer reviews could not have considered the model performance in the FFS Study Area in sufficient detail to say with confidence that the models are sufficiently accurate for the current use in the FFS. A detailed peer review of the models as applied to the FFS Study Area <u>must be completed</u> to improve confidence in the models before a remedy is selected.

9.1 The domain of the CARP model is quite large, including the entire New York/New Jersey Hudson-Raritan Estuary. The domain of the SWEM model is even larger extending all the way down the New Jersey coast past Cape May and along the Connecticut coast to Nantucket Shoals (as shown in Figure 2-1 from HydroQual (2002), which shown on the next page). It is clear that the Lower Passaic River comprises a very small portion of the overall domain of the CARP and SWEM models. Thus, whereas these models may have been peer reviewed, the peer review focused on the broad domain-wide performance of the models and not on their specific applications to small sub-regions of the model domain like the FFS Study Area. The needs to refine the CARP model to sub-regions like the Lower Passaic River and to validate the SWEM model to the Lower Passaic River as stated in HydroQual (2007) and HydroQual (2002), respectively, are discussed in detail in Comment 2 of this report. Thus, the models applied in the FFS really have not been peer-reviewed for their intended purpose in the FFS Study Area.

The various models should be submitted to a full peer review to improve the confidence in the use of these models for evaluating remedial actions. Without a thorough peer review and subsequent model revisions, as necessary, the uncertainty regarding the selected remedial actions is increased.

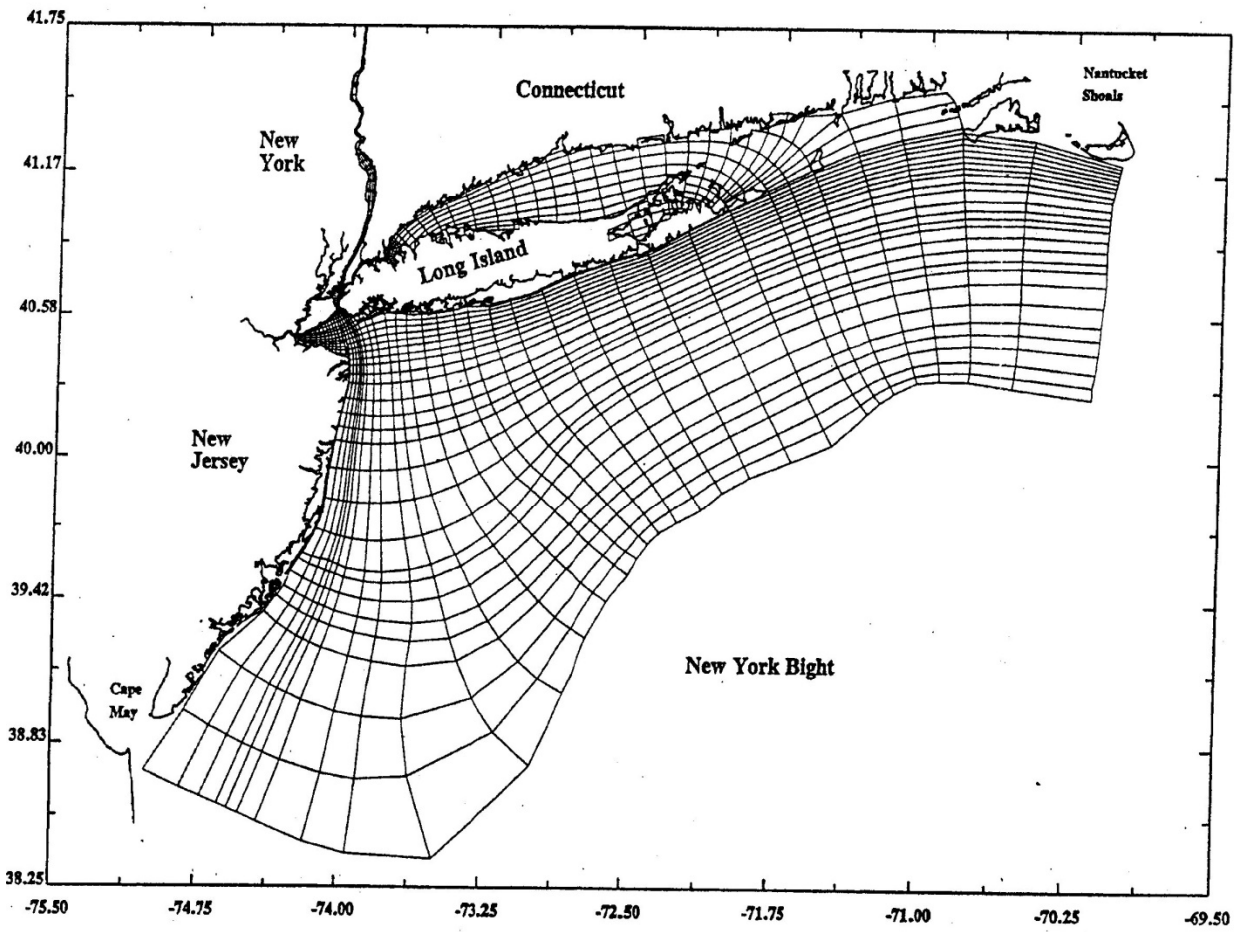


Figure 2-1 **Model Grid for System Wide Eutrophication Model: Complete Model Domain**

Source: HydroQual (2002)

10. The generation of a long-term inflow time series by repeating the same 15-year time period does not allow for sufficient confidence in the accuracy of the model and, thus, the long-term analysis of sediment movement and contaminant concentrations is flawed. A more reasonable approach to simulating long-term, post-remediation conditions in the FFS Study Area <u>must be applied</u> to improve confidence in the models before a remedy is selected.

10.1 HDR|HydroQual (2014c, p. 3-10) states "For the projection runs the time history for the period of time from October 1, 1995 through September 30, 2010 is repeated in a cycle from October 1, 2012 through September 30, 2059." No basis is provided to justify only considering these 15 years, and far better approaches are available, such as a measured 45 year time series or stochastically generating a long-term time series.

11. The approach used to determine the inflow loads of sediment and the various contaminants from the Upper Passaic River and tributary rivers is unclear. Because the loads from the Upper Passaic River may substantially affect whether the proposed Alternative remedial actions (Alternatives) can meet the PRGs, the procedure used to estimate the inflows loads <u>must be explained</u> in more detail.

11.1 The CFTM report (HDR|HydroQual 2014c, p. 5-2) notes: "The approach used to develop the boundary concentrations used for the calibration and projections represent a best estimate of the concentration based on the available data." Unfortunately, how this "best estimate" was obtained is not clearly explained, nor is any justification provided for limiting the study to the available data, rather than obtaining the additional data needed to clearly prove the model was adequately calibrated to and verified for the LPR.

12. The FFS assumes that the probability of a joint occurrence of a flood from the Upper Passaic River and a high storm surge is small, and thus, it did not evaluate such an event. However, the statistical analysis of flood and storm surge data was insufficient to reach this conclusion. Thus, a more complete analysis of the possible joint occurrence of a flood from the UPR and a high storm surge <u>must be done</u> to ensure the safety of the approach to remediation before a remedy is selected.

12.1 When discussing the simulation of conditions for Hurricane Donna (September 12, 1960) HDR|HydroQual (2014a, p. 4-1) noted: "While the surge elevation was one of the highest on record, the river inflow rates during the Hurricane were about 5,000 cfs, which is approximately the 1.25 year return flow rate for the station." Further, HDR|HydroQual (2014a, p. 6-7) states: "No meaningful correlation between high flow events and storm surge events was found, and it was concluded that there was no direct correlation between them. Therefore, in conducting the flood analyses, flooding due to high river inflow and storm surge were evaluated independently." However, this comparison was between measured harbor water levels at Bergen Point and Upper Passaic River flows at Little Falls for October 1981 to December 2004, which is too short a period to determine that floods and storm surges are independent. If an analysis were done between harbor water levels at Battery and Upper Passaic River flows at Little Falls, more than 100 years of data can be considered. If this analysis still finds no correlation between flood flows and storm surge levels, then it is more reasonable to independently evaluate floods and storm surges.

13. The statistical analyses done in the various reports to determine design flows (100-year flood, 500-year flood) are inconsistent with respect to the data used. Also, no corrections have been made to account for the urbanization of the watershed over time and space. These issues make the design flows highly uncertain. The design flows <u>should be determined</u> factoring in the effects of urbanization in time and space and <u>should be applied</u> consistently over all the modeling analyses.

13.1 HDR|HydroQual (2014a, p. 5-7) indicates Passaic River flow records from the USGS Little Falls gauging station for the period 1891 through 2005 were analyzed to determine flows of different recurrence intervals. These flows at Little Falls were adjusted to the full

area by drainage area ratio. The 173 mi^2 between Little Falls and the Study Area is much more urbanized than the most upstream portions of the basin. Thus, it would be more accurate to modify the area ratio to account for the effects of urbanization. Further, the frequency analysis should consider the large change in urbanization in the Passaic River Basin between 1897 and 2005 (and the present). For example, if the storm of October 10, 1903, occurred on today's Passaic River basin, a flow much higher than 28,000 cfs (daily maximum) and 31,700 cfs (instantaneous peak) is likely to result. Thus, appropriate adjustments for the effects of urbanization in time and space should be applied in the frequency analysis.

13.2 HDR|HydroQual (2014d, p. 3-2) notes: "The average annual river flow and annual peak flow between 1995 and 2011 are comparable to the average flow and peak flow over the past 55 years (1956-2011)." This report's focus only on 55 years, when more than 100 years of data are available at Little Falls, is not justified. Either all the data at Little Falls should be considered in this comparison, or an explanation provided of why it was not.

13.3 Use of the full data record at Little Falls will result in a more reliable, less uncertain estimate of the design flood peak flows for evaluation of bed stability after capping. Also, properly adjusting the record to consider the effects of urbanization will ensure the best possible estimate of the design flood peak flows likely to occur in the future, which will also increase the reliability of estimated design flood peak flows.

14. The assumption that the armor stone is non-erodible is unproven. The uncertainty in the determination of the critical shear stress for particle movement indicates that armor stone has some non-zero probability of movement. The probability of armor stone movement <u>should be evaluated</u> and the armor selection <u>should be modified</u> as appropriate.

14.1 HDR|HydroQual (2014a, p. 5-9) states "The armor stone (i.e. 6-inch angular rock) was considered to be non-erodible under the flow conditions simulated." This statement should be verified by an evaluation of the uncertainty in the critical shear stress in comparison with the computed near bed shear stress in the armored areas. Several researchers have developed estimates of the uncertainty in the critical shear stress.To facilitate an uncertainty evaluation for critical shear stress, Byrd and Melching (2005) developed a relation between critical shear stress and particle diameter for data provided by Leopold et al. (1964) with critical shear stresses greater than 0.479 N/m^2 (0.01 lb/ft^2) as shown in Figure 1 [shown on the next page]. This relation is expressed as follows

$$\tau_C = 0.7709\ D^{0.9078}$$

where τ_C is the critical shear in N/m^2 and D is the particle diameter in mm. The hypothesis that the residuals of this equation are normally distributed could not be rejected by the Chi-square test or the skewness test of normality at the 0.02 significance level. The standard deviation of the logarithms of the residuals was found to be 0.554. Thus, for armor stone with a diameter of 0.152 m (6 in., i.e. the size of the armor stone proposed for the sediment capping for the FFS Study Area) the estimated critical shear is 73.9 N/m^2. The logarithm of this value can be taken as the mean of the logarithms and can be combined with the standard deviation of the logarithms of the residuals to characterize the lognormal distribution of the critical shear. Alternatively, Grass (1970)

evaluated the uncertainty in the original Shields diagram of the critical shear stress and found that a CV of 0.3 was appropriate. Lopez and Garcia (1997) later used this value in their evaluation of the uncertainty in the initiation of sediment movement. Either of these two CVs could be considered in an uncertainty evaluation of the stability of the armor stones.

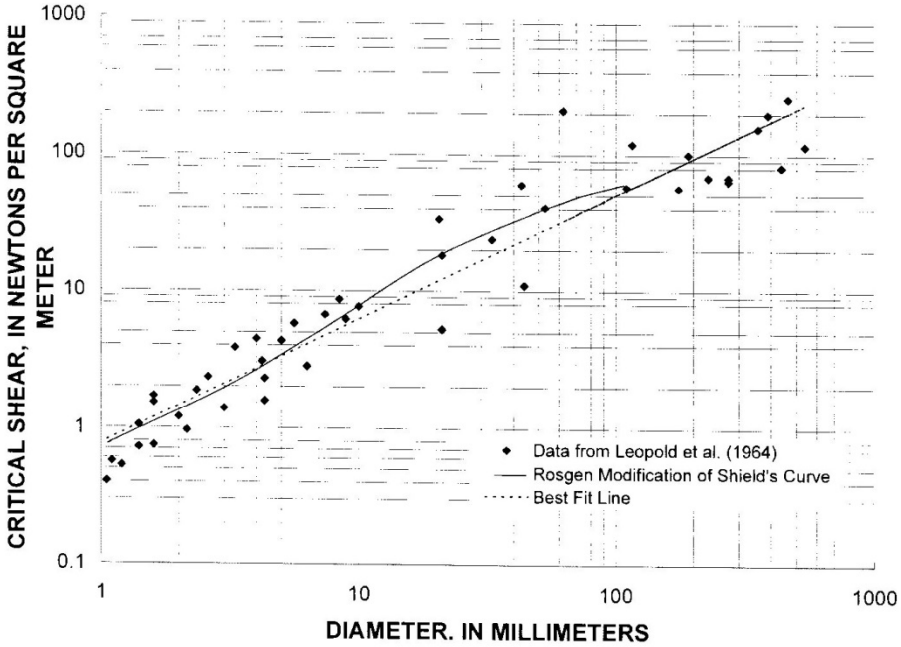


Fig. 1. Relation between particle diameter and critical shear stress on the basis of data from Leopold et al. (1964) as determined by linear regression of logarithms of the data (i.e. best fit line) and from Rosgen's modification of the Shield's curve from Leopold et al. (1998).

Source: Byrd and Melching (2005)

14.2 In order to understand the importance of considering the uncertainty in the assumption that the armor stone will not move, the study of Byrd and Melching (2005) is insightful. Bryd and Melching studied the possibility that a restored section of Piney Run Creek in Maryland could be eroded through a Monte Carlo Simulation analysis considering the uncertainty in the design discharge (25-, 50-, and 100-year peak flows), Manning's roughness coefficient, and critical shear stress for the 0.61 m (2 ft) diameter stones that comprised the key channel protection. In this study, the maximum shear stress was computed using the HEC-2 program of the U.S. Army Corps of Engineers (1990). When it was assumed that there was no uncertainty in the critical shear stress, the probability that the 0.61 m stones would move was 0.043, 0.061, and 0.072 for the 25-, 50-, and 100-yr peak flows, respectively. When the critical shear uncertainty as per Grass (1970) was applied, the probability of stone movement increased to 0.219, 0.258, and 0.305, respectively. Finally, when the critical shear uncertainty as per Figure 1 was applied, the probability of stone movement increased to 0.285, 0.325, and 0.342, respectively. The uncertainty in the estimated maximum shear stress in a small creek subject to high flood flows is larger than that in a tidal estuary, so the large increase in failure probability computed for Piney Run Creek would not be expected for the FFS Study Area. However, the Piney Run Creek example illustrates that even for a 2 ft diameter stone the

uncertainty regarding the critical shear stress is substantial, and a risk-based design of the armoring in the FFS Study Area considering all uncertainties should be performed.

General Comments

15. The order in which the remediation projects will be undertaken is inconsistent with standard procedures of cleaning upstream areas first and working downstream so that restored downstream locations are not re-contaminated as a result of later restoration of upstream areas. As proposed, the likelihood for re-contamination of the lower eight miles of the LPR seems high. The remediation of the lower eight miles of the LPR should be delayed until upstream locations have been restored by completing the RI/FS and determining the needed remedial action for the full 17 mile site.

15.1 In every other sediment contamination clean-up project or stream restoration project this reviewer is familiar with the project starts upstream and works its way downstream. This procedure was followed in the Lower Fox River, Sheboygan River, and Lincoln Creek and the Kinnickinnic River in Milwaukee among others. The principle being that if the downstream section is remediated first, it can be re-contaminated when the upstream sections are remediated. The Superfund Proposed Plan (SPP; EPA 2014b) merely states "EPA concluded that expediting the Superfund process for the lower 8.3 miles of the river, which was known to contain the bulk of the contaminated sediment, would best support the overall protection of human health and the environment" (EPA 2014b, p. 6) and "EPA has determined that the remedy for the FFS Study Area will be consistent with the expected remedies for the Lower Passaic River and Newark Bay Study Areas" (EPA 2014b, p. 11). The National Remedy Review Board and Contaminated Sediments Technical Advisory Group (hereafter known as "the Boards") also expressed concern over the latter statement (EPA 2014c, p. 19). In response to the Boards' concern, Region 2 (EPA 2014c, p. 20) stated that "as recommended by the Boards, this will be clearly described in the Proposed Plan" where the "this" is the rationale for the assumption of consistency with the other remedies. However, there is no clear justification in any of the FFS documents for this assumption of consistency. It would be far better to have developed a holistic plan for all the interrelated study areas rather than to act on one of them and assume all the rest will be consistent with that one solution, especially when re-contamination has a high probability of occurrence (as discussed in detail in Comment 16).

16. The contaminant loads coming from the Upper Passaic River are substantial for many of the Contaminants of Potential Concern (COPCs) and Contaminants of Potential Ecological Concern (COPECs). Thus, it cannot be assumed that the proposed Alternatives can result in achievement of the PRGs without mitigation methods being applied to upstream areas. The chance for re-contamination of the lower eight miles of the LPR is high. The remediation of the lower eight miles of the LPR should be deferred until upstream locations have been remediated by completing the NCP process for the full 17 mile site.

16.1 The FFS report (Louis Berger Group et al. 2014, p. 1-4) states

"The Upper Passaic River watershed is 805 square miles and includes approximately 1,200 known contaminated sites, 3 Chromate Waste Sites, 15 National Priorities List (NPL) sites and 200 Toxic Release Inventory Facilities as defined by USEPA and NJDEP. However, very few of these contaminated sites discharge directly into the Passaic River."

16.2 There are many sources of COPCs and COPECs in the Upper Passaic River (UPR) watershed. Considering the data in HDR|HydroQual (2014d) the average concentrations of DDx, Total PCBs, and mercury in the flows from the UPR exceed the PRGs for these constituents—DDx = 54 ppb vs. PRG = 0.3 ppb; Total PCB = 500 ppb vs. PRG = 44 ppb; and mercury = 700 ppb vs. PRG = 74 ppb. Thus, the background concentrations from the UPR exceed the PRGs and present a re-contamination threat for the LPR Study Area (RM 0 to 8.3). Further, HDR|HydroQual (2014d, p. 3-7) states:

"The data also suggest that the Upper Passaic River PCB congener pattern is more closely correlated with Lower Passaic River congener patterns [with correlation coefficient (R) values ranging from 0.93 to 0.96] than the Newark Bay congener pattern [with R values ranging from 0.75 to 0.8]. … the Upper Passaic River has a stronger impact on the Lower Passaic River PCB contaminant load than does Newark Bay."

16.3 HDR|HydroQual (2014d, p. 3-8) further states "The lack of contaminant concentration decline in the Upper Passaic River since 1990 suggests that the sediments transported over Dundee Dam will continue to provide contaminated solids that will influence sediment PCB concentrations in the Lower Passaic River." Louis Berger Group et al. (2014, p. 1-13) noted: "The Upper Passaic River is contributing contaminant concentrations on a fine grained particle basis that are comparable to those observed in the Lower Passaic River for contaminants such as PAHs, dieldrin and Total chlordane", and similarly Louis Berger Group et al. (2014, p. 1-15) states: "The level of concentration in Upper Passaic River fine-grained sediment is comparable to levels found in recently-deposited Lower Passaic River sediments for PAHs, PCBs, dieldrin, and Total chlordane." Thus, re-contamination of a restored LPR Study Area because of loads from the Upper Passaic River seems inevitable.

16.4 Similar concerns caused the Boards to note that re-contamination could prevent the attainment and maintenance of 5 ppt of dioxin in sediment over time (the PRG was later increased to 7.1 ppt); potential sources of recontamination include, but are not limited to, resuspension caused by the cleanup itself and transport from the yet-to-be remediated parts of the LPR and Newark Bay (EPA 2014c, p. 18).

16.5 In response to these concerns, in the SPP (EPA 2014b, p. 18-19) Region 2 states:

"While the Superfund program generally does not clean up to concentrations below natural or anthropogenic background levels, in the Lower Passaic River the flow of water and suspended sediment over Dundee Dam is just one of many sources of surface water into the FFS Study Area. Sediment particles coming from above Dundee Dam make up about one third of particles in the FFS Study Area water column. When those particles flow down to the FFS Study Area, they mix with other particles in the system (including cleaner particles in the water column that would result from a remediated FFS Study Area); after they are

deposited, they also mix with clean material placed on the river bed as part of remediation."

Despite all this mixing, EPA (2014b, p. 30) notes that concentrations of PCBs and mercury in the surface sediments will vary around the PRG, and surface sediment concentrations of DDT will be about 10 times higher than the PRG goal for both Alternatives 2 and 3. Further, EPA (2014b, p.19) notes that for PCBs, it is unlikely that the ecological PRG could be met under any of the Alternatives within a reasonable time frame, even with natural recovery processes. Finally, the CARP report (HydroQual 2007, p. ES-3) notes: "When there is disagreement between model and data for the DDT related contaminants, the model usually underestimates the highest measurements." Thus, the probability of compliance with the PRG for DDx may be even lower.

17. The thesis of uniform bank-to-bank contamination of the lower eight miles of the LPR is poorly supported by the data and the discussion in the reports. Thus, advocating cleanup alternatives involving bank-to-bank treatment of the contaminated sediments is unsupportable. A much more detailed study of contaminant heterogeneity within the FFS Study Area <u>must be done</u> to determine the best approach to remediate sediment contamination in the Study Area.

17.1 The dominant assumption supporting Region 2's primary remediation alternatives (Alternatives 2 and 3) considered in the FFS report (Louis Berger Group et al. 2014, p. 1-14) is that "the spatial distribution of the contaminants of concern in the Lower Passaic River is well explained by the occurrence of extensive tidal mixing and reworking of the sediment bed, generating locally variable concentrations as legacy sediments are exposed and reworked while recent deposition is evenly contaminated over distances of several miles." Further, the SPP report (EPA 2014b, p. 8) claims that ". . . [D]ata show that elevated concentrations of COCs are ubiquitous in surface sediments of the FFS Study Area, bank-to-bank." However, these statements conflict with others in the various reports related to the lower eight miles of the LPR. For example, the FFS report (Louis Berger Group et al. 2014, p. 1-12) states: "Concentrations of 2,3,7,8-TCDD in 0 to 6 inch samples can vary over 4 orders of magnitude within a single river mile interval." This is far from a uniform distribution of 2,3,7,8-TCDD throughout the FFS Study Area.

17.2 The FFS itself acknowledges the nonuniform spatial distribution of COPCs and COPECs in the FFS Study Area (Louis Berger Group et al. 2014, p. 1-14):

"Extreme values of the compounds of concern occurred somewhat randomly across the river bottom and do not always coincide with extreme values of other compounds of concern. These extreme values are likely the result of differences in release history for the various compounds such that different compounds reach maximum values at different horizons with the sediment bed."

Further, "Local measurements of the depth of contamination show the depth of contamination to vary widely throughout the river. This is attributed to local depositional and erosional histories and the continued reworking of the sediment bed to the present time." (Louis Berger Group et al. 2014, p. 1-17). This attribution is debatable and unsupported: The variation in high and low concentrations for the various contaminants

also could indicate different sources for the various contaminants as well as different time histories of release.

17.3 Thus, Region 2 concedes that there are differences in erosional and depositional history throughout the river, and, thus, the current "hot spots" (locations with high concentrations such as the four-fold range in 2,3,7,8-TCDD previously cited) also are a result of this history and are not the result of a random process. The observable locations of high concentrations undermine Region 2's hypothesis of uniform contamination, eliminating the key justification for a bank-to-bank capping or dredging solution.

17.4 Region 2's proposed approach is inconsistent with EPA's approach at other major sediment sites. In the clean-up of PCB contamination in the Lower Fox River, Wisconsin, more than 15,000 core samples were taken over a 39 mile reach (although the most contaminated areas span less than 30 miles). Therefore, in the Fox River the remediation plan of dredging and backfilling sand on all areas with surface PCB concentrations greater than 1 ppm and capping of other areas with surface concentrations between the remediation target of 0.25 ppm and 1 ppm was based on data derived from more than 500 cores per mile that were used to develop a geostatistical model of the PCB concentration in the sediments. This guided the targeting of dredging to the "hot spots". In contrast, for the LPR Region 2 is substituting an unproven model with insufficient spatial discretization and an unfounded theory of uniform, bank-to-bank concentrations for the rigor of the evaluation of a large database of measured sediment concentrations such as that collected for the Lower Fox River. The "unproven" and "unfounded" aspects of this are reflected in the lack of a relation between simulated and measured values of many contaminants seen in many of the scattergrams in the CFTM report (as discussed in Comment 1). It should be noted that 500 cores per mile is not the goal for targeting hot spots in the LPR, but rather an analysis of the available data for the LPR should be done comparing the density of samples to other remediation sites around the country to determine the appropriate level of detail to characterize the spatial distribution of contaminants of concern in the sediments of the FFS Study Area.

17.5 The various reports offer only weak evidence of the uniformity of sediment concentrations throughout the FFS Study Area. For example, HDR|HydroQual (2014d, p. 3-7) states: "The correlation matrix *[of PCB congeners]* shows that the Lower Passaic River recently-deposited (Be-7 bearing) surface sediment samples are well correlated with one another, which supports the observation that tidal action has mixed these solids over a long distance (between RM 1.4 and RM 12.6)" [note: words in italics added for clarification]. However, the presence of a similar pattern of congeners merely indicates that the mixture of PCBs is the same in this area, but it does not necessarily indicate the Total PCB concentration is the same in this area.

17.6 The STM report (HDR|HydroQual 2014b) offers substantial evidence that the FFS Study Area is a tidal reach in which sediments are redistributed. However, this evidence does not negate the fact that the measured contaminant concentrations in the sediment show distinct "hot spots." For example, HDR|HydroQual (2014b, p. 4-4) indicates that at maximum flood, the turbidity maximum is centered at approximately RM 5, with associated elevated TSS extending from approximately RM 1 to RM 9. Further, HDR|HydroQual (2014b, p. 4-5) notes that during high flows: "salt (and presumably the innermost extent of the estuarine circulation) intrudes up to RM 4.5, and the lower layer is well mixed." Finally, HDR|HydroQual (2014b, p. 4-4) offers the observation that even

up to RMs 10.2 and 13.5: “The strong ebb-dominance of the bottom shear stress pattern also indicates that sediment transport dynamics have switched to those of a tidal river at these locations.”

17.7 The STM report (HDR|HydroQual 2014b, p. 3-14) also offers a discussion of evidence of bidirectional flow from the bathymetric data noting at

- RM 2.7 – “there are perturbation features (i.e. lumps) at the river bed (possibly large detritus mounds or clumps of stiff material of unknown origin) that show a shallower slope of the upstream lee of the feature. This feature suggests a net upstream direction to near-bed sediment transport at the time of survey.”
- RM 8.3 during low flow – “The bedforms suggest that the bidirectional flow in this region was not significantly affecting the bed in this region at the time of the survey.”

However, neither the bathymetric data evidence of bidirectional flow nor the computational evaluations of the turbidity maximum or salt intrusion provide evidence of uniform bank-to-bank sediment contamination.

18. The Superfund Proposed Plan (SPP) discusses the Off-Site Sediment Disposal alternative as if it has minor social and environmental effects. This alternative may have very substantial social and environmental effects that <u>must be fully analyzed, documented, and considered</u> before a final sediment remedial alternative is selected.

18.1 EPA (2014a) indicates that in the currently preferred alternative including off-site sediment disposal “Sediment would be dewatered locally and prepared for transport by rail for incineration and/or disposal in landfills.” The SPP report (EPA 2014b, p. 41) further indicates “Dewatered, contaminated dredged materials would be transported by rail to incinerators and landfills in the U.S. or Canada for disposal.” Up to 7% of dredged sediment may require incineration at out-of-state facilities in the U.S. or Canada. Further, the SPP report (EPA 2014b, p. 29) notes “In contrast, DMM Scenarios B (Off-Site) and C (Local Decontamination) have no environmental impact on the aquatic environment of Newark Bay.” These scenarios, however, will substantially affect other environments, an issue that Region 2 appears not to have considered.

18.2 Shipping contaminants out-of-state poses unevaluated risks to other states or provinces, which should be considered in the remedy selection decision. Indeed, these potential risks are quite similar to objections made by the State of New Jersey to the use of a CAD or local treatment options. Region 2’s method of analysis biases the remedy selection to off-site disposal by ignoring the environmental and social costs of the off-site disposal alternatives.

References

Beck, M.B. 1987. Water quality modeling: A review of the analysis of uncertainty, *Water Resources Research*, 23(5), 1393-1441.

Brown, L.C. and Barnwell, T.O., Jr. 1987. The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS: Documentation and user manual, *Report EPA/600/3-87/007*, U.S. Environmental Protection Agency, Athens, GA.

Burges, S.J. and Lettenmaier, D.P. 1975.Probabilistic methods in stream quality management, *Water Resources Bulletin*, 11(1): 115-130.

Byrd, J.L. and Melching, C.S., 2005. Uncertainty evaluation in the design of instream structures for stream restoration," *Proceedings (CD-ROM)*, XXXI Congress of the International Association for Hydraulic Engineering and Research, Seoul, Korea, September 11-16, 2005.

Chang, C.H., Yang, J.C., and Tung, Y.K. 1993. Sensitivity and uncertainty analyses of a sediment transport model: A global approach, *Journal of Stochastic Hydrology and Hydraulics*, 7(4): 299-314.

Christiaens, K. and Feyen, J. 2002. Use of sensitivity and uncertainty measures in distributed hydrological modeling with an application to the MIKE SHE model, *Water Resources Research*, 38(9): 1169, doi:10.1029/2001 WR000478.

Connolly, J.P. and Tonelli, R. 1985. Modeling Kepone in the striped bass food chain of the James River Estuary, *Estuarine Coastal and Shelf Science*, 20: 349-366.

Donigian, A.S., Jr., Imhoff, J.C., Bicknell, B.R., and Kittle, J.L., Jr., 1984, Application Guide for Hydrological Simulation Program-FORTRAN (HSPF), *EPA-600/3-84-065*, Environmental Research, 177 p.

Garen, D.C. and Burges, S.J. 1981. Approximate error bounds for simulated hydrographs, *Journal of the Hydraulics Division, ASCE*, 107(HY11), 1519-1534.

Grass, A.J. 1970. Initial instability of fine bed sand, *Journal of the Hydraulics Division, ASCE*, 96(HY3), 619-632.

HDR|HydroQual. 2014a. Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River, Appendix BI, Hydrodynamic and Sediment Transport Evaluation: Capping/Armoring Analyses for the Focused Feasibility Study Area, report prepared for the U.S. Environmental Protection Agency, Region II, New York.

HDR|HydroQual. 2014b. Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River, Appendix BII, Lower Passaic River Sediment Transport Model, report prepared for the U.S. Environmental Protection Agency, Region II, New York.

HDR|HydroQual. 2014c. Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River, Appendix BIII, Lower Passaic River Contaminant Fate and Transport Model, report prepared for the U.S. Environmental Protection Agency, Region II, New York.

HDR|HydroQual. 2014d. Lower Eight Miles of the Lower Passaic River, Data Evaluation Report No. 2: Boundary Conditions, report prepared for the U.S. Environmental Protection Agency, Region II, New York.

Hornberger, G.M. and Spear, R.C. 1981. An approach to the preliminary analysis of environmental systems, *Journal of Environmental Management*, 12: 7-18.

HydroQual. 2002. Calibration Enhancement of the System-Wide Eutrophication Model (SWEM) in the New Jersey Tributaries, Report to the New Jersey Department of Environmental Protection. Final Technical Report April 23, 2001 through July 31, 2002. prepared under subcontract to the Passaic Valley Sewerage Commission, Newark, NJ.

HydroQual. 2006. Lower Passaic River Restoration Project, Final Modeling Work Plan, report prepared for the U.S. Environmental Protection Agency, Region II, New York and the U.S. Army Corps of Engineers, New York District.

HydroQual. 2007. A Model for the Evaluation and Management of Contaminants of Concern in Water, Sediment and Biota in the NY/NJ Harbor Estuary: Contaminant Fate & Transport & Bioaccumulation Sub-models. report prepared for the Contamination Assessment and Reduction Project (CARP) Management Committee, HydroQual, Inc., Mahwah, NJ 07430.

HydroQual. 2008. Lower Passaic River Restoration Project and Newark Bay Study—Final Hydrodynamic Modeling Report. report prepared for the U.S. Environmental Protection Agency, Region II, New York and the U.S. Army Corps of Engineers, New York District.

Iman, R.L. and Helton, J.C. 1985. A Comparison of Uncertainty and Sensitivity Analysis Techniques for Computer Models, *Report No. NUREGICR-3904, SAND 84-1461*, Sandia National Laboratories, Albuquerque, NM.

Jaffe, P.R. and Ferrara, R.A. 1984. Modeling sediment and water column interactions for hydrophobic pollutants, parameter discrimination and model response to input uncertainty, *Water Research*, 18(9): 1169-1174.

James, L.D. and Burges, S.J. 1982. Selection, calibration, and testing of hydrologic models, in *Hydrologic Modeling of Small Watersheds*, edited by C.T. Haan, H.P. Johnson, and D.L. Brakensiek, American Society of Agricultural Engineers, St. Joseph, Mich., 437-472.

Leopold, L.B., Wolman, MG., and Miller, J.P. 1964. *Fluvial Processes in Geomorpholgy*. W.H. Freeman and Company, San Francisco.

Leopold, L.B., Silvey, H.L., and Rosgen, D.L. 1998. *The Reference Reach Field Book*, Wildland Hydrology, Fort Collins, CO.

Lopez, F. and Garcia, M. 1997. Probability concepts in sediment transport mechanics, In: *Environmental and Coastal Hydraulics: Protecting the Aquatic Habitat*, edited by S.S.Y. Wang and T. Carstens, American Society of Civil Engineers, New York, p. 1197-2002.

Louis Berger Group, Inc., Battelle, and HDR|HydroQual. 2014. Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River. report prepared for the U.S. Environmental Protection Agency, Region II, New York.

Lu, Z. and Tung, Y.K. (2003). Effects of parameter uncertainties on forecast accuracy of Xinanjiang model. In: *Proceedings,* 1st International Yellow River Forum on River Basin Management, Zhengzhou, China, 12-15 May.

Manache, G. and Melching, C.S. 2004. Sensitivity analysis of a water-quality model using Latin hypercube sampling, *Journal of Water Resources Planning and Management*, 130(3): 232-242.

Manache, G. and Melching, C.S., 2007. Sensitivity of Latin hypercube sampling to sample size and distributional assumptions, In: *Proceedings (CD-ROM)*, 32nd Congress of the International Association of Hydraulic Engineering and Research, Venice, Italy, July 1-6, 2007.

McKay, M.D. 1988. Chapter 4: Sensitivity and uncertainty analysis using a statistical sample of input values. In: *Uncertainty Analysis*, edited by Y. Ronen, CRC press, Inc., Boca Raton, FL.

McKay, M.D., Beckman, R.J., and Conover, W.J. 1979. A comparison of three methods for selecting values of input variables in the analysis of output from a computer code, *Technometrics*, 21(2): 239-245.

Melching, C.S. 1994. Sensitivity of Monte Carlo simulation to the probability distribution of the input parameters, In: *Proceedings*, International Symposium on Water Resources Planning in a Changing World, Karlsruhe, Germany, June 28-30, p. II.81-II.91.

Melching, C. S. 1995. Reliability estimation, Chapter 3 in *Computer Models of Watershed Hydrology*, edited by V. P. Singh, Water Resources Publications, Littleton, CO, p. 69-118.

Melching, C. S. and Bauwens, W. 2000. Comparison of uncertainty-analysis methods applied to simulation of urban water quality, In: *Stochastic Hydraulics 2000*, edited by Z.Y. Wang and S.X. Hu, A.A. Balkema, Rotterdam, The Netherlands, p. 717-725.

Melching, C.S. and Bauwens, W. 2001. Uncertainty in coupled non-point source and stream water-quality models, *Journal of Water Resources Planning and Management*, 127 (6): 403-413.

Melching, C.S., Yen, B.C., and Wenzel, H.G., Jr. 1990. A reliability estimation in modeling watershed runoff with uncertainties, *Water Resources Research*, 26(10): 2275-2286.

Melching, C.S., Yen, B.C., and Wenzel, H.G., Jr. 1991. Output reliability as a guide for selection of rainfall-runoff models, *Journal of Water Resources Planning and Management*, 117(3): 383-398.

Novotny, V. and Olem, H. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*, Van Nostrand Reinhold, New York.

O'Brien, M. 2008. *Exxon and the Crandon Mine Controversy*, Badger Books LLC, Middleton, WI.

Plate, E.J. 1986. Reliability analysis in hydraulic design, in *Stochastic and Risk Analysis in Hydraulic Engineering*, edited by B.C. Yen, Water Resources Publications, Littleton, Colo., 37-47.

Rosenblueth, E. 1975. Point estimates of probability moments, *Proceedings, National Academy of Sciences, U.S.A*., 72(10): 3812-3814.

Scavia, D., Powers, W.F., Canale, R.P., and Moody, J.L. 1981. Comparison of first-order error analysis and Monte Carlo simulation in time-dependent lake eutrophication models, *Water Resources Research*, 17(4): 1051-1059.

Sohrabi, T.M., Shirmohammadi, A., Chu, T.W., Montas, H., and Nejadhashemi, A.P. 2003. Uncertainty analysis of hydrologic and water quality predictions for a small watershed using SWAT2000, *Environmental Forensics*, 4(4): 229-238.

TAMS Consultants Inc., 2000. *Phase 2 Report – Review Copy, Further Site Characterization and Analysis, Volume 2d - Revised Baseline Modeling Report, Hudson River PCBs Reassessment RI/FS*. January 2000. Prepared for U.S. Environmental Protection Agency, Region 2, and U.S. Army Corps of Engineers, Kansas City District. Volume 2D - Book 1 of 4, Fate and Transport Models. TAMS Consultants, Inc., Limno-Tech, Inc., Menzie-Cura & Associates, Inc., Tetra Tech, Inc.

The Johnson Company. 2002. *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay*. Prepared for the Appleton Paper, Inc. Panel by the Johnson Company, Inc., January 17.

Tung, Y.K., Ben, B.C., and Melching, C.S. 2006. *Hydrosystems Engineering Reliability Assessment and Risk Analysis*, McGraw-Hill, New York.

U.S. Army Corps of Engineers. 1990. *HEC-2 Water Surface Profiles: User's Manual*, Hydrologic Engineering Center, Davis, CA.

U.S. Environmental Protection Agency (EPA). 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, EPA-540-R-05-012, OSWER 9355.0-85, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2014a. Cleaning Up the Lower Passaic River, An Overview of EPA's Proposal for the Lower Eight Miles, Fact Sheet, USEPA, Region 2, New York.

U.S. Environmental Protection Agency (EPA). 2014b. Lower Eight Miles of the Lower Passaic River Part of the Diamond Alkali Superfund Site, Essex and Hudson Counties, New Jersey, Superfund Proposed Plan, USEPA, Region 2, New York.

U.S. Environmental Protection Agency (EPA). 2014c. Responses to National Remedy Review Board and Contaminated Sediments Technical Advisory Group Recommendations for the Lower Eight Miles of the Lower Passaic River, part of the Diamond Alkali Superfund Site in Newark, New Jersey, USEPA, Region 2, New York.

U.S. Geological Survey and Aqua Terra Consultants. 1998. *Quality Assurance Project Plan for Rainfall-Runoff Simulation Using the Hydrological Simulation Program-Fortran (HSPF) for the Proposed Crandon Mine Area Crandon, Wisconsin*, report prepared for the U.S. Environmental Protection Agency, Region V, Chicago, IL.

Weston Solutions Inc., 2004. *Model Calibration: Modeling Study of PCB Contamination in the Housatonic River, Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, Massachusetts*, Contract No. DACW33-00-D-0006, Task Order No. 0003, DCN: GE-122304-ACMG. Prepared for U.S. Army Corps of Engineers, New England District, Concord, MA, and U.S. Environmental Protection Agency, New England Region, Boston, MA. Prepared by Weston Solutions, Inc., West Chester, PA.

Yeh, K.C. and Tung, Y.K. 1993. Uncertainty and sensitivity of a pit migration model, *Journal of Hydraulic Engineering*, 119(2): 262-281.

Yu, P.S., Yang, T.C., and Chen, S.J. 2001. Comparison of uncertainty analysis methods for a distributed rainfall-runoff model, *Journal of Hydrology*, 244: 43-59.

Charles Steven Melching, Ph.D., P.E., BCEE, D.WRE

Environmental Engineering Consultant
4030 W. Edgerton Ave., Greenfield, WI 53221
Phone: 414-368-7018
steve.melching17@gmail.com

INTERESTS

Dr. Melching earned his Ph.D. in civil engineering at the University of Illinois in 1987. He has been an engineer and scientist in academia, government, and private practice and has participated in the science and management of rivers, lakes, and estuaries for 27 years. His research interests and experiences span a wide range of topics including uncertainty, sensitivity, and reliability analyses of hydrologic and environmental models (for which he received the 2001 ASCE Huber Prize); water-quality modeling and management for rivers and lakes; flood forecasting and management; urban hydrology and stormwater management; flow measurement methods and hydroacoustics; soil erosion and sediment transport; and statistical analysis of environmental data. Management issues he has been involved in include: the Great Lakes and Mississippi River Interbasin Study, the Use Attainability Analysis for the Chicago Area Waterways System (CAWS) and other water-quality issues in the CAWS, Lake Michigan diversion, the hydrologic effects of the proposed Crandon Mine in Wisconsin, and pollution studies in the Dender River and Senne River in Belgium. His experience in water-quality modeling and model uncertainty analysis brings important insight to the Focused Feasibility Study process.

EDUCATION

University of Illinois at Urbana	Civil Engineering	Ph.D.	1987
University of Illinois at Urbana	Civil Engineering	M.S.	1983
Arizona State University	Civil Engineering	B.S.	1981

APPOINTMENTS

2012-date	Environmental Engineering Consultant, Greenfield, Wis.
2009-2012	Professor, Civil and Environmental Engineering, Marquette University.
2005-2006	Visiting Professor, Hydraulic Engineering, Tsinghua University, Beijing, China.
2005-2006	Visiting Scholar, International Research and Training Center on Erosion and Sedimentation, Beijing, China.
1999-2009	Associate Professor, Civil and Environmental Engineering, Marquette University.
1998-1999	Visiting Scholar, Laboratory of Hydrology, Vrije Universiteit Brussel, Belgium.
1992-1999	Hydrologist/Hydraulic Engineer, U.S. Geological Survey, Urbana, Ill.
1989-1991	Assistant Professor, Civil and Environmental Engineering, Rutgers University.
1987-1989	Visiting Lecturer, Laboratory of Hydrology, Vrije Universiteit Brussel, Belgium.

PUBLICATIONS

Publications Most Closely Related to Project

- Wang, Z. Y., Lee, J. H. W., and **Melching, C. S.** (2014) *River Dynamics and Integrated River Management*, Springer-Verlag, in press.
- Missaghi, S., Hondzo, M., and **Melching, C. S.** (2013). Three-dimensional lake water quality modeling: Sensitivity and uncertainty analyses, *J. Environ. Qual.*, 42, 1684-1698.
- Manache, G. and **Melching, C. S.** (2008). Identification of reliable regression- and correlation-based sensitivity measures for importance ranking of water-quality model parameters. *Environ. Modell. Softw.*, 23(5), 549-562.
- Tung, Y. K., Yen, B. C., and **Melching, C. S.** (2006). *Hydrosystems Engineering Reliability Assessment and Risk Analysis*, McGraw-Hill, New York, 495 p.
- **Melching, C. S.** and Bauwens, W. (2001). Uncertainty in coupled nonpoint source and stream water-quality models. *J. Water Res. Pl.-ASCE*, 127(6), 403-413.
- **Melching, C. S.** and Yoon, C. G. (1996). Key sources of uncertainty in QUAL2E model of Passaic River. *J. Water Res. Pl.-ASCE*, 122(2), 105-113.

- **Melching, C. S.** (1995). Reliability Estimation. Chapter 3 in *Computer Models of Watershed Hydrology*, V. P. Singh, ed., Water Resources Publications, Littleton, CO, p. 69-118.

Other Selected Recent Publications

- **Melching, C. S.**, Ao, Y., and Alp, E. (2013). Modeling evaluation of integrated strategies to meet proposed dissolved oxygen standards for the Chicago Waterway System. *J. Environ. Manage.*, 116(2013), 145-155.
- **Melching, C. S.** (2013). Reallocation of discretionary diversion from Lake Michigan to improve water quality in the Chicago Area Waterways System, *35th IAHR Congress*, Chengdu, China, September 8-13, 2013, 11 p.
- Alp, E. and **Melching, C. S.** (2011). Allocation of supplementary aeration stations in the Chicago Waterway System for dissolved oxygen improvement. *J. Environ. Manage.*, 92, 1577-1583.
- **Melching, C. S.** and Smith, E. G. (2010). Post-audit of a water quality model applied to the East Branch Du Page River, *Proc., Hydrology, Hydraulics and Water Resources in an Uncertain Environment. 10th International Symposium on Stochastic Hydraulics and 5th International Conference on Water Resources and Environment Research*, Quebec City, Canada, July 5-7, 2010, 7 p.

PROFESSIONAL CREDENTIALS

- Professional Engineer (Civil) in Arizona since 1991, Registration No. 25326
- Professional Engineer in Illinois since 1992, Registration No. 062-047430

SYNERGISTIC ACTIVITIES

- Associate Editor, International Journal of Sediment Research (IJSR), 2002-present.
- Editor, Special Issue on Innovations and Advances in Sediment Research, a compilation of papers presented at the 35th IAHR Congress, Chengdu, China, IJSR (in progress).
- Member, Peer Review Team, Envisioning a Chicago Area Waterway System for the 21st Century, Great Lakes Commission and Great Lakes and St. Lawrence River Cities Initiative (2012).
- Member, Scientific Committee, Watermatex 2011, 8th International Symposium on Systems Analysis and Integrated Assessment, International Water Association, San Sabestian, Spain, June 20-22, 2011.
- Member, International Scientific Committee, RCEM2011, 7th IAHR Symposium on River, Coastal and Estuarine Morphodynamics, Beijing, China, September 6-8, 2011.

COLLABORATORS AND OTHER AFFILIATIONS (PAST 5 YEARS)

Collaborators and Co-editors: Z. Y. Wang (Tsinghua Univ., China); J. H. W. Lee (Hong Kong UST); Qi P. (Inst. of Yellow River Scientific Res., China); E. Alp (METU, Turkey); M. Muste (Univ. of Iowa); W. E. Espey (Espey Consultants); G. A. Yu (CAS); X. Duan (Jiangyin Environmental Monitoring Station, China); X. Xie (Qufu Normal University, China); R. Lanyon (MWRDGC); M. Hondzo (Univ. of Minnesota); Missaghi S. (Univ. of Minnesota); E. G. Smith (CDM); Y. Gyasi-Agyei (CQU, Australia).

Graduate Advisors: Ph.D. – B. C. Yen and H. G. Wenzel (University of Illinois).

Thesis Advisor and Postdoctoral-Scholar Sponsor: E. Alp (METU, Ph.D. and Post-doc); J. Liang (Marquette Univ., Ph.D. and Post-doc); Y. Ao (FDA, M.S.); E. G. Smith (CDM, M.S.); Y. Zhao (Ph.D. student Northeastern Univ., M.S.).

Total number of graduate students advised: 4 Ph.D., 29 M.S. as advisor.

COMMENTS

Lower Eight Miles of the Passaic River Focused Feasibility Study (FFS) Report: Human Health Risk Assessment

August 8, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
Paul T. Kostecki, Ph.D.
Edward J. Calabrese, Ph.D.
AEHS Foundation, Inc.

LOWER EIGHT MILES OF THE PASSAIC RIVER FOCUSED FEASIBILITY STUDY (FFS) REPORT: HUMAN HEALTH RISK ASSESSMENT

Dr. Paul Kostecki & Dr. Edward Calabrese
AEHS Foundation, Inc.
150 Fearing St.
Amherst, MA 01002

1. Summary of Major Comments

We have reviewed the USEPA Region 2 (Region 2) Focused Feasibility Study (FFS) Human Health Risk Assessment (HHRA) for (River Miles 0-8) of the Lower Passaic River (LPR) FFS Study Area. In our comments 2.1 through 2.4 below, we note several critical shortcomings that lead us to conclude that the data and assumptions used by Region 2 to develop the LPR HHRA grossly overstate the risks and hazards. Region 2 relies on these faulty risk and hazard estimates to support its conclusions that the proposed remediation measures are necessary to protect human health and the environment in the interim, even though Region 2 has yet to complete the Remedial Investigation/Feasibility Study (RI/FS) for the whole 17.4 mile stretch of the LPRSA. It is our opinion that the HHRA defects described in this comment document call into question the basic underpinnings of the conclusions that human health and the environment are being adversely affected at levels that Region 2 deems necessary for initiating remedial actions.

> Comment 2-1: The Focused Feasibility Study (FFS) ignored site-specific data for its fish consumption estimate in the human health risk assessment (HHRA), instead electing to base consumption estimates on non-site-specific studies. In adherence with EPA risk assessment guidance, we recommend the LPR FFS utilize data from the site-specific LPR creel angler surveys (CAS).
>
> Comment 2-2: The fish consumption rates used in the FFS HHRA were taken from a Region 2 non-peer reviewed document identified as a "Technical Memorandum." The Memorandum does not identify authors, nor does it identify who prepared it or why nor is there any published record of peer review as required by EPA policy. In contrast, the design and results of the 2001 LPR CAS involved a transparent process, as it received independent expert input, was peer-reviewed and published, all participants are clearly identified, and it is publically available. Thus we recommend using fish consumption rates derived from the site-specific LPR CAS data.
>
> Comment 2-3: The use of only one exposure pathway – consumption of LPR fish and shellfish – does not adequately characterize the risks and hazards in the LPR. We recommend that all complete pathways and associated COCs, as defined by Region 2, be included when qualifying potential human health effects associated with exposures in the LPR.
>
> Comment 2-4: The HHRA uses a cascade of conservative assumptions that results in a profound distortion of risk. Rather than using overly conservative toxicity values and irrelevant default exposure estimates, we recommend the use

of the most defensible peer-reviewed toxicity values and site-specific exposure data to determine risk estimates for the LPR.

2. Comments on the FFS HHRA Prepared by USEPA Region 2

Comment 2-1: The Focused Feasibility Study (FFS) ignored site-specific data for its fish consumption estimate in the human health risk assessment (HHRA), instead electing to base fish consumption estimates on non-site-specific studies. In adherence to EPA risk assessment guidance, we recommend the LPR FFS utilize data from the site-specific LPR creel angler surveys (CAS).

Region 2's FFS HHRA presents cancer risk and non-cancer hazard estimates associated with the LPR that are founded on fish and shellfish consumption rates derived in a 2012 technical memorandum drafted by Region 2 (Region 2, 2012). The studies on which these consumption estimates are based do not include empirical data from the LPR: One source was a four-month intercept survey of the Newark Bay Complex (Burger, 2002), and the other was an older mail survey of the residents of the State of New York (Connelly et al., 1992). The use of data that are not site specific is not consistent with EPA guidance, given that there are site-specific data based on a comprehensive creel angler survey (CAS) conducted within the LPR Study Area (discussed below). Region 2 completely ignored this site-specific data that is both more geographically relevant and more scientifically rigorous than the data relied upon by Region 2 (Burger 2002; Connelly et al. 1992) in developing consumption rates.

No two sites are identical, and with respect to angling several factors can have a profound impact on fish consumption rates, including: species, angler behavior, time of day/year, presence of migrating species, landscape characteristics, weather, and cultural influences. USEPA (USEPA, 2000a) provides guidance concerning what may be conditions valid for credible data transfer in assessing risks. The guidelines specifically state: "commodities must be essentially equivalent" as well as "the baseline condition and extent of change should be similar… and the affected populations should be similar." Given the distinct character of the LPR relative to the larger Newark Bay Complex and combined New York state water bodies used by state resident anglers, it is highly unlikely that fish consumption rates from these areas outside the FFS LPR Study Area fulfill these conditions and are representative of the Study Area (see below). Therefore, by using these non-site-specific studies, Region 2 introduced additional uncertainty into the FFS HHRA.

Indeed, USEPA guidance (and best practices) dictate using site-specific data when available (USEPA, 1989). The Agency's latest OSWER Directive 9200.1-120 (USEPA, 2014) restates that recommended default exposure factors for fish ingestion rates should be site-specific values. The initial directive came from USEPA (1991) *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* and has been in use for over 20 years. Regarding the LPR, Region 2 and interested parties (USEPA, 1995) had agreed that a Creel Angler Survey (CAS) for the Passaic River was essential to produce site-specific human exposure data to ensure an accurate human health risk assessment for the Site.

Importantly, a CAS for river miles 1-7 of the Lower Passaic River was performed in 2000 - 2001 to generate site-specific data for the development of fish consumption rates. In designing and conducting the 2001 LPR CAS, a blue ribbon panel of experts was organized, "charged with evaluating whether the conduct of a CAS is necessary to support an accurate risk assessment for the Study Area and whether the proposed CAS is sufficient to characterize local fish consumption behavior for risk assessment purposes" (Finley et al., 2003). We were members of

this blue ribbon expert panel, which was convened under the auspices of the Association for Environmental Health and Sciences (AEHS) [formerly the Association for Health in Soils]. The AEHS Expert Panel for the 2001 LPR CAS was convened in accordance with USEPA's guidance on expert panels (USEPA, 2000b), being comprised of professionals working in related areas of human and ecological risk assessment, exposure factors, fisheries biology/creel angler surveys and biostatistics. Panel members possessed broad backgrounds from academe and regulatory agencies as well as the private sector. The panel was comprised of Dr. Paul Kostecki, University of Massachusetts/AEHS, Inc. (fisheries biology, exposure assessment); Dr. Stan Lemeshow, Ohio State University (biostatistics, modeling); Dr. Edward Calabrese, University of Massachusetts/AEHS, Inc. (risk assessment, toxicology); Dr. Barry Johnson, Emory University/formerly of the Agency for Toxic Substances and Disease Registry (ATSDR) (human and environmental risk assessment, regulatory science); Dr. Kevin Boyle, University of Maine (fisheries biology, creel angler surveys); and Dr. Chris Teaf, Florida State University/Hazardous Substances and Waste Management, Inc. (environmental and human health risk assessment). Members were considered independent and had no interest/investment in the outcome of the project.

In their paper discussing the Passaic River CAS, Finley et al. (2003) stated, "Risk assessment expert panels often are convened by regulatory authorities and private firms to provide guidance on new policy and technical issues and to render opinions in situations where different parties maintain conflicting views." EPA has endorsed the use of expert panels and provided guidance on their development and use (USEPA, 2000b). This approach has been used successfully by AEHS at other Superfund Sites, most notably the Fox River. In that case, AEHS was enlisted to convene an expert panel of human and ecological risk experts to assist the Wisconsin Department of Natural Resources and the Fox River Group in resolving conflicting risk assessment issues between the two parties with respect to the Fox River Superfund Site. The expert panel critically reviewed each side's human and ecological risk assessments and provided significant recommendations that were instrumental in a negotiated agreement of final cleanup levels.

EPA guidance for expert panel use includes the need for written assessments and public access to panel findings. The 2001 LPR CAS Expert Panel's findings, as well as the results of the CAS itself, were published in four separate publications accessible to the general public as peer-reviewed publications in two separate professional journals (Finley et al., 2003; Ray et al., 2007a, 2007b; Kinnell et al., 2007). The 2001 LPR CAS Expert Panel was adamant that this CAS represented a valuable and detailed investigation that went "…well beyond any previous studies of its type in terms of scope and completeness." The Panel concluded: "The CAS is a major step forward in how fish consumption studies are designed and conducted in support of site-specific risk assessments, and will significantly contribute to the Passaic River Study Area risk assessment."

In addition to the 2001 LPR CAS, a follow up LPR CAS was performed in 2011 - 2012 by the Cooperating Parties Group (CPG). The 2012 survey was built upon the methodologies employed in the original CAS, but was also designed to 1) address Region 2's criticisms of the 2001 LPR CAS, and 2) add LPR river miles 0-1 and 7-17.4 consistent with Region 2's expansion of the original Passaic River Six-Mile Study Area to the LPR Study Area. Importantly, the more recent CAS provided researchers the opportunity to evaluate any change in human use of the LPR in the decade since the 2001 LPR CAS. As with the first LPR CAS, the 2012 CAS was designed and conducted under the auspices of an Expert Panel (different from the 2001 LPR CAS Expert Panel). Given the wealth of data specific to LPR angling activity that is

available, Region 2 should consider the data from the 2001 and 2012 LPR CAS studies to develop site-specific estimates of fish and shellfish consumption rates.

In summary, it is inexplicable why Region 2 has ignored the data from the 2001 and 2011 LPR CAS studies. These two CAS's were each designed under the direction of, and in collaboration with, expert panels comprised of independent, practicing professionals and were conducted by highly competent and experienced environmental assessment organizations. The resultant data are credible, highly relevant and incorporate site factors that are specific to the lower eight miles of the Passaic River; these are the only pertinent data to use to calculate fish consumption rates for the FFS Study Area. We recommend that the FFS use the data from the two studies in its LPR HHRA.

> Comment 2-2: The fish consumption rates used in the FFS HHRA were taken from an EPA Region 2 non-peer reviewed document identified as a "Technical Memorandum." The Memorandum does not identify authors, nor does it identify who prepared it or why. In contrast, the design and results of the 2001 LPR CAS involved a transparent process, as it received independent expert input, was peer-reviewed and published, all participants are clearly identified, and it is publically available. Thus we recommend using fish consumption rates derived from the site-specific LPR CAS data.

Fish and crab consumption rates are significant drivers of the risk and hazard estimates presented in the LPR FFS' HHRA (see ToxStrategies Comments 2-8, 3-1, and 3-3). These were the only exposure routes Region 2 considered (see section below) and, as such, their importance to the Region 2 FFS HHRA process cannot be overstated. Transparent, complete, accurate, and relevant data are essential for the determination of a risk assessment that both informs the remedial action decision and is protective of human health.

Fish and crab consumption rates used in the FFS HHRA were taken from an internal Region 2 memorandum entitled, "Technical Memorandum – Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment" (Memorandum). The Memorandum purportedly "…presents a detailed evaluation of LPRSA-pertinent angler and creel surveys to identify ingestion rates for the Lower Passaic River. " However, the Memorandum is unprofessional in that its provenance is undefined, and, technically, it falls far short of a complete and accurate evaluation of the existing data. In addition, there is no evidence that the Memorandum underwent an independent peer review. Given that the fish and shellfish ingestion rates proposed in the Memorandum clearly drive the FFS risk assessment results and – by extension – the billion dollar-plus remediation alternative proposed by Region 2, it is of the utmost importance that such an influential document undergo scientific scrutiny by independent experts as is contemplated in USEPA guidance, (USEPA, 2012). In our professional opinion there is no utility in this document since it does not meet any reasonable standard of professional work product.

Transparency is lacking with regard to the Memorandum as it lacks attribution. It is not known who wrote the Memorandum; who performed the analyses; who developed its conclusions; for whom the author(s) work; for whom the Memorandum was written; and what, if any, organization(s) or agency(ies) supported the work. Furthermore, there is no evidence that this Memorandum was peer-reviewed. From this standpoint alone, its use and its importance as the foundational analysis of the fish and shellfish consumption rates employed by Region 2 in the LPR FFS HHRA is questionable since it fails to satisfy standard professional and scientific quality control methods, in our opinion.

The Memorandum marginalizes site-specific fish consumption studies performed on the LPRSA, ignoring relevant data while "cherry-picking" data (see below) supporting high consumption rates. Although it includes the 2001 LPR CAS in its evaluation of regional fish and shellfish consumption studies, the Memorandum impermissibly discounts the data and conclusions. The 2001 LPR CAS calculated fish consumption rates based on a year-long, comprehensive intercept survey of the River's anglers, a survey design and effort that far surpassed the two studies selected by the author(s) of the Memorandum to develop the fish and crab consumption rates (neither of which included empirical data of LPR angling activities).

In defending their marginalization of the 2001 LPR CAS, the author(s) of the Memorandum claim the sample size was deficient for statistical analysis, and that the fish advisories in effect in the Study Area impacted the results. Additionally, while the LPR fish consumption rate was determined to be 1.8 g/day (95th percentile) based on survey data (Ray et al., 2007b), this value was discounted in the Memorandum because it accounted for both anglers who claimed to consume their catch as well as those who stated they did not consume the fish they caught.

We disagree with the assertions regarding the 2001 LPR CAS and believe the Memorandum's position is scientifically unsound. *All* data from experiments (studies) should be used in analyses. Unusually high or low values cannot be ignored. The 2001 LPR CAS was designed to determine fish consumption of anglers; the fact that a portion of the anglers did not consume fish and would have a zero value is completely relevant to the CAS, and is consistent with the historical approach used by USEPA for deriving fish consumption rates (see ToxStrategies Comment 2-8 for more details).

The 2001 LPR CAS methodology and data have been subjected to vigorous statistical analysis (Kinnell et al., 2007; Ray et al., 2007a, b). Kinnell et al. (2007) discussed the challenges of conducting 2001 LPR CAS, including the unique site conditions (industrialization and urbanization), lack of fishing license regulations, and limited access points. The authors note that the 2001 LPR CAS "…presents a survey methodology designed to overcome these challenges and to provide data for accurately estimating the Study Area's angling population and the fish and crabs they catch, keep and eat" (Kinnell et al., 2007). Ray et al. (2007b) developed a statistical methodology for analyzing the 2001 LPR CAS data "… for calculating site-specific, human exposure estimates from data collected in this unique urban/industrial setting." Importantly, the 2001 LPR CAS study design, results, and conclusions were not only peer-reviewed by an independent expert panel established according to USEPA peer-review guidance (as we describe in detail in Comment 2.1 above), but were then subjected to further peer-review critique prior to being published in the peer-reviewed literature (Finley et al., 2003; Ray et al., 2007a, 2007b; Kinnell et al., 2007).

In contrast, the fish consumption evaluation presented in the Memorandum appears to cherry-pick data to support its conclusions since it disregards the 2001 LPR CAS population fish consumption estimates, yet highlights the maximum LPR fish consumption rate reported by Ray et al. (2007b) to support the use of default values taken from EPA's Exposure Factors Handbook (USEPA, 2011) to justify Region 2's own estimated value of 34.6 g/day. The Memorandum justifies its recommended fish ingestion rate based on the fact that the Burger (2002) and Connelly et al. (1992) studies yielded similar results, further stating that their fish consumption rate estimate is "…consistent with rates calculated from other surveys conducted within EPA Region 2 and nationally," and is "…consistent with rates used in various EPA decisions within Region 2." To highlight the consistency of results from studies on different water bodies with different angling populations as justification for an exposure parameter estimate that is intrinsically dependent upon the distinct characteristics of these variables is

illogical, and to strive for such “consistency” is in contravention of generally accepted scientific methodology and of EPA guidance.

In addition to deriving fish and shellfish consumption estimates, the Memorandum also ventures a comment on another risk assessment exposure parameter: Fraction ingested (FI). The Memorandum contends that assuming a fraction ingested of less than 1.0 is inappropriate because 1) “The Lower Passaic River has adequate quantity and quality of fish and crabs to support the estimated level of ingestion…”, 2) the Lower Passaic River has adequate access to the river for fishing and crabbing, and 3) redevelopment of the Lower Passaic River will make the area more “amenable to fishing and crabbing. “

There is no support for the contention that there are adequate quantity and quality of fish to support the estimated levels of ingestion. What limited data are available on the size of fish populations in the Lower Passaic River indicates that, even in the absence of chemical contamination, fish may not be edible due to pathogen contamination from combined storm and sewage systems (Donovan, 2008a,b). In addition, several fish species found in the Lower Passaic River are migratory (e.g. white perch and American eels) and may be subjected to external areas of contamination such as New York Harbor.

In summary, since the fish consumption rates used in the FFS HHRA were taken from a non-peer reviewed document with no authorship or organizational attribution, and given the availability of relevant, scientifically defensible CAS data for the LPR Study Area, it is our opinion that the fish consumption rates derived in the Memorandum should not be used in the HHRA. Instead, we recommend using fish consumption rates derived from the LPR CAS data. We believe the 2001 LPR CAS fish consumption rate of 1.8g/day is valid and should be used in the HHRA for the LPRSA for a realistic assessment of human health risks that comports with USEPA guidance. In contrast to the fish consumption estimates derived in the Memorandum, the consumption rate based on the 2001 LPR CAS was derived from data collected from a study overseen by a panel of experts, analyzed using valid statistical methodologies, and underwent peer-review in a series of professional publications.

> Comment 2-3: The use of only one exposure pathway – consumption of LPR fish and shellfish – does not adequately characterize the risks and hazards in the LPR. We recommend that all complete pathways and associated COCs, as defined by Region 2, bebe included when qualifying potential human health effects associated with exposures in the LPR.

On page 3-9 and Fig. 3-1 of the Risk Assessment (Appendix D), Region 2 identifies 12 potential exposure routes associated with potential human exposures to site-related contaminants. These include incidental ingestion of sediments, surface water, and mudflat sediments, dermal contact with sediments, surface water, and mudflat sediments, as well as ingestion of species other than fish and shellfish. Region 2 characterized exposures as a “complete quantitative pathway” for five of these exposure routes. However, Region 2 then discounts all exposure routes except fish and shellfish consumption, but offers no scientific data/analysis to support its decision. The FFS states that the decision was based on the assumption that “Consumption of fish and shellfish is anticipated to be associated with the highest cancer risks and non-cancer health hazards compared to ingestion, dermal contact or inhalation of chemicals in surface water or sediment during recreational exposures.” This was “… based on the results of Superfund HHRAs conducted for other river sites with bio-accumulative contaminants, such as dioxins and PCBs…”

This approach is extremely problematic for several reasons. First, it ignores USEPA guidance with respect to evaluating all complete pathways. Second, it places the focus on dioxins and PCBs when there are other known COCs at the site (e.g., polycyclic aromatic hydrocarbons), which are inappropriately ignored by Region 2. Third, it is based on observations from other sites instead of using site-specific data to inform the approach. It is not proper to compare the results of "real" data in one area, such as risk estimates based on site-specific fish consumption, with hypothetical estimates in another area, such as sediment/mud consumption via ingestion. The selective use of a single exposure route to characterize risks and hazards is more fully addressed by ToxStrategies (see Comments 2-4, 2-5, 3-1, and 3-3).

> Comment 2-4: The HHRA uses a cascade of conservative assumptions that results in a profound distortion of risk. Rather than using overly conservative toxicity values and irrelevant default exposure estimates, we recommend the use of the most defensible peer-reviewed toxicity values and site-specific exposure data to determine realistic risk estimates for the LPR.

Region 2's's FFS HHRA suffers from the excessive use of unrealistic exposure assumption estimates and of similarly unrealistic hazard assumptions. These are factors that, when combined, result in greatly distorted likely human risks. This representation is a well-known and documented problem with Agency risk assessment activities that has been referred to as the "cascading of conservative assumptions" in the risk assessment process (Belzer, 1991; Nichols et al., 1986). The conservatism is compounded on both the toxicology side of the risk assessment process, as well as the exposure assessment side. For example, toxicity value estimates are commonly the products of several inherently conservative factors, including: study data from highly sensitive animal models, the use of a hazard-assessment protocol that is based on the use of the Maximum Tolerable Dose and only a few marginally lower doses, the use of linear low dose models, and the constraining for modeled responses to be forced through the origin. Many of these issues are factors that influence the TCDD cancer slope factor utilized by Region 2 in its LPR FFS HHRA (See ToxStrategies Comments 2-12 through 2-17 for additional shortcomings of the TCDD toxicity values). Similarly, the use of exposure parameters that are based on unrealistic levels of consumption, consumption frequencies, and durations of such consumption can lead to an even more unrealistically high assumption on overall exposure (Belzer, 1991; Nichols et al., 1986). See ToxStrategies Comments 2-8 through 2-11 for details on the overly conservative nature of several exposure assumptions used by Region 2. Combined, these conservative assumptions lead to an exaggeration of risks and hazards, and result in an incorrect and possibly dishonest risk communication message. It can also lead to excessive clean up costs that are not supported by sound science. As made clear in ToxStrategies Comment 2-23, the issue of cascading conservative assumptions is particularly relevant to the Region 2 LPR FFS HHRA.

References

Belzer, R. B. 1991. The Peril and Promise of Risk Assessment. *Regulation*: Fall 1991, pp. 40-46.

Burger J. 2002. Consumption Patterns and Why People Fish. Environ Res. 90(2):125-35.

Connelly NA, Knuth BA, Bisogni CA. 2002. Effects of the health advisory and advisory changes on fishing habits and fish consumption in New York fisheries. Human Dimension Research Unit, Department of Natural Resources, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, NY.

Donovan, E. P., Staskal, D. F., Unice, K. M., Roberts, J. D., Haws, L. C., Finley, B. L., and Harris, M. A. 2008a. Applied and Environmental Microbiology. 74: 4 1004 – 1018.

Donovan, E. P., Unice, K., Roberts, J. D., Harris, M., and Finley, B. 2008b. Applied and Environmental Microbiology. 74:4 994 – 1003.

Finley, B., Iannuzzi, T. J., Wilson, N. D., Kinnell, J. C., Craven, V., Lemeshow, S., Teaf, C. M., Calabrese, E. J., and Kostecki, P. T. 2003.The Passaic River Creel/Angler Survey: Expert Panel Review, Findings, and Recommendations. J. Human Ecol. Risk Assess. 9:829-856.

Kinnell, J. C., Bingham, M. F., Hastings, E. A., Ray, R., Craven, V., and Freeman, M. 2007. A Survey Methodolgy for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1). J. Toxicol. Environ. Health. 70: 477 -495.

Nichols, A. L. and R. J. Zeckhauser. 1986. The Perils of Prudence: How Conservative Risk assessments Distort Regulation. *Regulation*: November/December 1986. pp. 13-26.

Ray, R., Craven, V., Kinnell, J., Bingham, M., Freeman, M., and Finley, B. 2007a. A Statistical Method for Analyzing data Collected by a Creel/Angler Survey (Part 2). J. Toxicol. Environ. Health. 70: 496 – 511.

Ray, R., Craven, V., Bingham, M., Kinnell, J., Hastings, E., and Finley, B. 2007b. Human Health Exposure Factor Estimates Based Upon A Creel/Angler Survey of the Lower Passaic River (Part 3). J. Toxicol. Environ. Health. 70: 512- 528.

Region 2 (USEPA). 2012. Technical Memorandum Fish and Crab Consumption rates for the LPRSA Human Health Risk Assessment. February 2, 2012.

USEPA. 1989. Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December 1989.

USEPA. 1991. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance “Standard Default Exposure Factors”. Interim Final. Office of Emergency and Remedial response. Toxic Integration Branch. USEPA, Washington, D.C. OSWER Directive 9285.6-03, March 25, 1991.

USEPA. 1995. Letter to Occidental Chemical Corporation and Chemical Land Holdings, Inc., regarding Scope of the Ecological Sampling Plan for the Passaic River Study Area Diamond Alkali Superfund Site. Region 2Newark, New Jersey. October.

USEPA. 2000a. Guidelines for Preparing Economic Analyses. September 2000.

USEPA. 2000b. Science Policy Council Handbook. Peer review. 2nd Edition. EPA 100-B-00-001. Office of Science and Policy, Office of Research and Development, Washington, D. C.

USEPA. 2011. Exposure Factors Handbook 2011 Edition (Final). U. S. Environmental Protection Agency, Washington D.C. EPA/600/R-09/052F.

USEPA. 2012. Science Policy Council Handbook. Peer review. 3rd Edition. EPA/100/B-06/002. Office of Science and Policy, Office of Research and Development, Washington, D. C.

USEPA. 2014. Memorandum – Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120, February 6, 2014.

Paul T. Kostecki, Ph.D.

Professor of Environmental Health
Associate Director, Northeast Regional Environmental Public Health Center
Department of Public Health
School of Public Health
University of Massachusetts Amherst

President
Association for Environmental Health and Sciences

INTERESTS

Dr. Kostecki has 34 years of professional experience as an environmental scientist, first as a fisheries/fish biologist and later focusing on environmental and public health risk assessment. The extent of his research interests include the use of fish as indicators of environmental health and toxicological models; exposure pathways in risk assessment especially soil ingestion in sensitive populations; the application of environmental and public health parameters in the cleanup and regulation of contaminated soils and sediment; as well as knowledge dissemination and application in the field of environmental contamination management. He has been involved in environmental impact assessment activities for PCB pollution in the Fox River in Wisconsin; fish consumption rates for Passaic River in New Jersey; harbor sediment, chemical contamination in Sardinia, Italy; and petroleum contamination in Kuwait. His multidisciplinary education and experience in engineering, fisheries/fish biology and risk assessment in addition to his prior work on the Passaic River allows him a unique perspective in commenting on the Focused Feasibility Study plan.

EDUCATION

University of Michigan	Fish Physiology	Ph.D.	1981
University of Michigan	Fish Physiology	M.S.	1978
University of Mass. Amherst	Fisheries Biology	B.S.	1973
Northeastern University	Engineering	Transferred	1968-71

ACADEMIC EXPERIENCE

2005-present	Professor, Environmental Health Sciences, University of Massachusetts Amherst.
1998-present	Associate Director, Northeast Regional Environmental Public Health Center, University of Massachusetts Amherst.
1991-present	Adjunct Professor, Plant and Soils Science, University of Massachusetts Amherst.
2011-2012	Director, Simmons Online, Simmons College, Boston, MA.
2009-2011	Special Assistant to Vice President of Academic Affairs and International Relations, University of Massachusetts, Boston, MA.
2008-2009	Vice Chancellor for Research and Engagement, University of Massachusetts Amherst.
2003-2008	Vice Provost for Research, University of Massachusetts Amherst.
1996-2003	Research Professor, Depart of Environmental Health Sciences, University of Massachusetts Amherst.
1988-1996	Research Associate Professor, Department of Environmental Health Sciences, University of Massachusetts Amherst.
1983-1984	Lecturer, Zoology Department, University of Massachusetts Amherst.
1980-1983	Post-Doc, Depart of Fisheries Biology, University of Massachusetts Amherst.
1984-1988	Senior Post-Doc, Depart of Environmental Health Sciences, University of Massachusetts Amherst.

PRIVATE SECTOR EXPERIENCE

2009-present	President, Association for Environmental Health Sciences Foundation.
1990-2009	President, Association for Environmental Health and Sciences, Inc.
2012-present	Board of Directors (member), NextFuels, Denver, CO.

SELECTED RELEVANT PUBLICATIONS

- Stanek, E. J., Calabrese, E. J., Barnes, R. M., Danku, J. M. C., Zhou, Y., **Kostecki, P. T.**, and Zillioux, E. (2010). *Bioavailability of Arsenic in Soils: Pilot Study Results and Design Considerations*. *J. Human and Experimental Toxicology* 29:11, 945-960.
- Finley, B., T. J. Iannuzzi, N. D. Wilson, J. C. Kinnell, V. Craven, S. Lemeshow, C. M. Teaf, E. J. Calabrese, and **P. Kostecki** (2003). *The Passaic River Creel/Angler Survey: Expert Panel Review, Findings and Recommendations*. *Journal of Human and Ecological Risk Assessment*, 9(3): 829-855.
- **Kostecki, P. T.**, E. J. Calabrese, and M. Nascarella (2002). Survey of States' '2001' Soils Cleanup Standards for Petroleum Contamination. *Journal of Soil and Sediment Contamination*, 11(2): 117-239.
- Calabrese, E. J. and **P. T. Kostecki** (1992). *Risk Assessment and Environmental Fate Methodologies*. Lewis Publishers, Chelsea, MI. 150 pp.
- Calabrese, E. J., Barnes, R., Stanek, E. J. III, Pastides, H., Gilbert, C. E., Veneman, P., Wang., X., Lasztity, A., and **Kostecki, P. T.** (1989). *How Much Soil Do Young Children Ingest: An Epidemiologic Study*. Reg. Toxic. and Pharm., 10:123 137.

FUNDING

- Academic funding: secured and managed over $14M in grants and contracts (up to $750,000) as Principal Investigator and Co-Principal Investigator since 1985 for environmental contamination assessment from government and industry.
- Private sector funding: secured and managed over $12M in grants and contracts (up to $650,000) from academe, industry, state and federal agencies.

SYNERGISTIC ACTIVITIES

- Developed, organized, and conducted 60 national conferences on *Contaminated Soil, Sediments and Water* in Massachusetts, California, Louisiana and Texas each conference having 300 to 800 attendees (1985-present).
- Edited/Co-Edited (30+) and co-authored (2) books on the analysis, assessment, and remediation of contaminated soils including petroleum and MTBE contamination.
- Created and co-published the *Journal of Soil and Sediment Contamination* (1991 - 2003).
- Served as Co-Editor-in-Chief for *Journal of Soil and Sediment Contamination* (1991 - present).
- Created, co-produced and distributed the international journal of *Human & Ecological Risk Assessment (HERA)* (1994 - 2003). Served as Editorial Board member for HERA (1994 - 2005).
- Created and co-produced the international *Journal of Environmental Forensics* (2000 - 2003).
- Conducted annual U.S. State-by-State surveys for soil and water cleanup standards, 1985-2005, 2012 as well as surveys on innovative technology use, RBCA & MTBE.
- Created the environmental publishing company, *Amherst Scientific Publishers* (1994-present).
- Served as Scientific Advisor for workshops to *Kuwait Foundation for the Advancement of Science and the Arab School of Science & Technology* (1995-2001).
- Worked with Kuwait Institute for Scientific Research (KISR) on petroleum contamination assessment for the U.N.'s Compensation Commission on the Iraq Invasion of Kuwait (1999).
- Served as Independent Reviewer Team Leader, United Nations Decision 256 mandated cleanup of Kuwait, named (2007).
- Spring Valley Scientific Advisory Panel on Arsenic, Mayor's Health Council, Washington, D.C. (member) (2000-2003).
- Massachusetts Department of Environmental Protection - *Bureau of Waste Site Cleanup Subcommittee* (member) (1990-2005).
- U.S. Navy's *National Environmental Technologies Test Site Advisory Board* (member) (1993-2004).

Edward J. Calabrese, Ph.D.

Director, Northeast Regional Environmental Public Health Center
Professor, University of Massachusetts, Amherst, MA
Phone: 413-549-5264 (home), 413-545-3164 (work); Fax: 413-545-4692 (work)
edwardc@schoolph.umass.edu

ACADEMIC TRAINING

University of Massachusetts at Amherst, MA	Education, Science Ed.	Ed.D.	1974
University of Massachusetts at Amherst, MA	Physiology/Toxicology (Entomology Dept.)	Ph.D.	1973
State College at Bridgewater, MA	Biology	M.A.	1972
State College at Bridgewater, MA	Biology	B.A.	1968

WORK EXPERIENCE

- Director – Northeast Regional Environmental Public Health Center, October 1985-Present.
- Professor – Promoted from Associate Professor, June 1982-Present.
- Associate Professor – Promoted from Assistant Professor, June 1980.
- Assistant Professor – September 1976 – Environmental Health Sciences Program, Division of Public Health, University of Massachusetts, Amherst, MA. Duties include: teaching introductory and advanced courses in environmental toxicology, directing thesis research.
- Assistant Professor – July 1974 August 1976 – Department of Occupational and Environmental Medicine, University of Illinois, School of Public health, and Assistant Director of the Environmental Health Resource Center. Duties included: the identification and quantification of present and potential environmental health hazards within the state, the development and review of environmental health legislation, standards and regulations, testimony at regulatory and legislative hearings on standards of environmental quality and teaching courses in environmental health.

PUBLICATIONS

Below represents a sampling of published journal articles and books.

- **Calabrese E. J.**, Dhawan G., Kapoor R. (2014). Use of X-rays to treat shoulder tendonitis/bursitis: a historical assessment. *Archives of Toxicology* 88(8):1503-1517 press).
- **Calabrese E. J**. (2014). The genetics panel of the NAS BEAR I Committee (1956): Epistolary evidence suggests self-interest may have prompted an exaggeration of radiation risks that led to the adoption of the LNT cancer risk assessment model. *Archives of Toxicology* DOI:10.1007/s00204-014-1306-7.
- Cornelius C., Graziano A., Perrotta R., DiPaola R., Cuzzocrea S., **Calabrese E. J.**, Calabrese V. (2014). Cellular stress response, hormesis, and vitagens in aging and longevity: Role of mitochondrial "Chi". Chapter 26 in *Inflammation, Advancing Age and Nutrition*, Academic Press/Elsevier pp. 309-321.
- **Calabrese E. J.** (2014). Hormesis: A fundamental concept in biology. *Microbial Cell* 1(5):1-5.
- **Calabrese E. J.** (2014). Dose-response relationship. *Encyclopedia to Toxicology*, Third Edition, Volume 2 (P. Wexler, Editor). Academic Press pp. 224-226.
- Cornelius C., Koverech G., Crupi R., Lodato F., Scuto M., Salinaro A. T., Cuzzocrea S., **Calabrese E.J.**, Calabrese V. (2014). Osteoporosis and Alzheimer pathology: Role of cellular stress response and hermetic redox signaling in aging and bone remodeling. *Frontiers in Pharmacology* 5(120):1-13. doi:10.3389/fphar.2014.00120.
- **Calabrese, E. J.** (2014). Brief history of hormesis and its terminology. *Hormesis in Health and Disease* (Rattan S. and LeBourg E., Editors). CRC Press, Boca Raton FL, pp.3-12.
- **Calabrese, E. J.** (2014). Hormesis and risk assessment. *Hormesis in Health and Disease* (Rattan S. and LeBourg E., Editors). CRC Press, Boca Raton FL, pp.339-356.
- **Calabrese, E. J.** (2014). The dose-response: A fundamental concept in toxicology. *Principles and Methods of Toxicology*, Sixth Edition (Hayes, AW, editor). (in press).

- **Calabrese, E. J.** (2014). The dose response: Comparing hormesis and threshold models. *Fundamentals of Ecotoxicology*. The Science of Pollutions, 4th Edition. (in press).
- Iavicoli I., Fontana L., Leso V., **Calabrese E. J.** (2014). Biphasic dose-response in nanotechnology studies. *Science for the Total Environment* 487:361-374.

COMMENTS

FFS Human Health Risk Assessment – Comments on Use of TEFs

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
William Farland, Ph.D., ATS

FFS HUMAN HEALTH RISK ASSESSMENT – COMMENTS ON USE OF TEFS

Dr. William Farland

Comment Title: USEPA Region 2 provided limited discussion on the uncertainty related to the utilization of TEFs in the human health risk assessment associated with the FFS and should expand on these discussions of uncertainty in order to provide a more transparent perspective on the potential risks associated with exposure from the COPCs in the Lower Passaic River. Exposure estimates based on nominal TEQ values are expected to be higher, to some unknown degree, than actual exposure and so uncertain as to make the need for or selection of a preferred remedy among the options presented impossible to determine based on scientific grounds. Region 2 should present a more robust discussion of the uncertainties of the TEF approach, which is used as a central premise for the HHRA if decision-makers are to fully understand the choices they are making among modeled options for remediation or the setting of PRGs.

Comment:

2,3,7,8-TCDD (TCDD) and related compounds including dioxins, furans and PCBs, the so-called dioxin-like compounds (DLCs), have been detected in environmental media associated with the FFS Study Area; 2,3,7,8-TCDD, the most toxic congener, typically constitutes a significant majority of both the total dioxin and furan congener concentrations. In addition, dioxin-like PCB concentrations make up a significant portion of the overall risk.

The HHRA prepared for the FFS determined that under baseline conditions the cancer risks to individuals based on the RME are greater than the risk range established in the NCP of 10^{-4} (one in ten thousand) to 10^{-6} (one in one million) and that non-cancer health hazards are higher than USEPA's goal of protection of an HI equal to 1. The majority of the potential cancer and non-cancer risk calculated by Region 2 is associated with DLCs.

Characterization of TCDD toxicity has evolved over the last twenty-five years and is a critical component of the assessment of risks from exposure to all mixtures of DLCs. TCDD is the index chemical for the dioxin toxicity equivalence factors (TEF) approach which is recommended by the USEPA and other state, national and international organizations as the consensus approach to assess this group of structurally similar chemicals. In this approach, the toxicity of individual components of DLC mixtures is scaled to that of TCDD. Then, the dose-response information for TCDD is used to evaluate risks from exposure to mixtures of DLCs (USEPA, 2010; Van den Berg et al. 2006; Van den Berg et al. 1998).

However, the consensus around the use of the TEF approach does not mean that it is without uncertainties. These uncertainties should be fully evaluated and discussed as part of any well-developed risk assessment for use in human health and ecological risk-based decision-making. Rather than providing a transparent discussion of these uncertainties, Appendix D simply says: "Potential uncertainties associated with the evaluation of TEFs for dioxins and dioxin-like PCBs are provided in USEPA's 2010 document titled "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-like Compounds" (USEPA 2010). The document acknowledges the following uncertainties: "TEQ uncertainty only pertains to the confidence associated with the estimation of TCDD equivalents in a mixture. There is also uncertainty associated with assessing exposures to

environmental mixtures of TCDD and DLCs and with quantitatively linking health effects to the TCDD and DLC exposures." This brief summary of a large body of literature surrounding dioxin toxicity and the TEF approach is far from adequate to acquaint decision-makers with the issues associated with characterizing risk from mixtures of DLCs and consideration of various alternatives for remediation, setting of PRGs and public health and environmental protection, particularly when coupled with the large uncertainties in the site-specific information regarding potential exposure.

There are a number of critical aspects of uncertainty relating to the use of TEFs that Region 2 should assure are clearly articulated in its HHRA. First, because TCDD is used as the index chemical in the TEF approach, the most relevant, accurate and up-to-date information that specifically addresses quantitative dose response for TCDD exposures should be referenced. Because dioxin risk characterization is a work in progress, involving a broad segment of the scientific community, the state of the science around dioxin risk assessment should be acknowledged with the recognition that values for dose-response analysis (cancer slope factors and reference doses) may change over time. For instance, decision-makers should be aware that the cancer slope factor used in the HHRA is from 1985 and that a variety of alternatives, mostly less conservative, have been discussed over the intervening years. While the slope factor chosen for the HHRA is recognized as a "default" value by the USEPA, it is far from a consensus value. The slope factor yields an upper bound estimate on the risk with the true risk likely to be less than this value. The statement that these are upper bounds on risk appears only once in the 531-page Remedial Investigation Report for the Focused Feasibility Study (FFS Report) and the nature of the estimate is never discussed. A discussion of this uncertainty alone should add perspective to the uncharacterized risk numbers that are presented without detail in the Tables in Appendix D of the Region 2 HHRA.

Second, while there is consensus on the use of the TEF approach, significant uncertainties are inherent in the approach, which should be clearly discussed and understood by decision makers. Application of the TEF approach to the human health risk assessment of DLCs carries with it some of these uncertainties that have been discussed in detail elsewhere in the literature. (For example, see discussions in USEPA 2000, 2003, Haws et al. 2006, NAS 2006, and Van den Berg et al. 1998, 2006). TEFs are agreed-upon values that arose from a process of inspection of the underlying toxicology literature and scientific judgment. The World Health Organization (WHO) expert panel assigned TEF values from a conservative perspective that was intended to be health protective (Van den Berg et al. 2006). In the development of the TEFs, the WHO expert panel considered data from Haws et al. (2006), who present summary statistics of relative potency values assembled from selected in vivo and in vitro studies. For each individual DLC, the WHO expert panel typically assigned TEF values using an in vivo study whose relative potency value was above the 50th percentile of the ranges presented by Haws et al. (2006). Because the equivalent TCDD exposure for DLCs is derived from TEF methodology, which is conservative in nature (TEFs are typically higher than the median value for relative potency estimates), the total TEQ concentrations would likely be overestimated (relative to TCDD) and uncertain.

In addition, there is uncertainty in how the underlying data were used to derive the TEF values. The kinds of information available for calculating relative potencies within a study are highly variable across DLCs, including many types and numbers of in vivo (including different test species) and in vitro studies. In addition, a number of different methods are employed to calculate the range of relative potencies presented by Haws et al. (2006), ranging from comparing dose-response curves, to developing ratios of effective doses that cause an effect in 50% of the test units (ED50s), to estimating values from graphs of dose-response data.

To capture the uncertainty in these assumptions, all TEFs were provided as order-of-magnitude estimates, and the EPA described its application as a "useful interim approach" (U.S. EPA 1989, 2010). A stepwise scale was used to assign the TEFs using half order of magnitude increments on a logarithmic scale (e.g., 0.03, 0.1, 0.3, etc.) instead of the increments used in previous efforts (e.g., 0.01, 0.05, 0.1, etc.), with uncertainty assumed to be at least ± half a log. For example, the uncertainty for a TEF of 0.1 can be described as being within the interval of 0.03 and 0.3, and for a TEF value of 0.3, within an interval of 0.1 and 1. These estimates are generated by multiplying (dividing) the TEF value by half a log (i.e., 3.16). This aspect of uncertainty provides a crude range around the values as presented in the HHRA and should be discussed as one approach to a "sensitivity analysis" as recommended by USEPA (2010). This point will be discussed further in a separate comment.

In summary, Region 2 provided limited discussion on the uncertainty related to the utilization of TEFs in the human health risk assessment associated with the FFS. Region 2 should expand on these discussions of uncertainty in order to provide a more transparent perspective on the risks associated with exposure from the COPCs in the Lower Passaic Rivers site. The TEF methodology is designed to be health protective, in that the TEFs are not central tendency estimates but biased high by design (Van den Berg et al. 2006) and the approach for their derivation contains substantial uncertainties. Therefore, exposure estimates based on nominal TEQ values are expected to be higher, to some unknown degree, than actual exposure and, potentially, so uncertain as to make the selection of a preferred remedy impossible. This point should be clear in a more robust discussion of the uncertainties of the TEF approach, which is used as a central premise for the HHRA if decision-makers are to fully understand the choices they are making among modeled options for remediation or the setting of PRGs.

References:

Haws, L.C., Su, S.H., Harris, M., Devito, M.J., Walker, N.J., Farland, W.H., Finley, B.

Birnbaum, L.S., 2006. Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. Toxicol. Sci. 89, 4–30.

NAS (National Academy of Science). (2006) Health risks from dioxin and related compounds: evaluation of the EPA reassessment. National Academies Press, Washington, DC. Available online at http://www.nap.edu/catalog.php?record_id=11688.

USEPA (U.S. Environmental Protection Agency). (1989). Interim procedures for estimating risks associated with exposures to mixtures of chlorinated dibenzo-p-dioxins and -dibenzofurans (CDDs and CDFs) and 1989 update. EPA/625/3-89/016.

USEPA, 2000. Supplementary guidance for conducting health risk assessment of chemical mixtures. Risk Assessment Forum, Washington, DC.

USEPA (U.S. Environmental Protection Agency). (2003). Exposure and human health reassessment of 2,3,7,8-tetrachlorodibnzo-p-dioxin (TCDD) and related compounds. Part II Health assessment for 2,3,7,8- tetrachlordibenzo-p-dioxin (TCDD) and related compounds. Chapter 9: Toxic Equivalency Factors (TEF) for dioxin and related compounds. NCEA-I-0836. December 2003. NAS Review Draft.

USEPA, 2010. Recommended Toxicity Equivalence Factors (TEFs) for Human Risk.

Assessments of 2,3,7,8-tetrachlorodibenzo-p-dioxin and Dioxin-like Compounds. Risk Assessment Forum, Washington, DC.

Van den Berg, M., Birnbaum, L., Bosveld, A. T. C., Brunstrom, B., Cook, P., Feeley, M., Giesy, J. P., Hanberg, A., Hasegawa, R., Kennedy, S., et al. (1998). Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Perspect. 106, 775.

Van den Berg, M., Birnbaum, L., Denison, M., Devito, M.J., Farland, W.H., Feeley, M.

Fiedler, H., et al., 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol. Sci. 93, 223–241.

Comment Title: Region 2 should follow Agency guidance and perform a TEF sensitivity analysis as part of its human health risk assessment in support of the FFS. The use of such an approach will promote transparency and illustrate the inherent uncertainty that should be understood by decision-makers who are considering remediation options and/or setting PRGs. Only by understanding the sensitivities of the data, methods and models used can decision-makers judge whether any of the presented remediation options will have a meaningful positive impact on public health and the environment.

Comment: USEPA recommends that, for major risk assessments, as determined by USEPA Program Offices or Regions, the conduct of a sensitivity analysis be considered to illustrate the impact use of TEFs for DLCs has on the TCDD TEQ value, which is consistent with good risk assessment practices (U.S. EPA 2000). According to USEPA guidance, TEF sensitivity analysis has at least two purposes: (1) to identify plausible upper and lower estimates of the TEQ to assess the potential range the TEQ may have, and (2) to identify the influence of TEF values for specific compounds on the TEQ (USEPA, 2010).The use of such an approach will promote transparency and illustrate the inherent uncertainty that needs to be understood by decision-makers who are considering remediation options and/or setting PRGs. Only by understanding the sensitivities of the data, methods and models used can decision-makers judge whether any of the presented remediation options will have a meaningful positive impact on public health and the environment.

While ideally a full quantitative uncertainty analysis is desirable, few data sets allow such an analysis. This is certainly the case with the complex data sets available for the DLCs as described above and detailed in Haws et al (2006). While additional data sets have been added since the time of the Haws et al (2006) analysis, currently available toxicologic data on relative potency (RePs) that could be used to characterize the uncertainty in the individual TEF values remain limited and biased by the nature and the number of available RePs (USEPA 2010). In order to carry out an ideal quantitative uncertainty analysis, the underlying statistical distributions of the ReP data would be needed. Given the variable nature of the test data, differing end points and a wide range of RePs for any individual DLC, the “true” probability distributions of the TEFs cannot be determined or accurately inferred at this time. However, useful sensitivity analyses can be conducted using estimated ranges of the TEFs (USEPA 2010; Urban et al., 2009; Parvez et al. 2013), keeping in mind the limitations of the available data, and should be conducted for the FFS.

As a start, upper TEQ value (*TEQU*) and the lower TEQ value (*TEQL*) could be determined and presented using relatively simplistic approaches as suggested by USEPA (2010). In addition, the fraction of the TEQ attributable to TCDD and to each DLC should be identified. It would be useful, for instance, to include a table containing the range of tissue concentrations for each DLC with its potential contribution to total TEQ. This may be particularly important for the mixture of DLCs being evaluated in the human health risk assessment in the FFS where TEQ (D/F) is dominated by TCDD but where a half or more of the cancer and non-cancer risk is attributable to dioxin-like PCBs (TEQ (PCBS)). The differences in the data bases, assumptions, and scientific judgment in setting TEFs for D/Fs and for PCBs are noteworthy and should be discussed as a part of the sensitivity analysis in the HHRA.

EPA (2010) suggests two possible data choices for identifying compound-specific upper and lower bound values (*TEFiU* and *TEFiL*). First, as mentioned in previous comments, the WHO (van den Berg et al. 2006) states that the TEFs are assumed to have uncertainty of at least ± half a log (i.e., 3.16); thus, multiplying and dividing the compound-specific TEFs by 3.16 could provide estimates of *TEFiU* and TEF*i*L respectively.

Second, the EPA (2010) recognizes that Haws et al. (2006) has summarized distributions of the ReP values. Although limited to the available ReP data (i.e., not necessarily an unbiased sample of equivalence factors), the ReP ranges developed by Haws et al. (2006) may provide another source of data for *TEFU* and *TEFL* values. The USEPA (2010) has even presented (pp. 18-19, Tables 3 and 4) specific percentiles of the Haws et al. (2006) statistical summaries for the RePs derived from in vivo data and combined in vitro and in vivo data, respectively. USEPA (2010) suggests that the values for *TEFU* and *TEFL*, for example, could be based on the minimum and maximum data, the 10th and 90th percentiles, or the interquartile ranges from either Tables 3 or 4.

To identify the influence of specific compounds on the total TEQ and provide a perspective on the uncertainty and sensitivity of these findings, USEPA (2010) recommends that the list of compounds that are most influential to the TEQ be further explored. For each of these, the sensitivity of the TEQ to confidence in the TEF values for the individual compounds may be conducted (i.e., evaluating the influence of the TEF values for each DLC on the total TEQ contributing to potential risk). As discussed above, this might be particularly important to understand the uncertainty around toxicity values for dioxin-like PCBs. Dioxin-like PCBs and their nondioxin-like counterparts account for a substantial portion of the potential risk based on the values used in the HHRA. A more robust discussion of the PCBs might render as untenable the currently presented options for remediation as demonstrated by the alternative HHRA presented as part of these comments (Tox Srategies 2014).

In summary, Region 2 should follow Agency guidance and conduct a sensitivity analysis to characterize the impact of TEF variability on the TEQ as a part of a broader characterization of uncertainty in the FFS . For the *TEQU* and *TEQL* estimates that are generated, it should identify the fraction of the TEQ attributable to TCDD, each DLC and each chemical class, particularly the dioxin-like PCBs. In addition, it should identify the individual TEF values that are most influential to changing the TEQ estimate and ultimately, affect a decision-maker's confidence in the outcome of the risk assessment on upper bound cancer risk and on non-cancer hazard and remedy selection.

References:

Haws, L.C., Su, S.H., Harris, M., Devito, M.J., Walker, N.J., Farland, W.H., Finley, B.

Birnbaum, L.S., 2006. Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. Toxicol. Sci. 89, 4–30.

Parvez, S, et al. (2013) A sensitivity analysis using alternative toxic equivalency factors to estimate U.S. dietary exposures to dioxin-like compounds. Reg Tox Pharm 67, 278–284.

ToxStrategies (2014). Comments on the Lower Eight Miles of the Lower Passaic River Focused Feasibility Study Report Issued by Region 2, Prepared on behalf of Tierra Solutions, Inc.

Urban JD, et al. (2009) Assessment of human health risks posed by consumption of fish from the Lower Passaic River, New Jersey, Sci Total Environ, doi:10.1016/j.scitotenv.2009.03.004.

USEPA, 2000. Supplementary guidance for conducting health risk assessment of chemical mixtures. Risk Assessment Forum, Washington, DC.

USEPA, 2010. Recommended Toxicity Equivalence Factors (TEFs) for Human Risk.

Assessments of 2,3,7,8-tetrachlorodibenzo-p-dioxin and Dioxin-like Compounds. Risk Assessment Forum, Washington, DC.

Van den Berg, M., Birnbaum, L., Denison, M., Devito, M.J., Farland, W.H., Feeley, M.

Fiedler, H., et al., 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol. Sci. 93, 223–241.

Comment Title: In the Focused Feasibility Study (FFS) Human Health Risk Assessment (HHRA), USEPA Region 2 utilized static TEFs for PCDD/Fs and dioxin-like PCBs. Using TEF distributions could provide greater insight regarding robustness of the underlying data and degree of accuracy and attendant uncertainty in the cancer risks and non-cancer hazard posed by these compounds at this site, particularly in the case of dioxin-like PCBs.

Comment: As discussed in other comments, toxicity test data underlying TEFs for DLCs are varied and their application in combination to estimate total TEQ is uncertain (USEPA 2010). In many cases, ReP values for individual DLCs can span orders of magnitude (Finley et al 2003; Haws et al 2006). These RePs are derived from different in vitro and in vivo experimental systems and contain inherent uncertainty due to the nature of the study and its applicability in predicting human risk. These uncertainties are compounded and masked when a single TEF value for individual DLCs is chosen. The process for deriving the TEF value is based on scientific judgment and inherent conservatism, so as not to underestimate risk in the face of these uncertainties (Van den Berg et al. 2006). For upper-bound cancer risk estimates and non-cancer hazard indices involving both PCBs and D/Fs, this uncertainty is greatly compounded by the use of "point estimate" TEFs, due to the significant differences in the conservatism among the WHO TEFs for PCB and D/F congeners. Specifically, the PCB TEFs generally represent the central tendency of a relatively broad range of numerous ReP values, while the D/F TEFs generally represent the upper bound of a relatively narrow range of fewer ReP values. In short, it is reasonable to conclude that the dose-response analysis of large numbers of PCBs and D/Fs introduces the greatest degree of uncertainty in the associated health risk estimates. This uncertainty may be substantial in the case of the HHRA in the FFS since over 80% of the upper bound cancer risk and most of the non-cancer hazard is attributable to DLCs under baseline conditions and with the concern being split almost evenly between TEQ(D/F) and TEQ(PCBs) for remediation alternatives 2 and 3. In these cases, 2,3,7,8-TCDD is responsible for a majority of the TEQ(D/F) risk. Because 2,3,7,8-TCDD is not assigned a TEF value from a range of ReP distributions (it is assigned a default value of 1.0), the influence of using ReP distributions for TEQ(D/F) may be minimized. On the other hand, given the importance of the TEQ(PCBs) to the overall assessment of risk and hazard, the use of ReP distributions in a probabilistic analysis of dioxin-like PCB TEQ would theoretically allow for a more informed discussion of the uncertainty in the risk and hazard estimates, based on a better understanding of the data underlying these estimates and their attendant uncertainties.

Although widely accepted for risk assessment purposes, the TEF approach has been clearly identified by USEPA as "interim" and is subject to periodic review as new scientific information becomes available. There is a general recognition that the TEF methodology will be further improved with a better understanding of the modes of action underlying this class of compounds, with more data available concerning the relative potencies of these compounds, and with more sophisticated quantitative tools.(USEPA 2010). ToxStrategies (2014) has demonstrated the large impact on hazard/risk of simply using TEF distributions rather than point estimates.

Since the last review of the TEF database is now nine years old, efforts to assess the distributions of RePS for the dioxin-like PCBs would appear to be a worthwhile effort in support of the Lower Passaic River project. An updated database for the dioxin-like PCBs could be generated through a science panel process for the development of ReP distributions, as a supplement to the static TEFs. For example, ReP distributions for the dioxin-like PCBs could be used to establish consistent percentile-point-estimate TEFs to represent the "central tendency" and "plausible upper bound" for each dioxin-like PCB congener (e.g., the 50th and 90th percentiles of the distribution, respectively). The use of ReP distributions in a probabilistic

analysis of risk would theoretically allow for a more informed discussion of the uncertainty in the risk estimates for dioxin-like PCBs. Development of an updated database for the dioxin-like PCBs would benefit both this assessment and site-specific environmental decision-making.by providing an up-to-date basis and rationale for the use of more scientifically sound TEFs for the dioxin-like PCBs

In support of this approach, a recent publication by the USEPA highlights the importance of developing probability distributions for the TEFs (Parvez et al. 2013). These authors suggest that continued efforts are needed to increase quality data on selected DLCs and to develop new approaches for deriving representative TEF values for the DLCs. They acknowledge that Haws et al. (2011) proposed weighting criteria for improved determination of TEFs, and Van den Berg et al. (2006) suggested the use of lowest-observed-adverse-effect levels to estimate RePs, if dose-response relationships could not be confidently predicted. Similar efforts likely would improve the scientific basis of the TEF estimates and could be sources of meaningful distributions of the TEFs for the DLCs, the authors conclude.

In summary, the current Human Health Risk Assessment in support of options for remediation of the Lower Passaic River uses only static TEFs which fails to transparently convey the potential for risk and hazard of this mixture of DLCs. Using TEF distributions would provide greater insight into the cancer risks and non-cancer hazard posed by these compounds at this site, particularly in the case of dioxin-like PCBs.

References:

Finley, B. L., Connor, K. T., and Scott, P. K. (2003). The use of toxic equivalency factor distributions in probabilistic risk assessments for dioxins, furans, and PCBs. J. Toxicol. Environ. Health Part A 66, 533–550.

Haws, L.C., Su, S.H., Harris, M., Devito, M.J., Walker, N.J., Farland, W.H., Finley, B.

Birnbaum, L.S., 2006. Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. Toxicol. Sci. 89, 4–30.

Haws, L. C., DeVito, M. J., Walker, N. J., Harris, M. A., Tachovsky, J. A., Brinbaum, L. S., Farland, W. H., Wikoff, D. S., 2011. Development of a consensus-based weighting framework for evaluating estimates of relative potency for dioxin-like compounds that includes consideration of data from human cells. In: Dioxin 2011. Brussels, Belgium.

Parvez, S, et al. (2013) A sensitivity analysis using alternative toxic equivalency factors to estimate U.S. dietary exposures to dioxin-like compounds. Reg Tox Pharm 67, 278–284.

ToxStrategies (2014). Comments on the Lower Eight Miles of the Lower Passaic River Focused Feasibility Study Report Issued by Region 2, Prepared on behalf of Tierra Solutions, Inc.

USEPA, 2010. Recommended Toxicity Equivalence Factors (TEFs) for Human Risk.

Assessments of 2,3,7,8-tetrachlorodibenzo-p-dioxin and Dioxin-like Compounds. Risk Assessment Forum, Washington, DC.

Van den Berg, M., Birnbaum, L., Denison, M., Devito, M.J., Farland, W.H., Feeley, M.

Fiedler, H., et al., 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol. Sci. 93, 223–241.

William H. Farland, Ph.D., ATS

Senior Advisor to the Executive Vice President, and
Professor, Environmental and Radiological Health Sciences, and
Professor, Center for Environmental Medicine
College of Veterinary Medicine and Biomedical Sciences,
Colorado State University, Fort Collins, CO

Professor, Occupational and Environmental Science
Colorado School of Public Health, Denver, CO

Principal, William H. Farland Consulting, LLC
Independent Health and Environmental Risk Consulting
Rockport, Maine

PERSONAL STATEMENT

My scientific background and experience as a federal executive and scientist in the Office of Research and Development at the USEPA provide unique qualifications for providing comments to the Passaic River FFS that involves clean-up of dioxin-like and other chemicals. In addition to my research interests regarding the environmental health impacts of Agent Orange/dioxin and other environmental contaminants and my risk assessment expertise and leadership at EPA, I led a US effort to develop methods to clean-up Agent Orange/dioxin hot spots in Viet Nam from 2000-2006. I also chaired an External Advisory Group for the NIEHS Superfund Basic Research Program which developed a report on the future of Superfund research. In addition, I have been a key member of teams which developed risk assessment guidance and policy and evaluated many important Superfund chemicals.

EDUCATION

University of California, Irvine and Brookhaven National Laboratory, Post Doctoral Research Fellowship			1976-78
University of California, Los Angeles	Cell Biology/Biochemistry	Ph.D.	1976
University of California, Los Angeles	Zoology	M.A.	1972
Loyola University, Los Angeles	Biology	B.S.	1970

PROFESSIONAL EXPERIENCE (2003-2013)

2001-2006	Acting Deputy Assistant Administrator for Science (SES ES-05), Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
2003-2006	Chief Scientist to the Science Advisor (SES ES-05), Office of the Science Advisor, U.S. Environmental Protection Agency, Washington, D.C.
2005	Acting Science Advisor, Office of the Science Advisor, U.S. Environmental Protection Agency, Washington, D.C.
2006	Deputy Assistant Administrator for Science (SES ES-05), Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
2006-2013	Vice President for Research, and Professor, Environmental and Radiological Health Sciences, Colorado State University, Fort Collins, Colorado.

SELECTED AWARDS AND HONORS

- 2002 Society for Risk Analysis - “Outstanding Risk Practitioner Award”
- 2005 Named “Fellow” of the Society for Risk Analysis
- 2006 Presidential Rank Award-Meritorious Executive
- 2006 U.S. Environmental Protection Agency Distinguished Career Award
- 2007 Named “Fellow” of the Academy of Toxicological Sciences

SELECTED COMMITTEES, BOARDS, AND PROFESSIONAL SOCIETIES

- Councilor and Fellow (Elected), and Candidate for President (2001), Society for Risk Analysis.

- Public Member, Strategic Science Team, Long Range Research Initiative, American Chemistry Council.
- Programme Advisory Committee, Intern'l Programme on Chemical Safety, World Health Organization.
- Member, National Organizing Committee, Dioxin2000.
- Editorial Board: Risk Analysis, Environmental Health Perspectives, Chemosphere.
- Chair (elected) and Member of the National Toxicology Program's (NTP) Executive Committee.
- Co-Chair of the White House Office of Science and Technology's Committee on Environment and Natural Resources' (CENR) Toxics and Risk Subcommittee.
- EPA Liaison to the Public Health Service Environmental Health Policy Committee (EHPC).
- Society of Toxicology, Society for Risk Analysis, and American Association for the Advancement of Science.
- Subcommittee on Distinguishing Adverse from Adaptive, Non-functional and Pharmacologic Changes on Tox. Studies, Int'l Life Sciences Institute (ILSI), Health and Environmental Sciences Institute.
- Chair, External Advisory Group for the Superfund Basic Research Program.
- Chair, National Research Council (NAS), Standing Committee on Emerging Science for Environmental Health Decisions.

SELECTED PUBLICATIONS

- **Farland, W.**, J. Schaum, D. Winters, et al. (2000). USEPA's risk characterization of dioxin and related compounds. *Organohalogen Cpds*. 48: 248-251.
- Van Leeuwen, F. X., Feeley, M., Schrenk, D., Larsen, J. C., **Farland, W. H.**, Younes, M. (2000). Dioxins: WHO's Tolerable Daily Intake (TDI) Revisited. *Chemosphere*, Volume 40, Issues 9-11, May-June 2000, Pages 1095-1101.
- Van Den Berg, M., Van Birgelen, A., Birnbaum, L., **Farland, W.**, et al. (2000). Consultation on Assessment of the Health Risk of Dioxins; Re-evaluation of the Tolerable Daily Intake (TDI): Executive Summary. *Food Additives and Contam.*, 17: (4) 223-240 Apr 2000.
- Devito, M., **W. Farland**, and L. Birnbaum (2000). Margin of exposure estimates for TCDD for cancer and non-cancer effects in laboratory animals. *Organohalogen Cpds*. 48:292-295.
- Haws, L., Su, S., Harris, M., DeVito, M., Walker, N., **Farland, W.**, Finley, B., and Birnbaum, L. (2006). Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. *Toxicological Sciences*, Volume 89 (1):4-30.
- Van den Berg, M., Birnbaum, L. S., Denison, M., De Vito, M., **Farland, W.**, Feeley, M., Fiedler, H., Hakansson, H., Hanberg, A., Haws, L., Rose, M., Safe, S., Schrenk, D., Tohyama, C., Tritscher, A., Tuomisto, J., Tysklind, M., Walker, N., Peterson, R. E. (2006). The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol Sci.*, Oct; 93(2):223-41. Epub 2006 Jul 7.
- **Farland, William H.**, William P. Wood, and Kerry L. Dearfield (2006). Cancer Risk Assessment of Environmental Agents: Approaches to the Incorporation and Analysis of New Scientific Information. *Toxicological Testing Handbook: Principles, Applications and data interpretation*. David Jacobson-Kram and Kit A. Keller, Eds.; Informa Healthcare, pubs.
- Boobis, Alan R., Cohen, Samuel M., Dellarco, Vicki, McGregor, Douglas, Meek, M. E. Bette, Vickers, Carolyn, Willcocks, Deborah, **Farland, William** (2006). IPCS framework for analyzing the relevance of a cancer mode of action for humans. "Critical reviews" in *Toxicology* 36 (10):781-92.

COMMENTS

Comments on Navigational Dredging in Louis Berger Group, Inc. Focused Feasibility Study Report

July 1, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
James J. Opaluch, Ph.D.

COMMENTS ON NAVIGATIONAL DREDGING IN LOUIS BERGER GROUP, INC. FOCUSED FEASIBILITY STUDY REPORT

James J. Opaluch, Ph.D.

1. General Comments

1.1 *<u>Navigational dredging should be dropped as an element of Alternative 3</u> unless the navigation dredging component can be shown to be worthwhile, consistent with requirements of established principles for federal water resources projects.*

The 2014 Focused Feasibility Study (FFS; Louis Berger Inc. 2014) assesses four alternatives for remedial action in the Lower Passaic River. Alternative 3 includes "dredging of the existing 300-foot wide federally authorized navigation channel to accommodate the continued and reasonably-anticipated future use depths between RM0 to RM2.2." (FFS, page ES-9).

Federal statues, regulations and agency operating principles require that supporting analyses be carried out to ensure that federal water resources projects such as navigational dredging are worthwhile. For example, Principles and Guidelines for the US Army Corps of Engineers require that navigational dredging projects be subject to established principles of benefit-cost analysis, incremental analysis and cost-sharing (e.g., US Army Corps of Engineers, 2000).

It would be disingenuous for a federal agency to mandate the implementation of a water project that does not meet its own federal operating principles, irrespective of whether it is or is not legally mandated in the present context. Under the Army Corps guidance principles, project evaluation requires incremental analysis of National Economic Development (NED) and National Ecosystem Restoration (NER) benefits. For example, the Army Corps Planning Guidance Notebook (US Army Corps of Engineers, 2000) states:

> "Recommendations for multipurpose projects will be based on a combination of NED benefit-cost analysis, and NER benefits analysis, including cost effectiveness and incremental cost analysis." (US Army Corps of Engineers, 2000; page 2-7)

The Army Corps Planning Guidance Notebook defines incremental analysis as follows:

> "[Incremental analysis] consists of examining increments of plans or project features to determine their incremental costs and incremental benefits. Increments of plans continue to be added and evaluated as long as the incremental benefits exceed the incremental costs." (US Army Corps of Engineers, 2000; page 2-10).

Alternative 3 in the FFS is a multi-purpose project that includes both environmental dredging and navigational dredging. Army Corps Planning Guidance indicates that navigational actions be subject to analyses of National Economic Development (NED) benefits, and environmental actions be subject to analyses of National Environmental Restoration (NER) benefits. In order to justify the navigational dredging component in this context, established standards of the US Army Corps of Engineers require that the incremental benefits of adding navigational dredging exceed the incremental costs of the navigational component of dredging.

An analysis of the incremental benefits and cost of navigational dredging is outside the scope of these public comments. But a quick back-of-the-envelope calculation can be done of navigational dredged materials using only information readily available from the FFS. Such an analysis suggests that on the order of 40% of the dredged material is associated with navigational dredging, as opposed to environmental dredging. This is based on an estimate that the applicable region in the FFS is roughly 650 acres (FFS page 2-16) or about 2.83 x 10^7 sq. ft. Assuming dredging of an average depth of 2.5 feet (e.g., FFS page 4-39 or 4-45) throughout the full 650 acre area results in roughly 2.6 x 10^6 cubic yards of dredged materials. According to the FFS, Alternative 3 results in 4.3 x 10^6 cubic years of dredged materials (FFS page 4-38). As a consequence, roughly 60% (≈2.6/4.3) of the dredged material is associated with environmental dredging, while about 40% of dredged material results from navigational dredging. This navigational component of Alternative 3 must be justified using standard Army Corps of Engineers protocols for navigational dredging, which includes benefit-cost analysis for NED benefits.

Cost-sharing by local beneficiaries is also an important element in ensuring that federal projects are worthwhile. For example, a 2003 study by the National Academy of Sciences concluded:

> "Prior to the WRDA of 1986, there was little incentive for local, non-federal parties to reject any project that was proposed. These local parties could expect to receive the bulk of the project benefits, while being responsible for only a small part of project costs. ... A principal reason for changing pre-WRDA 1986 cost-sharing rules was to increase the likelihood of federal tax dollars being spent on economically and socially worthwhile water projects. Advocates for this change in WRDA 1986 argued that without more extensive cost-sharing requirements, the process of planning and executing federal water projects was biased in favor of approving many less-than-worthwhile projects." NRC, 2004; page 122)

There is no attempt whatsoever in the FFS or Army Corps 2010 navigational analysis to show that navigational dredging is worthwhile by quantifying the incremental benefits or incremental costs of navigational dredging, nor to compare the two, despite the recognized Corps mandate to do so. It is important to note that the issue of complying with federal standards is raised in the 2007 Corps of Engineers navigational analysis, which was included as Appendix F of the 2007 Draft FFS (US Army Corps of Engineers, 2007). The 2007 navigational analysis indicates even if the river were maintained at its federally approved depth, "... only bulk carriers could potentially be used efficiently on this waterway" and "[t]he number of bulk carriers/tankers that can be used is rapidly declining within the fleet because they cannot be operated in an economically efficient manner with such low payload."

This implies that in the judgment of the Army Corps, waterborne commerce in the Passaic River is not an efficient transportation operation, even if the channel were to be dredged to the federally approved depths. The 2007 Army Corps navigation analysis goes on to say:

> "In general, Corps' cost-sharing in navigation improvements is conditioned upon a showing of net National Economic Development (NED) benefit, or net monetary benefits to the nation. These benefits are generally derived through the reduction of transportation costs. Because the Lower Passaic River is depth - and more importantly – width constrained, additional benefits could not be derived through the employment of larger vessels.

> "Similarly, channel maintenance must be economically justified. The Executive Branch, acting through the Office of Management and Budget, requires that net benefits to the nation of navigation channels be calculated and arrayed against each other in order to determine funding priorities." (US Army Corps of Engineers, 2007, Appendix F in US EPA, 2007)

This 2007 Army Corps navigational analysis concludes that:

> "As there is very little commerce on this portion of the Passaic River, it is unlikely that dredging the Lower Passaic would be a funding priority." (US Army Corps of Engineers, 2007)

The P&Gs are intended to apply to all federal agencies. Indeed, a major purpose of the P&Gs is "...to increase consistency and comparability in federal water resources investment decision making across the federal government..." (Principles and Requirements, 2013). While the principles are a legal requirement that extends specifically to federal investments, the intent is to ensure federal projects are worthwhile. It would be disingenuous for a federal agency to compel an expensive action without complying with its own guiding principles.

Although the 2010 revised Army Corps analysis may be based on additional information on the potential for waterborne commerce, it is *nevertheless essential to comply with established principles of ensuring the project is worthwhile*, whether or not Army Corps is sharing in the cost. And the navigational analyses presented falls far short of tests required by these established principles.

It is also important that any such benefit-cost analysis consider the fact that the navigational channels will become filled over time with sediments. As a consequence, there will be a need for maintenance dredging in the future, and recontamination of the lower Passaic River will occur following dredging operations if other sources of pollution are not controlled first. Consequently, in estimating navigational benefits it is essential to recognize that benefits decline over time, and eventually maintenance dredging will be required to continue navigational benefits. The proper measure of navigational dredging is the discounted value of reduced transportation costs (Army Corps of Engineers, 2000; Army Corps of Engineers, 2007), where navigational benefits decline, and additional expenditures on maintenance dredging is required over time as sedimentation of the channel progresses.

Conclusion: *The navigational dredging component should be removed from Alternative 3 unless it is demonstrated that the navigation dredging component is worthwhile, based on established federal principles for water resource projects, including incremental benefit-cost analysis and cost-sharing.*

1.2 The navigational dredging component of Alternative 3 is not a response, removal or remedial action associated with a release or threatened release of a hazardous substance, and therefore *navigational dredging activities should not be included in Alternative 3*.

Under CERCLA, responsible parties are financially liable for response, removal and remedial actions due to a release or threatened release of hazardous substances (42 U.S. Code § 9607). However, filling in of navigational channels over time is the result of natural sedimentation, and is not an injury associated with releases, or threatened releases, of hazardous substances. As a consequence, responsible parties are not liable for the navigational

component of dredging operations, but only for the incremental costs associated with the release of hazardous substances. Indeed, navigational dredging is (wisely) not even included among the Remedial Action Objectives (RAOs) of the FFS (FFS; Page 2-1). Yet the FFS clearly indicates "Alternative 3 would include dredging of the existing 300-foot wide federally authorized navigation channel to accommodate the continued and reasonably-anticipated future use depths between RM0 to RM2.2" (FFS, 2014; page 4-18).

Sedimentation of the navigational channel of the Passaic River is the result of not having carried out maintenance dredging for at least 30 years, and is not a consequence of the alleged release of hazardous materials. The remedial action might be required to maintain the *current* depth of the channel (e.g., not allow caps to further constrain navigation), but remedial action should not include dredging the channel in order to provide navigational benefits.

If navigational dredging is to be carried out in the Passaic River, the navigational component of dredge operations should be funded completely by local beneficiaries of the project, or if it is to be part of federal action it should be subject to the standard administrative processes of the US Army Corps of Engineers, as outlined in the Principles and Guidelines for Water Resource Projects discussed above. Under this process, analyses are required to ensure economic benefits of the proposed navigational activity justify the cost, and potential projects are prioritized for federal action. Furthermore, the project is subject to cost-sharing among the federal government and local beneficiaries (US Army Corps of Engineer, 2000).

Conclusion: The cost of navigational dredging is not a remedy for a release or threatened release of hazard substances, and therefore *navigational dredging should not be included as part of Alternative 3.*

1.3 The survey used in the berth-by-berth analysis is purely hypothetical, and can be expected to overstate future use, particularly since the survey does not comply with best practices. The New Jersey Department of Transportation (DOT) survey is largely speculative, and is also likely to overstate future use. As a consequence, actual future use will likely be much less than that indicated in the two navigational analyses. The survey data obtained as part of these analyses are not reliable, and should not be used as a source of information for likely future use of the lower Passaic River. And more specifically, the information from the Corps of Engineers and the New Jersey DOT navigational surveys is not reliable, and should not be used to support the navigational dredging component of Alternative 3.

Hypothetical surveys are often viewed with considerable skepticism, even when rigorous standards are followed (e.g., Hausman, 2012; List and Gallet 2001; Little and Berrens 2003; Murphy et al 2005). Hypothetical surveys are recognized typically to overstate actual uses and values, even when based on state-of-the-art methods (e.g., Hausman, 2012; Jamieson and Bass, 1989; Hsiao et al., 2002).

The tendency for stated intentions to overstate actual behaviors is generally applicable to hypothetical surveys. But the problem is even worse for the 2010 US Army Corps of Engineers and the New Jersey DOT surveys, as they do not comply with best practices for surveys (e.g., Office of Management and Budget, 2003). The design of these two surveys makes matters worse because respondents are not required to make any sort of financial commitment--not even a hypothetical commitment--in the form of sharing in dredging costs. This is closely related to a problem indicated in the 2004 National Academy of Sciences report that was quoted above:

> "Prior to the WRDA of 1986, there was little incentive for local, non-federal parties to reject any project that was proposed. These local parties could expect to receive the bulk of the project benefits, while being responsible for only a small part of project costs." NRC, 2004; page 122).

In the context of the present analysis, survey respondents might see an advantage to dredging operations, irrespective of any future expansion in use, but are not required to pay *any cost whatsoever* (even hypothetically), so they face no penalty in overstating likely future use. As a consequence, they may overstate potential future use if they anticipate that such a response makes dredging more likely. Indeed respondents may anticipate a substantial benefit from overstating potential future use, as they may believe that they could qualify for compensation from the Responsible Parties if their use had previously been forcibly curtailed by inadequacy of the navigational channel. This is what survey researchers term "strategic bias" (e.g., Mitchell and Carson, 1989), where respondents purposely give biased responses to survey questions because they believe it may in their best interest to do so. Respondents may believe they could benefit from overstating potential use, and they certainly have nothing to gain from understating potential use. Therefore, one can expect the hypothetical surveys will overstate future use.

Office of Management and Budget directs studies using similar hypothetical methods to consider a set of best practices, including: "... hypothetical questions ... be posed to survey respondents in order to obtain *willingness-to-pay estimates* relevant to benefit or cost estimation." (Office of Management and Budget, 2003; emphasis added). This indicates that respondents to hypothetical surveys should be told that they would be required to pay if provided with the good (wider and/or deeper navigational channel). In the context of this analysis, best practices might be applied by asking respondents whether they would support a specific scenario for navigational dredging given that they would be required to pay a specifically stated amount in cost-sharing, as required by federal regulations. Given federal mandate for cost-sharing, the payment might be viewed by respondents as credible.

This would at least represent an attempt to use best practices, although the approach would still likely lead to hypothetical use being an overstatement of actual future use (Arrow et al., 1993; List and Gallet 2001; Little and Berrens 2003; Murphy et al 2005).

Stated intentions are commonly calibrated downwards to develop more reliable forecasts of actual behaviors, even when the analysis is based on state-of-the-art surveys using rigorous controls reflecting best practices (e.g., Arrow et al, 1993). For example "[a] standard response to this problem has long been to apply a "fudge factor ... to deflate the stated willingness to pay by some amount." (Hausman, 2012; page 45). A NOAA Blue Ribbon Panel, convened to assess the potential use of hypothetical surveys concluded that stated values should be divided by a factor of 2—a "calibration factor" that has been incorporated into federal regulations (Federal Register 1994).

The State of New Jersey DOT navigational analysis presents an even more optimistic view of the potential for use of the lower Passaic River. However, the New Jersey DOT report is better described as speculative rather than any sort of defensible analysis, and as a consequence it would fail to meet criteria for acceptable data contributing to analysis of a federal project. Just as one example, the State of New Jersey DOT speculates that "... water taxis, water tours and smaller ferries *could* be effective in optimizing waterfront usage ...". (New Jersey Department of Transportation, 2007; page 6; italics added). However, the report acknowledges that the community indicated no plans to develop these operations. Nor does the

New Jersey DOT report provide any analysis to quantify potential ridership or to assess the financial feasibility of such operations.

A key question in the New Jersey DOT Survey asks:

> "3. The federal channel in the Passaic River has not been maintained since 1983 (lower 2 miles), 1937 (miles 2.6 to 4.6) or before the 1950's in specific upper reach locations. Would the Passaic River be used more or would your municipality's development plans change if the federal navigational channel in the river be remediated and restored to its current authorized depth. ..." (New Jersey Department of Transportation 2007; Attachment 2)

Most (9 out of 13) of the survey responses included in the New Jersey DOT report indicated that their community would *not* benefit from navigational dredging of the Passaic River, even if the full navigational channel were dredged up to the federally authorized level. Of those communities who responded positively, their indicated benefits are not achieved by navigational dredging of the lower 2 miles of the Passaic River. As a consequence, they would not benefit from the navigational dredging component of Alternative 3.

Even if one were to accept the survey responses at face value, there is no attempt to quantify benefits from navigational dredging component in Alternative 3. As discussed above, existing federal principles require that navigational dredging benefits be quantified in the form of reduced shipping costs, and that these benefits be compared with the cost of navigational dredging to ensure the project is worthwhile (e.g., Corps of Engineers, 2000).

Conclusion: *The navigational analyses carried out by the Army Corps of Engineers and the New Jersey DOT rely upon hypothetical surveys, and at times on pure speculation. Neither of these analyses conform with best practices, and both are likely to dramatically overstate future use of the Passaic River. As a consequence, neither of these documents provide reliable information, and their results should not be used to justify the navigation dredging component of Alternative 3.*

1.4 The FFS proposes dredging in the lower Passaic River, prior to alleviating several significant sources of pollutants. If this is done, the newly remediated area will suffer recontamination from adjacent sources, which is economically, environmentally and socially wasteful. Dredging in the lower Passaic River should be part of a larger comprehensive plan for the region as a whole, and dredging should be delayed until a well-conceived plan is in place for all important sources of contamination.

The FFS recommends action in the lower 8 miles of the Passaic River, even though plans are not yet in place for the larger region that includes upstream and downstream waters. The FFS simply states "...the FFS for the sediments of the lower 8.3 miles is intended to be consistent with any future remedial actions that might be proposed for the 17-mile Lower Passaic River," but there is not yet in place a plan for remedial action for the upstream proportion. This is analogous to putting the proverbial cart before the horse, and violates common sense. When remedial action is complete in the 8 miles of the Passaic River, the newly cleaned sediments will be recontaminated by water flows both from upstream and tidal flows from downstream.

It is premature to move forward with remedial action on the lower Passaic River while significant sources of recontamination remain. Indeed, the proposed remedy would reduce

contaminant levels below EPA Region 2's stated baseline level of contamination. This despite the fact that the FFS recognizes "... the Superfund program generally does not clean-up to concentrations below natural or anthropogenic background levels (USEPA, 2002b)," (FFS, page 2-15). This means the recently dredged area will be subject to recontamination following a very expensive remedial action, which is economically, socially and environmentally wasteful. A well-conceived comprehensive plan should be in place before action is recommended for the lower 8 miles of the Passaic River.

Conclusion: *Common sense and policy guidance dictate that selected actions in the lower 8 miles of the Passaic River should be part of a well-conceived, comprehensive plan for remediating the larger region. It is economically, socially, and ecologically inefficient to carry out remedial action on the lower 8 miles of the Passaic River before addressing significant sources of contamination from both upstream and downstream. Dredging operations in the lower 8 miles should be postponed until a comprehensive plan is in place.*

2. Specific Comments

2.1 The 2010 Navigational Analysis should be updated to include the latest data on navigation in the Lower Passaic River.

The 2010 Army Corps of Engineers navigational analysis is based partly on Waterborne Commerce data from 1997-2006, which is available in the Army Corps publication *Waterborne Commerce of the United States*. The Army Corps navigational analysis indicates that "[s]ince 1999, the volume of commerce has been rising, reaching just over 4 million tons in 2006." (US Army Corps of Engineers, 2010; page 12) Although this suggests that the volume of waterborne transportation in the Passaic River has recently been following an upward trend, the more recent data indicates that shipping has been declining since 2006, reaching 2.6 million tons in 2012, the most recent data available in the publication *Waterborne Commerce of the United States*. As a consequence, it is not at all clear that navigation in the Passaic River is a promising enterprise, nor that investments in navigational dredging can be justified.

Conclusion: *If the Waterborne Commerce statistics are to be used as part of a navigational analysis, the data should be updated to the most recent statistics, which show that waterborne commerce is declining in the lower Passaic River.*

References

Arrow, Kenneth, Robert Solow, Paul R. Portney, Edward E. Leamer, Roy Radner, and Howard Schuman. 1993. "Report of the NOAA Panel on Contingent Valuation." National Oceanic and Atmospheric Administration (U.S. Department of Commerce).

Federal Register. 1994. May 14, 59(85): 1183.

Hausman, Jerry, 2012. "Contingent Valuation: From Dubious to Hopeless" Journal of Economic Perspectives, Vol. 26 No. 4, pp 43-56.

Hsiao, Cheng, Baohong Sun, Vicki G. Morwitz, 2002. "The Role of Stated Intentions in New Product Purchase Forecasting." In Advances in Econometrics, vol. 16, pp. 11-28. Emerald Group Publishing.

Jamieson, Linda F., and Frank M. Bass. 1989. "Adjusting Stated Intention Measures to Predict Trial Purchase of New Products: A Comparison of Models and Methods." Journal of Marketing Research 26(3): 336-45.

Kling, Catherine L., Daniel J. Phaneuf and Jinhua Zhao, 2012. "From Exxon to BP: Has Some Number Become Better than No Number?" Journal of Economic Perspectives, Vol. 26 No. 4, pp 3-26 (Fall).

List, J. A. and C. A. Gallet (2001). "What Experimental Protocol Influences Disparities Between Actual and Hypothetical Stated Values?" Environmental and Resource Economics 20: 241-254.

Little, J. and R. Berrens (2003). "Explaining Disparities between Actual and Hypothetical Stated Values: Further Investigation Using Meta-Analysis." Economics Bulletin 3(6): 1-13.

Louis Berger Group, Inc., 2014. Lower Eight Miles of the Passaic River Focused Feasibility Study Report. Carried out In conjunction with Battelle HDR|HydroQual,for US EPA Region 2 and the US Army Corps of Engineers.

Mitchell, R.C. and R.T. Carson, 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method, Washington D.C.: Resources for the Future Press.

Murphy, J.J., G.P. Allen, and T.H. Stevens (2005) "A Meta-analysis of Hypothetical Bias in Stated Preference Valuation." *Environmental and Resource Economics* 30(3): 313-325.

National Research Council, 2004. *River Basins and Coastal Systems Planning Within the U.S. Army Corps of Engineers*, Washington: National Academies Press.

New Jersey Department of Transportation, 2007. "New Jersey's Position on the Future Navigational Use on the Lower Passaic River, River Miles 0 – 8" March 29.

Principles and Requirements, 2013. "Principles and Requirements for Federal Investments in Water Resources. Available on-line at: http://www.whitehouse.gov/sites/default/files/final_principles_and_requirements_march_2013.pdf.

Office of Management and Budget, 2003. Circular A-4 (September 17).

US Army Corps of Engineers, 2000. "Planning Guidance Notebook" ER 1105-2-100, April 22.

US Army Corps of Engineers, 2007. Lower Passaic River Navigation Analysis, Appendix F in US EPA FFS.

US Army Corps of Engineers, 2010. Lower Passaic River Commercial Navigation Analysis, New York District, Original 2007, revised Dec 2008 and July 2010.

US Army Corps of Engineers, 2012. “Waterborne Commerce of the United States” Calendar year 2012 Part 1- Waterways and Harbors; Atlantic Coast. WR-WCUS-12-1.

US EPA, 2007. Draft Source Control Early Action Focused Feasibility Study (June 2007).

James J. Opaluch, Ph.D.

Professor of Environmental & Natural Resource Economics
University of Rhode Island, Kingston, RI

EDUCATIONAL HISTORY

University of California, Berkeley	Ag & Resource Econ	Ph.D.	1981
University of California, Berkeley	Statistics	M.A.	1977
University of Rhode Island	Economics	B.A.	1975

PROFESSIONAL ACTIVITIES AND HONORS (SINCE 2000)

- Department Chair, University of Rhode Island, Department of Environmental and Natural Resource Economics, 2009-present.
- National Science Foundation, Chair Site Visit Panel, Decision Center for a Desert City, Arizona State Univ.
- US Environmental Protection Agency, Member of Science Advisory Board, 2011-14.
- Chair of National Science Foundation Site Visit Panel, University of California, Berkeley.
- US EPA, Science Advisory Board, Advisory Committee on Hypoxia in the Gulf of Mexico, 2007-08.
- Associate Editor, Agricultural and Resource Economics Review, 2005-08.
- National Science Foundation, Biocomplexity Review Panel, MUSES Program, 2005.
- National Science Foundation, Chair of Site Visit Panel, Center for Decision Making Under Uncertainty, 2004.
- US EPA Science Advisory Board, Environmental Economics Advisory Committee, 2003-2009.
- National Science Foundation, BioComplexity Program Review Panel, 2001.
- National Academy of Science, Panel on PCB Contaminated Sediments, 1999-2000.
- National Academy of Science, Committee on Wetlands Functions and Values, 2000.
- National Science Foundation, BioComplexity Program Review Panel, 2000.
- Associate Editor, *American Journal of Agricultural Economics*, 1997-2000.

SYNERGISTIC ACTIVITIES (SINCE 2010)

Dr. Opaluch has been actively involved in issues related to environmental and behavioral economics for many years, and is an internationally recognized expert in natural resource valuation and damage assessment. Dr. Opaluch currently serves on the US EPA Science Advisory Board. He has served as an expert in over 25 major natural resource damage assessment cases. He chaired three National Science Foundation Site visit panels, and was invited to serve on the United Nations Environmental Program's Working Group of Consultative Experts to provide advice and training to policy professionals throughout the world. Dr. Opaluch has served on a number of national committees, including panels for the National Academy of Science, National Science Foundation, the United Nations, the US EPA and the United States Minerals Management Service. He also served on as executive officer and in an editorial capacity for many National and International Professional Associations. Dr. Opaluch has authored or co-authored numerous papers in peer reviewed, professional journals.

GRANTS (SINCE 2010)

- Rhode Island Sea Grant, 2014-16. Geospatial Inventory of Human Uses or RI Salt Ponds, $300 thousand.
- State of Rhode Island, Office of Energy Resources, 2012-13. Energy Siting, Permitting, Planning and Energy Analytics, $422 thousand.
- USDA, 2013-2015. "Values and management of ecosystem services from landscape in the rural-urban fringe in Northeast US", $94 thousand.
- State of Rhode Island, Office of Energy Resources, 2011-2012. Renewable Energy Siting Partnership, with Marion Gold, Jennifer McCann, and Multiple Investigators.
- USDA, 2010-2013. Managing Multiple Ecosystem Services from Agricultural and Forest Landscapes in the Rural-Urban Fringe, with Emi Uchida, Y.Q. Wang, Stephen Swallow and Arthur Gold. $500 thousand.

- Drinker Biddle and Reath LLP, 2008-present. “Damage Assessment of Toxic Contaminants in the Passaic River”.
- National Science Foundation, 2005-2011. “IGERT: Assessing Change in Coastal Ecosystems: Integrating Natural and Social Sciences”, $3.02 million (with Peter August, Richard Burroughs, Candice Oviatt and Judith Swift).

PUBLICATIONS (SINCE 2010)

- Lang, Corey, **James J. Opaluch**, and Georgios Sfinarolakis (2014). The Windy City: Property Value Impacts of Wind Turbines in an Urban Setting. *Energy Economics*.
- **Opaluch, James J.** with multiple authors (2012). Economic Valuation of Ecosystem Services Provided by Oyster Reefs. *BioScience* Vol. 62 No. 10 pp. 900-909 (October).
- Luo, M. F., **J. J. Opaluch**, J. L. Anderson, and K. Schnier (2012). Managing the Intentional Introduction of Nonnative Species. Chapter 5 in: *Oysters: Physiology, Ecological Distribution and Mortality*. Qin, J.G. (editor), Nova Science Publishers, New York.
- Lou, Meifeng and **James J. Opaluch** (2011). Analyzing the risks of biological invasion: An agent based simulation model for introducing non-native oysters in Chesapeake Bay, USA. *Stochastic Environmental Research and Risk Assessment*, Volume 25, Number 3 (March).
- **Opaluch, James J.** (2010). A Run on the Banks. *41° North*, Vol. 5 No. 2.
- **Opaluch, James J.**, with multiple authors (2010). *Hypoxia in the Northern Gulf of Mexico*, Springer.
- August, P. V., J. M. Swift, D. Q. Kellogg, G. Page, P. Nelson, **J. Opaluch**, J. S. Cobb, C. Foster, and A. J. Gold (2010). The T Assessment Tool: A Simple Metric for Assessing Multidisciplinary Graduate Education. *Journal of Natural Resources and Life Sciences Education*, 39 (1) 15-21.
- **Opaluch, James J.** (2010). Forecasting the Effects of Climate Change on the Rhode Island Economy. *41° North*, Vol. 5 No. 1.

COMMENTS

ARCADIS Comments on the Passaic River FFS Reports (April 2014) Regarding Ecological Risk and Preliminary Remediation Goals

August 14, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
Timothy Iannuzzi
Jacqueline Iannuzzi
Melissa Beauchemin

ARCADIS Comments on the Passaic River FFS Reports (April 2014) Regarding Ecological Risk and Preliminary Remediation Goals

Primary Authors: **Timothy Iannuzzi**
Jacqueline Iannuzzi
Melissa Beauchemin

August 14, 2014

General Comments

GENERAL COMMENT 1. The Baseline Ecological Risk Assessment (BERA) is flawed because it fails to utilize available site-specific data, resulting in an overstatement of ecological risk and leaving significant uncertainty. Therefore, the BERA does not support an ecological basis for remedial action.

The BERA (Appendix D) in the Remedial Investigation Report (RIR) does not follow the U.S. Environmental Protection Agency's (USEPA's) Framework for Ecological Risk Assessment (USEPA, 1992) or Ecological Risk Assessment Guidance for Superfund (USEPA, 1997; 1998) for conducting a BERA in that it ignores much of the available site-specific data and information that have been collected under the Superfund program over the last 20 years; does not accurately assess ecological conditions (i.e., Problem Formulation) in the lower eight miles of the Focused Feasibility Study (FFS) Study Area and fails to recognize that these conditions constrain the biology and potential for fish and wildlife occurrence and exposures; and does not provide a reasonable and thorough characterization of relevant toxicity data from the scientific literature for the types of organisms that may be exposed in the FFS Study Area. These shortcomings in the BERA, and their consequences for risk outcomes and management, are addressed in detail in the specific comments below.

There is very little change in the content, data analyses and level of detail of this BERA from the version published in the 2007 draft FFS, despite the fact that substantial site-specific data/information regarding the biology, chemistry and toxicity in the system have been generated since that time by the CPG (under the Superfund program) for the Lower Passaic River Study Area (LPRSA). In fact, this BERA ignores much of the site-specific ecological data collected over more than 20 years for this system, as well as a number of published, peer-reviewed studies that provide alternative perspectives and assessments of risk for the LPRSA (e.g., Iannuzzi et al., 2007; Ludwig & Iannuzzi, 2005; Iannuzzi et al., 2004). This results in: 1) a finding of substantive risks for fish and wildlife (i.e., bird and mammalian) receptors where likely none exist; 2) over-prediction and inaccurate characterization of risks for benthic organisms; and 3) differential treatment of dioxins/furans relative to other organic and inorganic contaminants of concern (COCs) in terms of toxicological benchmarks selected/used, extrapolations of such benchmarks between

non-related organisms, and an inappropriate correction factor applied to a portion of the sediment chemistry data for the FFS Study Area.

The flaws in this BERA are then compounded when utilized to: 1) compute ecological preliminary remediation goals (PRGs) for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and mercury (Appendix E of the RIR); and 2) assess ecological protectiveness in the alternatives analysis of the FFS.

The uncertainties assessment in this BERA (Section 4.5 of Appendix D) is inaccurate and suggests under-prediction of risk for many of the exposure assumptions and receptors. The opposite is actually true, as the over-conservative assumptions and inaccurate toxicity data used throughout the BERA result in an over-prediction of risk. This should be given substantial consideration in the uncertainties analysis and communications to the public. The RIR lacks openness and transparency on the part of USEPA Region 2 in terms of how selective and limited they were in what they included in the ecotoxicity assessment/assumptions used in this BERA.

Overall, the BERA is very conservative, much like that of a typical Superfund screening-level ecological risk assessment (SLERA) (USEPA, 1997). The selection of toxicity reference values (TRVs), assumptions of potential exposure and calculations of risk are not based on a thorough characterization of the site-specific data and the range of available toxicity information in the literature for the types of organisms that may occur in the FFS Study Area. In this regard, the document does not meet the standard of a BERA pursuant to USEPA (1992; 1997; 1999) guidance. For example, for the evaluation of benthic invertebrates, this BERA merely compares sediment chemical concentrations to sediment-screening benchmarks or sediment quality guidelines (SQGs), which is standard procedure for a SLERA. USEPA (1997) guidance, however, provides that, following the data "screen" conducted during the SLERA, additional site-specific data must be incorporated into the evaluation conducted for the BERA. This reduces much of the uncertainty in the screening-level risk estimates (USEPA, 1999). This BERA should have considered recent and historical site-specific data collected to date from the LPRSA (e.g., toxicity tests, benthic community analysis, and surface water) to reduce the uncertainties in the very conservative data "screen" in accordance with USEPA (1997) guidance, but it did not despite the recent availability of this data. Thus, the BERA is incomplete from a technical standpoint, and is therefore inadequate to support informed remedial decisions under the National Contingency Plan (NCP).

Detailed comments on the BERA are provided (below) in the specific section-by-section comments on Section 7.2 and Appendix D of the RIR.

<u>GENERAL COMMENT 2.</u> Limitations of the currently available tissue and sediment data preclude an adequate trends assessment and remedy effectiveness determination. From the existing data, it appears that natural recovery is occurring in the LPRSA. Additional tissue and sediment sampling should occur prior to making risk management decisions.

The FFS is intended to reduce risk, principally due to Region 2's conclusion that the proposed remedy is necessary to reduce fish and crab tissue concentrations in the future, and that these reductions will not

occur absent implementation of a remedy. The current fish and crab tissue data for the LPRSA are inadequate to support such a determination.

Nearly all the existing fish and crab tissue data available for the LPRSA were collected during only two sampling periods: 1999 to 2001 (Tierra Solutions, Inc. [Tierra]/USEPA) and 2009/2010 (Cooperating Parties Group [CPG]/USEPA). For each of these sampling events/periods, the sampled species and spatial areas of the river differed. In 1999 to 2001, Tierra sampled the lower six miles of the LPRSA and collected primarily marine/estuarine species. In 2009/2010, the CPG focused primarily on the upper eleven miles of the LPRSA and collected mostly freshwater species (e.g., catfish). The CPG collected some estuarine data from the lower eight miles of the LPRSA in 2009/2010 for three of the edible fish/shellfish species that were sampled by Tierra in 1999 to 2001: white perch (*Morone americana*), a resident fish species; American eel (*Anguilla rostrata*), a migratory fish species; and blue crab (*Callinectes sapidus*), a mostly resident shellfish species.

Because there are limited tissue data from only two time periods to compare, it is not possible to definitively establish the presence of a temporal trend in chemical concentrations, but the available data suggest, contrary to Region 2's assessment, that there is a downward trend. A review and statistical evaluation of the average (mean) tissue concentrations (in both the LPRSA as a whole and the lower eight miles only for these species) show a downward trend in the overall concentrations of 2,3,7,8-TCDD and PCBs (see tables below). The results of hypothesis testing by ARCADIS (2014a), as presented in Attachment 1 to these comments, indicate that most of the reductions in mean tissue concentrations are statistically significant, with the percent reduction in mean concentration ranging from 18% to 40%. A third sampling period/dataset is needed to appropriately evaluate this trend, especially before Region 2 requires remedial action on the basis of its current views, which are at odds with the best interpretation of the available data.

Table 1. Tissue Concentrations in Selected Species Collected in the Lower Passaic River Study Area (LPRSA) by Sampling Period

Chemical	Species	Tissue Type	Sampling Period	N	Number of Detects	Frequency of Detection	Mean	Standard Deviation	Minimum	Maximum
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	7	100%	21.7	6.49	14.6	32.2
	American Eel	Fillet	2009-2010	32	32	100%	13.5	9.84	0.31	41
	American Eel	Whole Body	1999-2001	6	6	100%	9.7	6.34	4.53	20.6
	American Eel	Whole Body	2009-2010	19	18	95%	16.8	15.0	0.11	47
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	262	45.0	195	371
	Blue Crab	Hepatopancreas	2009-2010	7	7	100%	143	63.8	41	210
	Blue Crab	Muscle	1999-2001	18	18	100%	17.6	3.94	10.9	22.7
	Blue Crab	Muscle	2009-2010	21	21	100%	7.48	5.65	0.82	20
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	75.0	24.8	28	141
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	41	41	100%	49.2	25.0	4	110
	White Perch	Fillet	1999-2001	6	6	100%	64.9	22.2	34.4	88.9
	White Perch	Fillet	2009-2010	19	19	100%	41.0	24.1	3.6	99
	White Perch	Whole Body	1999-2001	18	18	100%	212	81.1	73.6	352
	White Perch	Whole Body	2009-2010	19	19	100%	129	71.5	18.0	250
Total PCBs (ug/kg)	American Eel	Fillet	1999-2001	7	7	100%	1,624	745	670	2,800
	American Eel	Fillet	2009-2010	32	32	100%	1,185	882	310	4,900
	American Eel	Whole Body	1999-2001	6	3	50%	810	710	75	1,700
	American Eel	Whole Body	2009-2010	19	19	100%	1,849	1,681	670	7,500
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	5,513	1,958	3,200	11,000
	Blue Crab	Hepatopancreas	2009-2010	7	7	100%	3,300	1,233	1,200	5,100
	Blue Crab	Muscle	1999-2001	18	4	22%	64	22	16	75
	Blue Crab	Muscle	2009-2010	21	19	90%	31	27	3.5	100
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	777	467	140	1,800
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	41	41	100%	473	277	110	1,300
	White Perch	Fillet	1999-2001	6	6	100%	842	179	600	1,100
	White Perch	Fillet	2009-2010	19	19	100%	551	298	190	1,300
	White Perch	Whole Body	1999-2001	18	18	100%	3,989	1,821	1,200	10,000
	White Perch	Whole Body	2009-2010	19	19	100%	2,308	1,124	470	4,200

Notes: Includes all samples collected in the river. The 1999-2001 sampling events include the 1999 Late Summer/Early Fall RI-ESP Sampling Program; the 2000 Spring RI-ESP Sampling Program; andthe 2001 Supplemental RI-ESP Biota Sampling Program. The 2009-2010 sampling period includes samples collected by the Cooperating parties group during that period. 1/2 detection limit substituted for non-detected values. Field duplicate results were averaged. Total PCB concentrations are the sum of 7 Aroclors.

Table 2. Tissue Concentrations in Selected Species Collected in the Lower Passaic River below LPRSA Mile 8 by Sampling Period

Chemical	Species	Tissue Type	Sampling Period	N	Number of Detects	Frequency of Detection	Mean	Standard Deviation	Minimum	Maximum
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	7	100%	21.7	6.49	14.6	32.2
	American Eel	Fillet	2009-2010	16	16	100%	14.9	9.91	4.70	41
	American Eel	Whole Body	1999-2001	6	6	100%	9.7	6.34	4.53	20.6
	American Eel	Whole Body	2009-2010	8	8	100%	24.8	13.2	5.70	47
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	262	45.0	195	371
	Blue Crab	Hepatopancreas	2009-2010	5	5	100%	176	34.4	130	210
	Blue Crab	Muscle	1999-2001	18	18	100%	17.6	3.94	10.9	22.7
	Blue Crab	Muscle	2009-2010	11	11	100%	11.10	5.23	3.80	20
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	75.0	24.8	28	141
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	22	22	100%	61.6	22.1	24	110
	White Perch	Fillet	1999-2001	6	6	100%	64.9	22.2	34.4	88.9
	White Perch	Fillet	2009-2010	11	11	100%	48.9	22.5	22.0	99
	White Perch	Whole Body	1999-2001	18	18	100%	212	81.1	73.6	352
	White Perch	Whole Body	2009-2010	10	10	100%	158	45.8	73.0	250
Total PCBs (ug/kg)	American Eel	Fillet	1999-2001	7	7	100%	1,624	745	670	2,800
	American Eel	Fillet	2009-2010	16	16	100%	1,271	1086	450	4,900
	American Eel	Whole Body	1999-2001	6	3	50%	810	710	75	1,700
	American Eel	Whole Body	2009-2010	8	8	100%	2,780	2,299	760	7,500
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	5,513	1,958	3,200	11,000
	Blue Crab	Hepatopancreas	2009-2010	5	5	100%	3,900	725	3,200	5,100
	Blue Crab	Muscle	1999-2001	18	4	22%	64	22	16	75
	Blue Crab	Muscle	2009-2010	11	11	100%	40	30	17	100
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	777	467	140	1,800
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	22	22	100%	477	353	110	1,300
	White Perch	Fillet	1999-2001	6	6	100%	842	179	600	1,100
	White Perch	Fillet	2009-2010	11	11	100%	649	319	190	1,300
	White Perch	Whole Body	1999-2001	18	18	100%	3,989	1,821	1,200	10,000
	White Perch	Whole Body	2009-2010	10	10		2,630	748	1900	4,200

Notes: Includes only samples collected below LPRSA river mile 8. The 1999-2001 sampling events include the 1999 Late Summer/Early Fall RI-ESP Sampling Program; the 2000 Spring RI-ESP Sampling Program; andthe 2001 Supplemental RI-ESP Biota Sampling Program. The 2009-2010 sampling period includes samples collected by the Cooperating parties group during that period. 1/2 detection limit substituted for non-detected values. Field duplicate results were averaged. Total PCB concentrations are the sum of 7 Aroclors.

The comparative analysis of alternative remedies in the FFS rely on the assumption that little to no natural recovery is taking place in the LPR. This assumption is based on sediment and tissue trend analyses presented in the RI. Determination of whether a statistically significant trend in fish and crab tissue data does or does not exist is critical to drawing any conclusions regarding future risks in the river and for consideration of any remedial actions under the NCP. The present datasets are insufficient for this purpose. For this reason, the release of the FFS with proposed risk-based remedial actions that are primarily focused on reductions in COCs in fish and crab tissue in the LPRSA is premature. Instead, remedial decision making should be postponed until collection of another biota tissue dataset and the conduct of a statistical evaluation of any trends. A trend analysis will require the collection in the LPRSA of more tissue data for the same species and primary COCs as were collected and analyzed in the two previous time periods (1999 to 2001 and 2009/2010). A dataset collected in the near term would provide additional fish tissue concentrations approximately five years following the last sampling event and provide important information regarding potential spatial and temporal trends in tissue concentrations. Tierra submitted a conceptual plan to Region 2 in March 2014 for fish and crab sampling in the LPRSA to provide such a dataset in a timely fashion. This conceptual plan was documented in a memorandum entitled *Conceptual Fish and Crab Sampling Plan for Lower Passaic River Study Area*, which provided an expanded assessment of the apparent trends summarized in this comment, as well as a statistical basis and conceptual plan for a fish/crab sampling program (ARCADIS, 2014b). This memorandum is provided as Attachment 2 to these comments.

In addition, Region 2's conclusion that no temporal trend in 2,3,7,8-TCDD sediment concentrations has occurred is incorrect, and the analyses used to support this conclusion are technically and statistically flawed. Region 2 used inappropriate statistics and data manipulation to compare 2,3,7,8-TCDD sediment concentrations from each of the larger datasets collected in the LPRSA: the 1995 Remedial Investigation (RI) Sampling program; the 2008 CPG Low Resolution Sediment Coring program; the 2009 and 2010 CPG Benthic and Surface Sediment Programs; and the 2012 CPG Low Resolution Coring Supplemental Sampling Program. First, the data were divided into geographic subsets for analysis (i.e., river mile [RM] 0-2 and RM 2-8), which reduced the sample size for each comparison, thereby making it difficult to detect a difference in the results. Second, the 1995 data were only collected between RM 1-7; therefore, a meaningful historical comparison should have been limited to data from within this same stretch of the River (i.e., RM 1-7). Third, the analysis does not include a test of equal variance among the datasets. Equal variance is a well-known required assumption of analysis of variance testing that should be established before conducting this type of analysis. Box plots generated by Region 2 and displayed in Figure 2.2-1a of FFS *Data Evaluation Report No. 4: Sediment Analysis* clearly show unequal variance among the datasets. Finally, Region 2 utilized an arbitrary-adjustment factor for the 2008 2,3,7,8-TCDD dataset due to issues with its split-sample results, while not applying a similar adjustment factor to other chemicals in the analysis. This selective application of an adjustment factor to only 2,3,7,8-TCDD was shown to be technically inappropriate ARCADIS (2011), as the bias in the 2008 Region 2 split-sample dataset was demonstrated for multiple chemicals, not just 2,3,7,8-TCDD. As such, either no adjustment should be used, or the same adjustment factor should be applied to multiple chemicals. Otherwise, the result is a clear bias in the sediment trends analysis resulting in incorrect conclusions. Further detail on

this issue is provided in ARCADIS (2011)), which is provided as Attachment 3 to these comments, and in the specific comments to the RIR Appendix D. The impact of this adjustment is significant. All the 2008 CPG LRC 2,3,7,8-TCDD concentrations were multiplied by a factor of 1.9. The effect on the Region 2 trend assessment is that it obscures temporal trend estimates and understates the rate of natural recovery. Further, it causes risks due to sediment contamination to be overestimated.

A temporal analysis of historical 2,3,7,8-TCDD sediment concentrations within the spatial limits of the 1995 data (i.e., RM 1-7) was conducted by ARCADIS (2014a)—Attachment 1 to these comments. The results of the analysis demonstrate a statistically significant temporal decline in 2,3,7,8-TCDD concentrations (28% reduction; $p = 0.05$) when the 1995 dataset is compared to the data collected from 2008 through 2010. Five additional chemicals, mercury (45% reduction), dieldrin (77% reduction), DDT (54% reduction), and two individual PCB congeners (PCB-77 and PCB-118, 54% and 41% reduction, respectively) also exhibited a statistically significant decline.

While the 2012 dataset (i.e., the 2012 CPG Low Resolution Coring Supplemental Sampling Program) does not show a similar decline when compared with the 1995 dataset, this is to be expected because the 2012 data set was not spatially representative. Instead, it was designed to delineate chemical contaminant "hot spots." In fact, it has some of the highest concentrations of 2,3,7,8-TCDD, and several other chemicals (e.g., Total PCBs, mercury), ever detected in sediments within RM 1-7. This is to be expected from a sampling program such as this where samples were specifically collected in areas where the highest concentrations were previously noted. The 2012 dataset, because of its deliberately biased and limited purpose, should not be included in a statistical evaluation with the large-scale, spatially representative sampling events (i.e., 1995, 2008 to 2010). Instead, as with the biota tissue data, it is clear that an additional spatially representative sediment dataset is needed to evaluate whether the apparent temporal decline in sediment COC concentrations is occurring and at what rate (ARCADIS, 2014a). This is essential for an assessment of potential natural recovery and an evaluation of the need for selection of a remedy that is consistent with the NCP.

<u>GENERAL COMMENT 3.</u> The bioaccumulation modeling that forms the basis for PRG calculations and future risk assessments is flawed, unsupported, and should not be used as the basis for a sediment remedial action.

Data Evaluation Report No. 6: Biota Analysis presents EPA's basis for evaluating relationships between sediment and biota chemistry (i.e., bioaccumulation). The evaluation contained in the *Report* is based on a series of –multivariate regression models used to predict future tissue concentrations that presumably would be attained at predicted future sediment concentrations. These models were used to calculate both human health and ecological PRGs for sediment based on the risk-based tissue PRGs. The modeling was conducted using available site-specific biota concentrations for a limited set of species and tissue types paired with estimates of sediment exposure calculated as the mean of all sediment concentrations within a two mile window of where the organism was caught. The models were supplemented with biota concentration data collected off-site (i.e., New York/New Jersey (NY/NJ) Harbor (USEPA Regional Environmental Monitoring and Assessment Program [REMAP; USEPA, 2003] and

New York State Department of Environmental Conservation [NYSDEC] Contaminant Assessment and Reduction Program [CARP; NYSDEC, 2003]) and paired in a different way with sediment concentrations in the vicinity of where the organism was collected. Therefore the data handling of the site-specific and off-site biota-sediment pairing was inconsistent in the models. In addition there is much greater uncertainty in the sediment exposure concentrations for the off-site data used.

Data Evaluation Report No. 6: Biota Analysis graphically presents regression model results and provides parameter estimates and coefficient of variation (R^2) values; however, it provides little additional model fit information. The R^2 value is offered as evidence of good fit for the models, but the R^2 value is misleading because it is achieved by adding off-site data to the models with much lower sediment concentrations thereby securing the low end of the regression curve to increase the R^2 value.. The confidence intervals provided for model prediction are quite large in most instances. For example, for prediction of 2,3,7,8-TCDD in tissue, the confidence interval is -20% to +124% of the predicted value in the range of proposed sediment PRGs indicating that there is large uncertainty in the models in the range of the PRGs and this can drive the estimate of the sediment concentrations needed to achieve a tissue PRG much lower than they need to be. Most of the modeling has very sparse or no data throughout the range of the regression line, resulting in regression lines that have clumps of data at either end, site versus off-site, and no data in the middle. The off-site data points are often highly variable, have high leverage, and therefore, have a large influence on the slope of the regression line. The off-site data drive estimates of bioaccumulation rates to be much higher than the site-specific data used in the models. No confidence intervals are provided for the β parameter estimates, rendering it unclear, for example, whether they are significantly different from 1.0, which will change the relationship from linear to non-linear. This is of large consequence because, in the case of the non-linear models presented, the bioaccumulation rates are predicted to be higher and sometimes many times higher at lower sediment concentrations. When such models are used in the prediction of bioaccumulation, the result is that sediment PRGs, much lower than are actually necessary, are computed to attain a given tissue PRG.

The bioaccumulation modeling presented in *Data Evaluation Report No. 6: Biota Analysis* ignores recent 2009 laboratory bioaccumulation test results collected by the CPG (Windward, 2011a) on estuarine polychaetes and freshwater oligochaetes that were exposed to LPRSA sediments. ARCADIS (2014a)—Attachment 1 to these comments—conducted regression analyses of these site-specific data for the lower eight miles and found excellent correlation between sediment and tissue concentrations for both 2,3,7,8-TCDD and Total PCBs, with R^2 values ranging from 0.98 to 0.99, respectively. Regression slope confidence intervals reveal that bioaccumulation rates are fairly constant over the range of the sediment concentrations. This is in contrast to the regression models presented in the report, which, because of the use of off-site tissue data from organisms with unquantifiable sediment exposure (e.g., REMAP and CARP data), predict that bioaccumulation rates increase as sediment concentrations decrease.

Given the large uncertainty of these predictions, these models should not be used as the basis of a sediment remedy. For a given chemical, species, and tissue type, better predictions could be obtained

using a model that is strictly site-specific, incorporates all available site sediment and biota data, and uses a spatially weighted scheme (e.g., a spatially weighted average concentration [SWAC]) to relate the distribution of sediment concentrations to the observed distribution of biota concentrations in the system. ARCADIS (2014a) conducted such an analysis, the results of which were used to develop the specific comments on the future conditions/risks and PRGs (i.e., Section 7 and Appendices C, D, and E of the RIR).

<u>GENERAL COMMENT 4.</u> Because there is no technical basis for a benthic invertebrate community sediment screening threshold/benchmark for dioxin, this value should not be used to assess risk to invertebrates or as the basis for the development of PRGs.

A very substantial flaw in this BERA is the inclusion of a sediment benchmark for direct toxicity of 2,3,7,8-TCDD (dioxin) for benthic (infaunal) invertebrates. As discussed by USEPA (2008) and Iannuzzi et al. (1995), dioxins/furans have never been shown to be directly toxic to benthic invertebrates. Unlike vertebrate animals (e.g., fish, birds, mammals), invertebrates lack the cellular aryl hydrocarbon (Ah)cellular response that mediates toxicity of dioxins/furans (USEPA, 2008; Hahn, 1998). Available sediment benchmarks for dioxins/furans are based on food web bioaccumulation and potential effects in vertebrate organisms. In fact, Barber et al. (1998) conducted a spiked sediment bioassay with 2,3,7,8-TCDD using one of USEPA's standardized marine/estuarine test organisms—the amphipod *Ampelisca abdita*—that is considered by scientists to be one of the most sensitive organisms to sediment contaminants. Barber et al. (1998) found no toxicity at sediment exposure concentrations of 2,3,7,8-TCDD as high as 10 mg/kg (i.e., orders-of-magnitude higher than concentrations in surface sediments in the LPRSA). Similarly, in a site-specific sediment quality triad (SQT) study for the lower 6 miles of the LPRSA, Iannuzzi et al. (2007) found no evidence of an exposure-response relationship between dioxins/furans in sediments and toxicity to invertebrate test organisms (*A. abdita* and polychaete worms).

Region 2 calculated the potential sediment toxicity risks for all COCs in this BERA, ***except*** 2,3,7,8-TCDD, using available published and peer-reviewed SQGs. For 2,3,7,8-TCDD, Region 2 relied on a new, non-published and non-peer-reviewed sediment toxicity benchmark recently developed by the U.S. Fish & Wildlife Service (USFWS) for the site (3.2 ng/kg or parts per trillion [ppt]), presumably because no such values are available in the literature for direct toxicity to invertebrates. The basis of this new benchmark is a highly flawed extrapolation from a limited oyster study conducted by Wintermeyer and Cooper (2003) that, according to Region 2 and USFWS, linked 2,3,7,8-TCDD in Newark Bay to oyster reproduction effects. In fact, the Wintermeyer and Cooper (2003) study does not prove such a linkage and fails to consider all the contaminants and stressors other than 2,3,7,8-TCDD in its analysis of the Newark Bay data. In addition, the means by which the USFWS calculated the 2,3,7,8-TCDD sediment benchmark (using a non-statistical biota-sediment-accumulation factor [BSAF] to back-calculate from oysters to sediments) lacks scientific basis. A detailed critique of the Wintermeyer and Cooper (2003) study and its use for development of a sediment toxicity benchmark for 2,3,7,8-TCDD is provided hereafter in specific comments on Appendix D of the RIR.

Notwithstanding the issues with the Wintermeyer and Cooper (2003) misinterpretations and extrapolations, Region 2 should not utilize the results of an oyster study to compute a sediment toxicity benchmark for the benthic invertebrate communities in the LPRSA. Oysters do not exist in the LPRSA, cannot survive in most of the lower eight miles due to salinity and a number of other factors, and are not representative of the benthic community that does exist. Amphipods and polychaete worms are far more representative of the lower eight-mile LPRSA benthic community, and Barber et al. (1998) demonstrated that 2,3,7,8-TCDD is not toxic to these organisms. Published, peer-reviewed studies demonstrate that a sediment toxicity benchmark for dioxins/furans is not warranted; accordingly, no PRG should be developed for dioxins/furans for this endpoint.

<u>GENERAL COMMENT 5.</u> The use of modeled bird egg tissue concentrations based on fish-to-bird egg biomagnification factors (BMFs) developed for the Great Lakes rather than available site-specific data for cormorant eggs collected from Shooters Island in nearby Newark Bay is technically flawed and inconsistent with USEPA ecological risk assessment guidance that specifies the use of site-specific data when available (1992; 1997; 1999).

The local population of cormorants that breed on Shooters Island is reflective of the birds that forage in Newark Bay and its tributaries, including the LPR. Therefore, available direct egg tissue concentration data from Parsons (2003) should be used as site-specific data in the BERA to evaluate tissue concentrations in piscivorous bird eggs for the LPR, consistent with USEPA ecological risk assessment guidance (1992; 1997; 1999). Instead, Region 2 incorporates BMFs for chemical contaminant transfer from fish to herring gulls for its bird risk assessment in an attempt to predict egg tissue concentrations for birds in the LPR. This extrapolation model is based on non-site-related data from the Great Lakes. The entire model and rationale for the evaluation is technically flawed and inaccurate for the following reasons:

1. Herring gulls are not a receptor of concern for risk assessment in the LPR. These birds are opportunistic and will feed on carrion and garbage from nearby landfills, and their populations are very large in the urbanized Newark region.
2. Lake trout and alewife, upon which the gull egg BMF model is based, are not fish receptors or food sources for gulls in the LPRSA. These receptors from the Great Lakes do not occur in the Study Area and are not representative of fish found in a marine/estuarine system.
3. The modeled concentrations in herring gull eggs should not replace available site-specific data for cormorants in Region 2's BERA.

The fact that the modeled 2,3,7,8-TCDD egg results for gulls are so much higher than actual concentrations measured in local cormorants is evidence of the inaccuracy of the model used. Furthermore, Region 2's explanation/position that the higher modeled results for the herring gull eggs is actually expected because cormorants that would utilize the Study Area would contain higher 2,3,7,8-TCDD concentrations than those from Newark Bay is baseless. Shooters Island is located approximately five to six miles south of the mouth of the Passaic River, and cormorants have a foraging range of 18 to 25 miles from their colony (Custer & Bunck, 1992; Hatch & Weseloh, 1999; Ainley & Boekelheide, 1990).

Therefore, the population of cormorants on Shooters Island is representative of piscivorous birds who may forage on fish from the LPRSA, and the site-specific data for these species is the most appropriate data to use in the BERA for the bird egg risk assessment, consistent with USEPA ecological risk assessment guidance (1992; 1997; 1999).

According to Parsons (2003), non-lipid-normalized 2,3,7,8-TCDD concentrations in cormorant eggs for the Shooters Island population range from 8.6 to 201 ng/kg, with a mean 2,3,7,8-TCCD concentration of 59.8 ng/kg and a mean toxic equivalent (TEQ) of 92 ng/kg. These values are well below the established literature-based critical body residue (CBR) values for avian eggs, specifically cormorant 2,3,7,8-TCDD concentrations, which have no observed adverse effect levels (NOAELs) that range from 1,000 to 3,000 ng/kg and low observed adverse effect levels (LOAELs) that range from 4,000 to 10,000 ng/kg (Powell et al., 1997; 1998; Sanderson & Bellward, 1995). As such, there is no risk to avian eggs from exposure to fish in the LPRSA.

<u>GENERAL COMMENT 6.</u> Mink should not be considered ecological receptors for the BERA and FFS decision making, as they do not exist in heavily industrialized areas, and there is no documented evidence of mink occurring in the lower eight miles of the LPRSA.

The use of mink as a receptor of concern for the Study Area BERA is inconsistent with USEPA ecological risk assessment guidance (1992; 1997; 1999), which calls for the selection of receptors that represent potentially exposed populations at a site. There is no basis for the selection of mink for the lower eight miles of the LPRSA, as there is no suitable mink habitat along the urbanized/industrialized shorelines, nor have any mink ever been observed/reported in the LPRSA.

Other Superfund sites that have used mink as a receptor of concern for ecological risk assessment and for evaluating the need for remedial action (including those under Region 2 authority) have clearly documented the evidence of the existence of mink at the site. For instance, in the upper Hudson River, mink field investigations, including a trapping study and PCB tissue level analyses, were conducted and reported by Mayack and Loukas (2001). For the Housatonic River, the presence of mink was documented by Bernstein et al. (2003). Millsap et al. (2004) and Beckett et al. (2005) provide results of a mink trapping study and tissue residue levels in mink along the Kalamazoo River. For the Tittabawassee River, Zwiernik et al. (2008) and Zwiernik (2011) describe the results of a mink trapping study and tissue concentrations. Finally, the occurrence of mink in the lower Fox River was documented by Stratus Consulting (1999). Because there is no evidence that mink are present along the lower eight miles of the LPRSA, and in fact, the extensive site-specific reconnaissance data clearly show that there is no mink habitat in the Study Area, the inclusion of mink as a receptor is inconsistent with USEPA guidance (1992; 1997; 1999) and Superfund practice. Furthermore, there are no documented occurrences of any other piscivorous aquatic or semi-aquatic mammals in the Study Area. Therefore, piscivorous mammals should be altogether eliminated from consideration for the BERA.

<u>GENERAL COMMENT 7.</u> Because there are no apparent fish, bird, or mammalian wildlife risks from 2,3,7,8-TCDD (dioxin), no dioxin-based ecological PRGs or remedial actions are warranted.

The BERA (Section 7.2 and Appendix D of the RIR), in its conservative screening-level fashion, fails to consider the likely exposures of wildlife in the lower eight miles of the LPRSA and does not present or consider the range of TRVs for 2,3,7,8-TCDD that are relevant for the fish and wildlife that do occur at the site (as are readily available in the literature). When considering the appropriate wildlife receptors and ranges of TRVs under USEPA (1997) guidance, it becomes clear that there are no apparent risks to fish or wildlife along the Study Area, and even within reasonable bounds of uncertainty, there are no fish or wildlife risks for 2,3,7,8-TCDD that require, or can be addressed by, remedial actions contemplated in the FFS.

To illustrate this point, ARCADIS compiled whole-body TRVs from the literature for the species/types of fish that occur in the LPRSA, and dietary-based TRVs for water birds. No mammalian receptors were included due to the lack of aquatic or semi-aquatic piscivorous mammals in the Study Area (see previous General Comment 6). Food web dietary uptake models were run for great blue heron (as a representative water bird). Results were compared to the ranges of TRVs for birds. To evaluate risk to fish, site-specific, whole-body fish data were compared to the ranges of fish CBRs. The details of this assessment are provided in ARCADIS (2014c), which is provided as Attachment 4 to these comments. Specific comments on the various components and assumptions of fish and wildlife exposure and toxicity assessment in the BERA are provided below in comments on Section 7.2 and Appendix D of the RIR.

<u>GENERAL COMMENT 8.</u> Because the predicted lack of ecological risk under current conditions would be similar in the future without any remedial action, no sediment remediation is necessary.

Because the urbanized shoreline of the Study Area presents little, if any, opportunity for large-scale habitat improvement projects or restoration, the future ecology in this area will remain as it currently exists. The Draft 2009 Hudson Raritan Estuary Comprehensive Ecosystem Restoration Plan (U.S. Army Corps of Engineers [USACE] et al., 2009) identifies several target ecosystem characteristics (TECs) with specific restoration areas. While one of the TECs is the removal of toxic contaminants in sediments, none of the other TECs are supportable in the LPRSA, which is intensively industrialized with hardened shorelines, inter-pier areas, and enclosed basins. Shoreline structures have eliminated transitional intertidal and littoral areas. Hardened shorelines amplify wave energy, which increases erosion and deepens near-shore waters, affecting water quality/clarity and habitat availability. Pier construction reduces channel width and current velocities, and increases sedimentation, which in turn reduces available water column habitat and buries existing, natural hard substrates (Bain et al., 2007; USACE et al., 2009). Shading impacts of shoreline structures on aquatic flora and fauna are increasingly recognized in aquatic resource assessments, and recent research has documented fewer species, lower abundances, and fewer feeding opportunities beneath large, over-water structures compared to open water, pile fields, or edge habitat (Able & Duffy-Anderson, 2006). The National Oceanic and Atmospheric Administration Environmental Sensitivity Index Geospatial Data (National Oceanic and Atmospheric Administration, 2003/03) classified the entire LPR as hard shoreline.

While several potential, individual improvement projects have been proposed at various locations along the lower eight miles of the Passaic River, the majority of these projects are slated for recreational use, public access, and aesthetics, such as open park spaces, picnic areas, and boat launches (USACE et al., 2009). Although limited removal of some historical shoreline structures may occur, the aquatic habitat is unlikely to be greatly increased or affected through these efforts. In fact, many of the individual site-specific projects predict habitat improvements of less than 1 acre (USACE et al. 2009).

Aside from contaminated sediments, additional potential sources of contamination must be controlled to improve the aquatic habitat quality of the LPR. These include upstream/tributary contamination, contaminated suspended solids, dissolved contaminants, groundwater, combined sewer overflows, atmospheric deposition, industrial point sources, non-point source/overland runoff, and stormwater and municipal point sources. Many of these additional sources are not subject to the Comprehensive Environmental Response, Compensation, and Liability Act. Dozens of combined sewer overflows are located along the LPR. Water quality within the LPR did not meet Clean Water Act § 303(d) standards for 2006 and portions have shown hypoxic or anoxic conditions (USACE et al., 2009). Furthermore, the few existing patches of “habitat” along the lower eight miles of the Passaic River do not meet all four criteria required for restoration of oyster reef habitat: salinity range, dissolved oxygen, total suspended solids, and bathymetry (USACE et al., 2009). Therefore, the future ecology will not differ from the current state in the Study Area, and Region 2 should not propose remediation for ecological risk that does not exist.

Attachments to ARCADIS Ecological Risk Assessment/PRG Comments

Attachment 1: ARCADIS. 2014a. Evaluation of Historic Data and Development of a Bioaccumulation Predictive Tool for the Lower Passaic River Study Area. August.

Attachment 2: ARCADIS. 2014b. Conceptual Fish and Crab Sampling Plan for the Lower Passaic River Study Area. March.

Attachment 3: ARCADIS. 2011. Development of correction factors for split samples using the approach developed by CSC Analytical. Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons. July.

Attachment 4: ARCADIS. 2014c. Evaluation of Potential Ecological Risks for the Lower Passaic River Study Area. August.

1. **<u>RIR Specific Comments</u> – These comments address a single, specific concept or section of the RIR.**

Section 7 – Baseline Risk Assessment

<u>Section 7.2 – Baseline Ecological Risk Assessment</u>

Comment RIR1. *(General Comment) The overall text and evaluations do not match the language and phrasing used in Appendix D. For example, the table on page 7-14 does not match the table of assessment and measurement endpoints provided in Appendix D (Table 4-10). In some instances, statements made in this section directly contradict those made in Appendix D. Refer to Comment RIR5 below regarding surface water.*

Comment RIR2. *(General Comment) Refer to comments on the detailed BERA in Appendix D.*

Section 7.2.1 – Data Evaluation

Comment RIR3. *(Section 7-12, Paragraph 1) The full dataset is not provided in Appendix D.*

Section 7.2.3 – Exposure Assessment

Comment RIR4. *(Section 7-15, Paragraph 2) The qualifier "may be exposed" presents too much uncertainty for a BERA where a substantial amount of site-specific biological/ecological data is available. At this point in the process, the LPR has been studied for decades, as reported, for example, in: Wenning et al., 1994; Iannuzzi et al., 1996; Wolfskill and McNutt, 1998; Wallin et al., 2002; Iannuzzi et al., 2002; Iannuzzi and Ludwig, 2004; 2005; Ludwig and Iannuzzi, 2005; Ludwig et al., 2010; and the various LPRSA CPG studies. Considerable information exists regarding the wildlife present along the heavily industrialized Study Area. Receptors that "may be" present should not be modeled; rather, the evaluation should focus on animal types that have been observed frequently, and because no aquatic or semi-aquatic mammals have been shown to exist along the Study Area, no mammalian receptors are warranted. Refer to Section 3 of the RIR, which provides a better (albeit still incomplete) summary of the observed receptors along the LPRSA.*

Comment RIR5. *(Section 7-17, Paragraph 1) The last sentence states that: "few surface water data were available." This is not true. Surface water data have been collected by AECOM, on behalf of the CPG, since 2011 (www.ourpassaic.org), and therefore, should be included in this evaluation. As stated in Appendix D: "Surface water quality data were recently collected by the CPG for the 17-mile LPRSA RI/FS." The dataset includes several rounds of surface water samples from the LPR and Newark Bay, which were analyzed for a variety of chemicals and physical parameters at a scale that had not been conducted historically in this area.*

Samples were collected from different depths and at different tidal stages and seasons; data are provided from four stations within the LPRSA.

Comment RIR6. *(Section 7-17, Paragraph 3) Fish and avian egg residue analysis. The bird egg residue analysis is faulty because it uses different avian and fish species from another study area and tries to compare these modeled egg concentrations to cormorant eggs in Newark Bay. The last sentence of this paragraph is incorrect because the evaluation does not provide any useful comparisons. The focus of the BERA is on great blue herons in the Passaic River. Modeled egg concentrations in herring gulls, using uptake factors from another study area, provides no accurate or scientifically valid, logical comparisons to local bird populations. Refer to specific comments on Appendix D.*

Table and Figure Comments

Comment RIR7. *(Figure 7-2) This figure is too simplistic and needs to be updated to accurately reflect the evaluation that was conducted, including the correct receptor groups and pathways that were evaluated in the BERA. For example, an "aquatic birds" category is listed on the figure, and there are complete quantitative pathways shown; however, the general aquatic bird category was not evaluated in the BERA. "Sediment-probing birds" is another category listed on the figure that was not evaluated in the BERA. Furthermore, herons feed on mudflat sediment, but the piscivorous bird category has no boxes filled in for mudflat exposure. An alternative conceptual site model is provided in the attached alternative ecological risk assessment (ARCADIS, 2014c).*

2. Appendix A – Data Evaluation Reports – These comments address a single, specific concept or section of Appendix A.

Data Evaluation Report No. 4: Surface Sediment Contamination

Comment A1. *Data Evaluation Report No. 4: Surface Sediment Contamination concluded that no temporal trend in 2,3,7,8-TCDD sediment concentrations has occurred based on the results of Tukey-Kramer multiple comparison tests. These tests compared 2,3,7,8-TCDD sediment concentrations from each of the larger datasets collected in the LPRSA: the 1995 RI Sampling program; the 2008 CPG Low Resolution Sediment Coring program; the 2009 and 2010 CPG Benthic and Surface Sediment Programs; and the 2012 CPG Low Resolution Coring Supplemental Sampling Program. The analysis is flawed for several reasons. First, the data were divided into smaller sets for analysis (i.e., RM 0-2 and RM 2-8), which reduced the sample size for each comparison, thereby making it difficult to detect a difference in the results. Second, the 1995 data were collected only between RM 1-7; therefore, a meaningful historical comparison should have been limited to data from within*

this same stretch of the Passaic River. Third, the analysis does not include a test of equal variance among the datasets. Equal variance is a required assumption that should be established before conducting this type of analysis. Box plots displayed on Figure 2.2-1a of Data Evaluation Report No. 4 show different variance among the datasets.

Comment A2. *A historical comparison of 2,3,7,8-TCDD sediment concentrations within the spatial limits of the 1995 data (i.e., RM 1-7) was conducted by ARCADIS (2014a). Levene's test of homogeneity of variance, a standard test of variance used to test the assumptions of an analysis of variance (ANOVA)-type analysis, was conducted, and the result was significant (p = 0.0055), confirming that the datasets have unequal variance, rendering the ANOVA analysis inappropriate. These sampling programs (with the exception of the 2012 program) were designed to be spatially representative. However, each program included some judgmental sampling (i.e., collection of samples from specific locations suspected of having higher relative levels of contamination or near potential sources of contamination) and did not strictly adhere to a random design. Therefore, differences in the RM location of individual samples in each program, and the associated differences in expected concentrations, are potential confounders that should be controlled for in a statistical comparison. ARCADIS (2014a) conducted a spline regression analysis that allows for a comparison of concentrations among the temporally defined data groups while controlling for the spatial variation inherent in the RM location. This type of analysis can be used to compare concentrations over time, while controlling for the spatial variation by RM. The results of the analysis demonstrate a statistically significant temporal decline in 2,3,7,8-TCDD concentrations (28% reduction; p = 0.05) when the 1995 dataset is compared to the data collected from 2008 through 2010. Five additional chemicals, mercury (45% reduction), dieldrin (77% reduction), DDT (54% reduction), and two individual PCB congeners (PCB-77 and PCB-118, 54% and 41% reduction, respectively) also exhibited a statistically significant decline. The 2012 dataset (i.e., the 2012 CPG Low Resolution Coring Supplemental Sampling Program), when compared with the 1995 dataset, does not show a similar decline. This dataset is not comparable to the others in that it was not designed to be spatially representative, but instead was designed to delineate hot spots. In fact, it has some of the highest concentrations of 2,3,7,8-TCDD and several other chemicals (e.g., Total PCBs, mercury) ever detected in sediments within RM 1-7. In conclusion, a decline in 2,3,7,8-TCDD concentrations (and other chemicals) was demonstrated from the period of 1995 to 2008 through 2010, suggesting that natural recovery could be occurring in the system for chemicals without ongoing sources. However, this trend could not be confirmed by the 012 dataset, as that dataset was not spatially representative of the river, but instead was intentionally designed to sample locations suspected to have elevated*

levels of contaminants. Due to uncertainty of this significant driver of a very costly and disruptive remedy, an additional spatially representative sediment dataset should be collected to confirm whether natural recovery is taking place.

Data Evaluation Report No. 6: Biota Analysis

Comment A3. *(Section 2.2, General Comment) This section presents the results of spatial and temporal trend analyses. Broad generalizations are made about data characteristics and trends that are often not supported by the data presented. Summary point 1 indicates that tissue concentrations are "highly variable" on small spatial scales. However, this statement is based on summary statistics that combine tissue types and are, therefore, useless in making any assumptions about tissue concentrations, as they would vary considerably by tissue type. Summary point 3 indicates that lipid normalization reduced the variance of the data without the analysis necessary to support that statement. This was used to justify performing trend analyses on lipid-normalized data only. No trend analyses were presented for wet-weight–based concentrations, although it was implied that the wet-weight concentrations showed a downward trend in most cases. Because wet-weight concentrations are what are important for exposure estimates, trends in wet-weight concentrations should have been included in the analysis. This uncertainty with respect to temporal trends substantially impacts remedy selection decisions.*

Comment A4. *(Section 3, General Comment) This section presents the results of fitting multivariate regression models that include multiple species and as many as 15 parameters (β) per model. These models were used to predict future tissue concentrations that presumably would be attained at predicted future sediment concentrations. The results of these analyses were used to calculate PRGs for sediment based on the risk-based tissue PRGs. The analyses were conducted using some, but not all, of the available site-specific biota and sediment data and were supplemented with off-site data from the NY/NJ Harbor (USEPA REMAP [USEPA, 2003] and NYSDEC CARP [NYSDEC, 2003] sampling programs). The analysis required a pairing of each biota concentration with some estimate of the organism's sediment exposure concentration. A smoothing method by RM (2-mile increments) was used to estimate exposure in the FFS Study Area, while a polygon method was used to estimate exposure in the off-site samples where sediment sampling density was much lower. This inconsistency in data pairing adds uncertainty to the model results. The regression model results are presented graphically and parameter estimates and R^2 values are provided; however, little additional information about the model fit is provided. The R^2 value is provided as evidence of good model fit for the models; however, this value is misleading*

because it is achieved by adding the off-site data, with much lower sediment concentrations, to the model. Confidence intervals for model prediction are provided and are quite large in most instances. For example, for prediction of 2,3,7,8-TCDD in tissue, the confidence interval is -20% to +124% of the predicted value in the range of proposed sediment PRGs. Most of the models have very sparse or no data throughout the range of the regression line and consist of regression lines that have clumps of data at either end, site versus off-site, and no data in the middle. The off-site data points are often highly variable, have high leverage, and therefore, have a large influence on the slope of the regression line. No confidence intervals are provided for the β parameter estimates; therefore, it is unclear, for example, if they are significantly different from one, which changes the relationship from linear to non-linear. This is of large consequence because, in the case of the non-linear models presented, the bioaccumulation rates are predicted to be higher, and sometimes many times higher, at lower sediment concentrations. When such models are used in predictions, the result is that much lower sediment PRGs are predicted to attain a given tissue PRG. Given the large uncertainty of these predictions, this model should not be used as the basis of a sediment remedy. Better predictions would be obtained by a model that incorporates all available site sediment and biota data and uses an area-weighted scheme to relate the distribution of sediment concentrations to the observed distribution of biota concentrations in the system.

Comment A5. *(Pages 2-8 through 2-12) The comparison tests described here and presented on Figures 2-5 through 2-6 were incorrectly performed. These tests compared the entire biota sample to a subset of the entire sample, and therefore, do not provide meaningful results. When drawing inferences about the similarity of two groups within a sample, the sample must be divided into two, mutually exclusive groups before conducting the types of hypothesis tests described in this section (i.e., ANOVA [HSD] and equality of variances test). Therefore, no conclusions can be drawn about the similarity of the groups from the tests presented. These analyses should be conducted correctly to determine the propriety of grouping the subset groups with the rest of the sample in the subsequent analyses presented in Sections 2 and 3 of the report. Further, it is unclear from these analyses whether it is appropriate to include the seasonal subgroups into the subsequent analyses presented in Sections 2 and 3 of the report.*

Comment A6. *(Page 2-13, Paragraph 2) This paragraph references the tables of summary statistics for biota concentrations (Tables 2-3 through 2-5). These statistics are improperly presented. Statistics based on different tissue types (e.g. fillet, whole body, hepatopancreas) within a species are expected to be highly variable. Therefore, tissue types should be separated rather than grouped when calculating*

summary statistics. Qualitative observations made about these tables are meaningless because there is a high degree of variation among tissue types.

Comment A7. *(Page 2-14, Paragraph 1) Based on a qualitative examination of Figures 2-1 through 2-4, summary point 1 concludes that spatial trends are "shallow or non-existent." This does not appear to be true, as many of the plots presented on these figures show biota concentrations decreasing with RM.*

Comment A8. *(Page 2-15, Paragraph 1) Given that the lipid content was significantly lower in the post-2005 samples for three species and that no mechanism could be identified to explain the disparity, and given that "concentrations of several contaminants otherwise appear to decline in biota tissue with time," all trend analyses should have been performed on both a lipid-normalized and wet-weight basis. The wet-weight basis represents the concentrations to which receptors are exposed, and a natural decline in wet-weight concentrations would be a finding of great consequence to remedy selection.*

Comment A9. *(Page 2-16, Paragraph 1) Mean blue crab concentrations are compared to means of other species based on the summary statistics presented in Tables 2-3 through 2-5, which combine tissue types, and therefore, confound any meaningful inference. Different tissue types (e.g. fillet, whole body, hepatopancreas) are known to have very different organic contaminant concentrations within the same organism due to the varying lipid content. It is stated that blue crab and mummichog concentrations are lower than those of American eel. This statement is misleading. While some contaminants are greater in American eel, concentrations of 2,3,7,8-TCDD are considerably lower in American eel compared to blue crab or mummichog. Additional broad generalizations, such as "differences in organic contaminants… are consistent with trophic levels," are also misleading. Concentrations of 2,3,7,8-TCDD are independent of trophic level in the case of American eel, indicating that bioaccumulation is lower for 2,3,7,8-TCDD, as it may be with some of the other organic contaminants (e.g., PCBs, pesticides) and mercury.*

Comment A10. *(Page 2-17, Paragraph 3) The statistics concerning spatial trends are not presented, but should be an important part of the analysis given that the remedy is designed to remove sediment.*

Comment A11. *(Page 2-18, Paragraph 2) The two statements: "Overall, the diagrams show a high degree of variance within and among tissue types" and "The variance within the various studies is greatly reduced [by lipid normalization]" are not supported by the information presented (i.e., Figs. 2-1 through 2-4). Inferences about variance cannot be made from diagrams and can only be made by presenting the means*

and variances of tissue concentrations by species and tissue type. Further, reductions in variance can only be inferred by calculating and comparing the coefficient of variation (σ/μ) for each contaminant by species and tissue type on both a wet-weight and lipid-normalized basis. Therefore, the subsequent statement in this paragraph on page 2-18, indicating that a reduction in variability provides "support for this [lipid] basis of analysis," is baseless.

Comment A12. *(Page 2-19, Paragraph 1) The hypothesis testing shown on Figures 2-7 through 2-10 should have been conducted with the combined 1999 and 2000 concentration data. This would have resulted in higher statistical power to detect differences and would have avoided the use of a Tukey-Kramer adjustment of p-values where they were not needed.*

Comment A13. *(Page 2-19, Paragraph 3) Given that the wet-weight basis is the most important for exposure evaluations, and given that the apparent downward trend of lipid concentrations is unexplained, the trend analyses should have been conducted on both a wet-weight and lipid-normalized basis.*

Comment A14. *(Page 2-20, Paragraph 2) Figure 2-12, referenced in this paragraph, shows a statistically significant downward trend in both blue crab muscle and hepatopancreas. It is stated that this result conflicts with the muscle+hepatopancreas trend. No explanation is given. The RIR should discuss muscle+hepatopancreas as a tissue type that would be expected to be highly variable due to differences in sampling techniques affecting the relative proportions of each tissue type in a combined sample. This potential confounding factor of muscle+hepatopancreas tissue type (or any other type of whole-body sample type) is avoidable by analyzing and drawing inferences based on a more homogenous tissue type (e.g., muscle only, hepatopancreas only). Therefore, the fact that both muscle and hepatopancreas 2,3,7,8-TCDD concentrations decline with time is significant evidence of a reduction in exposure for blue crab. A similar analysis should be performed for all contaminants to confirm this trend.*

Comment A15. *(Page 2-21, Paragraph 1) The statement that the mean mummichog concentrations are "substantially less than white perch and American eel for organic contaminants and mercury, consistent with its trophic level" is misleading. For 2,3,7,8-TCDD, concentrations are greater in white perch, but lower in American eel, compared to mummichog. This is not consistent with trophic level.*

Comment A16. *(Page 2-22, Paragraph 4) The statement that 1999 mummichog samples were obtained from "caged fish" is inaccurate. Mummichog samples collected during the 1999/2000 Remedial Investigation Ecological Sampling Program (RI-ESP; Chemical Land Holdings, Inc. [CLH], 1999) were wild fish caught in baited traps*

making them comparable to the 2010 sampling program. Therefore, the result shown in Figure 2-2a, that mummichog concentrations in the 2010 sample were significantly lower than those of 1999, is a valid result and evidence of a decreasing trend in mummichog 2,3,7,8-TCDD concentrations. The finding that this trend is not shown on the lipid-normalized graph is explained by the difference in lipid measurements. Because there is no credible mechanism for a temporal decline in mummichog lipid concentrations, the disparity is likely explained by differences in measurement. Therefore, the downward trend supported by the wet-weight results cannot be refuted by the lipid-based results.

Comment A17. *(Page 2-25, Paragraph 1) The statement that "lipid-normalized concentrations for white perch yielded an increasing trend with time" is not supported by the results presented in Figure 2-10a. These plots indicate a decreasing trend with time for 2,3,7,8-TCDD and Total PCBs. Further, these tests should have been conducted with the combined 1999 and 2000 datasets to attain higher statistical power and to avoid the Tukey-Kramer adjustment of p-value where it is unnecessary.*

Comment A18. *(Page 2-25, Paragraph 1) Regarding temporal trends, an examination of Figures 2-3a and 2-3b show evidence of a decline in wet-weight concentrations of 2,3,7,8-TCDD and Total PCBs in the 2010 samples compared with the 1999 samples. This should be tested statistically.*

Comment A19. *(Page 2-25, Paragraph 3) It is stated that it is "unknown" why the mean 2,3,7,8-TCDD concentrations in American eel are not consistent with its trophic level (i.e., not higher than the other three species). It should be noted that 2,3,7,8-TCDD has a lower bioaccumulation rate than other contaminants.*

Comment A20. *(Page 3-2, Paragraph 2) NJ/NY Harbor data should not be combined with data from the LPR. Bioaccumulation modeling should be site-specific; exposure scenarios in NJ/NY Harbor are likely very different from those in the LPR.*

Comment A21. *(Page 3-4, Paragraph 1) The American eel samples include both whole body and whole body minus the head and viscera. These tissue types are not comparable and should not be combined in the same analysis.*

Comment A22. *(Page 3-12, Paragraph 3) This discussion of the 1999 mummichog sampling program (RI-ESP; CLH, 1999) is inaccurate. During the 1999 program, 45 co-located mummichog and sediment samples were collected from the LPR. No manipulation was needed for pairing. Because the sample size of the mummichog sample given in Table 3-1 is only 40, it appears that some of the available data were excluded from the analysis. No reason is given for the exclusion of this mummichog tissue data.*

Comment A23. *(Page 3-13, Paragraph 1) The median of the 2,3,7,8-TCDD concentrations were used to estimate the sediment exposure concentration for mummichog. While a median is an estimate of central tendency, it should never be used to estimate an exposure concentration. Even for small sample sizes, the sample mean is always the best unbiased estimate of the true mean. Using a median to represent exposure raises serious questions about the validity of this analysis, particularly because no manipulation of this dataset was needed (see comment above). In addition, the median was used for 2,3,7,8-TCDD only. For all other chemicals the mean was used. Since the median is lower than the mean, the BSAF for mummichog was overestimated for 2,3,7,8-TCDD but not the other chemicals.*

Comment A24. *(Page 3-13, Paragraph 3) Sediment pairing for the REMAP and CARP data is not comparable to the pairing in the LPR. The sample density of those programs was much sparser, adding much larger uncertainty to the estimation of an organism's sediment exposure.*

Comment A25. *(Page 3-31, Paragraph 3) One criterion that should have been included in the analysis is a test of the null hypothesis, expressed on page 3-24, that the* β *terms equal 1.*

Comment A26. *(Page 3-32, Paragraph 2) The plots shown on Figures 3-8 through 3-18 are regression residual plots, and therefore, do not assess the predictive ability of the model.*

Comment A27. *(Page 3-34, Paragraph 1) The confidence limits of the regression models given in Tables 3-5 and 3-6 are quite large compared to the mean predicted value. For example, confidence intervals for prediction of 2,3,7,8-TCDD in tissue range from -20% to as much as 124% of the mean in the range of proposed sediment PRGs leading to a high level of uncertainty in the calculation of sediment PRGs. For all chemicals modeled, confidence limits are as large as 5,000% of the mean. Over-prediction of tissue concentrations results in unnecessarily low sediment PRGs. Conversely, the under-prediction of tissue concentrations results in an erroneous assumption that a remedial alternative can achieve the expected risk reduction.*

Comment A28. *(Page 3-35, Paragraph 2) It is concluded, based on an examination of Figures 3-21 through 3-31, that there is direct evidence of a non-linear relationship between tissue and sediment. However, it could also be concluded that the addition of non-site data to the regression analysis is causing the apparent non-linearity, and therefore, it is unknown whether the relationship within the LPR is linear or not.*

Comment A29. *(Page 3-36, Paragraph 1) The regression plots in Figures 3-32 through 3-42 have no confidence bands; therefore, it is unknown whether the slope of the line could be consistent with that of the dotted line that indicates a linear relationship. In*

addition, no confidence intervals are given for the β terms, which obscure the degree of departure from linearity of these models.

Comment A30. *(Page 3-36, Paragraph 1) In Figures 3-21a and 3-32a for 2,3,7,8-TCDD in American eel, the slope of the regression line is greatly influenced by the few off-site data points added to the model. This results in the BSAF appearing to increase 10-fold with decreasing concentration (Fig. 3-21a). The BSAF in the range of LPR data is much lower (approximately 0.02) than the BSAF in the range of the off-site data (approximately 0.1), indicating that the sediment exposure concentration estimated for these off-site biota samples may have been incorrect. Further evidence of this is that the BSAFs from the USEPA database (http://www.epa.gov/med/Prods_Pubs/bsaf.htm) are more in line with that of the site data.*

Comment A31. *(Page 3-36, Paragraph 1) In Figure 3-32b for 2,3,7,8-TCDD in blue crab, the slope of the regression line is very close to the slope of the dotted line, and a statistical test should have been conducted to confirm whether bioaccumulation is increasing with decreasing sediment concentration by testing if the slope differs from one. In this case, similar to the American eel, the addition of off-site data appears to have greatly influenced the slope of the line, causing an increase in the BSAF at lower concentrations. Examination of Figure 3-21b indicates that, in particular, the addition of three off-site outliers with high leverage primarily influenced the slope of the line, resulting in inflated BSAF estimates at lower sediment concentrations.*

Comment A32. *(Page 3-36, Paragraph 1) In Figure 3-32c for 2,3,7,8-TCDD in mummichog, the slope of the regression line is highly influenced by the addition of four off-site data points. Examination of Figure 3-21c indicates that, in particular, the addition of two off-site outliers with high leverage primarily influenced the slope of the line, resulting in inflated BSAF estimates at lower sediment concentrations. These BSAFs are inconsistent with both site BSAFs and the BSAFs reported in the USEPA database, as depicted on the graphs.*

Comment A33. *(Page 3-36, Paragraph 3) In Figure 3-32d for 2,3,7,8-TCDD in white perch, the slope of the regression line is very close to the slope of the dotted line, and a statistical test should have been conducted to confirm this. Examination of Figure 3-21d indicates that there is little evidence that BSAFs increase with decreasing sediment concentration. Similar to the other three species, the addition of off-site data has resulted in inflated BSAF estimates.*

3. **Appendix D – Risk Assessment – These comments address a single, specific concept or section of Appendix D.**

Comment D1. *(General Comment) The BERA is not a true baseline assessment due to the lack of site-specific information, which leaves too much uncertainty to develop potential remedial actions. Overall, the BERA provides no more than a SLERA. While new (2009 to 2010) fish tissue and sediment data collected by the CPG were incorporated into the "screen," additional information from the CPG studies (e.g., benthic community surveys, toxicity, and bioaccumulation results) have not been added or evaluated.*

The assessment relies mostly on modeling of data collected from other sites and assessments of other species to make predictions on potential risk to the receptors of concern in the Passaic River. This is not sufficient for a baseline risk assessment on which PRGs and potential remedial action decisions are based (USEPA, 1997; 1998; 1999). There have been many studies of, and much data collected in, the Passaic River to date (i.e., Wenning et al., 1994; Iannuzzi et al., 1996; Wolfskill & McNutt, 1998; Wallin et al., 2002; Iannuzzi et al., 2002; Iannuzzi & Ludwig, 2004; 2005; Ludwig & Iannuzzi, 2005; Ludwig et al., 2010; and various studies conducted by the CPG), so much so that a more accurate representation of potential risk is possible. Furthermore, the evaluation only uses data collected from 2009/2010. All data collected under the Superfund process should be incorporated (USEPA 1997; 1998; 1999). Specific comments are below.

The wildlife exposure parameters are extremely conservative "default" values obtained directly from the Wildlife Exposure Factors Handbook (USEPA, 1993). A more in-depth evaluation should be conducted, including the incorporation of site-specific exposure factors and parameters. For example, Henning et al. (1999) provides a detailed analysis of exposure factors for the great blue heron that should be considered. Further, mink have never been observed and are unlikely to inhabit the very industrialized environment of the LPR in which no mink habitat exists. Specific comments are below.

Due to the lack of an in-depth analysis (i.e., the screening-level nature of this risk assessment/characterization), this BERA presents too many uncertainties to accurately predict risks in the system. These uncertainties reduce the value of the assessment and bring into question the validity of or need for ecologically based PRGs or remedial actions. In fact, ARCADIS' analysis of the site-specific data suggests that no actionable ecological risks exist (see general comments above).

Section 1 – Introduction

Section 2 – Available Data

Section 2.2 – Data Compilation for the BERA

Comment D2. *(Page 2-2, Paragraph 1) The revised FFS only includes sediment data collected in 2009/2010. This limited dataset does not include the vast amount of sediment data collected in the Passaic River to date. All surface sediment data collected under the Superfund process should be included (USEPA, 1997; 1998; 1999). Likewise, the tissue dataset is limited to 2009/2010 and should include additional tissue data collected since 1999/2000. This allows for a more robust analysis because the sample size is larger.*

Comment D3. *(Page 2-2, Paragraph 1) It is unclear how reconstituted whole-body samples were calculated. This should be explained so that the calculations are transparent. In addition, data tables for individual components used in the calculations should be presented.*

Section 2.3 – Data Usability Evaluation

Comment D4. *(Page 2-4, Tissue Data, Paragraph 1) Additional data reports recently prepared by Windward Environmental, LLC (Windward), on behalf of the CPG, should be incorporated into the BERA and should be included in the bulleted list. These reports document the latest data and information collected from along the entire 17-mile stretch of the river, including the lower 8-mile focus of the FFS. These reports include, but are not limited to:*

- Windward. 2011a. 2009 *Bioaccumulation Tissue Chemistry Data for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. September 19.
- Windward. 2011b. *Sediment Toxicity Test Data Report for the Lower Passaic River Study Area Fall 2009 Investigation*. Prepared on behalf of the Cooperating Parties Group. February 28.
- Windward. 2012a. *2011 Caged Bivalve Study Data for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. July 18.
- Windward. 2012b. *2010 Small Forage Fish Tissue Chemistry Data for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. July 18.
- Windward. 2013a. *Fall 2009 Benthic Invertebrate Community Survey and Benthic Field Data Collection for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. April 12.

- Windward. 2013b. *Habitat Identification Survey Data Report for the Lower Passaic River Study Area Fall 2010 Field Effort*. Prepared on behalf of the Cooperating Parties Group. April 12.

Comment D5. *(Page 2-4, Sediment Data, Paragraph 2) Additional sediment data have been collected along the river since 2004. These should be included in the bulleted list.*

Section 2.3.1 – Method Detection Limits

Comment D6. *(Page 2-7, Sediment Data, Paragraph 2) The adjustment of the 2008 2,3,7,8-TCDD data by a factor of 1.9 has obscured temporal sediment trend analysis and caused an overstatement of the sediment risk. The adjustment of the 2008 sediment data for dioxins and furans was arbitrary; the bias in the split-sample results found for other compounds, specifically polycyclic aromatic hydrocarbons (PAHs) and PCBs, was ignored by Region 2. This bias was first reported by the USEPA contractor Malcolm Pirnie, Inc. A technical memorandum addressed to Alice Yeh (USEPA) and Elizabeth Buckrucker (USACE) titled "Statistical Comparison of 2008 Low Resolution Split Sample Sediment Data Lower Passaic River Restoration Project W912DQ-08-D-0017, Task Order 0010, Correspondence. October 5, 2009" (Malcolm Pirnie, Inc. 2009) details the results of a comparison of the split samples for metals, dioxins/furans, PAHs, PCBs, pesticides, and total organic carbon. The report provides a table of results showing that the Region 2 splits had concentrations that were statistically significantly greater for many of the PAH and PCB compounds, in addition to the dioxin/furan compounds. Total organic carbon and seven of nine metals were found to be statistically significantly lower in the Region 2 splits. The memorandum concludes that "the PAH chemicals evaluated show systematic bias at the 95 percent confidence level" and that "PCB homologues and congeners evaluated show differing agreements." It is important to note that this analysis was applied to only six individual PCB congeners, and that there was little to no discussion of these results compared to the discussion of polychlorinated dibenzo-p-dioxin/polychlorinated dibenzofuran (PCDDs/PCDFs), while the results presented in the memorandum clearly demonstrated a similar bias for other PAH and PCB compounds. In the Computer Sciences Corporation (CSC) report (CSC, 2010), the geometric mean and 95% confidence intervals of the ratios of the Columbia Analytical Services (CAS) result values to those of AXYS result values were calculated and reported. The individual dioxin/furan congener-specific geometric mean ratios ranged between 0.53 (2,3,7,8-TCDD) and 0.91 (1,2,3,7,8-pentachlorodibenzofuran). For seven of the 14 dioxin/furan congeners evaluated by CSC, "the confidence interval did not include 1.0, thus indicating that the bias between laboratories was statistically significant at the 95% confidence level." An analysis of the PAH and PCB data was conducted (ARCADIS, 2011) in a*

similar fashion to that described in the CSC 2010 report for the dioxin/furan results. As was the case with the split samples analyzed for dioxins/furans, 30 samples were collected and split between two laboratories for PAH and PCB characterization. The PAH and PCB split samples collected by Region 2 were analyzed by AXYS; however, unlike split samples analyzed for dioxins/furans, the CPG PAH and PCB samples were analyzed by TestAmerica in Knoxville, TN. Geometric mean ratios for the 10 PCB homologue groups ranged from 0.57 to 0.92. Individual PCB congener geometric mean ratios ranged from 0.44 to 1.6. Out of 10 PCB homologue groups, 10 geometric mean ratios were less than 1.0 and five were statistically significantly less than 1.0. Out of 127 PCB congeners, 118 geometric mean ratios were less than 1.0 and 45 statistically significantly less than 1.0. By the logic applied in the CSC report, the PCB results are biased. Individual PAH geometric mean ratios ranged from 0.11 to 0.82, and 20 of the 31 ratios were statistically significantly less than 1.0. By the logic applied in the CSC report, the PAH results are biased as well. In conclusion, the geometric mean ratios of two other classes of chemicals, independent of the dioxin/furan analyses and independent of the CAS laboratory, point to bias when similar logic is applied, yet these results were ignored by USEPA when the decision was made to adjust the dioxin/furan datasets.

Comment D7. *(Page 2-8, Data Usability Summary, Paragraph 1) Replace the term "censored" with "qualified."*

Comment D8. *(Page 2-8, Data Usability Summary, Paragraph 1) Standard 95% upper confidence levels (UCLs) were used as exposure point concentrations (EPCs) for sediment, which are a conservative estimate of potential exposure. More accurate estimates of potential exposure should be conducted by spatially weighting the data (e.g., Theissen polygons). The ARCADIS (2014a) technical memorandum, included as Attachment 1 to these comments, provides results from such an analysis. Spatially weighted data account for areas of the river that may lack sufficient analytical data.*

Section 2.4 – Data Standardization and Summary Procedures

Comment D9. *(General Comment) Please clarify whether PCB congeners include dioxin-like PCB coplanar congeners.*

Table and Figure Comments

Comment D10. *(Table 3-1) This table should be moved to Section 2 because it discusses fish tissue data in terms of ecological feeding guilds and is actually more appropriate for the BERA.*

Comment D11. *(Figure 2-1) Figure 2-1 implies that fish and crabs were collected from only four sampling locations along the 8-mile stretch of river. This depiction is inaccurate. Attachment 1-1 clearly provides individual coordinates for all tissue data collected. The figure does not accurately represent the sampling locations for the tissue samples. Different symbols should be presented for each species captured. An additional map for the invertebrate data not yet included in this BERA (e.g., bioaccumulation studies, toxicity information) should also be included.*

Comment D12. *(Figure 3-2) It is unclear whether these data are based on the entire 17-mile stretch of river or just the lower eight miles. This figure is only called out in Section 3, Human Health Risk Assessment (HHRA). The fish tissue data and discussion that is part of the HHRA (specifically, the first three paragraphs of Section 3.4.2) should be moved to Section 2, as this discussion focuses on ecological feeding guilds.*

Comment D13. *(Figure 3-3) Title should say "….Fish Fillets".*

Comment D14. *(Figure 3-4) Clarify if these are whole body or fillets or both.*

Section 4 – Baseline Ecological Risk Assessment – Baseline Conditions

Comment D15. *(Page 4-1, Paragraph 1) The title says "baseline conditions," but the first sentence also states that future conditions are evaluated. Explain how future conditions are evaluated in this section or delete the term "future conditions," as they are evaluated in the next section (Section 5).*

<u>Section 4.1 – Problem Formulation</u>

Comment D16. *(General Comment) Failure to Properly Capture the Setting and Problem Formulation.*

The BERA fails to recognize the general lack of suitable habitat for wildlife receptors along the industrialized Study Area, and this results in an inaccurate portrayal of potential exposures in the FFS Study Area, including the selection of mink as a receptor for the risk assessment, when no mink or mink habitat exist in the LPR. No qualitative discussions regarding the lack of sufficient suitable habitat for wildlife are presented. Results of bird, mammal, or wildlife surveys are not provided. The Passaic River has been studied for more than 20 years (see, for example, Wenning et al., 1994; Iannuzzi et al., 1996; Wolfskill & McNutt, 1998; Iannuzzi & Ludwig, 2000; Wallin et al., 2002; Iannuzzi et al., 2002; Iannuzzi & Ludwig, 2004; 2005; Ludwig & Iannuzzi, 2005; Ludwig et al., 2010; and the various CPG study reports). Substantive historical data and information exist and should be incorporated into the Problem Formulation (and the rest of the BERA), even if only as a qualitative line of evidence (USEPA, 1997; 1998; 1999). Section 3.3 of the RIR provides a better (albeit limited) summary of the habitat surveys conducted to

*date along the Passaic River and demonstrates the lack of quality habitat along the riverbanks. For example, according to Ludwig and Iannuzzi (2005), only approximately 18% of the riverbanks supports any kind of ''natural'' ecosystem; the vast majority is occupied by bulkhead or riprap. Even the remaining 18% is highly disturbed, remnant habitat consisting of the invasive common reed (*Phragmites australis*), and weedy plants typical of unmanaged, urban, open spaces.*

The selection of wildlife receptors of concern, especially mammals, should consider the limited habitat along the riverbanks. Note that only squirrels, chipmunks, groundhogs (herbivores), and rats (omnivores) were periodically observed along the riverbanks during the CPG field investigation (Windward, 2013b). The only observed mink tracks were located near the Dundee Dam, which is above the 17-mile mark and well beyond the 8-mile boundary of the Study Area for the FFS. Therefore, mink should be eliminated as a receptor for the FFS Study Area.

Section 4.1.3 – Conceptual Site Model

Comment D17. *(Page 4-14, last paragraph) Invertebrates that live in the sediment should not be evaluated through sediment chemistry data only. They should be evaluated through additional lines of evidence, including, but not limited to, the bioaccumulation and toxicity data currently available (e.g., Iannuzzi et al., 2007; Kay et al., 2008), as well as those from recent CPG studies/reports:*

- Windward. 2011a. *2009 Bioaccumulation Tissue Chemistry Data for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. September 19.
- Windward. 2011b. *Sediment Toxicity Test Data Report for the Lower Passaic River Study Area Fall 2009 Investigation*. Prepared on behalf of the Cooperating Parties Group. February 28.
- Windward. 2012a. *2011 Caged Bivalve Study Data for the Lower Passaic River Study Area*. Prepared on behalf of the Cooperating Parties Group. July 18.
- Windward. 2013a. *Fall 2009 Benthic Invertebrate Community Survey and Benthic Field Data Collection for the Lower Passaic River Study Area*. Prepared on behalf of the CPG. April 12

Comment D18. *(Page 4-15, Paragraph 2) The BERA states that mink are a "possible" resident species. Because the area is so highly industrialized, mink are an unlikely receptor along the riverbank and should be eliminated from consideration. Predominant mammals observed in the Study Area are more human-tolerant animals, such as those documented and observed during the CPG survey in 2010 (e.g., rats, squirrels, chipmunks), none of which is piscivorous (Windward, 2013b).*

The purpose of the BERA is to reduce the uncertainties presented in the SLERA. Evaluating risks to a "possible" species does not reduce the uncertainties in the evaluation. The following paragraph states the unlikelihood that reptiles and amphibians reside in the Study Area. The same argument can be made for mink. Just because the receptor has many toxicity data and is thought to be sensitive to PCBs and dioxins, does not mean that it is an accurate, representative receptor for this highly industrialized area. The rationale for not including amphibians and reptiles applies as much, or more so, to mink. Therefore, mink should also be excluded from this assessment.

Further, the use of mink as an ecological receptor for the Study Area is counter to USEPA's (1999) Principle No. 1, because mink are not present and will not be present due to the lack of suitable habitat. This is true even of individuals, let alone "healthy local populations," as recommended under Principle No. 1. Therefore, mink are neither ecologically relevant for the Study Area (per this principle) nor exposed to site-related contaminants. The expectation that mink are sensitive to site-related contaminants is not sufficient for their selection as an ecological receptor. USEPA (1998) warns against this narrow and selective assessment of stressors, stating that: "A risk assessment that is too narrowly focused on one type of stressor in a system (e.g., chemicals) could fail to consider more important stressors (e.g., habitat alteration)." For these reasons and to comport with guidance, mink should be removed from evaluation in the BERA and FFS.

Comment D19. *(Table 4-10) Testable Hypotheses. Each of these hypotheses is a test of whether measured COPEC concentrations "might" adversely affect the assessment endpoint. This minimal level of confidence is appropriate for a screening assessment, but insufficient for a BERA or determining the need for remedial actions. Region 2 failed to follow its own Ecological Risk Assessment Guidance for Superfund (USEPA, 1997; 1998; 1999), which requires site-specific data to reduce uncertainties in the results of the screening-level assessment. Therefore, the entire process is flawed and cannot be used to support remedial decisions.*

Section 4.1.5 – Selected Measures of Effect

Comment D20. *(Page 4-17, Sentence 1) The first sentence is incorrect as written. Why does the magnitude of the exceedances of sediment-screening benchmarks preclude the need for site-specific data? It is actually quite the opposite. Per USEPA Ecological Risk Assessment Guidance for Superfund (USEPA, 1997; 1998), the exceedance of benchmarks in a SLERA moves the risk assessment to the next step, which is to collect site-specific information and perform a BERA. The lack of site-specific information in this BERA provides no new information and fails to move the ecological risk assessment beyond a simple data screen, as presented in the Draft*

FFS in 2007. Refer to General Comment 1. The "BERA," as presented, cannot lead to a scientific management decision point regarding ecological risks present in the LPR.

Comment D21. *(General Comment, Measure of Effects, three bullets) There are only three measures of effect, all of which rely on a simple data screen. There is substantial uncertainty associated with using very limited lines of evidence, such as relying on sediment benchmarks to evaluate potential risks to benthic invertebrates, CBRs to evaluate potential risks to fish, and TRVs to evaluate potential risks to wildlife. See below for an expanded discussion.*

Sediment Benchmarks

One of the major flaws of the benthic invertebrate evaluation in the BERA developed by USEPA Region 2 is that the benthic invertebrate community was evaluated solely by a comparison of sediment chemical data to literature-based, sediment-screening benchmarks or SQGs. SQGs were developed to evaluate the need for additional investigations and are not promulgated criteria to be used as cleanup levels. Numerical SQGs (e.g., effects-range low and median [ER-L/ER-M], threshold and probable effects levels [TEL/PEL] were developed to provide an effects-based, interpretive tool for assessing the quality of sediments. These values were intended to represent either the chemical concentrations below which adverse biological effects would not be expected, or those levels above which effects, such as acute toxicity, would be considered likely to occur. To derive SQGs, statistical evaluations were conducted using hundreds of individual data points from toxicity tests to identify sediment concentrations most commonly associated with observed effects, with the ultimate intent of using SQGs to quickly and easily "screen" chemical data. They can be used to classify sediment samples with regard to their potential for toxicity, to identify chemicals of potential concern, and to prioritize areas of concern. None of the SGQs have been promulgated and implemented for standards or U.S. criteria (Long & MacDonald, 1998).

However, oftentimes these SQGs are misused (as they appear to have been in the FFS BERA). SQGs cannot and should not be used to reliably predict actual site-specific toxicity from any particular chemical. The toxicity tests relied upon to develop the SQGs were frequently conducted using bulk sediment from industrial rivers and harbors that contained various mixtures of chemicals, making it difficult to establish cause-effect relationships for any particular chemical. In addition, SQGs do not account for additional physical factors in the system, such as, but not limited to, grain size, temperature, pH, salinity, and ammonia, that could affect bioavailability of chemicals or act as stressors themselves. As a result, instead of simply performing a screen of the sediment data, a full evaluation of the SQT data

collected by the CPG should be the primary measurement endpoint. These data include chemistry, toxicity, and benthic invertebrate community analysis as described below. Current site-specific benthic/sediment quality triad data and analyses are available in Iannuzzi et al. (2007) and Kay et al. (2008), among others. An alternative evaluation of the benthic invertebrate endpoint is provided in the attached Risk Assessment memo.

A very substantial flaw in the BERA is the inclusion of a sediment benchmark for direct toxicity of 2,3,7,8-TCDD (dioxin) for benthic (infaunal) invertebrates. As discussed by USEPA (2008) and Iannuzzi et al. (1995), dioxins/furans have never been shown to be directly toxic to benthic invertebrates. Unlike vertebrate animals (e.g., fish, birds, mammals) invertebrates lack the Ah cellular response that mediates toxicity of dioxins/furans (Hahn, 1998). Available sediment benchmarks for dioxins/furans are based on food web bioaccumulation and potential effects in vertebrate organisms. In fact, Barber et al. (1998) conducted a spiked sediment bioassay with 2,3,7,8-TCDD using one of USEPA's standardized marine/estuarine test organisms—the amphipod A. abdita*—that is considered by scientists to be one of the most sensitive organisms to sediment contaminants. Barber et al. (1998) found no toxicity at sediment exposure concentrations of 2,3,7,8-TCDD as high as 10 mg/kg (i.e., orders-of-magnitude higher than concentrations in surface sediments in the LPRSA). Similarly, the site-specific toxicity testing documented by Iannuzzi et al. (2007) and Windward (2011b) found no evidence of an exposure-response relationship between dioxins/furans in sediments and toxicity to invertebrate test organisms (*A. abdita *and polychaete worms) (See General Comment 4).*

Furthermore, the lack of observed oysters in the LPR, as documented by Iannuzzi et al. (2002) and Windward (2013a), precludes the use of these organisms in representing the infaunal organisms that dominate the benthic community. Minimal mollusks were observed in the lower portion of the Passaic River, and those species that are present are not as sensitive to chemical contamination as are oysters. Refer to General Comment 4.

Critical Body Residues

Likewise, CBRs are literature-based values for which few data are available for many constituents. As noted for the screening benchmarks derived for sediment, there is substantial uncertainty associated with the development of CBRs; therefore, comparisons should be cautiously interpreted. As with sediment, concentrations in tissues below these values can be interpreted as not causing an effect, but occurrence of concentrations above the CBRs indicates only that the potential for impact exists, but does not necessarily indicate a direct cause and

effect. Recent and historical literature was reviewed for fish and avian egg CBRs, as presented in the attached Risk Assessment memo. These values were compared to whole-body fish tissue concentrations and cormorant egg tissue concentrations as another line of evidence that demonstrates the lack of ecological risks from 2,3,7,8-TCDD in the Study Area.

Toxicity Reference Values for Birds

Region 2 appears to have selected TRVs based on non-target species and from conditions that are not reflective of the exposure or uptake of chemicals to wildlife receptors of concern in the Passaic River. Examples of the species that the TRVs are based upon include turkeys, Japanese quail, rats, mallards, red-winged blackbirds, pigeons, mice, chickens, and pheasants. None of these animals are piscivorous. Avian TRVs should not be based on reproductive endpoints in a domesticated species, such as chickens or Japanese quail, because these species are bred to have unnaturally high egg-laying rates and have very different toxicological reproductive sensitivities than wild bird species. It appears that no new literature searches or values for TRVs or CBRs were incorporated into the BERA.

Laboratory and field data should be combined, where feasible, to provide a realistic estimate of the concentrations of constituents that are likely to cause effects. For example, Seston et al. (2010) provide estimates of risk to great blue heron exposed to dioxin in the Tittabawassee River Study Area. Mean concentrations of PCDD/PCDFs in great blue heron eggs ranged from 45 ng/kg to 67 ng/kg wet weight for the rookeries studied, with a maximum concentration of 210 ng/kg wet weight. Minimal risk of adverse population-level effects was predicted when exposures measured in tissues of great blue heron collected from rookeries within the Tittabawassee River were compared with appropriate TRVs. This prediction is consistent with site-specific measures of population condition, which included clutch size and number of nestlings per successful nest (Seston et al., 2010).

Furthermore, there is a wide range of TRVs and CBRs in the literature that should be presented and considered. Refer to the ARCADIS (2014c) technical memorandum, provided as Attachment 4 to these comments, for a more complete range of TRVs. If ranges of fish and wildlife CBRs and TRVs from the literature are evaluated for the species of concern or species similar to those that utilize the LPRSA, the results of the risk calculations would show that risk is de minimis, *and that no ecological PRGs are warranted (see General Comment 5).*

<u>Section 4.2 – Ecological Exposure Assessment</u>

Comment D22. *(Page 4-19, Paragraph 1) Include the more recent benthic survey results from the CPG (see Windward, 2013a).*

Section 4.2.1 – Ecological Exposure Areas

Comment D23. *(Page 4-20 and Page 4-21, Paragraph 1) The entire eight-mile stretch of the Passaic River should not be characterized as a single exposure area. Additional effort should be made to focus on those portions of the Passaic River that actually provide habitat for wildlife and fish. A SWAC using a Theissen polygon approach is a more accurate method for this evaluation. Results of such an evaluation are provided in the ARCADIS (2014a) technical memorandum, provided as Attachment 1 to these comments.*

Comment D24. *(Page 4-21, Paragraph 2) The extent to which heron feed on larger non-forage fish is minimal; therefore, the "reasonableness" of this scenario is also minimal. Generic fish data include older, higher trophic-level fish, which likely leads to overestimating exposure to heron-consumed forage fish for biomagnifying COPECs. Without length information for the fish tissue data, it is difficult to evaluate the appropriateness for using the generic fish EPC as prey items for the great blue heron. EPCs calculated using whole-body tissue data for generic fish include American eel, white perch, white catfish, brown bullhead, common carp, smallmouth bass, and white sucker. Great blue heron consume fish that are generally between 5 and 30 cm (Henning et al., 1999). Using a probability density function, the mean size of fish reported by Henning et al. (1999) is 17.5 cm. Therefore, many individual fish that were incorporated into the generic diet (e.g., common carp, American eel, and catfish) for the great blue heron are too large and should be removed from the dataset.*

Section 4.2.2 – Exposure Point Concentrations

Comment D25. *(Page 4-22, EPCs, Paragraph 1)*

Baseline EPCs evaluated for all media (both abiotic and biotic) were calculated as the 95% UCL of the arithmetic means of the available data. Sedentary infaunal benthos do not integrate sediment exposures as do more mobile receptors such as fish and wildlife and, as a result, the exposures (and risks) encountered by this group may not be fully characterized using a single EPC based on the 95% UCL. Attachment 7 includes an assessment of the effects of spatial variability in contaminant concentrations within the FFS Study Area for each receptor group.

Although individual sedentary infaunal benthos do not spatially integrate exposures, individuals are not the assessment endpoint; the benthic community as

a whole (or whole populations within the community) is the endpoint. The spatial extent of exposure is highly relevant for the overall community. The 95% UCL is overly conservative and does not take into account site-specific attributes, including spatial variability and site use. A SWAC or a more reasonable, realistic estimate of the mean is more appropriate for a BERA.

Comment D26. *(Page 4-23, Benthic Invertebrates) Region 2 inappropriately used blue crab data to represent the vast community of benthic invertebrates. Infaunal invertebrates, such as polychaetes, and sessile invertebrates, such as bivalves, represent very different feeding guilds and different trophic levels than blue crabs. Additional benthic invertebrate data collected by Iannuzzi et al. (2007), as well as data from the CPG bioaccumulation study and bivalve tissue data from the caged bivalve CPG study (Windward, 2013b; 2012a), should be incorporated.*

Section 4.2.3 – Modeled Tissue Residues

Comment D27. *(General Comment) Overall, this section is confusing, lacks transparency, and does not appear to be relevant. Additional information is needed to defend these modeled concentrations, which are based upon different receptors from other Study Areas. ARCADIS (2014c)—Attachment 4 to these comments—provides an alternative evaluation of ecological risks for avian eggs.*

Comment D28. *(Page 4-24, Paragraph 1) "The lack of appropriate fish-to-egg transfer factors for some COPECs results in the potential risks to this life stage being underestimated, as discussed in Section 4.5." This would be the case only to the extent that the other COPECs have significant maternal transfer and for which egg concentrations have been shown to be reasonable predictors of adverse effects.*

Comment D29. *(Page 4-24, Bottom paragraph and equation) Because herring gulls are not a receptor for evaluation in this BERA, they should not be used as a species for modeling. They are opportunistic and are often observed foraging carrion and garbage from landfills and the urban center in general (refer to General Comment 5).*

Comment D30. *(Page 4-25, Paragraph 1) For the average lipid content of fish, why are only the American eel and white perch used? All site-specific fish lipid data should be pooled to provide the average lipid content.*

Comment D31. *(Page 4-25, Fish Eggs) There are site-specific mummichog egg lipid data available that appear to have been used in the BMF. However, the use of lipid data in lake trout (salmonid) eggs from a Great Lakes freshwater system, taken from Cook et al. (2003), does not inform a risk assessment of a tidal, brackish water system. The*

Study Areas are two completely different systems with different receptor species of fish and birds (refer to General Comment 5).

Comment D32. *(Page 4-25, Avian Eggs) The extrapolation of data from gull eggs and alewife BMFs from a Great Lakes freshwater system is not applicable or valid. Neither species are the focus for concern in the Passaic River. Without site-specific bird egg data, an avian egg evaluation cannot be conducted (refer to General Comment 5).*

Comment D33. *(Page 4-26, Paragraph 2) The comparison made here lacks scientific basis. There is no connection between modeled gull egg concentrations in the Passaic River (the use of which is unfounded, see previous comment) and cormorant egg concentrations in Newark Bay. Gulls and cormorants are separate species, have different size eggs that contain different lipid content as a result of different diets, and the Study Areas are different. The cormorant data from Newark Bay (Parsons, 2003) showed that, despite exposure to the contaminants of potential concern, including dioxins/furans in the Newark Bay system (which includes the Passaic River in the foraging range), there were no apparent reproductive effects. This direct evidence should be included in the BERA in place of non-site-specific modeling and extrapolation, which is baseless for this species (refer to General Comment 5).*

Section 4.2.4 – Wildlife Dose Model

Comment D34. *(General Comment) The fate and transport model indicates a high degree of chemical contamination in the dissolved phase, which can be linked to sediment transport from upriver or from Newark Bay. As such, it is surprising that the surface water pathway was not evaluated in the BERA. The analysis should include surface water in the food web dose model to evaluate the percentage of risk from the dissolved fraction.*

Comment D35. *(Page 4-27, Paragraph 1) Refer to comments in Table 4-11.*

Comment D36. *(Page 4-27, Paragraph 1) Results from the Tierra bird surveys (e.g., Ludwig et al., 2010) of the Passaic River should be included in the list of avian surveys provided. As documented in these surveys, herons do not remain on-site year-round; there is no rationale for a resident heron evaluation. USEPA Region 2 claims the resident heron evaluation is necessary due to the lone heron found during the winter months along the LPR (Ludwig et al., 2010). However, as discussed in the Ecological Risk Assessment Guidance for Superfund (USEPA 1997), ecological risk assessments focus on populations of organisms, not individuals. The resident heron should be eliminated from evaluation.*

Comment D37. *(Page 4-27, last paragraph)*

The percentage of different prey in the typical heron diet was presumed to consist of 85% fish and 15% macroinvertebrates, with an additional 5% of the daily food ingestion rate assumed to consist of surficial sediment incidentally consumed during foraging activities.

Sediment intake is being double-counted because fish and blue crabs were not depurated prior to analysis and use as tissue concentrations in the dietary exposure model. As such, the fish and crabs contain sediment that is being ingested, the concentration of which is being added to the incidental sediment ingestion rate value in the model. The incidental sediment ingestion rate is too high and should be adjusted to a lower value. For example, in the Hudson River BERA (USEPA, 2000c), a sediment ingestion rate of 2% was used for the great blue heron based on best professional judgment and Eckert and Karalus (1988). In addition, Beyer et al. (1994) recommends a rate of less than 2% for the blue-winged teal and ring-necked duck. As such, a value of 2% is considered conservatively representative of the sediment ingestion rate for the great blue heron.

Comment D38. *(Page 4-28, Paragraph 1) Generic fish data include older, higher trophic-level fish, which likely overestimates exposure to heron-consuming forage fish for biomagnifying COPECs. Without length information for the fish tissue data, it is difficult to evaluate the appropriateness for using the generic fish EPC as prey items for the great blue heron. EPCs calculated using whole-body tissue data for generic fish include American eel, white perch, white catfish, brown bullhead, common carp, smallmouth bass, and white sucker. It is more realistic to only include forage fish in the diet of great blue heron. Great blue heron consume fish that are generally between 5 and 30 cm (Henning et al., 1999). Using a probability density function, the mean size of fish reported by Henning et al. (1999) is 17.5 cm. Any fish larger than 30 cm should be eliminated from this evaluation. This includes carp, white catfish, and some of the American eel data.*

Comment D39. *(Page 4-28, Paragraph 2)*

Mink. Similar to the avian exposure model, literature values for home range, ED and BW were used to estimate the SUF, EF, and BW input parameters for the mink receptor, respectively. The SUF term was assumed to be 1 based on published home range data for adult females in a heavily vegetated riverine habitat in Montana (i.e., 8 hectares [Mitchell 1961]); resident minks were assumed to actively forage throughout the year in the Lower Passaic River (i.e., EF = 1).

There are no resident mink. The urbanized shoreline of the Study Area does not constitute a viable mink habitat. Mink should not be included in this FFS BERA. Risk-management decisions should only be made based on actual exposures that can occur in the lower 8 miles of the LPRSA (USEPA, 1997; 1998; 1999) (refer to General Comment 6).

Section 4.3 – Ecological Effects Assessment

Section 4.3.1 – Effects Data Evaluation

Comment D40. *(Page 4-29, Paragraph 2) The last sentence of this paragraph mentions that site-specific toxicity data were not included in this analysis. Site-specific data exist and should be included, as required by USEPA (1997; 1998; 1999). Toxicity test results, including those from Iannuzzi et al. (2007) and Kay et al. (2008), should be considered, as well as the recent CPG toxicity data (Windward, 2013b).*

Comment D41. *(Pages 4-30 and 4-31) A substantial flaw in the BERA is the inclusion of a sediment benchmark for direct toxicity of 2,3,7,8-TCDD (dioxin) for benthic (infaunal) invertebrates. As discussed by USEPA (2008) and Iannuzzi et al. (2005), dioxins/furans have never been shown to be directly toxic to benthic invertebrates. Unlike vertebrate animals (e.g., fish, birds, mammals), invertebrates lack the Ah cellular response that mediates toxicity of dioxins/furans (Hahn, 1998; Hahn, 2002; Butler et al., 2001). Therefore, a wide variety of invertebrates (including clams and shrimp) are recognized as being insensitive to 2,3,7,8-TCDD-induced toxicity (USEPA, 2008). Available sediment benchmarks for dioxins/furans are based on food web bioaccumulation and potential effects in vertebrate organisms. In fact, Barber et al. (1998) conducted a spiked sediment bioassay with 2,3,7,8-TCDD using one of USEPA's standardized marine/estuarine test organisms—the amphipod* A. abdita*—that is considered by scientists to be one of the most sensitive organisms to sediment contaminants. Barber et al. (1998) found no toxicity at sediment exposure concentrations of 2,3,7,8-TCDD as high as 10 mg/kg (i.e., orders-of-magnitude higher than concentrations in surface sediments in the LPRSA). Similarly, in a site-specific SQT study for the lower 6 miles of the LPRSA, Iannuzzi et al. (2007) found no evidence of an exposure-response relationship between dioxins/furans in sediments and toxicity to invertebrate test organisms (*A. abdita *and polychaete worms) (See General Comment 4).*

The USEPA calculated the potential sediment toxicity risks for all COCs in this BERA, ***except*** *2,3,7,8-TCDD (and dioxins/furan TEQ), using available (published) sediment-screening benchmarks. For 2,3,7,8-TCDD, the USEPA used a new non-published and non-peer-reviewed sediment toxicity benchmark recently developed*

by the USFWS for the site (3.2 ng/kg or ppt), presumably because no such values are available in the literature for direct toxicity to invertebrates. The basis of this new benchmark is a highly flawed extrapolation from a limited oyster study conducted by Wintermeyer and Cooper (2003) that, according to USEPA and USFWS, linked 2,3,7,8-TCDD in Newark Bay to oyster reproduction effects.

Notwithstanding the inappropriateness of calculating a sediment toxicity benchmark for dioxins/furans, the fundamental conclusion from the Wintermeyer and Cooper (2003) study regarding the linkage of 2,3,7,8-TCDD in Newark Bay to oyster reproduction issues despite the presence of a large range of other stressors to oysters in Newark Bay is flawed, and the derivation by USFWS of a sediment benchmark using a baseless BSAF compounds the flaw in this benchmark (see General Comment 4).

Risks for all COPECs, except 2,3,7,8-TCDD, were estimated by comparing sediment concentrations to screening benchmarks. Region 2 should not use the oyster-derived value (Kubiak et al., 2007), which is based on a single, unreproduced study, to characterize ecological risks and developed PRGs for the Passaic River. Furthermore, the rationale for using the 2,3,7,8-TCDD value to achieve "sediment concentrations that will allow the restoration of historically rich oyster beds (Kurlansky, 2006) in areas downstream of the Passaic River, including Newark Bay" (FFS, Appendix E, Section 2.2, page 2-6) is unrealistic given the complexity and variety of environmental stressors present in Newark Bay, and specifically around Shooters Island where the oyster field study (Wintermeyer & Cooper, 2003) was conducted.

The field component of the Wintermeyer and Cooper (2003) study included transplanting oysters for 10 months at three study sites: Newark Bay (near Shooters Island), Arthur Kill (near Pralls Island), and Raritan Bay (Sandy Hook Bay). The sediment chemistry at these three sites differs; chemistry observed around Shooters Island in Newark Bay is especially complex given the large number of sources and inputs to the system. Some chemicals present in Newark Bay (and the Arthur Kill) were not accounted for, analyzed for, or observed in Sandy Hook Bay. Known chemicals in Newark Bay and Arthur Kill sediment that have no available data in Sandy Hook Bay include bis(2-ethylhexyl) phthalate (BEHP; plasticizers), PCNs ("dioxin-like" compounds), and PBDEs (flame retardants). Further, a number of pesticides (such as aldrin, dieldrin, methoxychlor, heptachlor, heptachlor epoxide, Total $\alpha+\gamma$ chlordane, and Total DDT [4,4']) have been found in Newark Bay and Arthur Kill sediment, and in generally higher concentrations around Shooters Island and Pralls Island (relative to the rest of Newark Bay). In most cases, these pesticides not detected in the Sandy Hook Bay sediment samples (USEPA, 2003). In fact, of all of the surface sediment samples collected by Region 2

as part of the REMAP in the greater Raritan Bay, including Sandy Hook Bay, none had detectable concentrations of methoxychlor, dieldrin, aldrin, heptachlor, or heptachlor epoxide–unlike in the Arthur Kill and Newark Bay (data from Newark Bay RI). USEPA (2008) recognizes that many of these chemicals bind and activate the Ah-receptor, producing toxicity effects, although as already stated, Ah-receptor–mediated toxicity does not occur in benthic invertebrates.

To conclude that the oyster reproductive issues observed in the field sites is solely due to exposure to 2,3,7,8-TCDD in the sediment is flawed and misleading. Region 2 makes the following statement:

For 2,3,7,8-TCDD, Kubiak et al. (2007) derived a site-specific sediment PRG for bivalves based on the reproductive effects study by Wintermeyer and Cooper (2003) that identified significant adverse effects on gonadal and embryonic development associated with the bioaccumulation of 2,3,7,8-TCDD in transplanted oysters in Newark Bay and the Arthur Kill compared to Sandy Hook. *(FFS, Appendix E, Section 2.2, page 2-6)*

However, Wintermeyer and Cooper (2003) actually recognize that:

We cannot state that the field study results were solely due to 2,3,7,8-TCDD, but laboratory studies demonstrate that TCDD can result in a significant decrease in gametogenesis and egg viability.

No laboratory studies were conducted to explore the effects of the other chemicals present at these sites on the oysters. Further, the synergistic impact of many environmental stressors on biological function was not explored, or even considered.

Data collected by the Newark Bay RI sediment investigations (2005 and 2007), show maximum concentrations in the surface sediment of the Arthur Kill and its tributaries for a variety of chemicals, including Total DDT (4,4'), Total $\alpha+\gamma$ chlordane, six PCB congeners, one PCDD/PCDF congener (1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin), and five metals (antimony, barium, lead, nickel, and vanadium). In the southern portion of Newark Bay, maximum concentrations in surface sediment were observed for chemicals, such as Total Aroclor PCBs, Total PCB congeners (and more than 100 individual PCB congeners), Total PAHs, BEHP, and 11 PCDD/PCDF congeners and many metals (arsenic, cadmium, chromium, copper, cobalt, and selenium). Furthermore, surface sediment concentrations of Total DDT (4,4') (normalized to total organic carbon) were significantly greater in the Arthur Kill and the southern portion of Newark Bay compared to the rest of the 6-mile Study Area and even areas extending 2 miles into adjoining tributaries

(Table 4-8a of the Draft Phase I and Phase II Data Evaluation and Analysis Report Revision 1, Tierra 2013). To put this into perspective with the Wintermeyer and Cooper (2003) oyster field sites, average concentrations of Total DDT (4,4'), for example, in surface sediment samples around the Newark Bay, Arthur Kill, and Sandy Hook sites are approximately 127.7 parts per million (ppm), 1,097.5 ppm, and 7.3 ppm, respectively. (Data compiled from Newark Bay RI, CARP, REMAP, and USACE Stratified Sampling projects).

A snapshot of some chemicals observed near the Wintermeyer and Cooper (2003) oyster field sites compared to sediment benchmarks recommended by the Partner Agencies for the Newark Bay RI risk assessment program is provided below:

Chemical in Surface Sediment	Sediment Benchmark[2]	Fold-increase of average surface sediment concentrations compared to sediment benchmark[1,2,3]		
		Newark Bay	Arthur Kill	Sandy Hook Bay
Mercury	0.037 ppm	147-fold	171-fold	34-fold
Total DDT (4,4')	1.58 ppb	81-fold	695-fold	5-fold
Total PAHs	4000 ppb	3-fold	3-fold	1-fold
Total $\alpha+\gamma$ chlordane	3.24 ppb	2-fold	1-fold	0-fold
Total PCBs (Aroclor)	22.7 ppb	43-fold	27-fold	NA
2,3,7,8-TCDD	2.5 ppt	30-fold	20-fold	3-fold
bis(2-ethylhexyl)phthalate	182.16 ppb	74-fold	41-fold	NA

Notes:
1. Surface sediment chemistry used from sediment samples of the REMAP (2003), CARP (1998-2001), Newark Bay RI (2005 and 2007), and the USACE Stratified Sampling Project (2010) nearby the Wintermeyer and Cooper (2003) oyster field site locations.
2. Sediment benchmarks recommended by Partner Agencies for the Newark Bay RI risk assessment program.
3. NA = not available
4. ppb = parts per billion

The surface sediment chemistry data collected near these three field locations provides a snapshot of some of the chemical differences present at these sites–not simply for one chemical, 2,3,7,8-TCDD. Other environmental stressors compounding the differences between the field sites include turbidity from boating traffic and dredging around Shooter's Island, not to mention the numerous oil spills that have occurred around the docks and shipping channels.

Comment D42. *(Footnote 22) The sediment benchmark for 2,3,7,8-TCDD for oysters is flawed and misleading, and the footnote should be deleted. Refer to previous specific comments and General Comment 4.*

Section 4.3.2 – Stressor-Response Profiles

Comment D43. *(General Comment) Refer to comments in Measures of Effect.*

Comment D44. *(General Comment) In addition to the descriptions of the CBR and TRV toxicity studies, a database of CBR and TRV values that were discovered, reviewed, and considered should be provided in a table, as was done in the Risk Assessment and Risk Characterization (RARC) for the 17-mile BERA (Windward, 2012c). Furthermore, note that many of the TRVs cited in the draft FFS could not be replicated by the CPG (refer to the RARC). ARCADIS (2014c), provided as Attachment 4 to these comments, provides a range of TRVs for 2,3,7,8-TCDD (dioxin/furan TEQ) and PCBs.*

Comment D45. *(General Comment regarding Sediment Benchmarks) As stated previously, sediment-screening benchmarks should only be used to establish COPECs. They are extremely conservative values that are based on studies performed on sediments containing mixtures of chemicals. These studies have not demonstrated a true cause-effect relationship for any one chemical and fail to document or consider any confounding factors.*

Comment D46. *(General Comment regarding CBRs) For fish CBRs, salmonid species (i.e., trout and salmon) should be excluded from the CBR selection as they are cold-water species that do not (and cannot) occur in the LPRSA, and their sensitivities to 2,3,7,8-TCDD and PCBs are different from warm-water species (Steevens et al., 2005; Elonen et al., 1998).*

Comment D47. *(General Comment regarding CBRs and TRVs) Laboratory dosing studies using topical application or gavage exposure of one specific chemical do not mimic actual exposures to wildlife in the field that are exposed to a myriad of chemicals in small doses over a lifetime. The CBRs and TRVs presented here do not represent all values available in the literature. Additional existing studies (including field studies) should be explored for relevance.*

Comment D48. *(Page 4-37, last paragraph to Page 4-38) Fish CBR values for 2,3,7,8-TCDD have been selected from an inappropriate study. These values are based on a study by Couillard et al. (2011), who exposed early-life stages of* Fundulus heteroclitus *to PCB126 for up to 4 days post hatching (dph) to observe effects. Because no effects to the measurement endpoints of growth, reproduction, or mortality were observed from this study, it should not be used to evaluate the fish community in an ecological risk assessment. The only dose-response effect observed during the study was a sublethal response–the reduction in the prey-capture ability of 4 dph larvae, despite any lack of apparent abnormalities or morphological changes. Motor activity actually increased in the 4 dph larvae, while ethoxyresorufin-O-*

deethylase (EROD) activity also increased. No mortality, malformation, or delayed hatching rates were observed, even at the highest dose (50 pg PCB126 per egg).

Appendix D incorrectly states that:

Given the high stage-specific mortality experienced by larval fish under typical field conditions, the behavioral endpoint measured in this study was assumed to correlate directly with reduced survival and hence be relevant to the established AE.

Rather, the study fails to show any direct cause-effect relationship between altered behavior and mortality. In fact, the study clearly states that there was no effect on mortality, even at the highest dose.

Furthermore, the derived residue tissue concentration is based on the topical dose applied to the eggs. Table 6-1 in Attachment 6 of Appendix D states the following:

Larval mummichog derived from eggs topically applied with 0.1 µl of 100 pgPCB126/l had a tissue residue of 710 pg/g ww (Couillard et al., 2008); study NOAEL and LOAEL are based on eggs treated with 25 pg/l and 50 pg/l. Assuming linear relationship between egg treatment and larval tissue residue this equates to larval tissue residues of 180 and 360 pgPCB126/g ww, respectively. Larval concentrations were converted to TCDD toxic equivalency using the WHO fish TEF (i.e., 0.005). No extrapolation factors were deemed necessary because of the nature of the endpoint and the use of mummichogs from a naive population, which have been demonstrated to be as sensitive to PCB126 as lake trout based on EROD induction (Couillard et al., 2008).

This incorrectly makes the assumption that the amount of PCB126 absorbed into the egg is linear, and that which is retained in the larval stage of the fish is the same as that absorbed during the egg stage. Neither of these assumptions is likely to be true. Absorption of chemicals into egg tissue is unlikely to be linear, and growth and metabolism of the fish during the larval stage will affect the concentration of the nominal and absorbed dose that occurred earlier in the study. Without actual tissue residue values in the larvae to confirm, these assumptions are baseless and the calculation is faulty.

The estimated tissue residue values were then adjusted to a dioxin value using a toxic equivalent factor (TEF) of 0.005 for PCB126, which was estimated from data on early life stage mortality of rainbow trout (Zabel et al., 1995) and, according to Couillard et al. (2008), may not be appropriate for consideration of sublethal responses in mummichog. TEFs may differ between embryo-lethality and other

responses, such as EROD induction, and among different fish species (Harris et al., 1993).

This study should not be used in the BERA. Actual measured concentrations of TCDD in fish tissue, not PCBs, should be used as the basis of the CBRs.

The geometric mean (1.3 pg/g) of the NOAEL (0.9 pg/g) and LOAEL (1.8 pg/g) CBR values was selected as the biota tissue PRG for fish. It is unclear how the relationship between this value and a back-calculated sediment PRG was then derived. It appears that the CBR was plugged into equations provided in Attachment 1; the selected value is the lowest estimated value derived using specified models for white perch, American eel, and mummichog. This too is faulty. Because the CBR was only based on mummichog, it cannot and should not be applied to other species. Another sublethal study (Carvalho & Tillet, 2004) looked at 2,3,7,8-TCDD effects on larval rainbow trout. They noted biochemical and morphological changes in the brain and eyes, and behavioral differences. Swim-up rainbow trout had impaired visual/motor functions at 113 pg of TCDD/g egg, with reduction in prey capture ability at 300 pg of TCDD/g egg. These doses are much higher than Couillard et al. (2011) noted, with a lowest observed effective dose of 5 pg PCB126/g egg. The differences are likely based on the different chemicals and different species used in the studies. As such, the CBR for mummichog should not be used to back-calculate sediment concentrations for American eel and white perch, both of which have less site-specific fidelity to sediment than mummichog.

Comment D49. *(Page 4-38, Paragraph 2, last sentence) The rationale for not eliminating the chicken data is unfounded. The sentence states that there are a "number of avian species of special concern that <u>may</u> occur in the FFS Study Area that would warrant this more conservative approach." The statement should be revised or deleted. First, because the receptors <u>may</u> exist in the Study Area, does not mean that they do exist here or that they are even evaluated in the BERA. Second, the chicken is the most sensitive species to TEQ. No other receptor that utilizes the Passaic River for foraging grounds has genetic issues, feeding patterns, reproduction, or exposure scenarios that mimic a domestic chicken. The receptors being evaluated are piscivorous. There is no evaluation of domestic birds eating seeds off the ground. Therefore, no receptors warrant this "conservative approach."*

<u>Section 4.4 – Risk Characterization</u>

Comment D50. *(General Comment) This risk characterization ignores the extensive site-specific exposure and effects data available for the Study Area. Multiple lines of evidence are available for each receptor group. A true weight-of-evidence (WOE) approach*

based on all relevant data needs to be performed if the objective is to decide which, if any, remedial actions will be implemented, per USEPA Guidance (USEPA, 1997) and common standards of practice. Based on the results of previous evaluations (Kay et al., 2008; Iannuzzi et al., 2007; Ludwig & Iannuzzi, 2005), a comprehensive BERA using all existing data for the site would demonstrate that risks are likely de minimis*, or are not yet sufficiently characterized to justify any remedial actions, let alone the selection of specific actions.*

Section 4.4.1 – Benthic Invertebrate Hazard Estimates

Comment D51. *(Page 4-45, Paragraph 1) The text states that "Risks to benthic invertebrates were evaluated by comparing sediment EPCs to the lower and upper bound sediment benchmarks…" This constitutes only one line of evidence and does not meet established standards of practice or comply with USEPA guidance (USEPA, 1997). An SQT assessment for the site was published in the peer-reviewed literature (Iannuzzi et al., 2007), but ignored in the current BERA. That SQT concluded, in part, that:*

While there are many uncertainties in this type of assessment, the weight-of-evidence provided by the data makes it clear that impacts from multiple contaminants are occurring in the PRSA and that these impacts will need to be further evaluated and addressed as part of the ongoing restoration initiative for the lower Passaic River.

Given that the current BERA was less rigorous than the 2007 SQT assessment, and that additional site-specific exposure and effects data are now available, this BERA clearly failed to provide an adequate characterization of risks to the benthic invertebrate community.

Comment D52. *(Page 4-45, Paragraph 2) The texts states that: "Based on the magnitude of exceedance of the sediment benchmarks, 2,3,7,8-TCDD and Total DDx contribute most substantially to the benthic hazard estimates." This conclusion is directly contradicted by existing site-specific sediment toxicity studies. The aforementioned SQT assessment for this site (Iannuzzi et al., 2007) included an evaluation of toxicity for 14 sediment samples collected from the lower 6 miles of the LPRSA. The results of co-located sediment chemistry analyses indicated that:*

No single chemical, chemical class, or physical factor differentiates the PRSA stations with respect to sediment toxicity and BIC [benthic invertebrate community] structure and composition. The PCA [Principal Components Analysis] indicated that the concentrations of many organic and inorganic chemicals in the

PRSA were inter-correlated and co-varied with each other and, that most of these chemicals could be influencing sediment toxicity and BIC structure and composition in the PRSA as mixtures. Additionally, there were no consistent gradients of effects along the length of the river in the PRSA; thus, there does not appear to be a single factor(s) influencing the differences among stations in sediment toxicity and BIC structure and composition.

Kay et al. (2008) described the results of a Phase I toxicity identification evaluation (TIE) for Passaic River sediment interstitial water. Regarding the cause of observed toxicity, the authors concluded that:

While particle-bound neutral organic compounds are suspect based upon these Phase I TIE findings, the results are inconclusive as to which groups of such compounds are responsible for toxicity. It is entirely possible that the toxicity is the result of synergistic interactions of a variety of compounds. A Phase II TIE chemical analysis of what was retained by filtration would be required to seek to determine more definitively the causes of toxicity in lower Passaic River sediments.

Therefore, both sets of toxicity tests directly contradict the conclusion that 2,3,7,8-TCDD is the risk driver (or a surrogate risk driver) or that sufficient information is available to determine the risk drivers. These two readily available peer-reviewed publications were ignored in the current BERA. Furthermore, there is no basis to conclude that 2,3,7,8-TCDD poses a sediment toxicity hazard to benthic invertebrates, as these organisms lack the Ah cellular response that mediates dioxin/furan toxicity in vertebrate animals (Hahn 1998). Barber et al. (1998) clearly demonstrated that 2,3,7,8-TCDD is not toxic to even the most sensitive infaunal organism (the amphipod A. abdita*) at concentrations that are orders-of-magnitude higher than those in surface sediments in the LPRSA. As such, the USEPA's entire premise for concluding that 2,3,7,8-TCDD is a risk driver for benthic community toxicity/effects is baseless.*

Comment D53. *(Page 4-45, Paragraph 3) The text states that:*

The apparent differences in the HQs for the entire FFS Study Area as compared with the mudflat HQs are likely attributable to the statistical sampling size effects rather than actual differences in risk levels between the two areas. As noted in the geochemical evaluation of the spatial distribution of 2,3,7,8-TCDD and Total PCBs in surficial sediments in the FFS Study Area the channel and shoal areas are comparably contaminated, with local variations but no systematic trends with river mile (Section 3.1).

Iannuzzi et al. (2007) and Kay et al. (2008) determined that there is insufficient evidence to conclude that observed effects on benthic invertebrates can be attributable to 2,3,7,8-TCDD or any other set of constituents. Therefore, the hazard quotients (HQs) or variations in HQs are not a reliable measure of risk levels, regardless of sampling size.

(Page 4-46, Paragraph 5) The use of these two lines of evidence does not constitute a credible WOE analysis for benthic invertebrates in a BERA. The current assessment constitutes a refined screening level assessment, rather than a BERA.

Section 4.4.2 – Fish Hazard Estimates

Comment D54. *(Page 4-48, Paragraph 3) This section concludes that "…residue-based exposures associated with sediment-borne COPECs are large enough to potentially adversely affect the survival, growth, and/or reproduction of local fish populations." Even if true, the presence of potentially toxic concentrations does not demonstrate that adverse effects are likely to be occurring. Site-specific effects data are available and should be considered (e.g., fish population/community metrics).*

Section 4.4.3 – Wildlife Hazard Estimates

Comment D55. *(General Comment). As noted in General Comment 5 and various specific comments, the exposure assumptions and data utilized to evaluate risks to wildlife are flawed, creating extremely overestimated risks to wildlife. Refining the analysis by using more relevant, spatially weighted sediment data, the correct fish tissue datasets, more reasonable exposure assumptions, and a more appropriate range of TRVs would demonstrate a lack of risk from 2,3,7,8-TCDD to wildlife receptors in the Study Area.*

Comment D56. *(Page 4-48, Paragraph 5) As noted in this section:*

…chemical and congener-specific gull egg concentrations were estimated by multiplying the generic fish tissue EPC values by adult gull/fish prey BMFs developed by Braune and Norstom (1989) and summarized in Table 5-1 in Attachment 5. A second BMF was applied to model transfer from the maternal gull body tissue to the egg…

This multiplicative combining of uncertainties associated with each literature-derived BMF magnifies the conservatism of this line of evidence. This magnitude of uncertainty is too great to support the risk management decisions carried forward to the FFS.

The local population of cormorants that breed on Shooters Island is reflective of the birds that forage in Newark Bay and its tributaries, including the LPR. Therefore, available direct egg tissue concentration data from Parsons (2003) should be used as site-specific data in the BERA to evaluate tissue concentrations in piscivorous bird eggs for the LPR, consistent with USEPA ecological risk assessment guidance (1992; 1997; 1999). According to Parsons (2003), non-lipid normalized 2,3,7,8-TCDD concentrations in cormorant eggs for the Shooters Island population range from 8.6 ng/kg to 201 ng/kg, with a mean 2,3,7,8-TCCD concentration of 59.8 ng/kg and a TEQ of 92 ng/kg. These values are well below the established literature-based CBR values for avian eggs, specifically cormorant 2,3,7,8-TCDD concentrations, which have NOAELs that range from 1,000 ng/kg to 3,000 ng/kg and LOAELs that range from 4,000 ng/kg to 10,000 ng/kg (Powell et al., 1997; 1998; Sanderson & Bellward, 1995). As such, there is no risk to avian eggs from exposure to fish in the LPRSA.

Section 4.5 – Ecological Uncertainty Analysis

Section 4.5.1 – Conclusions

Comment D57. *(General Comment) There is no technical basis for the conclusions reached by Region 2 regarding ecological risks. There are far too many uncertainties in the evaluations conducted for this BERA to reasonably draw any conclusions for remedial actions in the Study Area.*

Table and Figure Comments

Comment D58. *(Tables 4-2, 4-3, 4-5, and 4-6) These tables appear to have hand-picked, select data and do not provide the full range of existing NOAEL and LOAEL TRVs that exist in the primary literature. Furthermore, many of the studies do not represent relevant receptors; see General Comment 7.*

Comment D59. *(Table 4-7) None of the receptors included in this table appear relevant for the Study Area. Additional data should be included.*

Comment D60. *(Table 4-11) Revise the exposure parameters to incorporate site specificity.*

- *The dietary exposure factors were obtained directly from the Exposure Factors Handbook (USEPA, 1993), without any modifications for site specificity. More accurate exposure parameters should be developed and a probabilistic range of factors should be incorporated. Refer to Henning et al. (1999) for a range of exposure factors for the great blue heron.*

- *The estimated amount of sediment in the diets of the heron and mink are extremely high and are unlikely. They should be reduced or eliminated completely because their prey tissue diets contain sediment in the gut.*
- *The maximum site use factor (SUF) of 1 is too high for both species, as much of the Passaic River is industrialized and inaccessible. As a migratory bird, heron are not a resident receptor. The citation for an SUF of 1 states a "heavily vegetated riverine habitat in Montana," which is not relevant for the Passaic River, as it is neither heavily vegetated nor in remote parts of the Montana wilderness.*

Comment D61. *(Table 4-14) This table selects one value for the NOAEL and LOAEL for each receptor. This deterministic evaluation does not account for the plethora of values for each receptor available in primary literature. Values appear to be selected without rationale. No field studies were incorporated. Provide the broad range of NOAELs and LOAELs for each receptor, such as that presented in ARCADIS (2014c)—Attachment 4 to these comments. The focus of the results should be based on the LOAEL-based TRVs.*

Comment D62. *(Tables 4-15, 4-16, 4-18, and 4-19) It is incorrect to sum different chemical groupings for an overall hazard index (HI). Aside from dioxin and dioxin-like PCBs, the constituents have different modes/mechanisms of action, causing toxicity to different systems/organs, and cannot be summed for an overall HI. Please delete the row that shows a total HI.*

Comment D63. *(Figure 4-1) The figure is fuzzy, difficult to read, and appears to be copied directly from another source. The figure is also inaccurate as it presents more pathways and receptor groups than were evaluated in this BERA. It should be updated to include the correct receptor groups and pathways that were evaluated in this BERA. Refer to the conceptual site model for estuarine receptors that was presented by the CPG in the Problem Formulation (Windward & AECOM, 2009).*

Section 5 – Remedial Alternatives Future Risk Assessment

Comment D64. *(General Comment) The future risk scenarios are built upon the results of the current/baseline risk evaluation. Based on the observed short-comings in the current assessment of ecological risks and the high uncertainty in the risk estimates (refer to previous comments on Attachment D), a detailed review of future risks was not conducted. However, because the urban ecology of the Study Area is not anticipated to improve in the future, the lack of ecological risk predicted under current conditions is likely to remain; therefore, remedial actions are not warranted (refer to General Comment 6).*

Section 6 – Summary and Conclusions

Section 6.2 – Ecological Risk Assessment Summary

Section 6.2.1 – Current Ecological Risk Assessment

Comment D65. *(General Comment) Overall conclusions are flawed and based on an extremely conservative and superficial data "screen" that fails to provide a thorough analysis using all available data and site-specific information. See Comments on Section 4.*

Comment D66. *(Page 6-3, last paragraph) Delete the word "reasonable" from the second sentence. All exposure assumptions are conservative and are not reasonable.*

Comment D67. *(Page 6-4, Paragraph 2) The utilization of an HI approach to sum ecological risk is inappropriate. As stated in the paragraph, "Typically, HIs are only calculated to characterize ecological risks when all COPECs cause effects by the same mechanism or mode of action and when those are additive." Because this is not the case with the wide range of COPECs at this site, the HI evaluation should be eliminated.*

Section 6.2.2 – Future Ecological Risk Assessment

Comment D68. *(General Comment) The future risk scenarios are built upon the results of the current/baseline risk evaluation. Based on the observed shortcomings in the current assessment of risks, a detailed review of the future risks was not conducted. However, because the urban ecology of the Study Area is not anticipated to improve in the future, the lack of ecological risk predicted under current conditions is likely to remain; therefore, remedial actions are not warranted (refer to General Comment 8).*

Attachment 1

Attachment 1.1 – Supporting Data

Comment D69. *(Attachment 1, General Comment) Overall, the two "data tables" that provide supporting fish tissue and sediment data used in the BERA are incomplete. While they do provide sample ID, location, and parameters analyzed, they should provide the actual numerical analytical data results so that it is transparent what calculations occurred and how the data were utilized in the BERA.*

Comment D70. *(Attachment 1, General Comment) It is unclear what the 1s in the table are meant to depict. If it is just the presence of data for that analyte from that sample, a check mark or "x" is more appropriate. While this is suitable for an overall summary table, the actual numerical data should have been included so that calculations are transparent and can be confirmed.*

Comment D71. *(Attachment 1, General Comment) It is unclear how reconstituted whole-body samples were calculated. This calculation needs to be more transparent. Attachment 1.1 should provide information/data for the portions of fish used to create the reconstituted whole-body samples (i.e., carcass and offal samples).*

Comment D72. *(Attachment 1, General Comment) Additional information for lengths and weights of each tissue sample is missing.*

<u>Attachment 1.3 – Summaries of Modifications Made to the 2007 HHRA and BERA to be Consistent with the 17-Mile LPRSA RI/FS Risk Assessments</u>

Comment D73. *(Attachment 1, Table 1-2) There is no discussion of sediment data in this table. What are the differences between the sediment dataset used in the 2007 version and the current BERA?*

Comment D74. *(Attachment 1, Figures 1-2 and 1-3) What is the purpose of these figures? They are presenting all data sampling points in the Passaic River, even those datasets that were not used in this BERA. This brings into question why all these data were not incorporated into the BERA. In addition, why are the figures displaying the entire 17-mile stretch of river, when the FFS Study Area is only the lower 8 miles? Figures should be replaced.*

Attachment 5 – Critical Body Residues for Fish and Avian Embryos

Comment D75. *(Attachment 5, Table 5-2) This table should use site-specific mummichog lipid and tissue data and should not require any reference or use of the Cook et al. (2003) data.*

Comment D76. *(Attachment 5, Table 5-3) This table presents data from a different study area and is completely irrelevant.*

Comment D77. *(Attachment 5, Table 5-4) This appears to present bird egg embryo data based on a generic fish diet. Where is the table that presents the bird egg embryo data based on the mummichog diet? Because it is incorrect to include the generic fish diet into the great blue heron evaluation, the table should provide an estimate based solely on the mummichog diet.*

Attachment 6 – Ecological Risk: Current Conditions

Comment D78. *(Attachment 6, General Comment) The figures are missing titles so it is unclear what these graphics are trying to display.*

Comment D79. *(Attachment 6, General Comment) Why are the benthos and the blue crab on the same plots? The benthos were evaluated solely through sediment-screening benchmarks; the blue crabs were evaluated by comparing tissue concentrations to*

CBRs. These evaluations are completely different. Blue crab tissue data does not reflect or act as a surrogate for infaunal tissue data.

Comment D80. *(Attachment 6, Tables 6-1 and 6-2) These tables indicate that they are "selected" CBR values and a "summary" of TRVs. Where is the database of studies that were reviewed? A full compilation of all available CBR and TRV data should be provided. Refer to General Comment 5.*

Comment D81. *(Attachment 6, Table 6-3) What does the word "Entire" refer to in the title? Revise title.*

Comment D82. *(Attachment 6, Table 6-22) The header for the sediment column is missing.*

Comment References

Able, K.W. and J. T. Duffy-Anderson. 2006. Impacts of piers on juvenile fishes in the Lower Hudson River. Pages 428-440 in Levinton, J.S., and J.R. Waldman, editors. The Hudson River Estuary. Cambridge University Press, Cambridge, New York.

Ainley, D.G. and R. J. Boekelheide. 1990. Seabirds of the Farallon Islands. Stanford Univ. Press, Stanford, CA.

ARCADIS. 2011. Development of correction factors for split samples using the approach developed by CSC Analytical. Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons. July.

ARCADIS. 2014a. Evaluation of Historic Data and Development of a Bioaccumulation Predictive Tool for the Lower Passaic River Study Area. August.

ARCADIS. 2014b. Conceptual Fish and Crab Sampling Plan for the Lower Passaic River Study Area. March.

ARCADIS. 2014c. Evaluation of Potential Ecological Risks for the Lower Passaic River Study Area. August.

Bain, M., J. Lodge, D.J. Suszkowski, D. Botkin, A. Brash, C. Craft, R. Diaz, K. Farley, Y. Gelb, J.S. Levinton, W. Matuszeski, F. Steimle, and P. Wilber. 2007. Target Ecosystem Characteristics for the Hudson Raritan Estuary: Technical Guidance for Developing a Comprehensive Ecosystem Restoration Plan. A report to the Port Authority of New York/New Jersey. Hudson River Foundation, New York, NY. 106 pp.

Barber, T.R., D.J. Chappie, K.J. Duda, P.C. Fuchsman, and B.L. Finley. 1998. Using a spiked sediment bioassay to establish a no-effect concentration for dioxin exposure to the amphipod *Ampelisca abdita*. *Environ. Toxicol. Chem.* 17(3):420-424.

Beckett, K.J., S.D. Millsap, A.L. Blankenship, M.J. Zwiernik, J.P. Giesy, and S.J. Bursian. 2005. Squamous epithelial lesion of the mandibles and maxillae of wild mink (*Mustela vison*) naturally exposed to polychlorinated biphenyls. *Environmental Toxicology and Chemistry* 24: 674-677.

Bernstein, P. and M. Chamberlain. 2003. Evaluation of Piscivorous Mammals - Presence/Absence, Distribution, and Abundance in the Housatonic River Floodplain. BBL Sciences, prepared for General Electric Company.

Beyer, W.N, E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *Journal of Wildlife Management* 58(2):375-382.

Butler R.B., M.L. Kelley, W.H. Powell, M.E. Hahn, and R.J. Van Beneden. 2001. An aryl hydrocarbon receptor homologue from the soft-shell clam, *Mya arenaria*: evidence that invertebrate AHR homologues lack TCDD and BNF binding. *Gene* 278:223–234

Carvalho, P.S. and D.E. Tillitt. 2004. 2,3,7,8-TCDD effects on visual structure and function in swim-up rainbow trout. *Environ. Sci. Technol.* 38:6300-6306.

Chemical Land Holdings. 1999. Passaic River Study Area Ecological Sampling Plan Work Plan/Field Sampling Plan. Volume 1. March.

Computer Sciences Corporation and Interface, Inc. 2010. Report on Suspected Causes of Disparities between the Results Produced by Columbia Analytical Services and AXYS Analytical Services in Analysis of Lower Passaic River Sediment Split Samples for Chlorinated Dibenzo-p-Dioxins and Dibenzofurans, and Development of a Conversion Factor to Adjust Results between the Two Laboratories, March.

Cook, P.M., J.A. Robbins, D.D. Endicott, K.B. Lodge, P.D. Guiney, M.K. Walker, E.W. Zabel, and R.E. Peterson. 2003. Effects of aryl hydrocarbon receptor-mediated early life stage toxicity on lake trout populations in Lake Ontario during the 20th Century, *Environ. Sci. Technol*. 37(17):3864-3877.

Couillard, C.M., M. Lebeuf, B. Legare, S. Trottier. 2008. Effects of diazinon on mummichog (*Fundulus heteroclitus*) larvae produced from eggs differentially treated with PCB126. *Archives of Environmental Contamination and Toxicology* 54: 283-291.

Couillard, C.M., B. Legare, A. Bernier, and Z. Dionne. 2011. Embryonic exposure to environmentally relevant concentrations of PCB126 affect prey capture ability of *Fundulus heteroclitus* larvae. *Mar. Environ. Research*, 71:257-265.

Custer, T.W. and C. Bunck. 1992. Feeding flights of breeding Double-crested Cormorants at two Wisconsin colonies. *J. Field Ornithol*. 63:203-211.

Eckert, A.W. and K.E. Karalus. 1983. *The Wading Birds of North America: North of Mexico*. Weathervane Books, New York, New York. 226 pp.

Elonen, G.E., R.L. Spehar, G.W. Holcombe, R.D. Johnson, J.D. Fernandez, R.J. Erickson, J.E. Tietge, and P.M. Cook. 1998. Comparative toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin to seven freshwater fish species during early life stage development. *Environ. Toxicol. Chem*. 17:472-483.

Hahn, M.E. 1998. The Aryl Hydrocarbon Receptor: A Comparative Perspective. *Comp. Biochem. Physiol.* 121C(3):23-53.

Hahn, M.E. 2002. Aryl hydrocarbon receptors: diversity and evolution. *Chemico-Biological Interactions*. 141: 131-160.

Hatch, Jeremy J. and D. V. Weseloh. 1999. Double-crested Cormorant (Phalacrocorax auritus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/441

Harris, M., T. Zacharewski, and S. Safe. 1993. Comparative potencies of Aroclors 1232, 1242, 1248, 1254, and 1260 in male Wistar rats: Assessment of the toxic equivalency factor (TEF) approach for polychlorinated biphenyls (PCBs). *Fund. Appl. Toxicol.* 20:456-463.

Henning, M.H., N.M. Shear Weinberg, N.D. Wilson, and T.J. Iannuzzi. 1999. Distributions for key exposure factors controlling the uptake of xenobiotic chemicals by great blue herons (*Ardea herodius*) through ingestion of fish. *Human Ecol. Risk Assess.* 5(1):125-144.

Iannuzzi, T. J., N. L. Bonnevie, and R.J. Wenning. 1995. An evaluation of current methods for developing sediment quality guidelines for 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Arch. of Environ. Contamin. Toxicol*. 28: 366-377.

Iannuzzi, T.J. and D.F. Ludwig. 2000. The role of food web models in the environmental management of bioaccumulation chemicals. *Soil Sediment Contam.* 9(3):181-195.

Iannuzzi, T.J. and D.F. Ludwig. 2004. Historical and current ecology of the lower Passaic River. *Urban Habitats* 2(1).

Iannuzzi, T.J. and D.F. Ludwig. 2005. An interdisciplinary investigation of ecological history and environmental restoration objectives in an urban landscape. *Ecol. Restoration* 22(3):157-166.

Iannuzzi, T.J., N.W. Harrington, N.M. Shear, C.L. Curry, H. Carlson-Lynch, M.H. Henning, S.H. Su, and D.E. Rabbe. 1996. Distributions of key exposure controlling the uptake of xenobiotic chemicals in an estuarine food web. *Environ. Toxicol. Chem.* 15(11):1979-1992.

Iannuzzi, T.J., D.F. Ludwig, J.C. Kinnell, J.M. Wallin, W.H. Desvousges, and R.W. Dunford. 2002. *A Common Tragedy: History of an Urban River*. Amherst, Massachusetts, USA. Amherst Scientific.

Iannuzzi, T.J., T.N. Armstrong, J.B. Thelen, D.F. Ludwig, and C.E. Firstenberg. 2004. Chemical Contamination of Aquatic Organisms from an Urbanized River in the New York/New Jersey Harbor Estuary. *Hum. Ecol. Risk Assess.* 10: 389-413.

Iannuzzi, T.J., T.N. Armstrong, E.R. Long, J. Iannuzzi, and D.F. Ludwig. 2007. Sediment quality triad assessment of an industrialized estuary of the northeastern USA. *Environ. Monit. Assess.* 139(1-3):257-275.

Kay, D.P., J.L. Newsted, M.T. BenKinney, T.J. Iannuzzi, and J.P. Giesy. 2008. Passaic River sediment interstitial water phase I toxicity identification evaluation. *Chemosphere* 70:1737-1747.

Kubiak, T.J., C. Stern, and M. Foster. 2007. Development of a 2,3,7,8-tetrachlorodibenzo–p-dioxin sediment-based preliminary remediation goal using the reproductive endpoint in the eastern oyster (*Crassostrea virginica*, Gemlin) for the Passaic River/Newark Bay and Raritan Bay Complex, New Jersey, U.S. Fish and Wildlife Service, New Jersey Field Office, presented at the Assessment and Remediation of Chemical Contamination in Tidal Estuary Sediments Session, SETAC 28th Annual Meeting, Milwaukee.

Long, E.R., and D.D. MacDonald. 1998. Recommended uses of empirically derived, sediment quality guidelines for marine and estuarine ecosystems. *Human and Ecol. Risk Assess.* 4(5): 1019-1039.

Ludwig, D.F. and T.J. Iannuzzi. 2005. Incremental ecological exposure risks from contaminated sediments in an urban estuarine river. *Integr. Environ. Assess. Manag.* 1(4):1-17.

Ludwig D.F., Iannuzzi, J., Iannuzzi, T.J., and J.K. Shisler. 2010. Spatial and Temporal Habitat Use Patterns by Water Birds in an Urban Estuarine Ecosystem: Implications for Ecosystem Management and Restoration. *Hum. Ecol. Risk Assess.: An International Journal* 16(1):163-184.

Malcolm Pirnie, Inc. 2009. Statistical Comparison of 2008 Low Resolution Split Sample Sediment Data Lower Passaic River Restoration Project W912DQ-08-D-0017, Task Order 0010, Correspondence. October 5.

Mayack, D.T. and J. Loukas. 2001. Progress Report on Hudson River Mammals: Polychlorinated Biphenyl (PCB) Levels in Mink, Otter, and Muskrat and Trapping Results for Mink, the Upper Hudson River Drainage, 1998-2000.

Millsap S.D., A.L. Blankenship, P.W. Bradley, P.D. Jones, D. Kay, A. Neigh, C. Park, K.D. Strause, M.J. Zwiernik, and J.P. Giesy. 2004. Comparison of risk assessment methodologies for exposure of mink to PCBs on the Kalamazoo River, Michigan. *Environ Sci Technol*: 38(24):6451-9.

National Oceanic and Atmospheric Administration. 2003/03. Rhode Island, Connecticut, New York, and New Jersey Environmental Sensitivity Index Shoreline Types (Geospatial Data). Available online at: htttp://response.restoration.noaa.gov.

NYSDEC. 2003. Contamination Assessment and Reduction Project (CARP): Water. Final Report. New York State Department of Environmental Conservation, Bureau of Water Assessment and Management, Division of Water.

Parsons, K.C. 2003. Chemical Residues in Cormorants from New York Harbor and Control Location. Final Report submitted to New York State Department of Environmental Conservation, Division of Fish, Wildlife and Marine Resources. Prepared by Manomet Center for Conservation Sciences, Manomet, Massachusetts. Contract No. C003858. February 28.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, J.F. Powell, J.C. Restum, K.L. Stromborg, and J.P. Giesy. 1997. Effects of 3,3',4,4',5-pentachlorobiphenyl (PCB 126), 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), or an extract derived from field-collected cormorant eggs injected into double-crested cormorant (*Phalacrocorax auritus*) eggs. E*nviron. Toxicol. Chem*., vol. 16, no. 7, pp. 1450-1455.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, M.E. Kelly, K.L. Stromborg, M.J. Melancon, S.D. Fitzgerald, and S.J. Bursian. 1998. Effects of 3,3',4,4',5-pentachlorobiphenyl and 2,3,7,8-tetrachlorodibenzo-p-dioxin injected into the yolks of double-crested cormorant (*Phalacrocorax auritus*) eggs prior to incubation. *Environ. Toxicol. Chem*., vol. 17, no. 10, pp. 2035-2040.

Sanderson, J.T. and G.D. Bellward. 1995. Hepatic microsomal ethoxyresorufin O-deethylase-inducing potency in ovo and cytosolic Ah receptor binding affinity of 2,3,7,8-tetrachlorodibenzo-p-dioxin: comparison of four avian species. *Toxicol Appl Pharmacol* 132: 131-145.

Seston, R.M., T.B. Fredricks, D.L. Tazelaar, S.J. Coefield, P.W. Bradley, J.L. Newsted, D.P. Kay, S.D. Fitzgerald, J.P. Giesy, and M.J. Zwiernik. 2010. Tissue-based risk assessment of great blue heron (*Ardea herodias*) exposed to PCDD/DF in the Tittabawasee River Floodplain, Michigan, USA. *Environ. Toxicol. Chem.* 29(11):2544–2558.

Steevens, J.A., M.R. Reiss, and A.V. Pawlisz. 2005. A methodology for deriving tissue residue benchmarks for aquatic biota: A case study for fish exposed to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin and equivalents. *Integr. Environ. Assess. Manag*. 1(2):142-151.

Stratus Consulting. 1999. Injuries to Fishery Resources, Lower Fox River/Green Bay Natural Resource Damage Assessment Final Report, prepared for USFWS, USDOI, USDOJ. November 8, 1999.

Stratus Consulting. 2008. Natural Resource Damage Assessment Plan for the Tittabawassee River System Assessment Area. Prepared under contract for MDEQ. April 2008.

Stratus Consulting, 1999. Injuries to Fishery Resources, Lower Fox River/Green Bay Natural Resource Damage Assessment Final Report, prepared for USFWS, USDOI. November 8, 1999.

Tierra. 2013. Draft Phase I and Phase II Data Evaluation and Analysis Report. Newark Bay Study Area. Remedial Investigation. Revision 1. March.

USACE, Port Authority of New York and New Jersey, and New York-New Jersey Harbor & Estuary Program. 2009. Hudson Raritan Estuary Comprehensive Restoration Plan. Draft. March. Available online at: http://www.harborestuary.org/watersweshare/resources.htm.

USACE. 2010. Stratified Sampling Project Summary Report and Evaluation of Data. New York District. March.

USEPA. 1992. Framework for Ecological Risk Assessment. Risk Assessment Forum. Washington, DC. EPA/630/R-92/001. February.

USEPA. 1993. Wildlife Exposure Factors Handbook. Volumes I and II. EPA/600/R-93/187a&b. Washington, DC.

USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. EPA 540-R-97-006. Office of Solid Waste and Emergency Response. June.

USEPA. 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. EPA/630/R-95/002F. April.

USEPA. 1999. Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites. Memorandum from Stephen D. Luftig, Director. OSWER Directive 9285.7-28 P.

USEPA. 2000. Phase 2 Report. Further Site Characterization and Analysis Volume 2E – Revised Baseline Ecological Risk Assessment. Hudson River PCBs Reassessment. Prepared by TAMS Consultants, Inc. and Menzie-Cura & Associates, Inc.

USEPA. 2003. Sediment Quality of the NY/NJ Harbor System: A 5-Year Revisit (1993/1994 – 1998). EPA/902-R-03-002. U.S. Environmental Protection Agency, Region II, Edison, New Jersey. December.

USEPA. 2008. Framework for Application of the Toxicity Equivalence Methodology for Polychlorinated Dioxins, Furans, and Biphenyls in Ecological Risk Assessment. Office of the Science Advisor. EPA 100/R-08/004. June.

Wallin, J.M., M.D. Hattersley, D.F. Ludwig, and T.J. Iannuzzi. 2002. Historical assessment of the impacts of chemical contaminants in sediments on benthic invertebrates in the tidal Passaic River, New Jersey. . *Human Ecol. Risk Assess.* 8(5):1155-1176.

Wenning, R.J., N.L. Bonnevie, and S.L. Huntley. 1994. Accumulation of metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons in sediments from the lower Passaic River, New Jersey. *Arch. Environ. Con. Toxicol.* 27:64-81.

Windward. 2011a. 2009 Bioaccumulation Tissue Chemistry Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. September 19.

Windward. 2011b. Sediment Toxicity Test Data Report for the Lower Passaic River Study Area Fall 2009 Investigation. Prepared for Cooperating Parties Group. February 28.

Windward. 2012a. 2011 Caged Bivalve Study Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. July 18.

Windward. 2012b. 2010 Small Forage Fish Tissue Chemistry Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. July 18.

Windward. 2012c. Revised Risk Analysis and Risk Characterization Plan for the Lower Passaic River Study Area. Draft. Prepared for Cooperating Parties Group by Windward Environmental, LLC and AECOM. April 13.

Windward. 2013a. Fall 2009 Benthic Invertebrate Community Survey And Benthic Field Data Collection For The Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. April 12.

Windward. 2013b. Habitat Identification Survey Data Report For The Lower Passaic River Study Area Fall 2010 Field Effort. Prepared on behalf of the Cooperating Parties Group. April 12.

Windward and AECOM. 2009. LPRSA Human Health and Ecological Risk Assessment Streamlined 2009 Problem Formulation. Final. Prepared for the Cooperating Parties Group, Newark, New Jersey. July 31.

Wintermeyer, M.L. and K.R. Cooper. 2003. Dioxin/furan and polychlorinated biphenyl concentrations in eastern oyster (*Crassostrea virginica*, Gmelin) tissues and the effects on egg fertilization and development. *J. Shellfish Res.* 22(3):737-746.

Wolfskill, L.A. and R.P. McNutt. 1998. An environmental study of the Passaic River and its estuary. *Seton Hall Law Review* 29(1):7-59.

Zabel, E.W., P.M. Cook, R.E. Peterson. 1995. Toxic equivalency factors of polychlorinated dibenzo-p-dioxin, dibenzofuran and biphenyl congeners based on early stage mortality in rainbow trout (*Oncorhynchus mykiss*). *Aquat. Toxicol.* 31:315-328.

Zwiernik, M.J., D.P. Kay, J.Moore, K.J. Beckett, J.S. Khim, J.L. Newsted, S.A. Roark, and J.P. Giesy. 2008. Exposure and effects assessment of resident mink (*Mustela vison*) exposed to polychlorinated dibenzofurans and other dioxin-like compounds in the Tittabawassee River basin, Midland, Michigan, USA. *Environ. Toxicol. Chem*. 10:2076-2087.

Zwiernik, M. 2011. Summary of Ecological Studies within the Tittabawassee River Floodplain. Presentation to the Community Advisory Committee, 20 June 2011.

ARCADIS

Attachment 1

ARCADIS U.S., Inc.
326 First Street
Suite 200
Annapolis
Maryland 21403
Tel 410 295 1205
Fax 410 295 1225

MEMO

To:
Cliff Firstenberg (Tierra)

Copies:
Alain Hebert (ARCADIS)
Emily Morrison (ARCADIS)
Melissa Beauchemin (ARCADIS)
Shannon Dunn (ARCADIS)

From:
Timothy Iannuzzi
Jacqueline Iannuzzi

Date:
August 14, 2014

ARCADIS Project No.:
B0009968.0000.00002

Subject:
Evaluation of Historical Data and Trends and Development of a Bioaccumulation Tool for Lower Passaic River Study Area (LPRSA)

Executive Summary

ARCADIS U.S., Inc. (ARCADIS), on behalf of Tierra Solutions, Inc. (Tierra), has conducted an ~~t~~ evaluation of existing data and information to characterize and quantify (to the extent practicable) the relationships among organic chemical contaminants in water, surface sediment, and biota in the Lower Passaic River Study Area (LPRSA). The LPRSA includes the tidal portion of the Passaic River from its confluence with Newark Bay upstream to Dundee Dam—approximately 17 river miles (Figure 1-1). This memorandum summarizes ARCADIS' work to: 1) compile and evaluate the sediment, water, and tissue chemistry data from the LPRSA, and 2) develop a food web bioaccumulation tool to help conduct present and future assessments of potential human health and ecological risks. The evaluation focused on 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and polychlorinated biphenyls (PCBs). These two groups of chemical compounds represent the chemicals that are perceived to pose the majority of the human health risks in the LPRSA and are the two most prominent groups of non-polar organic compounds that may pose risks to ecological receptors (i.e., fish, crabs, birds, and mammals) from food web bioaccumulation.

This evaluation was divided into two tasks. The first task was an exploratory data analysis to examine, using statistical methods, spatial and temporal relationships that may exist among biota, sediments, and/or water in the LPRSA. The second task used the output and findings from the first task including the site specific tissue and sediment data, to develop a predictive tool for the bioaccumulation of contaminants in the river's food web, focusing on the concentrations both in the whole bodies of organisms as well as

edible tissues that can be consumed by humans. This bioaccumulation tool will be used to evaluate remedial scenarios that are proposed under the FFS and the soon-to-be-completed Remedial Investigation/Feasibility Study (RI/FS), including human and ecological risk assessments.

Present and historical data sets for sediments, water, and biota tissues were included in this evaluation. Statistical evaluations were conducted over different spatial scales in the LPRSA to determine what relationships exist between chemicals (i.e., 2,3,7,8-TCDD and PCBs) in these media. In addition, ARCADIS evaluated temporal trends in the sediments and biota data sets from 1995 to present to determine whether evidence exists for natural attenuation of contaminants in the system. The objective of the spatial and temporal data evaluations was to inform the scale and relationships needed to construct the bioaccumulation tool to mimic (as closely as possible) current conditions in the LPRSA, and project future conditions under alternative remediation scenarios—a critical component of any feasibility study. An analysis of temporal trends suggests that natural attenuation may be occurring in the LPRSA, but additional data collection is needed to confirm such a trend. There were spatial trends in both the sediment and biota tissue data in the LPRSA, for both 2,3,7,8-TCDD and Total PCBs. For both constituents, concentrations tend to rise from LPRSA river mile 0 to 2, fluctuate slightly from LPRSA river miles 2 through 12 with a local maximum at river mile 10.9 for sediment, then decline upriver.

ARCADIS developed a bioaccumulation tool for the LPRSA using empirical relationships between sediments and various trophic levels of invertebrates and fish, based on the statistical evaluations developed in the trends assessment. The tool was designed using a probabilistic platform to predict future tissue concentrations under potential/hypothetical remedial scenarios.

Thiessen polygons were used to represent the distribution of sediment concentrations for 2,3,7,8-TCDD and Total PCBs. To simulate remediation, the concentrations of polygons exceeding a certain concentration were changed to post-remediation values (i.e. detection limits). Distributions of tissue concentrations were simulated under the “post-cleanup conditions. This was conducted for five hypothetical 2,3,7,8-TCDD target cleanup levels.

The bioaccumulation tool and associated probabilistic framework can be tailored for different temporal and spatial analyses within the LPRSA, and can be further expanded to include additional data sets and nonionic organic chemicals of concern to support both human and ecological risk assessment.

1 Introduction and Approach

ARCADIS U.S., Inc. (ARCADIS), on behalf of Tierra Solutions, Inc. (Tierra), conducted an evaluation of existing data and information to characterize and quantify (to the extent practicable) the relationships between organic chemical contaminants in water, surface sediment, and biota in the Lower Passaic River Study Area (LPRSA). The LPRSA includes the tidal portion of the Passaic River from its confluence with Newark Bay upstream to Dundee Dam—approximately 17 river miles (Figure 1-1).

ARCADIS conducted statistical evaluations and developed a food web predictive tool for the LPRSA to simulate/estimate current and future chemical contaminant concentrations in key receptors (i.e., crabs, fish) for human health and ecological risk assessment. This evaluation was divided into two tasks. The first task was an exploratory data analysis to examine statistical relationships that may exist among biota, sediments, and/or water in the LPRSA. The second task used the output and findings from the first task to develop a predictive tool for the bioaccumulation of contaminants in the river's food web, focusing on the concentrations both in the whole bodies of organisms as well as edible tissues that can be consumed by humans. The evaluation focused on 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and polychlorinated biphenyls (PCBs). These two groups of chemical compounds represent the majority of chemicals that are perceived as human health risks from fish and crab consumption in the LPRSA, and are the two most prominent groups of non-polar organic compounds that may pose risk to ecological receptors (i.e., fish, crabs, birds, and mammals) from food web bioaccumulation. Other chemicals of potential ecological concern are primarily inorganic constituents and non-bioaccumulative organic compounds that pose risk via direct exposure/toxicity in sediments and/or water. It is anticipated that the bioaccumulation tool and related analyses will be expanded in the future to evaluate other chemicals of ecological or human health concern in the LPRSA.

2 Evaluation of Historical Data from the LPRSA

Present and historical data sets for sediments, water, and biota tissues were included in this evaluation. Statistical evaluations were conducted over different spatial scales in the LPRSA to determine what relationships exist between chemicals (i.e., 2,3,7,8-TCDD and PCBs) in these media. In addition, ARCADIS evaluated temporal trends in the sediments and biota data sets from 1995 to present to determine whether evidence exists for natural attenuation of contaminants in the system. The objective of the spatial and temporal data evaluations was to inform the spatial scale and relationships needed to construct the bioaccumulation tool to mimic (as closely as possible) current conditions in the LPRSA, and project future conditions under different remediation scenarios—a critical component of any feasibility study.

2.1 Summary of Existing Data Sets

The various surface water, surface sediment (0 to 6-inch below sediment surface), and biota tissue data sets from sampling programs conducted within the LPRSA were compiled from the existing Tierra EQuIS™ database maintained by ARCADIS and databases downloaded from www.OurPassiac.org

Total PCB data are presented as Total PCB congeners, which is the sum of all 209 PCB congeners. For some of the historical samples, congener data were insufficient for the calculation of Total PCBs. Therefore, for completeness and to facilitate historical comparisons, Total Aroclor PCBs (sum of 7 Aroclors) concentrations are also presented and evaluated. For purposes of human health risk assessment, concentration data for select individual congeners, PCB-118 and PCB-126, were also evaluated and the results presented.

2.1.1 Surface Water

Very limited historical surface water data exist prior to the recent surface water column monitoring programs conducted by the Cooperating Parties Group (CPG). As such, the surface water evaluation is limited both spatially and temporally and includes only data collected since August 2011—six rounds of small-volume sampling events (August 2011 to March 2013), one low-flow, small-volume sampling event (August 2012), and one high-volume sampling event (December 2012). Samples were collected from two-depth intervals at each station, one near the surface (~3 feet below water surface) and one near the sediment bed. In addition, the samples were collected to characterize different phases of the tidal cycle (maximum ebb, maximum flood, high slack, and low slack). Summary statistics for surface water data are presented in Table 2-1. Figure 2-1 shows the surface water sampling locations in the LPRSA.

2.1.2 Surface Sediment

Table 2-2 presents a summary of the surface sediment sampling events, numbers of samples, and data sources for surface sediment data evaluated, including data collected throughout the LPRSA from 1990 through 2012. Figure 2-2 shows the surface sediment sampling locations in the LPRSA. For purposes of the bioaccumulation assessment, sediment data for 2,3,7,8-TCDD and PCBs were evaluated as both total wet-weight and organic carbon- (OC)-normalized concentrations. To evaluate spatial and temporal trends and to facilitate bioaccumulation modeling, the sediment sampling events were grouped into three time periods: 1990 to 1995, 1998 to 2003, and 2005 to 2012. Approximately two-thirds of all samples collected were taken from the lower eight miles of the LPRSA. Table 2-3 presents the surface sediment summary statistics by time period and river section and also by sampling event for each of the chemicals evaluated.

2.1.3 Tissue

Biota tissue data were available from six sampling events: the 1995 Biological Sampling Program, the 1999 Late Summer/Early Fall Remedial Investigation- (RI)-Ecological Sampling Program (ESP), the 2000 Spring RI-ESP Sampling Program, the 2001 Supplemental RI-ESP Biota Sampling Program and the 2009-2010 Tissue Data Collection. Table 2-4 presents a summary of the tissue sampling events, numbers of samples, species, and tissue types for the biota tissue samples collected from the LPRSA. In addition, this table indicates whether a species/tissue type was used as part of the bioaccumulation assessment (as described in Section 3).

Forage fish include several species and are defined as small fish species or juveniles that generally feed on detritus and would be considered prey for larger piscivorous fish, birds, and/or mammals. Tissue data for 2,3,7,8-TCDD and PCBs were evaluated as both total wet-weight and lipid-normalized concentrations. Since organic chemicals partition into the lipids of organisms, lipid normalization can be an effective method of comparing the concentrations in organisms of different size classes and often of different species. Summary statistics for the subset of species/samples used in the bioaccumulation assessment

task are presented in Tables 2-5 (chemistry) and 2-6 (body size). Sample locations in the LPRSA for the subset of species/tissue data used in the bioaccumulation assessment are shown on Figures 2-3(a-e).

2.2 Spatial and Temporal Trends Assessment

2.2.1 Surface Water

Surface water concentrations are plotted by depth and station for 2,3,7,8-TCDD, Total PCB congeners, and total suspended solids (TSS) on Figures 2-4 through 2-6. Examination of the plots shows that 2,3,7,8-TCDD and Total PCB congener surface water concentrations tend to be higher at the stations located between LPRSA river miles 2 and 7. Regression of log-transformed data was conducted to examine the relationship between 2,3,7,8-TCDD and Total PCB congener concentrations and TSS concentrations (Figures 2-7 and 2-8). Both 2,3,7,8-TCDD (R^2 = 0.44) and Total PCB congeners (R^2 = 0.77) concentrations increase with increasing TSS. An analysis of covariance was conducted to determine whether the relationship is consistent across stations (Figure 2-9). The results show that while the relationship is similar (i.e., 2,3,7,8-TCDD increases similarly with TSS), location is a significant predictor to the model (R^2 = 0.54), and the expected mean total 2,3,7,8-TCDD surface water concentrations, when controlling for TSS, are statistically significantly different among stations. The highest mean concentrations are found at station Tidal 1 (LPRSA river miles 3 to 7.6) followed by Tidal 2 (LPRSA river miles 2.2 to 4.2) and 102 (LPRSA river mile 10.2), which are very similar. The lowest mean concentrations are found at station 000 (LPRSA river mile 0). While location has an influence, TSS is the strongest predictor of concentration, and the expected concentration for a given TSS load varies less than 5 picograms per liter (pg/L) between the station with the highest expected mean concentration of 2,3,7,8-TCDD (Tidal 1) and the station with the lowest expected mean (station 000). A similar analysis was not conducted for Total PCB congeners due to the limitations of the small data set that was available.

The relationship between particulate organic carbon and TSS was also evaluated. Hydrophobic organic contaminants have a high affinity for organic matter in the water column and if associated with such, are thought to be unavailable for uptake via diffusion into organisms (Arnot and Gobas 2004). Figure 2-10 shows that particulate organic carbon is highly correlated with TSS and therefore, would be expected to reduce the amount of contaminant that is freely dissolved in the water column. The few results available for dissolved concentrations of 2,3,7,8-TCDD in surface water are evidence that this is the case as they are very low, ranging from 0.02 to 0.09 pg/L (Table 2-1).

2.2.2 Surface Sediment

Surface sediment concentrations (both dry-weight and OC-normalized) are plotted by river mile for 2,3,7,8-TCDD, Total PCB congeners and Total Aroclor PCBs on Figures 2-11 through 2-16. Total organic carbon is also plotted by river mile on Figure 2-17.

2.2.2.1 Spatial Trends

A smoothing spline regression model was used to further evaluate the spatial trend for 2,3,7,8-TCDD, as shown on Figures 2-18 and 2-19. The spline model is a non-parametric regression model in which a curve is fitted to the data using the penalized least squares method (SAS Institute Inc. [SAS] 2010). Penalized least squares estimation provides a way to balance fitting the data closely and avoiding excessive roughness or rapid variation in the curve. In practice, it is somewhat similar to ordinary least squares regression, but the minimized function has an additional penalty term that increases with over-fitting. This penalty term includes a smoothing parameter that can be adjusted.

Model calculated expected mean 2,3,7,8-TCDD surface sediment concentrations rise from 300 to 800 nanograms per kilogram (ng/kg) (10,000 to 14,000 ng/kg-OC) from LPRSA river mile 0 to 2, fluctuate between 700 and 900 ng/kg (14,000 to 20,000 ng/kg-OC) between LPRSA river miles 2 and 10, rise to a local maximum of 1200 ng/kg at river mile 10.9 (28,000 ng/kg-OC) then drop to less than 100 ng/kg (~3000 ng/kg-OC) above LPRSA river mile 13 and to less than 10 ng/kg (~500 ng/kg-OC) above LRSA river mile 14.

Total PCB congeners (available only for data collected after 2005) were also evaluated using a spline regression model as shown on Figures 2-20 and 2-21. Model calculated expected mean total PCB surface sediment concentrations fluctuate between $3x10^6$ and $6x10^6$ ng/kg ($4x10^7$ and $6x10^7$ ng/kg-OC) between LPRSA river miles 0 and 12, then drop to less than $2x10^6$ ng/kg (~$4x10^7$ng/kg-OC) above LPRSA river mile 13 and to less than $1x10^6$ng/kg (~$2x10^7$ ng/kg-OC) above LRSA river mile 14. Similar to the trend noted for 2,3,7,8-TCDD, there is a local maximum at LPRSA river mile 10.9.

2.2.2.2 Temporal Trends

Spline regression models were also used to evaluate temporal trends in the surface sediment concentrations. This method allows for a comparison of concentrations among the temporally defined data groups, while controlling for the spatial variation inherent in river mile location. Because very few samples were collected above LPRSA mile 7 prior to 2007 this analysis was limited to the lower 7 miles of the river. All available sediment data collected from sampling programs conducted from 1990 through 2012 (Table 2-2) where samples were located between LPRSA river mile 0 through 7 were used. The procedure allows for hypotheses testing of the differences among spline curves for the different time periods. The results of the temporal spline analysis for 2,3,7,8-TCDD are shown on Figure 2-22. No significant difference in concentrations among time periods was noted ($\alpha = 0.5$). Very limited PCB congener data are available for sediment samples collected prior to 2005; therefore, Total Aroclor PCBs (sum of 7 Aroclors) was used to evaluate the temporal Total PCB trend (Figure 2-23). Results show that mean concentrations for the 2005 to 2012 time period are slightly, but statistically significantly greater ($p = 0.013$) than the 1990 to 1995 time period. No significant difference is noted between the first two time periods (1990 to 1995 and 1998 to 2003).

Many of the sediment sampling programs shown in Table 2-2 and included in the trend analysis described above were small and not designed to be spatially representative of the entire study area. The 1995 RI Sampling Program was the first large program designed to characterize the nature and extent of contaminants. As shown on Figure 2-2, sample locations were designed to be spatially representative of the study area from LPRSA river miles 1 through 7 and therefore this data set is the most useful for historical comparisons to more recent data sets collected by the CPG. Therefore, a focused temporal trend analysis was conducted to compare the 1995 RI data set to the following CPG data sets within river miles 1 through 7 (i.e., the spatial limit of the 1995 RI Sampling Program):

- 2008 CPG Low Resolution Coring Program
- 2009/2010 CPG Benthic Sediment Sampling Program
- 2012 CPG Supplemental Sampling Program.

Initial review of the mean and standard deviations for several constituents of concern (COCs) identified in the FFS show that concentrations from 2008 to 2010 tend to be lower than those in 1995, and also that concentrations in 2012 tend to be higher and have much higher variance than those observed during the previous three programs (Table 2-7). With the exception of the 2012 program, these large sampling programs were designed to be spatially representative, while also including some judgmental sample locations. The 2012 dataset was designed to delineate chemical contaminant “hot spots.” In fact, it has some of the highest concentrations of 2,3,7,8-TCDD, and several other chemicals (e.g., Total PCBs, mercury), ever detected in sediments within RM 1-7. This is to be expected from a sampling program such as this where samples were specifically collected in areas where the highest concentrations were previously noted. This disparity in sampling design prompted a statistical comparison of the results. The four data sets, whether in raw scale or log-transformed scale, did not meet the assumptions of equal variance for 2,3,7,8-TCDD concentrations according to Levene’s test for homogeneity of variance ($p = 0.0096$). The equal variance assumption is required to conduct either simple t-tests or analysis of variance with post-hoc multiple comparison testing. Therefore, the spline regression method was used as described above, allowing a comparison of the concentrations among the data sets while controlling for the spatial variation inherent in river mile location. Figures 2-24 through 2-30 show the results for 2,3,7,8-TCDD, Total Aroclor PCBs, PCB-77, PCB-118, and other COCs identified in the FFS (mercury, dieldrin, and dichlorodiphenyl-trichloroethane). With the exception of Total Aroclor PCBs, all compounds tested showed a statistically significant decline in concentrations from 1995 to 2008 through 2010 (Table 2-7). This downward trend was not confirmed by the 2012 data set. However, the 2012 dataset, because of its deliberately biased and limited purpose, should not be included in a statistical evaluation with the large-scale, spatially representative sampling events (i.e., 1995, 2008 to 2010).

2.2.3 Tissue

Concentrations of 2,3,7,8-TCDD and total PCBs in fish and blue crab tissue, both whole body and edible fillet, are plotted by LPRSA river mile for all species on Figures 2-31 through 2-36. Forage fish (Figure 2-

31) are defined as small fish species or juveniles (less than 10 centimeters long) that generally feed on detritus and would be considered prey for larger piscivorous fish, birds, and/or mammals. Concentrations in tissue, both total and lipid-normalized, increase slightly from LPRSA river mile 0 to 9 and then, similar to sediment concentrations, begin to decrease upriver.

Temporal trends in tissue can be examined for several species for which samples were collected in both 1999 to 2000 and 2009 to 2010. Because tissue was only collected below LPRSA river mile 8 during the earlier time period, a temporal comparison should be limited to that section of the river. A comparison of mean concentrations by sampling period, both raw and normalized, for 2,3,7,8-TCDD and Total Aroclor PCBs is presented in Table 2-8 for river miles 0 to 8, along with the results of a statistical comparison of the log-transformed data (one-sided t-test of whether the 2009 to 2010 concentrations are less than the 1999 to 2001 concentrations). An examination of Figure 2-31 shows that wet-weight 2,3,7,8-TCDD concentrations in mummichog collected in 1999 to 2000 have higher concentrations than those collected in 2010, although with a similar pattern of variation from river mile 0 to 8. Excluding the three obvious outliers in the 1999 to 2000 mummichog data set, the mean concentration of 2,3,7,8-TCDD (52 ng/kg) is statistically significantly lower than the 2009 to 2010 mean (33.9 ng/kg), showing a declining temporal trend. A similar trend was not seen in the lipid-normalized means because mean lipid concentrations in the earlier data set (3.3 percent) are 50 percent higher than those of the later data set (1.9 percent) for mummichog. It is unclear why lipid concentrations would be so different in the two programs as the size of fish collected in the programs was similar. A statistically significant decrease in mean concentrations, raw and normalized, was seen in blue crab for all tissue types, with the exception of normalized whole body concentrations (Table 2-8, Figure 2-32). Again, this appears to be due to the difference in lipid concentrations for the whole body tissue. A statistically significant decrease in wet-weight mean concentrations for white perch occurs for both compounds and both tissue types (Table 2-8, Figure 2-35). This decrease was not seen in the normalized data, again due to the higher lipid concentrations measured in the earlier data set. Because the average specimen size in the two sampling programs was similar, it is difficult to determine why the lipid content was different however different methods for lipid analysis were used in each sampling program. For American eel, only the wet-weight fillet data indicate a statistically significant decrease in concentrations for both 2,3,7,8-TCDD and total Aroclor PCBs (Table 2-8). This difference is not seen in the normalized data set, again due to the difference in lipid content between the two time periods. In conclusion, there is strong evidence that wet weight tissue concentrations of organic contaminants have declined over time. Decreases in mean wet-weight concentrations are not always confirmed by the lipid-normalized mean comparison. However, given the uncertainty of the lipid measurements, conclusions about temporal trends should not be judged by the comparisons of the normalized tissue data. The apparent decline in wet weight concentrations coupled with the uncertainty related to differences in lipid content between the two sampling periods suggests that an additional data set is necessary to effectively evaluate temporal trends. From a statistical standpoint, at least one additional data set is needed to characterize a time series.

Tissue concentrations for selected species were further summarized (mean by river mile) and plotted with the mean sediment concentrations by river mile (Figures 2-37 through 2-39). Tissue concentrations tend to follow sediment trends, with the exception of an apparent spike in Total PCB congener sediment concentrations above LPRSA river mile 16. Sediment sample locations in this part of the river are scarce, and a comparison of Figures 38 and 39 to Figures 21 and 22 shows that this apparent spike in mean Total PCB concentration is attributable to one elevated sample concentration; therefore more sampling would be required to determine if an increase in PCB concentrations truly exists above LPRSA river mile 16. To further investigate the relationship between sediment and tissue concentrations, a spline regression model of 2,3,7,8-TCDD was created for forage fish, blue crab, and white perch (whole body tissue) (Figure 2-40). Tissue concentrations follow a similar spatial trend as the sediment, but the species with a larger home range (i.e., blue crab and white perch) have been exposed in locations other than where they were caught; therefore, their concentrations would not be expected to exactly mimic sediment concentrations where they were caught. Forage fish with their smaller home ranges tend to follow the sediment trend more closely.

2.2.4 Benthic Invertebrate Bioaccumulation Testing/Assessment

The CPG conducted a laboratory bioaccumulation study in 2009 with surface sediment collected from locations throughout the LPRSA. Based on the interstitial water salinity of the sediment, one of two organisms was selected, each for a 28-day test. Five tests were conducted with an estuarine Polychaete worm (*Nereis virens*), and 14 tests were conducted on the freshwater blackworm (*Lumbriculus variegatus*), an oligochaete. Tissue versus sediment concentrations for these data are shown on Figures 2-41 and 2-42 for 2,3,7,8-TCDD and Total PCBs, respectively. The plots show that bioaccumulation tends to be higher in the blackworm for both 2,3,7,8-TCDD and total PCBs, but it is also more variable, indicating that other factors are likely affecting bioaccumulation within the freshwater portion of the river. Therefore, to estimate bioaccumulation in benthic organisms in the estuarine portion of the river, regression analyses were conducted using two methods: 1) simple linear regression (lipid-normalized polychaete tissue versus total organic carbon-normalized sediment concentration), and 2) an analysis of covariance using data from both species with sediment collected from river miles 0 to 8. Regression results are shown in Table 2-9 and the analysis of covariance models are shown on Figures 2-43 and 2-44. All models are significant with high R^2 values, suggesting that bioaccumulation in benthic invertebrates of the LPRSA can be adequately estimated using surface sediment concentrations of 2,3,7,8-TCDD and Total PCBs. In all cases, the confidence intervals of the estimated slope parameters contain 1.0; therefore, there is no evidence that the rate of bioaccumulation is changing with sediment concentration. This is a good indication that biota-sediment accumulation factors (BSAFs) calculated using the site-specific data can be extrapolated to future conditions under hypothetical remedial scenarios. The use of polychaetes and oligochaetes as representative organisms of the benthic community is also reasonable and conservative, given their 1) widespread distribution in the LPRSA, 2) predominance in the benthic community samples collected in the 1990s and 2000s, and 3) generally larger size and lipid content than most other sediment (infaunal) invertebrates.

3 Development of Food Web Bioaccumulation Tool

The goal of this task was to develop a food web bioaccumulation predictive tool for estimating concentrations of 2,3,7,8-TCDD and PCBs in biota from the LPRSA, based on relationships established from the spatial and temporal statistical analyses described in Section 2. Existing empirical food-web relationships and available models were evaluated. The bioaccumulation tool described in this section was constructed and tested using data for 2,3,7,8-TCDD, Total PCBs, and select PCB congeners.

3.1 Evaluation of Existing Food Web Models and Predictive Tools/Relationships

Food web models describe the relationships between chemical contaminants in abiotic media (e.g., sediment, surface water, interstitial/pore water) and the organisms that make up the food web. The usual objective of food web modeling is to develop a tool, calibrated to current site-specific conditions, that can be used to predict tissue concentrations in different organisms from various scenarios of environmental exposure and estimate doses to humans or animals that may consume these organisms (e.g., see Gustavson et al. 2011 for a concise summary of food web model use at Superfund sites). The overarching goal of most food web model applications is to evaluate what site-specific remedial strategies for abiotic media (i.e., sediments, soils) might result in acceptable tissue concentrations from an ecological and/or human health risk perspective. In aquatic environments, the two primary approaches to food web bioaccumulation models are 1) empirical models that use site-specific data to calculate bioaccumulation factors (BAFs) and BSAFs; and 2) complex mechanistic models that incorporate the uptake of contaminants from water, sediment, diet, and their elimination through respiration, growth dilution, egestion, and metabolism (Arnot and Gobas 2004; USEPA 2000; Iannuzzi and Ludwig 2000; Iannuzzi et al. 1996; Thomann et al. 1992).

3.1.1 Empirical Models

Empirical models are site-specific and based on the observed relationships between sediment and the food web components of a specific waterway. The drawback to these models is that BSAFs are based on equilibrium partitioning theory, the assumptions of which are often violated, particularly among organisms of higher trophic levels, such as fish, that are mobile and have the capacity to metabolize organic contaminants (Gustavson et al. 2011; Iannuzzi et al. 2011). Attempts to measure BSAFs are often problematic due to the difficulty in pairing a measured tissue concentration with a precise estimate of the sediment concentration to which an organism has been exposed. Again this is particularly true of larger, more mobile organisms with varying abilities to metabolize organic chemicals. Finally, there is evidence that BSAFs can be concentration dependent (i.e., not constant across sediment concentrations), and it is sometimes reported that BSAFs increase with a decrease in sediment concentration (Iannuzzi et al. 2011). If this is true, it would reduce the predictive ability of the empirical model under varying sediment concentrations and in particular, could result in an overestimate of the reduction in fish tissue concentrations achievable under remedial scenarios. On the other hand, some investigators have

attributed the apparent decline in BSAFs with increasing sediment concentrations to the variable exposure of mobile organisms (i.e., they are exposed to more and less contaminated sites than where they were collected) (Gustavson et al. 2011). Essentially, the ability of empirical models to predict bioaccumulation needs to be evaluated on a site-specific basis and can only work if there is an apparent trend relationship between chemical concentrations in the abiotic (i.e., sediment) and biotic (organisms) components at the site—similar to the evaluation provided in Section 2 for the LPRSA.

3.1.2 Multi-Compartment/Complex Food Web Models

Because of the limitations of empirical models, more complex multi-compartment models have been adopted at some contaminated sites. Mass-balance models that attempt to describe the food web transfer of nonionic organic chemicals have been developed and used at various sites, and those described by Arnot and Gobas (2004), Gobas (1993) and Thomann et al. (1992) have gained the widest acceptance. A bioaccumulation model proposed by Arnot and Gobas (2004) was evaluated for the purpose of predicting bioaccumulation in the LPRSA. The "Gobas model," as this is typically referred to by scientists, has been used at large Superfund sites such as the Fox River, the Duwamish River, and the Hudson River. A detailed review of its use and parameterization at these sites is provided in Gustavson et al. (2011). The applied form of the Gobas model for a single organism is the steady-state equation as follows:

where:

C_B = chemical concentration in the organism

k_1 = the gill uptake rate constant

k_D = dietary uptake rate constant

k_2 = gill elimination rate constant

k_E = fecal egestion rate constant

k_G = growth dilution rate constant

k_M = metabolic transformation rate.

The organism's uptake of chemicals is described by the numerator of the equation and is composed of respiratory uptake from water (either the water column or sediment pore water) and dietary uptake from surface water, sediment, detritus, and prey, depending on the organism. Uptake via respiratory area (gills and skin) is described by the gill uptake rate constant (k_1) multiplied by the freely dissolved concentration in the water to which the organism is exposed. This is apportioned by the fraction of ventilation in overlying

water (m_O) times the freely dissolved concentration ($\Phi \cdot C_{WT,O}$) and the fraction of ventilation in sediment pore water (m_P) multiplied by the freely dissolved pore water concentration associated with sediment $C_{WD,S}$. Dietary uptake is described by the dietary uptake rate constant apportioned by the fraction of each dietary constituent, P_i, which is multiplied by the chemical concentration of each dietary constituent $C_{D,i}$. The denominator of the equation describes the organism's elimination of chemicals by depuration, growth dilution, metabolism and excretion.

The main site-specific inputs to the model are water and sediment concentrations. If not measured, sub-models are used to predict dissolved and pore water concentrations adding considerably more parameters (and uncertainty) to the modeling process. Similarly, none of the rate constants in the Gobas model are known or measurable, but are derived/predicted from sub-models which again add many more parameters (and uncertainty) to the modeling process. Literature values are suggested for many parameters, but these values can vary greatly, and they are not species- or site-specific. Dietary preferences are also an important part of the model and can be difficult to estimate without substantive site-specific data and information on the biological food web interactions at the site and chemistry data in multiple types of media (i.e., dissolved and solids fractions of surface and pore waters, and biotic components of the food web at all levels).

The food web model is generally structured such that the equation above is solved sequentially for each organism in order of trophic level. In this way the concentrations estimated in lower trophic organisms are then used as input to the dietary uptake portion of the model for the organisms of higher trophic levels. Therefore, uncertainty in the estimation of these concentrations at lower trophic levels is magnified with each trophic step. Table 3-1 is a list of all the parameters required to be estimated for a Gobas model and a description of the commonly used values for parameters that are not site-specific. As shown in this table, there is very limited site-specific information available for the LPRSA that can be used to develop, with any certainty, the parameters needed to construct a complex model like this for this system.

The Gobas model is deterministic, using a single value for sediment and water concentrations and producing a single tissue concentration for each organism, which is then compared to the mean observed tissue concentrations. The model structure is complex and to calibrate the model Region 2 would have to include many compartments (e.g. phytoplankton, zooplankton, invertebrates) for which no concentration data exist in the LPRSA. Due to these complexities and the scarcity of data with which to evaluate assumptions, this type of model was not used.

3.2 Selection and Description of Predictive Bioaccumulation Tool for the LPRSA

Given that data limitations preclude use of the Gobas model, a simpler modeling approach using empirical relationships between sediments and various trophic levels of invertebrates and fish was used. As discussed in Section 2, the exposure of aquatic organisms in the LPRSA to 2,3,7,8-TCDD and PCBs is dependent on the surface sediment concentrations, and there is a relationship between the two that co-

varies for most of the area making empirical modeling the most reasonable predictive bioaccumulation tool for the system, subject to the limitations and variability in the existing datasets.

A brief description of this empirically-based bioaccumulation tool follows. Total OC-normalized sediment concentrations are used to predict a range of expected lipid-normalized tissue concentrations for benthic and demersal (near bottom) invertebrates and fish (i.e., forage fish and carp) using BSAFs; and forage fish-based accumulation factors (AFs) are used for piscivorous fish and blue crab that feed on small fish. The predictive bioaccumulation tool is described in detail below.

The bioaccumulation tool is based on the concept of a BSAF, which is a unitless chemical and organism-specific ratio given by the following equation:

where:

C_{biota} is the wet-weight tissue concentration in the organism

f_{lipid} is the lipid fraction of the tissue

C_{sed} is the dry-weight surface sediment concentration

f_{oc} is the organic carbon (oc) fraction of the surface sediment.

Assuming a BSAF is known, a rearrangement of this equation gives a means to predict a tissue concentration from a given sediment concentration:

The bioaccumulation tool was structured to first predict the range of concentrations observed in forage fish based on the range of sediment concentrations using a BSAF. Then, trophic AFs were derived based on the predicted forage fish concentrations. First, however, the distribution of sediment concentrations had to be appropriately described and as spatially accurate as possible. Because sediment sample locations were not randomly located, the usual non-weighted descriptive statistics (i.e., mean, standard deviation) would tend to give a biased representation. Therefore, a spatially weighted approach was applied.

Surface sediment data collected from 2005 to present were used to represent the current spatial distribution of chemical concentrations in the LPRSA. A total of 406 locations were sampled during this time (co-located analytical results were averaged). Eight of these locations had missing PCB data, so a regression relationship between 2,3,7,8-TCDD and Total PCB congeners (R^2 = 0.78) was used to estimate total PCB sediment concentrations at those locations. A Thiessen polygon map was prepared, and each sample location was then assigned an “area of influence” based on the size of its associated Thiessen polygon. This area of influence can then be used to calculate a spatially weighted average for each of the chemicals being evaluated. The Thiessen-based spatial representation of 2,3,7,8-TCDD and

Total PCB congeners is shown on Figures 3-1 and 3-2, respectively. While there is some evidence of temporal trends in tissue data, due to the scarcity of available data from the 2009-2010 CPG data set, data from the earlier biota programs were combined with the later data for calibration, as specified in Table 2-4.

Forage fish such as mummichog have a very limited home range and, therefore, their tissue concentrations would be expected to be more closely associated with the sediment concentrations where they were caught (Iannuzzi et al. 2011). Each individual is expected to have a tissue concentration well described by the BSAF relationship. However, due to analytical sample size requirements, the concentration in an individual forage fish is not measured, and usually composite samples of 30 or more individuals comprise the sample associated with an individual observed tissue concentration. Other species are more mobile and, therefore, their tissue concentrations would represent the exposure to sediments in their entire home range, as well as their exposure to the available prey (Iannuzzi and Ludwig 2000). For these reasons, rather than using individual observed sediment concentrations to predict a tissue concentration for any species, the mean of a simulated random sample of 30 OC-normalized sediment observations (comparable to the number of forage fish in a representative composite tissue sample) was used to predict a single lipid-normalized tissue concentration. Five thousand simulated samples of 30 sediment observations were generated in the modeling process with the following constraints: each sample of 30 was constrained to within a river mile; the probability of an individual sediment sample location being selected was proportional to its area of influence defined by the Thiessen polygon map; and the allocation of the 5,000 samples are proportional to the area of each river mile. As shown on the maps (Figures 3-1 and 3-2), there are only four polygons above LPRSA river mile 16, resulting in relatively large areas of influence for the observed concentrations at those locations; i.e., in some cases more than half of the river mile. In addition very few tissue samples were collected above LPRSA river mile 16. Therefore, predictions were limted to the area between LPRSA river miles 0 and 16.

For each of the 5,000 predicted OC-normalized sediment concentrations, lipid-normalized tissue concentrations were calculated for forage fish and common carp (fillet and whole body) using the BSAF relationship. Tissue concentrations for all other species were calculated by multiplying an AF by the predicted, lipid-normalized forage fish concentrations. The predicted normalized tissue concentrations were then divided by the mean observed lipid fraction for the species and tissue type to calculate a total wet-weight concentration. Initial values for BSAFs and AFs were estimated using observed sediment/tissue ratios for each river mile. These values were then adjusted during the calibration process such that predicted mean tissue concentrations best agreed with observed mean tissue concentrations.

3.3 Bioaccumulation Tool Output, Calibration, and Performance

Performance was first evaluated to confirm that the predicted mean sediment concentrations agreed with the spatially weighted average sediment concentrations by river mile (Figures 3-3 and 3-4). The output was then evaluated for the species whose tissue concentrations are expected to be most closely

associated with the sediment concentrations (i.e., forage fish and common carp) (Figures 3-5 through 3-8). Agreement between the LPRSA-wide observed and predicted mean concentrations are shown graphically on Figures 3-9 and 3-10. Tissue data for some species were not collected from the entire LPRSA; therefore, predictions were limited to the portion of the LPRSA where the species were observed: LPRSA river miles 0 through 8 for adult striped bass (Figure 2-3e) and LPRSA river miles 8 through 16 for channel catfish (Figure 2-3c). Three outliers were removed from the forage fish data set before calibrating the tool. These outliers are three mummichog samples from the same location, with 2,3,7,8-TCDD concentrations (381, 468, and 828 ng/kg) that greatly exceeded the remaining mummichog sample concentrations which were all less than 100 ng/kg. Summary statistics for the observed and predicted tissue distributions are provided in Table 3-2. Calibrated BSAFs and AFs are provided in Table 3-3.

The sensitivity of the tool to the effects of the simulation sampling and the river mile constraint was tested. The simulated sediment sampling was conducted using the SURVEYSELECT procedure of SAS/STAT® software (version 9.2; SAS 2010). The probability sampling methods use random numbers in the selection algorithms. The procedure uses a uniform random number function to generate streams of pseudo-random numbers from an initial starting point, or seed. The seed can be specified so that the simulation will produce the same results each time it is run. To test the effect of the seed, the simulation was run with a different seed and the results were compared to the initial simulation. The predicted values were compared and found to be virtually identical to three significant figures. The effect of the river mile sampling constraint was tested by shifting the river mile cutoffs by .5 mile and re-running the simulation with the sediment samples constrained within the new river mile cutoffs. The predicted results were then compared to the original predictions. Predicted means of the shifted river mile simulation were within 2 percent of the original predictions, demonstrating the low sensitivity of the tool to the within-river-mile constraint.

The bioaccumulation tool was designed to predict future tissue concentrations under potential remedial scenarios. The mechanism for simulating remediation is to assign new concentration values (characteristic of a remedial scenario) to the polygons shown on Figures 3-1 and 3-2 and to re-run the simulation. This can be done on a concentration basis or a river mile basis. In addition, individual polygons can be selected for simulated remediation. Initial test runs of future tissue concentration predictions were generated by substituting hypothetical post-remediation concentration values in polygons that exceeded a set value. Values at the detection limit for 2,3,7,8-TCDD were substituted for the polygons that were above the hypothetical target cleanup level and predicted tissue concentrations were simulated under “post cleanup” conditions. The predicted mean tissue concentrations under five hypothetical 2,3,7,8-TCDD target cleanup levels are shown in Table 3-4. These target levels were selected by ToxStrategies and ARCADIS to evaluate a reasonable range of both human health and ecological exposure risk estimates.

3.4 Bioaccumulation Tool Uncertainties

The bioaccumulation tool is based on the assumption that lipid-normalized tissue concentrations are proportional to OC-normalized sediment concentrations for a given chemical, species, and tissue type, and that this relationship is estimable by a constant, the BSAF. It is further assumed that this relationship captures the uptake by organisms from the water column (i.e., that exposure in the water column is dependent upon surface sediment concentrations). Criticism of empirical models is largely of the attempts to relate tissue and sediment on a local scale without understanding or capturing the true exposure of the organism, particularly larger, more mobile organisms. BSAFs for forage fish calculated with tissue and sediment means paired by river mile vary by as much as an order of magnitude in the LPRSA. However, these localized estimates of BSAFs do not account for varying exposure in the water column, which has been shown to be a function of the sediment load. This sediment load in turn has both spatial and tidal variability. Therefore, while overall, an organism's exposure is dependent upon sediment concentrations, there is a localized variability that is not captured by the simple empirical relationship. The assumption of the bioaccumulation tool, however, is that this LPRSA-wide calibrated BSAF describes the relationship between tissue and sediment and that this relationship will not vary under changes to the sediment distribution, which is a source of uncertainty with respect to future predictions.

The bioaccumulation tool is based on the assumption that an accurate characterization of the spatial sediment distribution of chemicals is available. There are 401 sample locations between river miles 0 and 16, which cover an area of 918.5 acres; this is an average of one sample per 2.3 acres. Individual polygons range from 0.01 to 19.8 acres. The number of polygons per river mile varies from 10 (LPRSA river mile 14) to 63 (LPRSA river mile 11) and the average size of polygons within river miles varies from 0.65 (LPRSA river mile 11) to 6.8 (LPRSA river mile 1). In this type of spatial analysis, an entire polygon is assumed to have the same concentration as the sample location at the center of it. The impact of this assumption will vary based on the size of the polygon as well as the expected variability in the vicinity.

The bioaccumulation tool is calibrated to predict tissue concentrations that approximate the observed tissue concentrations. The inherent assumption is that the tissue data set is representative of actual distributions of tissue concentrations in the LPRSA. Further, with respect to risk assessment, the assumption is that the sampled organisms are representative of those to which a potential receptor is exposed. Confidence in the first assumption would increase with sample size and spatial distribution of the sampled organisms. With respect to the second assumption and human health risk assessment, the sampling programs were designed to collect fish for fillet samples of a size that consuming anglers would be expected to catch and keep.

Finally, the bioaccumulation tool is expected to be used to predict future tissue concentrations under various remedial scenarios and changing sediment distributions. In order to test this assumption it would be necessary to have temporally distinct tissue data sets collected under various sediment concentration distributions. This assumption cannot be tested with the data sets available for the LPRSA.

4 Conclusions

ARCADIS conducted statistical evaluations and developed a predictive food web bioaccumulation tool for the LPRSA to simulate/estimate current and future chemical contaminant concentrations in key receptors (i.e., crabs, fish) for human health and ecological risk assessment. The overarching objective of this work was to develop a bioaccumulation tool to estimate potential future concentrations of chemical contaminants in these organisms under different remediation scenarios, and to evaluate the likelihood of achieving human and ecological risk-based goals under each scenario. The evaluation focused on 2,3,7,8-TCDD and PCBs, as these two groups of chemical compounds represent the majority of the perceived human health risk in the LPRSA and are the two most prominent groups of non-polar organic compounds that may pose a risk to ecological receptors (i.e., fish, crabs, birds, and mammals) from food web bioaccumulation. Other chemicals of potential ecological concern are primarily inorganic constituents and non-bioaccumulative organic compounds that pose risk via direct exposure/toxicity in sediments and/or water. These will be evaluated by examining the site-specific data on sediment chemistry, toxicity and aquatic community structure collected in the LPRSA. It is anticipated that the bioaccumulation tool and related analyses will be expanded in the future to evaluate other chemicals of ecological or human health concern in the LPRSA.

Statistical evaluations were conducted over different spatial and temporal scales in the LPRSA to determine what relationships exist between chemicals (i.e., 2,3,7,8-TCDD and PCBs) in these media. The analysis of temporal trends suggests that natural attenuation may be occurring in the LPRSA, but additional data collection is needed to confirm such a trend. There were spatial trends in both the sediment and biota tissue data in the LPRSA for both 2,3,7,8-TCDD and total PCBs. For both constituents, concentrations tend to rise from LPRSA river mile 0 to 2, fluctuate slightly from LPRSA river miles 2 through 12 with a local maximum at river mile 10.9 for sediment, then decline upriver.

ARCADIS developed a bioaccumulation tool for the LPRSA using empirical relationships (i.e., BSAFs and AFs) between sediments and various trophic levels of invertebrates and fish, based on the statistical evaluations developed in the trends assessment. The tool was designed in a probabilistic platform to predict future tissue concentrations under potential/hypothetical remedial scenarios. The mechanism for simulating remediation is to represent the surface sediment data for the river with spatially weighted Thiessen polygons, assign new values to select groups of polygons (i.e., remediate them) and then re-run the simulation. Initial test runs of future tissue concentration predictions were generated by substituting hypothetical post-remediation concentration values in polygons that exceeded a set value. Values at the detection limit for 2,3,7,8-TCDD were substituted for the polygons that were above the hypothetical target cleanup level and predicted tissue concentrations were simulated under “post cleanup” conditions. This was conducted for five hypothetical 2,3,7,8-TCDD target cleanup levels. This tool can be tailored for different temporal and spatial analyses within the LPRSA, and can be further expanded to include additional data sets and nonionic organic chemicals of concern to support both human and ecological risk assessment.

5 References

Arnot, J.A and F.A.P.C. Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environ. Toxicol. Chem*. 23: 2343-2355.

Gobas, F.A.P.C. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: Application to Lake Ontario. *Ecological Modeling* 69:1-17. December 8.

Gustavson, K., T. von Stackelber, I. Linkov, and T. Bridges. 2011. Bioaccumulation models: State of the application at large Superfund sites. United States Army Corps of Engineers Dredging Operations and Research. ERDC TN-DOER-R17.

Iannuzzi, J., M. Butcher, and T.J. Iannuzzi. 2011. Evaluation of potential relationships between chemical contaminants in sediments and aquatic organisms from the lower Passaic River, New Jersey, USA. *Environ. Toxicol. Chem*. 30(7):1721-1728.

Iannuzzi, T.J. and D.F. Ludwig. 2000. The Role of food web models in the environmental management of bioaccumulative chemicals. *Soil Sed. Contam.* 9(3): 181-195.

Iannuzzi, T.J., N.W. Harrington, N.M. Shear, C.L. Curry, H. Carlson-Lynch, M.H. Henning, S.H. Su, and D.E. Rabbe. 1996. Distributions of key exposure factors controlling the uptake of xenobiotic chemicals in an estuarine food web. *Environ. Toxicol. Chem.* 15(11): 1979-1992.

SAS. 2010. **SAS/STAT® software, version 9.2.** Cary, North Carolina. Available online at: www.sas.com.

Thomann, R. V., J. P. Connolly, and T. F. Parkerton. 1992. An equilibrium model of organic chemical accumulation in aquatic food webs with sediment interaction. *Environ Toxicol Chem.* 11:615–629.

USEPA. 2000. Bioaccumulation testing and interpretation for the purpose of sediment quality assessment; status and needs. United States Environmental Protection Agency Bioaccumulation Analysis Workgroup. EPA-823-R-00-001.

Tables

List of Tables

Table 2-1 Surface Water Summary Statistics: 2011-2013

Table 2-2 Summary of Surface Sediment Samples in the LPRSA

Table 2-3 Surface Sediment Summary Statistics: 1990-2012

Table 2-4 Summary of Aquatic Tissue Samples in the LPRSA

Table 2-5 Aquatic Tissue Summary Statistics

Table 2-6 Aquatic Organism Size Statistics

Table 2-7 Mean and Standard Deviation of Sediment Samples Collected Within River Miles 1 through 7 from Selected Sampling Programs in the LPRSA and Results of Mean Comparison

Table 2-8 Summary Statistics of Tissue Concentrations by Time Period of Collection for River Miles 0 to 8

Table 2-9 Results of Regression Analysis of Bioaccumulation Testing of LPRSA Sediments

Table 3-1 Gobas Food Web Model Parameters

Table 3-2 Summary Statistics for the Observed and Predicted Tissue Concentration Distributions

Table 3-3 Model-Calibrated BSAFs and AFs

Table 3-4 Predicted Future Mean Tissue Concentrations under Hypothetical Remedial Scenarios

Table 2-1
Surface Water Summary Statistics: 2011-2013

Chemical Name	Sample Type	Unit	LPRSA River Mile	Station Number	Sample Size	Number of Detects	Mean	SD	Minimum	Maximum
2,3,7,8-TCDD	Total	pg/L	0	000	56	35	1.57	1.25	0.4	5.63
2,3,7,8-TCDD	Total	pg/L	1.4	014	56	46	3.73	3.66	0.48	15.4
2,3,7,8-TCDD	Total	pg/L	2.2 - 4.2	TR2	48	46	8.71	10.6	0.77	56
2,3,7,8-TCDD	Total	pg/L	4.2	042	8	6	4.27	4.42	0.7	13.6
2,3,7,8-TCDD	Total	pg/L	3 - 6.7	TR1	48	47	91	371	0.41	1870
2,3,7,8-TCDD	Total	pg/L	6.7	067	8	5	3.87	4.11	0.45	12.9
2,3,7,8-TCDD	Total	pg/L	10.2	102	57	49	7.61	13.9	0.07	81.3
2,3,7,8-TCDD	Total Solid	pg	4.2	042	3	3	434	739	4.36	1290
2,3,7,8-TCDD	Total Solid	pg	10.2	102	3	3	170	285	3.76	499
2,3,7,8-TCDD	Dissolved	pg/L	4.2	042	2	2	0.04	0.02	0.02	0.05
2,3,7,8-TCDD	Dissolved	pg/L	10.2	102	2	2	0.06	0.03	0.04	0.09
2,3,7,8-TCDD	Solids	pg/g	4.2	042	1	1	587	--	587	587
2,3,7,8-TCDD	Solids	pg/g	10.2	102	1	1	177	--	177	177
Dissolved Organic Carbon	Dissolved	mg/L	0	000	56	56	2.28	1.07	0.41	4.46
Dissolved Organic Carbon	Dissolved	mg/L	1.4	014	56	55	2.66	1.07	0.25	4.43
Dissolved Organic Carbon	Dissolved	mg/L	2.2 - 4.2	TR2	48	48	3.05	1.07	0.77	4.6
Dissolved Organic Carbon	Dissolved	mg/L	4.2	042	15	15	3.53	0.63	2.7	4.52
Dissolved Organic Carbon	Dissolved	mg/L	3 - 6.7	TR1	48	48	3.66	0.82	1.28	4.93
Dissolved Organic Carbon	Dissolved	mg/L	6.7	067	8	8	3.09	0.19	2.85	3.37
Dissolved Organic Carbon	Dissolved	mg/L	10.2	102	63	63	4.01	0.99	2.34	5.56
Particulate Organic Carbon	Total	mg/L	0	000	48	30	0.88	0.69	0.2	3.4
Particulate Organic Carbon	Total	mg/L	1.4	014	48	39	1.42	0.94	0.2	5.5
Particulate Organic Carbon	Total	mg/L	2.2 - 4.2	TR2	40	34	2.29	1.73	0.2	7.9
Particulate Organic Carbon	Total	mg/L	4.2	042	12	8	2.57	2.3	0.2	7.6
Particulate Organic Carbon	Total	mg/L	3 - 6.7	TR1	40	37	2.84	1.82	0.2	9.2
Particulate Organic Carbon	Total	mg/L	6.7	067	8	8	2.7	1.51	1	5.5
Particulate Organic Carbon	Total	mg/L	10.2	102	55	48	2.49	1.59	0.65	11.2
Suspended Solids Concentration (0.7 µm)	Total	mg/L	0	000	40	40	17.3	8.63	6.4	49.4
Suspended Solids Concentration (0.7 µm)	Total	mg/L	1.4	014	40	40	21.5	17.2	7.5	96.7
Suspended Solids Concentration (0.7 µm)	Total	mg/L	2.2 - 4.2	TR2	32	32	37.5	40.4	10.5	221
Suspended Solids Concentration (0.7 µm)	Total	mg/L	4.2	042	15	15	26.9	25.2	8.7	102
Suspended Solids Concentration (0.7 µm)	Total	mg/L	3 - 6.7	TR1	32	32	40.9	31.7	15	134
Suspended Solids Concentration (0.7 µm)	Total	mg/L	6.7	067	8	8	28	19.6	6.9	63.2
Suspended Solids Concentration (0.7 µm)	Total	mg/L	10.2	102	47	47	30.7	23.4	4.6	153

Table 2-1
Surface Water Summary Statistics: 2011-2013

Chemical Name	Sample Type	Unit	LPRSA River Mile	Station Number	Sample Size	Number of Detects	Mean	SD	Minimum	Maximum
Total PCB Congeners (209)	Total	ng/L	0	000	24	24	11.4	7.01	5.77	39.6
Total PCB Congeners (209)	Total	ng/L	1.4	014	24	24	15.8	8.5	6.76	43.1
Total PCB Congeners (209)	Total	ng/L	2.2 - 4.2	TR2	24	24	34.7	28	11.1	102
Total PCB Congeners (209)	Total	ng/L	3 - 6.7	TR1	24	24	26.9	17.6	11.4	71.3
Total PCB Congeners (209)	Total	ng/L	10.2	102	24	24	11.6	7.74	1.96	29.4

Notes:
Summary of surface water data collected by the Cooperating Parties group from August 2011 through include March 2013.
Total PCB Congener (209) statistics include only data collected from August 2011 through March 2012.
Field duplicates averaged.
One-half of the detection limit was substituted for non-detects.
Station number locations are shown on Figure 2-1.
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
LPRSA = Lower Passaic River Study Area
mg/L = milligrams per liter
ng/L = nanograms per liter
PCB = polychlorinated biphenyl
pg = picograms
pg/L = picograms per liter
SD = standard deviation
TR1 = Tidal 1
TR2 = Tidal 2
µm = micromoles

Table 2-2
Summary of Surface Sediment Samples in the LPRSA

Year	Sampling Event	Sample Size				
		2,3,7,8-TCDD	PCB-118	PCB-126	Total Aroclor PCBs (Sum of 7 Aroclors)	Total PCB Congeners (209)
1990	Surface Sediment Investigation	6	--	--	6	--
1991	Core Sediment Investigation	17	17	17	17	--
1992	Core Sediment Investigation	4	4	4	4	--
1993	Core Sediment Investigation - 01 (March)	5	5	5	5	--
1993	Core Sediment Investigation - 02 (July)	10	10	10	10	--
1993/1994	REMAP Sediment Investigation	--	4	4	--	--
1994	Surface Sediment Investigation	17	17	17	17	--
1995	RI Sampling Program	92	93	92	91	--
1995	Surface Sediment Sampling Program	2	--	--	--	--
1997	CSO Sampling Program	--	--	--	3	--
1998	USEPA REMAP Sediment Investigation	1	--	--	--	--
1999	Late Summer/Early Fall RI-ESP Sampling Program	41	41	38	41	--
1999	Preliminary Toxicity Identification Evaluation Study	2	2	2	4	--
1999/2000	Minish Park Monitoring Program	8	8	8	8	--
2000	Spring RI-ESP Sampling Program	13	13	13	13	--
2000	Toxicity Identification Evaluation Study	6	6	6	6	--
1999-2006	Honeywell International Sampling Programs	3	--	3	--	--
2005	USEPA High Resolution Coring Program	10	10	10	--	10
2007/2008	USEPA High Res/Low Res Supplemental Sediment Sampling Progra	42	29	29	18	13
2008	CPG Low-Resolution Coring Program	114	115	115	91	115
2009	CPG Benthic Sediment Study	111	111	111	111	111
2010	CPG Benthic Sediment Study	21	21	21	21	21
2011	CPG River Mile 10.9 Investigation	54	54	54	--	53
2011	JDG High Resolution Coring Program	2	--	--	--	--
2012	CPG Supplemental Sediment Program	78	78	78	--	78
2012	HCX Focused Sediment Investigation	6	--	--	--	--
Total		**665**	**638**	**637**	**466**	**401**

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
-- No samples.
CPG = Cooperating Parties Group
CSO = combined sewer outfall
HCX = 1,2,4,5,7,8-hexachloro(9H)xanthene
JDG = Joint Defense Group
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
RI = remedial investigation
RI-ESP = Remedial Investigation Ecological Sampling Program
REMAP = Regional Environmental Monitoring and Assessment Program
USEPA = United States Environmental Protection Agency

Table 2-3
Surface Sediment Summary Statistics: 1990-2012

Chemical Name	Year of Sampling	Unit	Number of Samples	Number of Detects	Mean	Standard Deviation	Minimum	Maximum	Mean TOC (%)
2,3,7,8-TCDD	1990-1995	ng/kg	153	149	654	1,620	2.00	13,500	8.88
2,3,7,8-TCDD	1998-2003	ng/kg	73	73	378	268	130	2,300	3.36
2,3,7,8-TCDD	2005-2012	ng/kg	439	432	1,170	3,600	0.03	34,100	4.92
PCB-118	1990-1995	ng/kg	150	150	57,900	54,800	130	340,000	8.75
PCB-118	1998-2003	ng/kg	70	70	46,200	23,400	32.5	198,000	3.36
PCB-118	2005-2012	ng/kg	418	418	60,200	137,000	24.3	1,700,000	4.87
PCB-126	1990-1995	ng/kg	149	96	546	2,070	0.36	17,200	8.73
PCB-126	1998-2003	ng/kg	69	14	352	288	0.01	1,260	3.38
PCB-126	2005-2012	ng/kg	419	377	221	405	1.15	4,090	4.87
Total Aroclor PCBs (Sum of 7 Aroclors)	1990-1995	µg/kg	150	120	1,200	2,000	0.0	17,000	8.90
Total Aroclor PCBs (Sum of 7 Aroclors)	1998-2003	µg/kg	75	70	1,000	600	33	3,500	3.30
Total Aroclor PCBs (Sum of 7 Aroclors)	2005-2012	µg/kg	241	238	1,000	1,600	0.3	17,000	4.40
Total PCB Congeners (209)	2005-2012	ng/kg	401	401	2,190,000	4,510,000	5,480	33,900,000	4.85

Notes:
Field duplicates were averaged.
One-half of the detection limit was substituted for non-detects.
% = percent
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
LPRSA = Lower Passaic River Study Area
ng/kg = nanograms per kilogram
PCB = polychlorinated biphenyl
TOC = total organic carbon
µg/kg = micrograms per kilogram

Table 2-4
Summary of Aquatic Tissue Samples in the LPRSA

Species	Tissue Type	Used in Bioaccumulation Model?[a]	Sampling Event	Number of Samples
Gizzard Shad	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	3
Mixed Forage Fish	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	4
Mummichog	Whole Body	YES (Forage Fish)	1995 Biological Sampling Program	5
Mummichog	Whole Body	YES (Forage Fish)	1999 Late Summer/Early Fall RI-ESP Sampling Program	45
Mummichog	Whole Body	YES (Forage Fish)	2000 Spring RI-ESP Sampling Program	4
Mummichog	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	18
Pumpkinseed	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	1
Silver Shiner	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	1
Silverside	Whole Body	YES (Forage Fish)	1999 Late Summer/Early Fall RI-ESP Sampling Program	9
Spottail Shiner	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	1
White Perch	Whole Body	YES (Forage Fish)	2009-2010 CPG Tissue Data Collection	2
Blackworm	Bioaccumulation tissue[b]	YES (Invertebrate)	2009-2010 CPG Tissue Data Collection	14
Polychaeta	Bioaccumulation tissue[b]	YES (Invertebrate)	2009-2010 CPG Tissue Data Collection	5
Adult Striped Bass	Fillet	YES	1999 Late Summer/Early Fall RI-ESP Sampling Program	7
Adult Striped Bass	Fillet	YES	2000 Spring RI-ESP Sampling Program	3
American Eel	Fillet	YES	2001 Supplemental RI-ESP Biota Sampling Program	7
American Eel	Fillet	YES	2009-2010 CPG Tissue Data Collection	32
Channel Catfish	Fillet	YES	2009-2010 CPG Tissue Data Collection	11
Common Carp	Fillet	YES	2009-2010 CPG Tissue Data Collection	12
White Catfish	Fillet	YES	2009-2010 CPG Tissue Data Collection	19
White Perch	Fillet	YES	2000 Spring RI-ESP Sampling Program	6
White Perch	Fillet	YES	2009-2010 CPG Tissue Data Collection	19
Blue Crab	Muscle	YES	1995 Biological Sampling Program	4
Blue Crab	Muscle	YES	1999 Late Summer/Early Fall RI-ESP Sampling Program	15
Blue Crab	Muscle	YES	2000 Spring RI-ESP Sampling Program	3
Blue Crab	Muscle	YES	2009-2010 CPG Tissue Data Collection	21
American Eel	Whole Body	YES	2000 Spring RI-ESP Sampling Program	6
American Eel	Whole Body	YES	2009-2010 CPG Tissue Data Collection	19
Common Carp	Whole Body	YES	2009-2010 CPG Tissue Data Collection	12
White Perch	Whole Body	YES	1999 Late Summer/Early Fall RI-ESP Sampling Program	9
White Perch	Whole Body	YES	2000 Spring RI-ESP Sampling Program	9
White Perch	Whole Body	YES	2009-2010 CPG Tissue Data Collection	19
Blue Crab	Whole Body (Soft Tissue)	YES	1999 Late Summer/Early Fall RI-ESP Sampling Program	15
Blue Crab	Whole Body (Soft Tissue)	YES	2000 Spring RI-ESP Sampling Program	4
Blue Crab	Whole Body (Soft Tissue)	YES	2009-2010 CPG Tissue Data Collection	41
American Eel	Carcass	NO	2009-2010 CPG Tissue Data Collection	2
Blue Crab	Carcass	NO	2009-2010 CPG Tissue Data Collection	24
Channel Catfish	Carcass	NO	2009-2010 CPG Tissue Data Collection	11
Largemouth bass	Carcass	NO	2009-2010 CPG Tissue Data Collection	3
Northern pike	Carcass	NO	2009-2010 CPG Tissue Data Collection	1
Smallmouth bass	Carcass	NO	2009-2010 CPG Tissue Data Collection	3
White Catfish	Carcass	NO	2009-2010 CPG Tissue Data Collection	19
White Perch	Carcass	NO	2009-2010 CPG Tissue Data Collection	1
White Sucker	Carcass	NO	2009-2010 CPG Tissue Data Collection	5
Adult Striped Bass	Fillet	NO	1995 Biological Sampling Program	2
Bluefish	Fillet	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	1
Brown Bullhead	Fillet	NO	2001 Supplemental RI-ESP Biota Sampling Program	6
Largemouth bass	Fillet	NO	2009-2010 CPG Tissue Data Collection	3
Northern pike	Fillet	NO	2009-2010 CPG Tissue Data Collection	1
Smallmouth bass	Fillet	NO	2009-2010 CPG Tissue Data Collection	3
White Sucker	Fillet	NO	2009-2010 CPG Tissue Data Collection	5
Blue Crab	Hepatopancreas	NO	1995 Biological Sampling Program	2
Blue Crab	Hepatopancreas	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	15
Blue Crab	Hepatopancreas	NO	2009-2010 CPG Tissue Data Collection	7

Table 2-4
Summary of Aquatic Tissue Samples in the LPRSA

Species	Tissue Type	Used in Bioaccumulation Model?[a]	Sampling Event	Number of Samples
Adult Striped Bass	Whole Body	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	3
Adult Striped Bass	Whole Body	NO	2000 Spring RI-ESP Sampling Program	3
Atlantic Menhaden	Whole Body	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	6
Bluefish	Whole Body	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	2
Brown Bullhead	Whole Body	NO	2009-2010 CPG Tissue Data Collection	6
Juvenile Striped Bass	Whole Body	NO	1999 Late Summer/Early Fall RI-ESP Sampling Program	3

Notes:
[a] Indicates whether the species/tissue type was used in calibration of the bioaccumulation model
[b] Bioaccumulation tissue represents laboratory bioaccumulation testing utilizing test organisms introduced to surface sediment samples collected from the LPRSA.
CPG = Cooperating Parties Group
LPRSA = Lower Passaic River Study Area
RI-ESP = Remedial Investigation Ecological Sampling Program

Table 2-5
Aquatic Tissue Summary Statistics

Species	Tissue Type	Chemical Name	Units	Number of Samples	Number of Detects	Mean	Standard Deviation	Minimum	Maximum	Mean Lipid (%)
Blackworm	Bioaccumulation tissue[a]	2,3,7,8-TCDD	ng/kg	14	14	27	37	1	140	0.98
Blackworm	Bioaccumulation tissue[a]	PCB-118	ng/kg	14	14	6486	7263	1900	29000	0.98
Blackworm	Bioaccumulation tissue[a]	PCB-126	ng/kg	14	9	11	9	3	28	0.98
Blackworm	Bioaccumulation tissue[a]	Total PCB Congeners (209)	ng/kg	14	14	180343	155932	55200	529000	0.98
Polychaeta	Bioaccumulation tissue[a]	2,3,7,8-TCDD	ng/kg	5	5	6	7	2	19	1.18
Polychaeta	Bioaccumulation tissue[a]	PCB-118	ng/kg	5	5	1066	914	630	2700	1.18
Polychaeta	Bioaccumulation tissue[a]	PCB-126	ng/kg	5	1	5	4	2	11	1.18
Polychaeta	Bioaccumulation tissue[a]	Total PCB Congeners (209)	ng/kg	5	5	54300	45419	26200	135000	1.18
Adult Striped Bass	Fillet	2,3,7,8-TCDD	ng/kg	10	10	25	14	2	49	1.78
Adult Striped Bass	Fillet	PCB-118	ng/kg	10	10	43095	26631	13450	108000	1.78
Adult Striped Bass	Fillet	PCB-126	ng/kg	10	10	153	82	60	347	1.78
Adult Striped Bass	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	10	10	552	347	195	1200	1.78
American Eel	Fillet	2,3,7,8-TCDD	ng/kg	39	39	15	10	0	41	4.68
American Eel	Fillet	PCB-118	ng/kg	39	39	77582	55432	14000	240000	4.68
American Eel	Fillet	PCB-126	ng/kg	39	20	32	32	3	122	4.68
American Eel	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	39	39	1264	867	310	4900	4.68
American Eel	Fillet	Total PCB Congeners (209)	ng/kg	32	32	1073938	766411	274000	4340000	3.93
Channel Catfish	Fillet	2,3,7,8-TCDD	ng/kg	11	11	28	21	10	77	2.52
Channel Catfish	Fillet	PCB-118	ng/kg	11	11	24573	18206	6000	64000	2.52
Channel Catfish	Fillet	PCB-126	ng/kg	11	11	50	35	15	130	2.52
Channel Catfish	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	11	11	744	464	340	1900	2.52
Channel Catfish	Fillet	Total PCB Congeners (209)	ng/kg	11	11	500455	335708	190000	1270000	2.52
Common Carp	Fillet	2,3,7,8-TCDD	ng/kg	12	12	269	240	10	730	4.02
Common Carp	Fillet	PCB-118	ng/kg	12	12	192667	101273	42000	430000	4.02
Common Carp	Fillet	PCB-126	ng/kg	12	12	437	284	83	1200	4.02
Common Carp	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	12	12	4292	2165	1100	8500	4.02
Common Carp	Fillet	Total PCB Congeners (209)	ng/kg	12	12	4763000	3673814	846000	14800000	4.02
White Catfish	Fillet	2,3,7,8-TCDD	ng/kg	19	19	56	51	4	170	1.83
White Catfish	Fillet	PCB-118	ng/kg	19	19	46205	46803	6900	190000	1.83
White Catfish	Fillet	PCB-126	ng/kg	19	18	99	106	2	450	1.83
White Catfish	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	19	19	1252	1152	160	4700	1.83
White Catfish	Fillet	Total PCB Congeners (209)	ng/kg	19	19	981158	949362	128000	3910000	1.83
White Perch	Fillet	2,3,7,8-TCDD	ng/kg	25	25	47	25	4	99	2.23
White Perch	Fillet	PCB-118	ng/kg	25	25	34024	27474	5600	94000	2.23
White Perch	Fillet	PCB-126	ng/kg	25	24	109	105	7	368	2.23
White Perch	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	25	25	621	299	190	1300	2.23
White Perch	Fillet	Total PCB Congeners (209)	ng/kg	19	19	580263	331944	149000	1470000	2.03
White Sucker	Fillet	2,3,7,8-TCDD	ng/kg	5	5	14	13	1	29	1.37

Table 2-5
Aquatic Tissue Summary Statistics

Species	Tissue Type	Chemical Name	Units	Number of Samples	Number of Detects	Mean	Standard Deviation	Minimum	Maximum	Mean Lipid (%)
White Sucker	Fillet	PCB-118	ng/kg	5	5	12360	5333	8300	21000	1.37
White Sucker	Fillet	PCB-126	ng/kg	5	5	37	16	24	60	1.37
White Sucker	Fillet	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	5	5	406	233	160	740	1.37
White Sucker	Fillet	Total PCB Congeners (209)	ng/kg	5	5	333800	199838	160000	583000	1.37
Blue Crab	Muscle	2,3,7,8-TCDD	ng/kg	43	43	12	7	1	23	0.47
Blue Crab	Muscle	PCB-118	ng/kg	41	41	6943	4192	1500	17700	0.48
Blue Crab	Muscle	PCB-126	ng/kg	35	29	18	15	4	71	0.50
Blue Crab	Muscle	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	43	23	45	28	4	100	0.47
Blue Crab	Muscle	Total PCB Congeners (209)	ng/kg	21	21	41824	28647	11400	107000	0.50
American Eel	Whole Body	2,3,7,8-TCDD	ng/kg	25	24	15	14	0	47	6.34
American Eel	Whole Body	PCB-118	ng/kg	25	25	93904	58102	30000	260000	6.34
American Eel	Whole Body	PCB-126	ng/kg	25	12	87	107	6	320	6.34
American Eel	Whole Body	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	25	22	1600	1559	75	7500	6.34
American Eel	Whole Body	Total PCB Congeners (209)	ng/kg	19	19	1536632	1219942	419000	5690000	6.55
Common Carp	Whole Body	2,3,7,8-TCDD	ng/kg	12	12	409	380	5	1400	5.41
Common Carp	Whole Body	PCB-118	ng/kg	12	12	167750	79317	81000	320000	5.41
Common Carp	Whole Body	PCB-126	ng/kg	12	12	386	170	120	690	5.41
Common Carp	Whole Body	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	12	12	4817	2808	1700	11000	5.41
Common Carp	Whole Body	Total PCB Congeners (209)	ng/kg	12	12	4133333	2020555	1520000	7860000	5.41
Forage Fish	Whole Body	2,3,7,8-TCDD	ng/kg	93	93	63	100	2	828	2.68
Forage Fish	Whole Body	PCB-118	ng/kg	93	92	40664	18244	17	78000	2.68
Forage Fish	Whole Body	PCB-126	ng/kg	93	92	119	61	16	295	2.68
Forage Fish	Whole Body	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	91	90	573	283	75	2200	2.70
Forage Fish	Whole Body	Total PCB Congeners (209)	ng/kg	30	30	533367	317824	172000	1850000	2.19
White Perch	Whole Body	2,3,7,8-TCDD	ng/kg	37	37	169	86	18	352	6.34
White Perch	Whole Body	PCB-118	ng/kg	37	37	111705	59598	13000	262000	6.34
White Perch	Whole Body	PCB-126	ng/kg	37	37	399	261	22	866	6.34
White Perch	Whole Body	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	37	37	3126	1710	470	10000	6.34
White Perch	Whole Body	Total PCB Congeners (209)	ng/kg	19	19	2175474	1193440	289000	5140000	4.39
Blue Crab	Whole Body (Soft Tissue	2,3,7,8-TCDD	ng/kg	60	60	57	28	4	141	1.88
Blue Crab	Whole Body (Soft Tissue	PCB-118	ng/kg	60	60	44030	23279	10000	115000	1.88
Blue Crab	Whole Body (Soft Tissue	PCB-126	ng/kg	60	55	107	64	4	280	1.88
Blue Crab	Whole Body (Soft Tissue	Total Aroclor PCBs (Sum of 7 Aroclors)	µg/kg	60	60	570	373	110	1800	1.88
Blue Crab	Whole Body (Soft Tissue	Total PCB Congeners (209)	ng/kg	41	41	325212	135332	75700	786000	1.73

Notes:
Field duplicates were averaged.
One-half of the detection limit was substituted for non-detects.
[a] Bioaccumulation tissue represent laboratory bioaccumulation testing utilizing test organisms introduced to surface sediment samples collected from the LPRSA.
2,3,7,8-TCDD = tetrachlorodibenzo-*p*-dioxin
PCB = polychlorinated biphenyl
ng/kg = nanograms per kilogram
µg/kg = micrograms per kilogram

Table 2-6
Aquatic Organism Size Statistics

Species	Tissue Type	Sampling Event	Sample Size	Mean Length, mm (min-max)	Mean Weight, g (min-max)
Adult Striped Bass	Fillet - skin off	1999 Late Summer/Early Fall RI-ESP Sampling Program	7	362 (206-613)[a]	667 (88-2590)[a]
Adult Striped Bass	Fillet - skin off	2000 Spring RI-ESP Sampling Program	3	512 (255-730)[a]	1830 (165-3682)[a]
Adult Striped Bass	Whole body	1999 Late Summer/Early Fall RI-ESP Sampling Program	3	362 206-613)[a]	667 (88-2590)[a]
Adult Striped Bass	Whole body	2000 Spring RI-ESP Sampling Program	3	512 (255-730)[a]	1830 (165-3682)[a]
American Eel	Fillet	2009-2010 CPG Tissue Data Collection	32	541 (275-750)[a]	NA
American Eel	Fillet - skin on	2001 Supplemental RI-ESP Biota Sampling Program	6	NA	369 (124-750)
American Eel	Whole body	2000 Spring RI-ESP Sampling Program	6	366 (230-630)[a]	121 (20-499)[a]
American Eel	Whole body	2009-2010 CPG Tissue Data Collection	19	439 (275-635)	NA
Blue crab	Hepatopancreas	2009-2010 CPG Tissue Data Collection	7	141 (137-144)	NA
Blue crab	Muscle	2009-2010 CPG Tissue Data Collection	21	140 (120-153)	NA
Blue crab	Whole body - soft tissue	2009-2010 CPG Tissue Data Collection	41	137 (121-149)	NA
Blue crab	Whole body - soft tissue	1999 Late Summer/Early Fall RI-ESP Sampling Program	15	121 (64-192)[a]	106 (34-269)[a]
Blue crab	Whole body - soft tissue	2000 Spring RI-ESP Sampling Program	4	110 (61-158)[a]	85 (19-217)[a]
Channel catfish	Fillet	2009-2010 CPG Tissue Data Collection	11	442 (352-510)	849 (488-1490)
Common carp	Fillet	2009-2010 CPG Tissue Data Collection	12	640 (549-779)	4687 (3162-7130)
Common carp	Whole body	2009-2010 CPG Tissue Data Collection	12	581 (524-610)	3067 (2200-3898)
White Perch	Fillet	2009-2010 CPG Tissue Data Collection	19	201 (149-321)	155 (56-630)
White Perch	Fillet - skin off	2000 Spring RI-ESP Sampling Program	6	NA	233 (178-261)
White Perch	Whole body	1999 Late Summer/Early Fall RI-ESP Sampling Program	9	176 (140-300)[a]	95 (57-428)[a]
White Perch	Whole body	2000 Spring RI-ESP Sampling Program	9	218 (132-310)[a]	189 (45-396)[a]
White Perch	Whole body	2009-2010 CPG Tissue Data Collection	21	183 (129-262)	98 (32-272)
White catfish	Carcass/Fillet	2009-2010 CPG Tissue Data Collection	19	406 (315-541)	905 (422-1695)

Notes:
[a] All specimens caught during sampling event.
NA = not available
CPG = Cooperating Parties Group
g = grams
LPRSA = Lower Passaic River Study Area
mm = millimeters
RI-ESP = Remedial Investigation Ecological Sampling Program

Table 2-7
Mean and Standard Deviation of Sediment Samples Collected Within River Miles 1 through 7 from Selected Sampling Programs in the LPRSA and Results of Mean Comparison

Chemical	Mean (Standard Deviation)					Spline Regression: Reduction in Mean Concentration from 1995 to 2008-2010 (p-value)	
	1995 RI Sampling Program (N=92)	2008 CPG LRC Program (N=45)	2009 CPG BSSP (N=39)	2010 CPG BSSP (N=15)	2012 CPG SSP (N=49)		
2,3,7,8-TCDD (ng/kg)	833 (2,050)	237 (238)	417 (762)	319 (280)	1,580 (4,280)	28%	(0.05)
Total Aroclor PCBs[a] (µg/kg)	1,500 (2,400)	920 (780)	1,600 (,1200)	1,100 (160)	NA	No significant difference	
Total PCB Congeners[b] (µg/kg)	NA	1,400(1,160)	1,180 (1,110)	866 (215)	3,090 (5,970)	Not Tested	
PCB-77 (ng/kg)	12,000 (13,200)	4,280 (4,070)	5,420 (5,470)	4,770 (1,210)	14,600 (31,000)	54%	(<0.0001)
PCB-118 (ng/kg)	66,200 (58,400)	38,300 (28,000)	30,600 (25,800)	28,200 (7,070)	76,500 (144,000)	41%	(0.0001)
Mercury (µg/kg)	3,300 (1,900)	1,750 (974)	1,720 (715)	2,020 (414)	3,560 (3,940)	45%	(<0.0001)
4,4'-DDT (µg/kg)	130 (390)	23 (44)	110 (390)	45 (94)	10 (18)	54%	(0.001)
Dieldrin (µg/kg)	26 (24)	8.9 (11)	5.2 (2.8)	3.4 (1.4)	5.5 (6.9)	77%	(<0.0001)

Notes:
[a]Sum of 7 aroclors
[b]Sum of 209 congeners
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
BSSP = Benthic Sediment Sampling Program
CPG = Cooperating Parties Group
DDT = dichlorodiphenyl-trichloroethane
LRC = Low Resolution Coring
N = number of samples
NA = not available
ng/kg = nanograms per kilogram
PCB = polychlorinated biphenyl
SSP = Supplemental Sampling Program
µg/kg = micrograms per kilogram

Table 2-8
Summary Statistics of Tissue Concentrations by Time Period of Collection for River Miles 0 to 8

Chemical	Species	Tissue Type	Year of Sampling	N	Number of Detects	Mean (Raw)[a]	Result of Comparison with p-value[b]		Mean (Lipid Normalized)[a]	Result of Comparison with p-value[b]		Mean lipid (%)
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	7	21.7	Decrease	0.021	286			8.1
			2009-2010	16	16	14.9			361			4.2
		Whole Body	1999-2001	6	6	9.7			172			5.7
			2009-2010	8	8	24.8			376			6.7
	Blue crab	Hepatopancreas	1999-2001	15	15	262	Decrease	0.000	4820	Decrease	<.0001	5.8
			2009-2010	5	5	176			2441			7.3
		Muscle	1999-2001	18	18	17.6	Decrease	0.004	4885	Decrease	<.0001	0.4
			2009-2010	11	11	11.1			2161			0.5
		Whole Body (Soft Tissue)	1999-2001	19	19	75.0	Decrease	0.046	3595			2.2
			2009-2010	22	22	61.6			4088			1.5
	Mummichog	Whole Body	1999-2001[c]	46	46	52.0	Decrease	0.002	1612			3.3
			2009-2010	15	15	33.9			1668			1.9
	White Perch	Fillet	1999-2001	6	6	64.9	Decrease	0.082	2282	Decrease	0.4364	2.9
			2009-2010	11	11	48.9			2235			2.3
		Whole Body	1999-2001	18	18	212	Decrease	0.066	2480			8.4
			2009-2010	10	10	158			3276			5.0
Total Aroclor PCBs[d] (µg/kg)	American Eel	Fillet	1999-2001	7	7	1624	Decrease	0.094	21661			8.1
			2009-2010	16	16	1271			28724			4.2
		Whole Body	1999-2001	6	3	810			14017			5.7
			2009-2010	8	8	2780			39814			6.7
	Blue crab	Hepatopancreas	1999-2001	15	15	5513	Decrease	0.027	101242	Decrease	0.0016	5.8
			2009-2010	5	5	3900			53902			7.3
		Muscle	1999-2001	18	4	64	Decrease	0.007	19528	Decrease	0.0038	0.4
			2009-2010	11	11	40			8321			0.5
		Whole Body (Soft Tissue)	1999-2001	19	19	777	Decrease	0.002	38228	Decrease	0.2842	2.2
			2009-2010	22	22	477			29368			1.5
	Mummichog[c]	Whole Body	1999-2001	49	48	517			16083			3.3
			2009-2010	14	14	676			35788			1.9
	White Perch	Fillet	1999-2001	6	6	842	Decrease	0.069	29215			2.9
			2009-2010	11	11	649			29274			2.3
		Whole Body	1999-2001	18	18	3989	Decrease	0.012	46886			8.4
			2009-2010	10	10	2630			53830			5.0

Notes:
[a]Half detection limit
[b]One-sided t-test assume lognormal distribution
[c]Excludes 3 outliers
[d]Sum of 7 aroclors
N = number of samples
ng/kg = nanograms per kilogram
µg/kg = micrograms per kilogram

Table 2-9
Results of Regression Analysis of Bioaccumulation Testing of LPRSA Sediments

Model Type	Chemical	Species	Intercept	Slope	R^2	BSAF Range
Simple Linear Regression	2,3,7,8-TCDD (ng/kg)	Polychaete	-4.814 (-6.4, -3.2)	1.197 (1.0, 1.4)	0.99	0.02 - 0.05
	Total PCB Congeners[a] (µg/kg)	Polychaete	-3.026 (-4.8, -1.2)	1.058 (0.95, 1.2)	0.99	0.12 - 0.14
Analysis of Covariance	2,3,7,8-TCDD (ng/kg)	Polychaete	-4.569 (-6.4, -2.8)	1.170 (0.97, 1.37)	0.99	0.02 - 0.05
		Blackworm	+2.75			0.35 - 0.75
	Total PCBs Congeners[a] (µg/kg)	Polychaete	-1.326 (-5.4, 2.8)	0.96 (0.71, 1.2)	0.98	0.12 - 0.14
		Blackworm	+2.28			1.2 - 1.4

Notes:
[a]Sum of 209 congeners
Analysis of covariance includes only river miles 0 to 8.
Polychaete sample size = 5
Oligochaete sample size = 3
Biota Sediment Accumulation Factors (BSAFs) are given using the regression equations within the range of sediment concentrations in the LPRSA.
2,3,7,8-TCDD = tetrachlorodibenzo-*p*-dioxin
LPRSA = Lower Passaic River Study Area
ng/kg = nanograms per kilogram
PCB = polychlorinated biphenyl
µg/kg = micrograms per kilogram

Table 3-1
Gobas Food Web Model Parameters

Model Parameter	Units	Derivation	Gobas Model Value	Gobas Reference/Justification	Comments
Gobas Model Parameters					
Density of lipids	kg/L	Default	0.9	Gobas 1993	
Density of water	kg/L	Default	1		
NLOM-octanol proportionality constant	L/kg	Default	0.035	Gobas et al. 1999	Based on Gobas et al. (1999) field and laboratory experiments on rainbow trout and rock bass.
NLOC-octanol proportionality constant	unitless	Default	0.35	Seth et al. 1999	Based on Seth et al. (1999) for chemicals with log Kow ranging from 1.5-7.5; constant can vary by a factor of 2.5 (Arnot and Gobas 2004).
Proportionality constant for particulate organic carbon	L/kg	Default	0.35	Seth et al. 1999	Based on Seth et al. (1999) for chemicals with log Kow ranging from 1.5-7.5; constant can vary by a factor of 2.5 (Arnot and Gobas 2004).
Proportionality constant for dissolved organic carbon	unitless	Default	0.08	Burkhard 2000	Similar magnitude of variability as proportionality constant for particulate organic carbon (Arnot and Gobas 2004).
Lipid fraction of sediment	%	Always 0	0		
Water content fraction for sediment	%	Calculated	1-(Lipid fraction sediment + organic carbon fraction sediment)		
Organic carbon fraction of sediment	%	Site-Specific	Equals sediment organic carbon content		
Site-Specific Parameters					
Mean water temperature	Celsius	Site-Specific	Site-Specific		
Dissolved organic carbon content water	kg/L	Site-Specific	Site-Specific		
Particulate organic carbon content	kg/L	Site-Specific	Site-Specific		
Concentration of suspended solids	kg/L	Site-Specific	Site-Specific		
Sediment organic carbon content	%	Site-Specific	Site-Specific		
Total water concentration	ng/L	Site-Specific	Site-Specific		
Sediment concentration	ng/g dry weight	Site-Specific	Site-Specific		
Mean water column DO saturation	%	Site-Specific or Default	90%	Benson and Krause 1980	
DO content	mg O_2/L	Site-Specific or Calculated	Site Specific or calculated (DO = (-0.24*mean water temp+14.04)*DO saturation)	Benson and Krause 1980	
Chemical-Specific Parameters					
Octanol-water partitioning coefficient (Kow; chemical-specific)	unitless	Chemical-Specific	Site-Specific	none	Kow values can vary for a single chemical. 2,3,7,8-TCDD log Kow values range 6.14-7.02.
Henry's Law Constant (chemical-specific)	Pa*m_3/mol	Chemical-Specific	20	none	Derived HLC values can vary for a single chemical. 2,3,7,8-TCDD HLC values range 0.15-1.64.

Table 3-1
Gobas Food Web Model Parameters

Model Parameter	Units	Derivation	Gobas Model Value	Gobas Reference/Justification	Comments
Species-Specific Parameters					
Phytoplankton					
Lipid content of organism	kg/kg	Default/Organism-Specific	0.005	none given	none given
NLOC of organism	kg/kg	Default/Organism-Specific	0.065	none given	none given
Water content of organism	kg/kg	Default/Organism-Specific	0.93	none given	none given
Growth rate constant	per day	Default/Organism-Specific	0.08	none given	none given
Metabolic transformation rate constant	per day	Default/Organism-Specific	0	none given	none given
Resistance to chemical uptake through the aqueous phases of algae, phytoplankton, or macrophyte	unitless		6.00E-05	Swackhamer and Skoglund 1993; Gobas and MacLean 2003	Derived from calibration to phytoplankton field-BCF data from the Great Lakes, such that kG (growth rate) begins to control the BCF for chemicals with a log Kow larger than 6.0.
Resistance to chemical uptake through the organic phases of algae, phytoplankton, or macrophyte	unitless	Default/Organism-Specific	5.5	Koelmans et al. 1993, Koelmans et al. 1995, Koelmans et al. 1999, Wang et al. 1996	Derived from calibration to empirical k2 (gill elimination rate constant) values from various phytoplankton, algae, and cyanobacteria species over a range of Kow values.
All other organisms (zooplankton, benthic invertebrates, fish)					
Organism wet weight	kg	Default/Organism-Specific			Arnot and Gobas (2004) suggest using databases such as Payne et al. (1999) for organism-specific parameters.
Lipid content of organism	%	Default/Organism-Specific			
NLOM of organism	%	Default/Organism-Specific			
NLOC of organism	%	Default/Organism-Specific			
Water content of organism	%	Default/Organism-Specific			
Metabolic transformation rate constant	per day	Default/Organism-Specific	0		Value is chemical and species dependent. Methods of estimation described in Arnot and Gobas (2003), Van der Linde et al. (2001), Fisk et al. (2000).
Lipid absorption efficiency	%	Default/Organism-Specific	Zooplankton = 72%, invertebrates = 75%, fish = 92%	Zooplankton: Conover 1966, Lehman 1993; invertebrates: Parkerton 1993, Gordon 1966, Berg et al. 1996, Roditi and Fisher 1999; fish: Gobas et al. 1999, Nichols et al. 2001	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, laboratory experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid, NLOM, and NLOC assimilation efficiencies. Invertebrate dietary assimilation efficiencies for inverts range from 15-96% (see refs), reflect dietary matrix (OM quality and quantity) and digestive physiology of organism. Arnot and Gobas (2004) suggest lipid and NLOM assimilation efficiencies = 75%. Fish assimilation efficiencies from rainbow trout laboratory study where lipid absorption efficiency was 92%. Another laboratory study of rainbow trout (Nichols et al. 2001) found 91% lipid absorption efficiency.
NLOC absorption efficiency	%	Default/Organism-Specific	Zooplankton = 72%, invertebrates = 75%, fish = 60%	Zooplankton: Conover 1966, Lehman 1993; invertebrates: Parkerton 1993, Gordon 1966, Berg et al. 1996, Roditi and Fisher 1999; fish: Gobas et al. 1999, Nichols et al. 2001	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, laboratory experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid, NLOM, and NLOC assimilation efficiencies. Invertebrate dietary assimilation efficiencies for inverts range from 15-96% (see refs), reflect dietary matrix (OM quality and quantity) and digestive physiology of organism. Arnot and Gobas (2004) suggest lipid and NLOM assimilation efficiencies = 75%. Fish assimilation efficiencies from rainbow trout laboratory study where lipid absorption efficiency was 92%. Another laboratory study of rainbow trout (Nichols et al. 2001) found 91% lipid absorption efficiency.
NLOM absorption efficiency	%	Default/Organism-Specific	Zooplankton = 72%, invertebrates = 75%, fish = 60%	Zooplankton: Conover 1966, Lehman 1993; invertebrates: Parkerton 1993, Gordon 1966, Berg et al 1996, Roditi and Fisher 1999; fish: Gobas et al. 1999, Nichols et al. 2001	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, lab experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid, NLOM, and NLOC assimilation efficiencies.

Table 3-1
Gobas Food Web Model Parameters

Model Parameter	Units	Derivation	Gobas Model Value	Gobas Reference/Justification	Comments
Water absorption efficiency	%	Default/Organism-Specific	Zooplankton = 25%, invertebrates = 25%, fish = 25%	none	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, laboratory experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid, NLOM, and NLOC assimilation efficiencies. Invertebrate dietary assimilation efficiencies for inverts range from 15-96% (see refs), reflect dietary matrix (OM quality and quantity) and digestive physiology of organism. Arnot and Gobas (2004) suggest lipid and NLOM assimilation efficiencies = 75%. Fish assimilation efficiencies from rainbow trout laboratory study where lipid absorption efficiency was 92%. Another laboratory study of rainbow trout (Nichols et al. 2001) found 91% lipid absorption efficiency.
Fraction of pore water ventilated	unitless	Default/Organism-Specific	Zooplankton = 0.0, invertebrates = 0.05, fish = 0.0	Winsor et al. 1990	Laboratory study of tellinid clam (*Macoma nasuta*) found pore water made up 4% of total volume of water ventilated (Winsor et al. 1990).
Fraction of an organisms' diet that contain each of the other organisms and sediment	unitless	Default/Organism-Specific			Data specific to organisms should be used in model (Arnot and Gobas 2004)
Dietary transfer efficiency constant (A)	unitless	Default	3.00E-07	Arnot and Gobas 2004	Empirical dietary chemical transfer efficiency (Ed) observations range from 0-100% in invertebrates, and 0-90% in fish due to differences in digestibility, dietary composition metabolic transformation, etc. It is difficult to develop accurate models for Ed. Arnot and Gobas (2004) used n=6 invertebrate and n=15 fish studies to develop equation Ed = 1/(A*Kow+B).
Gut uptake constant (B)	unitless	Default	2	Arnot and Gobas 2004	Empirical dietary chemical transfer efficiency (Ed) observations vary from 0-100% in invertebrates, and 0-90% in fish due to differences in digestibility, dietary composition metabolic transformation, etc. It is difficult to develop accurate models for Ed. Arnot and Gobas (2004) used n=6 invertebrate and n=15 fish studies to develop equation Ed = 1/(A*Kow+B).
Zooplankton lipid absorption efficiency	%	Default	72	Conover 1966; Lehman 1993	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, laboratory experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid and NLOM assimilation efficiencies.
Zooplankton NLOC and NLOM absorption efficiency	%	Default	72	Conover 1966; Lehman 1993	Zooplankton assimilation efficiencies for organic matter range from 55-85% (Conover 1966, laboratory experiment), whereas carbon and phosphorous assimilation are 85% (Lehman 1993, laboratory experiment). Value of 72% assumed for lipid and NLOM assimilation efficiencies.
Zooplankton water absorption efficiency	%	Default	25	none given	Assumed 25% for all freshwater species; no reference.

Table 3-1
Gobas Food Web Model Parameters

Model Parameter	Units	Derivation	Gobas Model Value	Gobas Reference/Justification	Comments
Invertebrate lipid absorption efficiency	%	Default	75	Parkerton 1993; Gordon 1966; Berg et al. 1996; Roditi and Fisher 1999	Dietary assimilation efficiencies for invertebrates range from 15-96%. Arnot and Gobas (2004) suggest lipid and NLOM assimilation efficiencies = 75%.
Invertebrate NLOC and NLOM absorption efficiency	%	Default	75	Parkerton 1993; Gordon 1966; Berg et al. 1996; Roditi and Fisher 1999	Dietary assimilation efficiencies for invertebrates range from 15-96%. Arnot and Gobas (2004) suggest lipid and NLOM assimilation efficiencies = 75%.
Invertebrate water absorption efficiency	%	Default	25	none given	Assumed 25% for all freshwater species; no reference.
Fish lipid absorption efficiency	%	Default	92	Gobas et al. 1999; Nichols et al. 2001	Gobas et al. (1999) - laboratory study of rainbow trout, 92% lipid absorption efficiency, 57% organic carbon absorption efficiency. Nichols et al. (2001) - laboratory study of rainbow trout, 91% lipid absorption efficiency
Fish NLOC and NLOM absorption efficiency	%	Default	60	Gobas et al. 1999; Nichols et al. 2001	Gobas et al. (1999) - laboratory study of rainbow trout, 92% lipid absorption efficiency, 57% organic carbon absorption efficiency. Nichols et al. (2001) - laboratory study of rainbow trout, 91% lipid absorption efficiency.
Fish water absorption efficiency	%	Default	25	none given	Assumed 25% for all freshwater species, no reference

Notes:
% = percent
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
BCF = bioconcentration factor
DO = dissolved oxygen
HLC = Henry's Law Constant
kg/kg = kilograms per kilogram
kg/L = kilograms per liter
L/kg = liters per kilogram
LPRSA = Lower Passaic River Study Area
m_3/mol = cubic meters per mole
mg = milligrams
ng/g = nanograms per gram
ng/L = nanograms per liter
NLOC = non-lipid organic carbon
NLOM = non-lipid organic matter
O_2/L = oxygen per liter
OM = organic matter
Pa = Pascal

References (see next page)

Table 3-1
Gobas Food Web Model Parameters

References:

Arnot, J.A. and F.A.P.C. Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environ. Toxicol. Chem.* 23:2343-2355.

Arnot, J.A. and F.A.P.C. Gobas. 2003. A generic QSAR for assessing thebioaccumulation potential of organic chemicals in aquatic foodwebs. *QSAR and Combinational Science* 22:337–345.

Benson, B.B. and D. Krause. 1980. The concentration of isotopic fractionation of gases dissolved in freshwater in equilibrium with the atmosphere. 1. Oxygen. *Limnol Oceanogr* 25:662–671

Berg, D.J., S.W. Fisher, and P.F. Landrum. 1996. Clearance and processing of algal particles by Zebra mussels (Dreissena polymorpha). *J Gt Lakes Res* 22:779–788.

Burkhard, L.P. 2000. Estimating dissolved organic carbon partition coefficients for nonionic organic chemicals. *Environ Sci Technol* 34:4663–4668.

Conover, R.J. 1966. Assimilation of organic matter by zooplankton. *Limnol Oceanogr* 11:338–345.

Fisk, A.T., G.T. Tomy, C.D. Cymbalisty, and D.C.G. Muir. 2000. Dietary accumulation and quantitative structure–activity relationships for depuration and biotransformation of short (C10), medium (C14), and long (C18) carbon-chain polychlorinated alkanes by juvenile rainbow trout (Oncorhynchus mykiss). *Environ Toxicol Chem* 19:1508–1516

Gobas, F.A.P.C. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food webs: Application to Lake Ontario. *Ecol Model* 69:1–17.

Gobas, F.A.P.C. and L.G. Maclean. 2003. Sediment–water distribution of organic contaminants in aquatic ecosystems: The role of organic carbon mineralization. *Environ Sci Technol* 7:735–741.

Gobas, F.A.P.C., J. Wilcockson, R.W. Russell and G.D. Haffner. 1999. Mechanism of biomagnification in fish under laboratory and field conditions. *Environ Sci Technol* 33:133–141.

Gordon, D.C.J. 1966. The effects of the deposit feeding polychaete Pectinaria gouldii on the intertidal sediments of Barnstable Harbor. *Limnol Oceanogr* 11:327–332.

Koelmans, A.A., S.F.M. Anzion, and L. Lijklema. 1995. Dynamics of organic micropollutant biosorption to cyanobacteria and detritus. *Environ Sci Technol* 29:933–940.

Koelmans, A.A., C.J. Jiminez, and L. Lijklema. 1993. Sorption of chlorobenzenes to mineralizing phytoplankton. *Environ Toxicol Chem* 12:1425–1439.

Koelmans, A.A., H. van der Woude, J. Hattink, and D.J.M. Niesten. 1999. Long-term bioconcentration kinetics of hydrophobic chemicals in Selensatrum capricornutum and Microcystis aeruginosa. *EnvironToxicol Chem* 18:1164–1172.

Lehman, J.T. 1993. Efficiencies of ingestion and assimilation by an invertebrate predator using C and P dual isotope labeling. *Limnol Oceanogr* 38:1550–1554.

Nichols, J.W., P.N. Fitzsimmons, F.W Whiteman, D.W. Kuehl, B.C. Butterworth, and C.T. Jenson. 2001. Dietary uptake kinetics of 2,29,5,59-tetrachlorobiphenyl in rainbow trout. *Drug Metab Dispos* 29:1013–1022.

Parkerton, T.F. 1993. Estimating toxicokinetic parameters for modeling the bioaccumulation of nonionic organic chemicals in aquatic organisms. PhD thesis. Rutgers University of New Jersey, New Brunswick, NJ, USA.

Payne, S.A., B.A. Johnson, and R.S. Otto. 1999. Proximate composition of some northeastern Pacific forage fish species. *Fish Oceanogr* 8:159–177.

Roditi, H.A. and N.S. Fisher. 1999. Rates and routes of trace element uptake in zebra mussels. *Limnol Oceanogr* 44:1730–1749.

Seth, R., D. Mackay and J. Muncke. 1999. Estimating the organic carbon partition coefficient and its variability for hydrophobic chemicals. *Environ Sci Technol* 33:2390–2394.

Swackhamer, D.L. and R.S. Skoglund. 1993. Bioaccumulation of PCBs by algae: Kinetics versus equilibrium. *Environ Toxicol Chem* 12:831–838.

van der Linde, A., A.J. Hendriks and D.T.H.M. Sijm. 2001. Estimating biotransformation rate constants of organic chemicals from modeled and measured elimination rates. *Chemosphere* 44:423-435.

Wang, X., S. Harada, M. Watanabe, H. Koshikawa and H.J. Geyer. 1996. Modeling the bioconcentration of hydrophobic organic chemicals in aquatic organisms. *Chemosphere* 32:1783–1793.

Winsor, M.H., B.L. Boese, H. Lee, R.C. Randall, and D.T. Specht. 1990. Determination of the ventilation rates of interstitial and overlying water by the clam Macoma nasuta. *Environ Toxicol Chem* 9:209–213.

Table 3-2
Summary Statistics for the Observed and Predicted Tissue Concentration Distributions

LPRSA River Miles	Chemical	Units	Species	Tissue Type	Number of Observed Tissue Samples	Mean		Standard Deviation		95th Percentile	
						Observed	Predicted	Observed	Predicted	Observed	Predicted
0-8	2,3,7,8-TCDD	ng/kg	Adult Striped Bass	Fillet	10	25	26	14	31	49	105
0-16	2,3,7,8-TCDD	ng/kg	American Eel	Fillet	35	17	17	9	19	35	59
0-16	2,3,7,8-TCDD	ng/kg	American Eel	Whole Body	22	17	17	13	20	37	60
0-16	2,3,7,8-TCDD	ng/kg	Blue Crab	Muscle	43	12	13	7	15	22	46
0-8	2,3,7,8-TCDD	ng/kg	Blue Crab	Muscle	33	15	13	5	16	23	53
0-16	2,3,7,8-TCDD	ng/kg	Blue Crab	Whole Body (Soft Tissue)	59	58	58	27	68	100	206
8-16	2,3,7,8-TCDD	ng/kg	Channel Catfish	Fillet	11	28	28	21	31	77	89
0-16	2,3,7,8-TCDD	ng/kg	Common Carp	Fillet	12	269	273	240	319	730	974
0-16	2,3,7,8-TCDD	ng/kg	Common Carp	Whole Body	11	442	453	380	529	1400	1614
0-16	2,3,7,8-TCDD	ng/kg	Forage Fish	Whole Body	89	47	48	23	56	80	171
0-16	2,3,7,8-TCDD	ng/kg	White Catfish	Fillet	19	56	56	51	66	170	201
0-16	2,3,7,8-TCDD	ng/kg	White Perch	Fillet	25	47	46	25	54	89	164
0-16	2,3,7,8-TCDD	ng/kg	White Perch	Whole Body	37	169	170	86	199	320	606
0-8	PCB-118	ng/kg	Adult Striped Bass	Fillet	10	43,100	43,800	26,600	20,700	108,000	92,000
0-16	PCB-118	ng/kg	American Eel	Fillet	35	82,900	81,900	56,000	153,000	235,000	135,700
0-16	PCB-118	ng/kg	American Eel	Whole Body	22	99,700	99,000	59,000	185,000	190,000	164,100
0-16	PCB-118	ng/kg	Blue Crab	Muscle	41	6,900	7,200	4,200	13,400	13,900	11,900
0-16	PCB-118	ng/kg	Blue Crab	Whole Body (Soft Tissue)	59	44,400	44,500	23,300	83,200	90,100	73,800
8-16	PCB-118	ng/kg	Channel Catfish	Fillet	11	24,600	25,400	18,200	45,400	64,000	147,800
0-16	PCB-118	ng/kg	Common Carp	Fillet	12	193,000	193,000	101,000	361,000	430,000	320,000
0-16	PCB-118	ng/kg	Common Carp	Whole Body	11	176,000	179,000	78,000	334,000	320,000	296,000
0-16	PCB-118	ng/kg	Forage Fish	Whole Body	92	40,900	41,300	18,200	77,200	69,000	68,400
0-16	PCB-118	ng/kg	White Catfish	Fillet	19	46,200	46,500	46,800	86,900	190,000	77,000
0-16	PCB-118	ng/kg	White Perch	Fillet	25	34,000	34,400	27,500	64,300	88,100	57,000
0-16	PCB-118	ng/kg	White Perch	Whole Body	37	111,700	111,700	59,600	208,600	225,000	185,000
0-8	PCB-126	ng/kg	Adult Striped Bass	Fillet	10	153	157	82	54	347	279
0-16	PCB-126	ng/kg	American Eel	Fillet	35	33	32	34	17	119	63
0-16	PCB-126	ng/kg	American Eel	Whole Body	22	92	93	113	48	319	180
0-16	PCB-126	ng/kg	Blue Crab	Muscle	35	18	18	15	9	52	34
0-16	PCB-126	ng/kg	Blue Crab	Whole Body (Soft Tissue)	59	107	108	64	56	247	209
8-16	PCB-126	ng/kg	Channel Catfish	Fillet	11	50	51	35	34	130	119
0-16	PCB-126	ng/kg	Common Carp	Fillet	12	437	433	284	225	1200	839

Table 3-2
Summary Statistics for the Observed and Predicted Tissue Concentration Distributions

LPRSA River Miles	Chemical	Units	Species	Tissue Type	Number of Observed Tissue Samples	Mean		Standard Deviation		95th Percentile	
						Observed	Predicted	Observed	Predicted	Observed	Predicted
0-16	PCB-126	ng/kg	Common Carp	Whole Body	11	403	418	167	217	690	810
0-16	PCB-126	ng/kg	Forage Fish	Whole Body	92	120	127	61	66	231	247
0-16	PCB-126	ng/kg	White Catfish	Fillet	19	99	97	106	50	450	188
0-16	PCB-126	ng/kg	White Perch	Fillet	25	109	105	105	55	354	204
0-16	PCB-126	ng/kg	White Perch	Whole Body	37	399	387	261	201	808	751
0-8	Total PCB Congeners	ng/kg	Adult Striped Bass	Fillet	.		564,000		289,000		1,203,000
0-8	Total Aroclor PCBs	µg/kg	Adult Striped Bass	Fillet	10	550		350		1,200	
0-16	Total PCB Congeners	ng/kg	American Eel	Fillet	28	1,160,000	1,290,000	780,000	1,220,000	2,290,000	2,780,000
0-16	Total Aroclor PCBs	µg/kg	American Eel	Fillet	35	1,300		900		2,800	
0-16	Total PCB Congeners	ng/kg	American Eel	Whole Body	16	1,680,000	1,690,000	1,270,000	1,600,000	5,690,000	3,650,000
0-16	Total Aroclor PCBs	µg/kg	American Eel	Whole Body	22	1,700		1,600		4,400	
0-16	Total PCB Congeners	ng/kg	Blue Crab	Muscle	21	41,800	41,600	28,600	39,300	102,000	90,000
0-16	Total Aroclor PCBs	µg/kg	Blue Crab	Muscle	43	45		28		75	
0-16	Total PCB Congeners	ng/kg	Blue Crab	Whole Body (Soft Tissue)	40	329,000	340,000	135,000	321,000	579,000	735,000
0-16	Total Aroclor PCBs	µg/kg	Blue Crab	Whole Body (Soft Tissue)	59	570		370		1,400	
8-16	Total PCB Congeners	ng/kg	Channel Catfish	Fillet	11	500,000	526,000	336,000	579,000	1,270,000	1,975,000
0-16	Total PCB Congeners	ng/kg	Common Carp	Fillet	12	4,760,000	4,730,000	3,670,000	4,470,000	14,800,000	10,230,000
0-16	Total PCB Congeners	ng/kg	Common Carp	Whole Body	11	4,360,000	4,450,000	1,960,000	4,210,000	7,860,000	9,630,000
0-16	Total PCB Congeners	ng/kg	Forage Fish	Whole Body	29	538,000	544,000	322,000	514,000	933,000	1,177,000
0-16	Total Aroclor PCBs	µg/kg	Forage Fish	Whole Body	90	570		280		1,000	
0-16	Total PCB Congeners	ng/kg	White Catfish	Fillet	19	981,000	977,000	949,000	923,000	3,910,000	2,113,000
0-16	Total PCB Congeners	ng/kg	White Perch	Fillet	19	580,000	595,000	332,000	563,000	1,470,000	1,288,000
0-16	Total Aroclor PCBs	µg/kg	White Perch	Fillet	25	620		300		1,100	
0-16	Total PCB Congeners	ng/kg	White Perch	Whole Body	19	2,180,000	2,280,000	1,190,000	2,150,000	5,140,000	4,930,000
0-16	Total Aroclor PCBs	µg/kg	White Perch	Whole Body	37	3,100		1,700		5,100	

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ng/kg = nanograms per kilogram
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
µg/kg = micrograms per kilogram

Table 3-3
Model-Calibrated BSAFs and AFs

Species	Tissue Type	Type of Factor Used in Model	Value of Calibrated Factor			
			2,3,7,8-TCDD	PCB-118	PCB-126	Total PCB Congeners (209)
Forage Fish	Whole Body	BSAF	0.12	1.25	1.25	0.52
Common Carp	Fillet	BSAF	0.45	3.85	2.80	2.98
Common Carp	Whole Body	BSAF	0.58	2.77	2.10	2.18
Adult Striped Bass	Fillet	AF	0.78	2.40	2.00	1.85
American Eel	Fillet	AF	0.19	1.09	0.14	1.30
American Eel	Whole Body	AF	0.15	1.02	0.31	1.32
Blue Crab	Muscle	AF	1.50	0.98	0.78	0.43
Blue Crab	Whole Body (Soft Tissue)	AF	1.70	1.52	1.19	0.88
Channel Catfish	Fillet	AF	0.65	0.35	0.35	0.72
White Catfish	Fillet	AF	1.70	1.63	1.10	2.60
White Perch	Fillet	AF	1.14	0.99	0.98	1.30
White Perch	Whole Body	AF	1.48	1.13	1.27	1.75

Notes:

AFs were constructed as tropic AFs from lipid-normalized forage fish tissue to lipid-normalized blue crab and adult piscivorous fish tissue.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

AF = accumulation factor

BSAF = biota-sediment accumulation factor

PCB = polychlorinated biphenyl

Table 3-4
Predicted Future Mean Tissue Concentrations under Hypothetical Remedial Scenarios

LPRSA River Miles	Species	Tissue Type	Chemical	Observed Tissue Concentration (ng/kg)	Predicted Current Mean Tissue Concentration (ng/kg)	Predicted Future Mean Tissue Concentration (ng/kg) Assuming Remediation of Polygons with 2,3,7,8-TCDD Concentration in Excess of Value Shown (ng/kg)				
						10,000	5,000	1,000	750	500
0-16	American Eel	Fillet	2,3,7,8-TCDD	16.7	16.6	10.7	8.3	4.9	4.6	4.1
0-16	American Eel	Whole Body	2,3,7,8-TCDD	17.1	17.0	11.0	8.5	5.0	4.7	4.2
0-16	Blue Crab	Muscle	2,3,7,8-TCDD	12.0	12.8	8.3	6.4	3.8	3.6	3.2
0-16	Blue Crab	Whole Body (Soft Tissue)	2,3,7,8-TCDD	58.1	58.0	37.5	29.0	17.0	16.1	14.3
0-16	Common Carp	Fillet	2,3,7,8-TCDD	269.4	273.4	176.8	136.9	80.4	76.1	67.5
0-16	Common Carp	Whole Body	2,3,7,8-TCDD	442.2	453.2	293.0	226.9	133.3	126.1	111.8
0-16	Forage Fish	Whole Body	2,3,7,8-TCDD	47.1	48.1	31.1	24.1	14.1	13.4	11.9
0-16	White Catfish	Fillet	2,3,7,8-TCDD	55.8	56.4	36.5	28.3	16.6	15.7	13.9
0-16	White Perch	Fillet	2,3,7,8-TCDD	46.7	46.1	29.8	23.1	13.6	12.8	11.4
0-16	White Perch	Whole Body	2,3,7,8-TCDD	169.4	170.2	110.0	85.2	50.0	47.3	42.0
0-16	American Eel	Fillet	PCB-118	82,934	81,888	74,270	69,087	62,873	62,147	59,578
0-16	American Eel	Whole Body	PCB-118	99,709	99,045	89,832	83,563	76,046	75,168	72,062
0-16	Blue Crab	Muscle	PCB-118	6,943	7,194	6,525	6,070	5,524	5,460	5,234
0-16	Blue Crab	Whole Body (Soft Tissue)	PCB-118	44,369	44,540	40,396	37,577	34,197	33,802	32,405
0-16	Common Carp	Fillet	PCB-118	192,667	192,984	175,032	162,817	148,172	146,461	140,408
0-16	Common Carp	Whole Body	PCB-118	175,636	178,569	161,958	150,655	137,103	135,521	129,920
0-16	Forage Fish	Whole Body	PCB-118	40,866	41,304	37,462	34,847	31,713	31,347	30,051
0-16	White Catfish	Fillet	PCB-118	46,205	46,493	42,168	39,225	35,697	35,285	33,826
0-16	White Perch	Fillet	PCB-118	34,024	34,410	31,209	29,031	26,420	26,115	25,035
0-16	White Perch	Whole Body	PCB-118	111,705	111,664	101,277	94,209	85,735	84,745	81,242
0-16	American Eel	Fillet	PCB-126	33	32	30	27	24	24	22
0-16	American Eel	Whole Body	PCB-126	92	93	84	79	69	68	62
0-16	Blue Crab	Muscle	PCB-126	18	18	16	15	13	13	12
0-16	Blue Crab	Whole Body (Soft Tissue)	PCB-126	107	108	98	91	80	79	72
0-16	Common Carp	Fillet	PCB-126	437	433	394	366	324	317	290
0-16	Common Carp	Whole Body	PCB-126	403	418	380	353	312	305	279
0-16	Forage Fish	Whole Body	PCB-126	120	127	116	108	95	93	85
0-16	White Catfish	Fillet	PCB-126	99	97	88	82	72	71	65
0-16	White Perch	Fillet	PCB-126	109	105	96	89	79	77	70
0-16	White Perch	Whole Body	PCB-126	399	387	352	328	289	283	259
0-16	American Eel	Fillet	Total PCB Congeners	1,164,214	1,286,554	1,136,460	1,033,706	899,494	881,504	830,474
0-16	American Eel	Whole Body	Total PCB Congeners	1,684,438	1,688,495	1,491,509	1,356,652	1,180,510	1,156,901	1,089,927
0-16	Blue Crab	Muscle	Total PCB Congeners	41,824	41,584	36,733	33,412	29,073	28,492	26,843
0-16	Blue Crab	Whole Body (Soft Tissue)	Total PCB Congeners	328,868	339,686	300,057	272,927	237,492	232,742	219,268
0-16	Common Carp	Fillet	Total PCB Congeners	4,763,000	4,730,169	4,178,332	3,800,543	3,307,095	3,240,955	3,053,335
0-16	Common Carp	Whole Body	Total PCB Congeners	4,358,182	4,450,219	3,931,042	3,575,611	3,111,368	3,049,143	2,872,627
0-16	Forage Fish	Whole Body	Total PCB Congeners	538,069	544,106	480,629	437,172	380,411	372,803	351,222
0-16	White Catfish	Fillet	Total PCB Congeners	981,158	976,927	862,955	784,930	683,018	669,358	630,609
0-16	White Perch	Fillet	Total PCB Congeners	580,263	595,232	525,790	478,250	416,156	407,833	384,223
0-16	White Perch	Whole Body	Total PCB Congeners	2,175,474	2,278,059	2,012,293	1,830,349	1,592,704	1,560,851	1,470,492
0-8	Adult Striped Bass	Fillet	2,3,7,8-TCDD	24.7	25.7	17.8	13.4	7.9	7.6	7.0
0-8	American Eel	Fillet	2,3,7,8-TCDD	17.0	17.0	11.7	8.9	5.2	5.0	4.6
0-8	American Eel	Whole Body	2,3,7,8-TCDD	18.3	17.3	12.0	9.0	5.3	5.1	4.7
0-8	Blue Crab	Muscle	2,3,7,8-TCDD	14.6	13.1	9.1	6.8	4.0	3.9	3.6
0-8	Blue Crab	Whole Body (Soft Tissue)	2,3,7,8-TCDD	67.8	59.1	41.0	30.9	18.1	17.5	16.2

Table 3-4
Predicted Future Mean Tissue Concentrations under Hypothetical Remedial Scenarios

LPRSA River Miles	Species	Tissue Type	Chemical	Observed Tissue Concentration (ng/kg)	Predicted Current Mean Tissue Concentration (ng/kg)	Predicted Future Mean Tissue Concentration (ng/kg) Assuming Remediation of Polygons with 2,3,7,8-TCDD Concentration in Excess of Value Shown (ng/kg)				
						10,000	5,000	1,000	750	500
0-8	Common Carp	Fillet	2,3,7,8-TCDD	288.5	279.0	193.2	145.6	85.5	82.6	76.2
0-8	Common Carp	Whole Body	2,3,7,8-TCDD	630.0	462.4	320.2	241.4	141.7	136.9	126.3
0-8	Forage Fish	Whole Body	2,3,7,8-TCDD	49.0	49.0	34.0	25.6	15.0	14.5	13.4
0-8	White Catfish	Fillet	2,3,7,8-TCDD	65.0	57.6	39.9	30.1	17.6	17.0	15.7
0-8	White Perch	Fillet	2,3,7,8-TCDD	54.5	47.0	32.6	24.6	14.4	13.9	12.9
0-8	White Perch	Whole Body	2,3,7,8-TCDD	192.8	173.6	120.2	90.6	53.2	51.4	47.4
0-8	Adult Striped Bass	Fillet	PCB-118	43,095	43,829	38,709	33,484	28,544	28,354	26,819
0-8	American Eel	Fillet	PCB-118	92,465	53,901	47,606	41,179	35,104	34,871	32,983
0-8	American Eel	Whole Body	PCB-118	121,971	65,195	57,580	49,807	42,459	42,177	39,894
0-8	Blue Crab	Muscle	PCB-118	8,350	4,736	4,182	3,618	3,084	3,064	2,898
0-8	Blue Crab	Whole Body (Soft Tissue)	PCB-118	51,776	29,318	25,893	22,398	19,093	18,966	17,940
0-8	Common Carp	Fillet	PCB-118	200,000	127,029	112,192	97,047	82,729	82,179	77,731
0-8	Common Carp	Whole Body	PCB-118	174,250	117,540	103,811	89,798	76,549	76,041	71,924
0-8	Forage Fish	Whole Body	PCB-118	43,950	27,188	24,012	20,771	17,706	17,589	16,637
0-8	White Catfish	Fillet	PCB-118	46,167	30,603	27,029	23,380	19,931	19,798	18,726
0-8	White Perch	Fillet	PCB-118	42,776	22,650	20,004	17,304	14,751	14,653	13,860
0-8	White Perch	Whole Body	PCB-118	130,182	73,501	64,916	56,153	47,868	47,550	44,976
0-8	Adult Striped Bass	Fillet	PCB-126	153	157	145	131	115	113	109
0-8	American Eel	Fillet	PCB-126	40	30	27	25	22	21	21
0-8	American Eel	Whole Body	PCB-126	124	85	79	71	62	61	59
0-8	Blue Crab	Muscle	PCB-126	22	16	15	14	12	12	11
0-8	Blue Crab	Whole Body (Soft Tissue)	PCB-126	124	99	91	83	72	71	68
0-8	Common Carp	Fillet	PCB-126	403	398	366	332	290	286	275
0-8	Common Carp	Whole Body	PCB-126	425	384	353	320	280	276	265
0-8	Forage Fish	Whole Body	PCB-126	129	117	108	98	85	84	81
0-8	White Catfish	Fillet	PCB-126	97	89	82	74	65	64	61
0-8	White Perch	Fillet	PCB-126	139	97	89	81	70	69	67
0-8	White Perch	Whole Body	PCB-126	479	356	328	297	259	255	246
0-8	Adult Striped Bass	Fillet	Total PCB Congeners	550,000*	563,713	498,769	430,927	359,410	353,740	334,108
0-8	American Eel	Fillet	Total PCB Congeners	1,194,125	1,072,647	949,069	819,979	683,894	673,104	635,749
0-8	American Eel	Whole Body	Total PCB Congeners	2,320,625	1,407,760	1,245,573	1,076,153	897,553	883,393	834,367
0-8	Blue Crab	Muscle	Total PCB Congeners	57,600	34,670	30,676	26,503	22,105	21,756	20,549
0-8	Blue Crab	Whole Body (Soft Tissue)	Total PCB Congeners	376,455	283,209	250,581	216,497	180,567	177,718	167,856
0-8	Common Carp	Fillet	Total PCB Congeners	4,640,000	3,943,715	3,489,364	3,014,749	2,514,416	2,474,748	2,337,407
0-8	Common Carp	Whole Body	Total PCB Congeners	4,625,000	3,710,310	3,282,850	2,836,324	2,365,603	2,328,283	2,199,070
0-8	Forage Fish	Whole Body	Total PCB Congeners	603,500	453,641	401,378	346,783	289,231	284,668	268,869
0-8	White Catfish	Fillet	Total PCB Congeners	967,833	814,500	720,662	622,639	519,305	511,112	482,747
0-8	White Perch	Fillet	Total PCB Congeners	721,727	496,266	439,092	379,368	316,407	311,416	294,133
0-8	White Perch	Whole Body	Total PCB Congeners	2,441,000	1,899,301	1,680,485	1,451,909	1,210,948	1,191,844	1,125,700
8-16	American Eel	Fillet	2,3,7,8-TCDD	16.0	15.8	8.3	7.0	4.1	3.6	2.8
8-16	American Eel	Whole Body	2,3,7,8-TCDD	14.8	16.1	8.4	7.1	4.2	3.7	2.8
8-16	Blue Crab	Muscle	2,3,7,8-TCDD	3.5	12.2	6.4	5.4	3.2	2.8	2.2
8-16	Blue Crab	Whole Body (Soft Tissue)	2,3,7,8-TCDD	36.0	55.0	28.8	24.4	14.4	12.7	9.7
8-16	Channel Catfish	Fillet	2,3,7,8-TCDD	27.7	28.2	14.8	12.5	7.4	6.5	5.0
8-16	Common Carp	Fillet	2,3,7,8-TCDD	259.9	259.6	136.0	115.2	67.8	59.9	45.8

Table 3-4
Predicted Future Mean Tissue Concentrations under Hypothetical Remedial Scenarios

LPRSA River Miles	Species	Tissue Type	Chemical	Observed Tissue Concentration (ng/kg)	Predicted Current Mean Tissue Concentration (ng/kg)	Predicted Future Mean Tissue Concentration (ng/kg) Assuming Remediation of Polygons with 2,3,7,8-TCDD Concentration in Excess of Value Shown (ng/kg)				
						10,000	5,000	1,000	750	500
8-16	Common Carp	Whole Body	2,3,7,8-TCDD	334.9	430.2	225.4	191.0	112.4	99.3	75.9
8-16	Forage Fish	Whole Body	2,3,7,8-TCDD	33.2	45.6	23.9	20.3	11.9	10.5	8.1
8-16	White Catfish	Fillet	2,3,7,8-TCDD	51.6	53.6	28.1	23.8	14.0	12.4	9.5
8-16	White Perch	Fillet	2,3,7,8-TCDD	30.1	43.8	22.9	19.4	11.4	10.1	7.7
8-16	White Perch	Whole Body	2,3,7,8-TCDD	96.4	161.6	84.6	71.7	42.2	37.3	28.5
8-16	American Eel	Fillet	PCB-118	64,667	151,415	140,514	138,419	131,859	129,910	125,650
8-16	American Eel	Whole Body	PCB-118	60,750	183,140	169,955	167,421	159,487	157,130	151,977
8-16	Blue Crab	Muscle	PCB-118	2,580	13,303	12,345	12,161	11,585	11,413	11,039
8-16	Blue Crab	Whole Body (Soft Tissue)	PCB-118	27,500	82,356	76,427	75,288	71,720	70,660	68,342
8-16	Channel Catfish	Fillet	PCB-118	24,573	25,419	23,589	23,238	22,136	21,809	21,094
8-16	Common Carp	Fillet	PCB-118	189,000	356,838	331,148	326,212	310,752	306,159	296,119
8-16	Common Carp	Whole Body	PCB-118	176,429	330,183	306,412	301,844	287,540	283,289	273,999
8-16	Forage Fish	Whole Body	PCB-118	18,164	76,373	70,875	69,818	66,509	65,526	63,378
8-16	White Catfish	Fillet	PCB-118	46,223	85,967	79,778	78,589	74,865	73,758	71,339
8-16	White Perch	Fillet	PCB-118	15,425	63,626	59,045	58,165	55,409	54,590	52,799
8-16	White Perch	Whole Body	PCB-118	54,222	206,473	191,608	188,752	179,807	177,148	171,339
8-16	American Eel	Fillet	PCB-126	19	39	35	34	31	29	24
8-16	American Eel	Whole Body	PCB-126	35	111	99	97	87	84	70
8-16	Blue Crab	Muscle	PCB-126	6	21	19	18	17	16	13
8-16	Blue Crab	Whole Body (Soft Tissue)	PCB-126	69	129	115	112	101	98	81
8-16	Channel Catfish	Fillet	PCB-126	50	51	45	44	40	39	32
8-16	Common Carp	Fillet	PCB-126	454	519	462	451	407	394	326
8-16	Common Carp	Whole Body	PCB-126	390	500	445	435	393	380	314
8-16	Forage Fish	Whole Body	PCB-126	48	153	136	133	120	116	96
8-16	White Catfish	Fillet	PCB-126	101	116	103	101	91	88	73
8-16	White Perch	Fillet	PCB-126	46	126	112	109	99	96	79
8-16	White Perch	Whole Body	PCB-126	151	464	413	403	364	352	291
8-16	American Eel	Fillet	Total PCB Congeners	1,124,333	1,817,968	1,602,001	1,564,673	1,435,113	1,399,236	1,314,232
8-16	American Eel	Whole Body	Total PCB Congeners	1,048,250	2,385,931	2,102,493	2,053,502	1,883,466	1,836,381	1,724,820
8-16	Blue Crab	Muscle	Total PCB Congeners	24,470	58,760	51,780	50,573	46,386	45,226	42,479
8-16	Blue Crab	Whole Body (Soft Tissue)	Total PCB Congeners	270,706	479,995	422,973	413,118	378,910	369,438	346,994
8-16	Channel Catfish	Fillet	Total PCB Congeners	500,455	526,416	463,880	453,071	415,555	405,167	380,553
8-16	Common Carp	Fillet	Total PCB Congeners	4,824,500	6,683,975	5,889,948	5,752,707	5,276,363	5,144,459	4,831,931
8-16	Common Carp	Whole Body	Total PCB Congeners	4,205,714	6,288,391	5,541,358	5,412,239	4,964,087	4,839,989	4,545,958
8-16	Forage Fish	Whole Body	Total PCB Congeners	431,000	768,850	677,514	661,727	606,934	591,761	555,812
8-16	White Catfish	Fillet	Total PCB Congeners	987,308	1,380,449	1,216,458	1,188,113	1,089,733	1,062,491	997,944
8-16	White Perch	Fillet	Total PCB Congeners	385,750	841,093	741,175	723,905	663,963	647,365	608,037
8-16	White Perch	Whole Body	Total PCB Congeners	1,880,444	3,219,016	2,836,611	2,770,515	2,541,107	2,477,582	2,327,068

Notes:

Future predicted values were modeled by setting the concentration values of polygons that exceed a set observed concentration to a value near the detection limit. This is 0.5 ng/kg for 2,3,7,8-TCDD; 5,000 ng/kg for Total PCB congeners and 5 ng/kg for individual PCB congeners. These values are then organic carbon-normalized assuming a total organic carbon value of 2%.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

LPRSA = Lower Passaic River Study Area

ng/kg = nanograms per kilogram

PCB = polychlorinated biphenyl

Figures

List of Figures

Figure 1-1 Lower Passaic River Study Area

Figure 2-1 Surface Water Sample Locations in the LPRSA

Figure 2-2 Surface Sediment (0-6") Sample Locations

Figures 2-3a Forage Fish Sample Locations

Figure 2-3b Common Carp Sample Locations

Figure 2-3c White Perch and Catfish Sample Locations

Figure 2-3d Blue Crab Sample Locations

Figure 2-3e American Eel and Striped Bass Sample Locations

Figure 2-4 Total 2,3,7,8-TCDD in Surface Water by Station 2011-2013

Figure 2-5 Total PCB Congeners in Surface Water by Station: 2011-2012

Figure 2-6 Total Suspended Solids (0.7 µm) in Surface Water by Station: 2011-2012

Figure 2-7 2,3,7,8-TCDD vs. Total Suspended Solids in Surface Water by Station with Regression Line

Figure 2-8 Total PCB Congeners vs. Total Suspended Solids in Surface Water by Station with Regression Line

Figure 2-9 2,3,7,8-TCDD vs. Total Suspended Solids in Surface Water by Station: Analysis of Covariance

Figure 2-10 Total PCB Congeners vs. Total Suspended Solids in Surface Water by Station with Regression Line

Figure 2-11 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

Figure 2-12 Organic Carbon-Normalized 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

Figure 2-13 Total PCB Congeners in Surface Sediment by LPRSA Mile

List of Figures (continued)

Figure 2-14 Organic Carbon-Normalized Total PCB Congeners in Sediment by LPRSA Mile

Figure 2-15 Total Aroclor PCBs (Sum of 7 Aroclors) in Sediment by LPRSA Mile

Figure 2-16 Organic Carbon-Normalized Total Aroclor PCBs (Sum of 7 Aroclors) in Sediment by LPRSA Mile

Figure 2-17 Percent Total Organic Carbon in Surface Sediment by LPRSA Mile

Figure 2-18 Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

Figure 2-19 Spline Model of Organic Carbon-Normalized 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

Figure 2-20 Spline Model of Total PCB Congeners in Surface Sediment by LPRSA Mile

Figure 2-21 Spline Model of Organic Carbon-Normalized Total PCB Congeners in Surface Sediment by LPRSA Mile

Figure 2-22 Temporal Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile: All Data

Figure 2-23 Temporal Spline Model of Total Aroclor PCBs (Sum of 7 Aroclors) in Surface Sediment by LPRSA Mile: All Data

Figure 2-24 Temporal Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

Figure 2-25 Temporal Spline Model of Total Aroclor PCBs (Sum of 7 Aroclors) in Surface Sediment by LPRSA Mile

Figure 2-26 Temporal Spline Model of PCB-77 in Surface Sediment by LPRSA Mile

Figure 2-27 Temporal Spline Model of PCB-118 in Surface Sediment by LPRSA Mile

Figure 2-28 Temporal Spline Model of Mercury in Surface Sediment by LPRSA Mile

Figure 2-29 Temporal Spline Model of DDT (4,4) in Surface Sediment by LPRSA Mile

List of Figures (continued)

Figure 2-30 Temporal Spline Model of Dieldrin in Surface Sediment by LPRSA Mile

Figure 2-31 2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Forage Fish

Figure 2-32 2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Blue Crab (Whole Body Soft Tissue)

Figure 2-33 2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Fish Fillet Tissue

Figure 2-34 2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Whole Body Fish Tissue

Figure 2-35 2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in White Perch (Whole Body)

Figure 2-36 2,3,7,8-TCDD and Total PCB Congeners in Catfish Fillet

Figure 2-37 Normalized 2,3,7,8-TCDD in Tissue and Sediment Averaged by LPRSA Mile

Figure 2-38 Normalized Total Aroclor PCBs (Sum of 7 Aroclors) in Tissue and Sediment Averaged by LPRSA Mile

Figure 2-39 Normalized Total PCB Congeners in Tissue and Sediment Averaged by LPRSA Mile

Figure 2-40 Predicted and Actual Normalized 2,3,7,8-TCDD in Sediment, Blue Crab, Forage Fish, White Perch by LPRSA Mile

Figure 2-41 Bioaccumulation of Lipid-Normalized 2,3,7,8-TCDD in Invertebrate Tissue

Figure 2-42 Bioaccumulation of Lipid-Normalized Total PCBs in Invertebrate Tissue

Figure 2-43 Regression Model of Bioaccumulation of 2,3,7,8-TCDD in Invertebrate Tissue for LPRSA Miles 0 to 8

Figure 2-44 Regression Model of Bioaccumulation of Total PCBs in Invertebrate Tissue for LPRSA Miles 0 to 8

List of Figures (continued)

Figure 3-1 2,3,7,8-TCDD in Surface Sediment (0-6”) Thiessen Polygons

Figure 3-2 Total PCB Congeners in Surface Sediment (0-6”) Thiessen Polygons

Figure 3-3 Observed and Predicted Spatially Weighted Mean 2,3,7,8-TCDD in Surface Sediment

Figure 3-4 Observed and Predicted Spatially Weighted Mean Total PCB Congeners in Surface Sediment

Figure 3-5 Observed and Predicted 2,3,7,8-TCDD in Forage Fish Tissue

Figure 3-6 Observed and Predicted 2,3,7,8-TCDD in Common Carp (Whole Body)

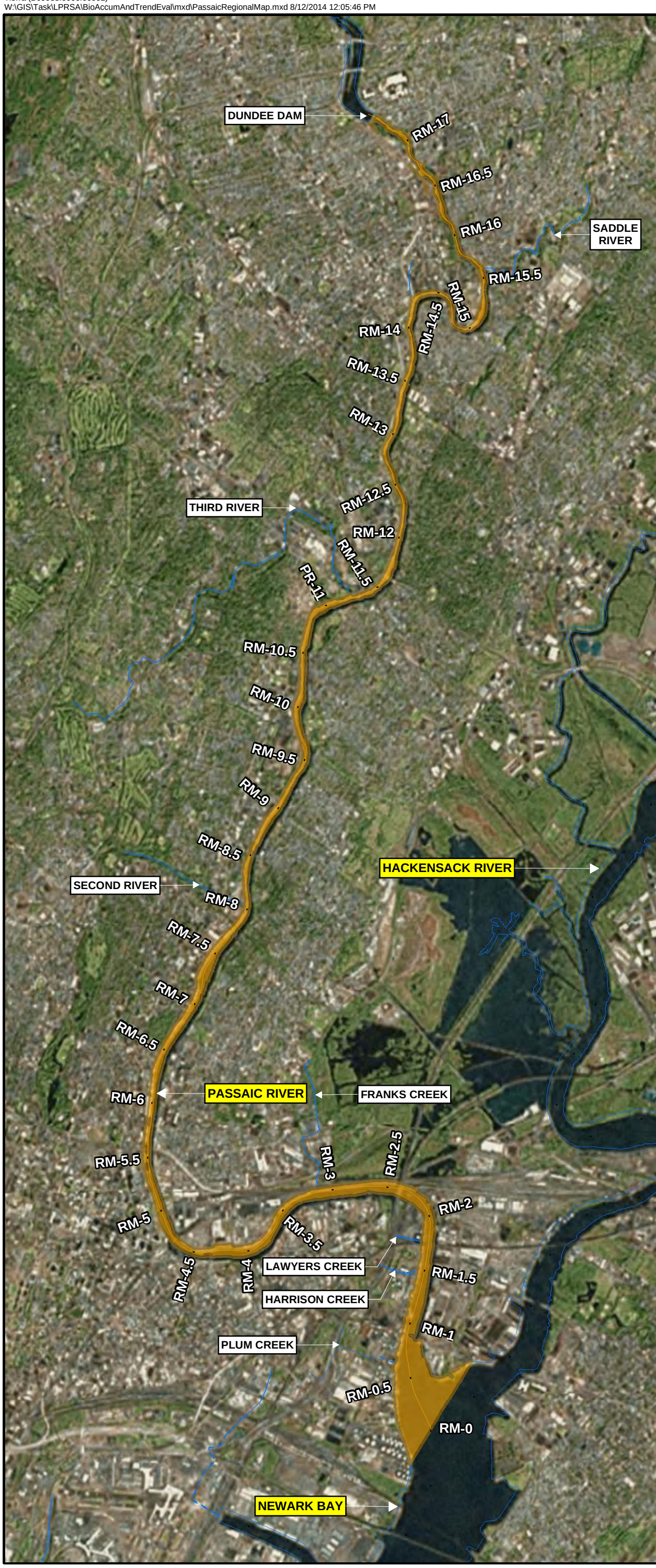
Figure 3-7 Observed and Predicted Total PCB Congeners in Forage Fish Tissue

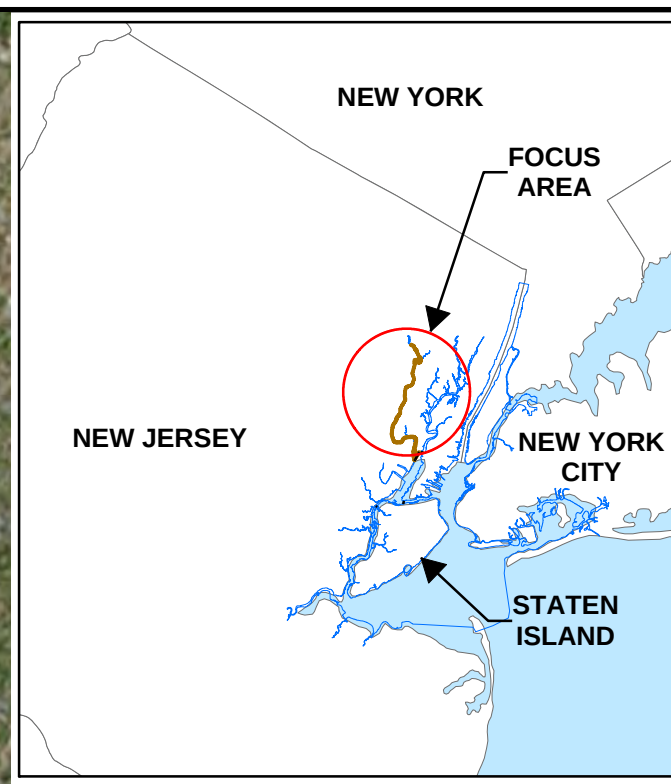
Figure 3-8 Observed and Predicted Total PCB Congeners in Common Carp (Whole Body)

Figure 3-9 Observed and Predicted River-Wide Mean Tissue Concentrations (Whole Body)

Figure 3-10 Observed and Predicted River-Wide Mean Tissue Concentrations (Fillet)

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B09988.0006.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\PassaicRegionalMap.mxd 8/12/2014 12:05:46 PM





LEGEND:

LPRSA RIVER MILE

LOWER PASSAIC RIVER STUDY AREA

NOTES:

1. BASEMAP INFORMATION FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995.
2. 2007 IMAGERY FROM ESRI BING IMAGERY.

0 0.9 1.8 Miles

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

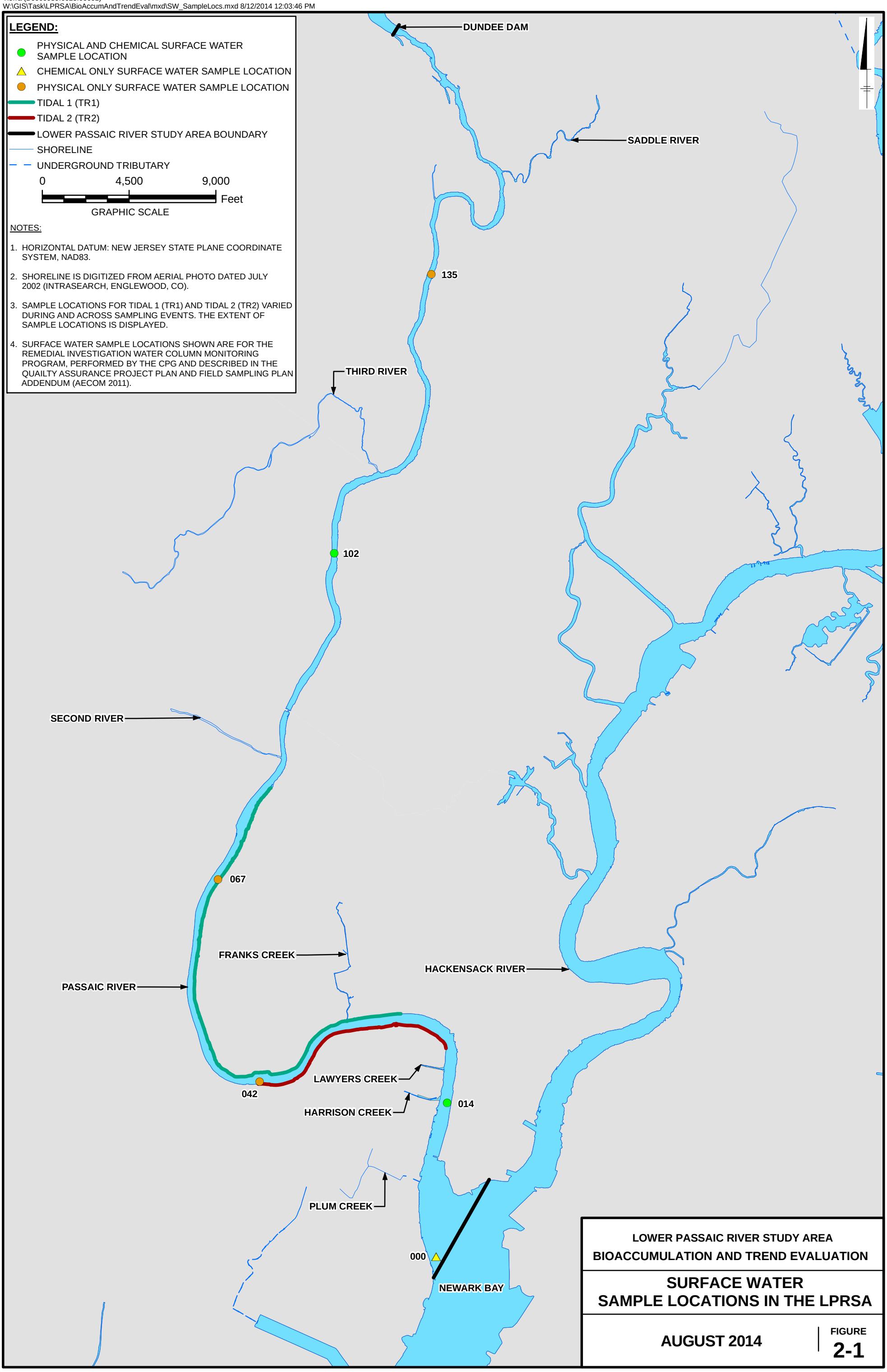
BIOACCUMULATION AND TREND EVALUATION

LOWER PASSAIC RIVER STUDY AREA

AUGUST 2014

FIGURE **1-1**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B0009989.0025.00001)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SW_SampleLocs.mxd 8/12/2014 12:03:46 PM



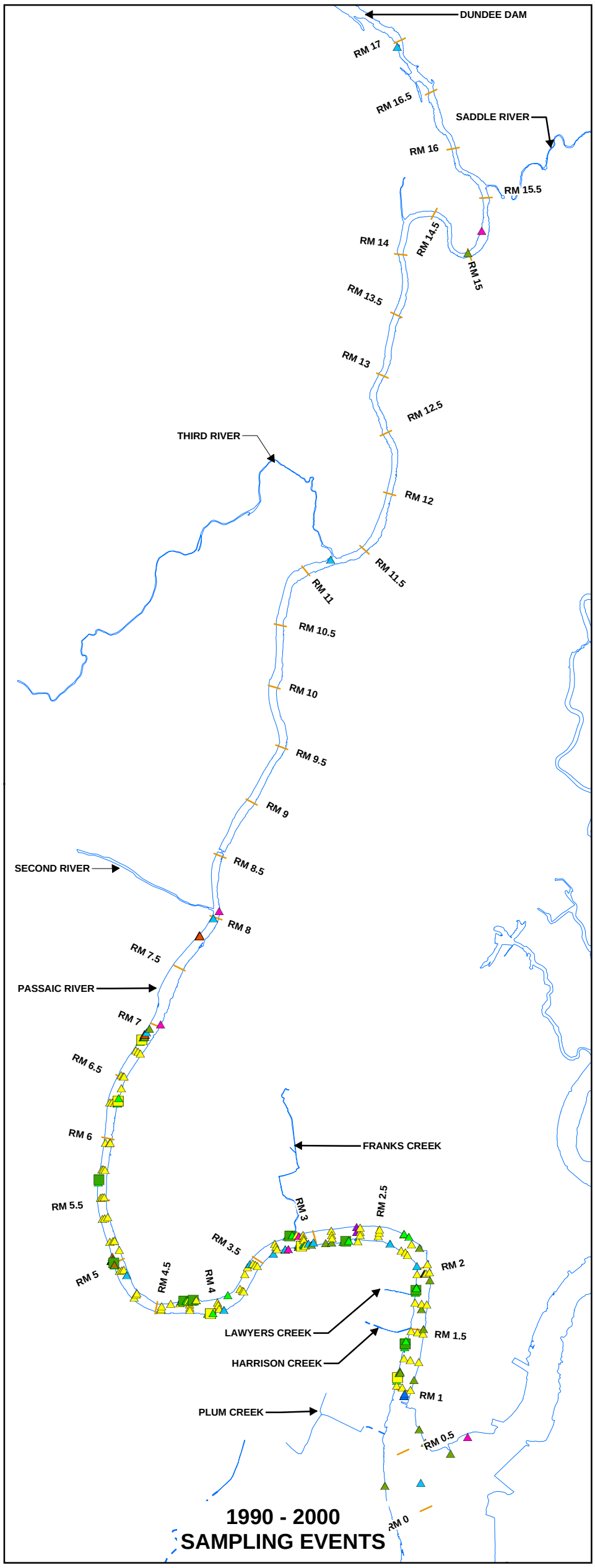
LOWER PASSAIC RIVER STUDY AREA
BIOACCUMULATION AND TREND EVALUATION

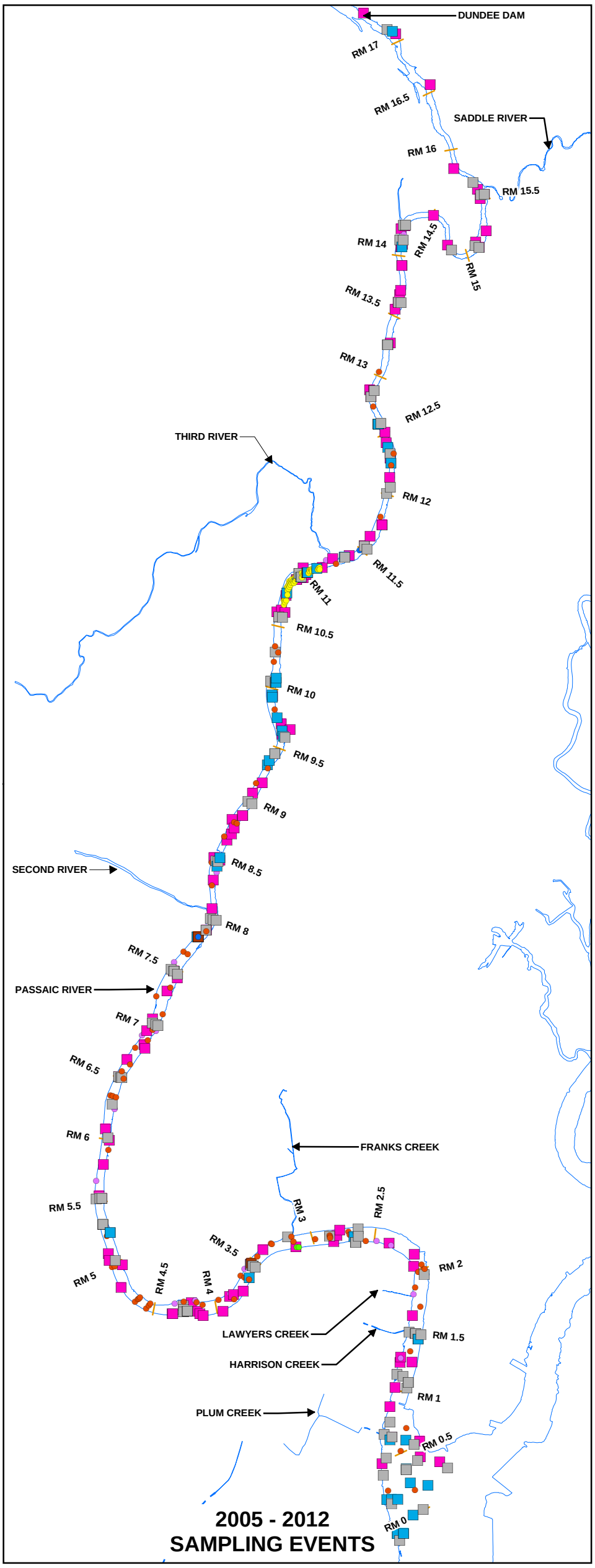
SURFACE WATER SAMPLE LOCATIONS IN THE LPRSA

AUGUST 2014

FIGURE
2-1

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_SedSamps.mxd 8/12/2014 12:04:15 PM





LEGEND:

SAMPLING EVENT
- 1990 TIERRA
- 1991 TIERRA
- 1993 TIERRA
- 1994 TIERRA
- 1995 RI-IWP
- 1995 TIERRA
- 1998 REMAP
- 1999 RI-ESP
- 1999 TIE
- 1999-2006 HI
- 1999/2000 MP
- 2000 RI-ESP
- 2000 TIE
- 2005 EPA HRC
- 2007-08 EPA
- 2008 CPG LRC
- 2009 CPG BMI
- 2010 CPG BMI
- 2011 CPG 10.9
- 2011 JDG HRC
- 2012 CPG SSP
- 2012 HCX FSI
- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

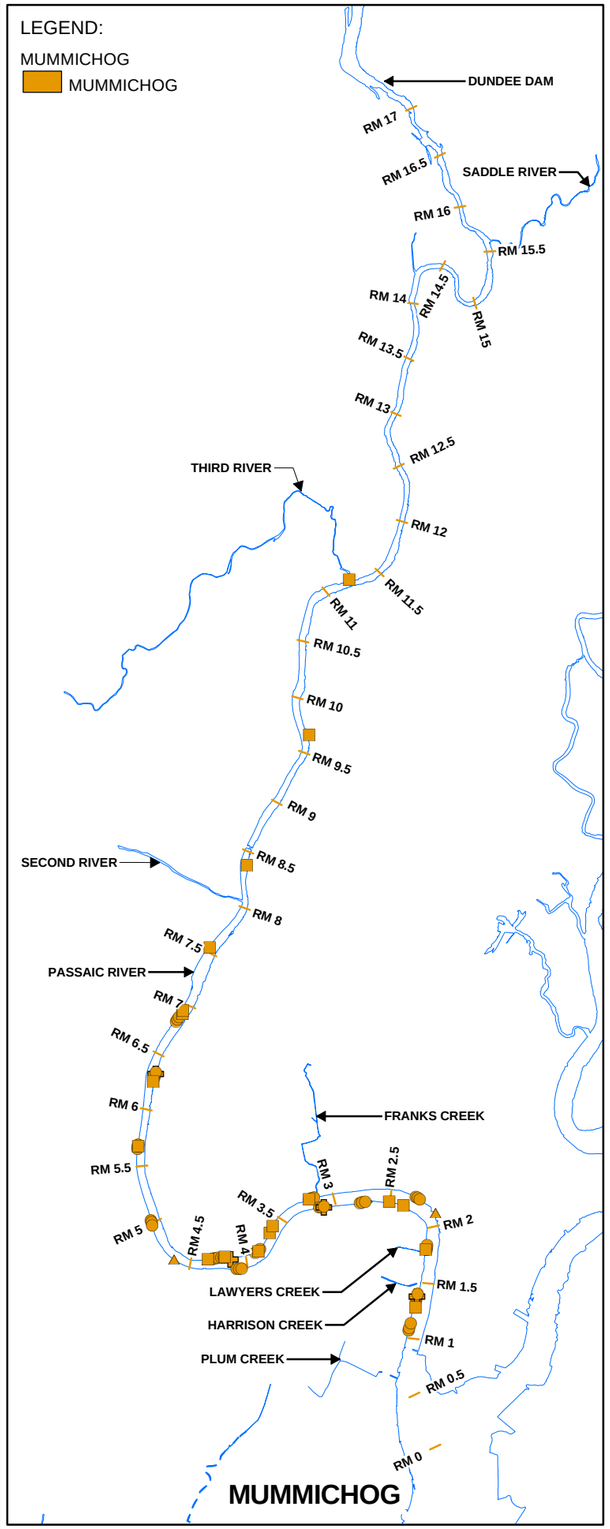
0 5,000 10,000 Feet
GRAPHIC SCALE

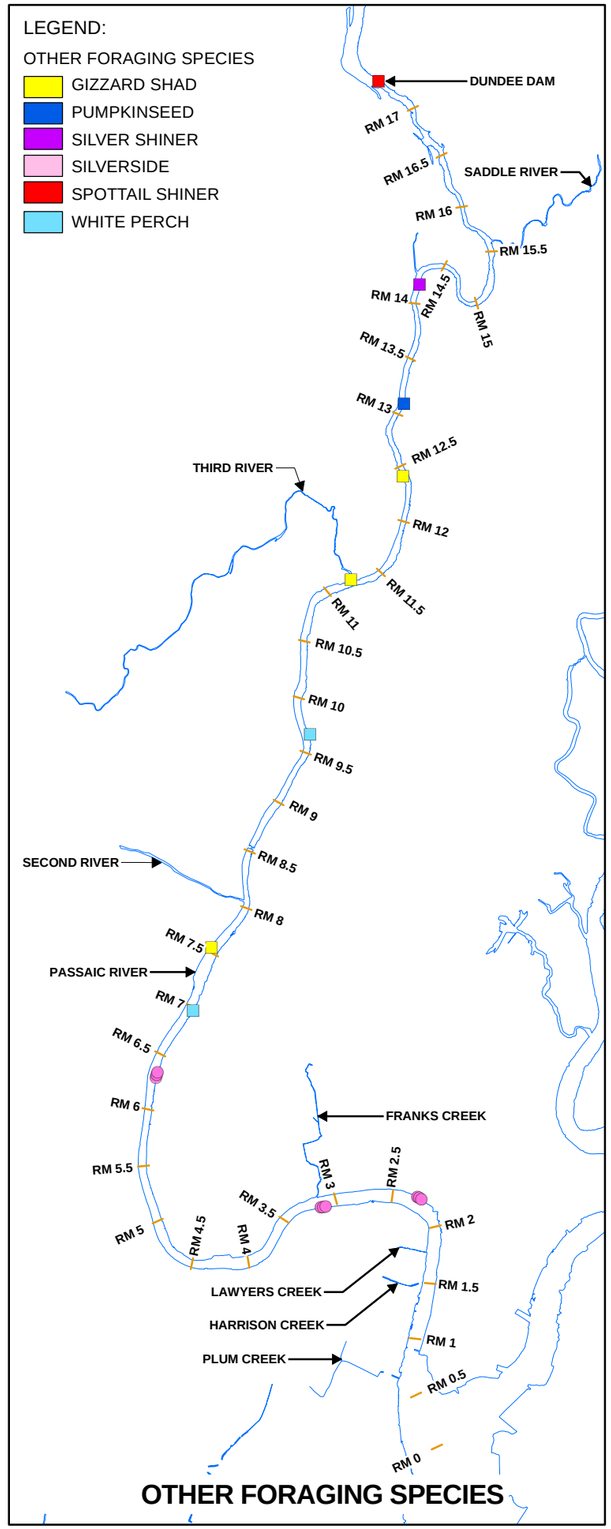
LOWER PASSAIC RIVER STUDY AREA
BIOACCUMULATION AND TREND EVALUATION

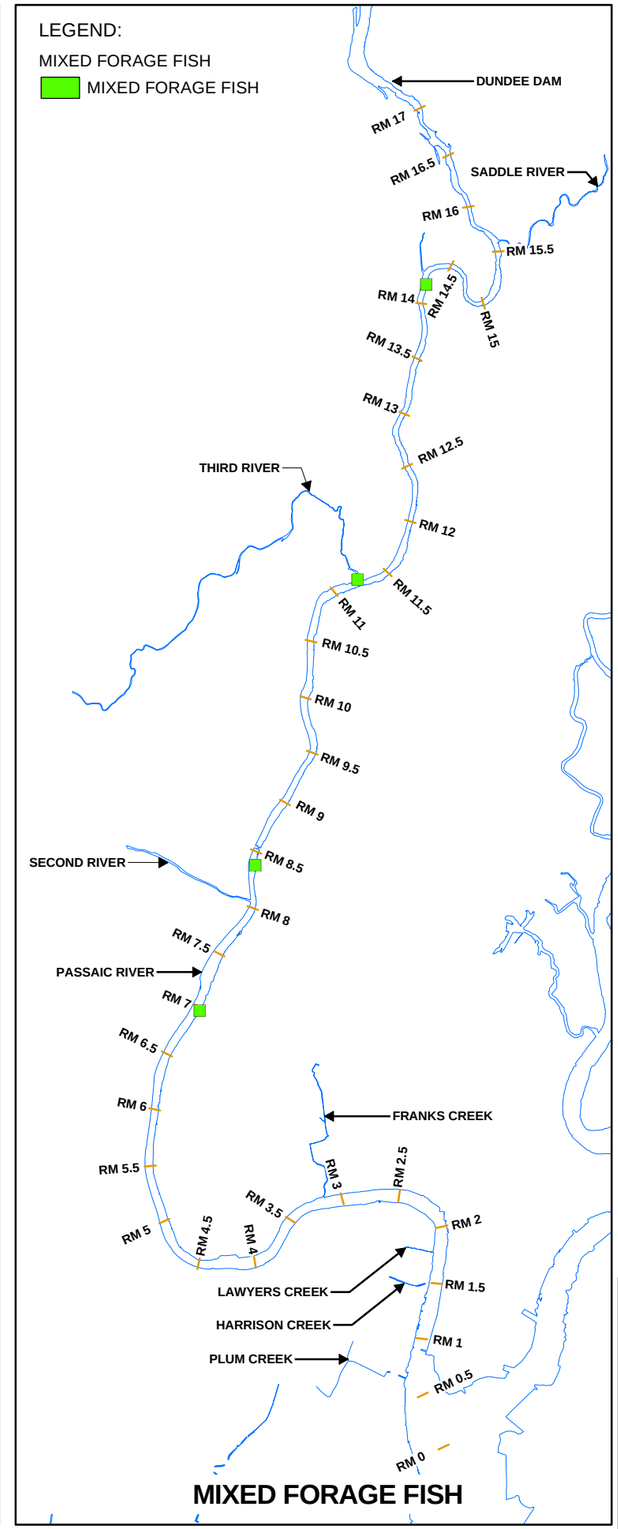
SURFACE SEDIMENT (0-6") SAMPLE LOCATIONS

AUGUST 2014

FIGURE
2-2







LEGEND:

SAMPLING EVENT

- ▲ 1995 TIERRA BIOLOGICAL
- ● 1999 RI-ESP
- ✚ 2000 RI-ESP
- ■ 2009-2010 CPG TISSUE
- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTE:

1. LOCATIONS REPRESENT WHOLE BODY SAMPLES.

0 7,000 14,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

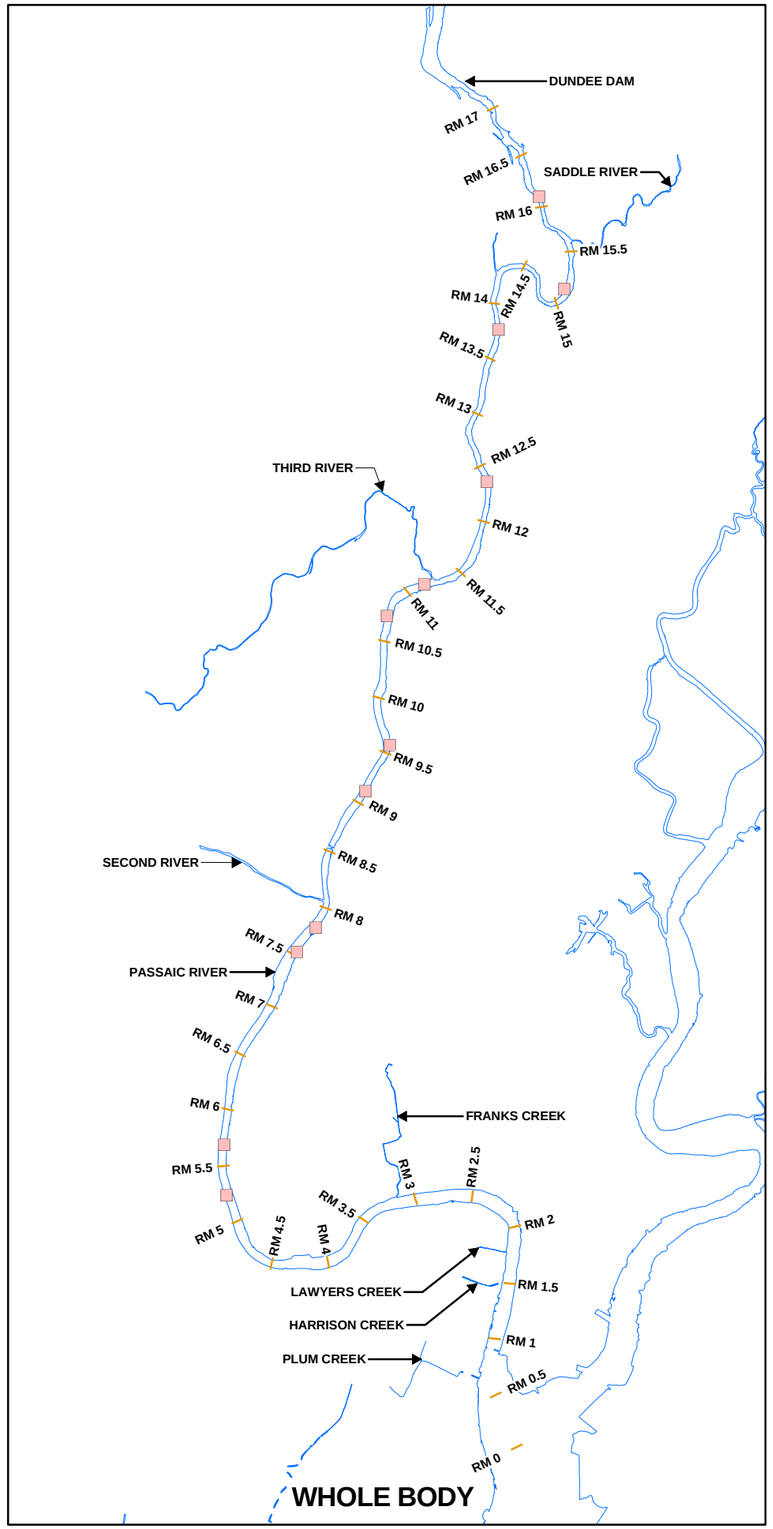
BIOACCUMULATION AND TREND EVALUATION

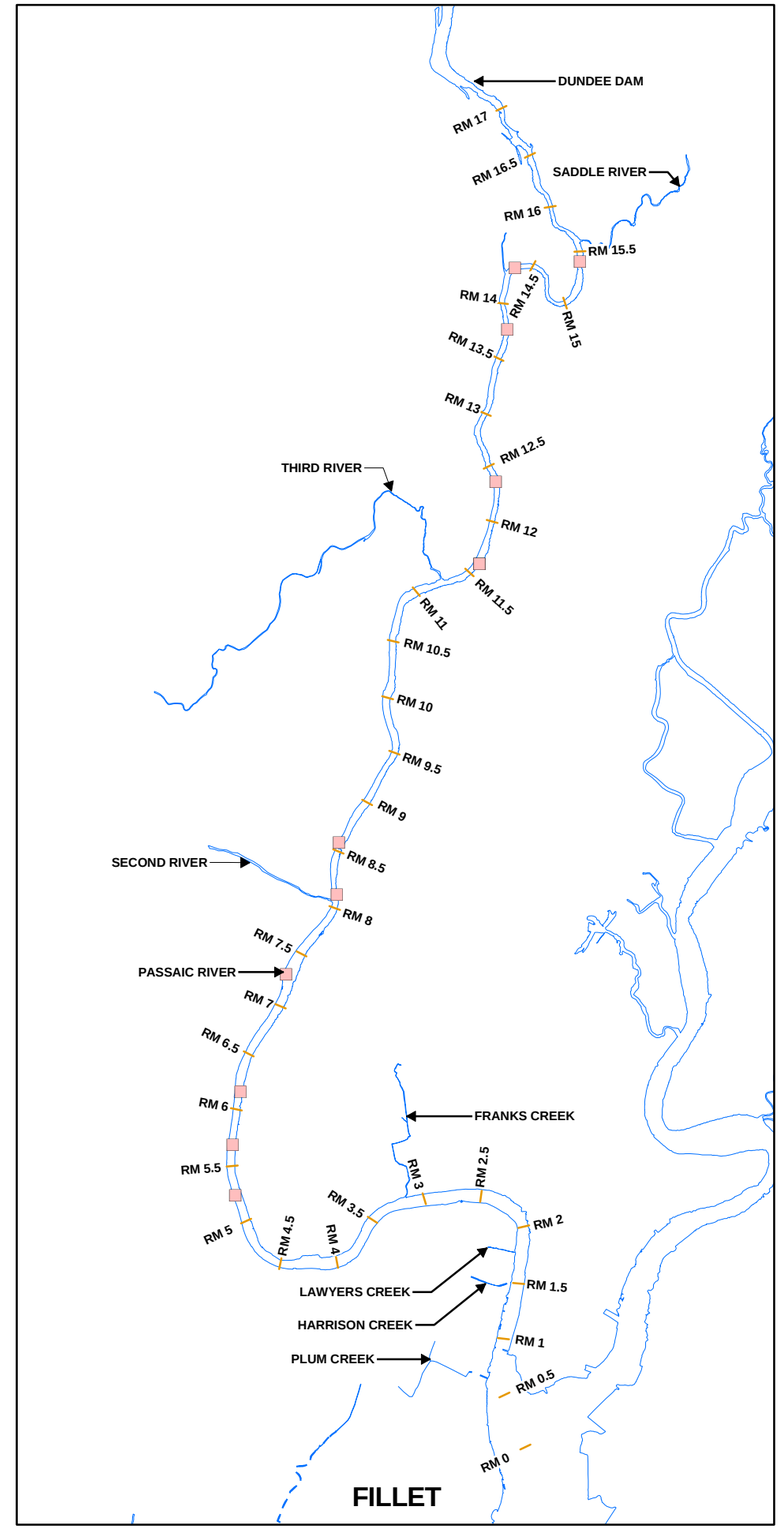
FORAGE FISH SAMPLE LOCATIONS

AUGUST 2014

FIGURE **2-3a**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_ForageFish.mxd 8/12/2014 12:04:31 PM





LEGEND:

ADULT FISH

COMMON CARP

SAMPLING EVENT

2009-2010 CPG TISSUE

LPRSA RIVER MILE

SHORELINE

UNDERGROUND TRIBUTARY

0 7,000 14,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

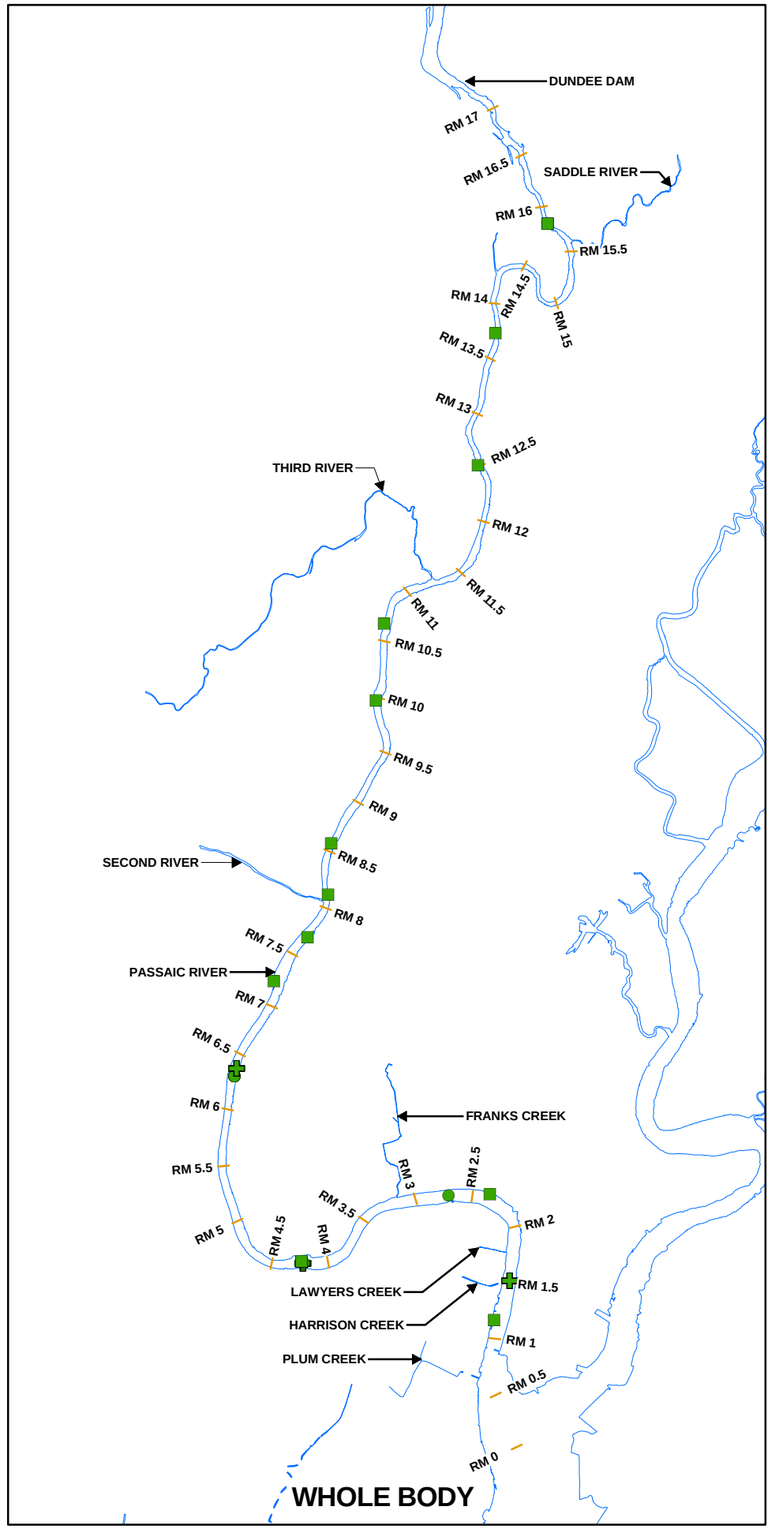
BIOACCUMULATION AND TREND EVALUATION

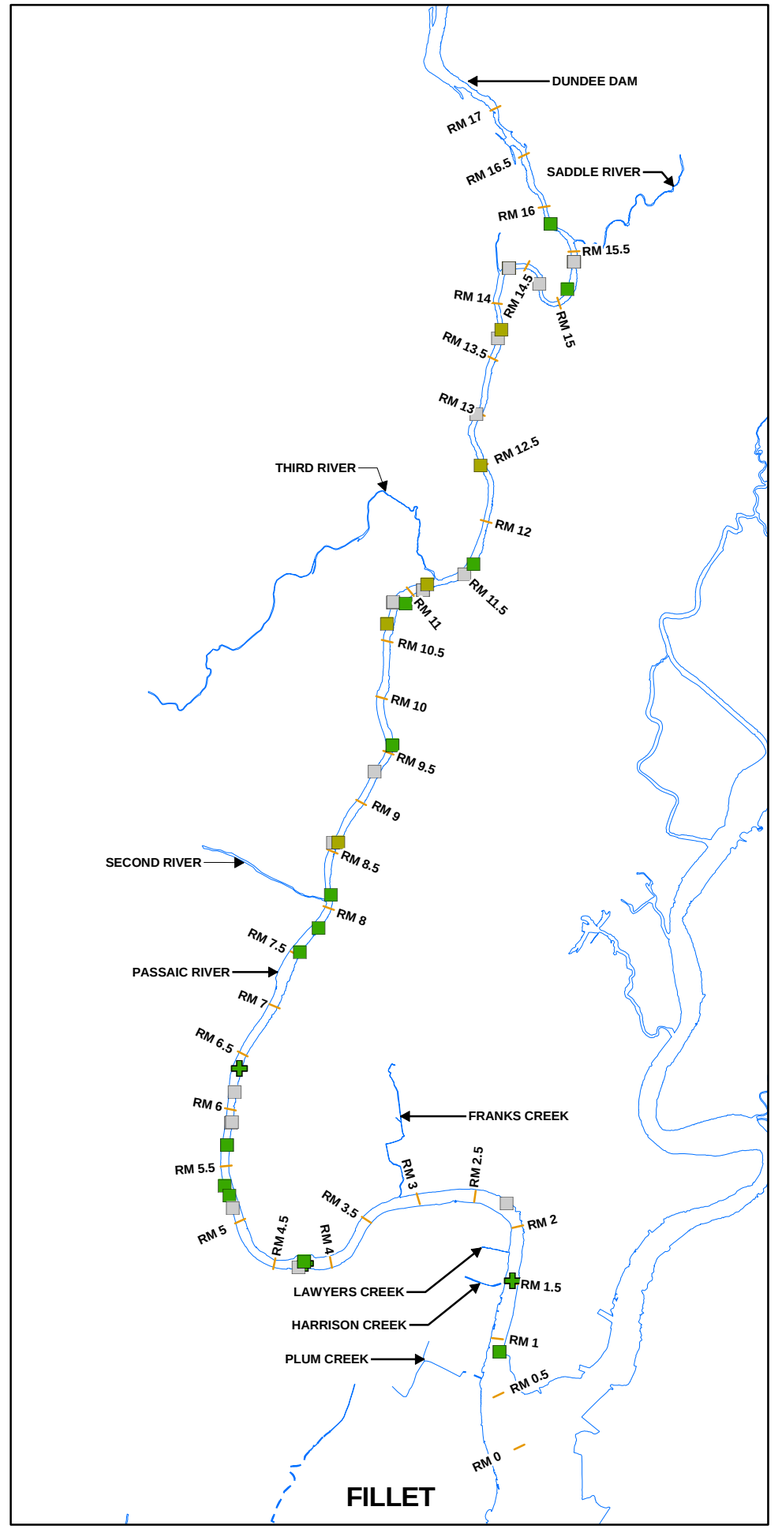
COMMON CARP SAMPLE LOCATIONS

AUGUST 2014

FIGURE **2-3b**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_CommonCarp.mxd 8/12/2014 12:05:20 PM





LEGEND:

ADULT FISH
- CHANNEL CATFISH
- WHITE PERCH
- WHITE CATFISH

SAMPLING EVENT
- 1999 RI-ESP
- 2000 RI-ESP
- 2009-2010 CPG TISSUE
- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

0 7,000 14,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

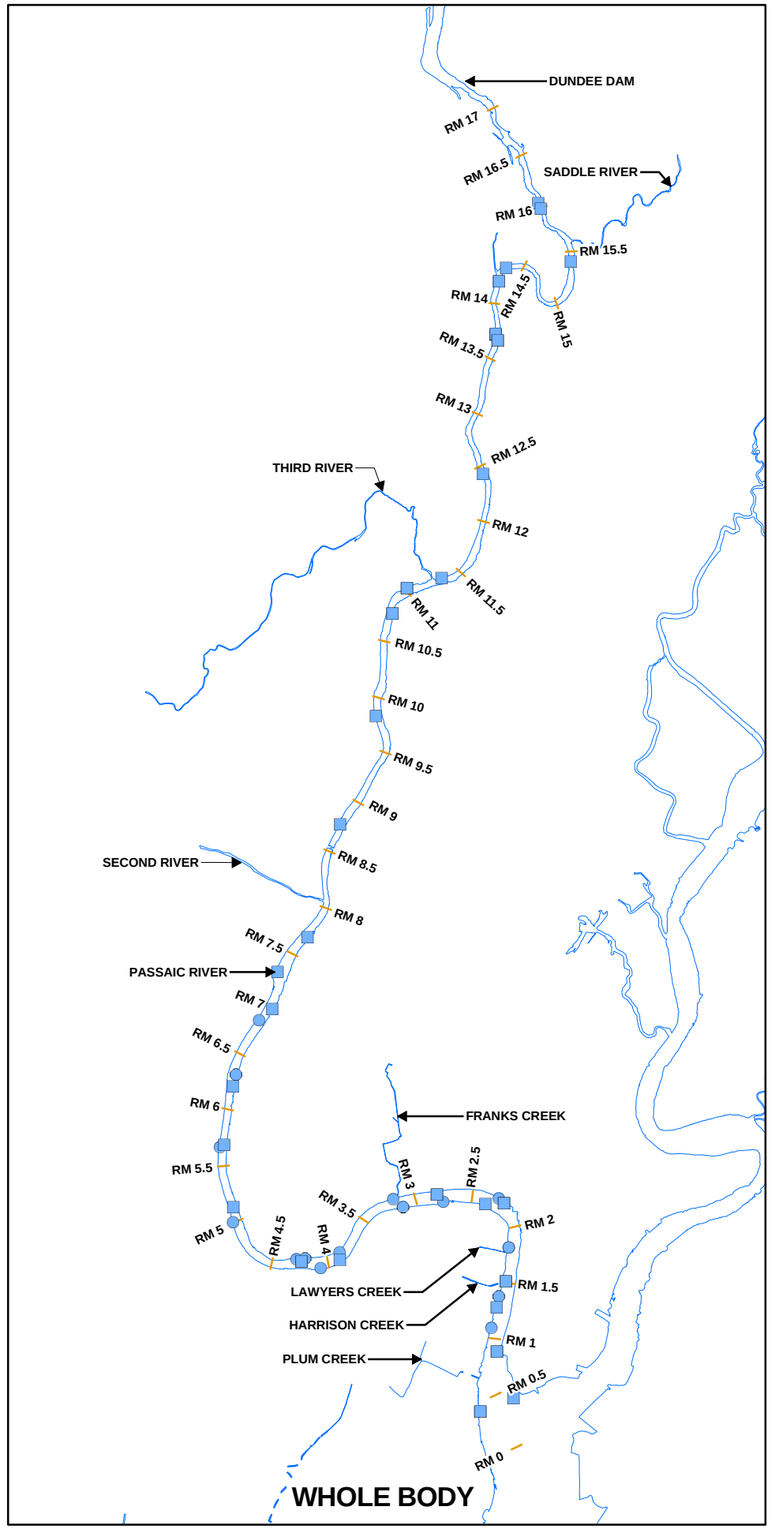
BIOACCUMULATION AND TREND EVALUATION

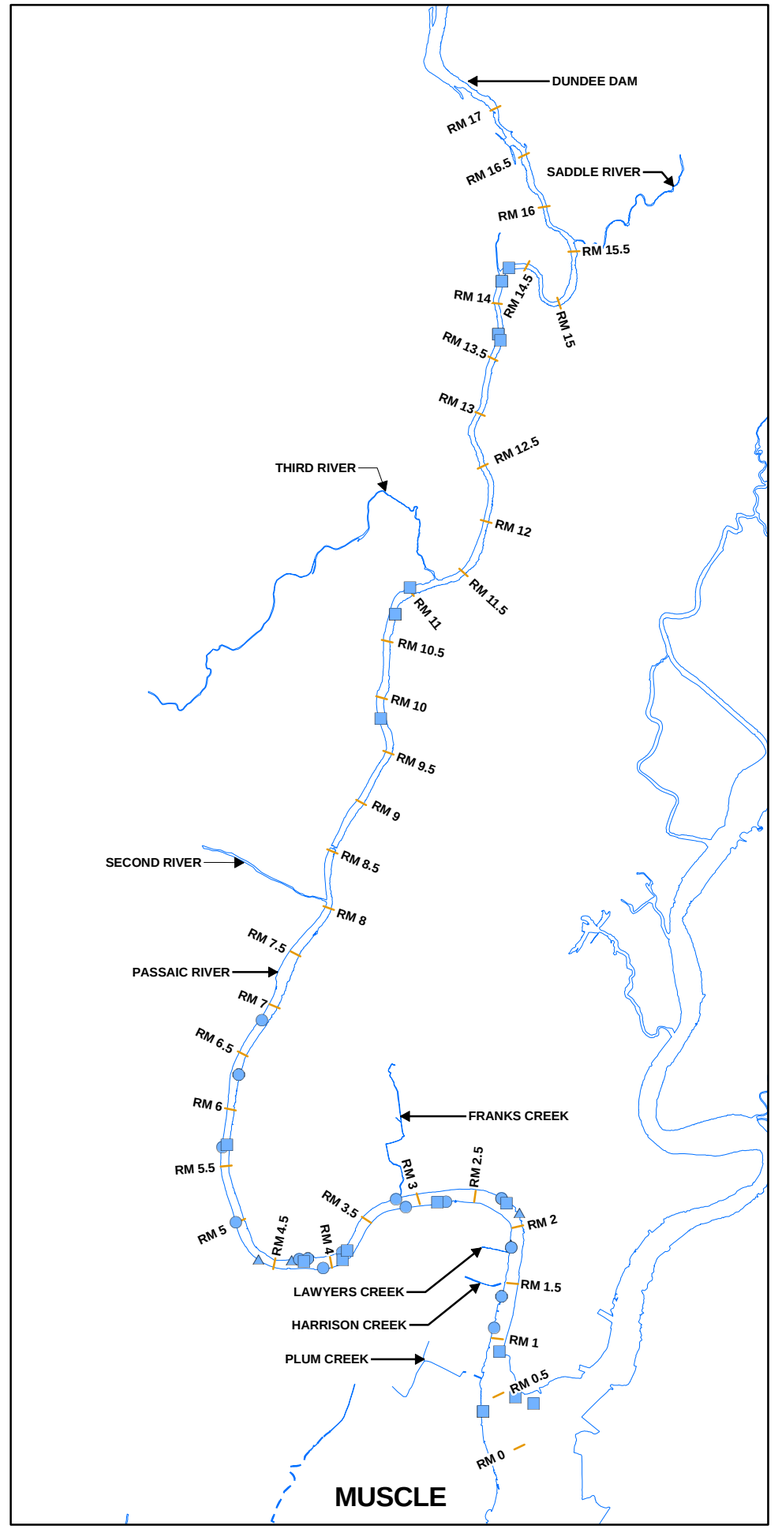
WHITE PERCH AND CATFISH SAMPLE LOCATIONS

AUGUST 2014

FIGURE **2-3c**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_WhitePerchCatfish.mxd 8/12/2014 12:04:07 PM





LEGEND:

- BLUE CRAB
- SAMPLING EVENT
  - ▲ 1995 TIERRA BIOLOGICAL
  - ● 1999 RI-ESP
  - ✚ 2000 RI-ESP
  - ■ 2009-2010 CPG TISSUE
- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

0 7,000 14,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

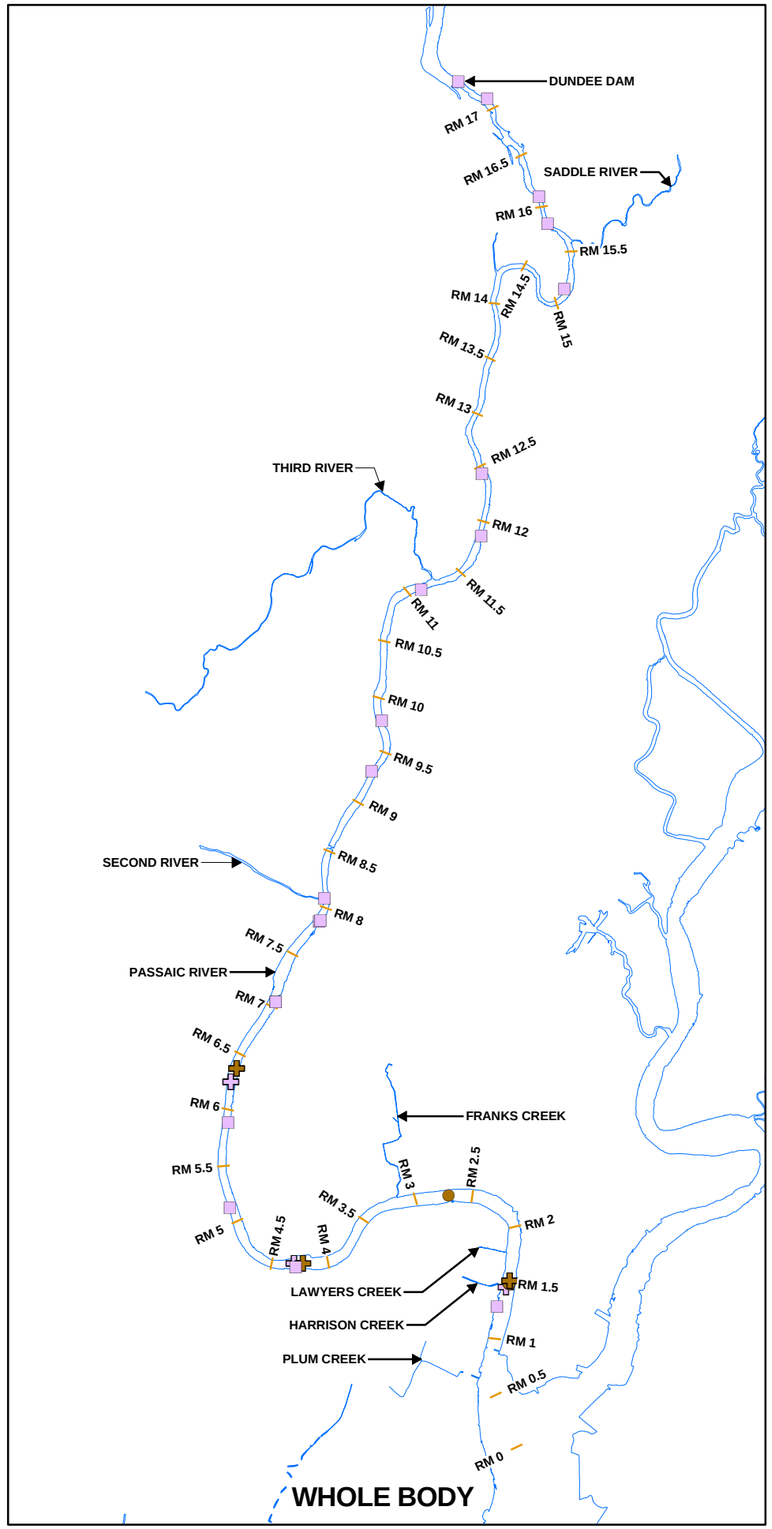
BIOACCUMULATION AND TREND EVALUATION

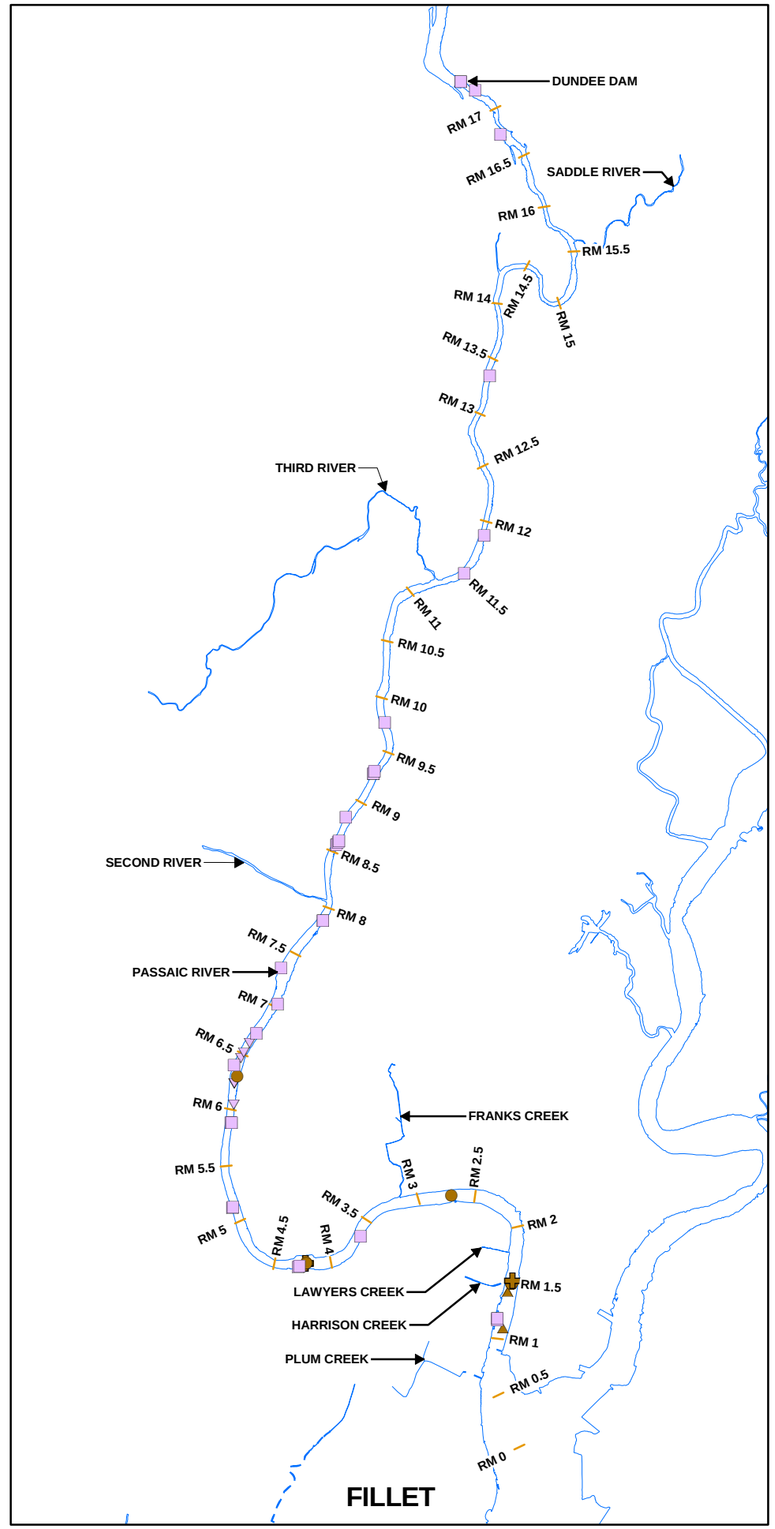
BLUE CRAB SAMPLE LOCATIONS

AUGUST 2014

FIGURE **2-3d**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_BlueCrab.mxd 8/12/2014 12:05:08 PM





LEGEND:

ADULT FISH

- ADULT STRIPED BASS
- AMERICAN EEL

SAMPLING EVENT

- ▲ 1995 TIERRA BIOLOGICAL
- ● 1999 RI-ESP
- ✚ 2000 RI-ESP
- ▼ 2001 SUPPLEMENTAL RI-ESP
- ■ 2009-2010 CPG TISSUE
- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

0 7,000 14,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

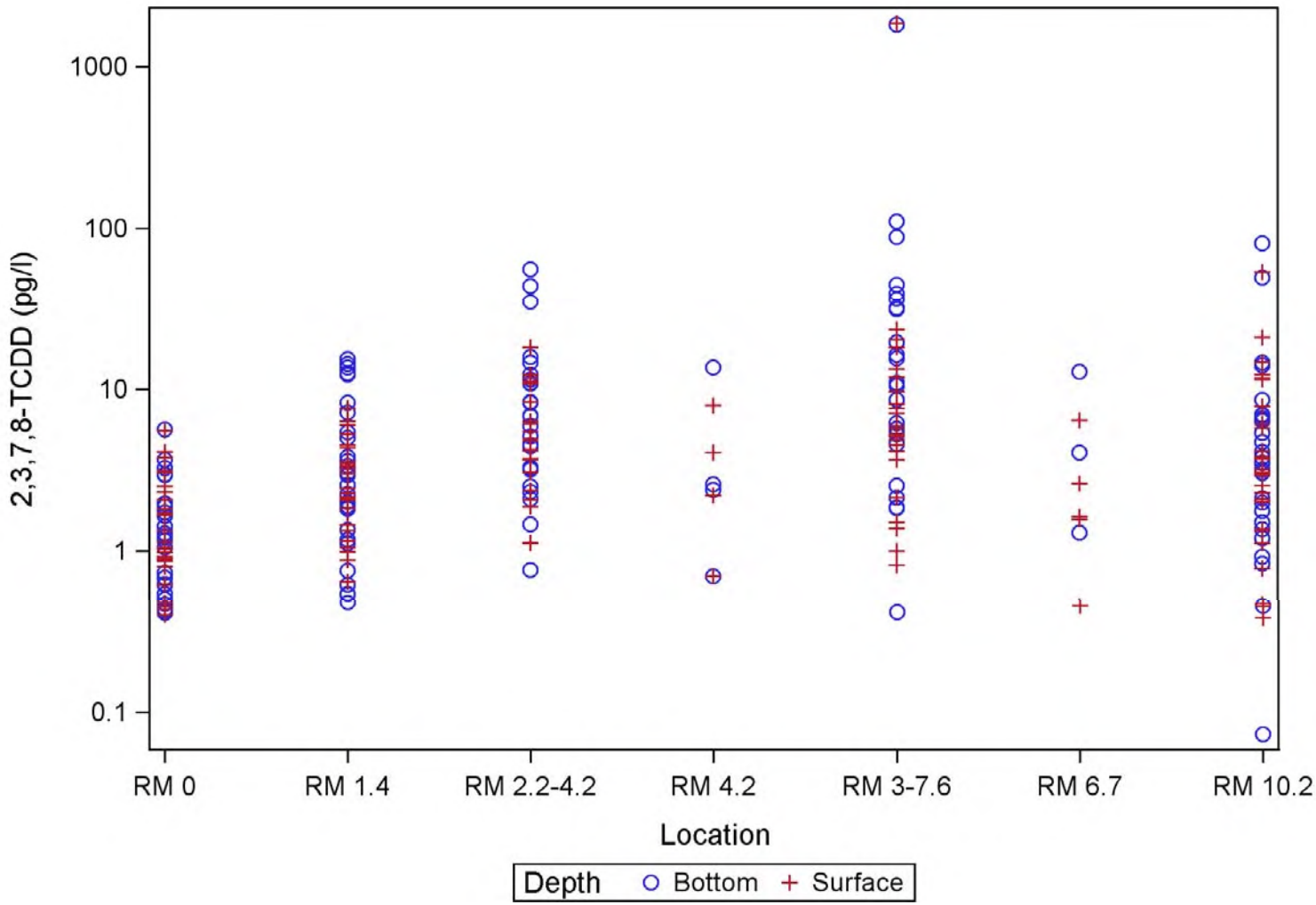
BIOACCUMULATION AND TREND EVALUATION

AMERICAN EEL AND STRIPED BASS SAMPLE LOCATIONS

AUGUST 2014

FIGURE **2-3e**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\SampleLocMap_AmericanEelStripedBass.mxd 8/12/2014 12:04:58 PM



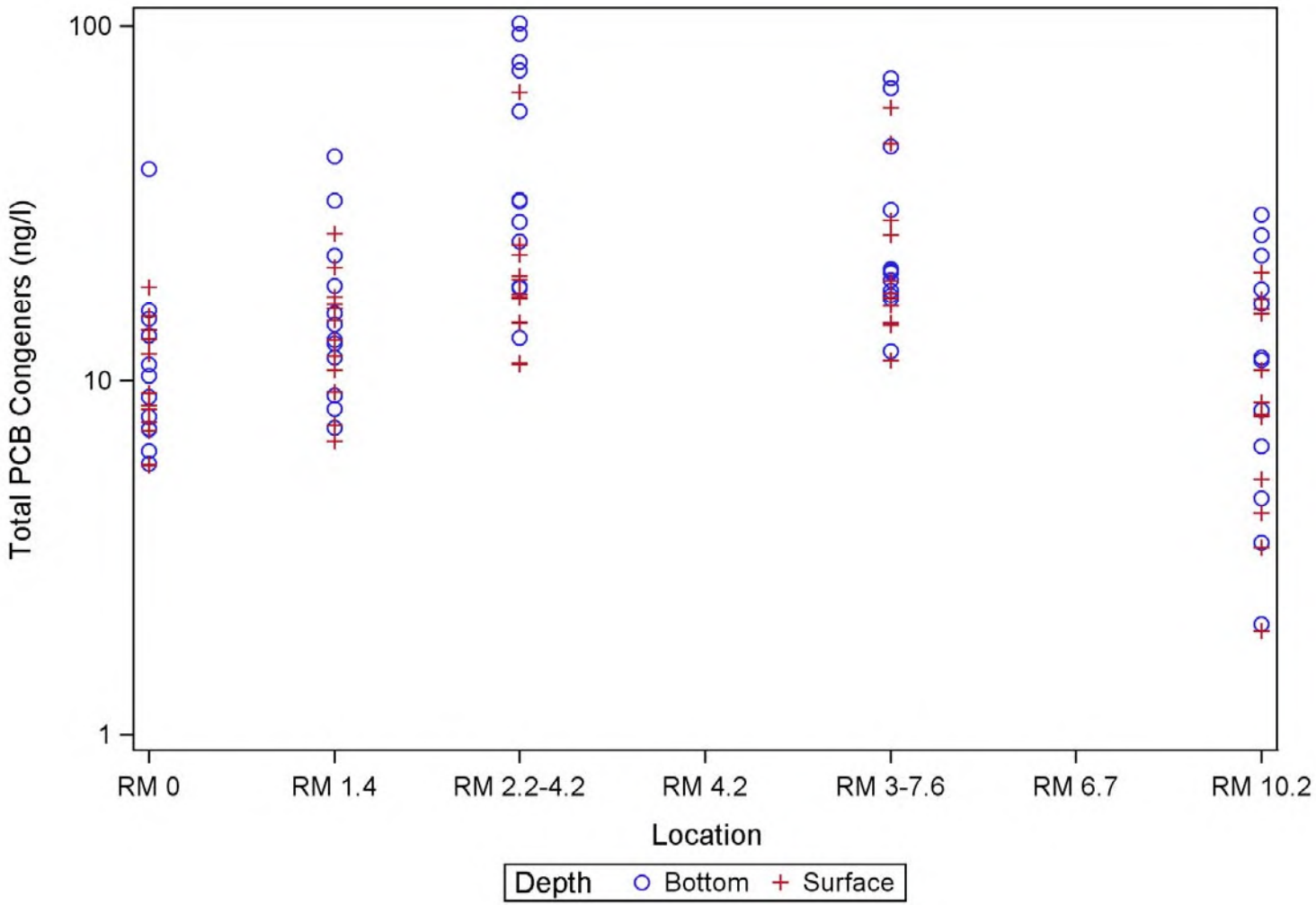
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
pg = picogram
RM = River Mile, these are LPRSA river miles where the surface water station are located
TCDD = tetrachloro-*p*-dibenzodioxin
Includes data from seven rounds of Small -Volume Chemical Water Column Monitoring and one round of High-Volume Chemical Water Column Monitoring.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total 2,3,7,8-TCDD in Surface Water by Station 2011-2013

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-4



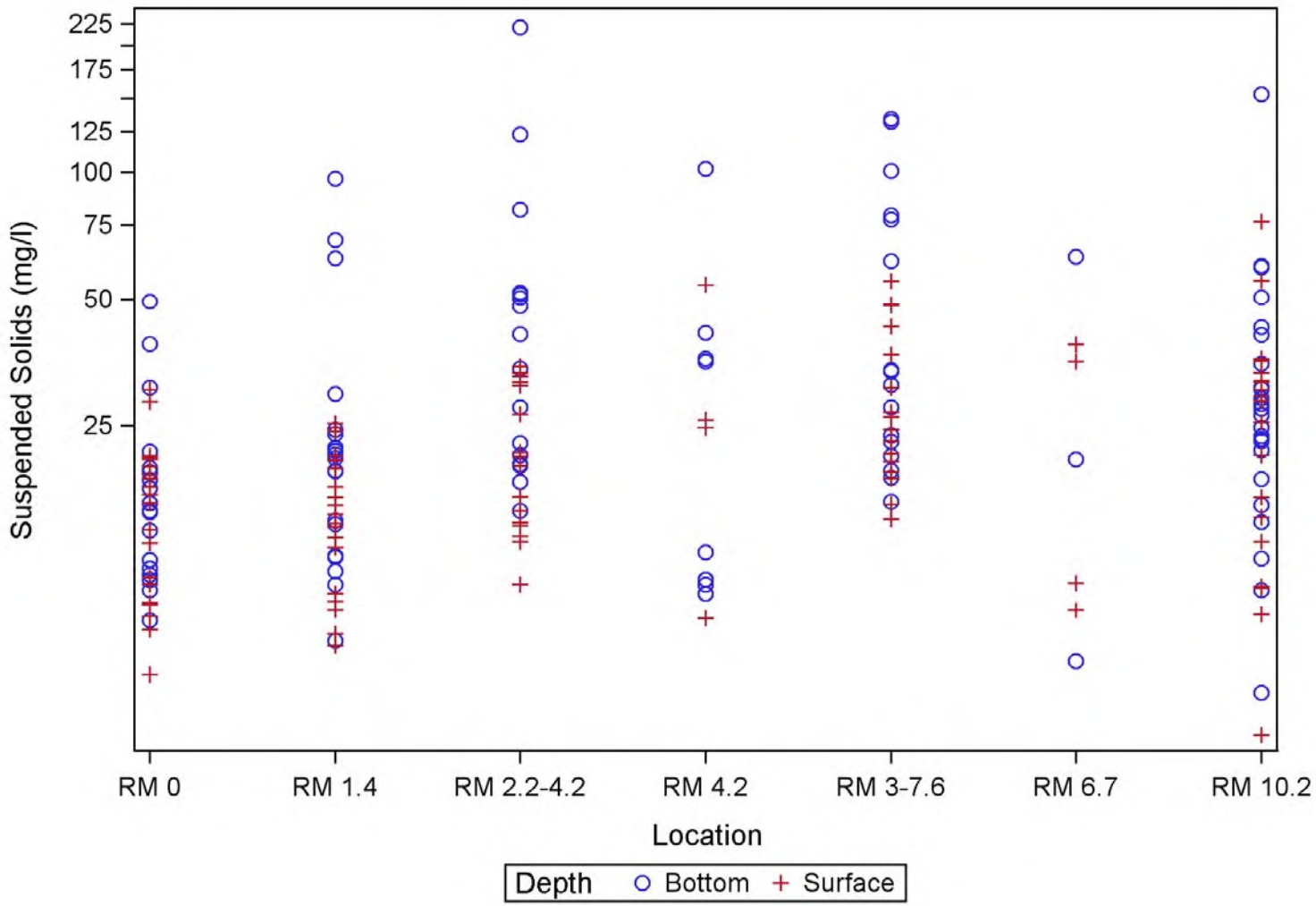
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
ng = nanogram
PCB = polychlorinated biphenyl
RM = River Mile, these are LPRSA river miles where the surface water stations are located
Includes data from the first three rounds of Small-Volume Chemical Water Column Monitoring.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total PCB Congeners in Surface Water by Station: 2011-2012

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-5



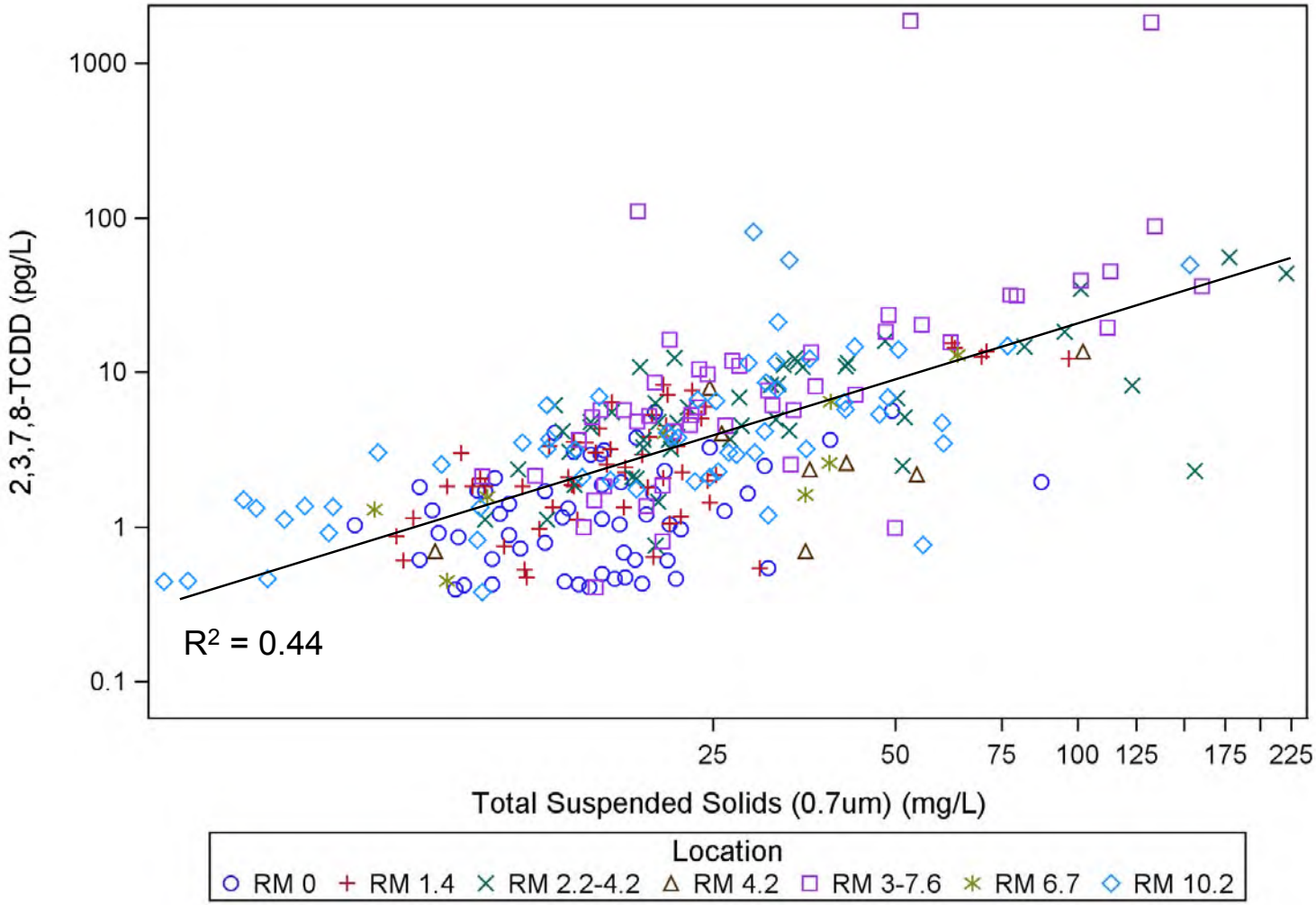
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
mg = milligram
PCB = polychlorinated biphenyl
RM = River Mile, these are LPRSA river miles where the surface water stations are located
Includes data from seven rounds of Small-Volume Chemical Water Column Monitoring and one round of High-Volume Chemical Water Column Monitoring.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total Suspended Solids (0.7 µm) in Surface Water by Station: 2011-2013

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-6



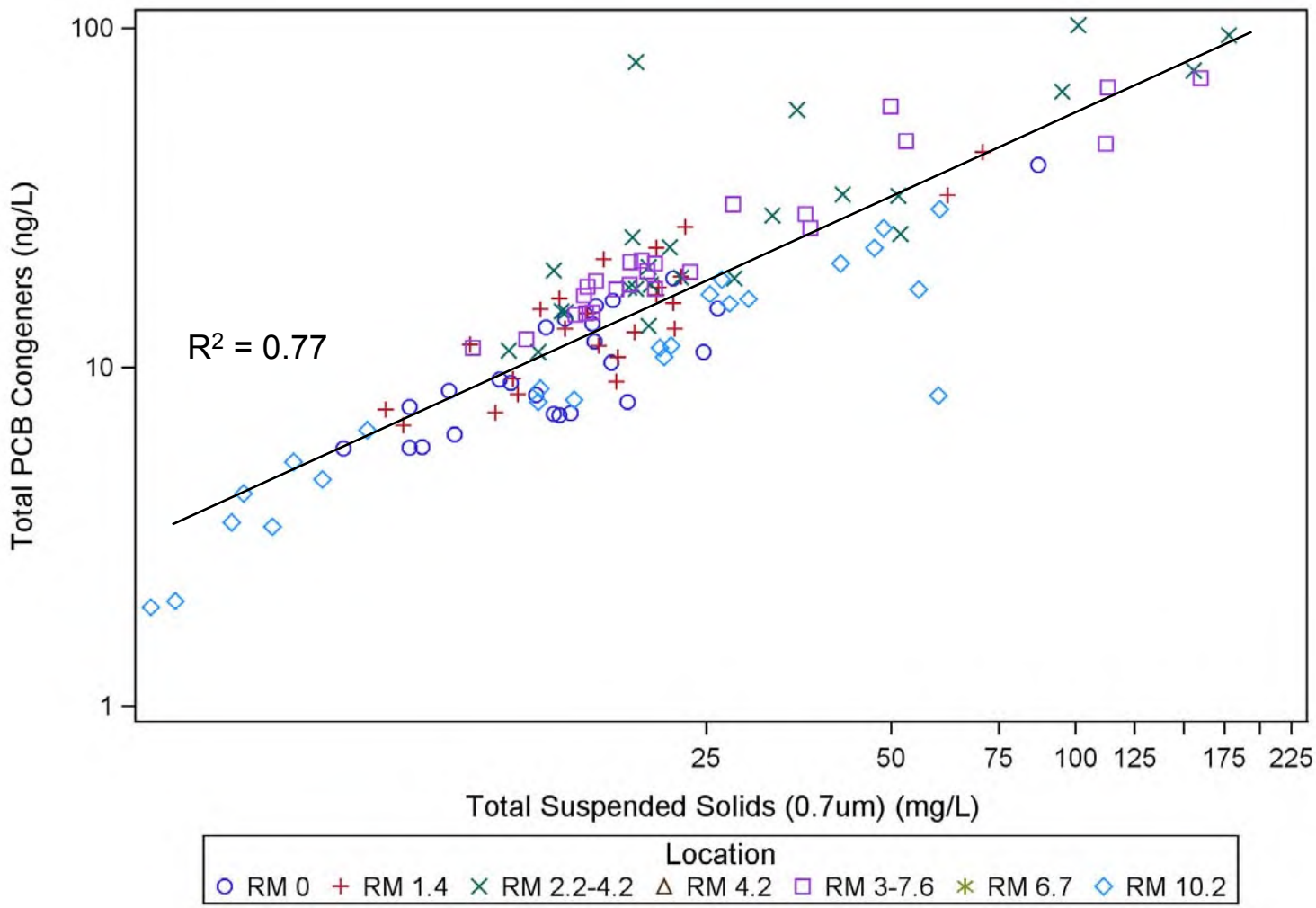
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
mg = milligram
µm = micrometer
pg = picogram
RM = River Mile, these are LPRSA river miles where the surface water stations are located
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD vs. Total Suspended Solids in Surface Water by Station with Regression Line

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-7



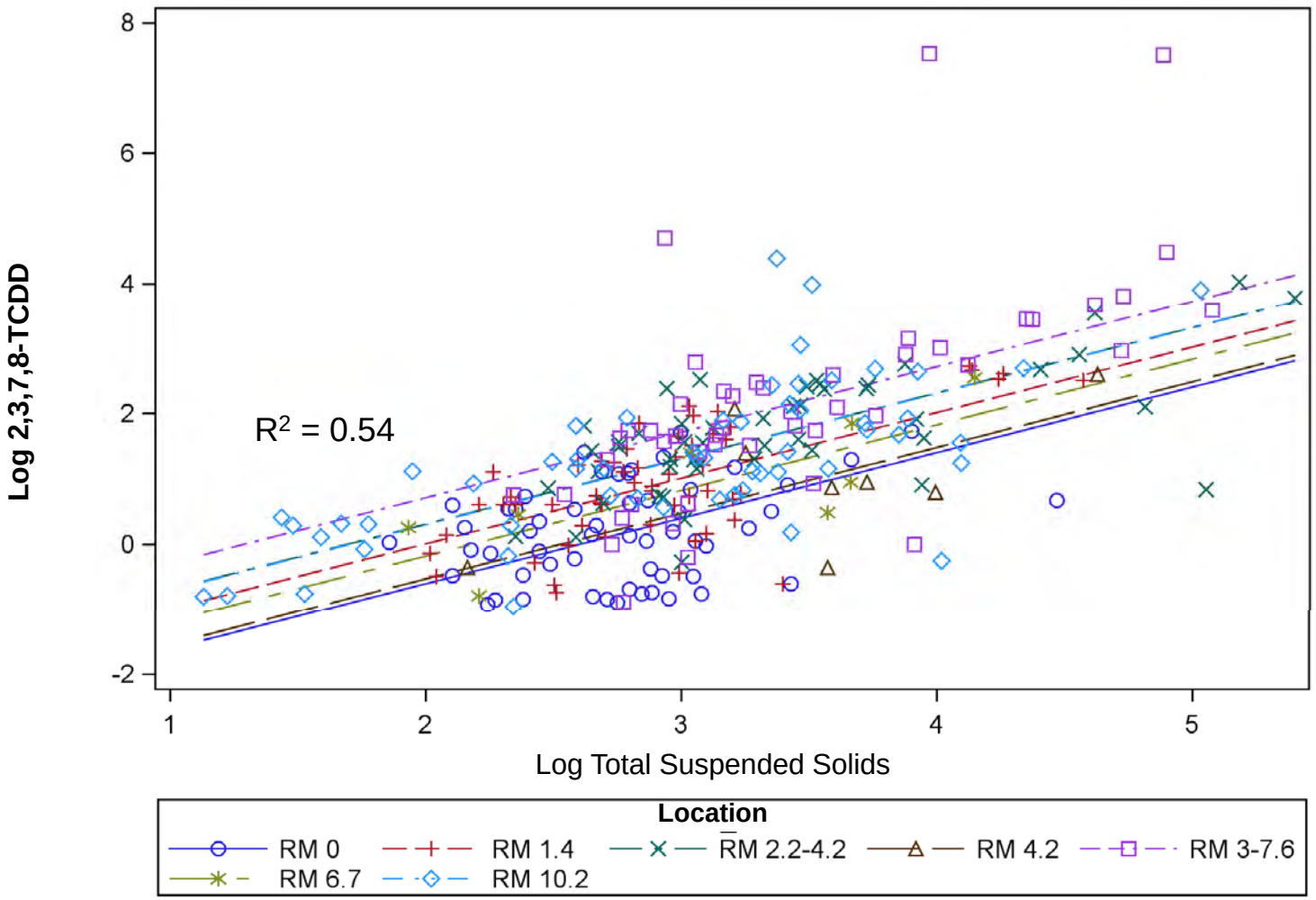
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
mg = milligram
µm = micrometer
ng = nanogram
PCB = polychlorinated biphenyl
RM = River Mile, these are LPRSA river miles where the surface water stations are located

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total PCB Congeners vs. Total Suspended Solids in Surface Water by Station with Regression Line

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-8



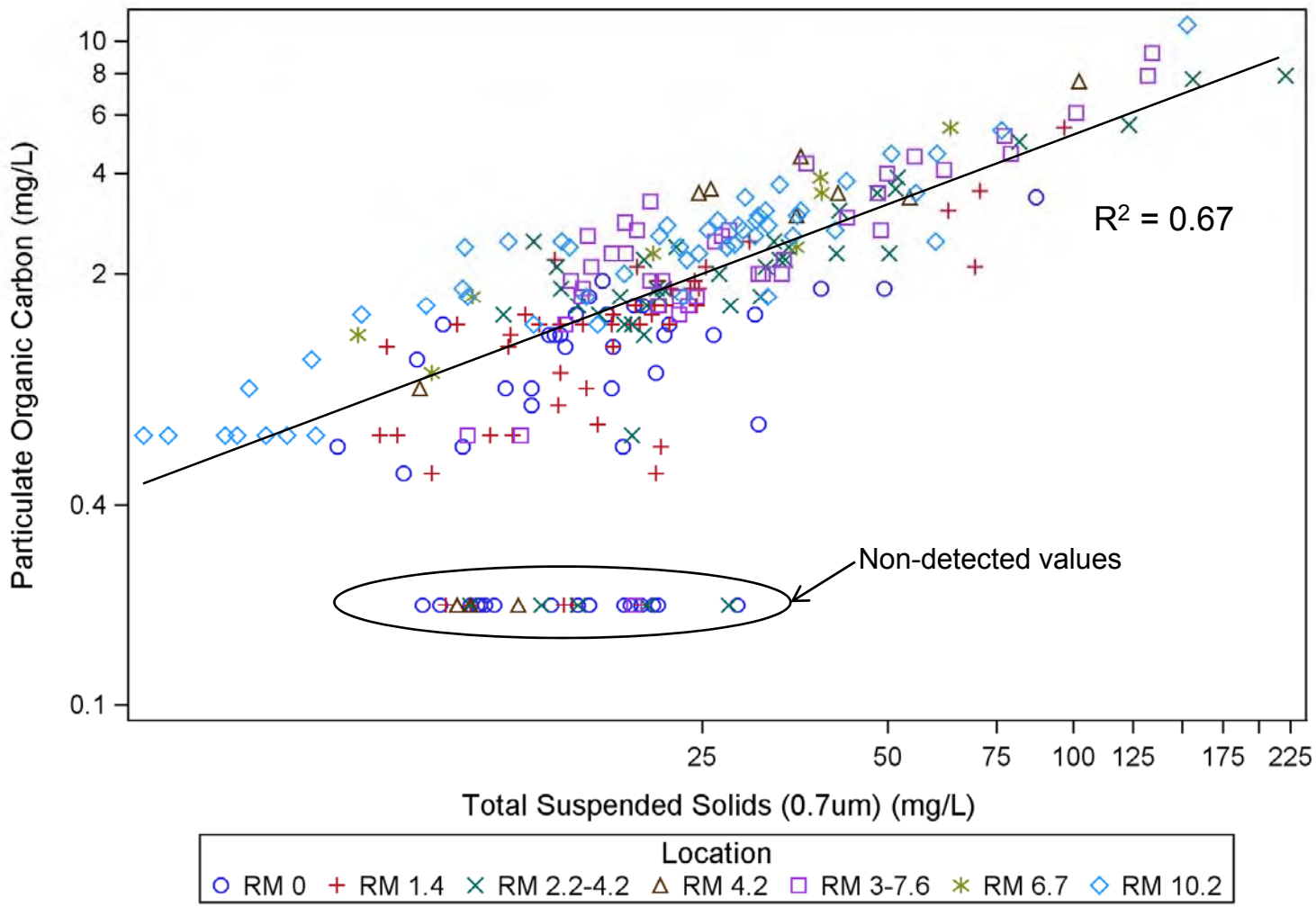
Notes:
LPRSA = Lower Passaic River Study Area
RM = River Mile, these are LPRSA river miles where the surface water stations are located
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD vs. Total Suspended Solids in Surface Water by Station: Analysis of Covariance

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-9



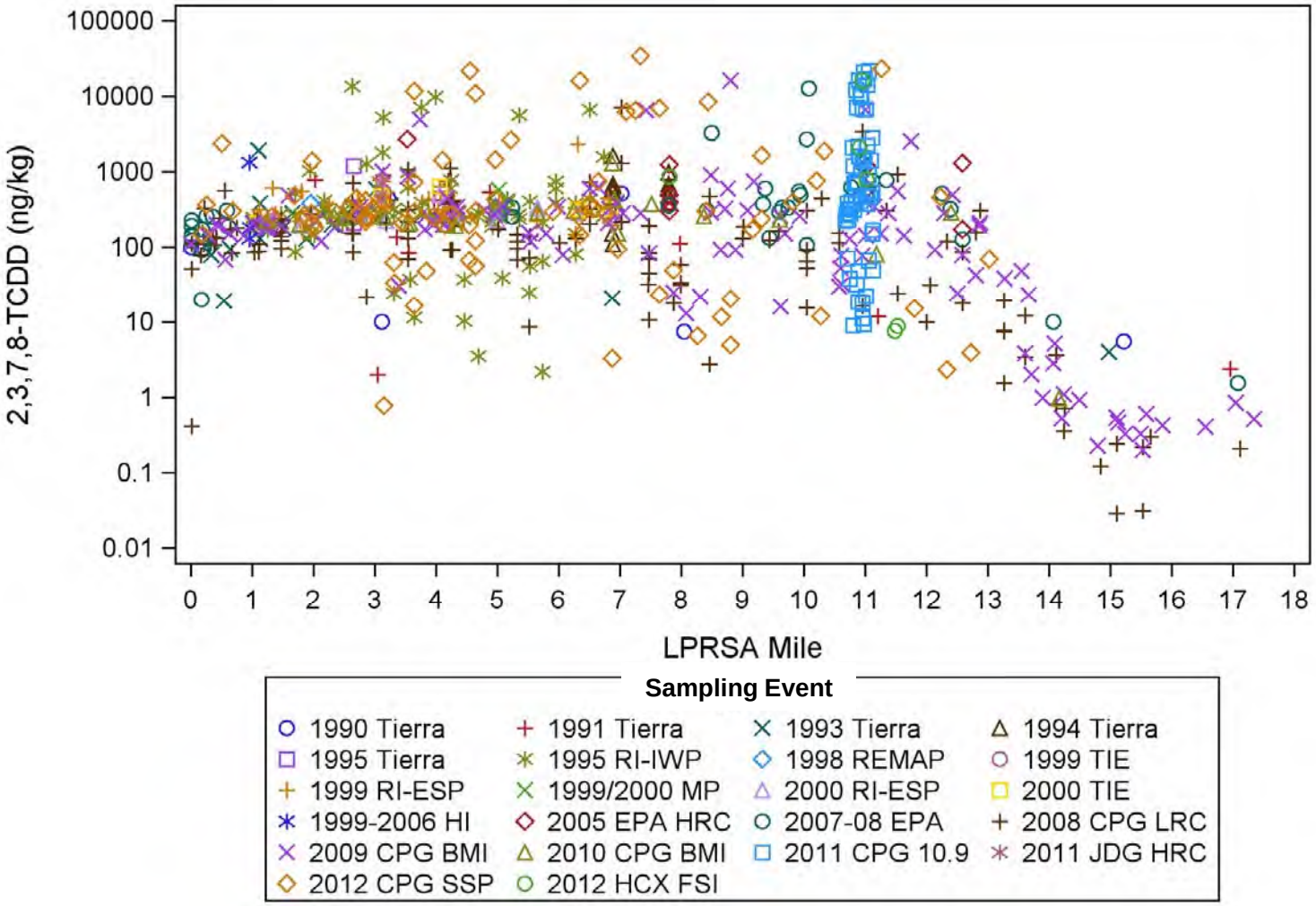
Notes:
L = liter
LPRSA = Lower Passaic River Study Area
mg = milligram
µm = micrometer
PCB = polychlorinated biphenyl
RM = River Mile, these are LPRSA river miles where the surface water stations are located
Non-detects excluded from the regression analysis.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total PCB Congeners vs. Total Suspended Solids in Surface Water by Station with Regression Line

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-10



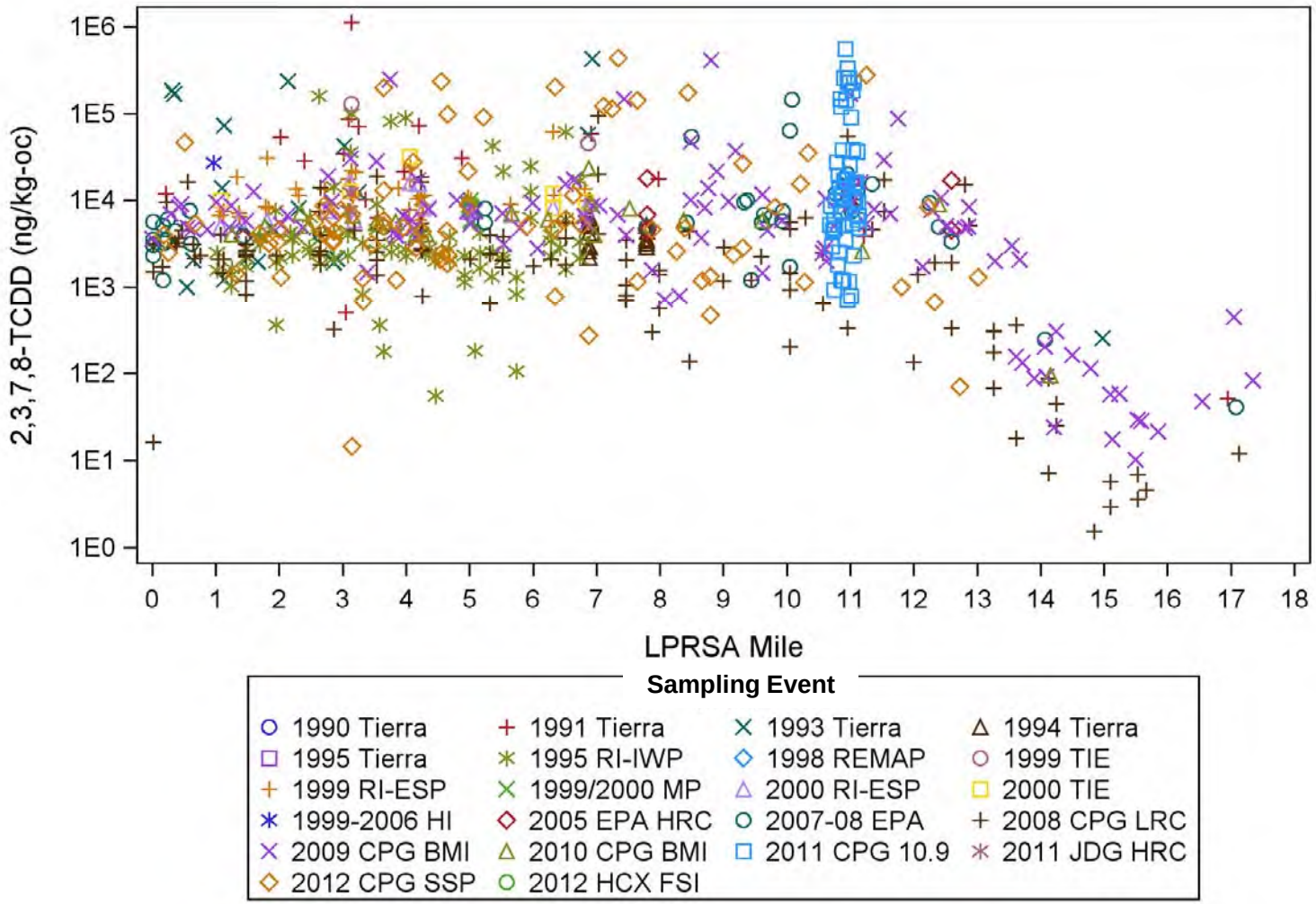
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-11



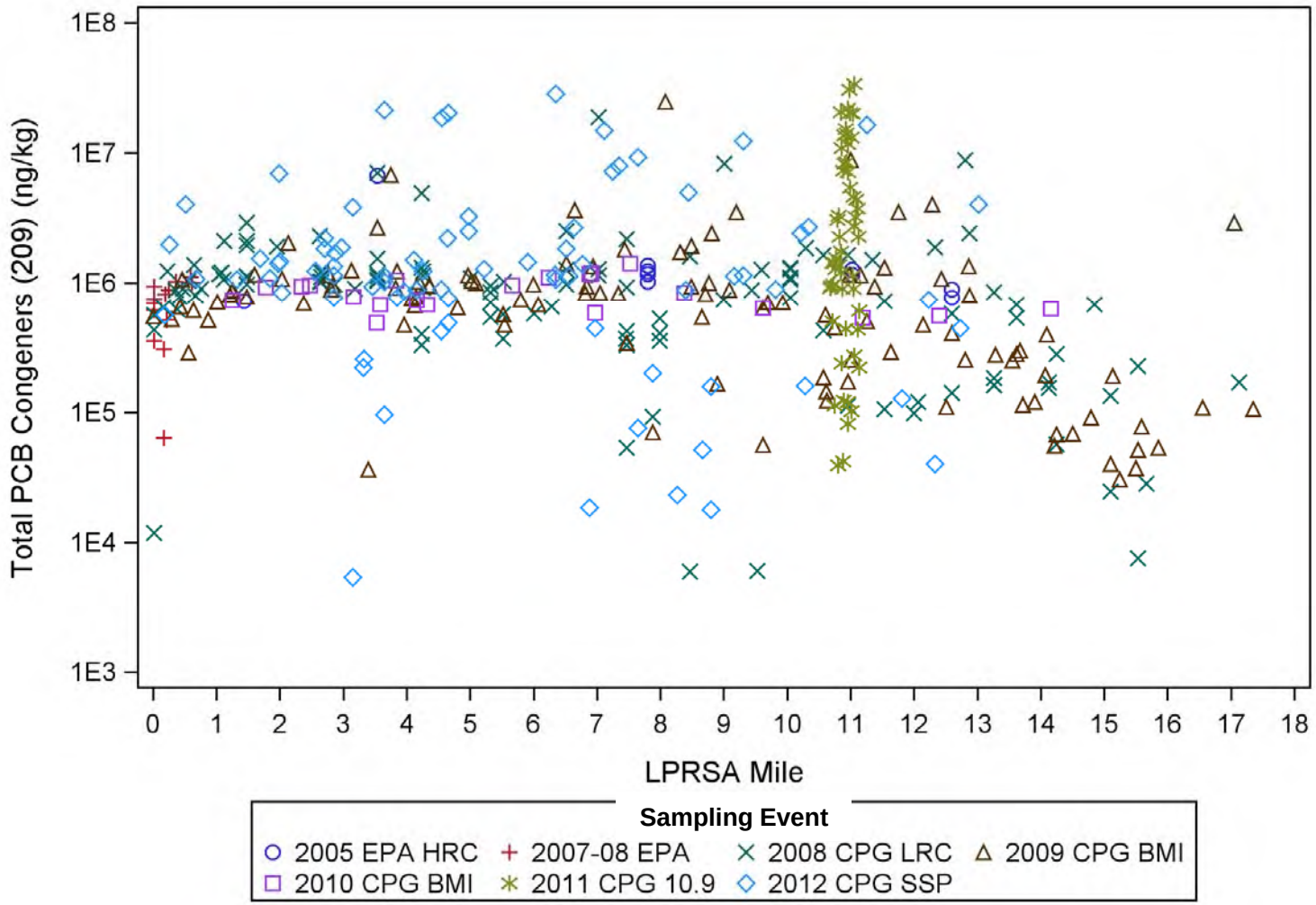
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Organic Carbon-Normalized 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-12



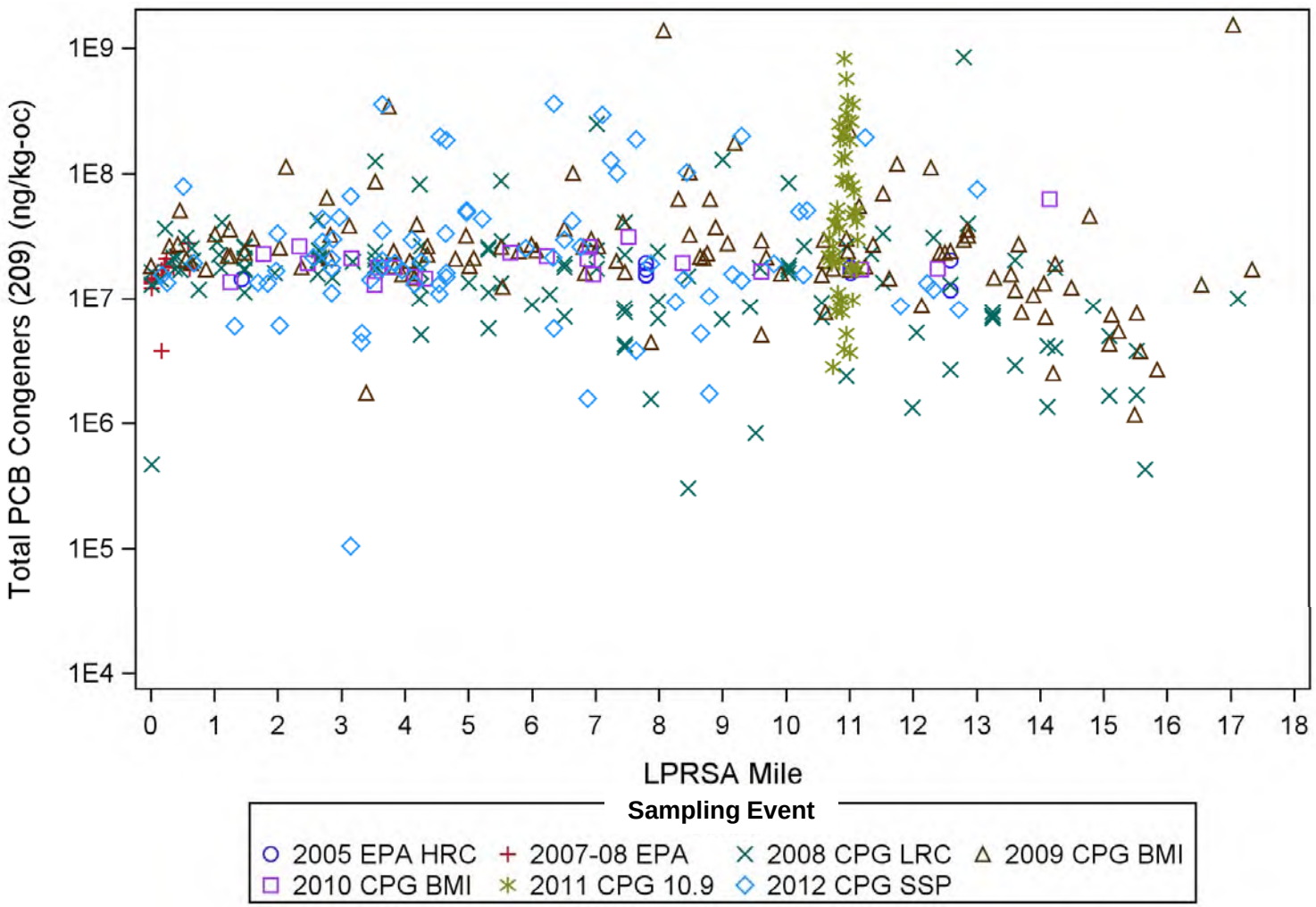
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total PCB Congeners in Surface Sediment
by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-13



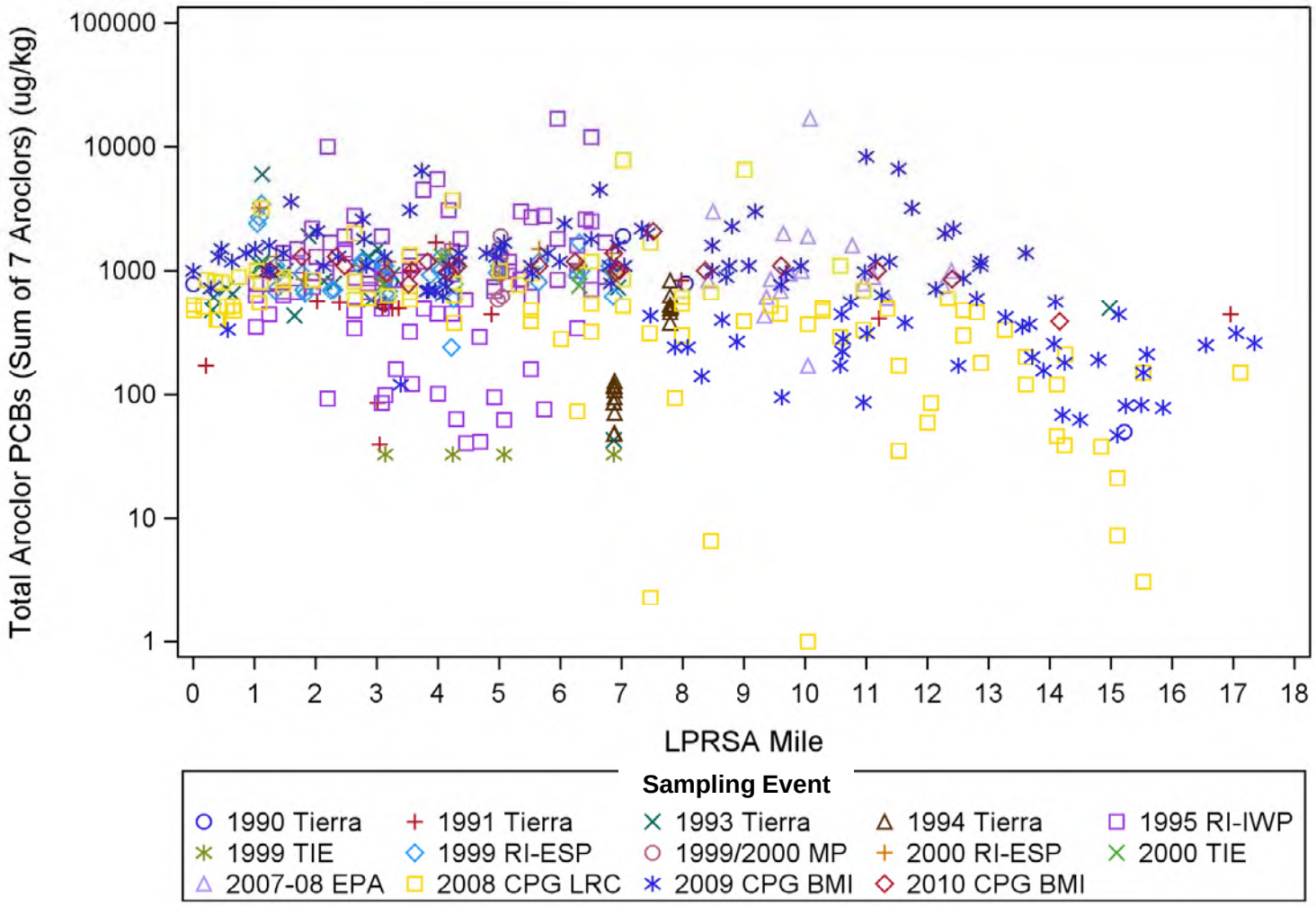
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Organic Carbon-Normalized Total PCB Congeners in Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-14



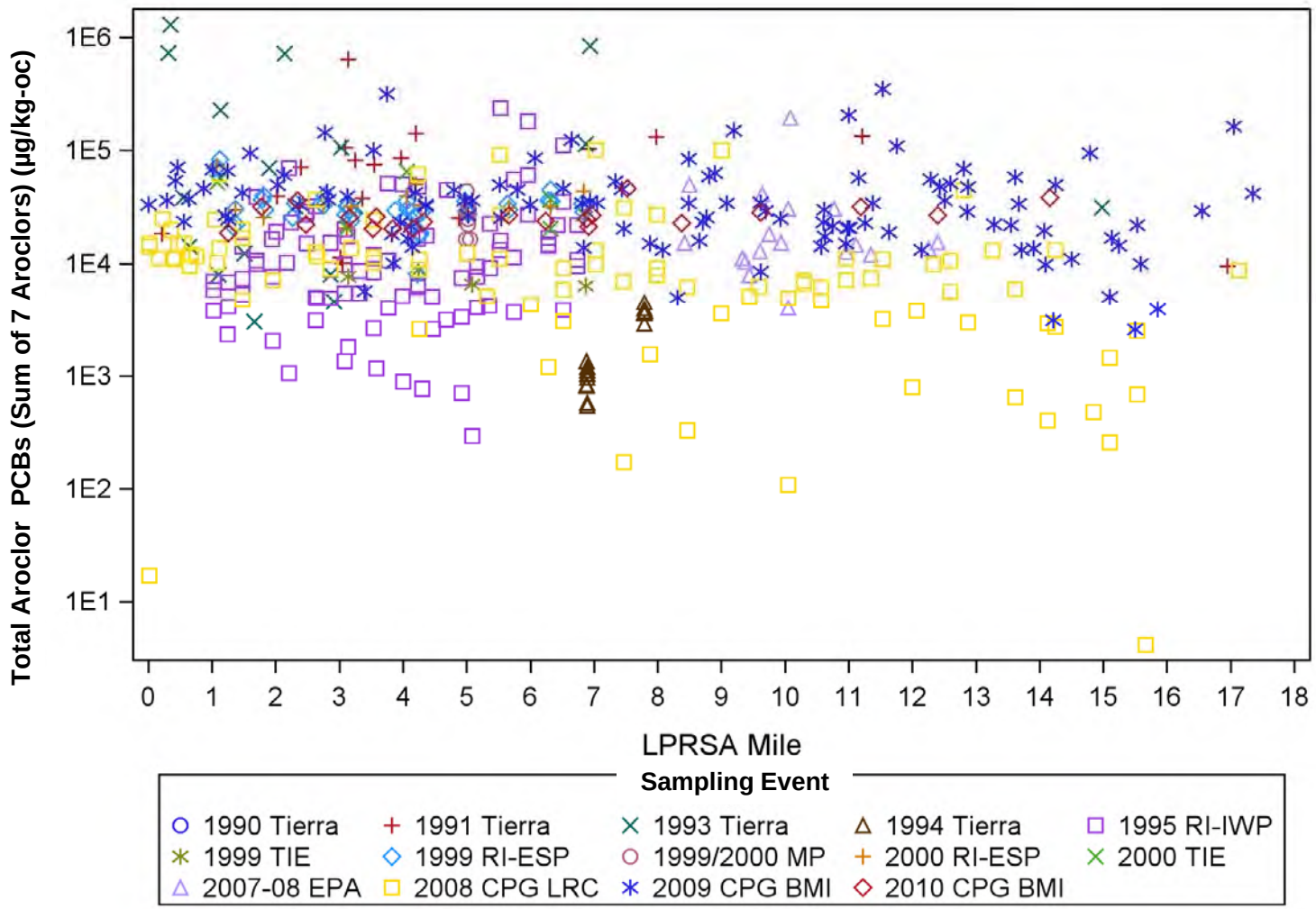
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Total Aroclor PCBs (Sum of 7 Aroclors) in Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-15



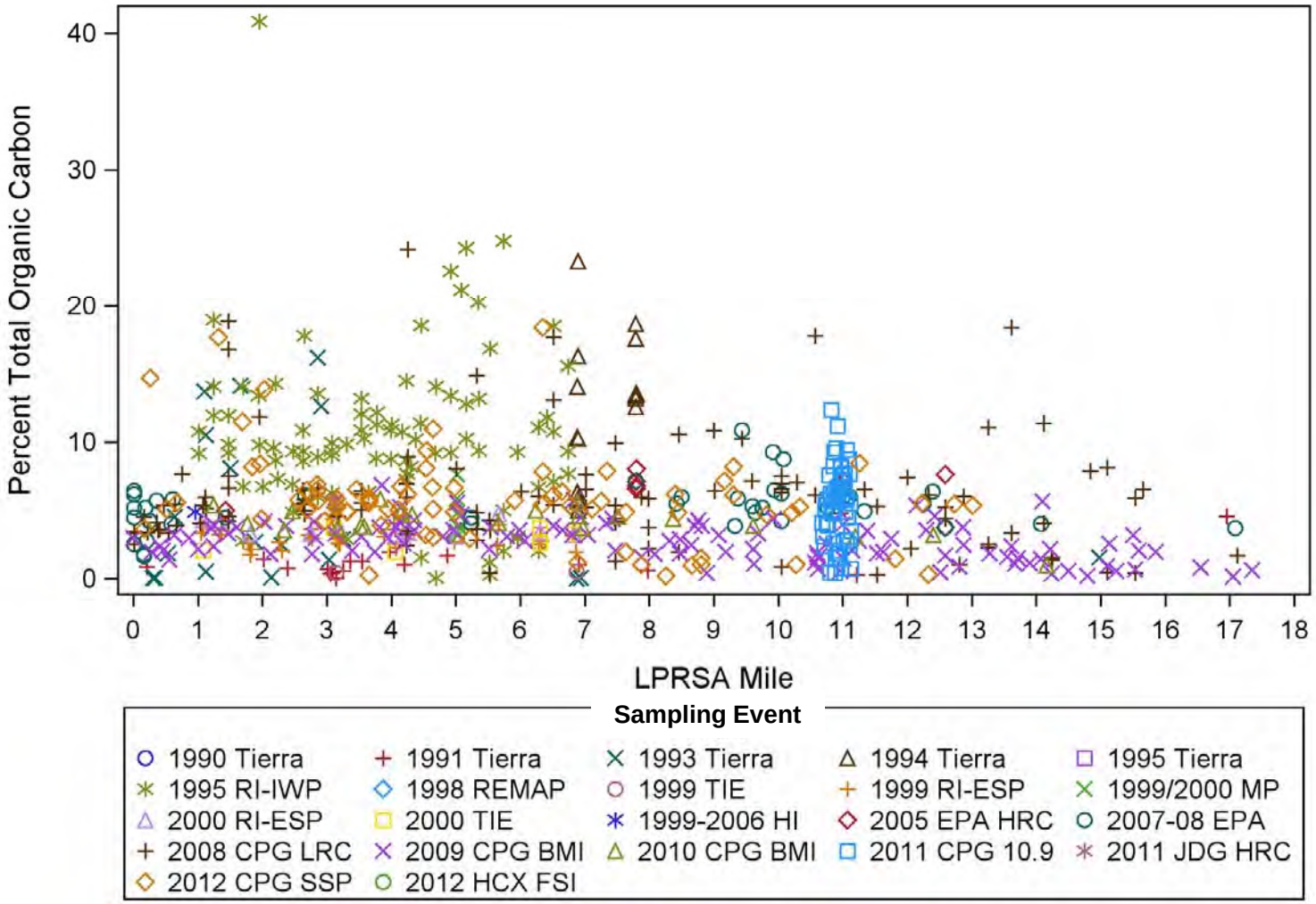
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
oc = organic carbon
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Organic Carbon-Normalized Total Aroclor PCBs
(Sum of 7 Aroclors) in Sediment by LRPSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-16



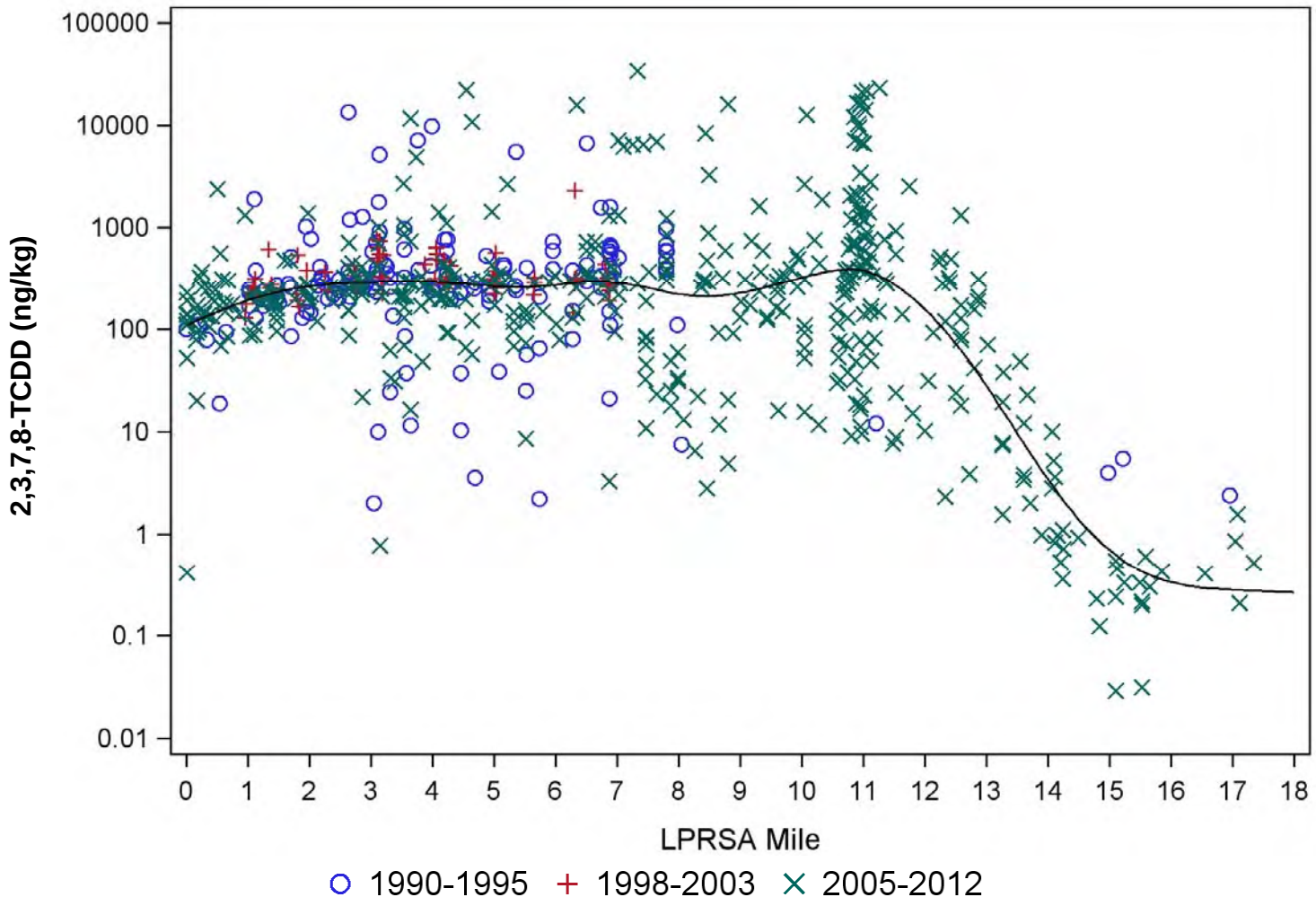
Note:
LPRSA = Lower Passaic River Study Area

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Percent Total Organic Carbon in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-17



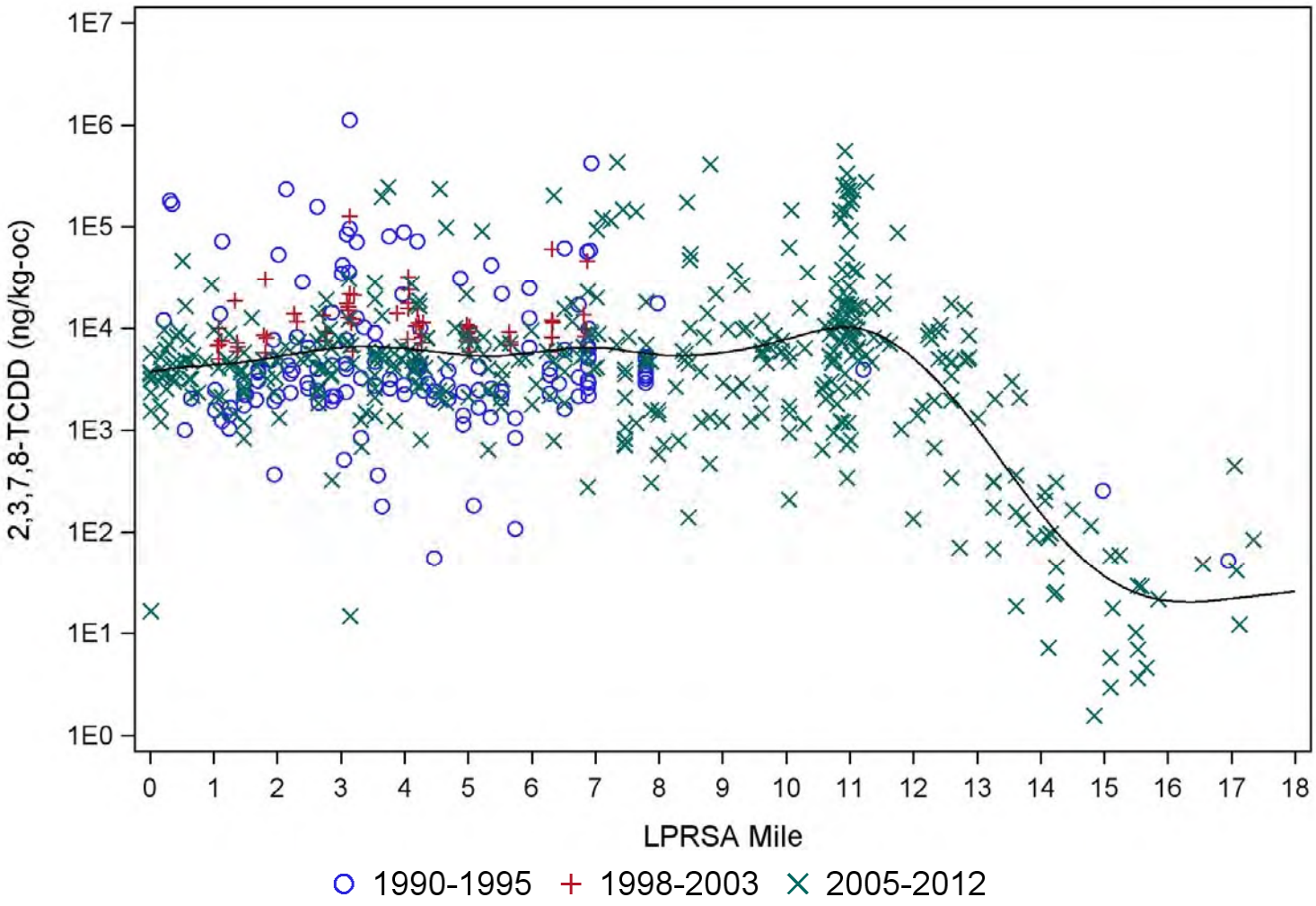
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-18



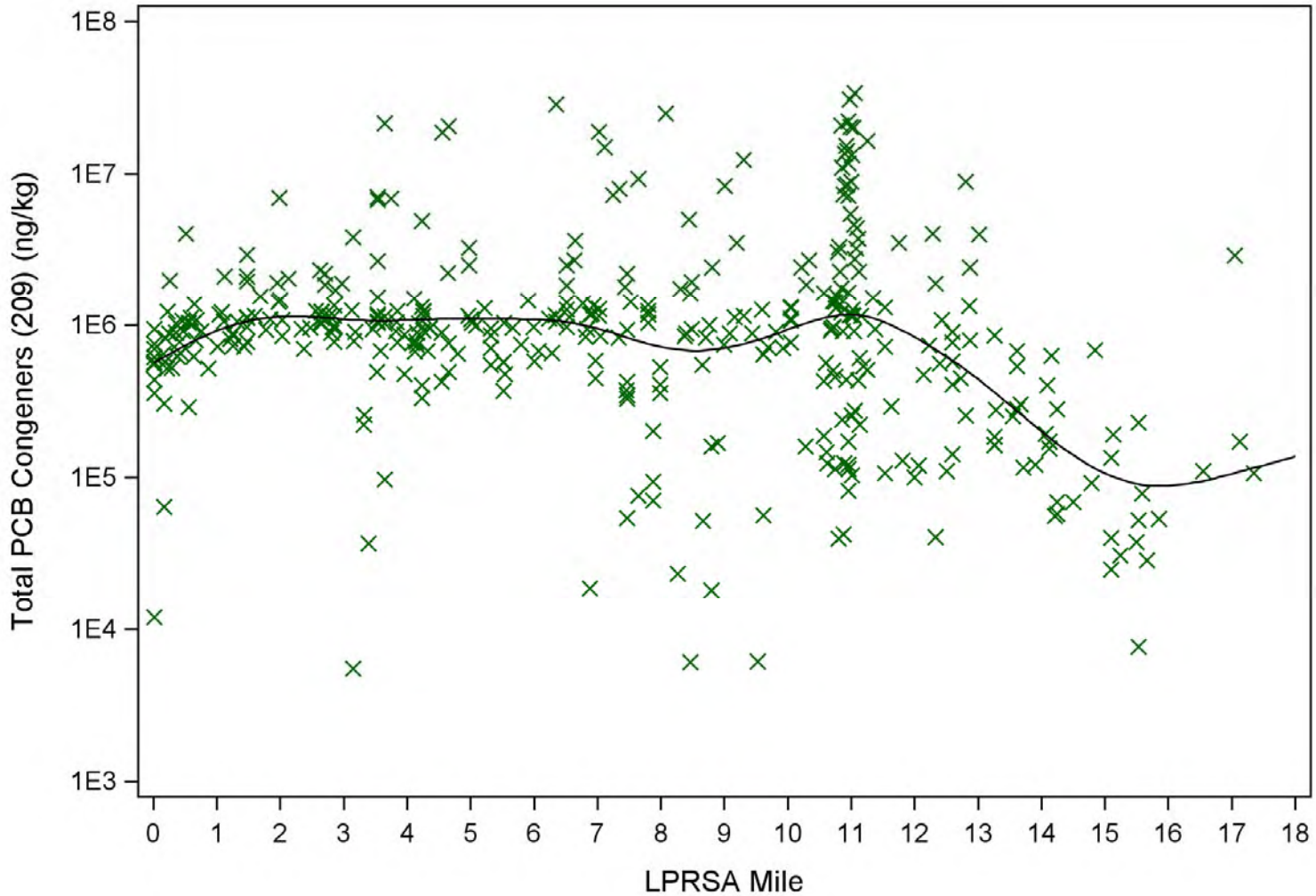
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Spline Model of Organic Carbon-Normalized 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-19



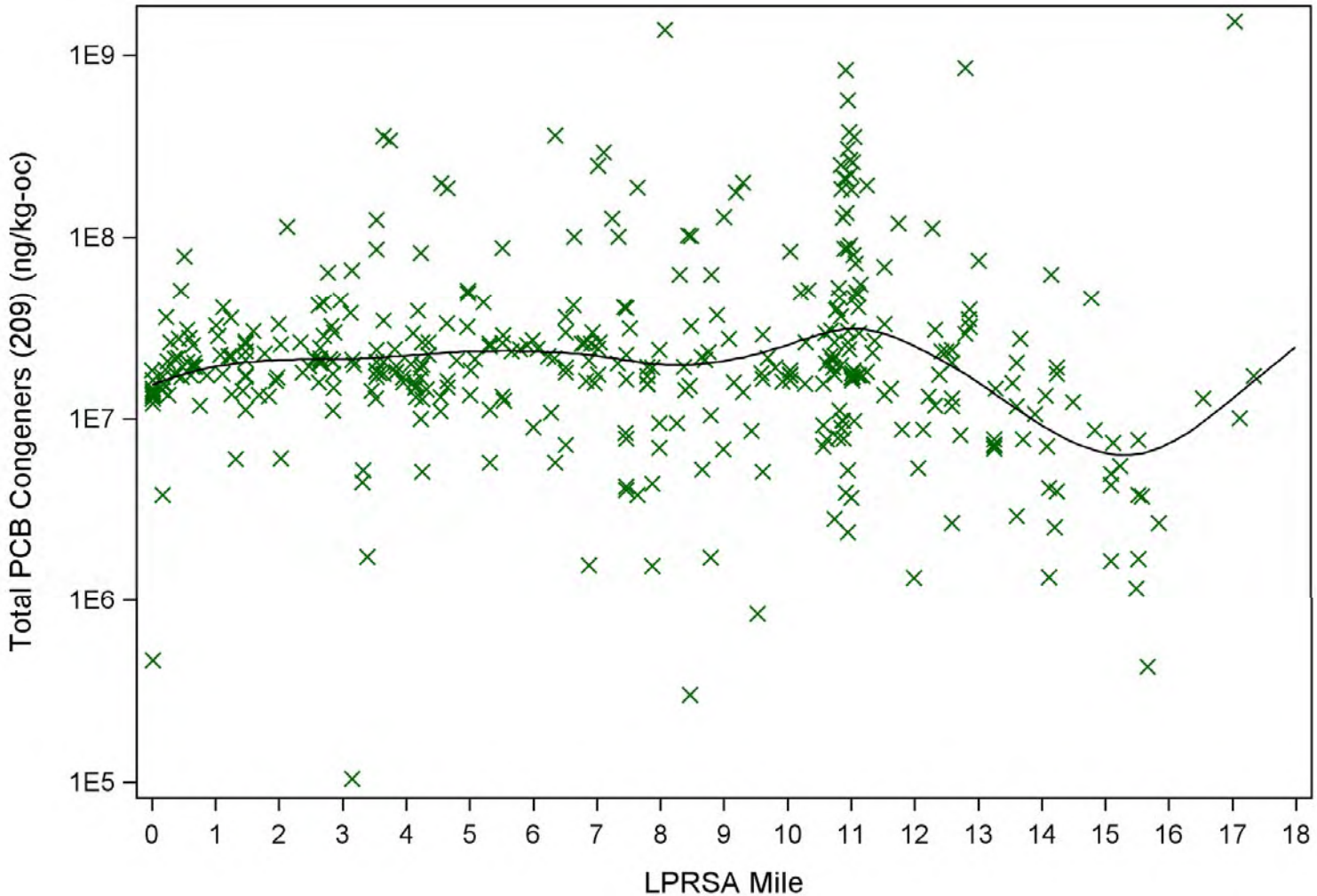
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Spline Model of Total PCB Congeners in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-20



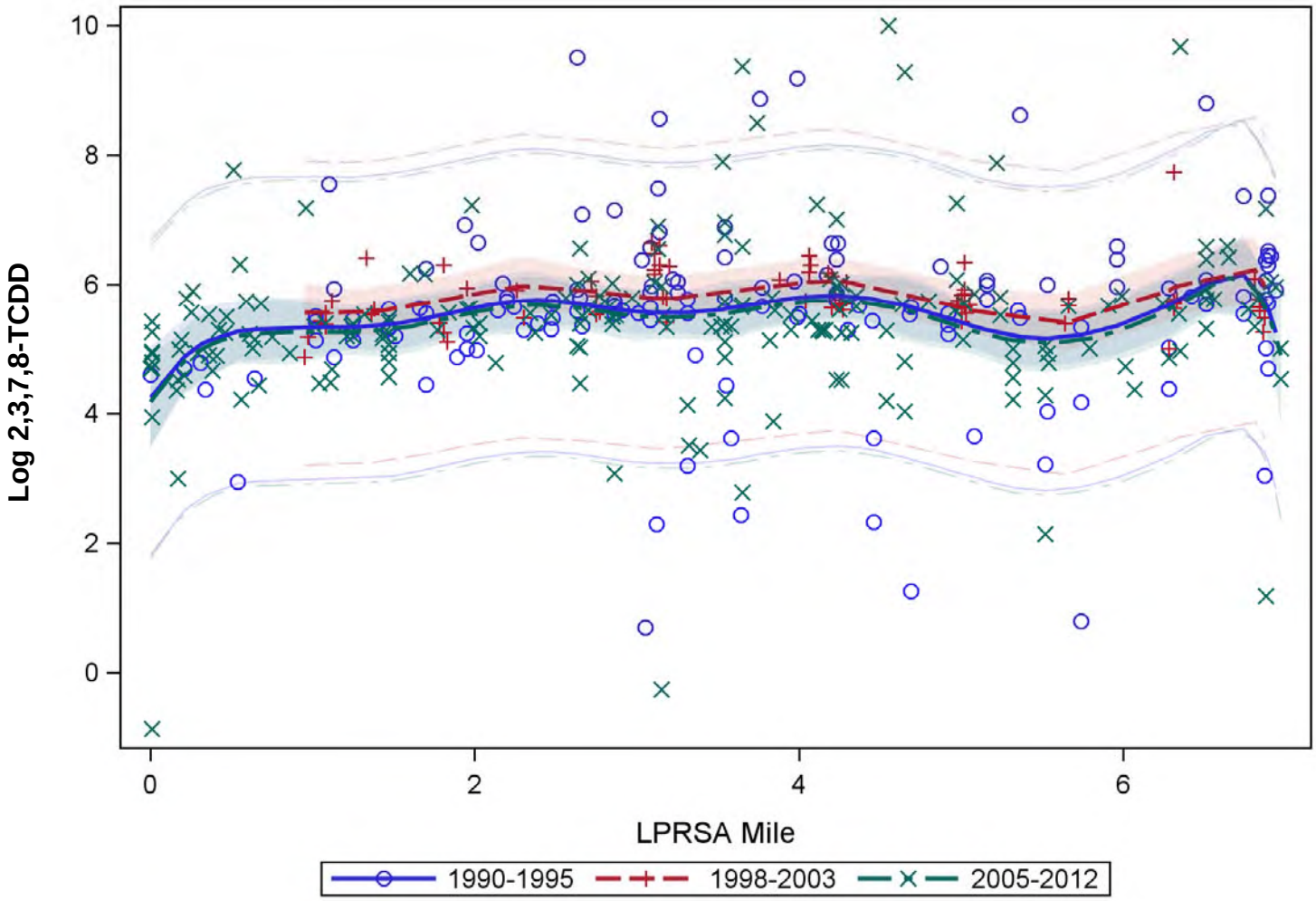
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Spline Model of Organic Carbon-Normalized Total PCB Congeners in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-21



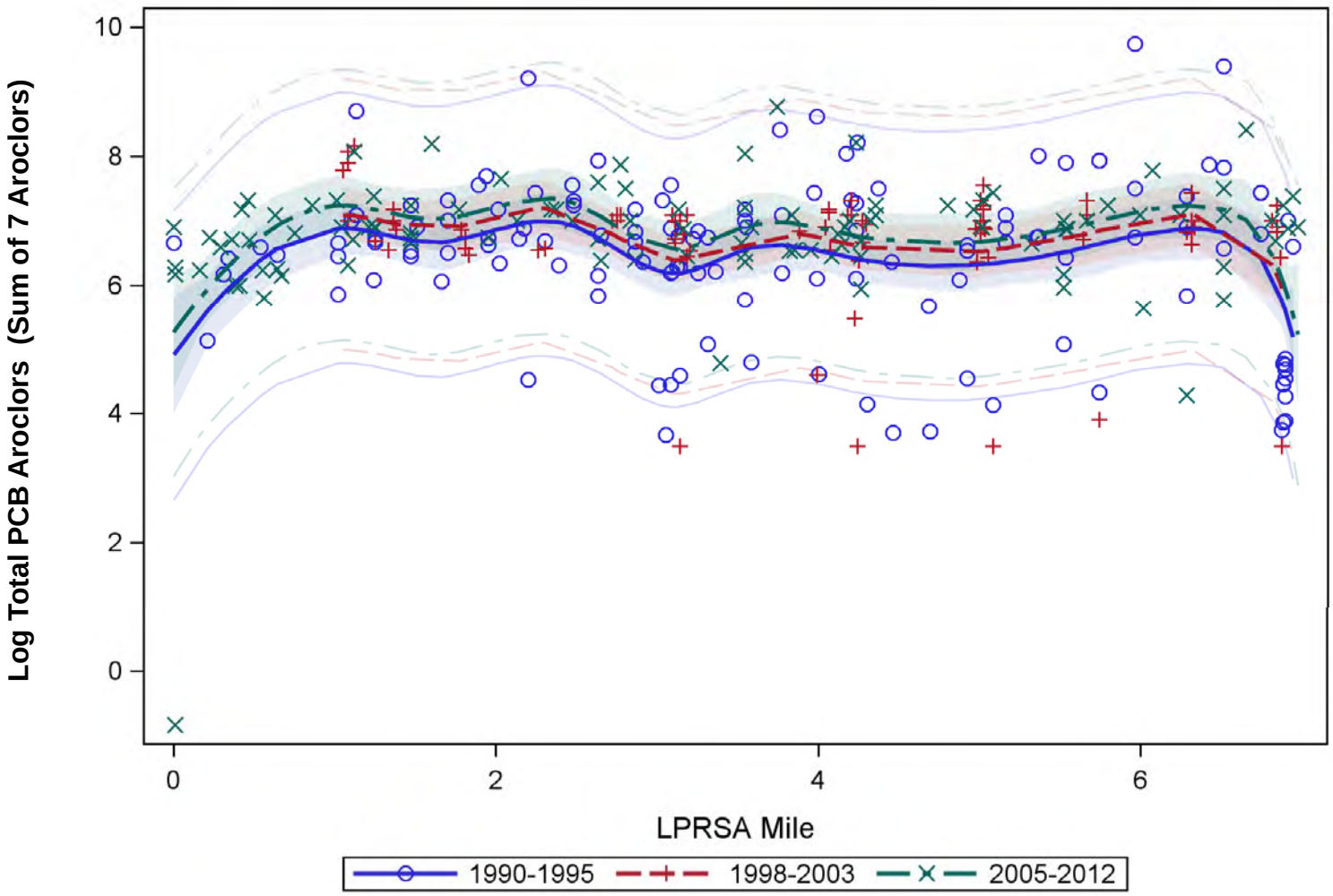
Notes:
LPRSA = Lower Passaic River Study Area
TCDD = tetrachloro-*p*-dibenzodioxin
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile: All Data

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-22



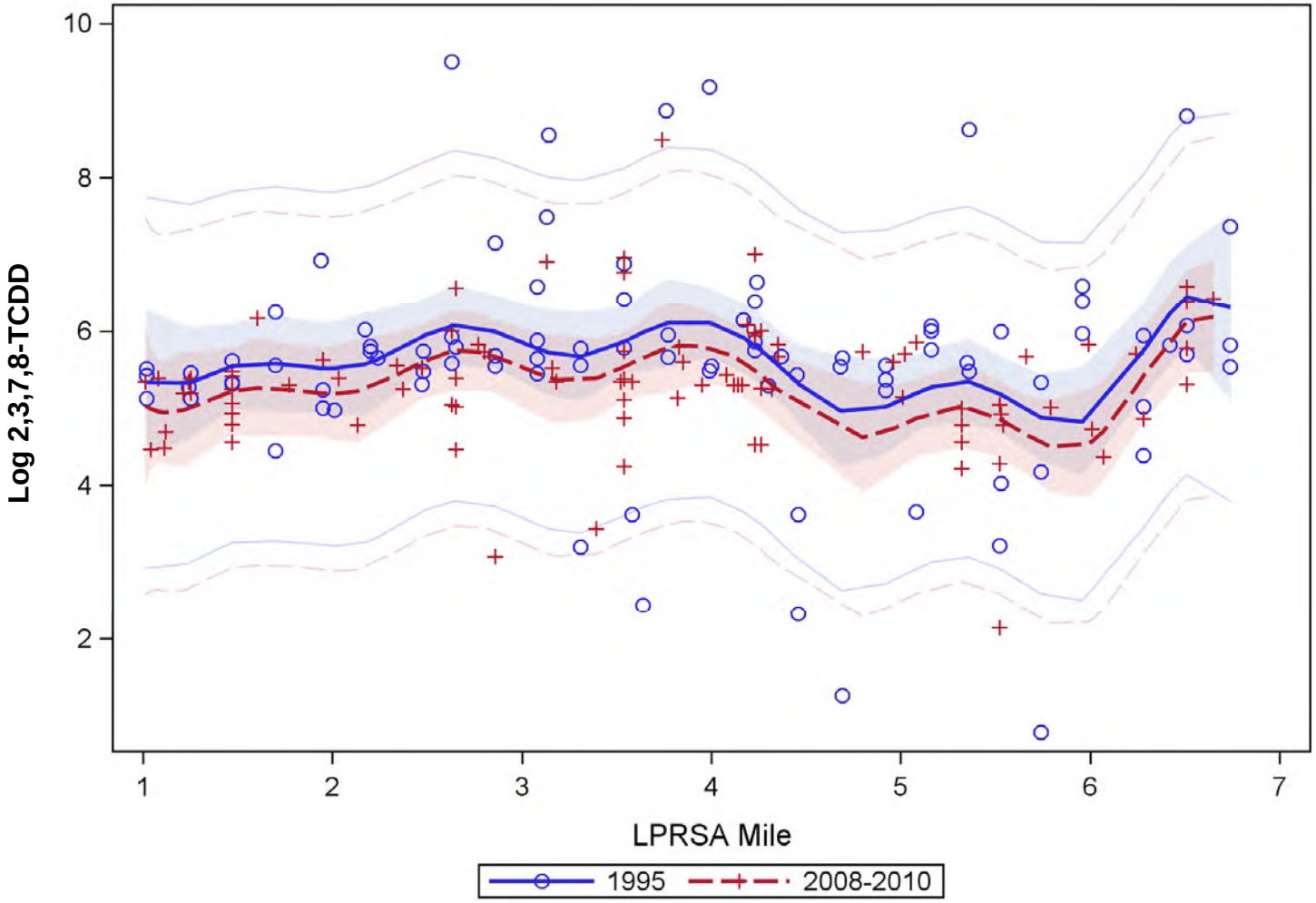
Notes:
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of Total Aroclor PCBs (Sum of 7 Aroclors) in Surface Sediment by LPRSA Mile: All Data

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-23



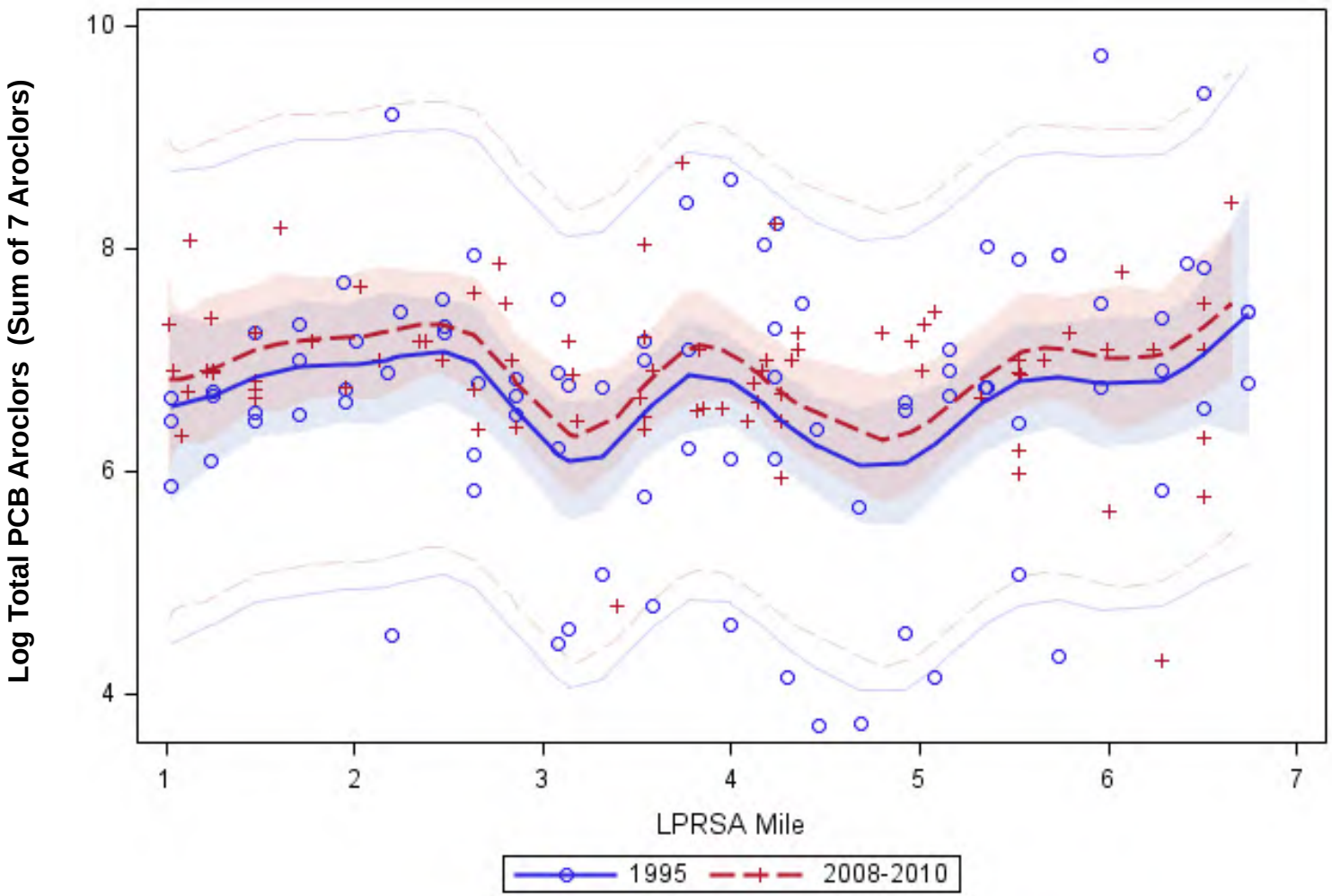
Notes:
LPRSA = Lower Passaic River Study Area
TCDD = tetrachloro-*p*-dibenzodioxin
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of 2,3,7,8-TCDD in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-24



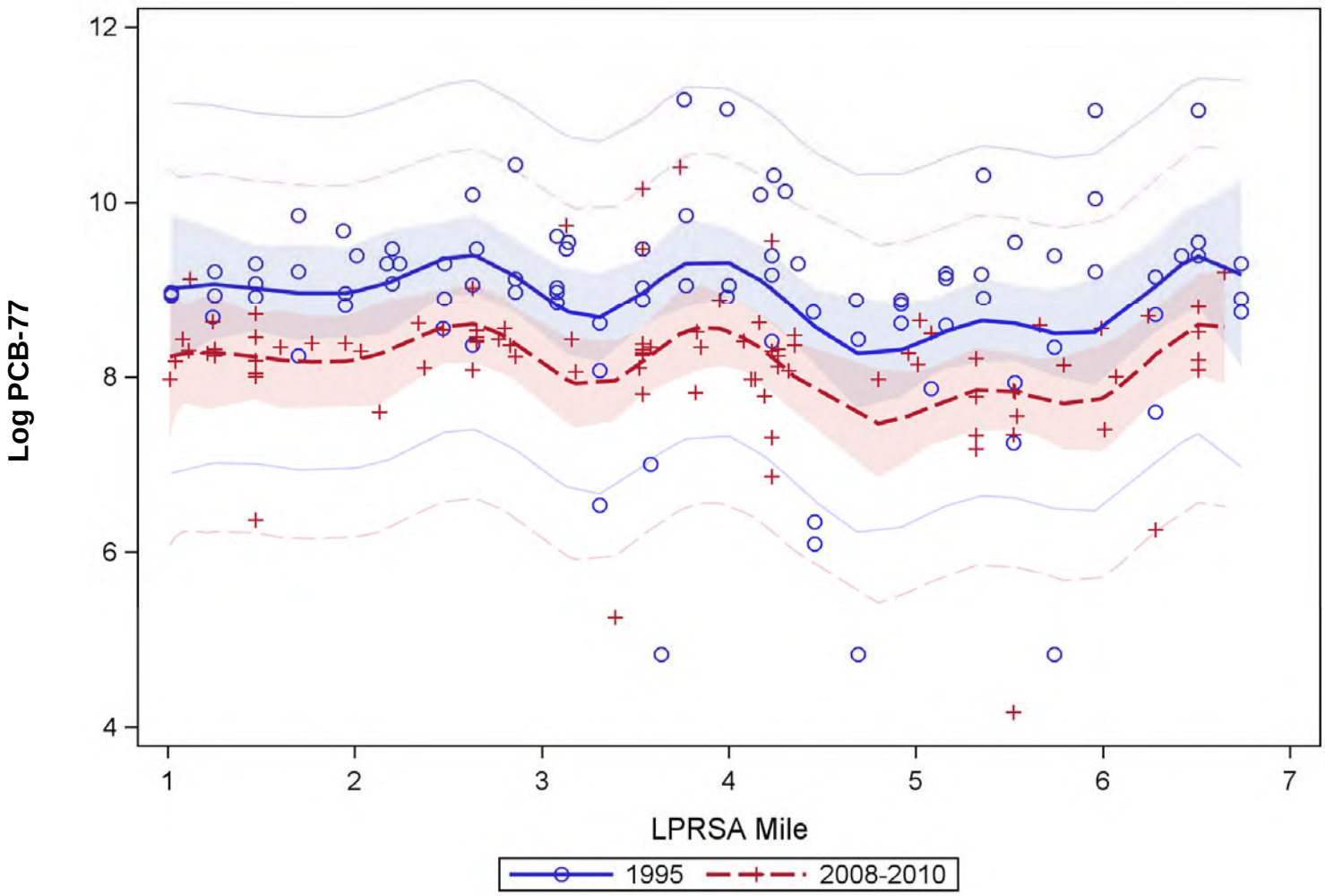
Notes:
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of Total Aroclor PCBs (Sum of 7 Aroclors) in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-25



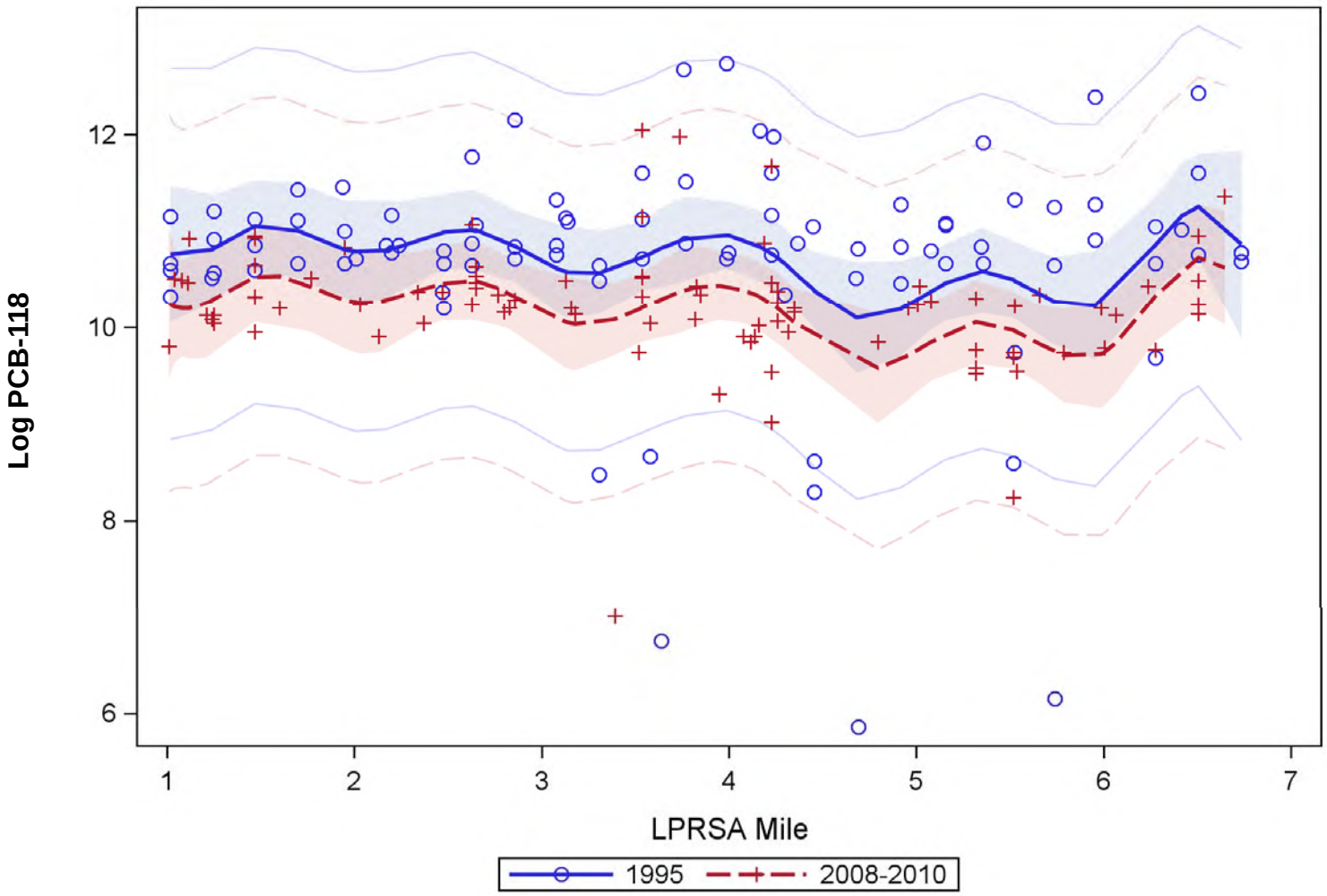
Notes:
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of PCB-77 in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-26



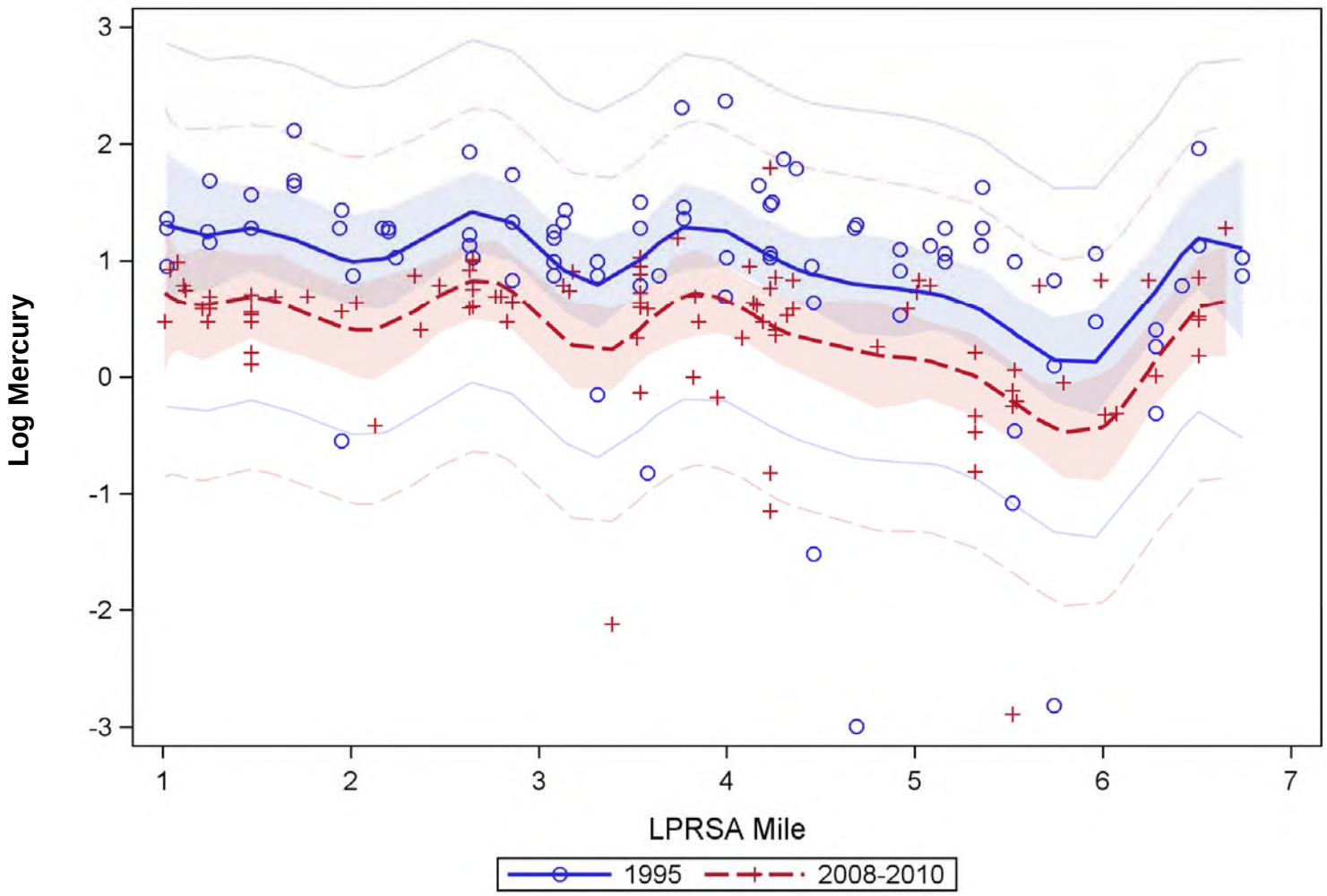
Notes:
LPRSA = Lower Passaic River Study Area
PCB = polychlorinated biphenyl
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of PCB-118 in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-27



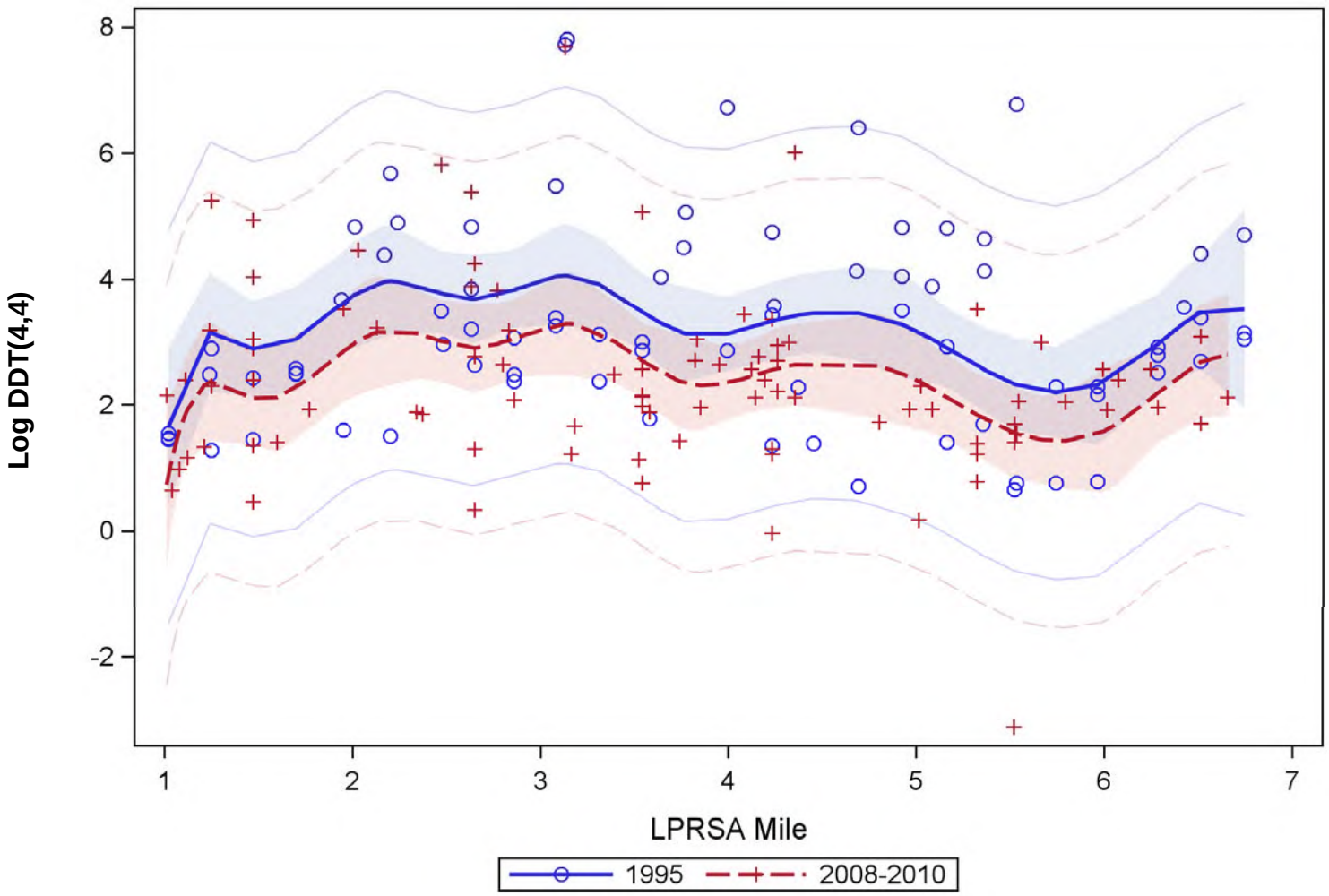
Notes:
LPRSA = Lower Passaic River Study Area
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of Mercury in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-28



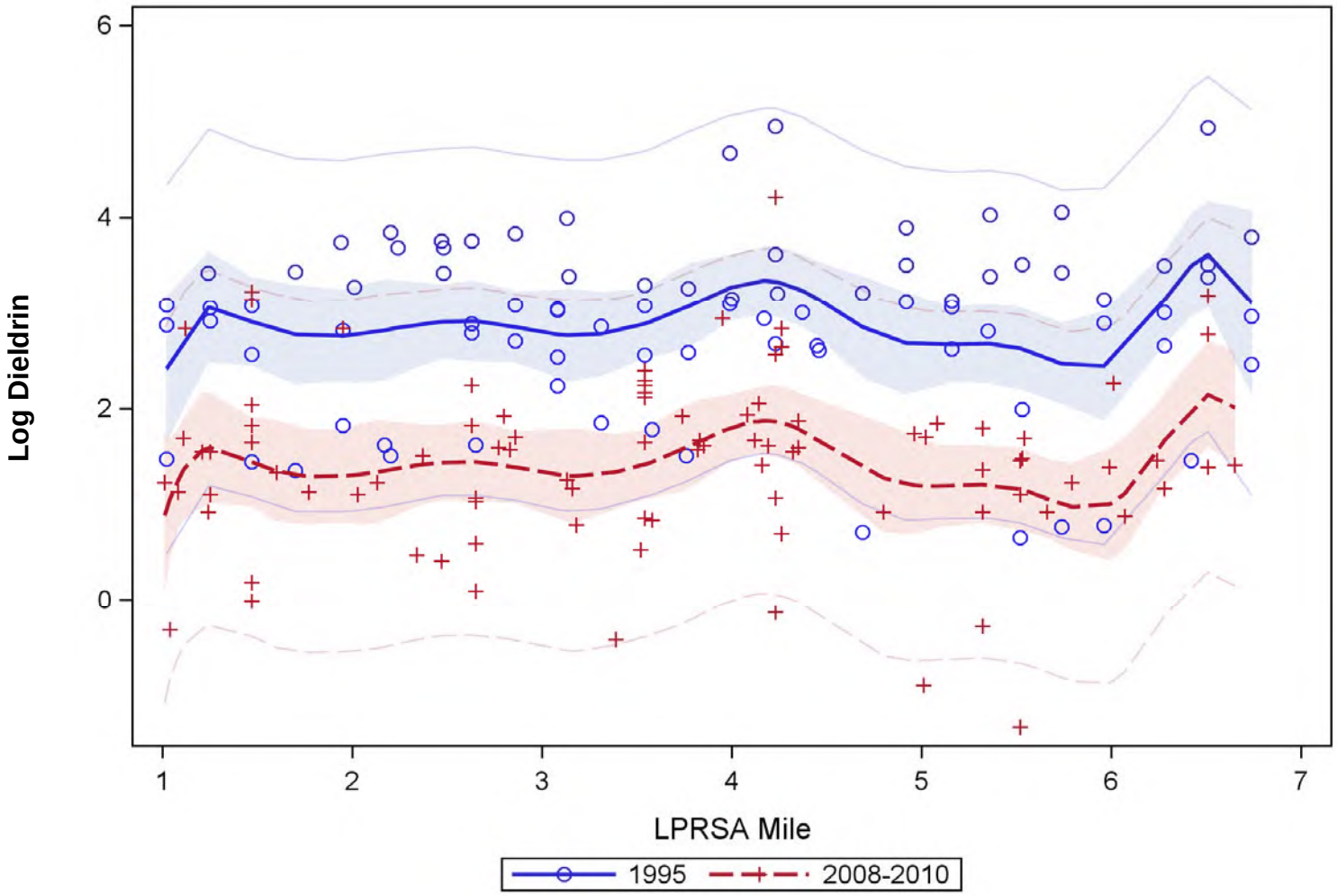
Notes:
LPRSA = Lower Passaic River Study Area
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of DDT (4,4) in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-29



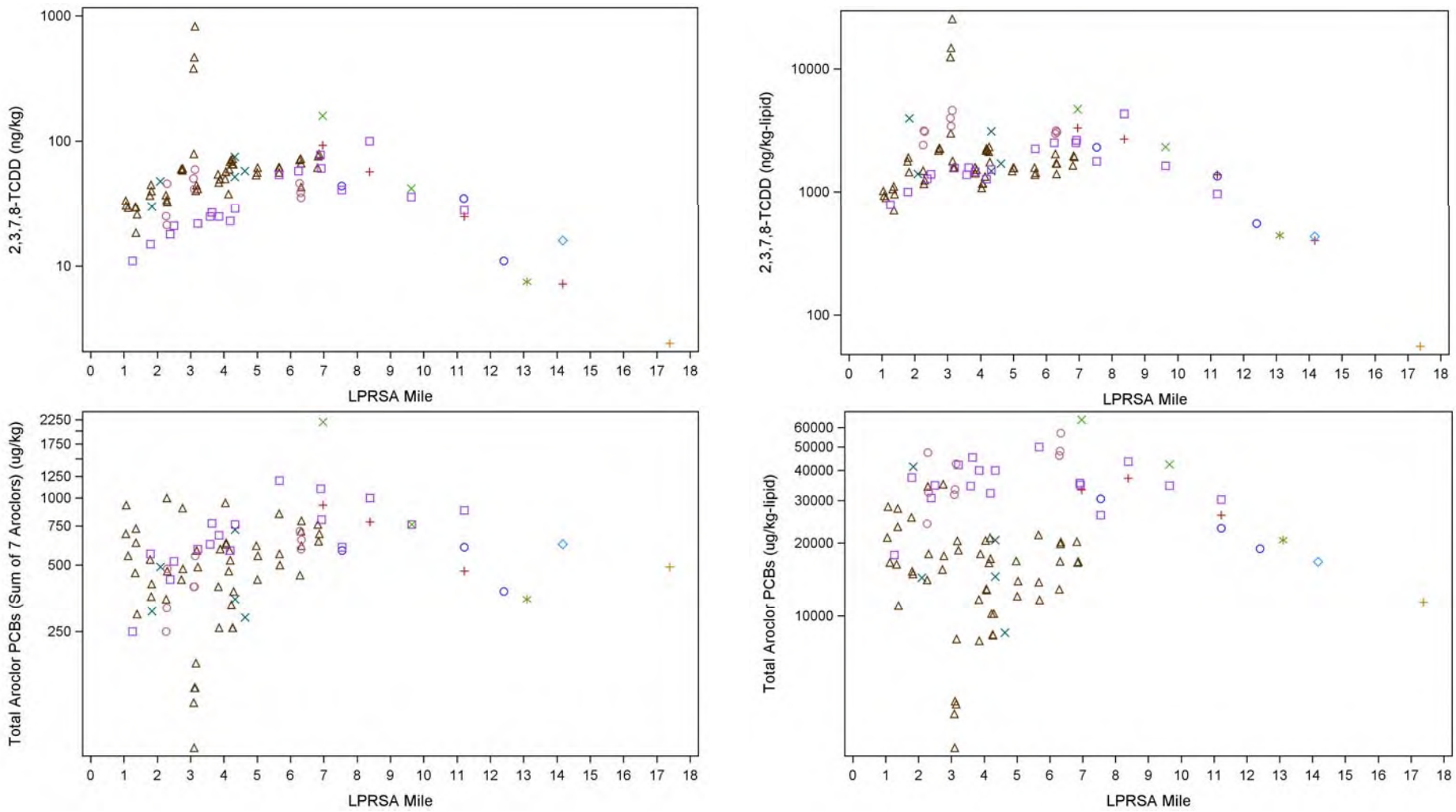
Notes:
LPRSA = Lower Passaic River Study Area
Concentration shown is transformed by natural logarithm.
Shaded areas represent 95% confidence intervals on the mean.
Dot and dash lines represent 95% Prediction Limits of Individual Observation.
1995 data is from the 1995 RI Sampling Program. 2008-2010 data is from 2008 CPG Low –Resolution Coring Program and 2009-2010 CPG Benthic Sediment Study.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Temporal Spline Model of Dieldrin in Surface Sediment by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-30



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

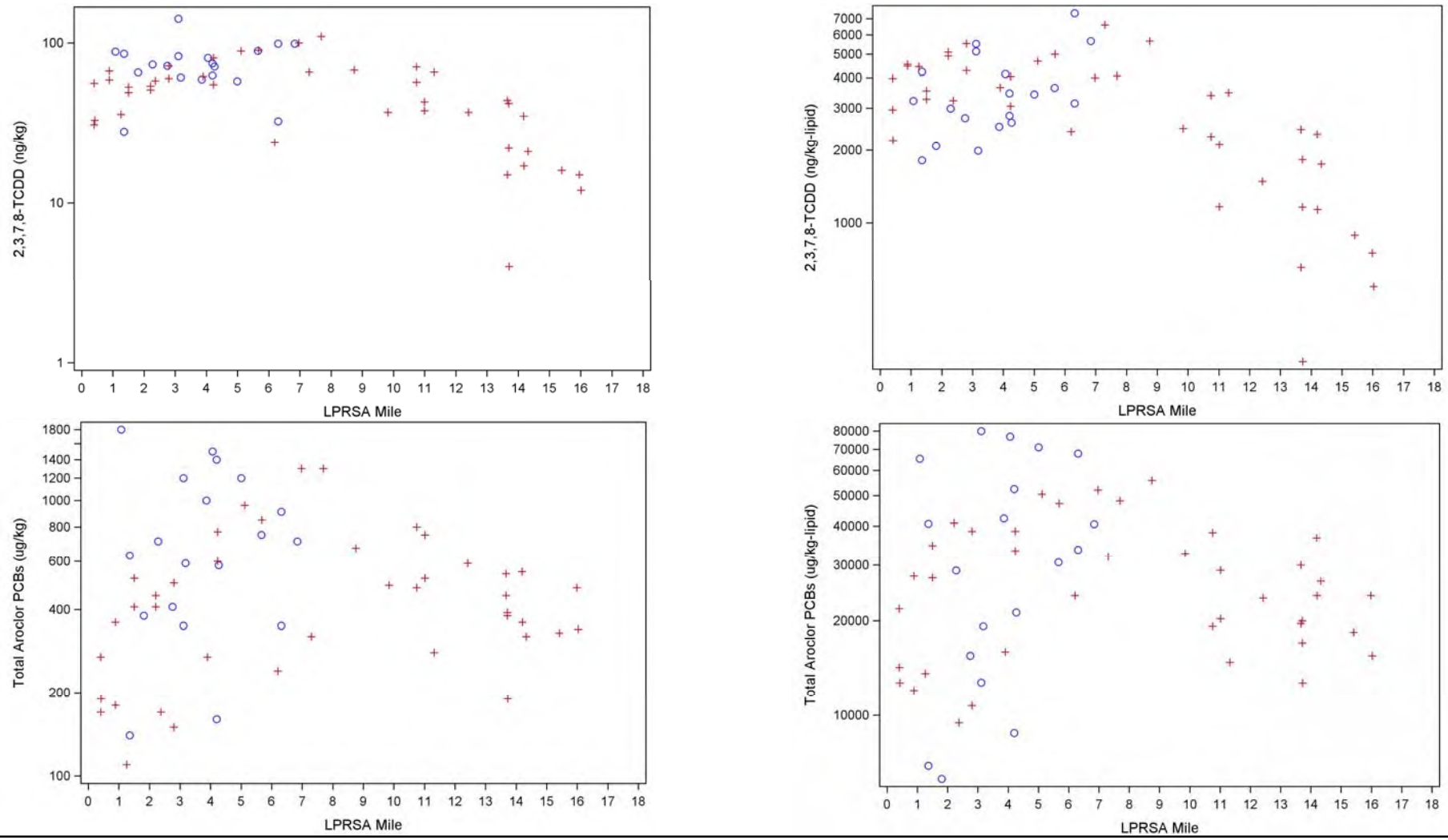
Species
- Gizzard Shad
- Mixed Forage Fish
- Mummichog:1995
- Mummichog:1999/2000
- Mummichog:2010
- Pumpkinseed
- Silver Shiner
- Silverside
- Spottail Shiner
- White Perch

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Forage Fish

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-31



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

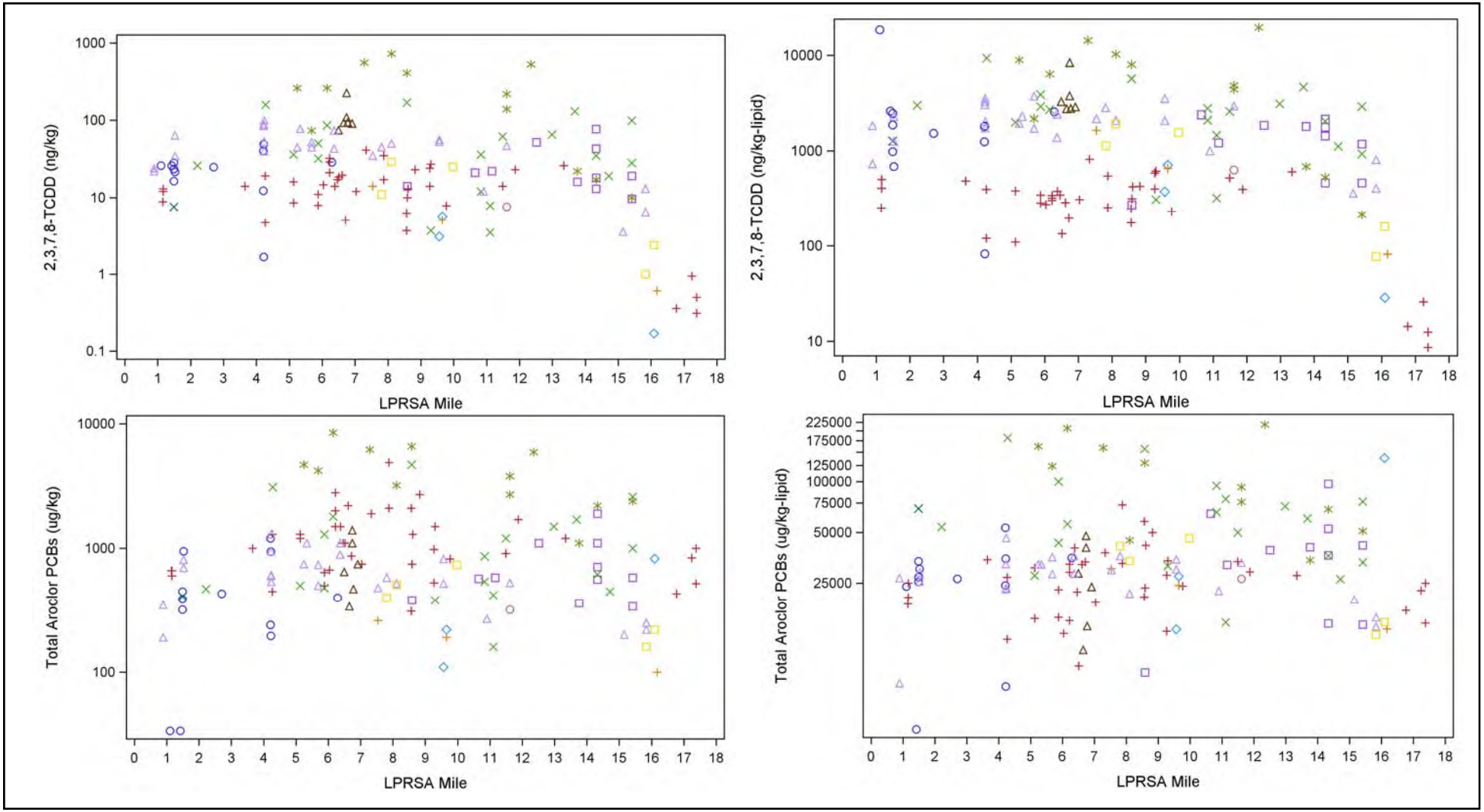
Year of Sampling ○ 1999-2001 + 2009-2010

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Blue Crab (Whole Body Soft Tissue)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-32



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

Species

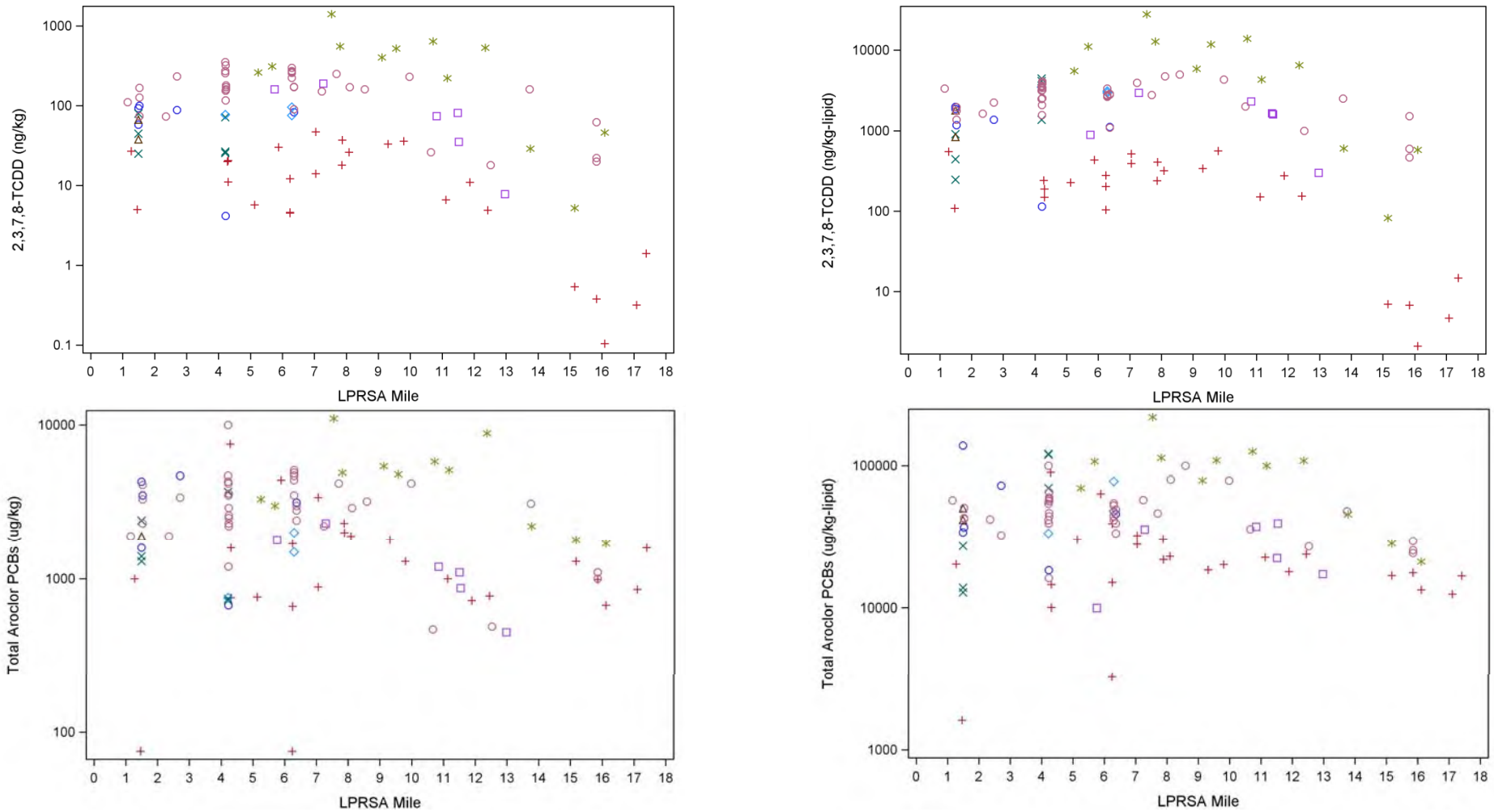
○ Adult Striped Bass	+ American Eel	× Bluefish
△ Brown Bullhead	□ Channel Catfish	✳ Common Carp
◇ Largemouth Bass	○ Northern Pike	+ Smallmouth Bass
× White Catfish	△ White Perch	□ White Sucker

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Fish Fillet Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-33



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

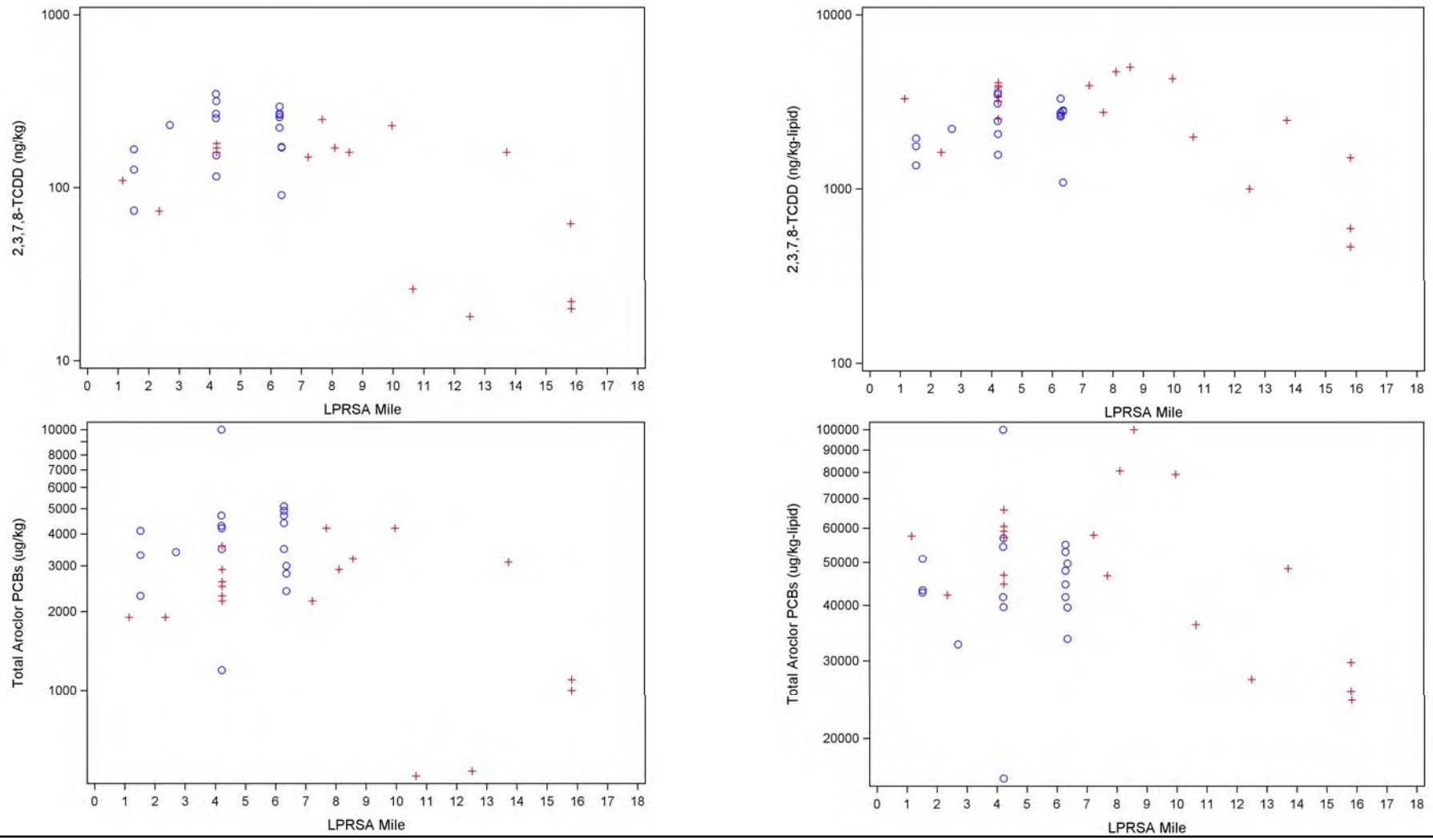
Species
○ Adult Striped Bass + American Eel × Atlantic Menhaden △ Bluefish
□ Brown Bullhead ✳ Common Carp ◇ Juvenile Striped Bass ○ White Perch

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in Whole Body Fish Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-34



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

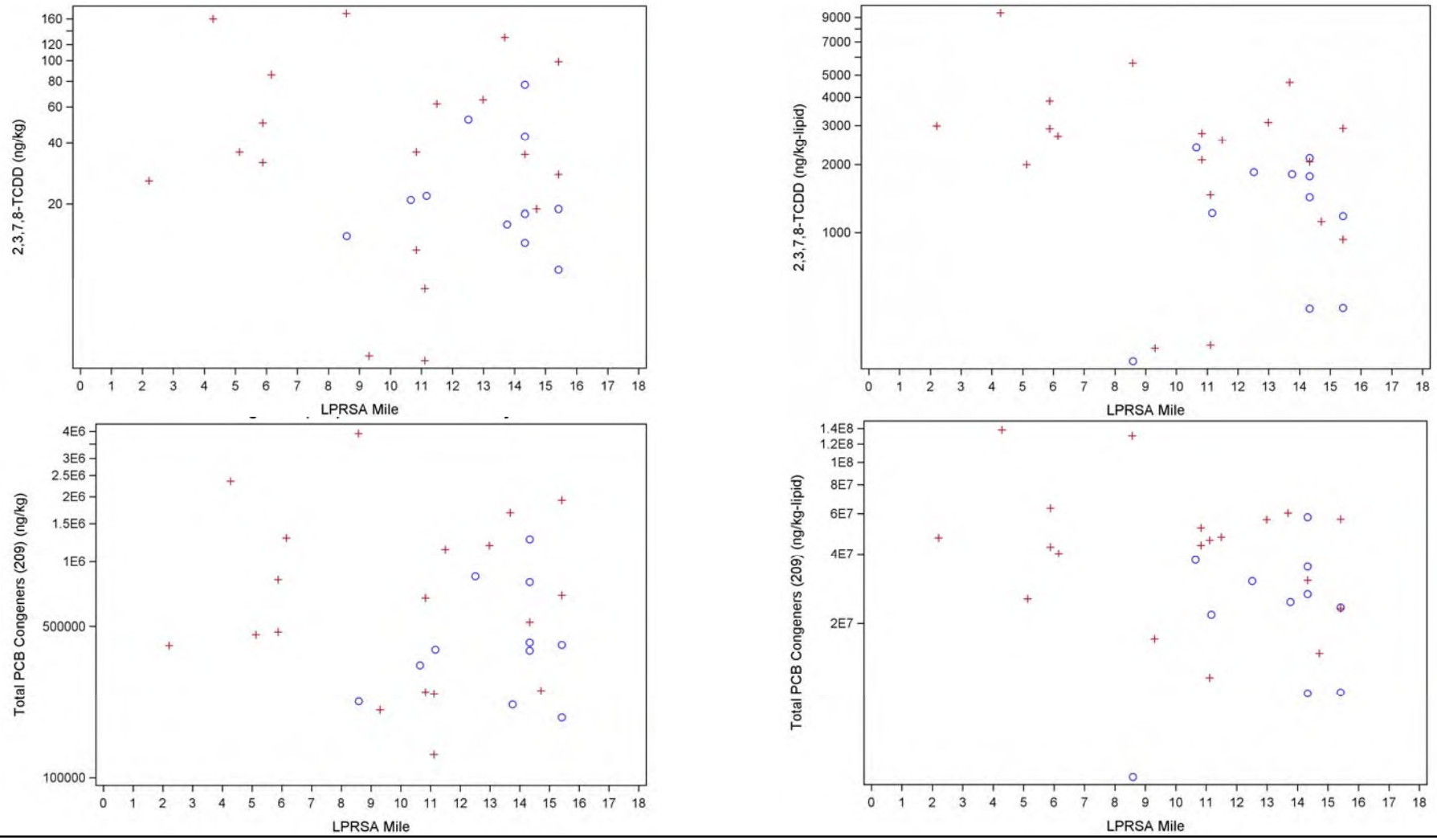
Year of Sampling ○ 1999-2001 + 2009-2010

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total Aroclor PCBs (Sum of 7 Aroclors) in White Perch (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-35



Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachloro-*p*-dibenzodioxin

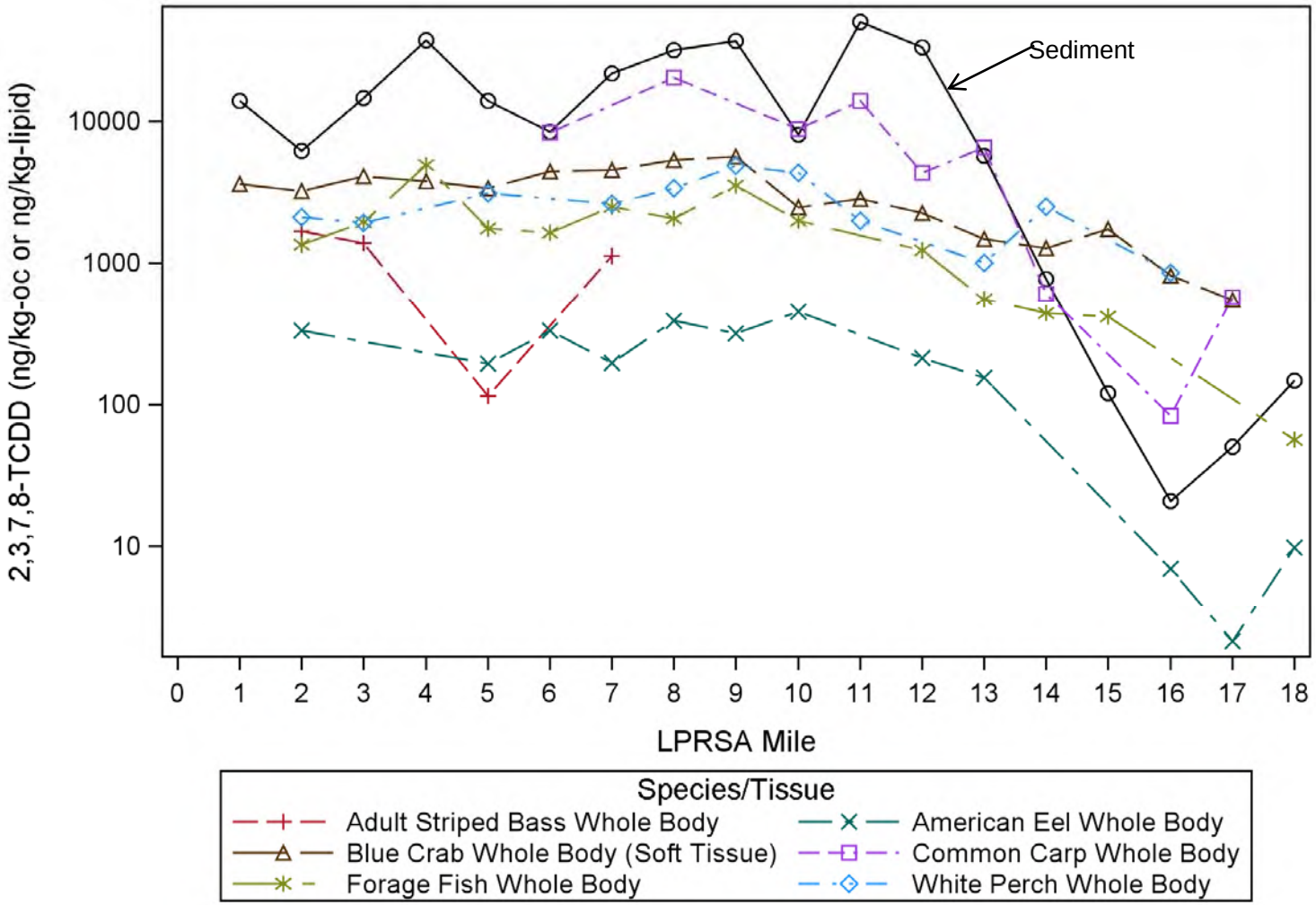
Species ○ Channel Catfish + White Catfish

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

2,3,7,8-TCDD and Total PCB Congeners
in Catfish Fillet

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-36



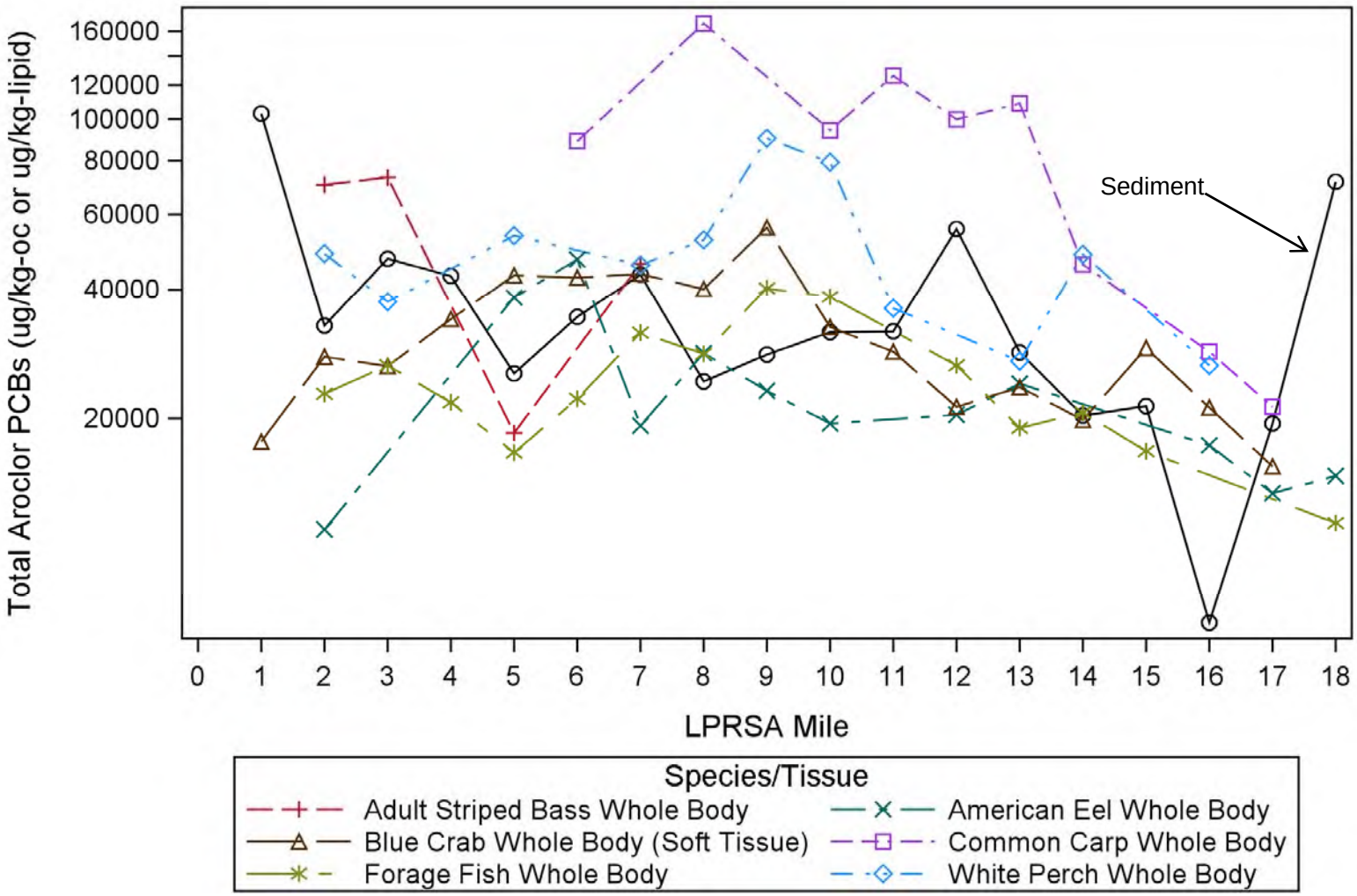
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin
Sediment concentrations are normalized to organic carbon while tissue concentrations are normalized to lipid.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Normalized 2,3,7,8-TCDD in Tissue and Sediment Averaged by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-37



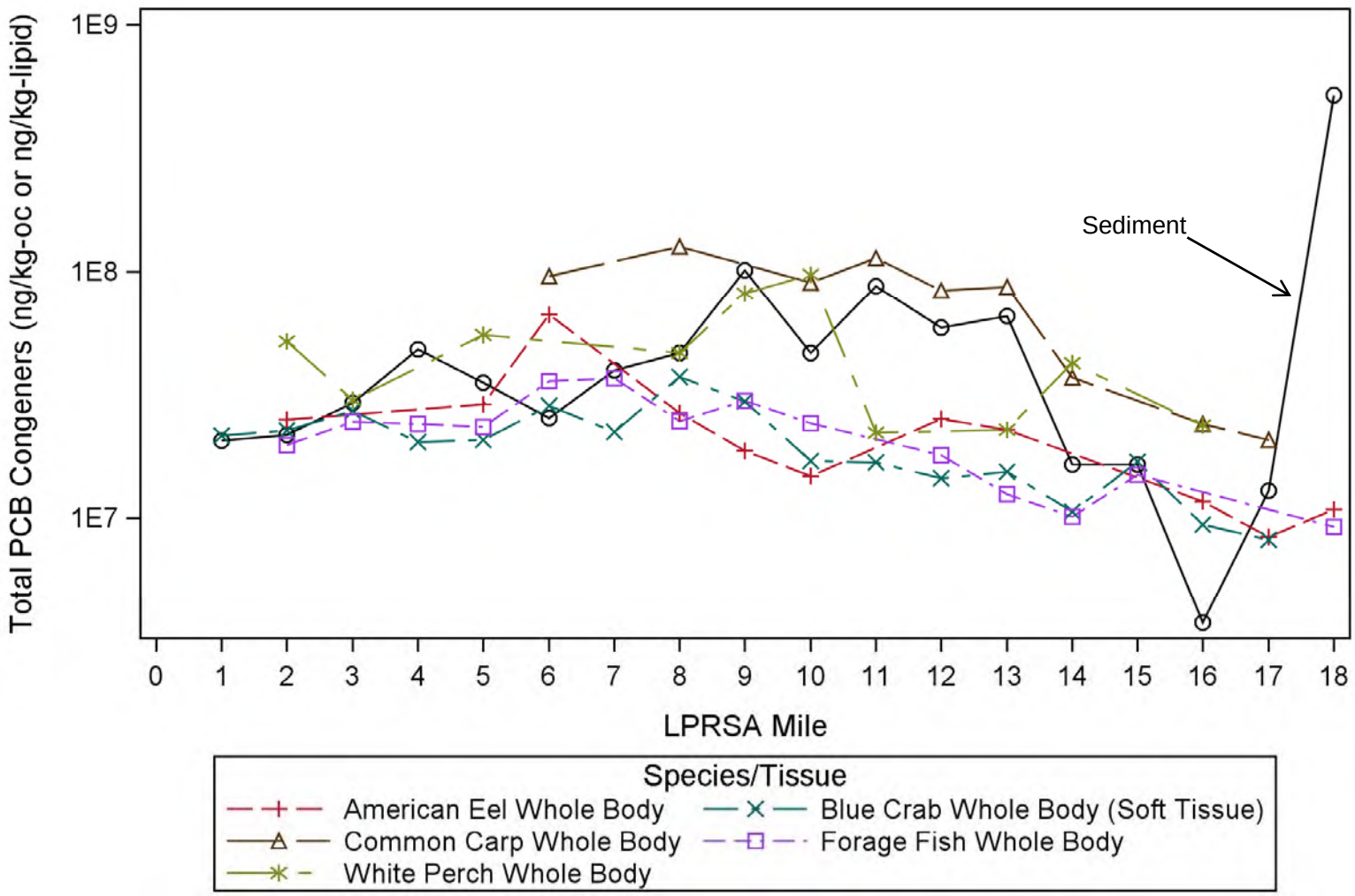
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
µg = microgram
oc = organic carbon
PCB = polychlorinated biphenyl
Sediment concentrations are normalized to organic carbon while tissue concentrations are normalized to lipid.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Normalized Total Aroclor PCBs (Sum of 7 Aroclors) in Tissue and Sediment Averaged by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-38



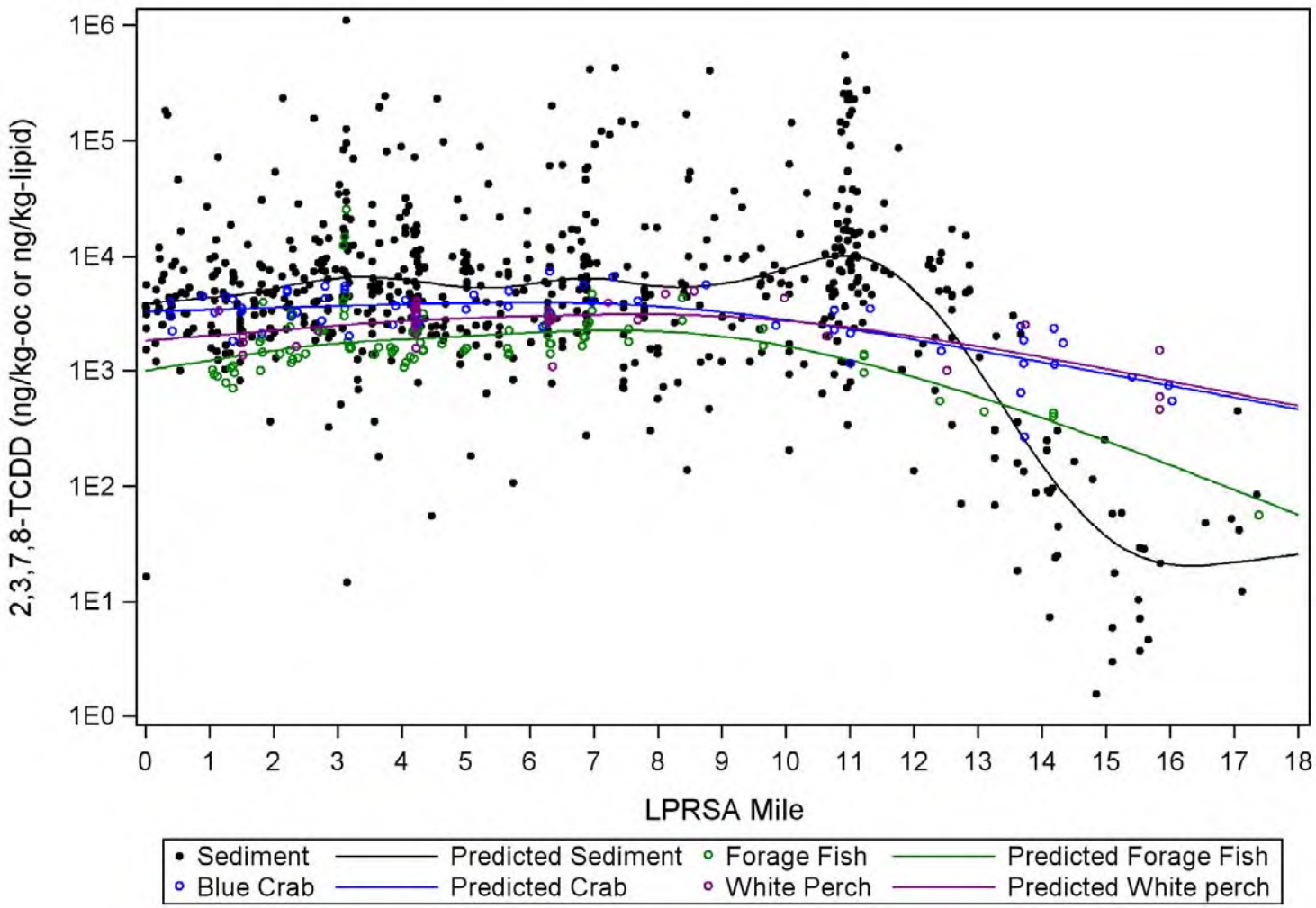
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
PCB = polychlorinated biphenyl
Sediment concentrations are normalized to organic carbon while tissue concentrations are normalized to lipid.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Normalized Total PCB Congeners in Tissue and Sediment Averaged by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-39



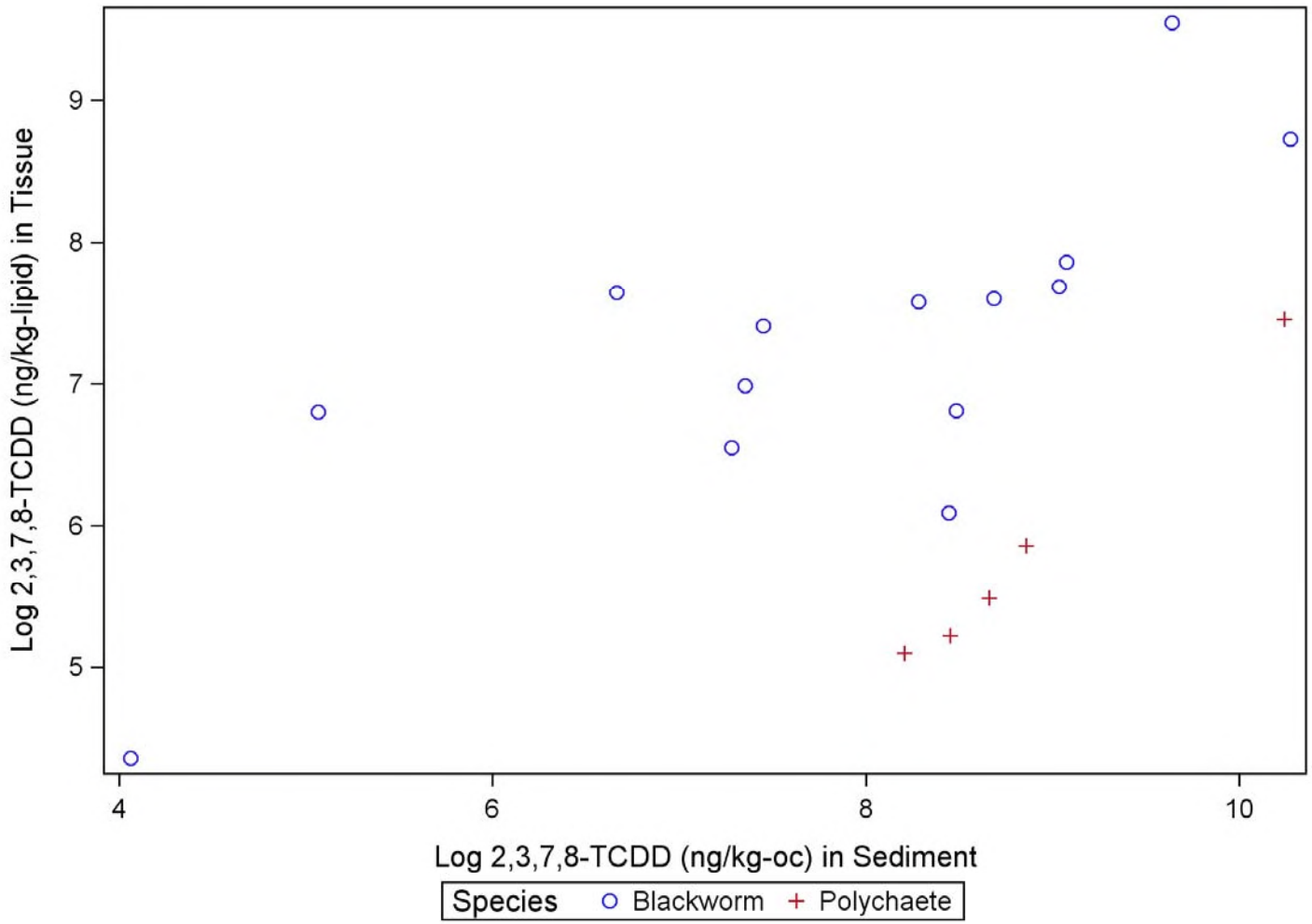
Notes:
kg = kilogram
LPRSA = Lower Passaic River Study Area
ng = nanogram
oc = organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin
Sediment concentrations are normalized to organic carbon while tissue concentrations are normalized to lipid.
Tissue concentrations are whole body.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Predicted and Actual Normalized 2,3,7,8-TCDD in Sediment, Blue Crab, Forage Fish, White Perch by LPRSA Mile

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-40



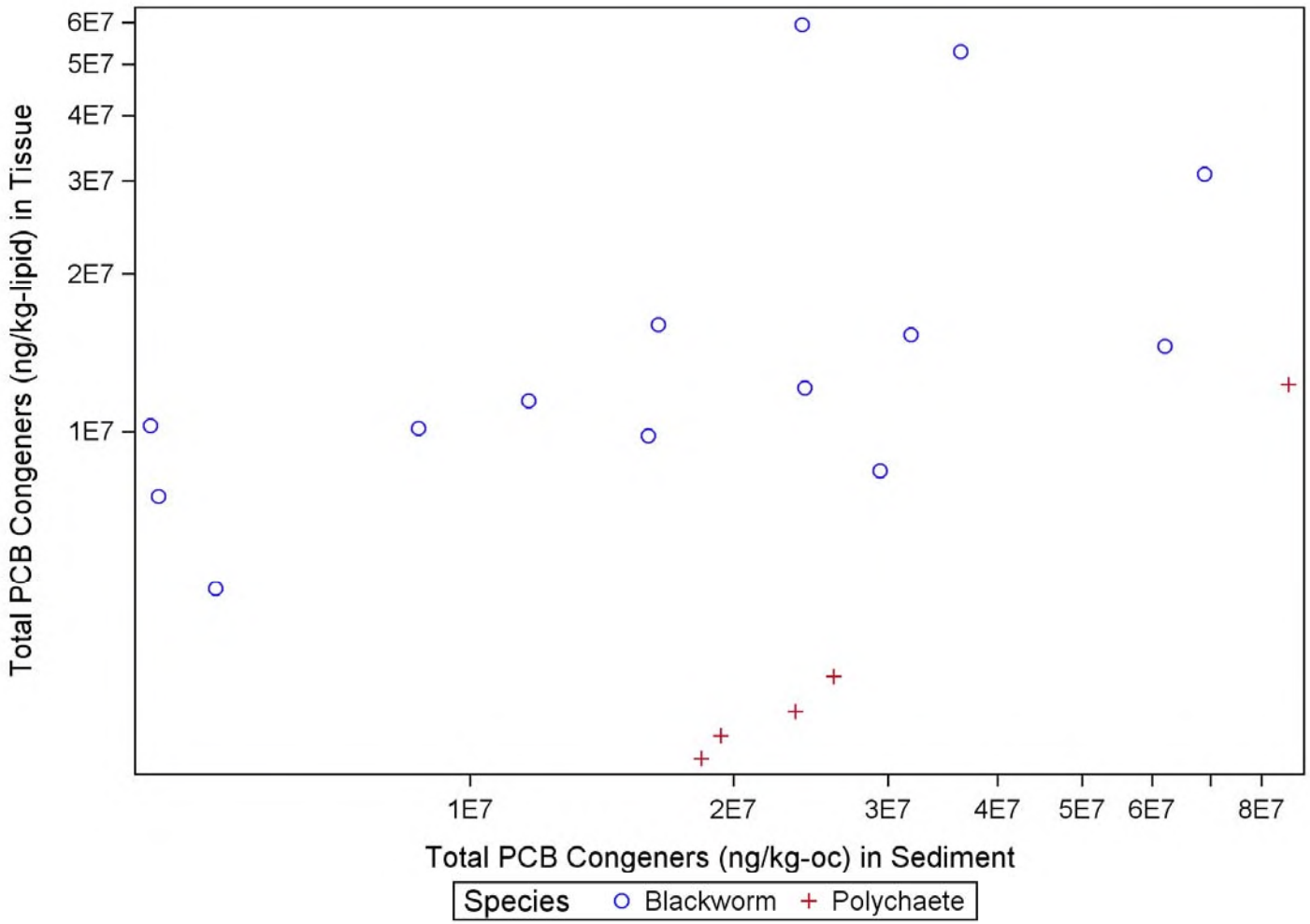
Notes:
kg = kilogram
ng = nanogram
oc = organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin
Sediment Concentrations are organic carbon normalized.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Bioaccumulation of Lipid-Normalized 2,3,7,8-TCDD in Invertebrate Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-41



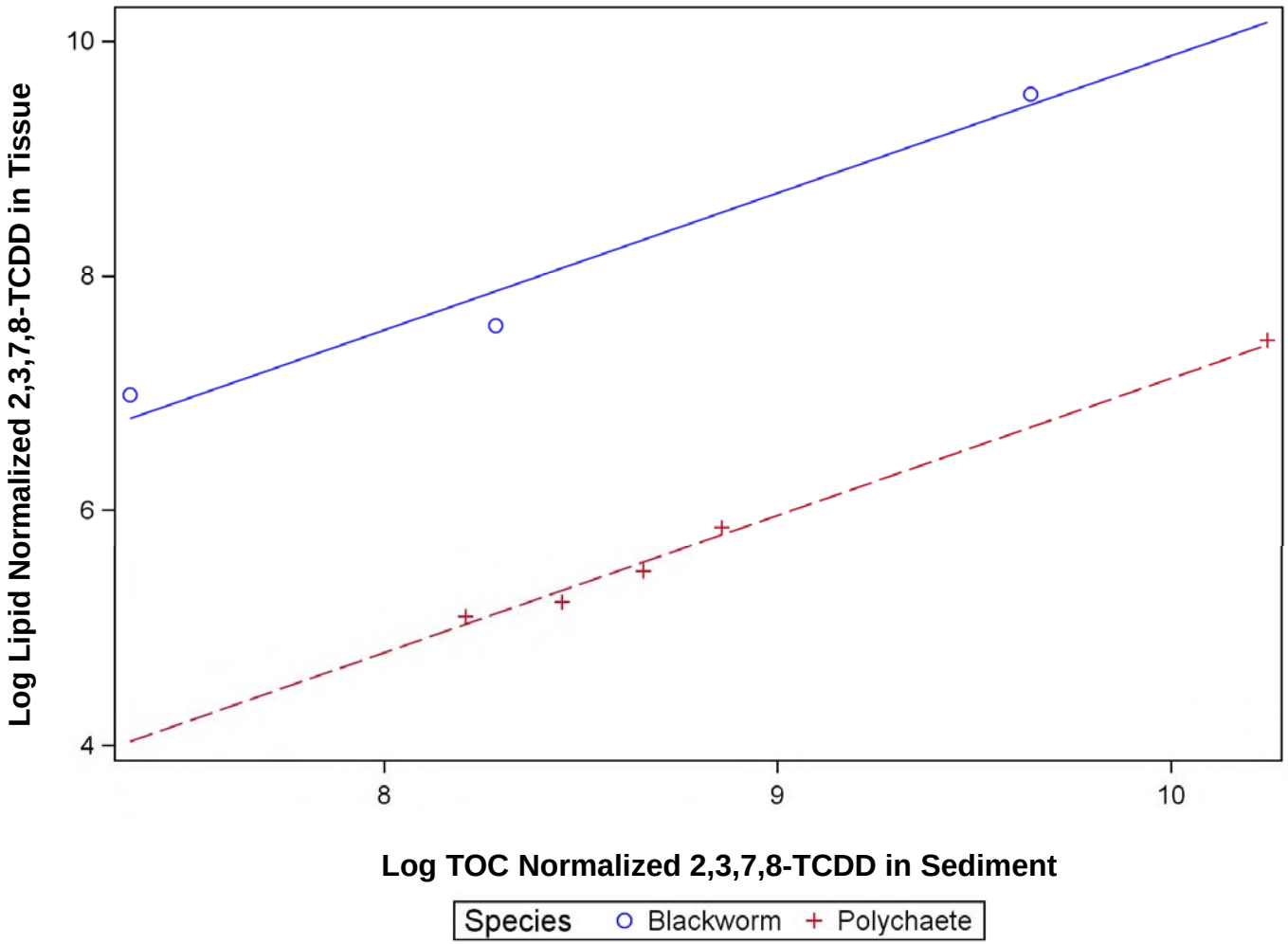
Notes:
kg = kilogram
ng = nanogram
oc = organic carbon
PCB = polychlorinated biphenyl
PCBs are reported as sum of 209 congeners

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Bioaccumulation of Lipid-Normalized Total PCBs in Invertebrate Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-42



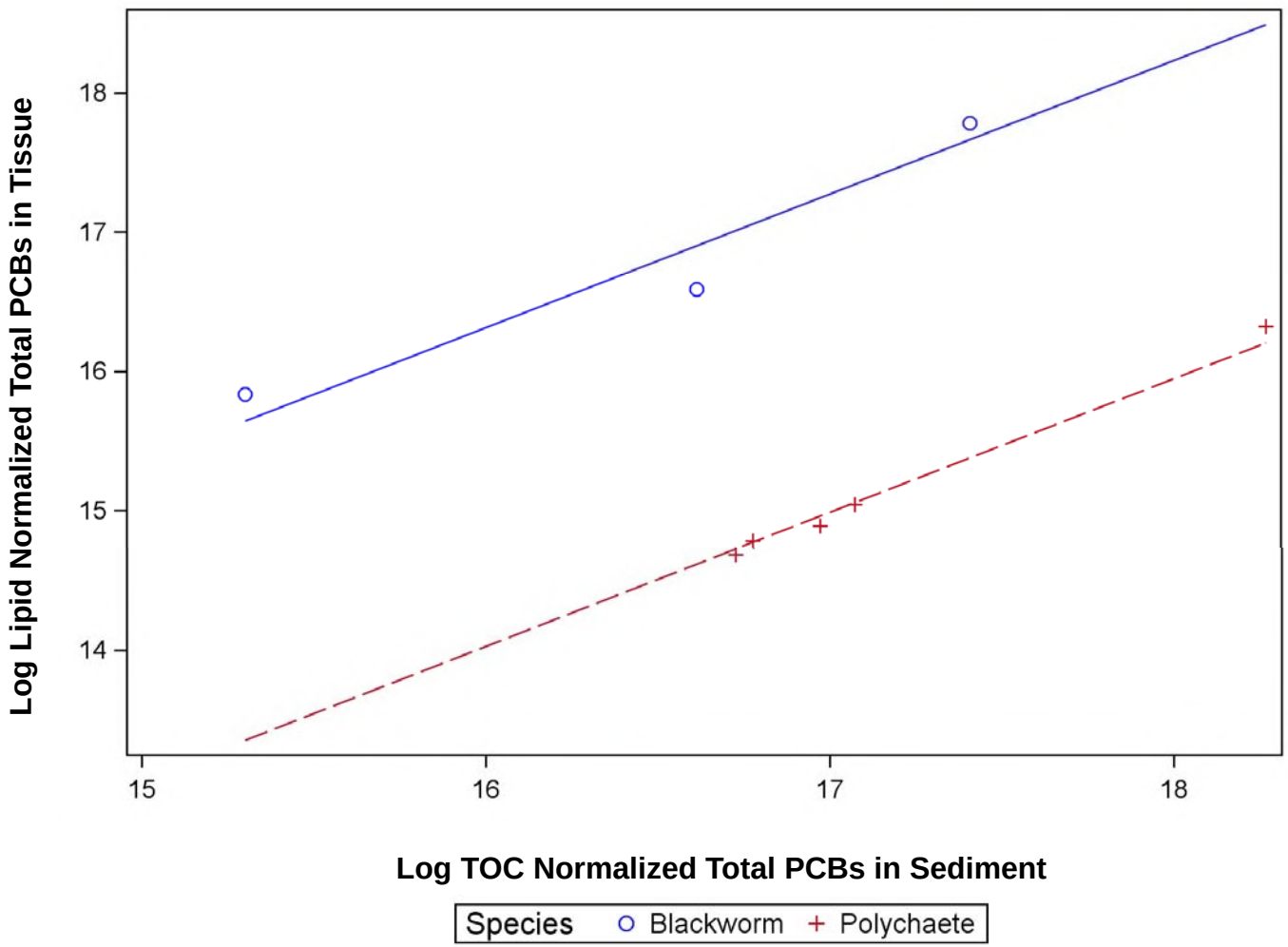
Notes:
kg = kilogram
ng = nanogram
toc = total organic carbon
TCDD = tetrachloro-*p*-dibenzodioxin
Sediment Concentrations are organic carbon normalized.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Regression Model of Bioaccumulation of 2,3,7,8-TCDD in Invertebrate Tissue for LPRSA Miles 0 to 8

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2-43



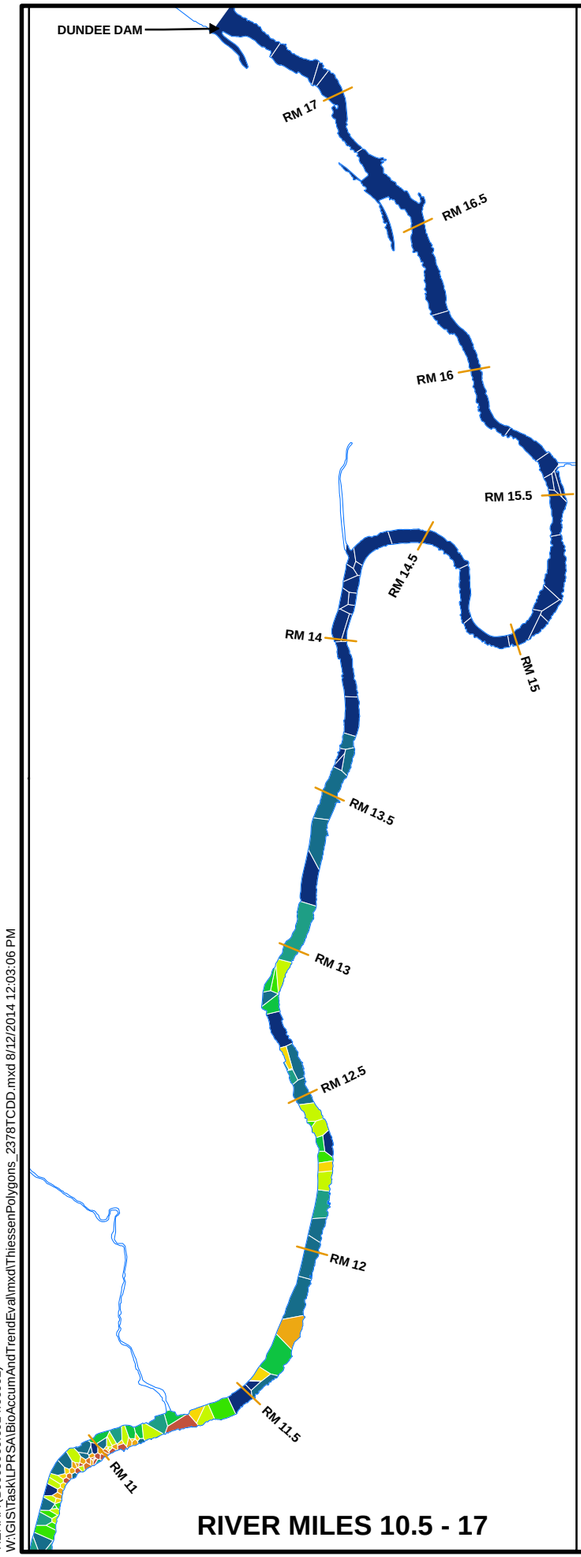
Notes:
kg = kilogram
ng = nanogram
toc = total organic carbon
PCB = polychlorinated biphenyl
PCBs are reported as sum of 209 congeners.

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

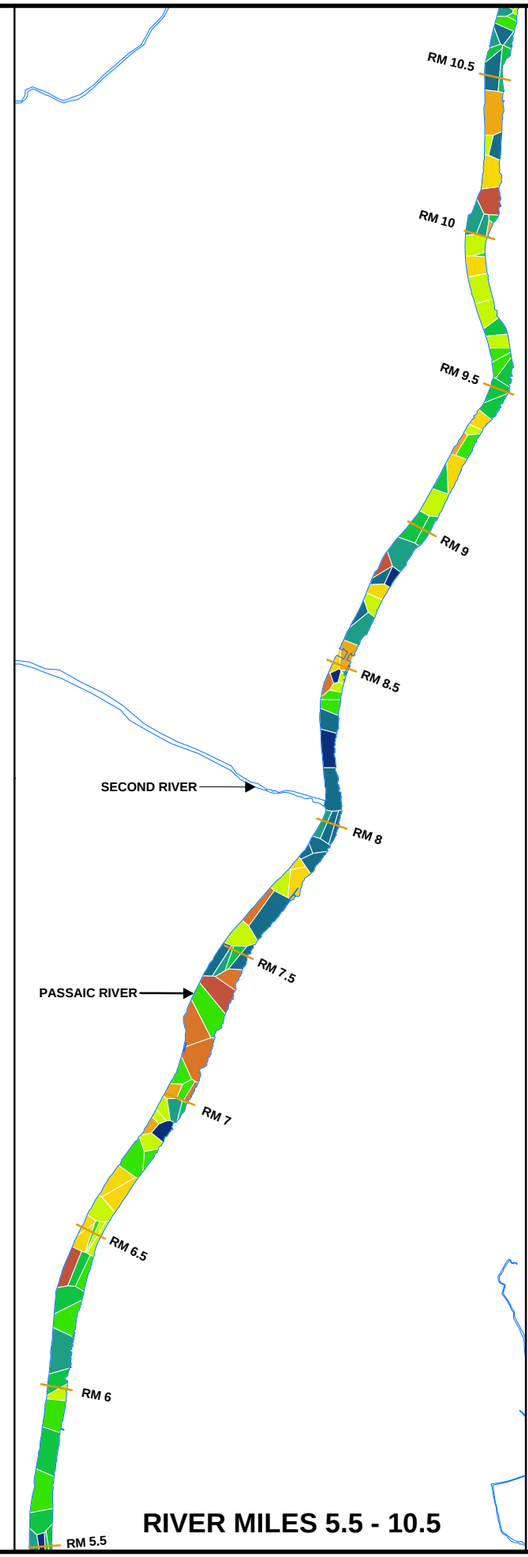
Regression Model of Bioaccumulation of Total PCBs in Invertebrate Tissue for LPRSA Miles 0 to 8

ARCADIS
Infrastructure · Water · Environment · Buildings

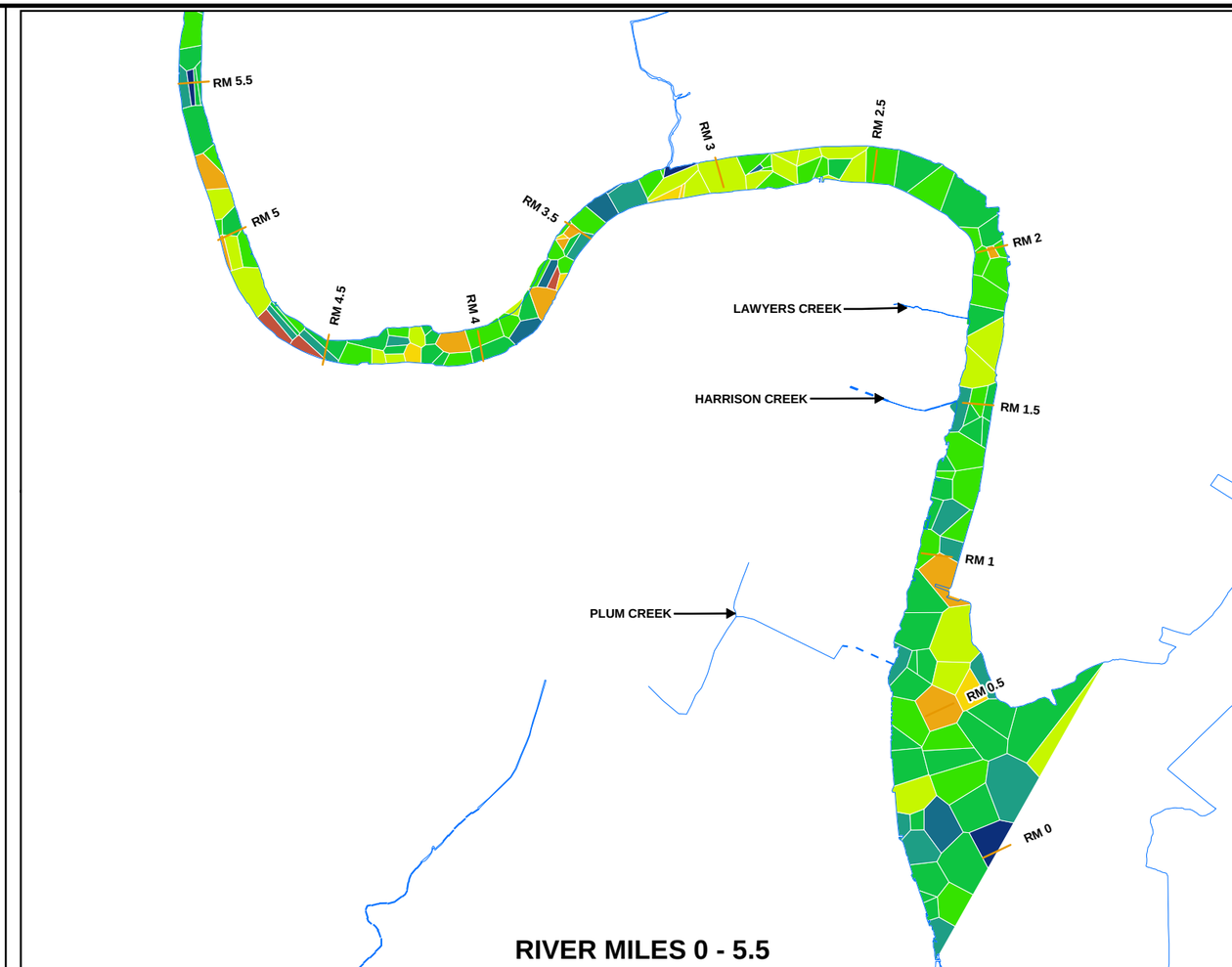
FIGURE
2-44



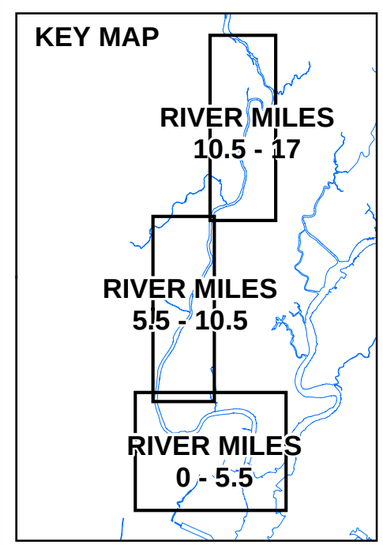
RIVER MILES 10.5 - 17



RIVER MILES 5.5 - 10.5



RIVER MILES 0 - 5.5



LEGEND:

- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

2,3,7,8-TCDD (ng/kg)

- < 10
- 10 - 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 10,000
- >10,000

NOTE:

1. THIESSEN POLYGONS SHOWN REPRESENT SURFACE SEDIMENT DATA FROM 2005 TO PRESENT. (SEE FIGURE 2-2 FOR SAMPLE LOCATIONS.)

0 3,000 6,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

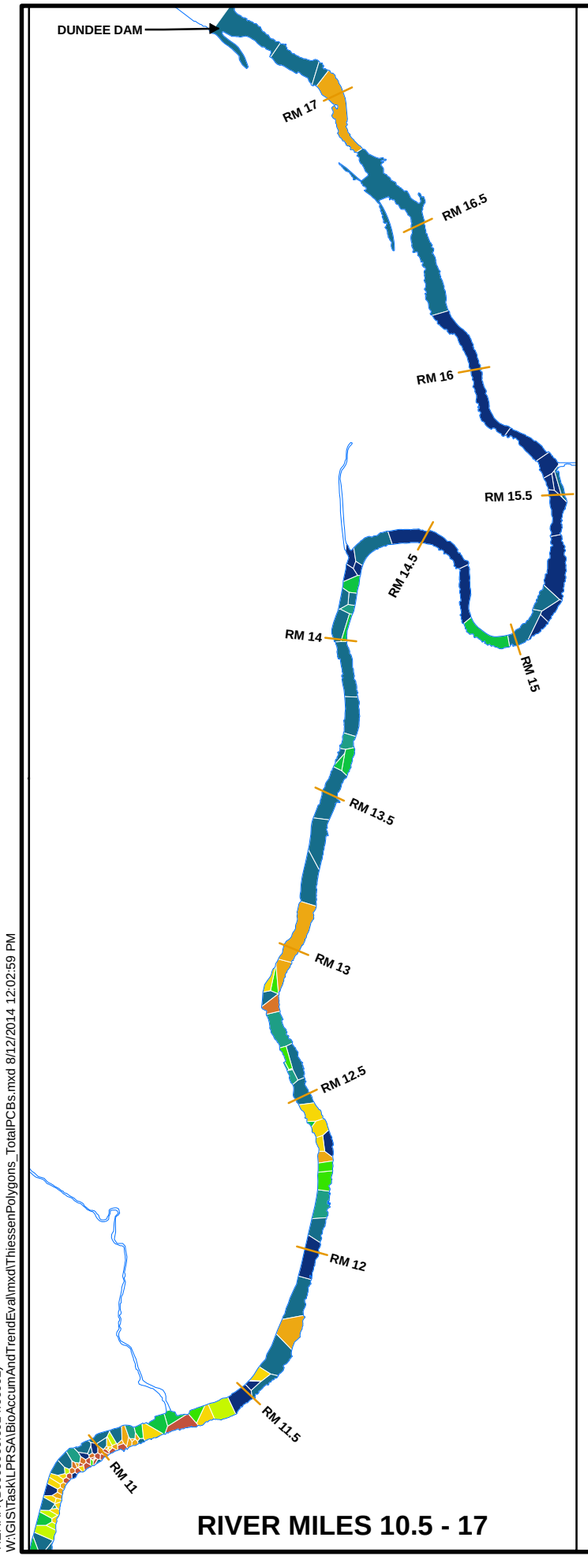
BIOACCUMULATION AND TREND EVALUATION

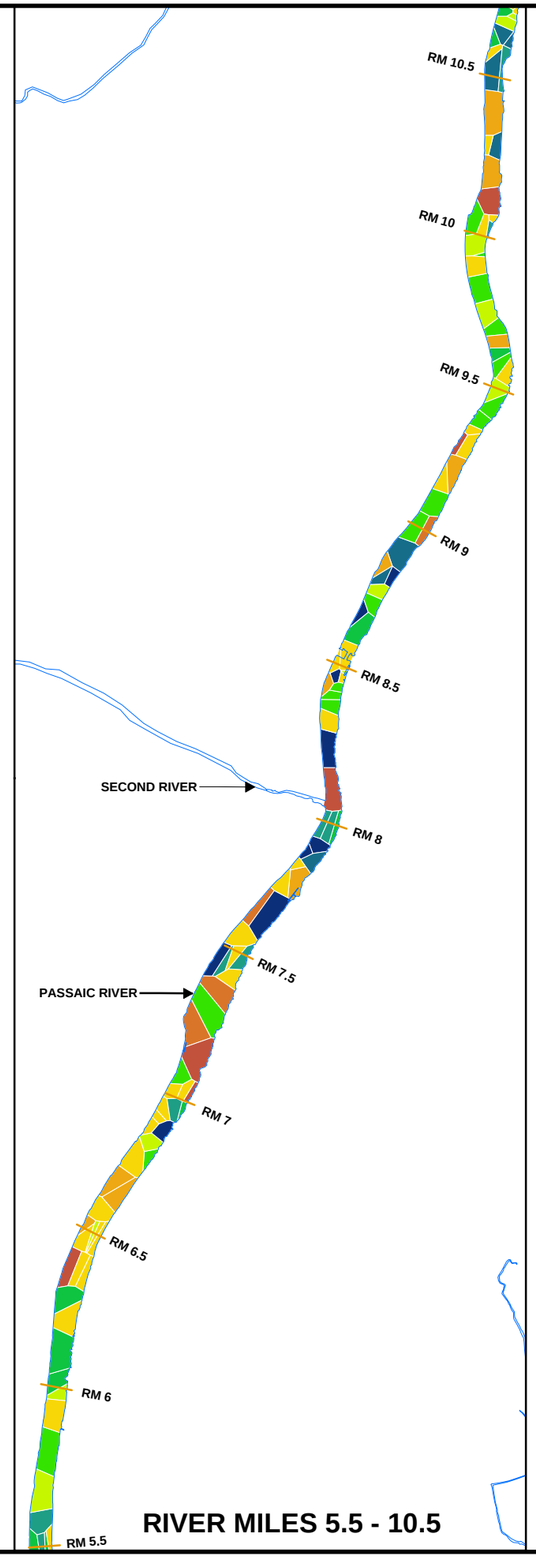
2,3,7,8-TCDD IN SURFACE SEDIMENT (0-6") THIESSEN POLYGONS

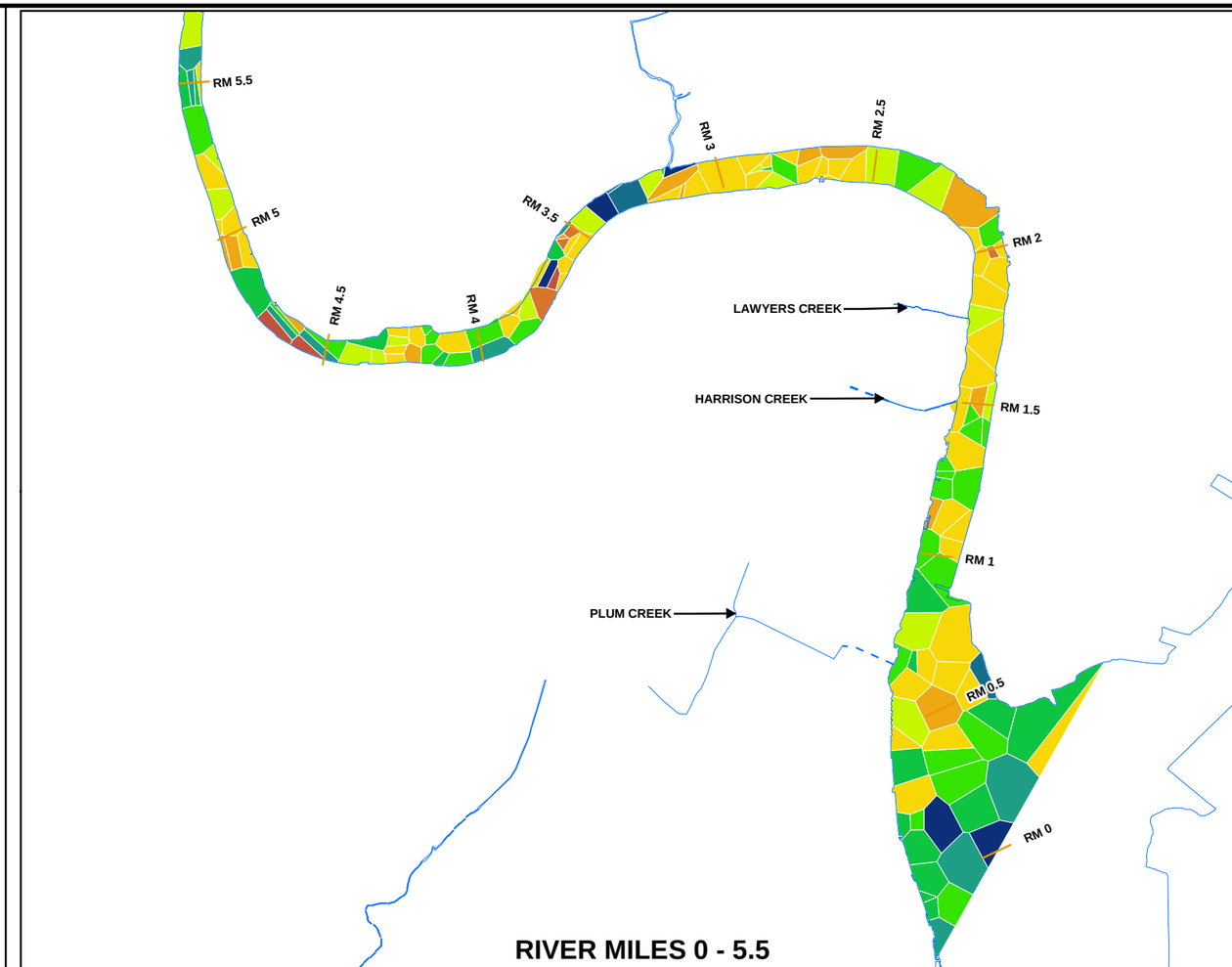
AUGUST 2014

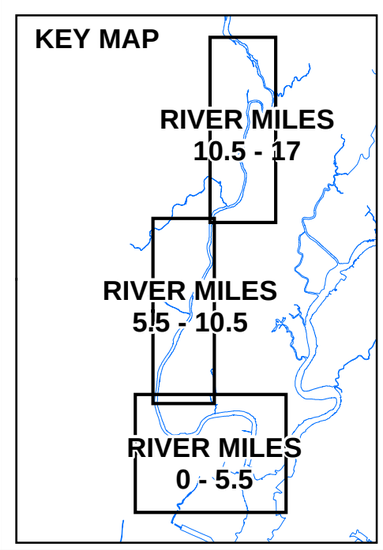
FIGURE **3-1**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\ThiessenPolygons_2378TCDD.mxd 8/12/2014 12:03:06 PM









LEGEND:

- LPRSA RIVER MILE
- SHORELINE
- UNDERGROUND TRIBUTARY

TOTAL PCB CONGENERS (ng/kg)

- <100,000
- 100,000 - 300,000
- 300,000 - 500,000
- 500,000 - 700,000
- 700,000 - 900,000
- 900,000 - 1,000,000
- 1,000,000 - 2,000,000
- 2,000,000 - 5,000,000
- 5,000,000 - 10,000,000
- >10,000,000

NOTE:

1. THIESSEN POLYGONS SHOWN REPRESENT SURFACE SEDIMENT DATA FROM 2005 TO PRESENT. (SEE FIGURE 2-2 FOR SAMPLE LOCATIONS.)

0 3,000 6,000 Feet

GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA

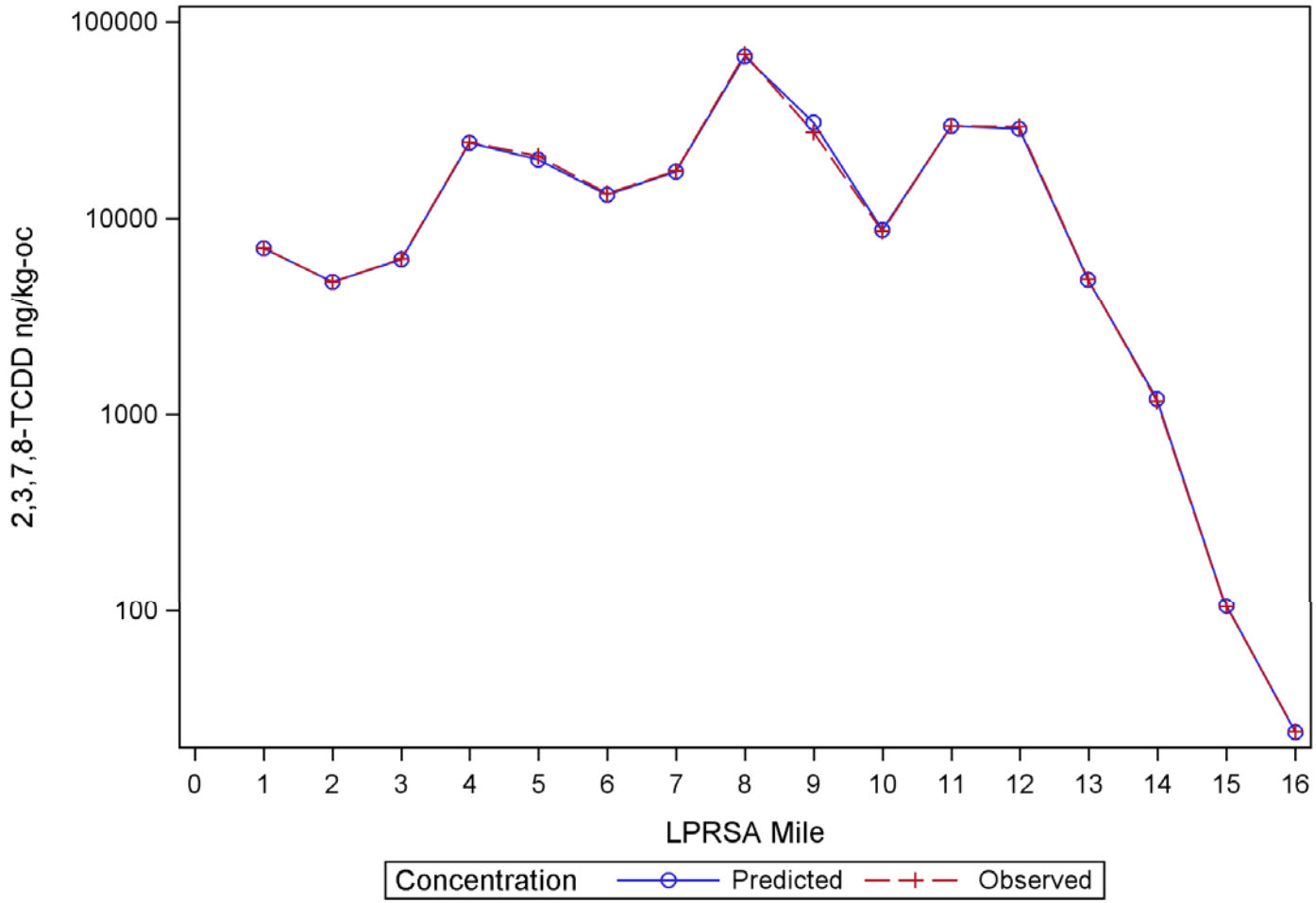
BIOACCUMULATION AND TREND EVALUATION

TOTAL PCB CONGENERS IN SURFACE SEDIMENT (0-6") THIESSEN POLYGONS

AUGUST 2014

FIGURE **3-2**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
TIERRA (B0009960.0014.00002)
W:\GIS\Task\LPRSA\BioAccumAndTrendEval\mxd\ThiessenPolygons_TotalPCBs.mxd 8/12/2014 12:02:59 PM



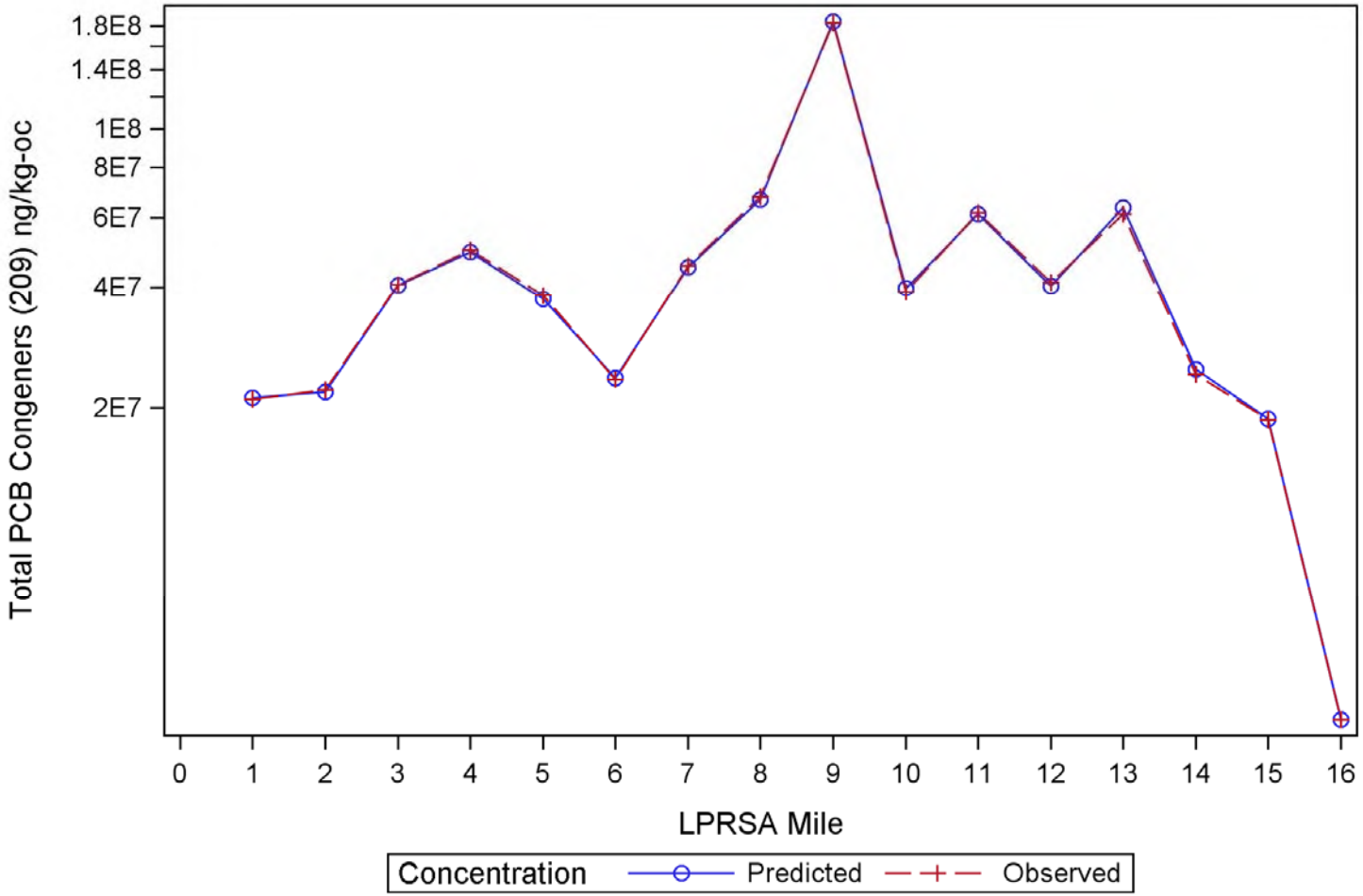
Notes:
Sediment concentrations are organic carbon-normalized.
kg = kilogram
ng = nanogram
oc = organic carbon
TCDD = tetrachlorodibenzo-*p*-dioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted Spatially Weighted Mean
2,3,7,8-TCDD in Surface Sediment

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-3



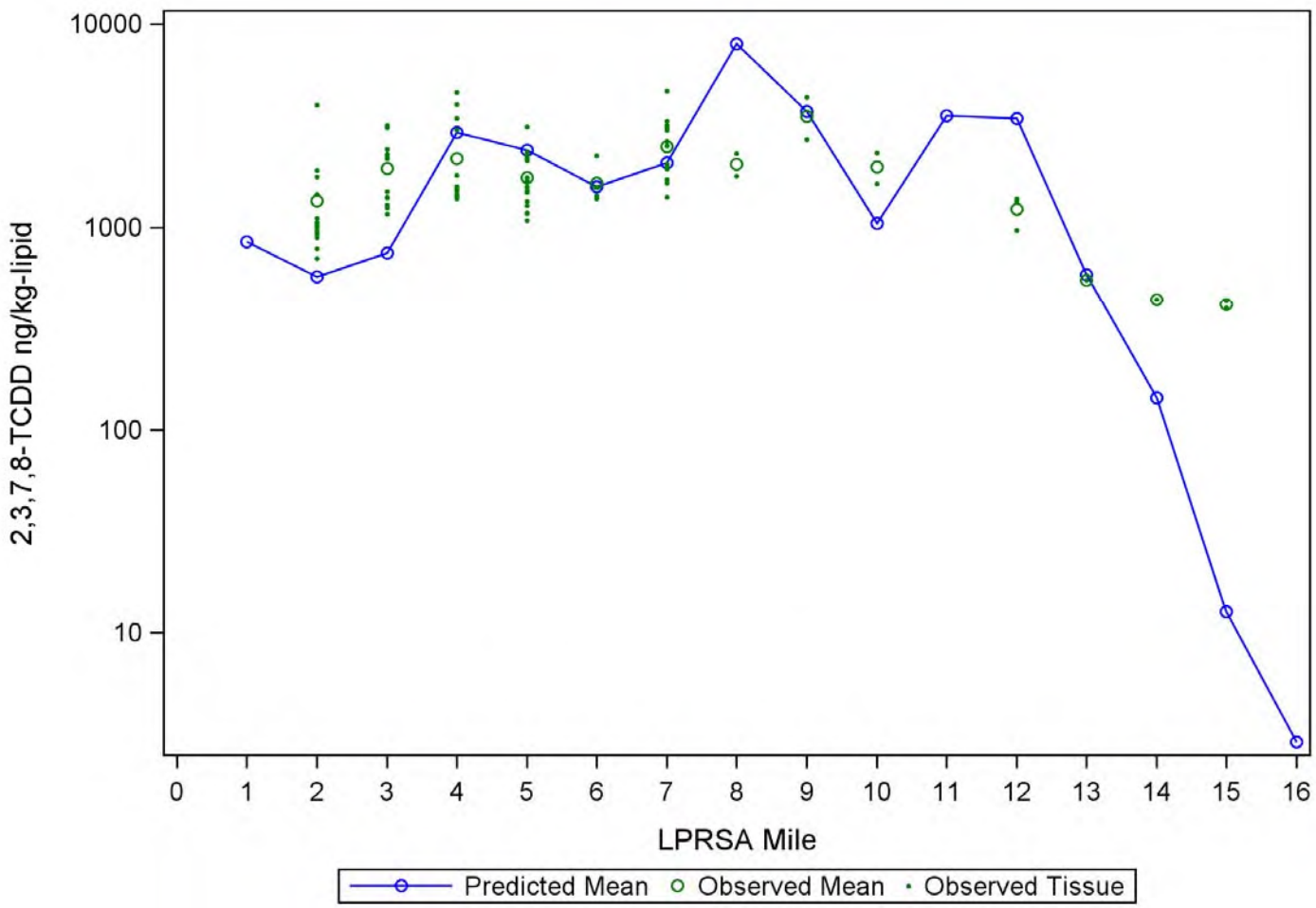
Notes:
Sediment concentrations are organic carbon- normalized.
kg = kilogram
ng = nanogram
oc = organic carbon
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted Spatially Weighted Mean Total PCB Congeners in Surface Sediment

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-4



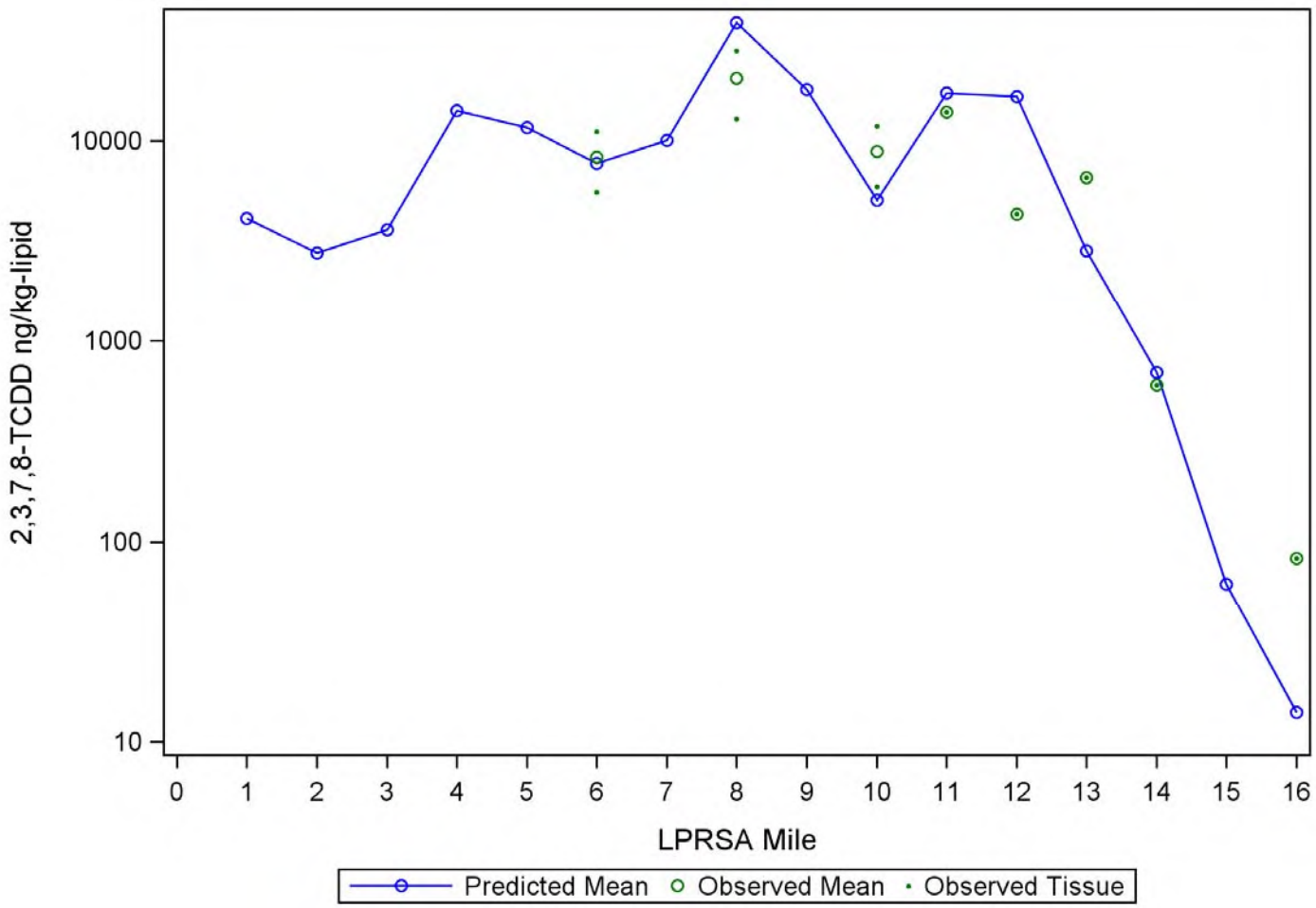
Notes:
Tissue concentrations are lipid-normalized.
kg = kilogram
ng = nanogram
TCDD = tetrachlorodibenzo-*p*-dioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted 2,3,7,8-TCDD in Forage Fish Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-5



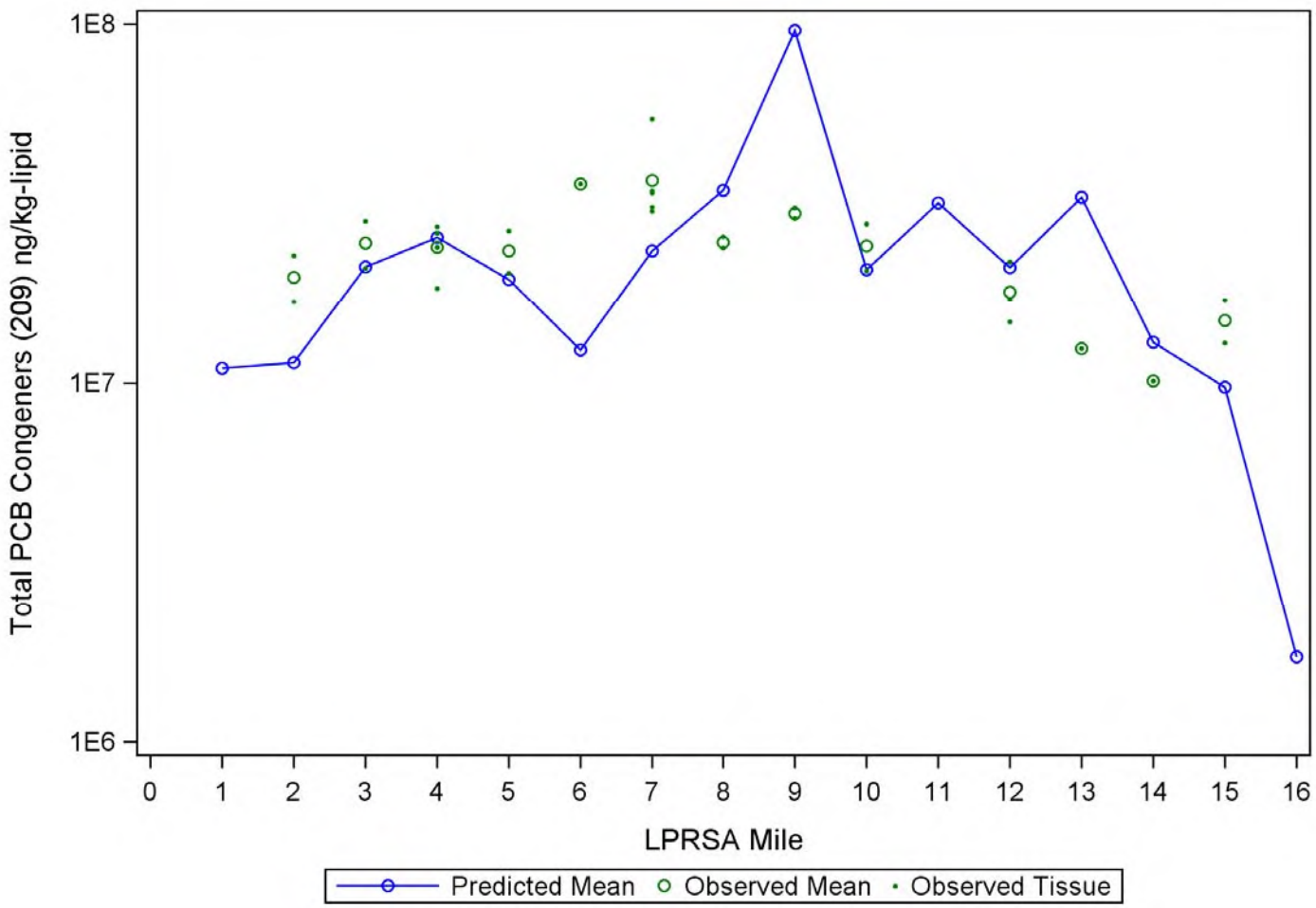
Notes:
Tissue concentrations are lipid-normalized.
kg = kilogram
ng = nanogram
TCDD = tetrachlorodibenzo-*p*-dioxin

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted 2,3,7,8-TCDD in Common Carp (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-6



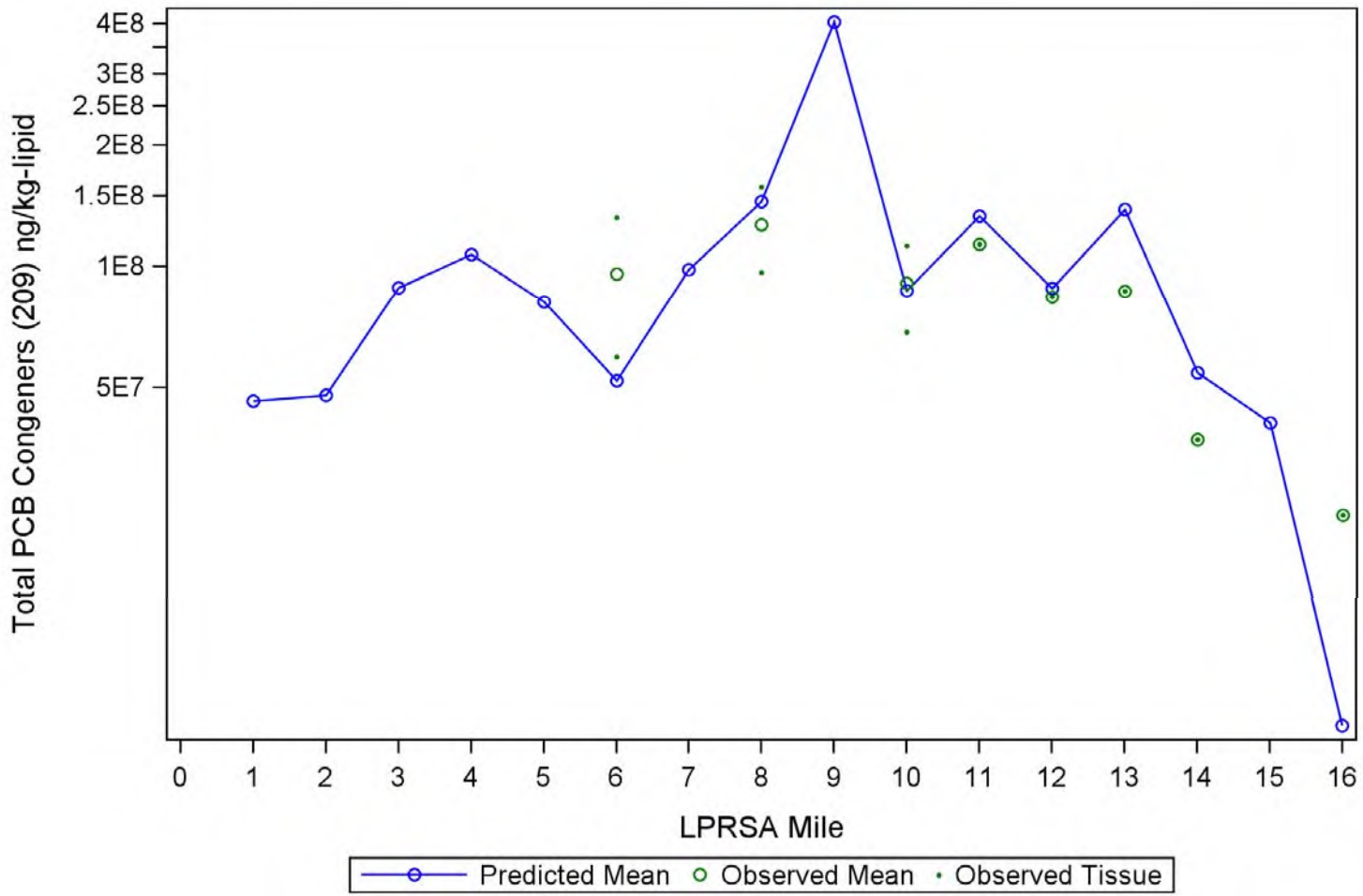
Notes:
Tissue concentrations are lipid-normalized.
kg = kilogram
ng = nanogram
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted Total PCB Congeners in Forage Fish Tissue

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-7



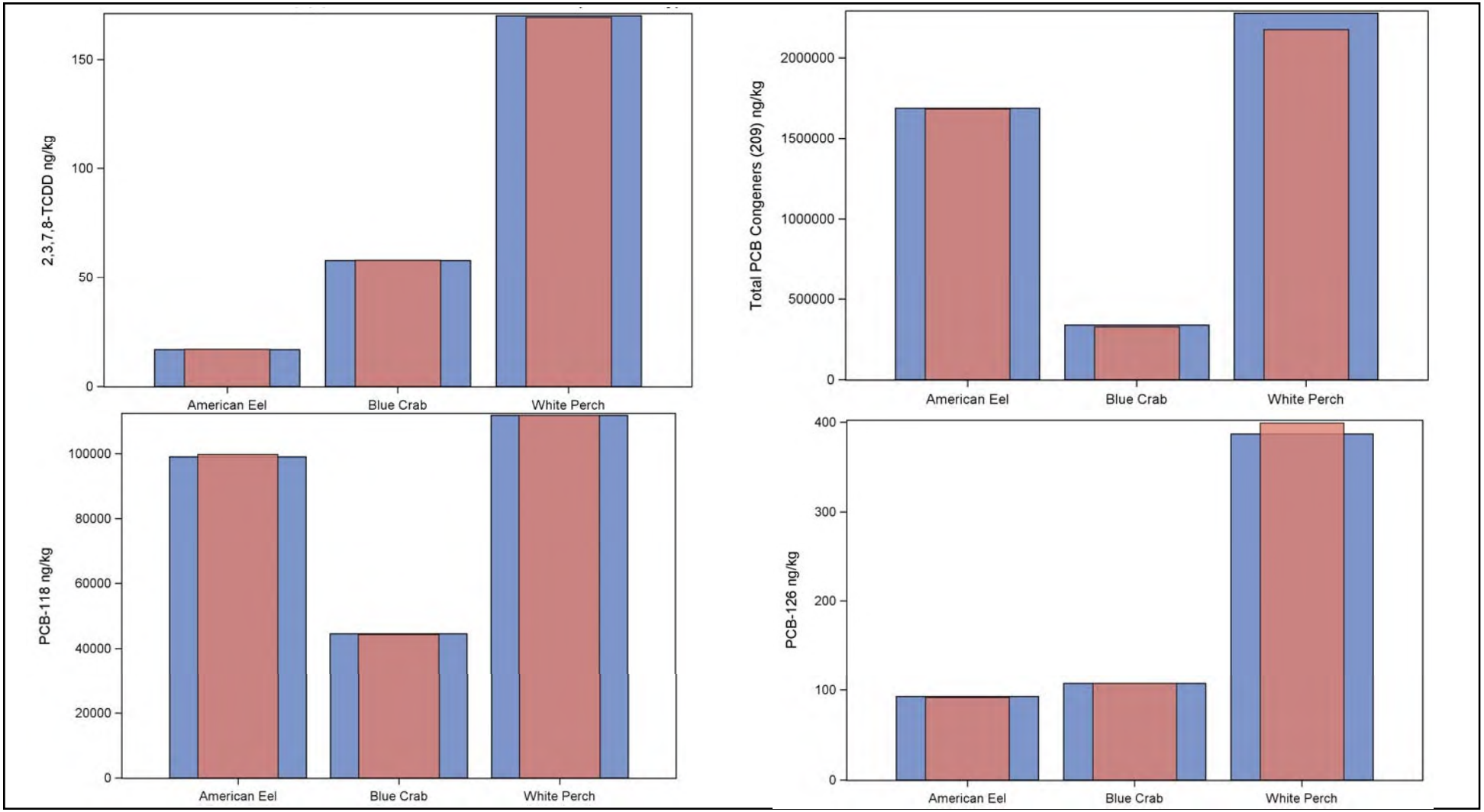
Notes:
Tissue concentrations are lipid-normalized.
kg = kilogram
ng = nanogram
PCB = polychlorinated biphenyl

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted Total PCB Congeners in Common Carp (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-8



Notes:
kg = kilogram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachlorodibenzo-*p*-dioxin

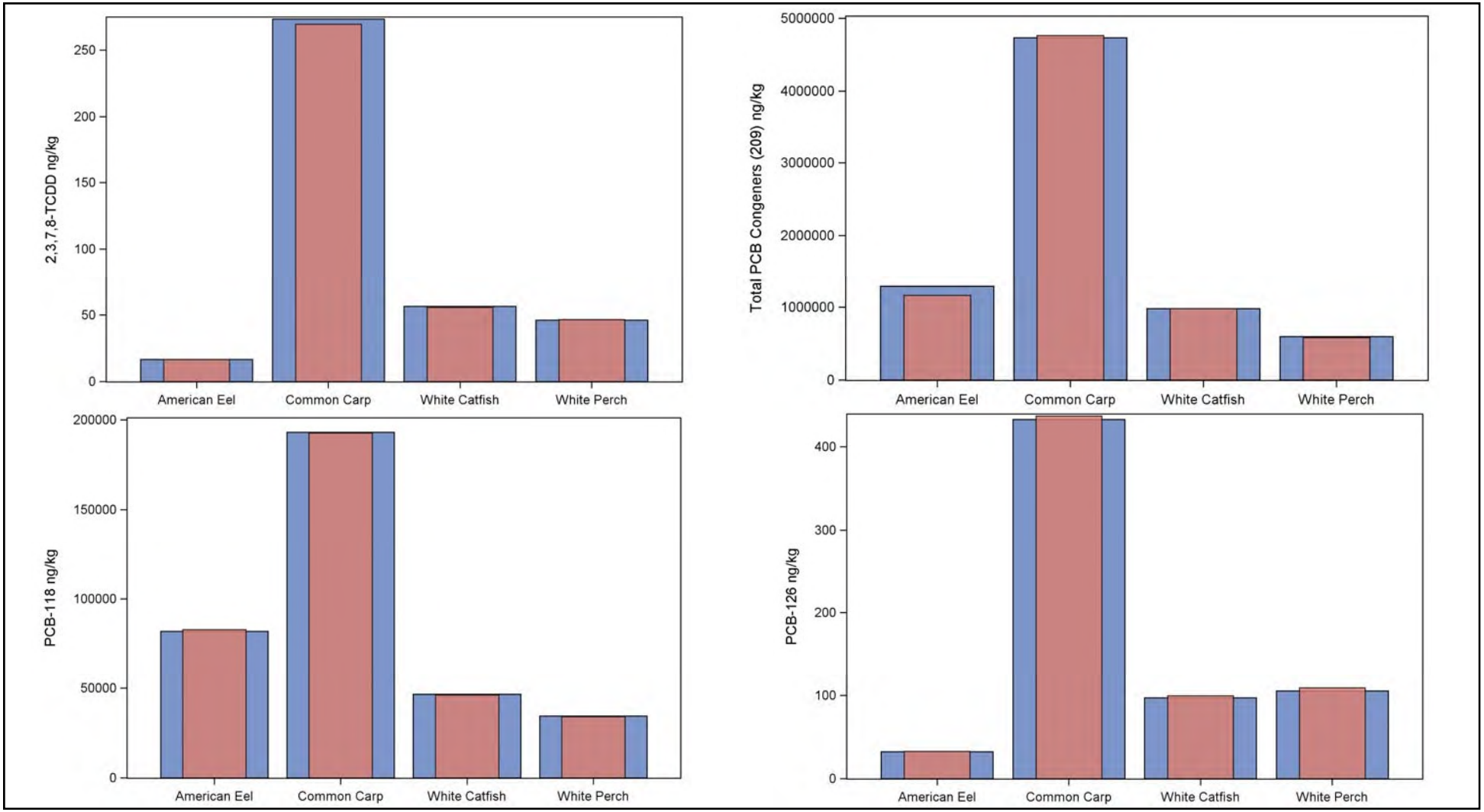
Predicted Mean Observed Mean

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted River-Wide Mean Tissue Concentrations (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-9



Notes:
kg = kilogram
ng = nanogram
PCB = polychlorinated biphenyl
TCDD = tetrachlorodibenzo-*p*-dioxin

Predicted Mean Observed Mean

Lower Passaic River Study Area
Bioaccumulation and Trend Evaluation

Observed and Predicted River-Wide Mean Tissue Concentrations (Fillet)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3-10

ARCADIS

Attachment 2

Vinson&Elkins

Carol E. Dinkins cdinkins@velaw.com
Tel +1.713.758.2528 **Fax** +1.713.615.5311

March 31, 2014

James E. Woolford
Director
Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation
1200 Pennsylvania Avenue, N.W.
Room S5622 (MC5201P)
Washington, DC 20460

Dear Mr. Woolford:

In our letter of March 20, 2014, we noted an observation of Mr. Steve Ells concerning the amount of fish tissue data that exists for the Lower Passaic River, in response to which we submitted Maxus' proposal to conduct additional fish tissue sampling. At Maxus' request, its consultant, ARCADIS, has prepared a conceptual sampling plan for fish and crab, which is enclosed. Our clients, Occidental, Maxus and Tierra, would appreciate the opportunity to meet with you and Mr. Ells to discuss the plan and receive feedback and questions.

We look forward to hearing from you.

Very truly yours,

Carol Dinkins

Carol E. Dinkins

cc: Walter Mugdan
Steve Ells
Eric Schaaf

ARCADIS U.S., Inc.
326 First Street
Suite 200
Annapolis
Maryland 21403
Tel 410 295 1205
Fax 410 295 1225

MEMO

To:
Dave Rabbe, Tierra
Derrick Vallance, Maxus

Copies:
Cliff Firstenberg, Tierra
Melissa Beauchemin, ARCADIS
Jen Bryz-Gornia, ARCADIS
Shannon Dunn, ARCADIS
Jackie Iannuzzi, ARCADIS

From:
Tim Iannuzzi

Date:
March 26, 2014

ARCADIS Project No.:
B0009968.0000.00001

Subject:
Conceptual Fish and Crab Sampling Plan for Lower Passaic River Study Area

---

This technical memorandum (memo) presents a proposed plan and approach for the collection of fish and crab tissue data in the Lower Passaic River Study Area (LPRSA) in 2014. The LPRSA includes the tidal portion of the Passaic River from its confluence with Newark Bay upstream to the Dundee Dam—approximately 17 river miles (Figure 1). In June 2007, a group of 73 potentially responsible parties, named the Cooperating Parties Group (CPG), entered into an Administrative Order on Consent (AOC) with U.S. Environmental Protection Agency (USEPA) to conduct the Comprehensive Environmental Response, Compensation and Liability Act – Water Resources Development Act Remedial Investigation/Feasibility Study for the LPRSA (USEPA 2007). Subsequent to the CPG entering into the 2007 AOC, USEPA and other agencies developed a draft Focused Feasibility Study (FFS) to evaluate the need to undertake an early action in the lower 8 miles of the river. This FFS process is ongoing, with a subsequent report set to be released by USEPA in the near future. This memo has been prepared to describe a data collection program to fill a known data gap that would inform the pending FFS. It presents a conceptual sampling plan to collect additional fish and crab tissue data for the primary chemicals of concern (COCs) in order to conduct statistical trends analysis for biota tissue chemistry data in the LPRSA. The need and justification for such a program is described herein, along with the details of a sampling program that can be implemented in 2014.

Background

Nearly all of the fish and crab tissue data available for the LPRSA were collected during only two sampling periods: 1999-2001 (Tierra Solutions, Inc. [Tierra]/USEPA) and 2009/2010 (CPG/USEPA). For each of these sampling events/periods, the species and spatial area of the river that was sampled differed. In 1999-2001, Tierra sampled the lower 6 miles of the LPRSA and collected primarily marine/estuarine species. In 2009/2010, the CPG focused primarily on the upper 11 miles of the LPRSA and collected mostly freshwater species (e.g., catfish). The CPG collected some estuarine data from the lower 6 miles of the LPRSA in 2009/2010 for three of the edible fish/shellfish species that were sampled by Tierra in 1999-2001: white perch (*Morone americana*), a resident fish species; American eel (*Anguilla rostrata*), a migratory fish species; and blue crab (*Callinectes sapidus*), a mostly resident shellfish species.

Because there are limited tissue data from only two time periods, some of which lack spatial overlap, it is not possible to conduct a defensible statistically-based evaluation of potential trends in chemical concentrations. However, in looking at the averages for the LPRSA as a whole and the lower 8 miles only for these species[1], it appears that there may be a downward trend in the overall concentrations of both TCDD and PCBs. Figures 2 and 3 show blue crab TCDD and total PCB data by river mile and time period for the LPRSA. Data for blue crab are the most robust in terms of sample numbers and spatial overlap between the 1999-2001 and 2009/2010 sampling events. Figures 2 and 3 appear to indicate that both TCDD and PCB concentrations are generally lower in 2009/2010 than they were in 1999-2001; however, a third dataset is needed to confirm the trend.

Determination of whether a statistically significant trend in fish and crab tissue data does or does not exist is critical to drawing any conclusions regarding future risks in the river, and for consideration related to any remedial actions. The present datasets are insufficient for this purpose. For this reason, the release of the FFS with proposed risk-based remedial actions that are primarily focused on reductions in COCs in fish and crab tissue in the LPRSA is premature. Instead, the FFS should be postponed until another biota tissue dataset can be collected, and a statistical evaluation of any trends is performed. A trend analysis will require more tissue data to be collected for the same species and primary COCs as were collected in both the previous time periods (1999-2001 and 2009/2010) throughout the LPRSA. Assuming these data are collected this calendar year, the dataset would represent additional fish tissue concentrations 4 to 5 years newer than the latest dataset and provide important information about potential spatial and temporal trends in tissue concentrations. The conceptual plan for fish and crab sampling in the LPRSA is presented in the remainder of this memo. Because we have the collective knowledge regarding successful fishing/crabbing methods and locations, and related Quality Assurance Project Plans (QAPPs) and reports from the previous two LPRSA programs, it will be fairly straightforward to develop a detailed QAPP and

[1] The summary statistics for concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and total polychlorinated biphenyls (PCBs) in these species are provided in Table1 for the entire 17-miles of the LPRSA, and Table 2 for river mile (RM) 0 to RM 8 only.

related documentation for this sampling plan, in order to expedite its approval by USEPA and its Partner Agencies, and the mobilization for and implementation of the sampling program in 2014.

General Sampling Design

The objective of this sampling plan is to collect fish and crab tissue from the LPRSA to evaluate potential statistical trends in COC concentrations from data representing different timeframes. In addition to evaluating potential spatial and temporal trends in COCs, human health risk, ecological risk, and possible remedial alternatives within the LPRSA, will also be evaluated using the new data. This tissue sampling event can be conducted any time between the late spring and early fall of 2014. A goal of this program is to maintain consistency in the types of species/tissue types that have been collected/analyzed in the past programs, and the (successful) sampling approaches used to obtain the historic samples.

The tissue sampling and analysis program proposed herein includes targeting several species of fish and shellfish that were sampled in the previous two programs. The target species were chosen based on their relative importance to assessing potential human health and ecological risk, and their relative abundance in the LPRSA (i.e., those species that have been shown to be most widespread and abundant in the river during the two historical sampling events). Target species include catfish, a benthic omnivore; white perch, an epibenthic/pelagic invertivore; American eel, a demersal piscivore; and blue crab, a benthic omnivore. These species have been collected throughout the LPRSA in substantial numbers and represent species consumed by both humans and wildlife. Tissue samples will consist of composites of multiple fish or crabs [2] of the same species to provide sufficient tissue mass for chemical analysis and for consistency with the previous USEPA-approved 1999-2001 Ecological Sampling Program (ESP; Tierra 1999) and the CPG's Tissue Sampling for the entire 17-mile stretch of the river (Windward 2009a,b).

The general sampling design divides the LPRSA into two major zones according to surface water salinity: the estuarine zone (RM 0 to RM 8) and the freshwater zone (RM 8 to RM 17.4). Each zone is subdivided into 2-mile river reaches and sampling locations are allocated among these reaches. Sampling locations will be located within each 2-mile river reach in areas of known or likely habitat based on results of the 2010 field reconnaissance (Windward 2013) and prior field sampling events (Tierra 1999; Windward 2010, 2011). This will ensure that tissue samples targeted in each zone are collected spatially throughout the zone. Figures 4a and 4b depict previous samples collected from the estuarine zone (Figure 4a) and freshwater zone (Figure 4b), and show the breakdown of the sampling reaches within each zone. A breakdown of the major zones, reaches and river miles is as follows:

---

[2] Composite tissue sampling provides a cost-effective approach for developing an estimate of the mean concentration of chemicals in tissue (USEPA 2002), is consistent with the human health risk assessment data use objective of estimating mean concentrations in tissue consumed by humans over a long-term period of exposure (USEPA 1989a, 1989b, 2000), ensures sufficient tissue mass for the program's extensive analytical requirements, and provides comparability with the sampling that was conducted under the ESP and CPG programs.

Zone	Reach	River Mile
Estuarine	1	0 – 2
	2	2 – 4
	3	4 – 6
	4	6 – 8
Freshwater	5	8 – 10
	6	10 – 12
	7	12 – 14
	8	14 –17.4

The target sampling area for all species will focus on localized habitat areas (i.e., areas with a radius of approximately 100 ft). At least two target sampling locations will be sampled in each reach based on the locations identified by CPG and so that sampling locations are distributed evenly per zone; however, additional sampling areas may be identified in the field in order to collect sufficient numbers of fish to meet the tissue mass requirements. Composites will be created for each target tissue type and analyzed separately. The number of individuals in a single composite will be based on analytical mass requirements.

A full suite of chemical (COC) analyses will be conducted on the tissue samples. These include metals[3] (including mercury and methylmercury), organochlorine pesticides (excluding toxaphene), butyltins, PCBs (Aroclors and 209 individual congeners), dioxins/furans, semi-volatile organic compounds, polycyclic aromatic hydrocarbons (PAHs; excluding alkylated PAHs), percent moisture, and lipid content. Herbicides and volatile organic compounds (VOCs) will not be analyzed. All analyses will have low level detection limits, which will be identified in advance in the (QAPP).

Target tissue types for the human health risk assessment (HHRA) include fish fillets, edible crab muscle, and hepatopancreas composite samples. Target tissue types for the ecological risk assessment (ERA) include whole-body fish and whole-body crab (all soft parts without shell). To meet the needs of both risk assessments with one sampling event, catfish fillets will be analyzed separately from the remaining tissue (carcass). Catfish fillet chemical concentrations then will be combined mathematically (proportionally to the average weight of the species) with carcass chemical concentrations to compute whole-body concentrations. This is consistent with the USEPA-approved approach used in the 2009/2010 CPG sampling program and will reduce the number of catfish samples required for analysis. Because white

[3] Metals analysis will include the following metals: aluminum, antimony, arsenic (total and inorganic), barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, thallium, titanium, vanadium, zinc.

perch and American eel are anticipated to be more abundant throughout the river than catfish, separate fillet and whole-body composite samples will be analyzed.

A maximum number of sampling attempts per location will be established; however, it may not be possible to collect adequate tissue mass at each specified sampling location to constitute a full analytical sample. In such cases, Tierra will work closely with USEPA during sampling to make decisions regarding compositing. If insufficient tissue has been collected after the maximum number of attempts, the target area will be expanded, or alternative species may be collected, depending on the fish catch. Tissue from different species will not be combined. After additional attempts have been exhausted, a chemical prioritization scheme will be employed for the analysis of the volume of tissue collected. Some sampling locations may need to be relocated or abandoned.

Estimates of Sample Size

When sampling an aquatic system the size of the LPRSA, reasonable estimates of the distribution of chemical concentrations in fish and shellfish tissue are needed to estimate potential risks to wildlife and humans that may consume them. To determine the number of samples sufficient for the sampling objectives, ARCADIS conducted statistical evaluations using the existing fish and shellfish tissue datasets from the 1999-2001 ESP and 2009/2010 CPG tissue sampling programs in the LPRSA.

Sample sizes for each species/tissue type were selected with the following objectives:

- To estimate 95% upper confidence limits on the mean (95UCL) with reasonable precision (i.e., small relative error)

- To have sufficient power to detect differences in the mean when the new dataset is compared to data collected in the two previous time periods (i.e., 1999-2001 and 2009/2010).

For mean estimation, sample sizes can be calculated according to the following formula found in Chapter 8 of the USEPA's ProUCL 5.0 Technical Guidance Document (USEPA 2013):

$$n = Z^2_{1-(\alpha/2)} (\text{standard deviation/difference from true mean})^2 + Z^2_{1-(\alpha/2)}/2$$

where Z is the standard normal deviate that cuts off (1-(α/2))% of the distribution and 1-α/2 is the required confidence interval range. This equation can be modified to calculate sample size using relative error (as fraction of true mean) and coefficient of variation (CV) instead of using actual variance and margin of error (Gilbert 1987). The resulting equation is as follows:

$$n = Z^2_{1-(\alpha/2)} (\text{CV/relative error})^2 + Z^2_{1-(\alpha/2)}/2$$

Sample size estimates were calculated for the range of CVs that have been observed in the existing tissue datasets and a range of relative errors, as provided below:

Sample Size Estimates as a Function of Relative Error and CV

Relative Error	Coefficient of Variation					
	0.25	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
20%	6	13	19	26	35	45
25%	5	9	13	17	23	30
30%	4	7	9	13	17	21
35%	3	5	7	10	13	16

Because CVs for the tissue data are generally less than 0.6, a sample size of 13 will result in 95UCLs with a relative error of 30% or less. The mean differences in concentrations noted between time periods in Tables 1 and 2 are generally in the range of 20 to 30%. Therefore, a sample size of 13 was selected as the minimum sample size for most species and tissue types where a 95UCL could be calculated by zone. The exception to this was for blue crab muscle and hepatopancreas, which tend to show lower CV and can be characterized with a smaller sample size.

Sample Numbers and Rationale

The statistics presented in Tables 1 and 2 provide evidence that tissue concentrations may be decreasing over time in the LPRSA. If such a trend truly exists, it is important that sample sizes be adequate to detect differences in mean concentrations over time. Power (β) is the probability of detecting a statistically significant difference in the mean of two populations at a prescribed Type I[4] error rate (α) when the means are in fact different. Power calculations require assumptions of the true difference in the means between the populations, the size of the sample collected from each population, and the standard deviation of the two populations.

Power calculations for this analysis were performed using SAS 9.3 (SAS Institute 2012) and are based on the observed attributes of the previous tissue datasets for 2,3,7,8-TCDD and total PCBs (sum of 7 Aroclors). Assumptions of the mean difference are based on the observed difference in means between the 1999-2001 ESP dataset and the 2009/2010 CPG dataset for RM 0 to 8. No tissue data are available for RM 8 to17 for the 1999-2001 time period. The standard deviation is assumed to be equal to the observed standard deviation in the 2009/2010 dataset. The power equation can be rearranged to calculate the required sample size of a new sample given the samples collected and α and β are

[4] The Type I error rate is the probability of rejecting a hypothesis when it is in fact true. In this case the Type I error rate refers to the probability of rejecting the hypothesis that two means are equal when in fact they are equal. The Type II error rate is equal to 1-β, and is the probability of accepting a hypothesis when it is false.

specified. The sample size for the first sample is the actual sample size of the 2009/2010 dataset (RM 0 to 8). The sample size for the proposed dataset is calculated to, at a minimum, provide 70% power to detect a difference between means at an alpha = 0.10 using a one-sided two sample t-test. Table 3 provides the results of the power analysis.

The sample size estimates provided in Table 3 represent the sample size necessary for a comparison of data from RM 0-8 only. Since we do not have the data to support a power calculation for a river-wide (i.e., 0-17 miles) analysis, we estimate that using double the sample size would result in adequate power ($\beta > 0.7$) to detect temporal differences. The results of the power analysis indicate that for some species/tissue types a sample size greater than 13 may be needed to provide adequate power to detect a difference at least as small as the difference already observed between the 1999-2001 and 2009/2010 datasets, particularly for whole body blue crab samples. The target sample size for blue crab was increased to 22 to ensure that statistical comparisons for 2,3,7,8-TCDD would have adequate power. For white perch fillet, the power analysis indicates that a sample size of 17 is needed for a RM 0-8 calculation. The sample size for white perch fillet was not increased since a river-wide comparison will have adequate power. Another consideration in assessing sample size requirements is the number of comparisons being made. Since multiple comparisons will be made (i.e., one comparison for every combination of species, tissue type, and chemical constituent), the probability of detecting an overall temporal trend in the river will be much greater than the power of an individual test. Therefore these minimum sample sizes are very conservative.

Based on the power evaluation and considering the sample size estimates as a function of relative error and CV, proposed sample sizes for fish and crab tissue are below.

Feeding Guild	Species	No. of Composite Samples per Tissue Type per Zone	Type of Sample	Total No. of Analytical Samples
Invertivore	white perch[a]	13 13	skinless fillet whole body	52
Benthic omnivore	catfish[b]	13 13	skinless fillet remaining carcass	26
Piscivore	American eel[a]	13 13	skin-on fillet whole body	52
Epibenthic omnivore	blue crab	22 8 8	whole body edible muscle hepatopancreas[b]	44 16 16
			Total	**206**

Notes:

a. White perch and American eel samples may be analyzed as individual fish or composite samples, depending on size.

b. While white catfish (*Ameiurus catus*) will be targeted, other types of catfish including channel catfish (*Ictalurus punctatus*) and brown bullhead (*Ameiurus nebulosus*) may be considered depending on abundance. Catfish only targeted in the freshwater zone, which is the extent of their range in the LPRSA.

c. From a subset of crabs collected for edible muscle analysis.

Proposed Sampling Methods

Several methods are proposed to collect fish and blue crab throughout the LPRSA, including minnow/eel traps, crab traps, trotlines, and gillnets. While the majority of fish will be captured from the shoal areas near the shoreline, gillnets will also be positioned mid-channel as necessary. Boat and/or backpack electrofishing will be conducted as salinity and conductivity allow, but will likely be restricted to reaches 4 through 8 (RM 6 through 17.4). Bait will vary by method but may include bologna, cheese dough, chicken legs, blood dough, commercially processed blue crab, shrimp, worms, and chicken livers. Additional information on sampling methods will be provided in the standard operating procedures (SOPs). The SOPs and QAPP for this sampling event will be adopted from the comparable documents developed by the CPG for the 2009/2010 sampling program. These will be developed and submitted to USEPA in an expedited manner for review and approval, so that this program can proceed in 2014.

Summary

Fish and shellfish tissue samples will be collected from various locations throughout the LPRSA. A summary of the total number of fish and shellfish samples is presented above and summarized below.

- Blue crabs: A total of 44 whole body blue crab samples will be collected from the LPRSA; 22 crabs will be collected from each zone (estuarine and freshwater) and submitted to the analytical laboratory. Eight additional crab tissue samples will be collected from each zone and will consist of separate samples of edible tissue and hepatopancreas tissue samples.

- White perch: A total of 52 white perch samples will be collected from the LPRSA; 26 white perch samples will be collected from each zone (estuarine and freshwater) and submitted to the analytical laboratory. 13 samples will be submitted as skinless fillets; 13 samples will be submitted as whole body fish. Composite samples will consist of fish smaller than 30 centimeters. Larger fish will be submitted as individual samples.

- American eel: A total of 52 American eel samples will be collected from the LPRSA; 26 American eel samples will be collected from each zone (estuarine and freshwater) and submitted to the analytical laboratory. 13 samples will be submitted as skin-on fillets; 13 samples will be submitted as whole body eels. Composite samples will consist of fish smaller than 30 centimeters. Larger fish will be submitted as individual samples.

- Catfish: White catfish (*Ameiurus catus*) will be the targeted species; however, other types of catfish including channel catfish (*Ictalurus punctatus*) and brown bullhead (*Ameiurus nebulosus*) may be considered depending on abundance. A total of 26 catfish samples will be collected, primarily from the freshwater zone (i.e., RM 8 to 17) of the LPRSA. 13 samples will be submitted to the laboratory as skinless fillets; the remaining skin-on carcass will also be analyzed and used

to derive whole body chemical concentrations. Composite samples will consist of fish smaller than 30 centimeters. Larger fish will be submitted as individual samples.

Overall, this conceptual sampling program is anticipated to provide the additional fish and crab tissue dataset required to evaluate potential statistically significant trends in concentrations of COCs in tissue over time and throughout the LPRSA. These data are also paramount in evaluating ecological and human health risks and possible remedial options as part of the FFS for the LPRSA. This sampling program has been developed taking into consideration prior sampling programs/events, including target species, numbers and locations of previous samples, necessary statistical power, as well as the sampling methods and effort required to capture fish from the LPRSA.

References

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, 115 Fifth Avenue, New York, NY. ISBN 0-442-23050-8.

SAS Institute Inc. 2012. SAS® 9.3. Cary, NC

USEPA. 1989a. Assessing human health risks from chemically contaminated fish and shellfish: a guidance manual. EPA/503-8-89-002. US Environmental Protection Agency, Washington, DC.

USEPA. 1989b. Risk assessment guidance for Superfund, volume 1: Human health evaluation manual, Part A. EPA/540/1-89/002. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

USEPA. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis. Third ed. EPA 823-B-00-007. US Environmental Protection Agency, Washington, DC.

USEPA. 2002. Guidance on choosing a sampling design for environmental data collection for use in developing a quality assurance project plan. EPA QA/G-5S. EPA/240/R-02/005. Office of Environmental Information, US Environmental Protection Agency, Washington, DC.

USEPA. 2007. Administrative Order on Consent with the Cooperating Parties Group. U.S. Environmental Protection Agency. May.

USEPA. 2013. ProUCL Version 5.0.00 Technical Guide. EPA/600/R-07/041. September, 2013.

Windward. 2009a. Fish/Decapod (Crab/Crayfish) Tissue Sampling Design for the Lower Passaic River Restoration Project. Memorandum from Lisa Saban, Windward to Technical Committee/Risk Assessment Subcommittee. March 30, 2009.

Windward. 2009b. Lower Passaic River Restoration Project. Lower Passaic River Study Area RI/FS. Quality Assurance Project Plan. Fish and Decapod Crustacean Tissue Collection for Chemical Analysis and Fish Community Survey. Final. Prepared for Cooperating Parties Group. Newark, NJ. August 6, 2009.

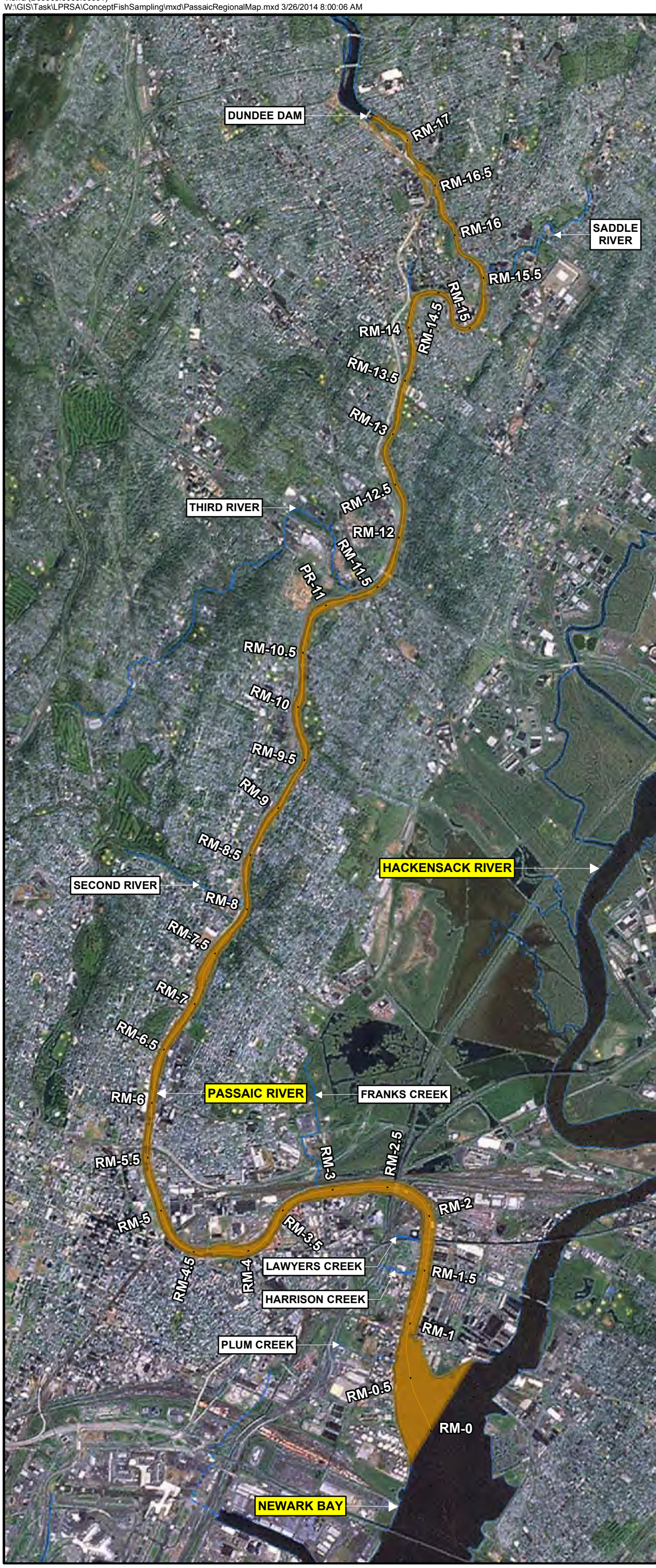
Windward. 2010. Lower Passaic River Restoration Project. Fish and decapod field report for the late summer/early fall 2009 field effort. Final. Prepared for Cooperating Parties Group. Newark, NJ. September 14, 2010.

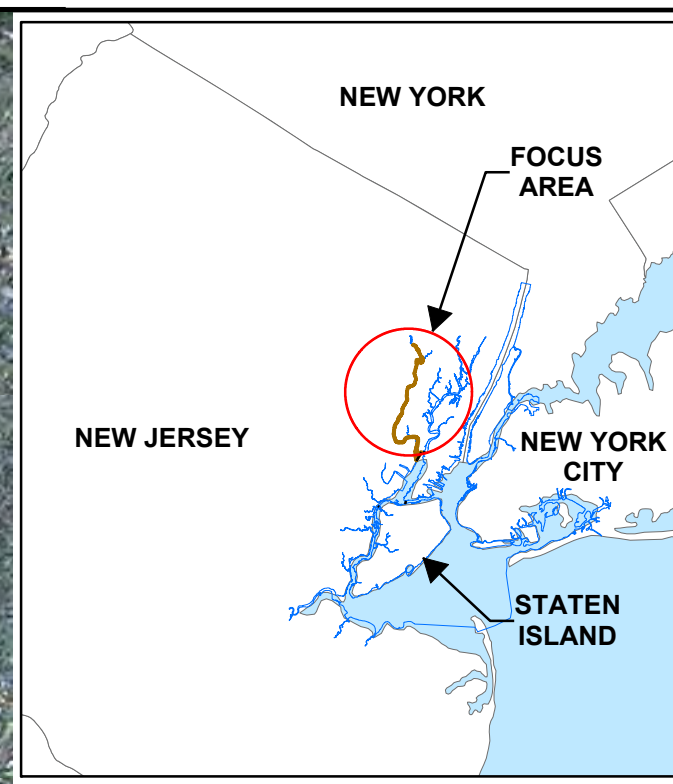
Windward. 2011. Lower Passaic River Restoration Project. Lower Passaic River Study Area RI/FS. Fish community survey and tissue collection data report for the Lower Passaic River Study Area 2010 field efforts. Final. Prepared for Cooperating Parties Group. Newark, NJ. July 20, 2011.

Windward. 2013. Lower Passaic River Restoration Project. Habitat Identification Survey Data Report for the Lower Passaic River Study Area Fall 2010 Field Effort. Draft. Prepared for Cooperating Parties Group, Newark, NJ. April 12, 2013.

Windward/AECOM. 2009. LPRSA Human Health and Ecological Risk Assessment Streamlined 2009 Problem Formulation. Final. Prepared for Cooperating Parties Group. Newark, NJ. July 31, 2009.

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B09968.0006.00001)
W:\GIS\Task\LPRSA\ConceptFishSampling\mxd\PassaicRegionalMap.mxd 3/26/2014 8:00:06 AM





LEGEND:

LPRSA RIVER MILE

LOWER PASSAIC RIVER STUDY AREA

NOTES:

1. BASEMAP INFORMATION FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995.
2. 2007 IMAGERY FROM ESRI BING IMAGERY.

0 0.9 1.8 Miles

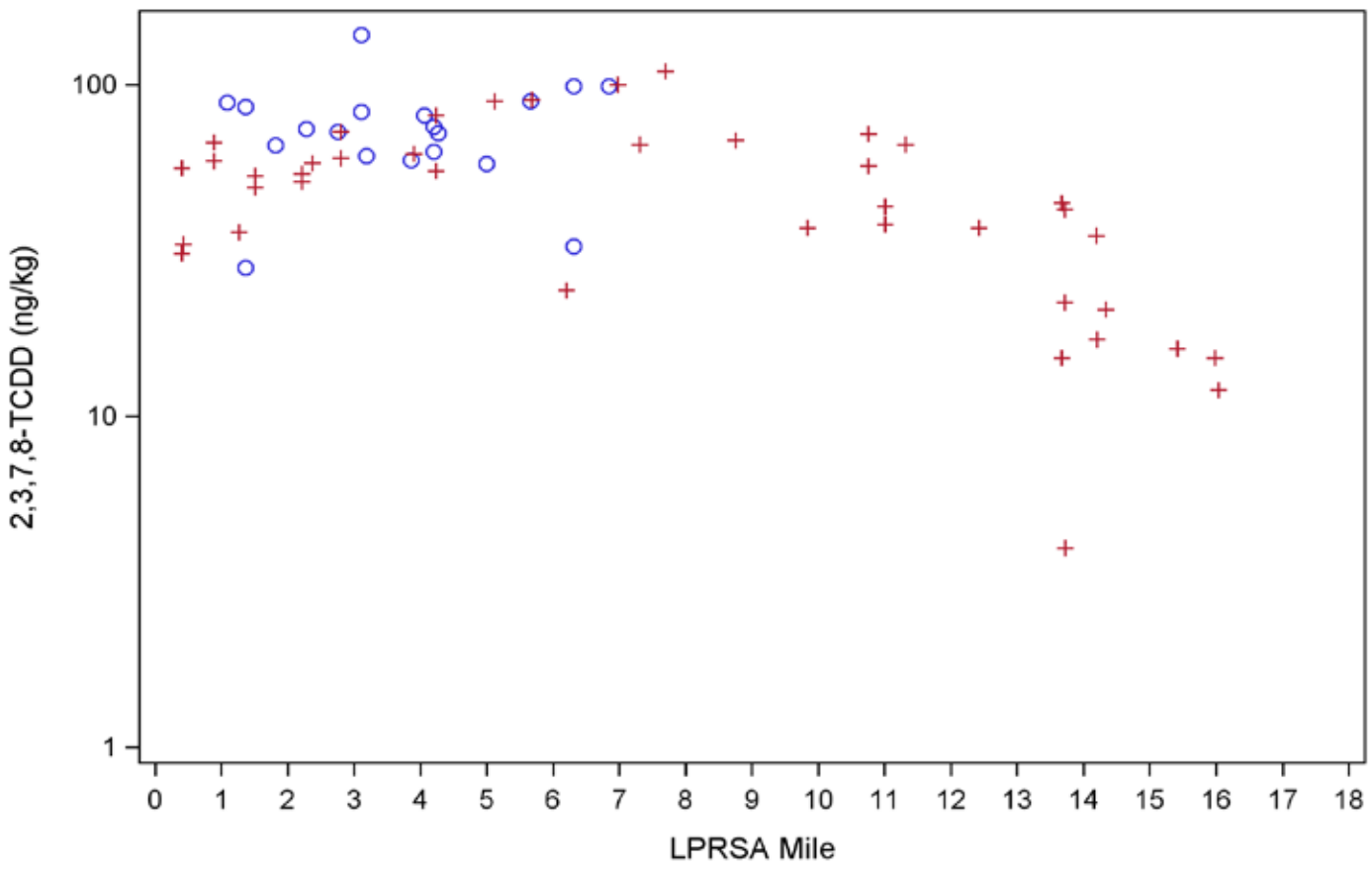
GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA
CONCEPTUAL FISH AND CRAB SAMPLING PLAN

LOWER PASSAIC RIVER STUDY AREA

MARCH 2014

FIGURE
1



Notes:
LPRSA = Lower Passaic River Study Area
ng = nanogram ; kg = kilogram
TCDD = tetrachloro-*p*-dibenzodioxin

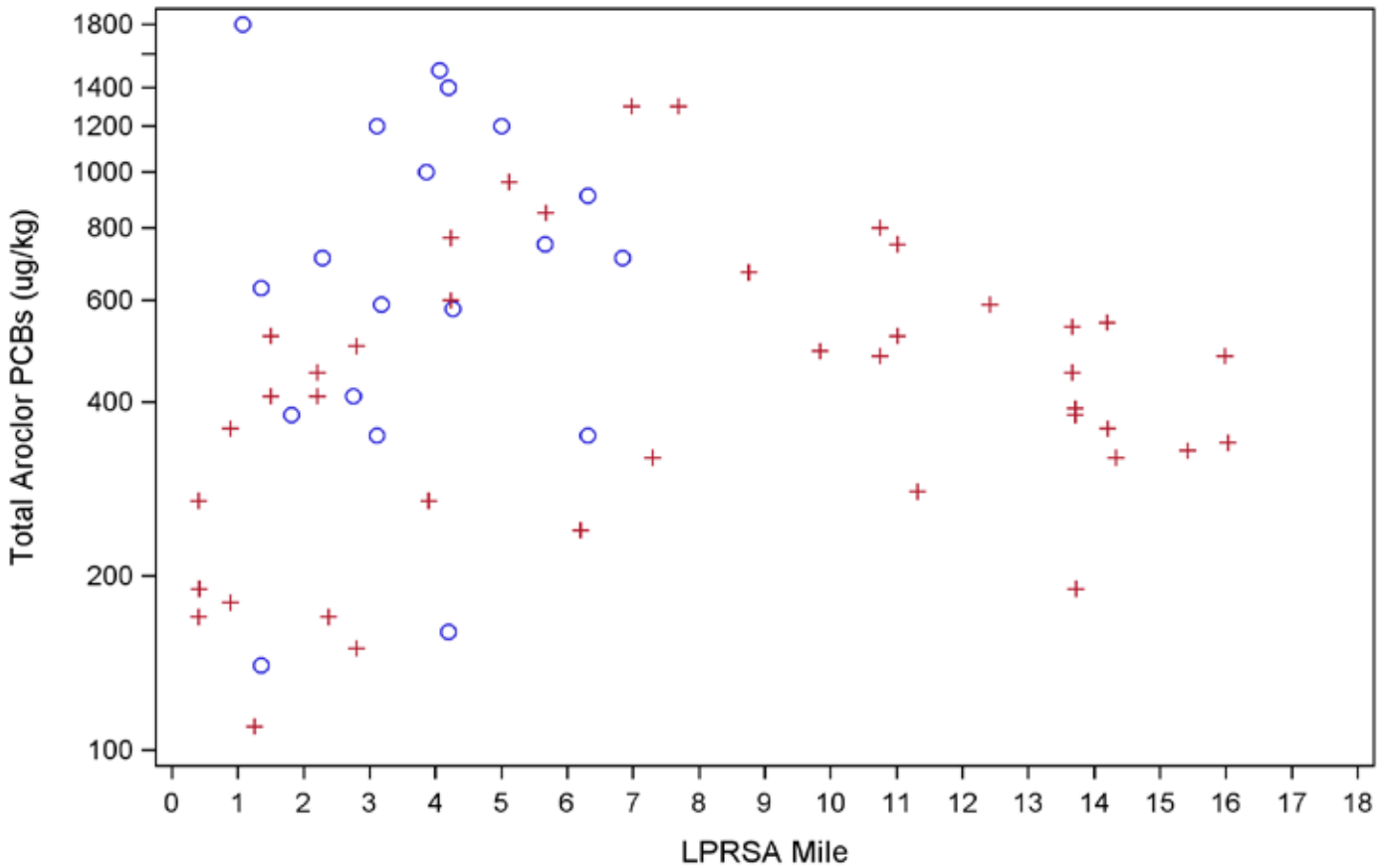
Year of Sampling ○ 1999-2001 + 2009-2010

Lower Passaic River Study Area
Conceptual Fish and Crab Sampling Plan

2,3,7,8-TCDD in Blue Crab (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
2



Notes:
LPRSA = Lower Passaic River Study Area
µg = microgram ; kg = kilogram
PCB = polychlorinated biphenyl

Year of Sampling ○ 1999-2001 + 2009-2010

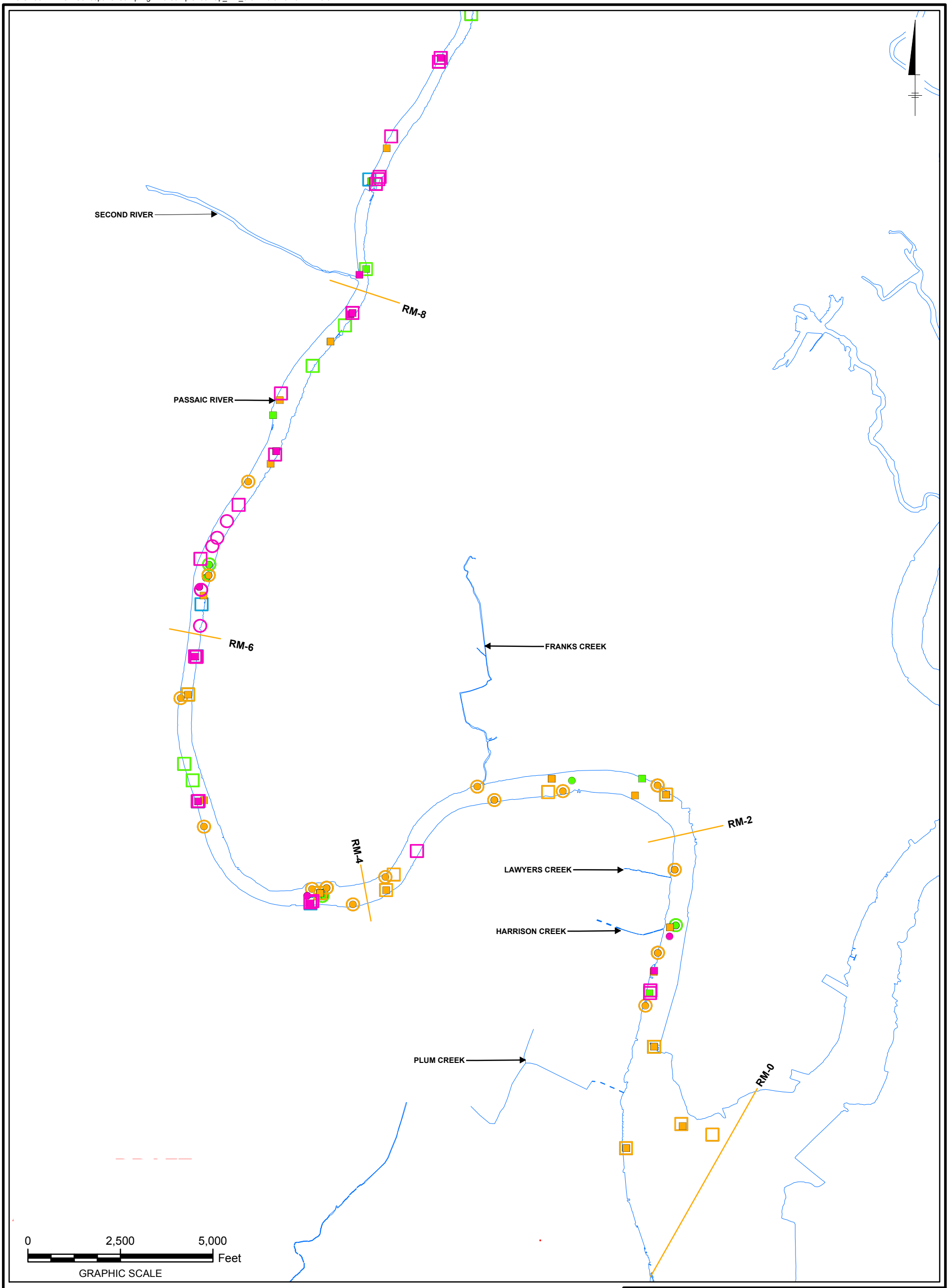
Lower Passaic River Study Area
Conceptual Fish and Crab Sampling Plan

Total PCBs (7 Aroclors) in Blue Crab (Whole Body)

ARCADIS
Infrastructure · Water · Environment · Buildings

FIGURE
3

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B09968.0006.00001)
W:\GIS\Task\LPRSA\ConceptFishSampling\mxd\SampleLocMap_RM_0-8.mxd 3/26/2014 1:43:07 PM



LEGEND:

SAMPLING EVENT
- ● 1999-2001 ESP
- ■ 2009-2010 CPG TISSUE

WHOLE BODY	FILLET OR MUSCLE	
■	□	AMERICAN EEL
■	□	BLUE CRAB
■	□	WHITE PERCH
■	□	WHITE CATFISH

- PROPOSED SAMPLING REACH
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTES:

1. BLUE CRAB HEPATOPANCREAS SAMPLE LOCATIONS ARE NOT SHOWN.
2. PROPOSED SAMPLING REACHES ARE DEPICTED BY LPRSA RIVER MILES.

LOWER PASSAIC RIVER STUDY AREA

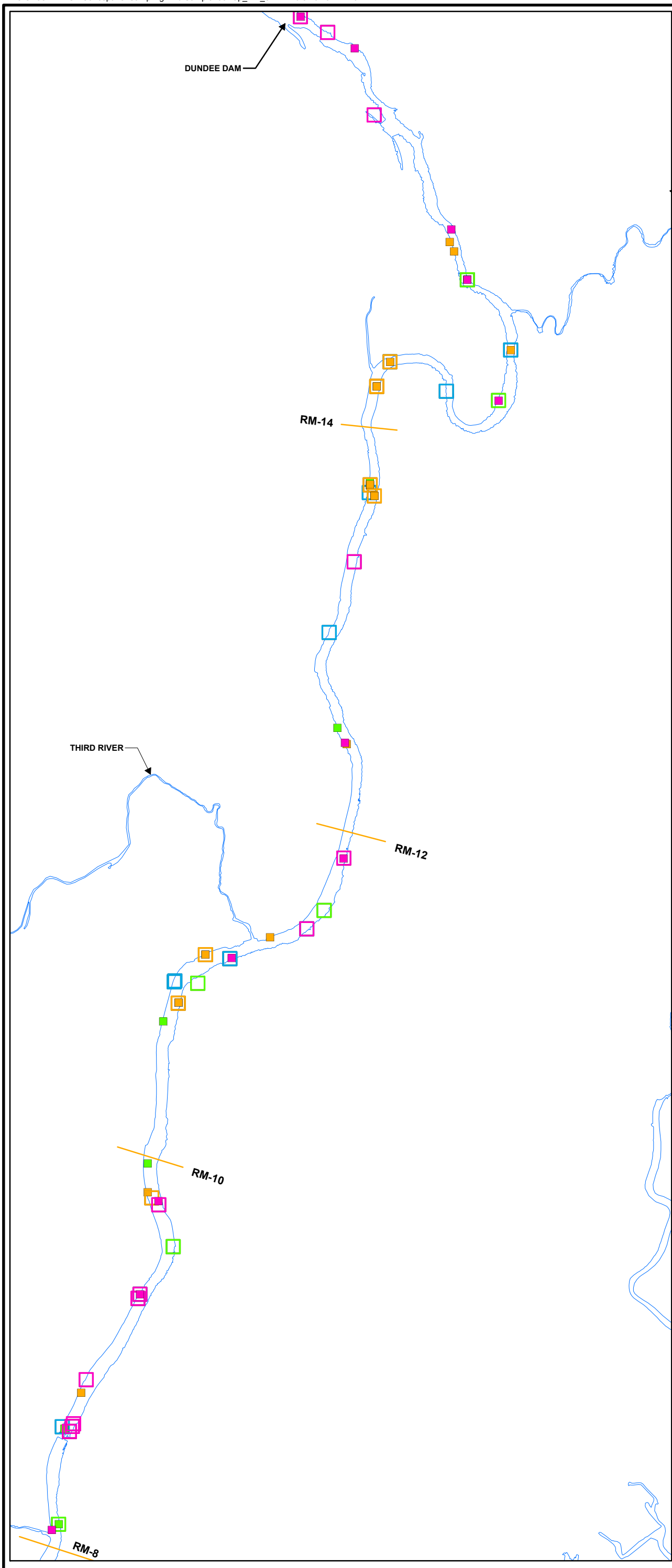
CONCEPTUAL FISH AND CRAB SAMPLING PLAN

PROPOSED SAMPLING REACHES IN THE ESTUARINE ZONE (RM 0 - 8) AND LOCATIONS OF HISTORICAL SAMPLES

MARCH 2014

FIGURE **4a**

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B09968.0006.00001)
W:\GIS\Task\LPRSA\ConceptFishSampling\mxd\SampleLocMap_RM_8-17.mxd 3/26/2014 1:46:24 PM



LEGEND:

SAMPLING EVENT

- ● 1999-2001 ESP
- ■ 2009-2010 CPG TISSUE

WHOLE BODY	FILLET OR MUSCLE	
■	□	AMERICAN EEL
■	□	BLUE CRAB
■	□	WHITE PERCH
■	□	WHITE CATFISH

- PROPOSED SAMPLING REACH
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTES:

1. BLUE CRAB HEPATOPANCREAS SAMPLE LOCATIONS ARE NOT SHOWN.
2. PROPOSED SAMPLING REACHES ARE DEPICTED BY LPRSA RIVER MILES.

0 2,500 5,000 Feet
GRAPHIC SCALE

LOWER PASSAIC RIVER STUDY AREA
CONCEPTUAL FISH AND CRAB SAMPLING PLAN

PROPOSED SAMPLING REACHES IN THE FRESHWATER ZONE (RM 8 - 17) AND LOCATIONS OF HISTORICAL SAMPLES

MARCH 2014

FIGURE
4b

Table 1. Tissue Concentrations in Selected Species Collected in the Lower Passaic River Study Area (LPRSA) by Sampling Period

Chemical	Species	Tissue Type	Sampling Period	N	Number of Detects	Frequency of Detection	Mean	Standard Deviation	Minimum	Maximum
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	7	100%	21.7	6.49	14.6	32.2
	American Eel	Fillet	2009-2010	32	32	100%	13.5	9.84	0.31	41
	American Eel	Whole Body	1999-2001	6	6	100%	9.7	6.34	4.53	20.6
	American Eel	Whole Body	2009-2010	19	18	95%	16.8	15.0	0.11	47
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	262	45.0	195	371
	Blue Crab	Hepatopancreas	2009-2010	7	7	100%	143	63.8	41	210
	Blue Crab	Muscle	1999-2001	18	18	100%	17.6	3.94	10.9	22.7
	Blue Crab	Muscle	2009-2010	21	21	100%	7.48	5.65	0.82	20
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	75.0	24.8	28	141
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	41	41	100%	49.2	25.0	4	110
	White Perch	Fillet	1999-2001	6	6	100%	64.9	22.2	34.4	88.9
	White Perch	Fillet	2009-2010	19	19	100%	41.0	24.1	3.6	99
	White Perch	Whole Body	1999-2001	18	18	100%	212	81.1	73.6	352
	White Perch	Whole Body	2009-2010	19	19	100%	129	71.5	18.0	250
Total PCBs (ug/kg)	American Eel	Fillet	1999-2001	7	7	100%	1,624	745	670	2,800
	American Eel	Fillet	2009-2010	32	32	100%	1,185	882	310	4,900
	American Eel	Whole Body	1999-2001	6	3	50%	810	710	75	1,700
	American Eel	Whole Body	2009-2010	19	19	100%	1,849	1,681	670	7,500
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	5,513	1,958	3,200	11,000
	Blue Crab	Hepatopancreas	2009-2010	7	7	100%	3,300	1,233	1,200	5,100
	Blue Crab	Muscle	1999-2001	18	4	22%	64	22	16	75
	Blue Crab	Muscle	2009-2010	21	19	90%	31	27	3.5	100
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	777	467	140	1,800
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	41	41	100%	473	277	110	1,300
	White Perch	Fillet	1999-2001	6	6	100%	842	179	600	1,100
	White Perch	Fillet	2009-2010	19	19	100%	551	298	190	1,300
	White Perch	Whole Body	1999-2001	18	18	100%	3,989	1,821	1,200	10,000
	White Perch	Whole Body	2009-2010	19	19	100%	2,308	1,124	470	4,200

Notes: Includes all samples collected in the river. The 1999-2001 sampling events include the 1999 Late Summer/Early Fall RI-ESP Sampling Program, the 2000 Spring RI-ESP Sampling Program, and the 2001 Supplemental RI-ESP Biota Sampling Program. The 2009/2010 sampling period includes samples collected by the CPG during that period. 1/2 detection limit substituted for non-detected values. Field duplicate results were averaged. Total PCB concentrations are the sum of 7 Aroclors.

Table 2. Tissue Concentrations in Selected Species Collected in LPRSA River Mile 0 to 8

Chemical	Species	Tissue Type	Sampling Period	N	Number of Detects	Frequency of Detection	Mean	Standard Deviation	Minimum	Maximum
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	7	100%	21.7	6.49	14.6	32.2
	American Eel	Fillet	2009-2010	16	16	100%	14.9	9.91	4.70	41
	American Eel	Whole Body	1999-2001	6	6	100%	9.7	6.34	4.53	20.6
	American Eel	Whole Body	2009-2010	8	8	100%	24.8	13.2	5.70	47
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	262	45.0	195	371
	Blue Crab	Hepatopancreas	2009-2010	5	5	100%	176	34.4	130	210
	Blue Crab	Muscle	1999-2001	18	18	100%	17.6	3.94	10.9	22.7
	Blue Crab	Muscle	2009-2010	11	11	100%	11.10	5.23	3.80	20
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	75.0	24.8	28	141
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	22	22	100%	61.6	22.1	24	110
	White Perch	Fillet	1999-2001	6	6	100%	64.9	22.2	34.4	88.9
	White Perch	Fillet	2009-2010	11	11	100%	48.9	22.5	22.0	99
	White Perch	Whole Body	1999-2001	18	18	100%	212	81.1	73.6	352
	White Perch	Whole Body	2009-2010	10	10	100%	158	45.8	73.0	250
Total PCBs (ug/kg)	American Eel	Fillet	1999-2001	7	7	100%	1,624	745	670	2,800
	American Eel	Fillet	2009-2010	16	16	100%	1,271	1086	450	4,900
	American Eel	Whole Body	1999-2001	6	3	50%	810	710	75	1,700
	American Eel	Whole Body	2009-2010	8	8	100%	2,780	2,299	760	7,500
	Blue Crab	Hepatopancreas	1999-2001	15	15	100%	5,513	1,958	3,200	11,000
	Blue Crab	Hepatopancreas	2009-2010	5	5	100%	3,900	725	3,200	5,100
	Blue Crab	Muscle	1999-2001	18	4	22%	64	22	16	75
	Blue Crab	Muscle	2009-2010	11	11	100%	40	30	17	100
	Blue Crab	Whole Body (Soft Tissue)	1999-2001	19	19	100%	777	467	140	1,800
	Blue Crab	Whole Body (Soft Tissue)	2009-2010	22	22	100%	477	353	110	1,300
	White Perch	Fillet	1999-2001	6	6	100%	842	179	600	1,100
	White Perch	Fillet	2009-2010	11	11	100%	649	319	190	1,300
	White Perch	Whole Body	1999-2001	18	18	100%	3,989	1,821	1,200	10,000
	White Perch	Whole Body	2009-2010	10	10		2,630	748	1900	4,200

Notes: Includes only samples collected below LPRSA river mile 8. The 1999-2001 sampling events include the 1999 Late Summer/Early Fall RI-ESP Sampling Program, the 2000 Spring RI-ESP Sampling Program, and the 2001 Supplemental RI-ESP Biota Sampling Program. The 2009/2010 sampling period includes samples collected by the CPG during that period. 1/2 detection limit substituted for non-detected values. Field duplicate results were averaged. Total PCB concentrations are the sum of 7 Aroclors.

Table 3. Results of Power Calculations Using Tissue Data from the LPRSA (RM 0 to 8)

Chemical	Species	Tissue Type	Sampling Period	N[a]	Mean	SD	Mean Difference	Number of Samples (α = 0.1; β = 0.70)[b]
2,3,7,8-TCDD (ng/kg)	American Eel	Fillet	1999-2001	7	21.7	6.49	6.8	13
			2009/2010	16	14.9	9.91		
	Blue Crab	Hepatopancreas	1999-2001	15	262	45.0	86	2
			2009/2010	5	176	34.4		
		Edible Muscle	1999-2001	18	17.6	3.94	6.5	3
			2009/2010	11	11.10	5.23		
		Whole Body (Soft Tissue)	1999-2001	19	75.0	24.8	13	22
			2009/2010	22	61.6	22.1		
	White Perch	Fillet	1999-2001	6	64.9	22.2	16	17
			2009/2010	11	48.9	22.5		
		Whole Body	1999-2001	18	212	81.1	54	4
			2009/2010	10	158	45.8		
Total PCBs (ug/kg)	American Eel	Fillet	1999-2001	7	1,624	745	354	--
			2009/2010	16	1,271	1086		
	Blue Crab	Hepatopancreas	1999-2001	15	5,513	1,958	1613	1
			2009/2010	5	3,900	725		
		Edible Muscle	1999-2001	18	64	22	23	12
			2009/2010	11	40	30		
		Whole Body (Soft Tissue)	1999-2001	19	777	467	300	6
			2009/2010	22	477	353		
	White Perch	Fillet	1999-2001	6	842	179	193	54
			2009/2010	11	649	319		
		Whole Body	1999-2001	18	3,989	1,821	1359	2
			2009/2010	10	2,630	748		

Notes:

a) Number of samples from LPRSA RM 0-8.

b) Number of samples needed to detect a significant difference using a one-sided t-test with a probability of 70% at an alpha of 0.10 assuming that the sample size of the first group is equal to the 2009/2010 sample size.

-- Indicates sample size is incalculable.

ARCADIS

Attachment 3

Vinson&Elkins

Carol E. Dinkins cdinkins@velaw.com
Tel +1713.758.2528 **Fax** +1713.615.5311

July 27, 2011

Ms. Alice L. Yeh
Remedial Project Manager
U.S. EPA, Region 2
290 Broadway, 19th Floor
New York, New York 10007

Re: Administrative Order on Consent, CERCLA Docket No. 02-2007-2009: Application of a "correction" factor to low resolution coring program dioxin data

Dear Ms. Yeh:

On behalf of our client, Tierra Solutions, Inc. (Tierra), acting on behalf of Occidental Chemical Corporation pursuant to contractual agreement, by this letter we provide information in addition to that which the Cooperating Parties Group ("CPG") submitted yesterday identifying fundamental quality assurance failures that underlie EPA's directive that the CPG apply a "correction" factor to the dioxin data in the low resolution coring program report.

As an initial matter, please be advised that Tierra contests the application of the correction factor to the dioxin data, for all the reasons put forth by the CPG. EPA's contractor developed that "correction" factor from unvalidated data and in various respects contravened the requirements of the above-referenced AOC, the Malcolm Pirnie project QAPP and the Uniform Federal Policy on QAPPs. On behalf of Tierra, by this letter we bring to your attention an additional concern regarding the application of a "correction" factor to dioxins alone. Tierra engaged its consultant, Arcadis, to conduct an independent analysis to evaluate PCB and PAH split samples employing the techniques used by EPA's contractor to develop the dioxin "correction" factor. Attached please find a copy of Arcadis' report on its analysis. As summarized in the following table and explained in more detail below and in the attached report, this analysis shows that similar correction factors for PCBs and PAHs are warranted if EPA compels adjustment of dioxins.

Geometric Mean Ratios AXYS/CPG Lab								
	Min	Max	Median	Total No. of Analytes	No. Analytes where AXYS is greater	No. Analytes where AXYS is significantly greater*	No. Analytes where CPG lab is greater	No. Analytes where CPG lab is significantly greater*
PCDDs/Fs	1.099	1.887	1.408	14	14	7	0	0
PCB Congeners	0.63	2.25	1.24	127	118	45	8	0
PCB Homologue Groups	1.08	1.75	1.26	10	10	5	0	0
PAHs	1.21	9.11	1.52	31	31	20	0	0
*$\alpha = 0.05$								

As recounted in the CPG letter, the CSC Environmental Solutions ("CSC") March 2010 Report concludes that the dioxin data produced by the CPG's laboratory, Columbia Analytical Services, were biased and warranted correction.[1] In a subsequent report, CSC calculated "corrections" for each of the dioxin congeners by taking the geometric means of the ratios between the results produced by Columbia Analytical Services and EPA's validation lab.[2] On the basis of this analysis CSC recommended the application of "correction" factors ranging from 1.099 for 1,2,3,7,8-PeCDF to 1.887 for 2,3,7,8 TCDD.[3] The median correction factor for all dioxins from CSC's analysis is 1.408.

[1] CSC Environmental Solutions, Report on Suspected Causes of Disparities Between Results Produced by Columbia Analytical Services and AXYS Analytical Services in Analysis of Lower Passaic River Sediment Split Samples for Chlorinated Dibeno-*p*-Dioxins and Dibenzofurans, and Development of a Conversion Factor to Adjust Results Between the Two Laboratories (2010).

[2] CSC Environmental Solutions, The Effect of Application of a Correction Factor on Chlorinated Dibenzo-*p*-Dioxins and Dibenxofuran Results Produced by Columbia Analytical Services for Lower Passaic River Sediment Samples.

[3] *Id.* at 2-3

Based on CSC's March 2010 report, it appears that CSC has not independently evaluated whether the PCB split sample data demonstrate evidence of potential bias.[4] Arcadis applied to PCBs the techniques that CSC employed in the dioxin analysis and found that PCB correction factors ranging from 0.63 for PCB-152 to 2.25 for PCB-79 (the PCB congeners) would parallel the dioxin "correction." This assessment concluded that applying CSC's technique, the median correction factor for PCB congeners would be 1.24. Arcadis conducted the same analysis for PCB homologue split samples, the results of which are presented in the table above.

Arcadis conducted the same analysis with the low resolution coring program PAH data. To our knowledge no systematic investigation for bias in these data have been conducted to date. Again applying the techniques from the March 2010 CSC Report, Arcadis found that correction factors ranging from 1.21 for Fluorene to 9.11 for C4-Phenanthrenes/anthracenes were warranted for PAHs. The median PAH correction factor calculated using CSC's technique is 1.52.

By this letter Tierra seeks an explanation regarding the finding that the low resolution coring program's dioxin data are biased and in need of correction, but that no similar corrections are warranted for PCBs or PAHs. It is not clear why dioxins must be "corrected" with factors ranging from 1.099 to 1.887, but the PCB and PAH data, demonstrating similar correction factor ranges do not warrant correction. The application of CSC's technique to the low resolution coring program PCB and PAH data produces a prediction of bias similar to that for dioxin. The low resolution coring report either should not require the "correction" of dioxin data, which we firmly believe, or it should "correct" PCBs and PAHs in addition to dioxins.

EPA's decision requiring the low resolution coring report to be finalized in accordance with its directive requiring the "correction" of dioxin data alone is arbitrary and capricious and therefore inconsistent with the NCP. EPA's actions in a CERCLA cleanup may be deemed arbitrary and capricious where, as is the case here, the Agency has failed to articulate a satisfactory explanation for its action, including a rational connection between the facts found and the choices made.[5] Arcadis' analysis clearly demonstrates that "corrections" for PCB and PAH data from the LRC program are equally warranted. If anything, the range

---

[4] CSC Environmental Solutions, *supra* note 1, at 9.

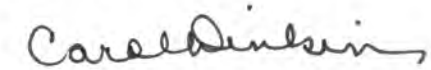
[5] *In re* Bell Petroleum Services, 3 F.3d 889, 905 (5th Cir. 1993).

of "correction" factors for PAHs suggests that the low resolution coring PAH data are more highly biased than the dioxin data. EPA's directive to correct the dioxin data merely states that the CPG should apply "correction" factors as outlined in CSC's March 16, 2010 report and provides no independent explanation of the need for this "correction."[6] We believe that EPA did not and cannot articulate a rational reason for directing the "correction" of dioxins but require no similar "correction" for PCBs and PAHs.

Because we believe that EPA's decision to apply the "correction" only to dioxins has not been and cannot be justified, by this letter Tierra invokes the dispute resolution procedures of the AOC.

Should you have any questions about this letter or the enclosed analysis, we are available to meet with you at your convenience and make our technical consultants available to discuss their application of CSC's techniques. Please include this letter in the Diamond Alkali Superfund Site administrative record.

Sincerely,



Carol E. Dinkins

cc: Patricia C. Hick, Office of Regional Counsel

encl: Arcadis, Development of Correction Factors for Split Samples Using the Approach Developed by CSC Analytical: Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons (2011).

[6] Letter from Stephanie Vaughn, Remedial Project Manager Lower Passaic River Study Area RI/FS to Robert Law, de maximis Inc. (Jan. 25, 2011).

ARCADIS
Infrastructure · Water · Environment · Buildings

Imagine the result

Tierra Solutions

Development of Correction Factors for Split Samples Using the Approach Developed by CSC Analytical[1]

Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons

CPG Low Resolution Coring Program Sediment Chemistry Data

July 26, 2011

---

[1] CSC. 2010. Report on Suspected Causes of Disparities between the Results Produced by Columbia Analytical Services and AXYS Analytical Services in Analysis of Lower Passaic River Sediment Split Samples for Chlorinated Dibenzo-p-Dioxins and Dibenzofurans, and Development of a Conversion Factor to Adjust Results between the Two Laboratories, CSC Environmental Solutions and Interface, Inc., March 2010.

CSC. 2011. The Effect of Application of a Correction Factor on Chlorinated Dibenzo-p-Dioxins and Dibenzofurans Results Produced by Columbia Analytical Services for Lower Passaic River Sediment Samples, January 2011.

Jacqueline Iannuzzi
Senior Scientist/Statistician/Geologist

Development of Correction Factors for Split Samples Using the Approach Developed by CSC Analytical PCBs and PAHs

CPG Low Resolution Coring Program Sediment Chemistry Data

Prepared for:
Tierra Solutions

Prepared by:
ARCADIS U.S., Inc.
326 First Street
Suite 200
Annapolis
Maryland 21403
Tel 410 295 1205
Fax 410 295 1225

Our Ref.:
B0009988.0004.00001

Date:
July 26, 2011

Table of Contents

References 3

Tables

1 Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for PAHs 4

2 Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for PAHs by AXYS Method MLA-021 Revision 5

3 Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for Polychlorinated Biphenyls 6

4 Correction Factors for Polycyclic Aromatic Hydrocarbon Data if Calculated by Methodology in CSC Report for Dioxin Congeners 10

5 Correction Factors for Polychlorinated Biphenyls Data if Calculated by Methodology in CSC Report for Dioxin Congeners 11

Attachments

A report developed by USEPA's contractor (CSC, 2010) attempts to identify the cause of disparities between 30 split sample dioxin/furan results from the 2008 Lower Passaic River Low Resolution Coring (LPR LRC) Program. These samples were analyzed both by CPG's contracted laboratory, Columbia Analytical Services (CAS) and by USEPA's laboratory, AXYS Analytical Services (AXYS). In the CSC report, the geometric mean and 95% confidence intervals of the ratios of the CAS result values to those of AXYS were calculated and reported. The mean ratios included data for which both laboratories' results were greater than their corresponding quantitation limits. In the discussion of these results the report makes the following statement:

"The individual congener-specific geometric means [of the ratios] ranged between 0.53 (2,3,7,8-TCDD) and 0.91 (1,2,3,7,8-PeCDF), with a median geometric mean of 0.71. For seven of the fourteen congeners [evaluated by CSC], the confidence interval did not include 1.0, thus indicating that the bias between laboratories was statistically significant at the 95% confidence level." Note, CSC 2010 indicates that a total of only fourteen of the seventeen dioxin/furan target analyte congeners reported by each of the laboratories were evaluated. As stated, seven congeners were shown to have significant differences among laboratories, seven congeners were not shown to be significantly different as their confidence intervals did not include the value of 1.0 and three congners (1,2,3,7,8-pentachlorodibenzo-p-dioxin, 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin, and 1,2,3,7,8,9-hexachlorodibenzofuran) were not evaluated since they were not reported by both laboratories at levels above their respective quantitation limits in the any of the samples.

Split samples collected during the LPR LRC were also analyzed for polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)[2]. An analysis of the PAH and PCB data was conducted by Arcadis in a similar fashion to that described in the CSC, 2010 report for the dioxin/furan results. The PAH and PCB comparison data evaluation is described here.

As was the case with LPR LRC split samples analyzed for dioxins/furans, 30 samples were collected and split between 2 laboratories for PAH and PCB characterization. The

---

[2] All analyses in this report are based upon data provided by the Cooperating Parties Group (CPG) and AXYS Analytical.

PAH and PCB split samples collected by USEPA were analyzed by AXYS, however unlike split samples analyzed for dioxins/furans, the CPG PAH and PCB samples were analyzed by TestAmerica in Knoxville, Tennesse (TA KNOX).

It should be noted also that AXYS used two methodologies for PAH analysis; some samples were analyzed by laboratory-specific standard operating procedure (SOP) Method MLA-021 Rev 8 and some by Method MLA-021 Rev 9. TA KNOX analyzed all samples using their laboratory-specific SOPID-0016. Note that TestAmerica Pittsburgh, PA also analyzed split samples for PAHs using the USEPA SW-846 analytical method 8270. The PAH results generated via USEPA SW-846 are not included in this comparison. After excluding paired results for which either laboratory reported a value below the quantitation limit, the geometric mean ratios (TA KNOX/AXYS) for all PAHs and PCBs (congeners and homologue groups) were calculated. Individual PAH geometric mean ratios ranged from 0.11 to 0.82 with a median of 0.66 (Table 1). Twenty of the 31 upper confidence limits were less than 1.0 indicating that for these analytes the mean ratio is significantly less than 1.0. To determine if there were differences in agreement between the two method revisions used by AXYS, the geometric mean ratios were also calculated separately by method (Table 2). For all analytes and both method revisions, geometric mean TA KNOX/AXYS ratios are less than 1.0. However, there are differences in significance among methods. For method revision 9, 25 out of 31 upper confidence limits were less than 1.0 (i.e, mean is significantly less than 1.0) while for method revision 8, only 3 upper confidence limits are less than 1.0. This would seem to indicate that the method revisions performed differently as compared to the TA KNOX methodology and that more bias is present in the revision 9 comparison. However, the confidence intervals of the geometric means for each analyte of each revision method overlap (Table 2), therefore, it is difficult to say with any certainty that the methods are in fact performing differently. Geometric mean ratios for the ten homologue groups ranged from 0.57 to 0.92 with a median of 0.80 (Table 3). Individual PCB congener geometric mean ratios ranged from 0.44 to 1.6 with a median of 0.81 (Table 3). Out of ten PCB homologue groups, ten geometric mean ratios were less than 1.0 and five were significantly less than 1.0. Out of 127 PCB congeners, 118 geometric mean ratios were less than 1.0 and 45 of the upper confidence limits were less than 1.0. Note, the total number of congeners evaluated for PCBs (127) represents the number of common target analyte results reported by both laboratories at a positive concentration above their respective quantitation limits in the same samples, excluding cases where identified analyte co-elutions were not identical. By the line of reasoning applied to the dioxin/furan results

described above, bias would be indicated for both PAHs and PCBs. Agreement plots for each PAH and PCB analyte are presented in Attachments 1 and 2 respectively. Each point represents a sample plotted with respect to the concentration reported by each laboratory. The 1:1 line on the plot represents the line of perfect agreement. If the labs agree the points should generally fall along this line. Bias is indicated when most points fall above or below the 1:1 line. For PAHs, each result pair is identified by the AXYS method revision used.

A second report from CSC (2011) proposes correction factors be applied to the CAS dioxin/furan data set and concludes that the error introduced by applying a correction factor "would only be slight compared to an uncorrected result without the low bias." The correction factors were calculated as the geometric mean AXYS/CAS ratios (results below quantitation limit excluded) and are to be multiplied by CAS dioxin/furan results above the quantitation limit. They range from 1.099 to 1.887 (median = 1.408). Using the same methodology, Arcadis has calculated similar correction factors for PAH and PCB data. PAH correction factors range from 1.21 to 9.11, with a median value of 1.52 (Table 4), not unlike the ranges reported for dioxin/furan congeners (CSC, 2011). For the ten PCB homologue groups, correction factors range from 1.08 to 1.75 with a median value of 1.26. Five of the ten correction factors are significantly greater than 1.0 (Table 5). Correction factors for PCB congeners range from 0.63 to 2.25 with a median value of 1.24 (Table 5). However, 118 of the 127 congeners have correction factors greater than 1.0, 50 significantly so. Of the eight congeners that have calculated correction factors less than or equal to 1.0, none are significantly less than 1.0 (i.e. all of the confidence intervals include 1). One congener has a calculated correction factor equal to 1, however this is based on only one sample pair.

The objective of this analysis of PAH and PCB split data is not to propose that correction factors be applied to TA KNOX results but to shed light on the fact that the geometric mean ratios of two other classes of chemicals, independent of the dioxin/furan analyses and independent of the CAS laboratory, point to bias when similar logic is applied. Split sample results for all constituents should be handled in a consistent manner and correction factors should not arbitrarily be applied to only one group of analytes.

References

CSC, 2010. Report on Suspected Causes of Disparities between the Results Produced by Columbia Analytical Services and AXYS Analytical Services in Analysis of Lower Passaic River Sediment Split Samples for Chlorinated Dibenzo-p-Dioxins and Dibenzofurans, and Development of a Conversion Factor to Adjust Results between the Two Laboratories, CSC Environmental Solutions and Interface, Inc., March 2010.

CSC, 2011. The Effect of Application of a Correction Factor on Chlorinated Dibenzo-p-Dioxins and Dibenzofurans Results Produced by Columbia Analytical Services for Lower Passaic River Sediment Samples, January 2011.

ARCADIS

Table 1. Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for PAHs

Polycyclic Aromatic Hydrocarbons	Number of Pairs	Geometric Mean of Ratios TA KNOX/AXYS	95% Confidence Limits	
			Upper	Lower
1-Methylnaphthalene	19	0.67	0.87	0.52
1-Methylphenanthrene	25	0.77	1.11	0.53
2,3,5-Trimethylnaphthalene	19	0.45	0.66	0.30
2,6-Dimethylnaphthalene	20	0.57	0.82	0.40
2-Methylnaphthalene	23	0.82	1.09	0.61
Acenaphthene	25	0.66	0.93	0.47
Acenaphthylene	23	0.62	0.81	0.48
Anthracene	26	0.78	1.24	0.49
Benzo(a)anthracene	26	0.65	0.98	0.43
Benzo(a)pyrene	26	0.64	0.99	0.42
Benzo(b)fluoranthene	26	0.76	1.20	0.49
Benzo(E)pyrene	26	0.67	1.02	0.44
Benzo(g,h,i)perylene	26	0.62	0.94	0.40
Benzo(k)fluoranthene	26	0.58	0.89	0.38
C1-Phenanthrene/anthracenes	28	0.69	1.09	0.44
C2-NAPHTHALENES	27	0.54	0.80	0.36
C2-Phenanthrene/anthracenes	28	0.67	1.09	0.41
C3-NAPHTHALENE	26	0.56	0.85	0.37
C3-Phenanthrene/anthracenes	27	0.61	0.95	0.39
C4-NAPHTHALENE	22	0.43	0.66	0.27
C4-Phenanthrenes/anthracenes	27	0.11	0.18	0.07
Chrysene	26	0.68	1.03	0.45
Dibenzo(a,h)anthracene	25	0.72	0.92	0.56
Dibenzothiophene	20	0.69	1.08	0.44
Fluoranthene	26	0.51	0.74	0.36
Fluorene	23	0.82	1.29	0.53
Indeno(1,2,3-cd)pyrene	26	0.62	0.94	0.41
Naphthalene	23	0.81	0.97	0.68
Perylene	27	0.67	0.995	0.45
Phenanthrene	25	0.79	1.22	0.51
Pyrene	26	0.59	0.83	0.42
	Median	**0.66**		

Notes: Light shading indicates ratio is less than 1.0. Dark shading indicates ratio is significantly less than 1.0 (i.e., confidence interval does not include 1.0). All result values reported as below the corresponding laboratory's quantitation limit were excluded from calculations. TA KNOX results include only the methodology ID-0016.

ARCADIS

Table 2. Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for PAHs by AXYS Method MLA-021 Revision

Analyte	MLA-021 Rev 8 N	MLA-021 Rev 8 Geometric Mean of Ratios TA KNOX/AXYS (95%LCL, UCL)	MLA-021 Rev 9 N	MLA-021 Rev 9 Geometric Mean of Ratios TA KNOX/AXYS (95%LCL, UCL)
1-Methylnaphthalene	11	0.78 (0.56, 1.08)	8	0.55 (0.35, 0.87)
1-Methylphenanthrene	15	0.83 (0.46, 1.51)	10	0.69 (0.49, 0.97)
2,3,5-Trimethylnaphthalene	12	0.47 (0.25, 0.89)	7	0.4 (0.26, 0.64)
2,6-Dimethylnaphthalene	10	0.6 (0.31, 1.14)	10	0.55 (0.35, 0.86)
2-Methylnaphthalene	13	0.88 (0.61, 1.28)	10	0.74 (0.43, 1.27)
Acenaphthene	15	0.8 (0.49, 1.33)	10	0.48 (0.31, 0.76)
Acenaphthylene	13	0.77 (0.55, 1.07)	10	0.48 (0.31, 0.74)
Anthracene	16	0.94 (0.45, 1.94)	10	0.58 (0.38, 0.89)
Benzo(a)anthracene	16	0.71 (0.37, 1.4)	10	0.55 (0.39, 0.78)
Benzo(a)pyrene	16	0.7 (0.35, 1.41)	10	0.56 (0.39, 0.8)
Benzo(b)fluoranthene	16	0.91 (0.45, 1.84)	10	0.58 (0.38, 0.9)
Benzo(E)pyrene	16	0.76 (0.39, 1.48)	10	0.55 (0.38, 0.8)
Benzo(g,h,i)perylene	16	0.68 (0.34, 1.35)	10	0.53 (0.37, 0.76)
Benzo(k)fluoranthene	16	0.58 (0.29, 1.17)	10	0.59 (0.42, 0.83)
C1-Phenanthrene/anthracenes	16	0.76 (0.37, 1.56)	12	0.61 (0.34, 1.09)
C2-NAPHTHALENES	16	0.6 (0.33, 1.07)	11	0.46 (0.26, 0.83)
C2-Phenanthrene/anthracenes	16	0.71 (0.36, 1.41)	12	0.62 (0.28, 1.37)
C3-NAPHTHALENE	16	0.69 (0.36, 1.33)	10	0.4 (0.27, 0.6)
C3-Phenanthrene/anthracenes	16	0.63 (0.33, 1.22)	11	0.58 (0.3, 1.14)
C4-NAPHTHALENE	12	0.5 (0.23, 1.12)	10	0.35 (0.23, 0.53)
C4-Phenanthrenes/anthracenes	16	0.07 (0.04, 0.13)	11	0.2 (0.09, 0.48)
Chrysene	16	0.75 (0.39, 1.47)	10	0.57 (0.4, 0.82)
Dibenzo(a,h)anthracene	15	0.86 (0.62, 1.19)	10	0.55 (0.37, 0.81)
Dibenzothiophene	12	0.7 (0.33, 1.5)	8	0.67 (0.44, 1.03)
Fluoranthene	16	0.54 (0.31, 0.95)	10	0.47 (0.31, 0.71)
Fluorene	14	0.93 (0.46, 1.9)	9	0.68 (0.44, 1.08)
Indeno(1,2,3-cd)pyrene	16	0.69 (0.35, 1.34)	10	0.53 (0.37, 0.76)
Naphthalene	13	0.95 (0.76, 1.18)	10	0.66 (0.5, 0.88)
Perylene	16	0.93 (0.57, 1.52)	11	0.42 (0.22, 0.78)
Phenanthrene	15	0.93 (0.46, 1.91)	10	0.61 (0.43, 0.88)
Pyrene	16	0.67 (0.41, 1.12)	10	0.48 (0.32, 0.73)
Median	**0.71**		**0.55**	

Notes: Light shading indicates ratio is less than 1.0. Dark shading indicates ratio is significantly less than 1.0 (i.e., confidence interval does not include 1.0). N = number of pairs per method revision.

ARCADIS

Table 3. Geometric Means of 2008 Lower Passaic River TA KNOX/AXYS Ratios and Associated Confidence Intervals for Polychlorinated Biphenyls

Polychlorinated Biphenyls	Number of Pairs	Geometric Mean of Ratios TA_KNOX/AXYS	95% Confidence Limits	
			Upper	Lower
Monochlorobiphenyl	20	0.57	0.72	0.45
Dichlorobiphenyl	24	0.69	0.80	0.59
Trichlorobiphenyl	25	0.78	0.91	0.66
Tetrachlorobiphenyl	26	0.81	0.97	0.67
Pentachlorobiphenyl	26	0.79	0.99	0.63
Hexachlorobiphenyl	26	0.82	1.02	0.66
Heptachlorobiphenyl	24	0.83	1.10	0.64
Octachlorobiphenyl	24	0.78	1.06	0.57
Nonachlorobiphenyl	24	0.81	1.04	0.62
Decachlorobiphenyl (PCB-209)	24	0.92	1.08	0.79
MEDIAN (Homologue Groups)		**0.80**		
PCB-1	20	0.56	0.71	0.44
PCB-2	10	0.66	0.77	0.57
PCB-3	16	0.53	0.66	0.43
PCB-4	21	0.71	0.89	0.56
PCB-5	5	0.68	0.92	0.51
PCB-6	20	0.81	0.92	0.71
PCB-7	13	0.76	1.04	0.56
PCB-8	23	0.83	0.99	0.70
PCB-9	14	0.86	0.95	0.77
PCB-10	6	0.73	1.65	0.33
PCB-11	21	0.69	0.74	0.64
PCB-12 / PCB-13	20	0.65	0.73	0.58
PCB-15	23	0.62	0.71	0.53
PCB-16	23	0.84	1.02	0.69
PCB-17	23	0.86	1.04	0.71
PCB-18 / PCB-30	22	0.94	1.15	0.77
PCB-19	21	0.76	0.93	0.62
PCB-20 / PCB-28	23	0.77	0.91	0.65
PCB-21 / PCB-33	24	0.91	1.34	0.61
PCB-22	23	0.68	0.81	0.57
PCB-24	9	0.88	1.54	0.50
PCB-25	21	0.81	0.94	0.69
PCB-26 / PCB-29	22	0.74	0.87	0.63
PCB-27	21	0.85	1.03	0.70
PCB-31	23	0.79	0.95	0.66
PCB-32	23	0.84	0.99	0.70

Polychlorinated Biphenyls	Number of Pairs	Geometric Mean of Ratios TA_KNOX/AXYS	95% Confidence Limits	
			Upper	Lower
PCB-34	4	0.68	1.03	0.45
PCB-35	17	0.63	0.77	0.51
PCB-37	23	0.68	0.80	0.58
PCB-39	6	0.65	0.84	0.50
PCB-40 / PCB-41 / PCB-71	24	0.83	0.96	0.72
PCB-42	22	0.88	1.05	0.75
PCB-44 / PCB-47 / PCB-65	25	0.85	1.03	0.70
PCB-45 / PCB-51	21	0.87	1.04	0.73
PCB-46	21	0.85	0.99	0.72
PCB-48	22	0.84	1.01	0.70
PCB-49 / PCB-69	24	0.88	1.06	0.74
PCB-50 / PCB-53	21	0.80	0.94	0.68
PCB-52	25	0.87	1.08	0.70
PCB-54	8	0.76	0.85	0.69
PCB-55	16	1.04	1.55	0.70
PCB-56	22	0.76	0.94	0.62
PCB-57	6	0.83	1.03	0.68
PCB-58	4	0.83	1.35	0.52
PCB-59 / PCB-62 / PCB-75	21	0.83	0.97	0.71
PCB-60	22	0.78	0.98	0.62
PCB-61 / PCB-70 / PCB-74 / PCB-76	24	0.80	1.01	0.64
PCB-63	20	0.73	0.90	0.59
PCB-64	23	0.82	0.99	0.68
PCB-66	25	0.82	0.99	0.69
PCB-67	19	0.81	0.98	0.66
PCB-68	8	0.88	1.08	0.72
PCB-72	13	0.87	1.06	0.72
PCB-77	21	0.68	0.82	0.57
PCB-79	8	0.44	0.98	0.20
PCB-82	22	0.87	1.12	0.68
PCB-83 / PCB-99	24	0.84	1.08	0.65
PCB-84	22	0.79	1.03	0.60
PCB-85 / PCB-116 / PCB-117	23	0.78	1.01	0.61
PCB-86 / PCB-87 / PCB-97 / PCB-119 / PCB-125	24	0.83	1.06	0.64
PCB-88 / PCB-91	23	0.79	0.999	0.62
PCB-89	12	0.67	1.02	0.44
PCB-90 / PCB-101 / PCB-113	24	0.83	1.06	0.65
PCB-92	23	0.77	0.98	0.60

Polychlorinated Biphenyls	Number of Pairs	Geometric Mean of Ratios TA_KNOX/AXYS	95% Confidence Limits	
			Upper	Lower
PCB-94	11	0.59	0.94	0.37
PCB-96	11	0.69	1.08	0.44
PCB-103	14	0.74	1.09	0.50
PCB-104	5	0.74	1.85	0.29
PCB-105	23	0.76	0.98	0.59
PCB-110 / PCB-115	24	0.87	1.11	0.68
PCB-114	18	0.79	1.10	0.57
PCB-118	23	0.82	1.06	0.64
PCB-120	2	1.08	1.57	0.73
PCB-122	13	0.94	1.46	0.60
PCB-123	14	0.72	1.11	0.46
PCB-128 / PCB-166	23	0.94	1.26	0.71
PCB-129 / PCB-138 / PCB-160 / PCB-163	24	0.90	1.13	0.72
PCB-130	21	0.83	1.06	0.65
PCB-131	10	0.76	1.34	0.43
PCB-132	24	0.83	1.03	0.67
PCB-133	16	0.82	1.13	0.60
PCB-134 / PCB-143	21	0.92	1.18	0.72
PCB-136	24	0.77	0.98	0.61
PCB-137	21	0.80	1.05	0.62
PCB-139 / PCB-140	16	0.79	1.14	0.56
PCB-141	24	0.92	1.14	0.74
PCB-144	21	0.71	0.93	0.54
PCB-146	24	0.88	1.09	0.72
PCB-147 / PCB-149	24	0.88	1.10	0.70
PCB-148	3	1.26	11.74	0.14
PCB-150	4	1.05	4.08	0.27
PCB-152	3	1.60	25.08	0.10
PCB-153 / PCB-168	24	0.87	1.08	0.69
PCB-155	10	0.73	0.99	0.54
PCB-156 / PCB-157	23	0.75	0.96	0.59
PCB-158	23	0.88	1.11	0.70
PCB-159	7	0.56	1.48	0.22
PCB-162	1	1.16	NA	NA
PCB-164	21	0.86	1.11	0.67
PCB-167	21	0.70	0.91	0.53
PCB-170	24	0.90	1.17	0.70
PCB-171 / PCB-173	22	0.81	1.08	0.60

Polychlorinated Biphenyls	Number of Pairs	Geometric Mean of Ratios TA_KNOX/AXYS	95% Confidence Limits	
			Upper	Lower
PCB-172	23	0.80	1.07	0.60
PCB-174	24	0.84	1.10	0.65
PCB-175	10	0.69	1.40	0.34
PCB-176	23	0.79	1.05	0.59
PCB-177	24	0.81	1.06	0.62
PCB-178	23	0.80	1.08	0.59
PCB-179	24	0.88	1.15	0.67
PCB-180 / PCB-193	24	0.86	1.14	0.65
PCB-182	1	1.02	NA	NA
PCB-183 / PCB-185	24	0.82	1.09	0.61
PCB-184	1	1.00	NA	NA
PCB-187	24	0.80	1.05	0.60
PCB-189	8	0.74	1.83	0.30
PCB-190	23	0.78	1.04	0.58
PCB-191	9	0.81	1.79	0.36
PCB-194	24	0.87	1.17	0.65
PCB-195	23	0.86	1.18	0.62
PCB-196	23	0.72	1.005	0.51
PCB-198 / PCB-199	24	0.77	1.04	0.57
PCB-202	24	0.75	0.98	0.58
PCB-203	24	0.74	1.02	0.54
PCB-205	8	1.10	1.97	0.61
PCB-206	24	0.86	1.11	0.66
PCB-207	12	0.68	1.24	0.37
PCB-208	20	0.71	0.95	0.53
Median (Congeners)		**0.81**		

Notes: Light shading indicates ratio is less than 1.0. Dark shading indicates ratio is significantly less than 1.0 (i.e., confidence interval does not include 1.0). All result values reported as below the corresponding laboratory's quantitation limit were excluded from calculations. Co-elutions that differed among laboratories were excluded as they are not comparable.

ARCADIS

Table 4. Correction Factors for Polycyclic Aromatic Hydrocarbon Data if Calculated by Methodology in CSC Report for Dioxin Congeners

Polycyclic Aromatic Hydrocarbons	N	Correction Factor*: Geometric Mean of Ratio AXYS/TA KNOX	95% Confidence Limits	
			Lower	Upper
1-Methylnaphthalene	19	1.49	1.16	1.92
1-Methylphenanthrene	25	1.30	0.90	1.87
2,3,5-Trimethylnaphthalene	19	2.24	1.50	3.33
2,6-Dimethylnaphthalene	20	1.75	1.22	2.50
2-Methylnaphthalene	23	1.22	0.92	1.64
Acenaphthene	25	1.52	1.08	2.15
Acenaphthylene	23	1.60	1.23	2.09
Anthracene	26	1.28	0.81	2.03
Benzo(a)anthracene	26	1.54	1.02	2.34
Benzo(a)pyrene	26	1.56	1.01	2.39
Benzo(b)fluoranthene	26	1.31	0.83	2.05
Benzo(E)pyrene	26	1.49	0.98	2.26
Benzo(g,h,i)perylene	26	1.62	1.06	2.48
Benzo(k)fluoranthene	26	1.71	1.12	2.62
C1-Phenanthrene/anthracenes	28	1.45	0.92	2.28
C2-NAPHTHALENES	27	1.86	1.25	2.76
C2-Phenanthrene/anthracenes	28	1.50	0.92	2.44
C3-NAPHTHALENE	26	1.79	1.17	2.73
C3-Phenanthrene/anthracenes	27	1.63	1.05	2.54
C4-NAPHTHALENE	22	2.34	1.51	3.65
C4-Phenanthrenes/anthracenes	27	9.11	5.52	15.04
Chrysene	26	1.47	0.97	2.23
Dibenzo(a,h)anthracene	25	1.39	1.08	1.79
Dibenzothiophene	20	1.45	0.92	2.27
Fluoranthene	26	1.95	1.36	2.79
Fluorene	23	1.21	0.78	1.89
Indeno(1,2,3-cd)pyrene	26	1.60	1.06	2.42
Naphthalene	23	1.23	1.03	1.47
Perylene	27	1.49	1.00	2.21
Phenanthrene	25	1.27	0.82	1.96
Pyrene	26	1.69	1.21	2.37
	Median	**1.52**		

***Correction factors calculated using the same method as for dioxin/furan congeners in CSC, 2011. Light shading indicates correction factor is greater than 1.0. Dark shading indicates correction factor is significantly greater than 1.0 (i.e., confidence interval does not include 1.0).**

ARCADIS

Table 5. Correction Factors for Polychlorinated Biphenyls Data if Calculated by Methodology in CSC Report for Dioxin Congeners

Polychlorinated Biphenyls	N	Correction Factor*: Geometric Mean of Ratios AXYS/TA_KNOX	95% Confidence Limits	
			Lower	Upper
Monochlorobiphenyl	20	1.75	1.39	2.21
Dichlorobiphenyl	24	1.45	1.25	1.68
Trichlorobiphenyl	25	1.29	1.10	1.51
Tetrachlorobiphenyl	26	1.24	1.03	1.49
Pentachlorobiphenyl	26	1.27	1.01	1.60
Hexachlorobiphenyl	26	1.22	0.98	1.51
Heptachlorobiphenyl	24	1.20	0.91	1.57
Octachlorobiphenyl	24	1.28	0.94	1.74
Nonachlorobiphenyl	24	1.24	0.96	1.61
Decachlorobiphenyl (PCB-209)	24	1.08	0.92	1.27
MEDIAN(Homologue Groups)		**1.26**		
PCB-1	20	1.79	1.40	2.29
PCB-2	10	1.51	1.30	1.75
PCB-3	16	1.88	1.51	2.33
PCB-4	21	1.41	1.13	1.77
PCB-5	5	1.46	1.09	1.96
PCB-6	20	1.23	1.08	1.40
PCB-7	13	1.31	0.96	1.78
PCB-8	23	1.21	1.01	1.44
PCB-9	14	1.17	1.05	1.30
PCB-10	6	1.36	0.61	3.08
PCB-11	21	1.45	1.34	1.56
PCB-12 / PCB-13	20	1.53	1.36	1.73
PCB-15	23	1.62	1.41	1.87
PCB-16	23	1.19	0.98	1.45
PCB-17	23	1.16	0.96	1.40
PCB-18 / PCB-30	22	1.06	0.87	1.30
PCB-19	21	1.32	1.08	1.61
PCB-20 / PCB-28	23	1.30	1.10	1.54
PCB-21 / PCB-33	24	1.10	0.75	1.63
PCB-22	23	1.48	1.23	1.77
PCB-24	9	1.14	0.65	2.00
PCB-25	21	1.24	1.06	1.45
PCB-26 / PCB-29	22	1.36	1.15	1.60
PCB-27	21	1.18	0.97	1.44
PCB-31	23	1.27	1.06	1.52

Polychlorinated Biphenyls	N	Correction Factor*: Geometric Mean of Ratios AXYS/TA_KNOX	95% Confidence Limits	
			Lower	Upper
PCB-32	23	1.20	1.01	1.42
PCB-34	4	1.46	0.97	2.20
PCB-35	17	1.59	1.31	1.95
PCB-37	23	1.46	1.24	1.72
PCB-39	6	1.55	1.19	2.00
PCB-40 / PCB-41 / PCB-71	24	1.20	1.04	1.40
PCB-42	22	1.13	0.96	1.34
PCB-44 / PCB-47 / PCB-65	25	1.18	0.97	1.43
PCB-45 / PCB-51	21	1.14	0.96	1.36
PCB-46	21	1.18	1.01	1.38
PCB-48	22	1.19	0.99	1.43
PCB-49 / PCB-69	24	1.13	0.94	1.36
PCB-50 / PCB-53	21	1.25	1.06	1.46
PCB-52	25	1.15	0.92	1.44
PCB-54	8	1.31	1.18	1.46
PCB-55	16	0.96	0.65	1.42
PCB-56	22	1.32	1.07	1.62
PCB-57	6	1.20	0.97	1.48
PCB-58	4	1.20	0.74	1.94
PCB-59 / PCB-62 / PCB-75	21	1.21	1.04	1.40
PCB-60	22	1.28	1.02	1.61
PCB-61 / PCB-70 / PCB-74 / PCB-76	24	1.25	0.99	1.57
PCB-63	20	1.38	1.11	1.71
PCB-64	23	1.21	1.01	1.46
PCB-66	25	1.21	1.01	1.45
PCB-67	19	1.24	1.02	1.51
PCB-68	8	1.13	0.92	1.39
PCB-72	13	1.15	0.94	1.39
PCB-77	21	1.46	1.22	1.76
PCB-79	8	2.25	1.02	4.97
PCB-82	22	1.15	0.89	1.48
PCB-83 / PCB-99	24	1.20	0.93	1.54
PCB-84	22	1.27	0.97	1.67
PCB-85 / PCB-116 / PCB-117	23	1.28	0.99	1.65
PCB-86 / PCB-87 / PCB-97 / PCB-119 / PCB-125	24	1.21	0.94	1.56
PCB-88 / PCB-91	23	1.27	1.001	1.62
PCB-89	12	1.50	0.98	2.29

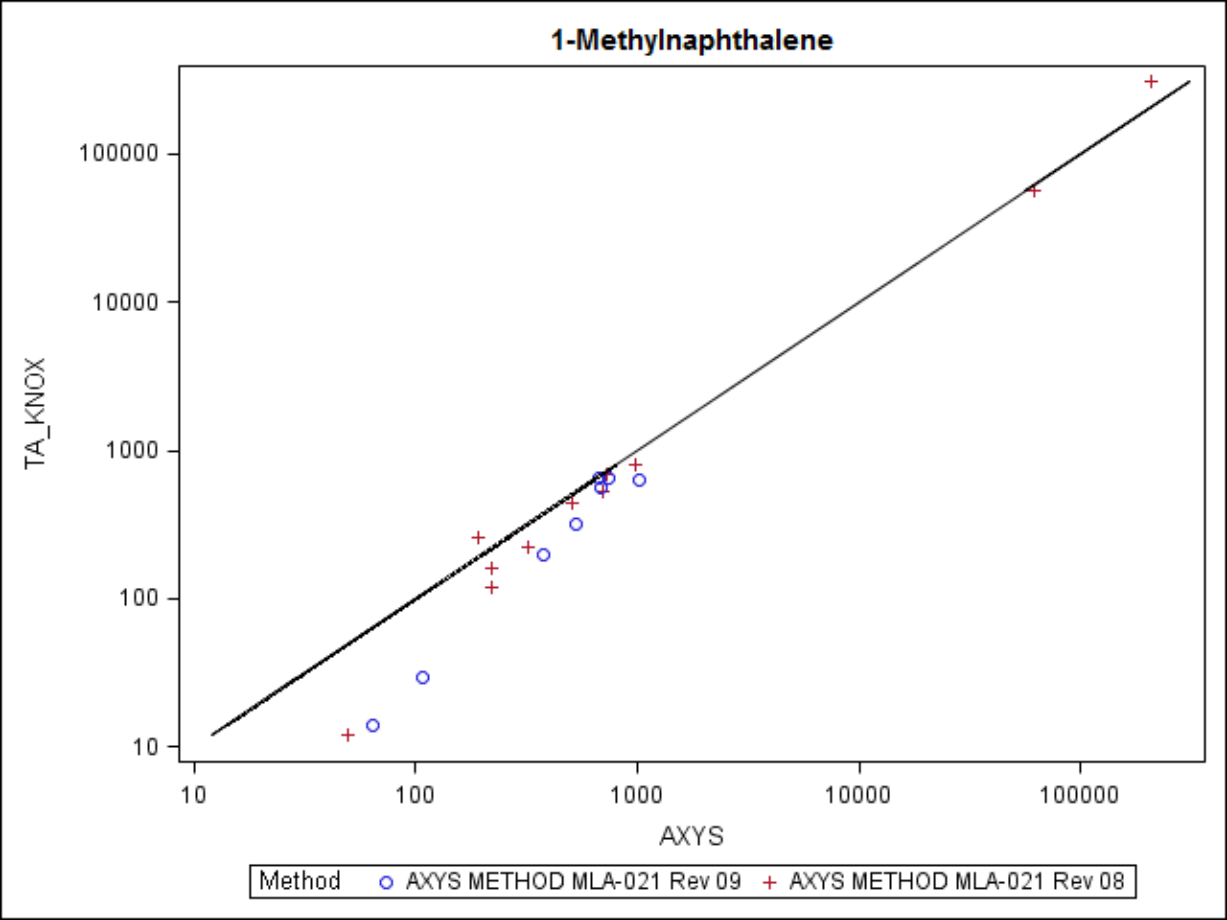
Polychlorinated Biphenyls	N	Correction Factor*: Geometric Mean of Ratios AXYS/TA_KNOX	95% Confidence Limits	
			Lower	Upper
PCB-90 / PCB-101 / PCB-113	24	1.21	0.95	1.55
PCB-92	23	1.31	1.02	1.68
PCB-94	11	1.69	1.07	2.67
PCB-96	11	1.46	0.93	2.29
PCB-103	14	1.35	0.92	2.00
PCB-104	5	1.36	0.54	3.40
PCB-105	23	1.32	1.02	1.69
PCB-110 / PCB-115	24	1.15	0.90	1.46
PCB-114	18	1.27	0.91	1.76
PCB-118	23	1.22	0.94	1.57
PCB-120	2	0.93	0.64	1.36
PCB-122	13	1.07	0.69	1.66
PCB-123	14	1.40	0.90	2.16
PCB-128 / PCB-166	23	1.06	0.79	1.42
PCB-129 / PCB-138 / PCB-160 / PCB-163	24	1.11	0.89	1.38
PCB-130	21	1.20	0.94	1.53
PCB-131	10	1.31	0.75	2.31
PCB-132	24	1.21	0.97	1.50
PCB-133	16	1.22	0.89	1.67
PCB-134 / PCB-143	21	1.08	0.84	1.39
PCB-136	24	1.29	1.02	1.63
PCB-137	21	1.24	0.95	1.62
PCB-139 / PCB-140	16	1.26	0.88	1.80
PCB-141	24	1.09	0.88	1.34
PCB-144	21	1.41	1.08	1.85
PCB-146	24	1.13	0.92	1.40
PCB-147 / PCB-149	24	1.14	0.91	1.43
PCB-148	3	0.79	0.09	7.34
PCB-150	4	0.95	0.25	3.71
PCB-152	3	0.63	0.04	9.83
PCB-153 / PCB-168	24	1.16	0.93	1.44
PCB-155	10	1.37	1.02	1.84
PCB-156 / PCB-157	23	1.34	1.05	1.71
PCB-158	23	1.13	0.90	1.43
PCB-159	7	1.77	0.68	4.65
PCB-162	1	0.87	NA	NA
PCB-164	21	1.16	0.90	1.48
PCB-167	21	1.43	1.10	1.87

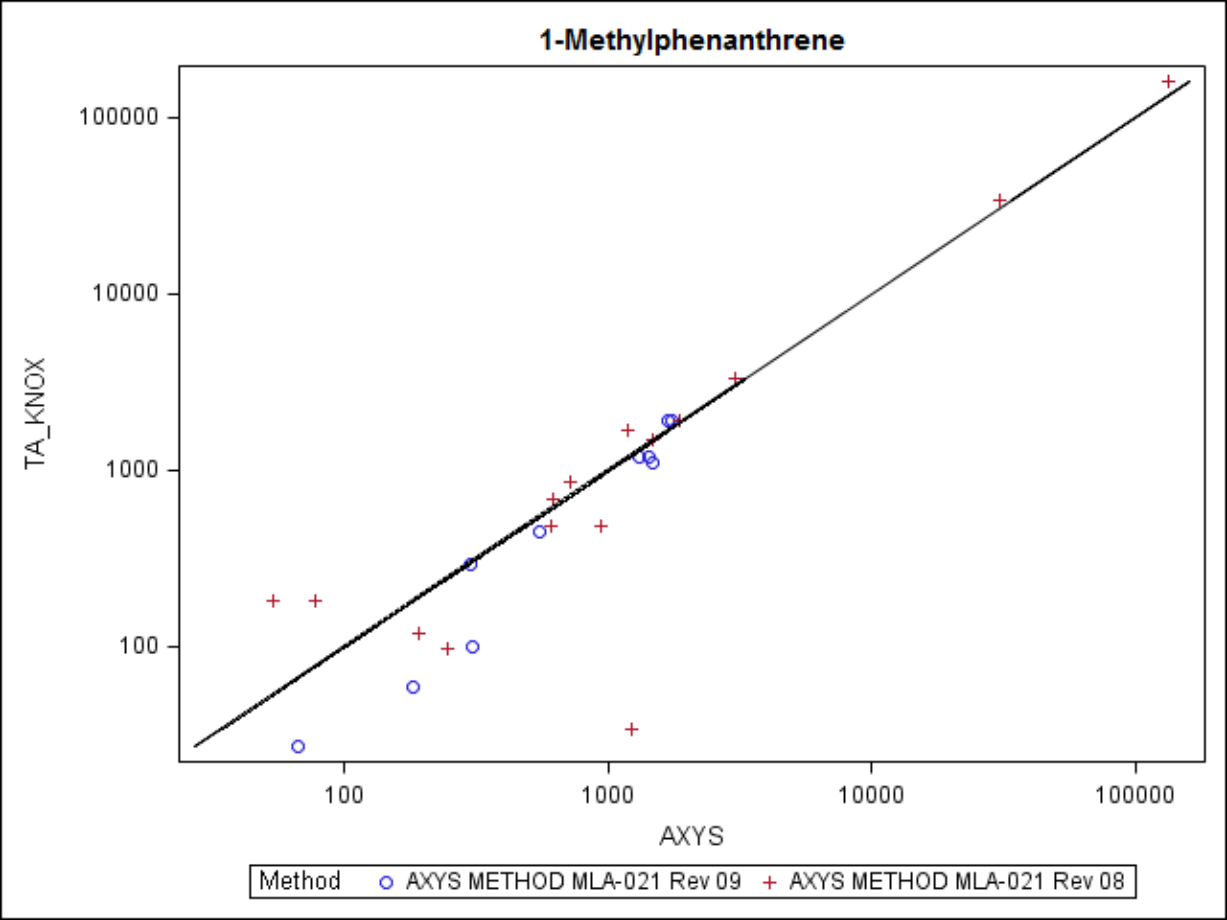
Polychlorinated Biphenyls	N	Correction Factor*: Geometric Mean of Ratios AXYS/TA_KNOX	95% Confidence Limits	
			Lower	Upper
PCB-170	24	1.11	0.85	1.44
PCB-171 / PCB-173	22	1.24	0.93	1.66
PCB-172	23	1.24	0.93	1.66
PCB-174	24	1.19	0.91	1.55
PCB-175	10	1.44	0.71	2.93
PCB-176	23	1.27	0.95	1.69
PCB-177	24	1.24	0.95	1.61
PCB-178	23	1.25	0.93	1.68
PCB-179	24	1.14	0.87	1.49
PCB-180 / PCB-193	24	1.17	0.88	1.55
PCB-182	1	0.98	NA	NA
PCB-183 / PCB-185	24	1.23	0.92	1.64
PCB-184	1	1.00	NA	NA
PCB-187	24	1.25	0.95	1.65
PCB-189	8	1.36	0.55	3.37
PCB-190	23	1.28	0.96	1.71
PCB-191	9	1.24	0.56	2.75
PCB-194	24	1.15	0.85	1.54
PCB-195	23	1.17	0.85	1.60
PCB-196	23	1.39	0.995	1.94
PCB-198 / PCB-199	24	1.30	0.96	1.77
PCB-202	24	1.33	1.02	1.72
PCB-203	24	1.35	0.98	1.85
PCB-205	8	0.91	0.51	1.64
PCB-206	24	1.17	0.90	1.52
PCB-207	12	1.47	0.81	2.69
PCB-208	20	1.41	1.06	1.88
Median (Congeners)		**1.24**		

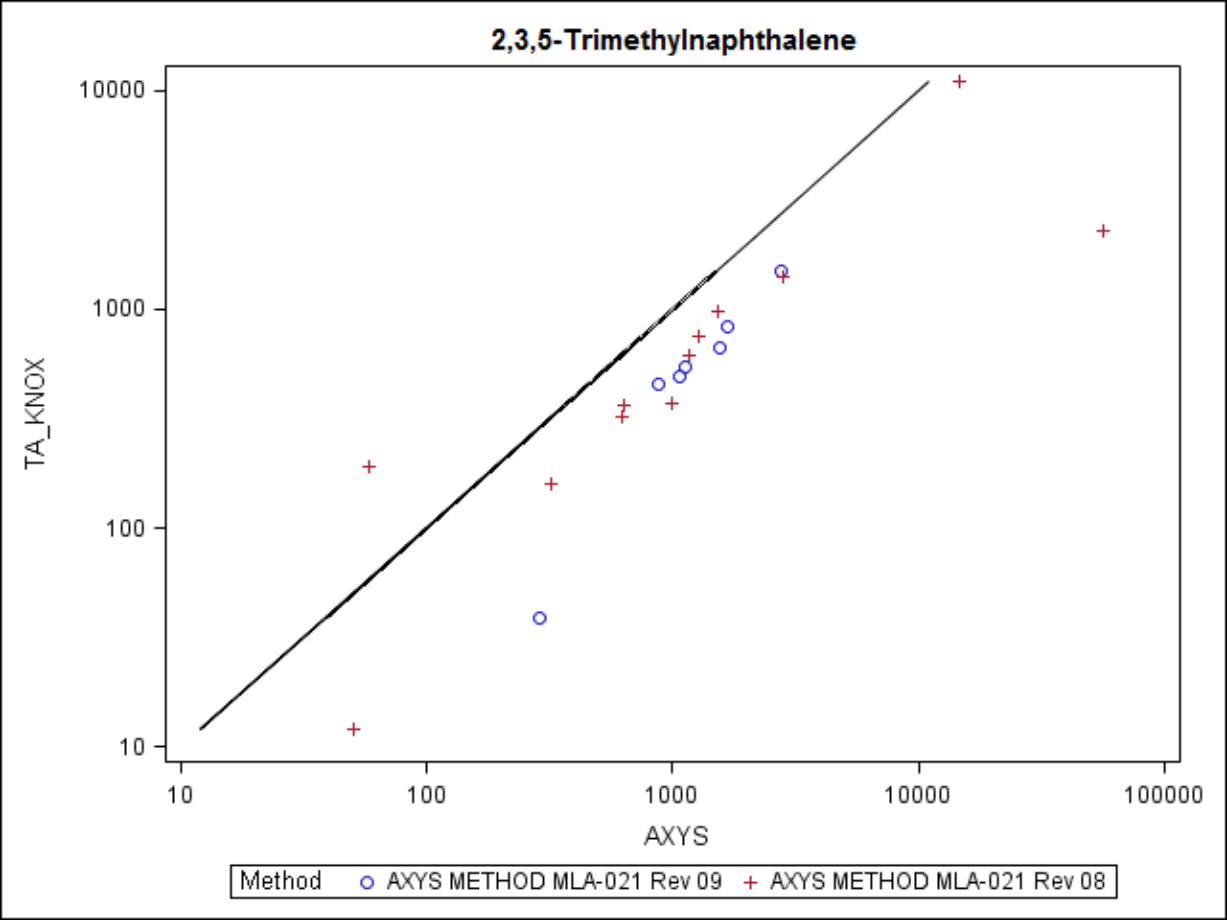
***Correction factors calculated using the same method as for dioxin/furan congeners in CSC, 2011. Light shading indicates correction factor is greater than 1.0. Dark shading indicates correction factor is significantly greater than 1.0 (i.e., confidence interval does not include 1.0).**

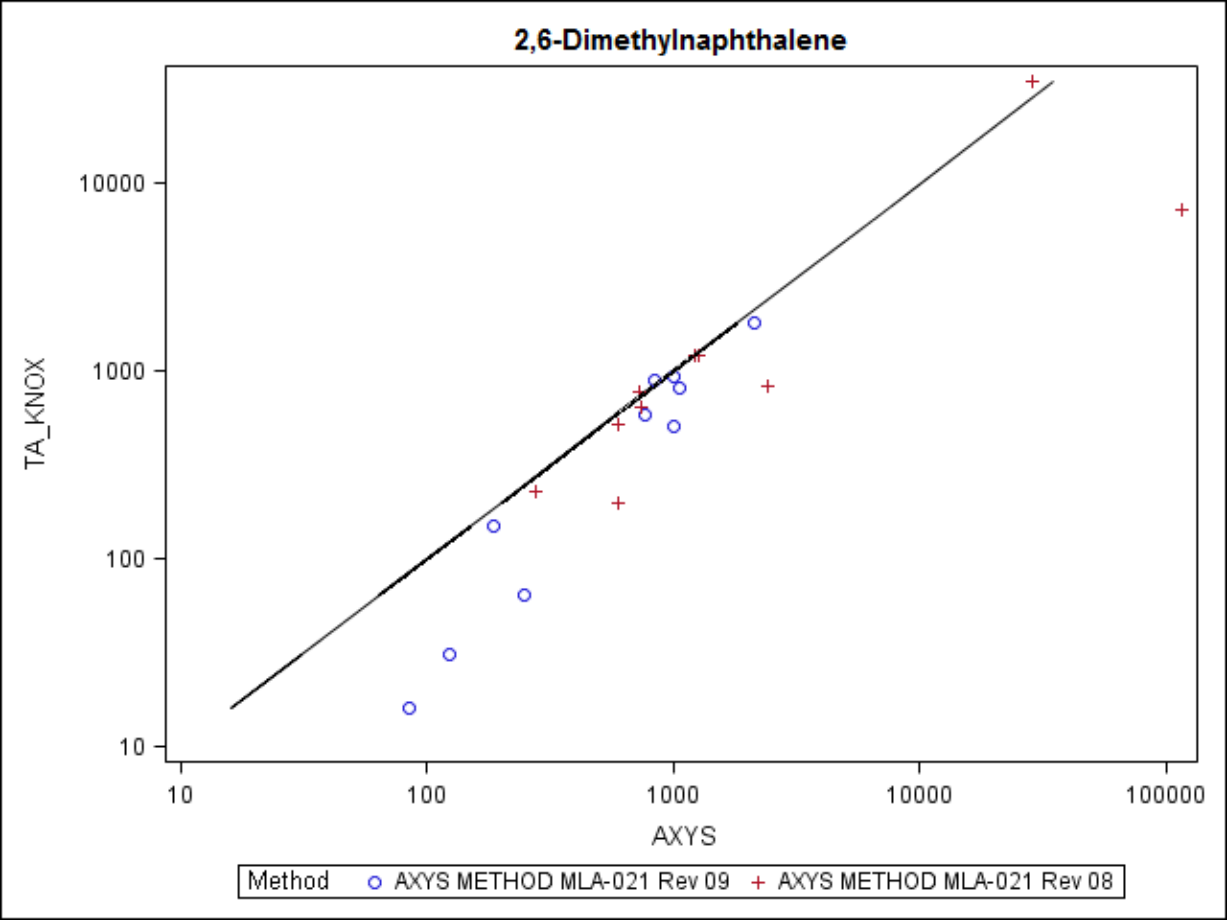
Attachment 1

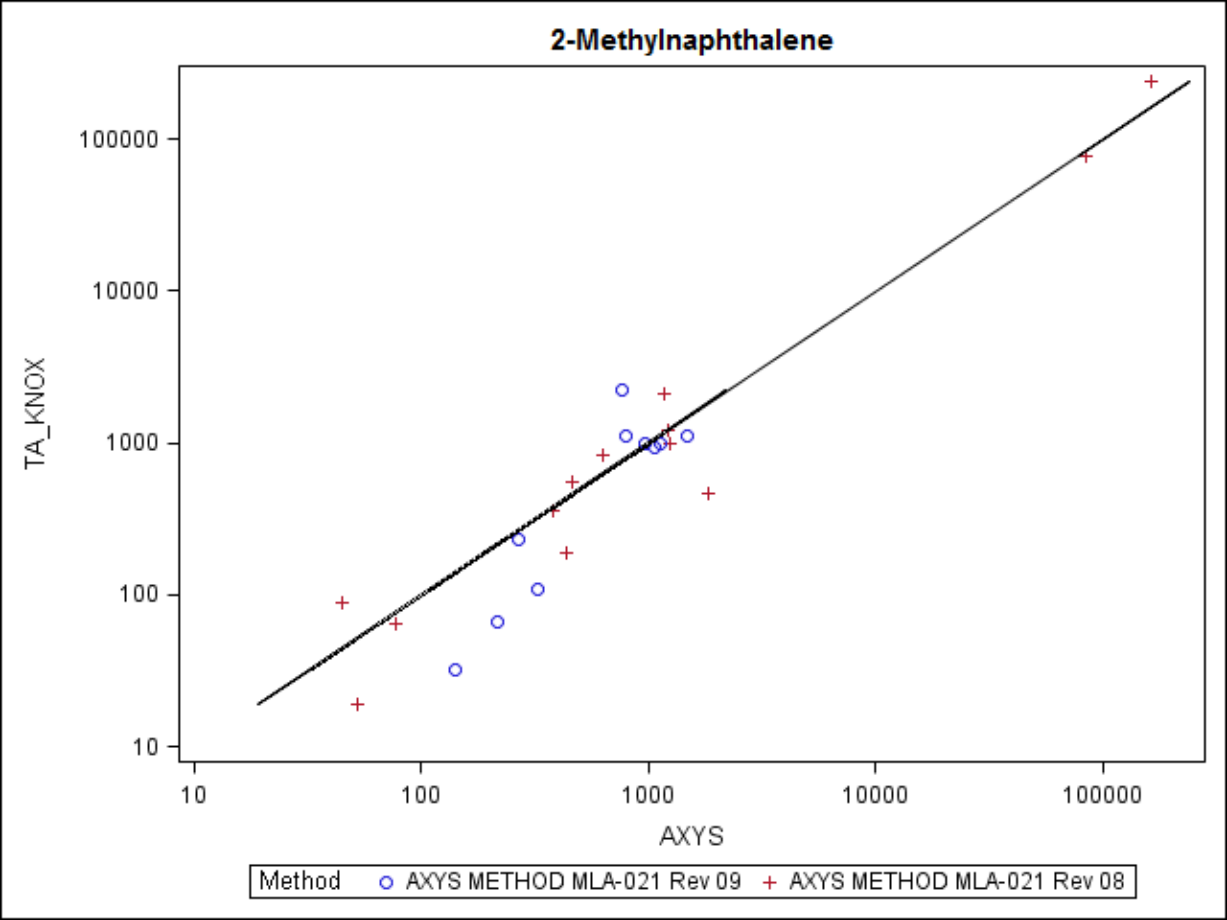
Log PAH Agreement Plots by Laboratory

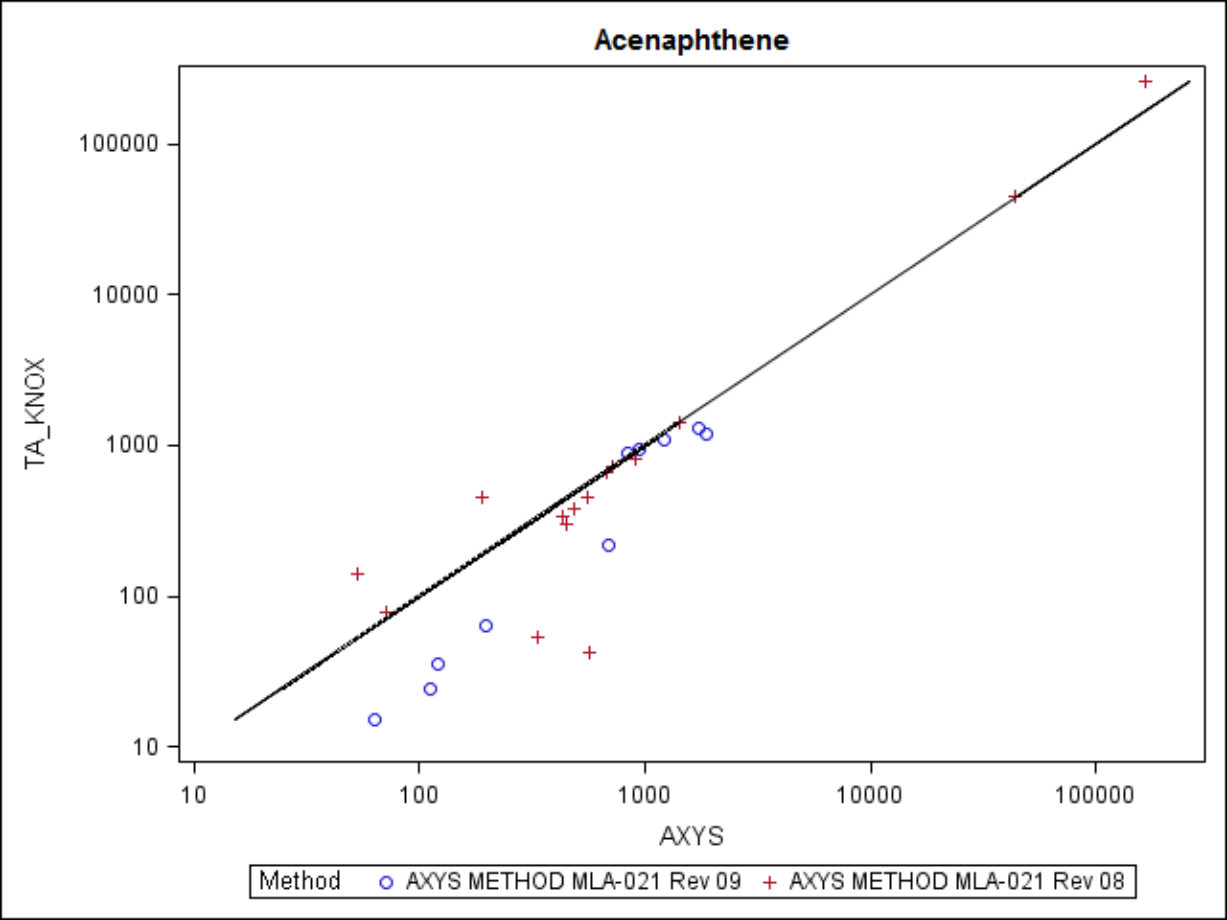

1-Methylnaphthalene
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

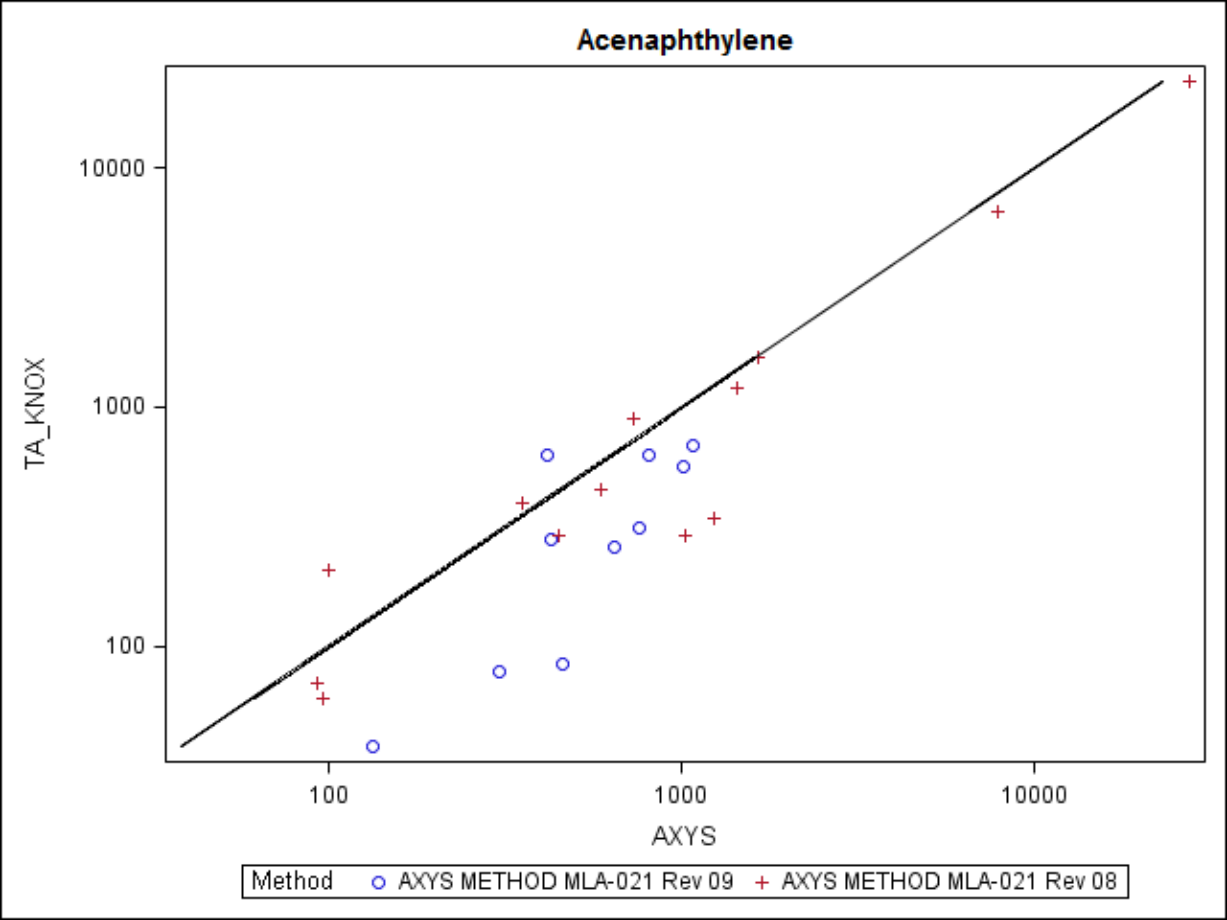

1-Methylphenanthrene
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

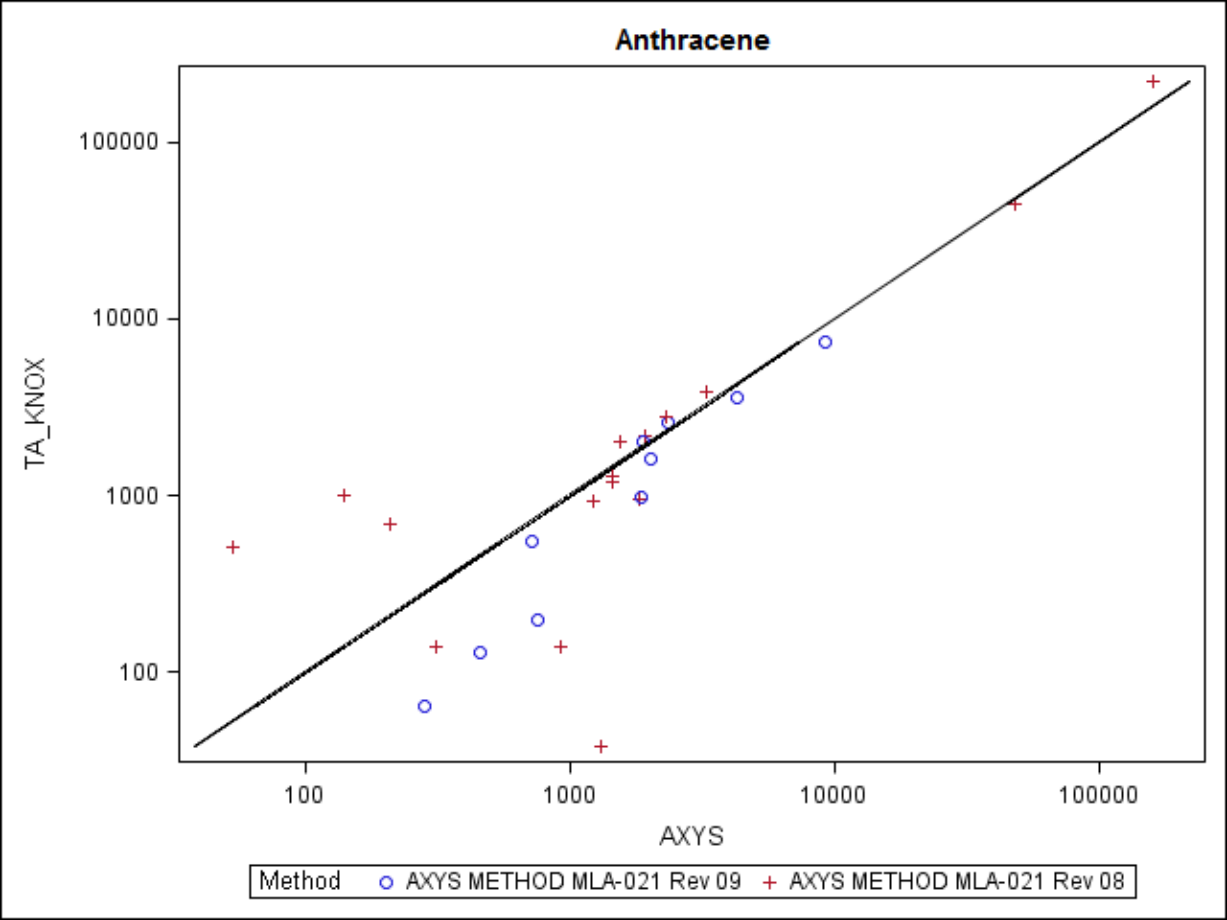

2,3,5-Trimethylnaphthalene
10000
1000
100
10
TA_KNOX
10
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

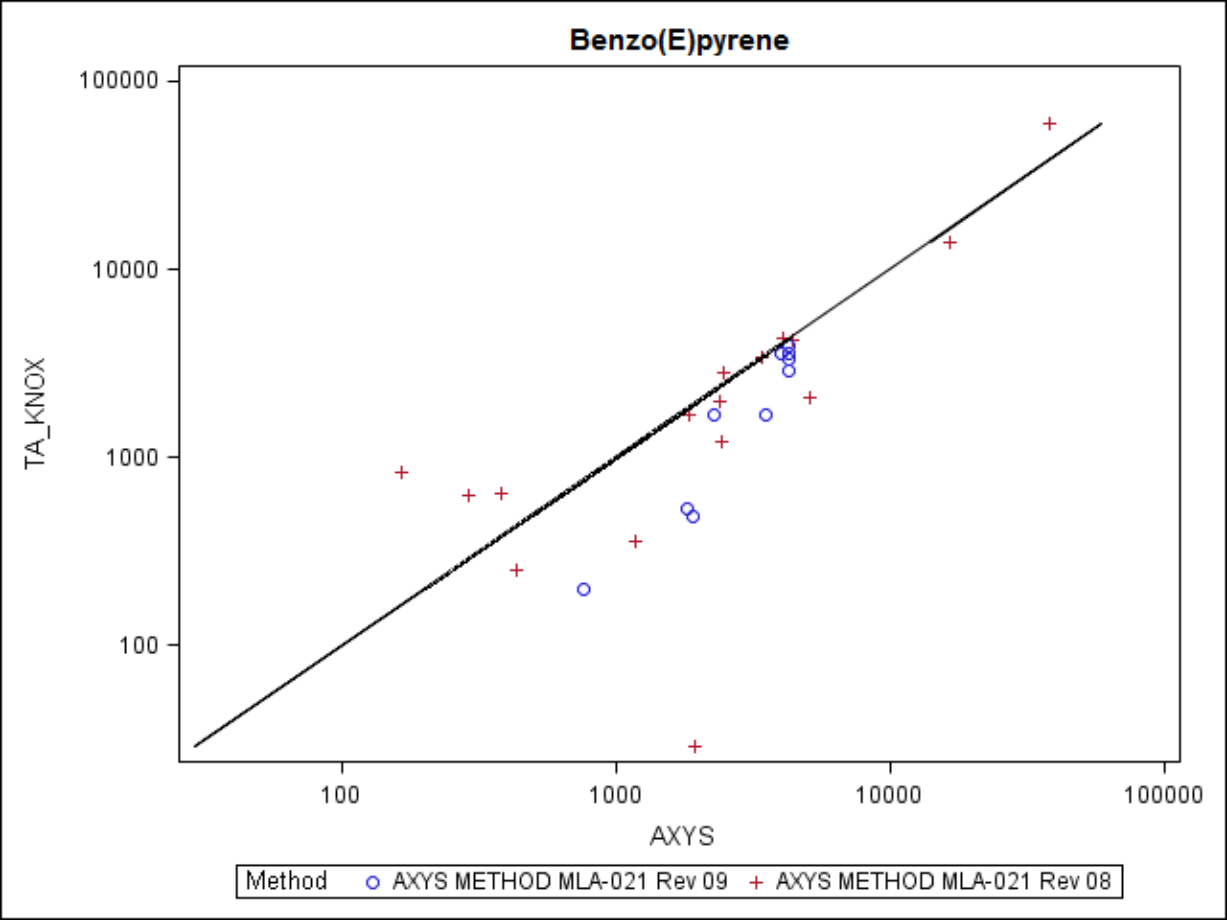

2,6-Dimethylnaphthalene
TA_KNOX
10000
1000
100
10
10
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

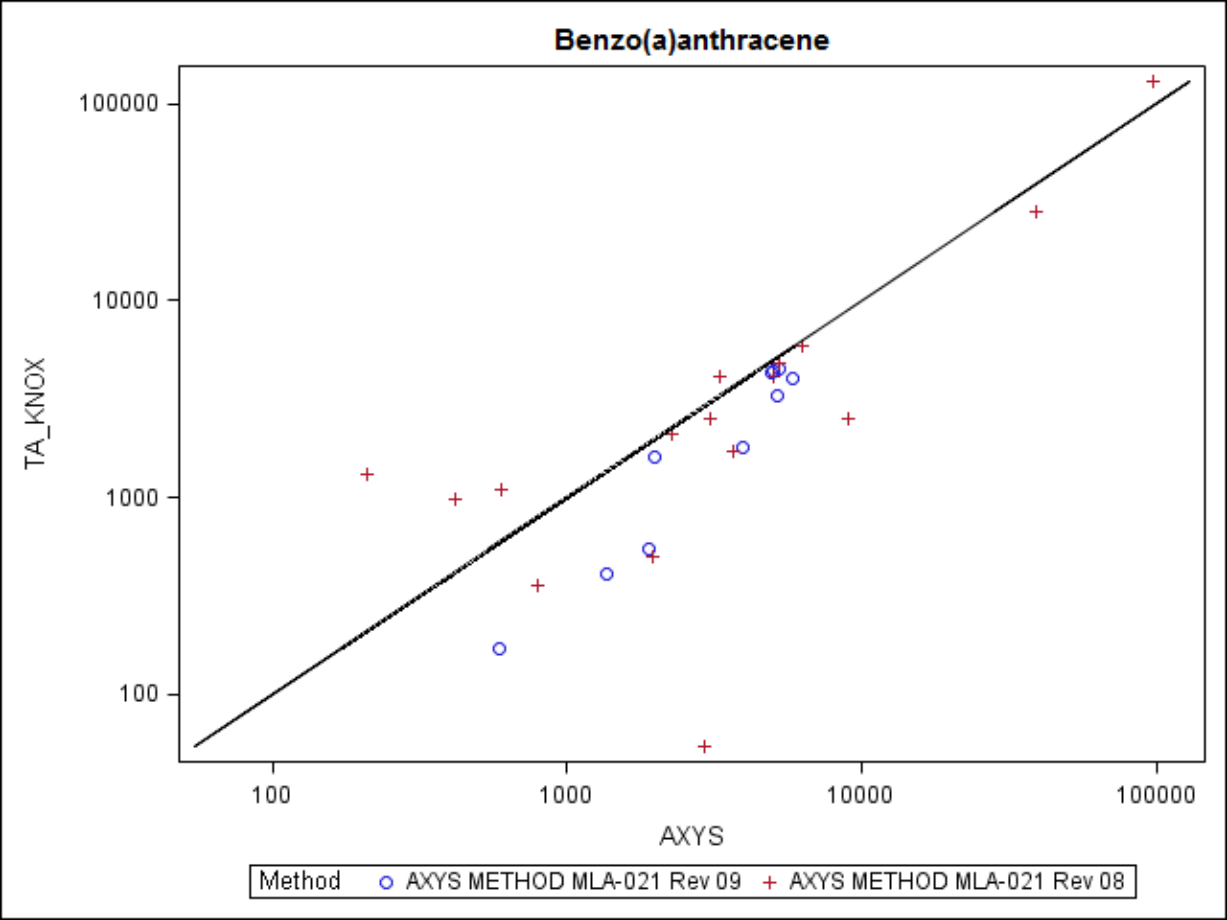

2-Methylnaphthalene
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

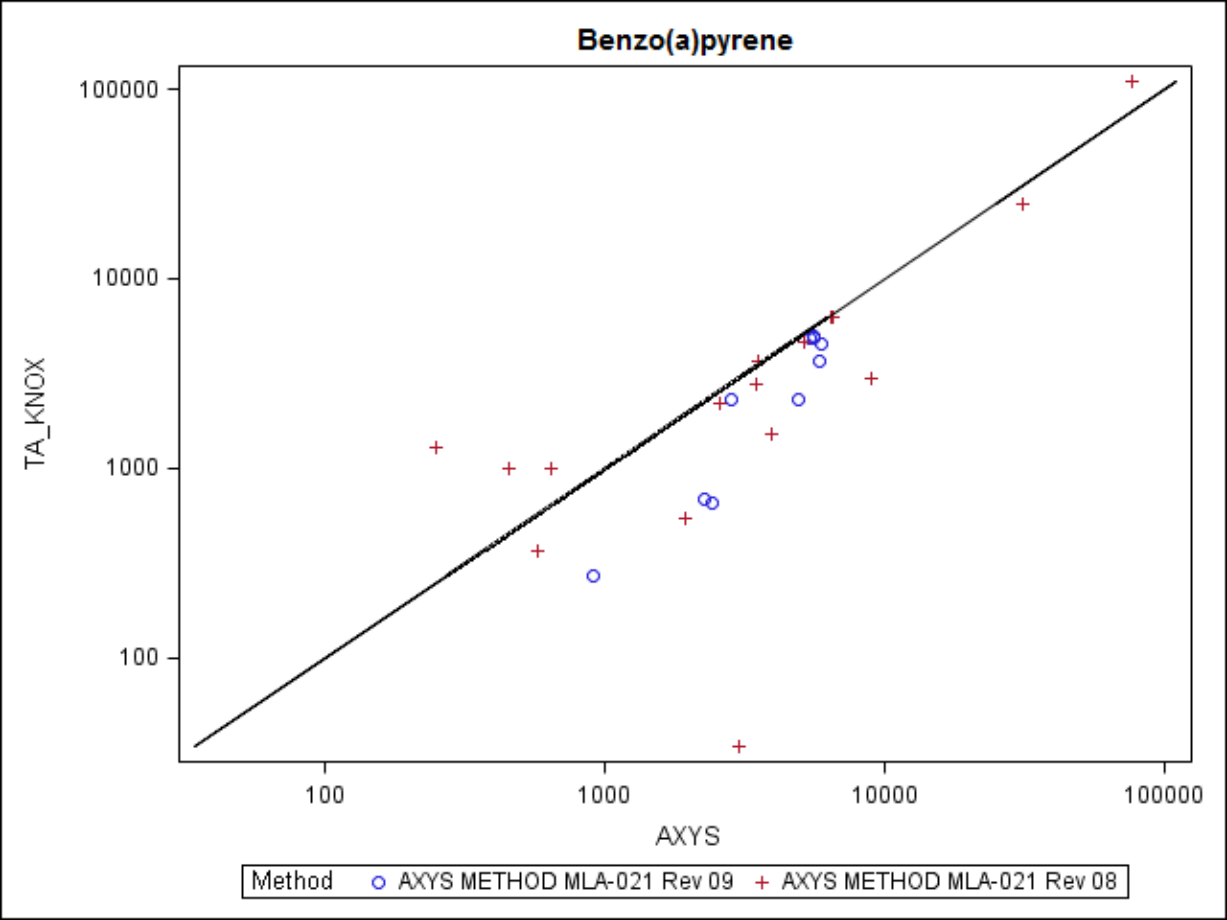

Acenaphthene
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

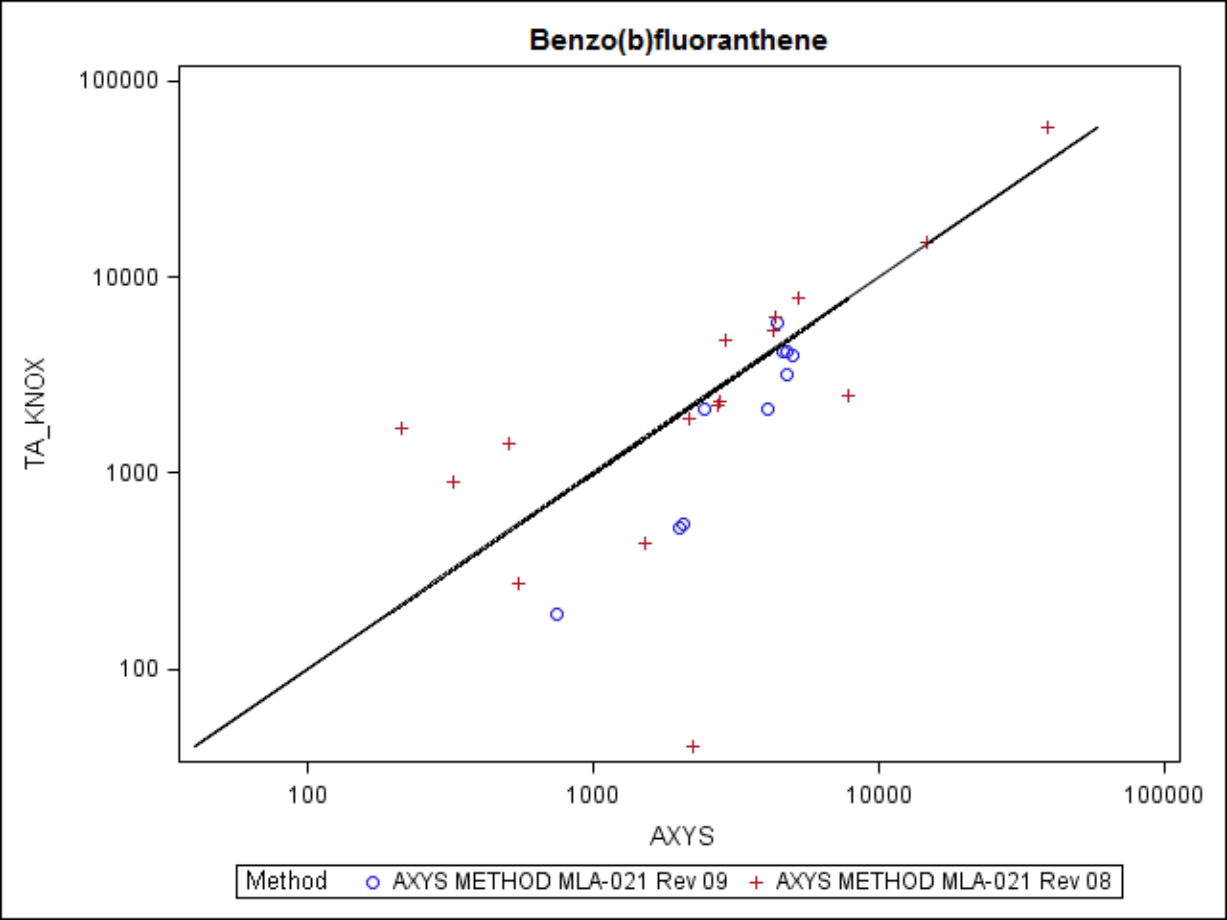

Acenaphthylene
TA_KNOX
10000
1000
100
100
1000
10000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

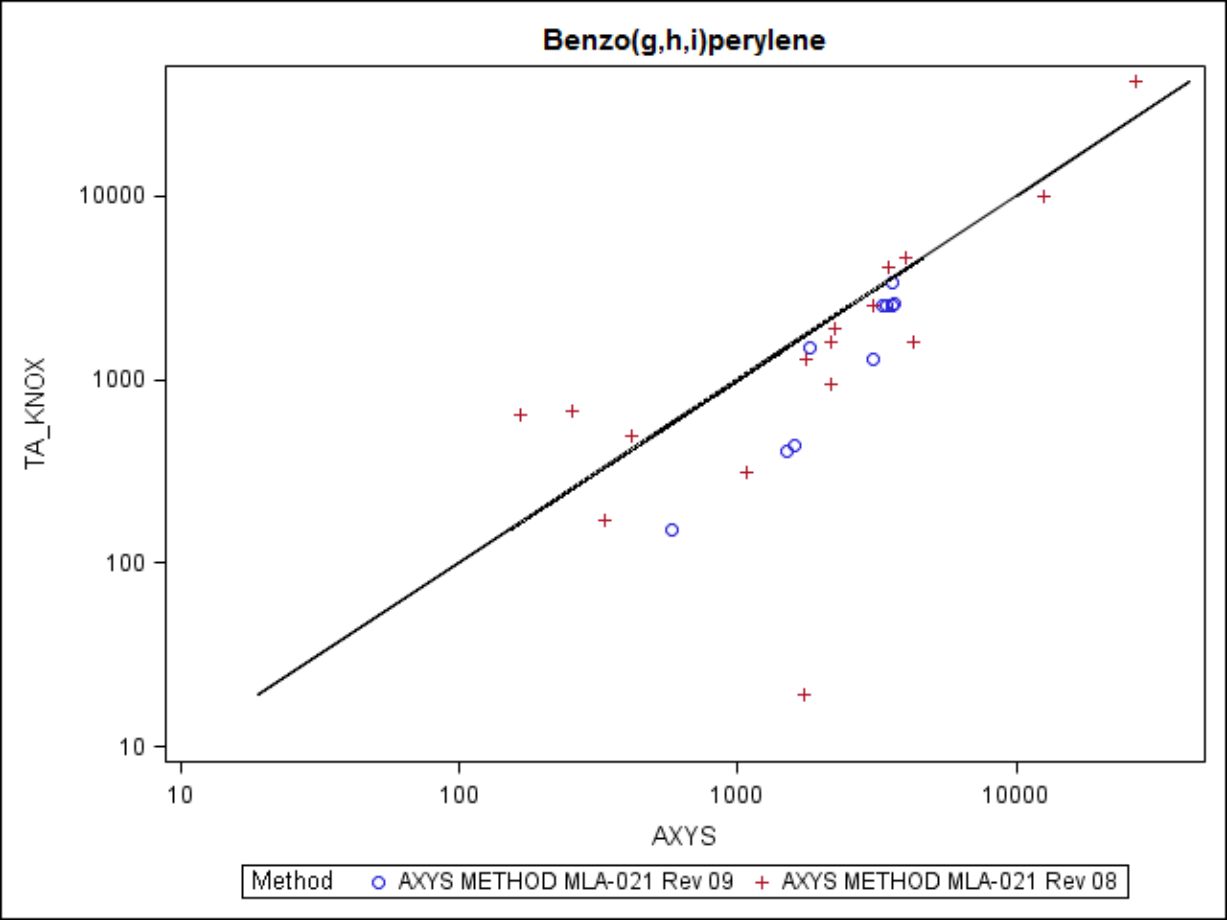

Anthracene
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

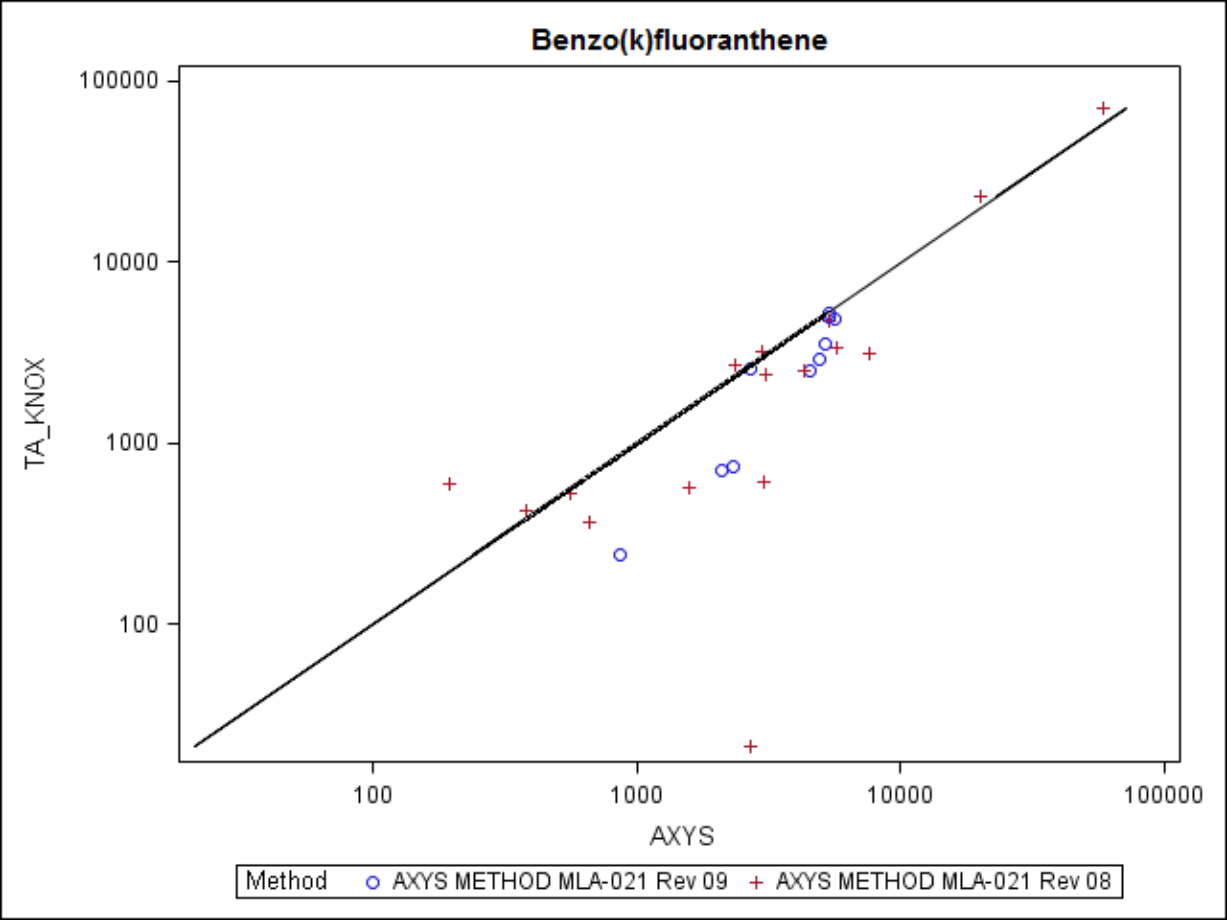

Benzo(E)pyrene
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

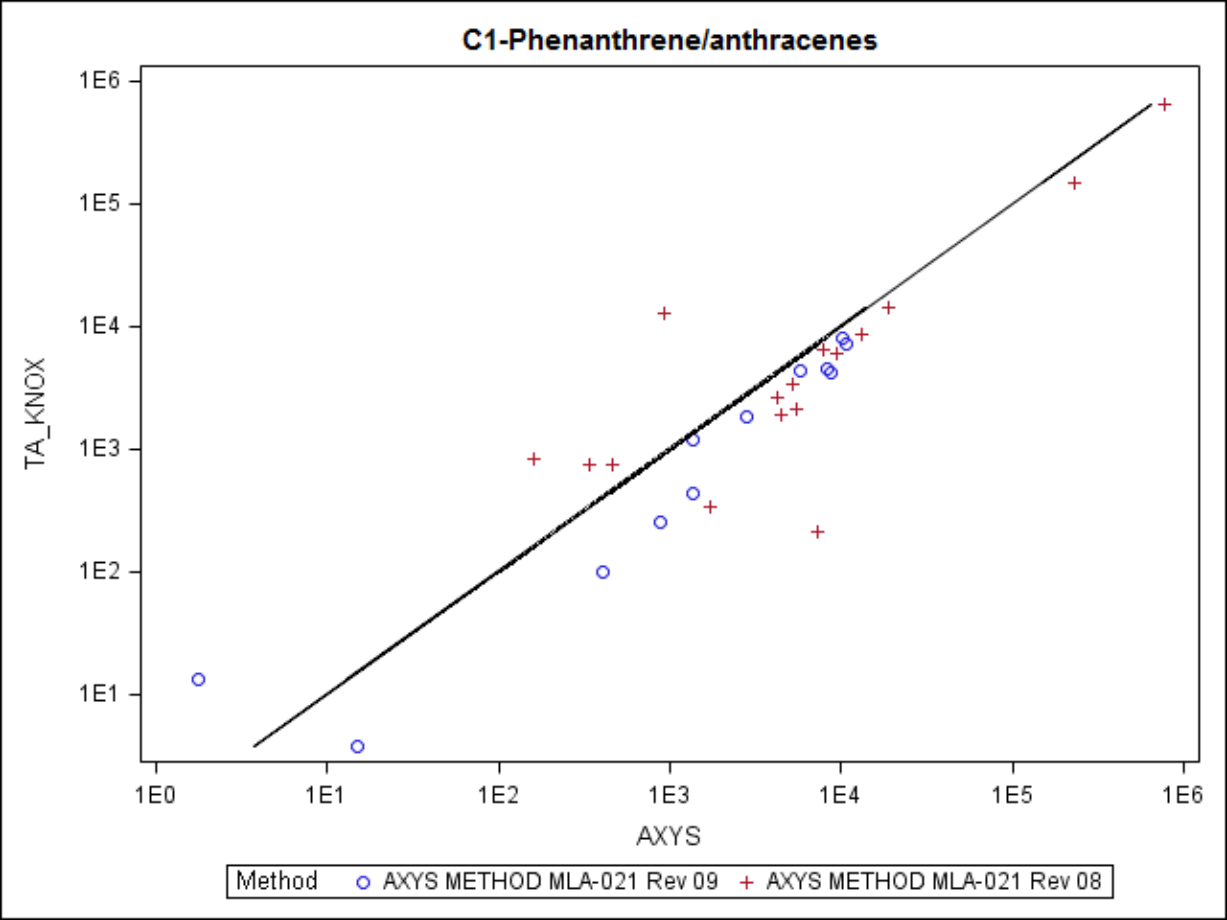

Benzo(a)anthracene
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

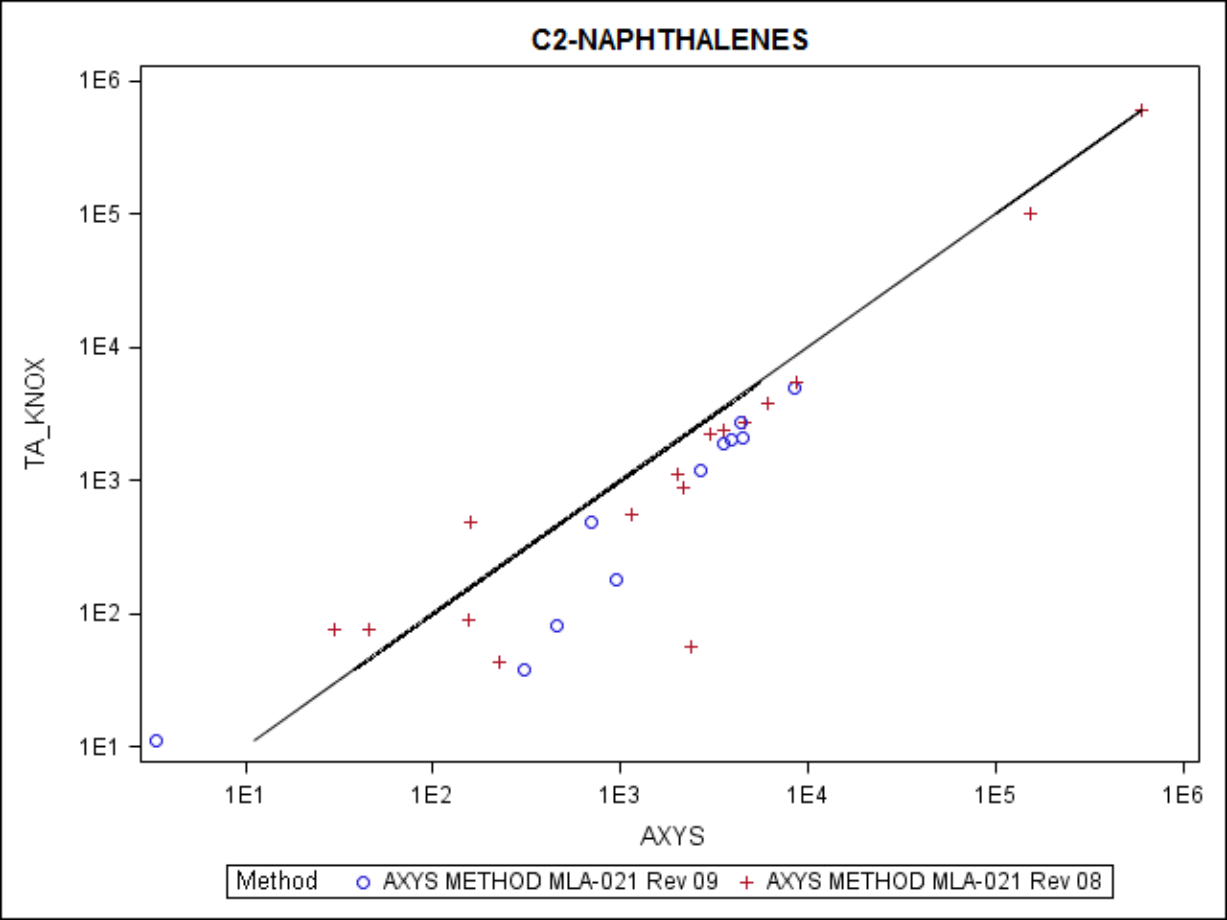

Benzo(a)pyrene
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

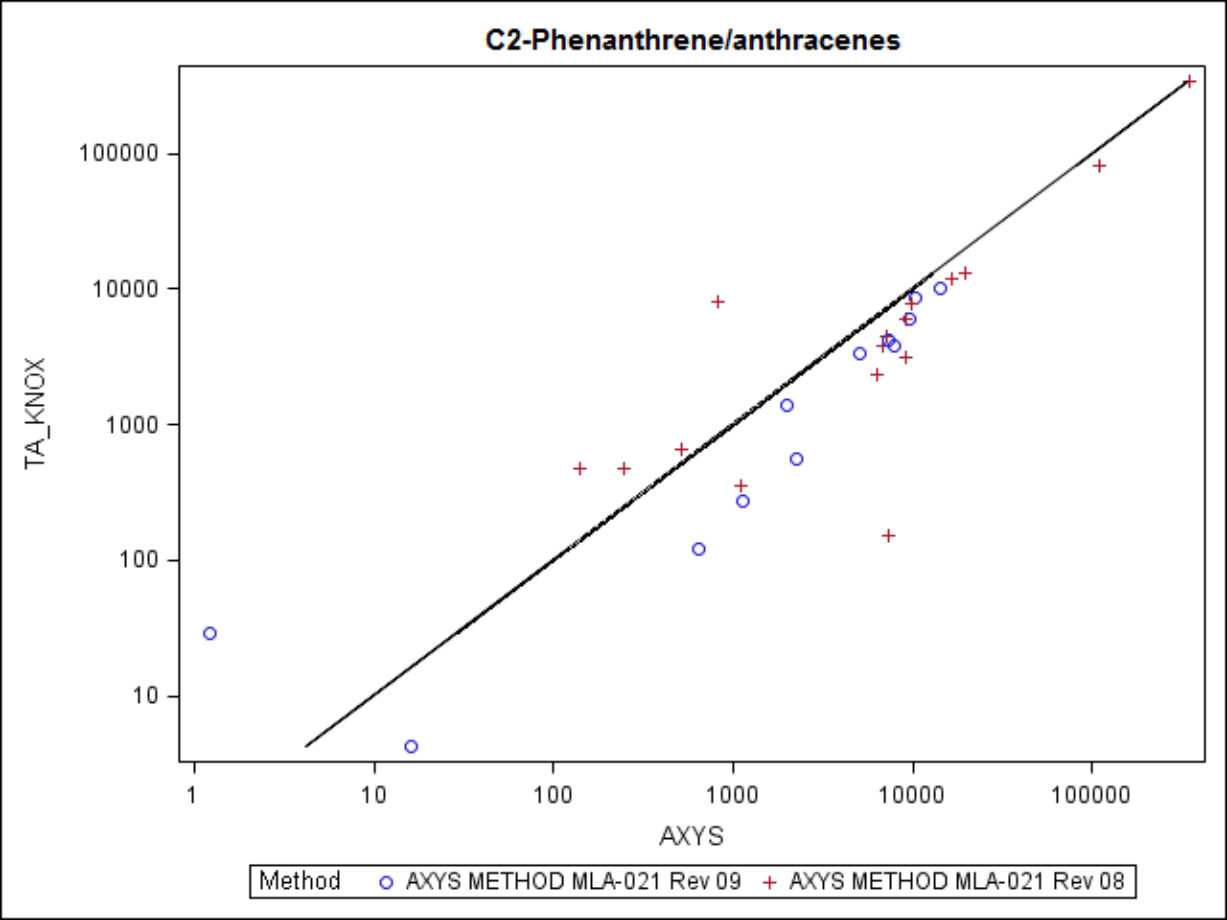

Benzo(b)fluoranthene
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

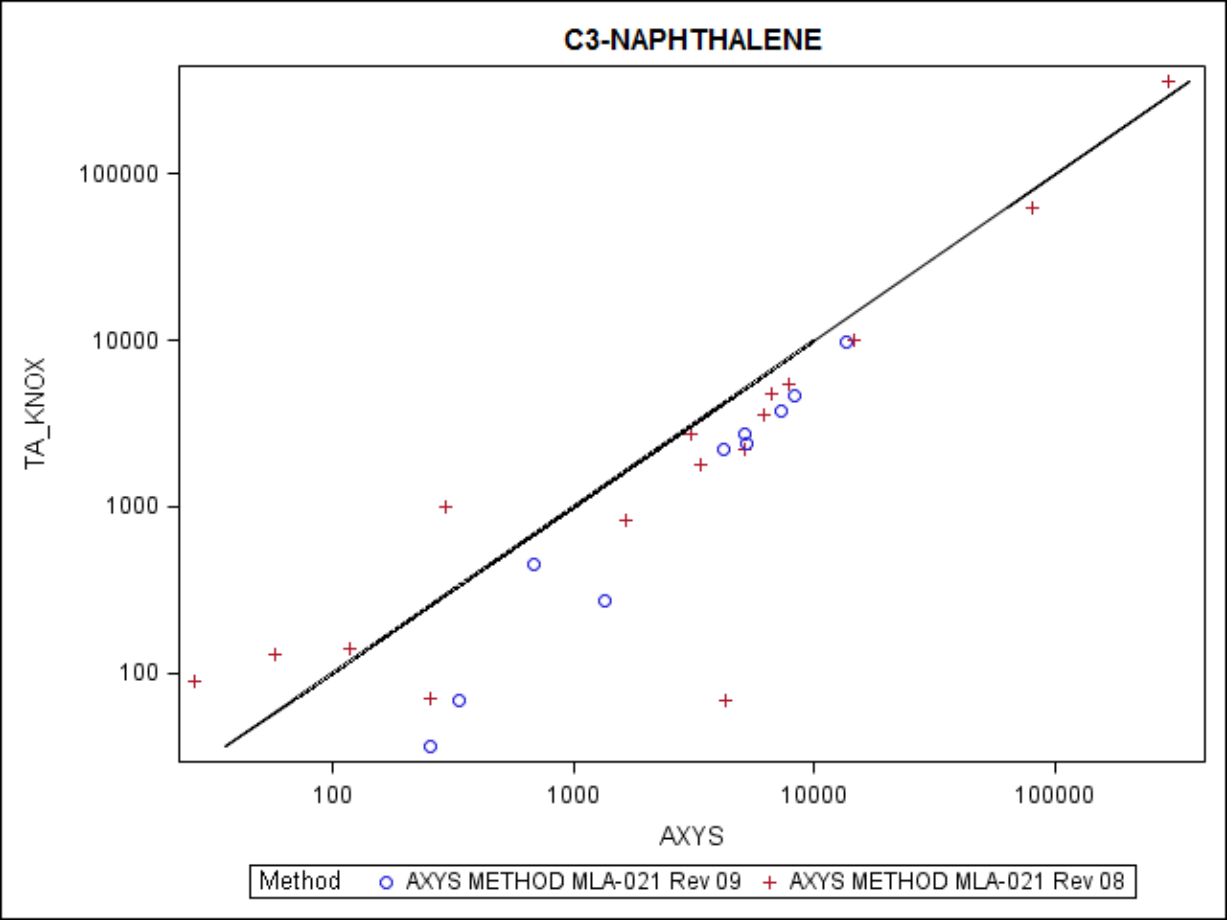

Benzo(g,h,i)perylene
TA_KNOX
AXYS
10
100
1000
10000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

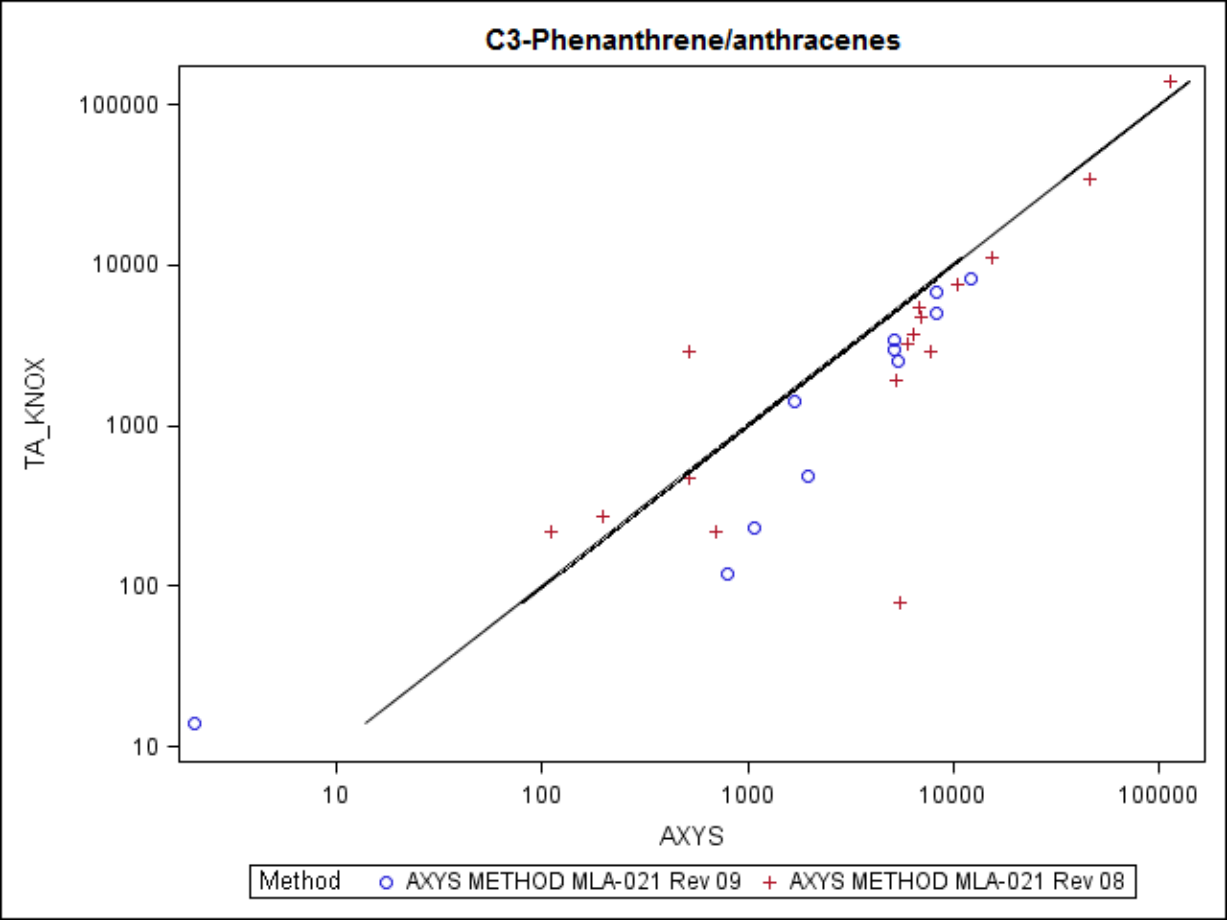

Benzo(k)fluoranthene
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

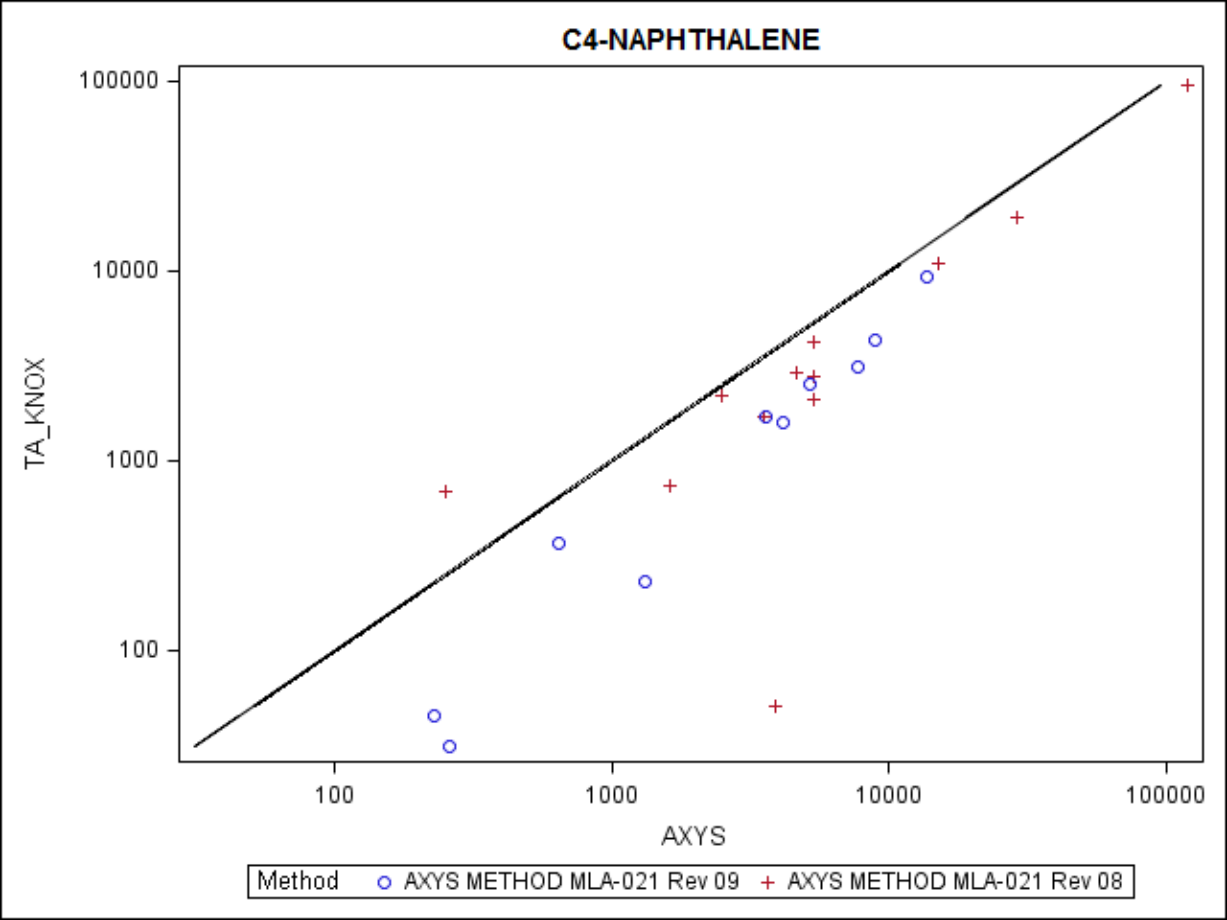

C1-Phenanthrene/anthracenes
TA_KNOX
AXYS
1E1
1E2
1E3
1E4
1E5
1E6
1E0
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

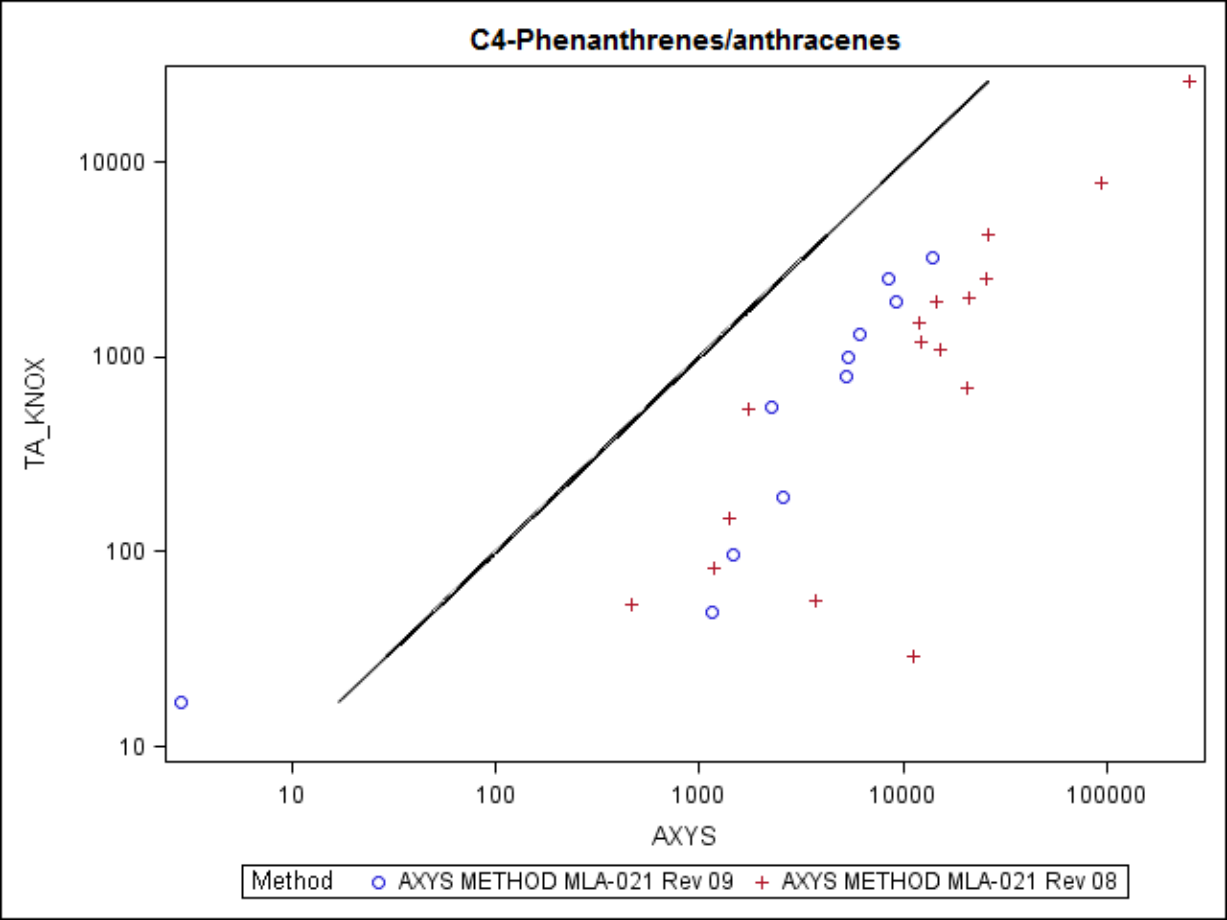

C2-NAPHTHALENES
TA_KNOX
AXYS
1E1
1E2
1E3
1E4
1E5
1E6
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

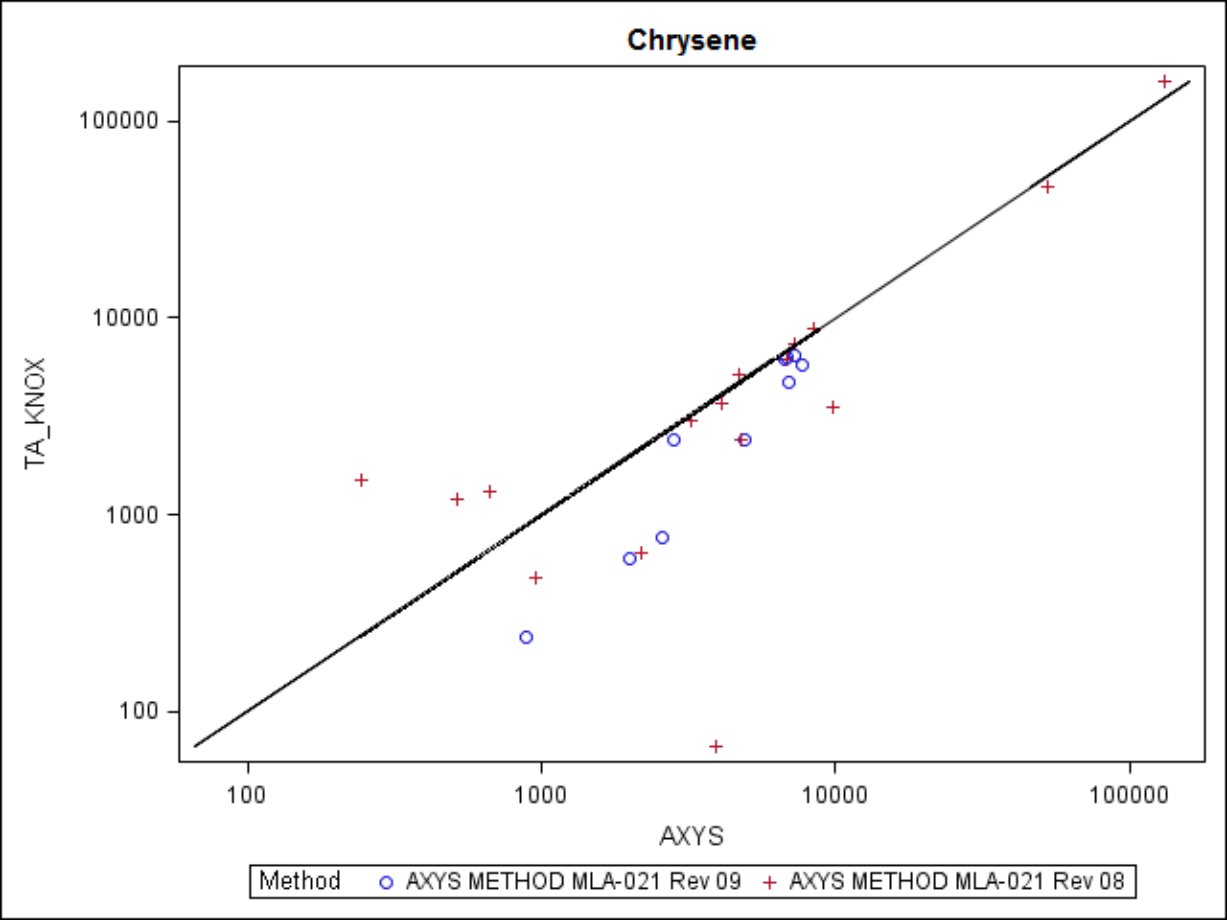

C2-Phenanthrene/anthracenes
TA_KNOX
100000
10000
1000
100
10
1
10
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

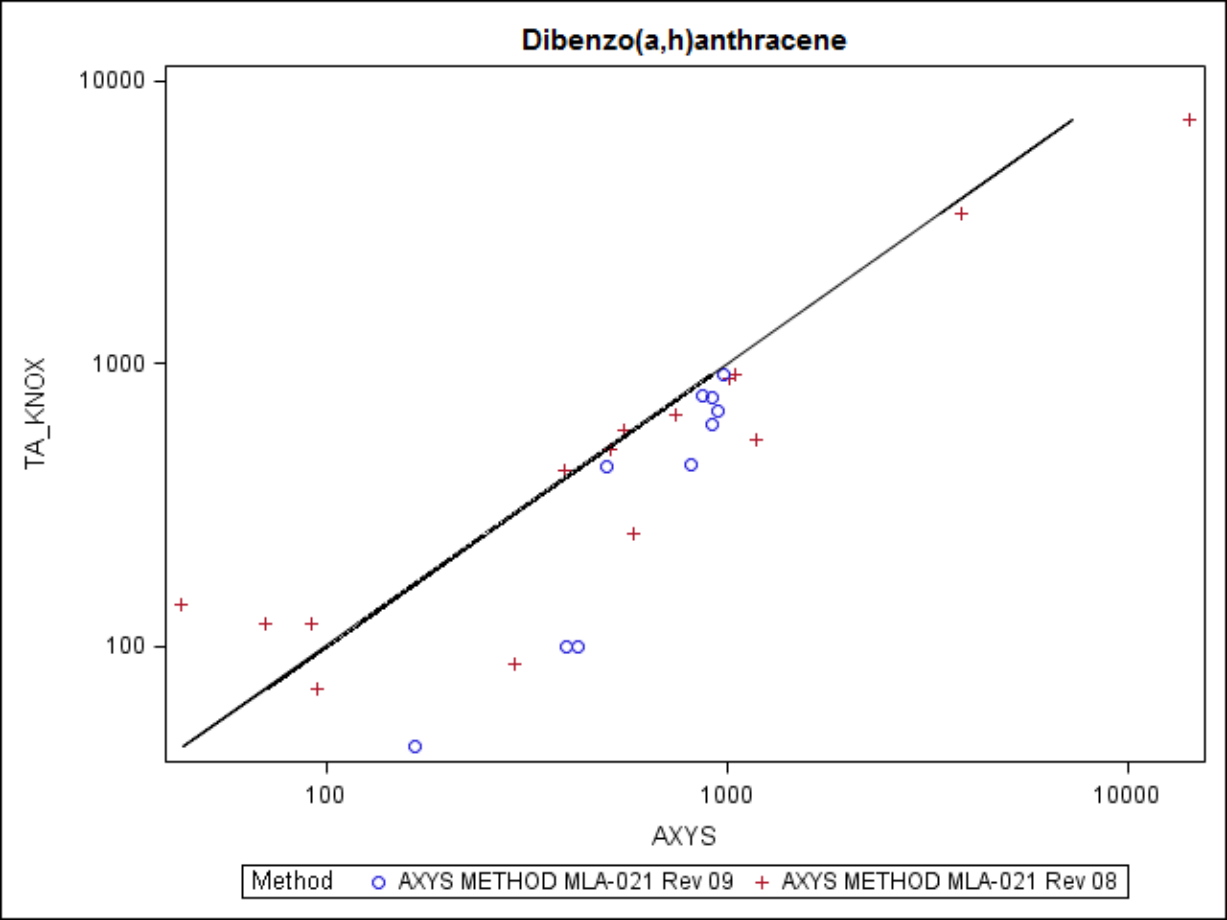

C3-NAPHTHALENE
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

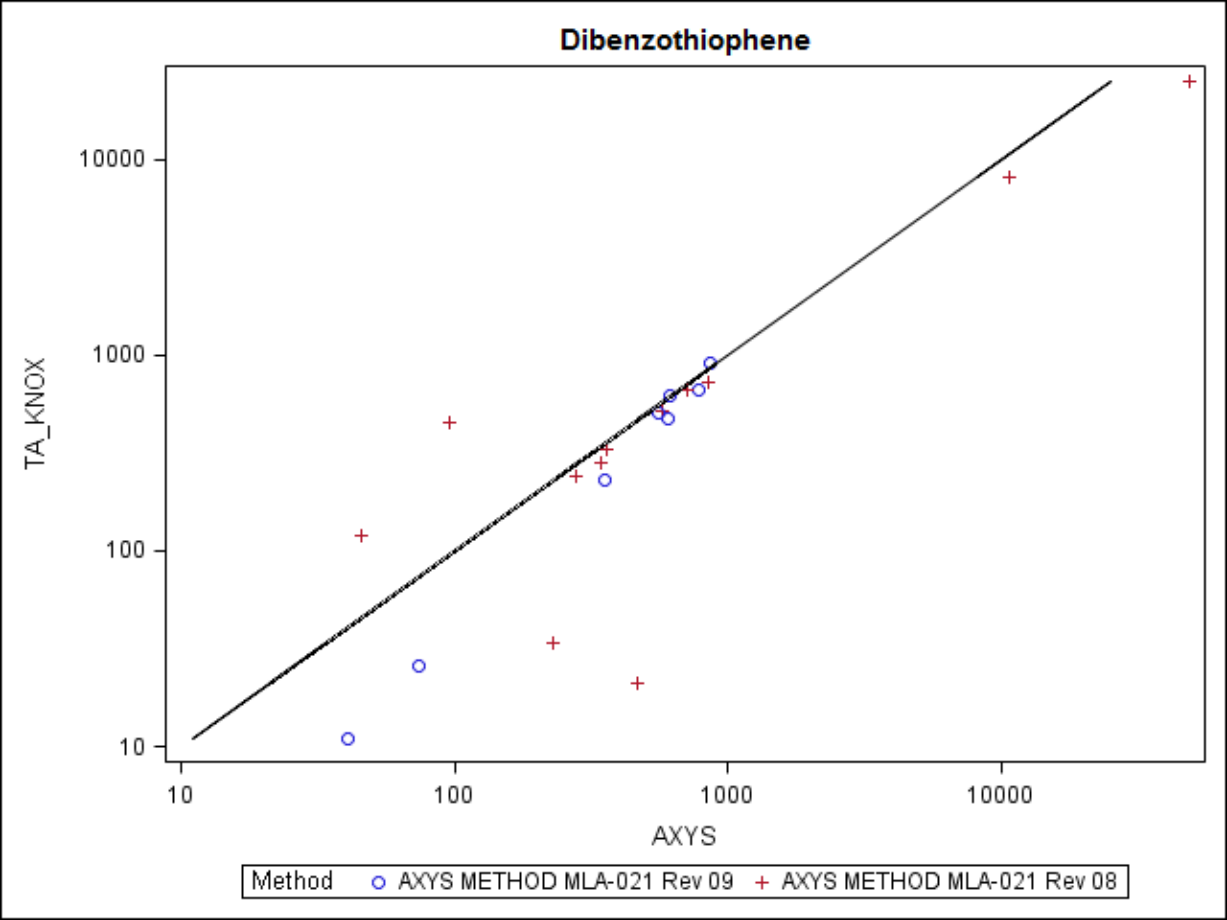

C3-Phenanthrene/anthracenes
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

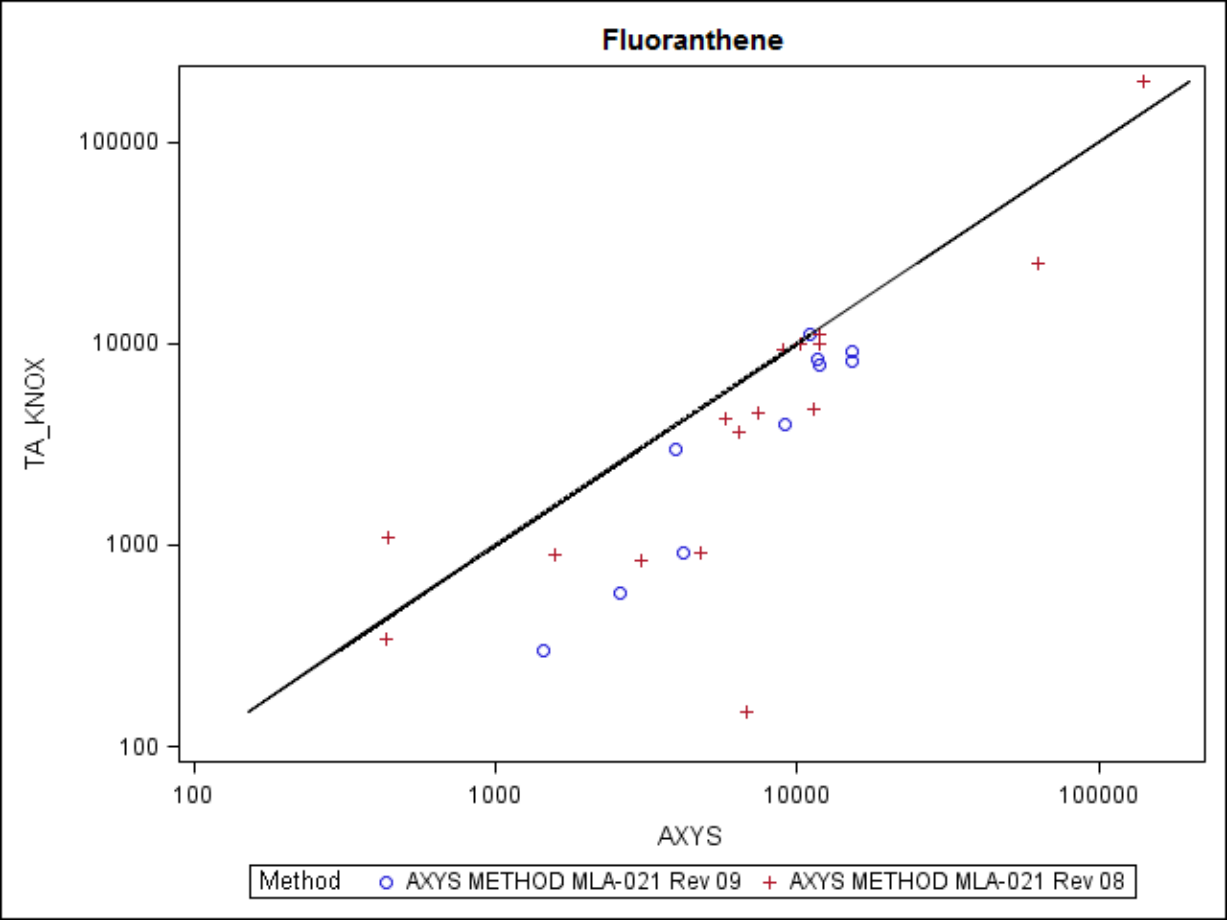

C4-NAPHTHALENE
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

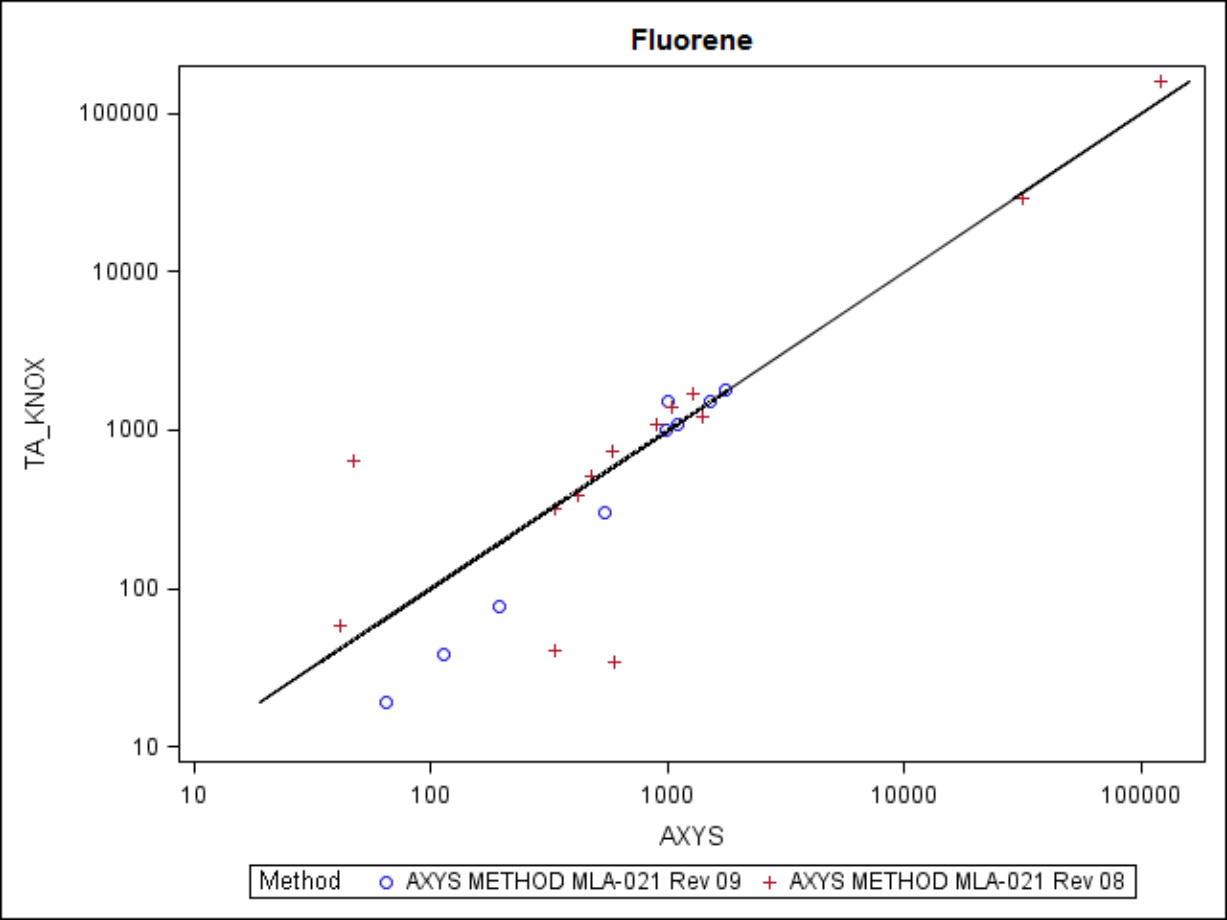

C4-Phenanthrenes/anthracenes
TA_KNOX
10000
1000
100
10
10
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

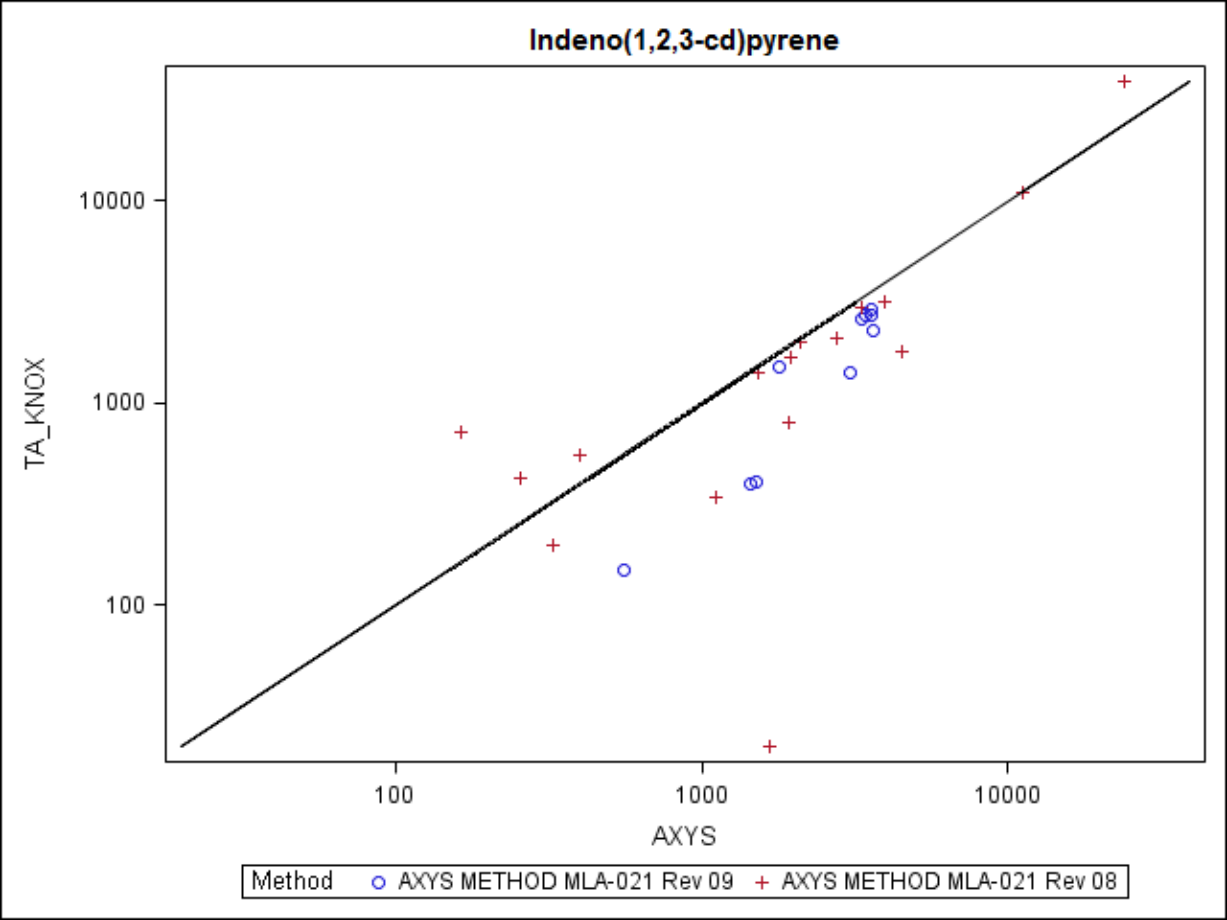

Chrysene
TA_KNOX
AXYS
100000
10000
1000
100
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

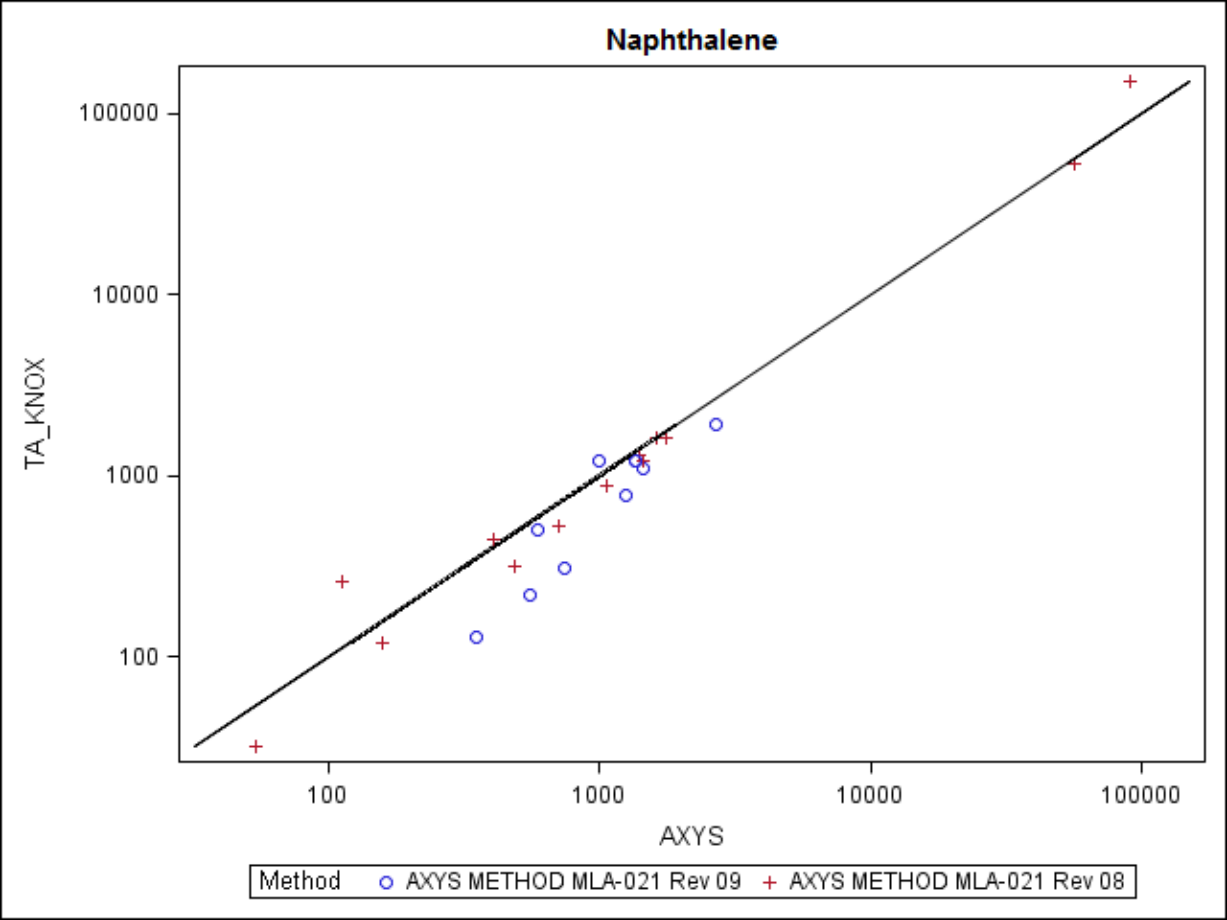

Dibenzo(a,h)anthracene
10000
1000
100
TA_KNOX
100
1000
10000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

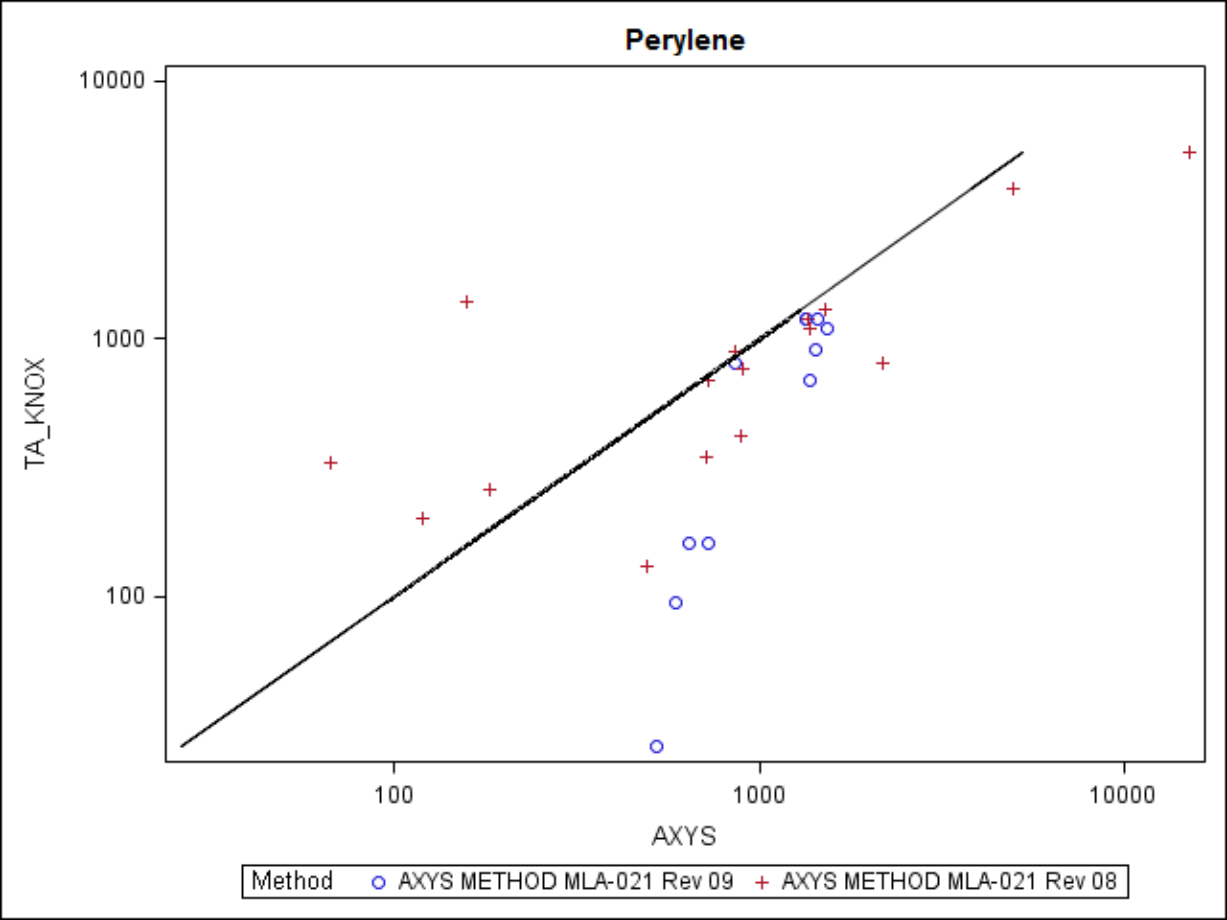

Dibenzothiophene
TA_KNOX
AXYS
10
100
1000
10000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

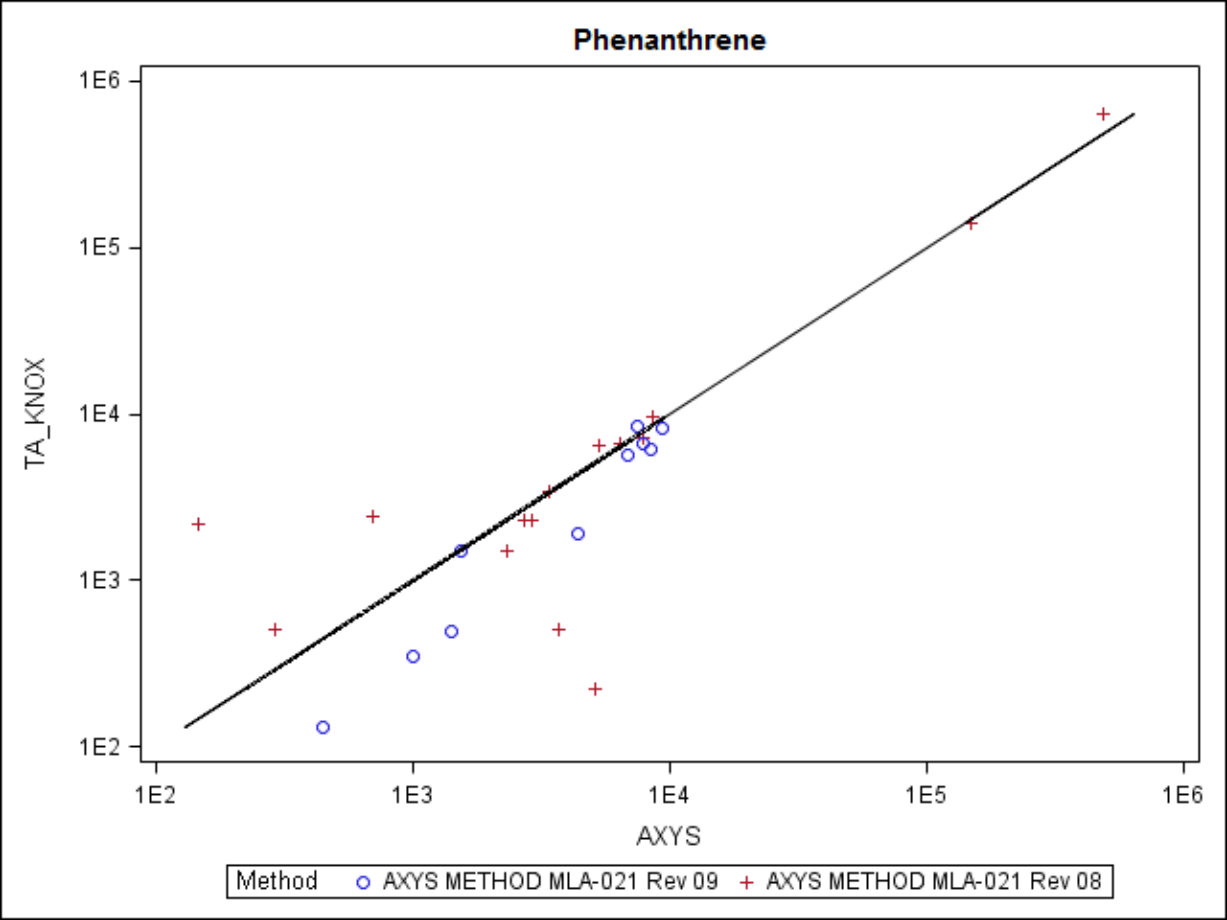

Fluoranthene
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

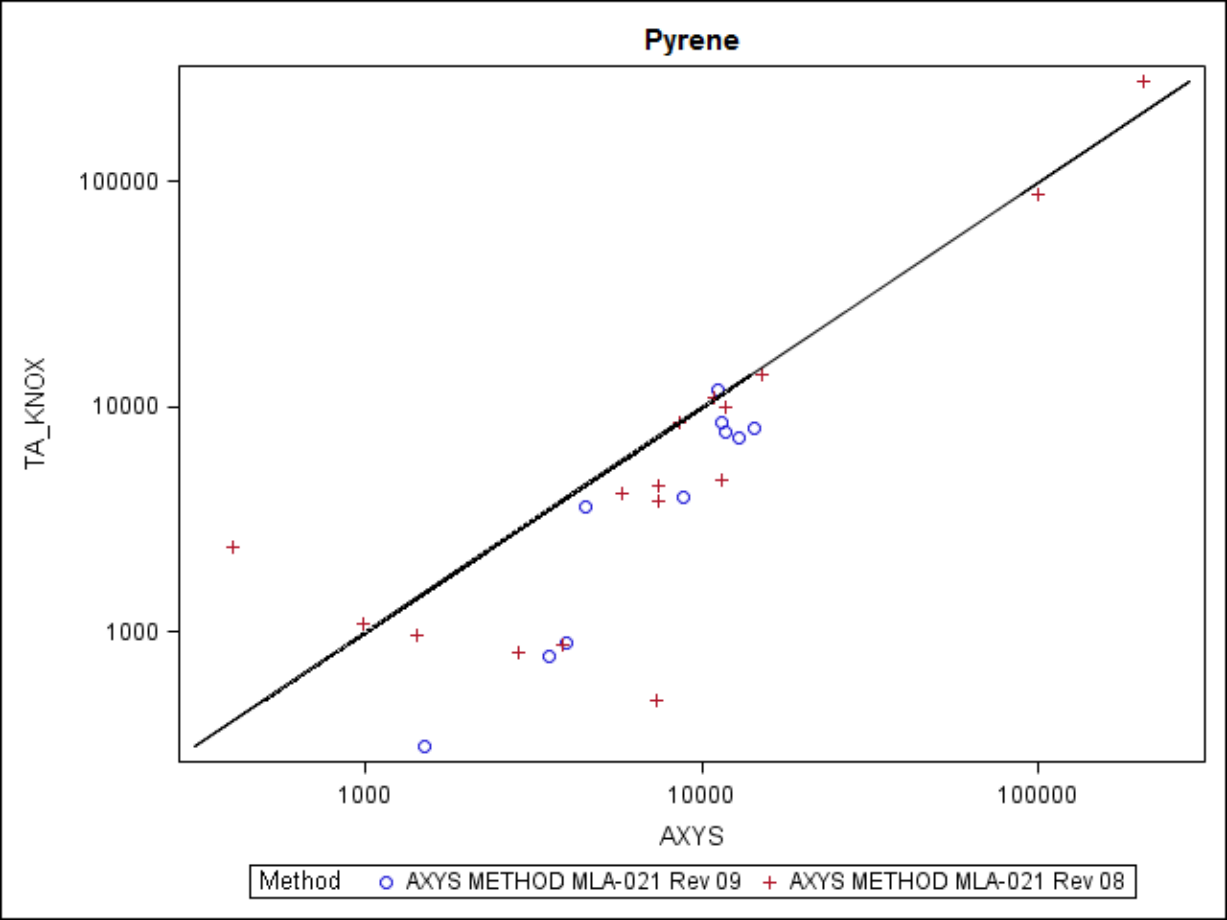

Fluorene
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08


Indeno(1,2,3-cd)pyrene
TA_KNOX
10000
1000
100
100
1000
10000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08


Naphthalene
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

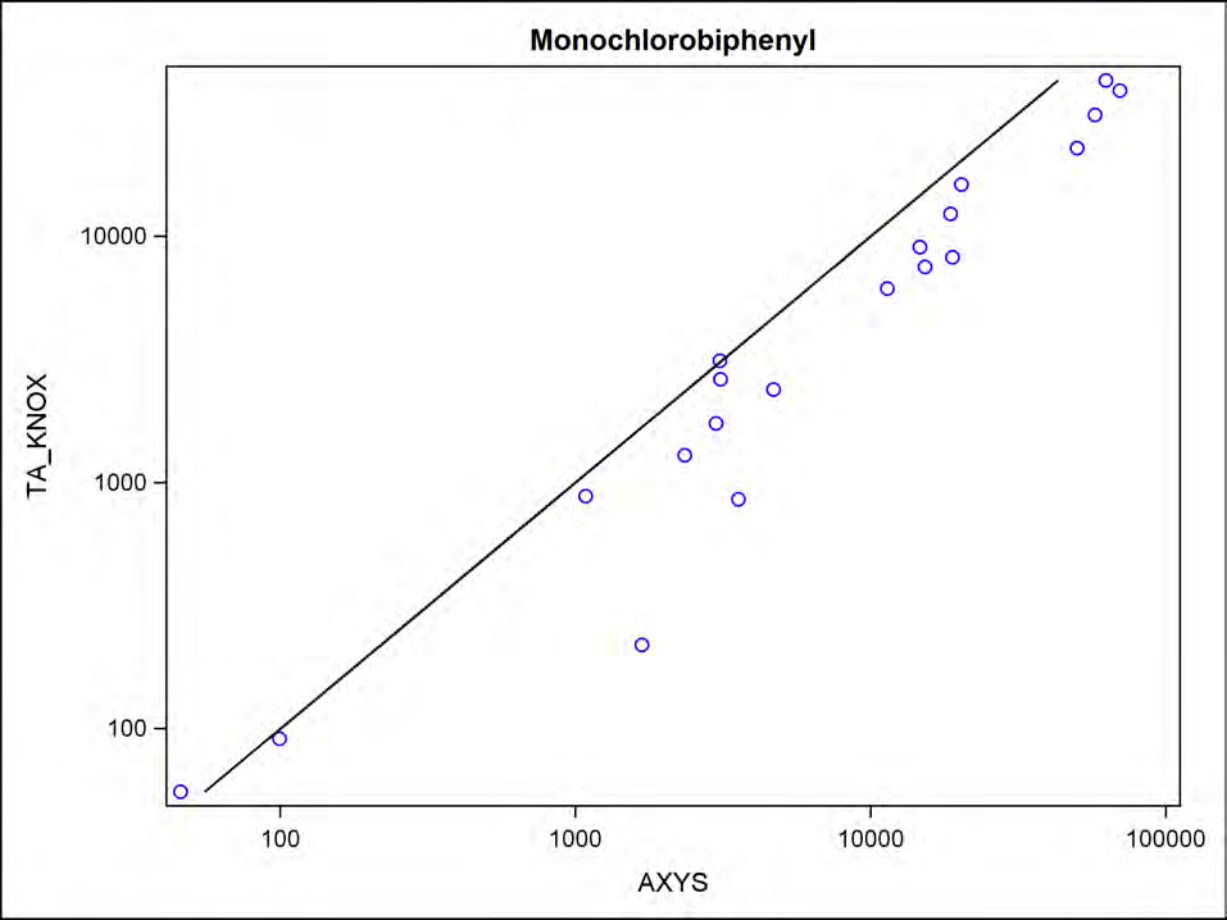

Perylene
10000
1000
100
TA_KNOX
100
1000
10000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

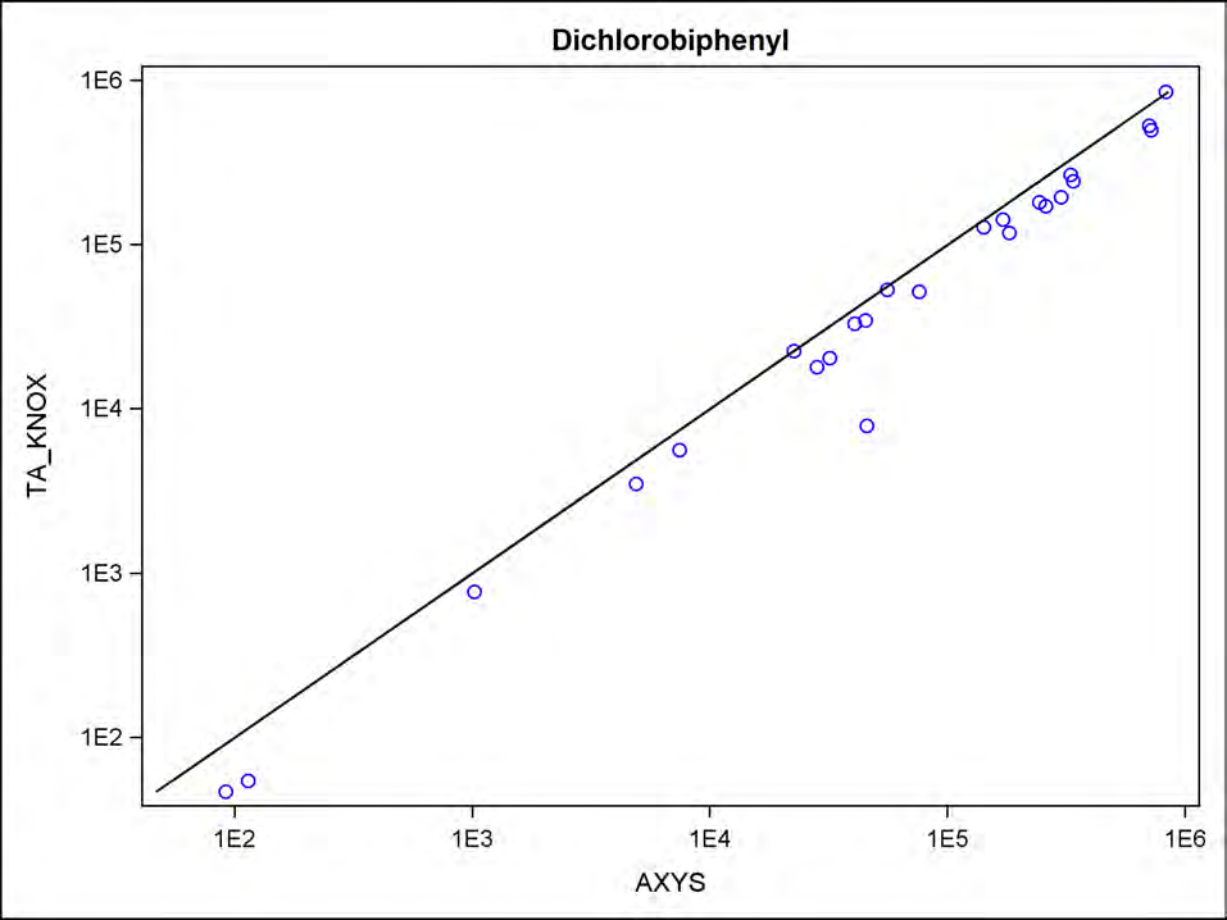

Phenanthrene
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

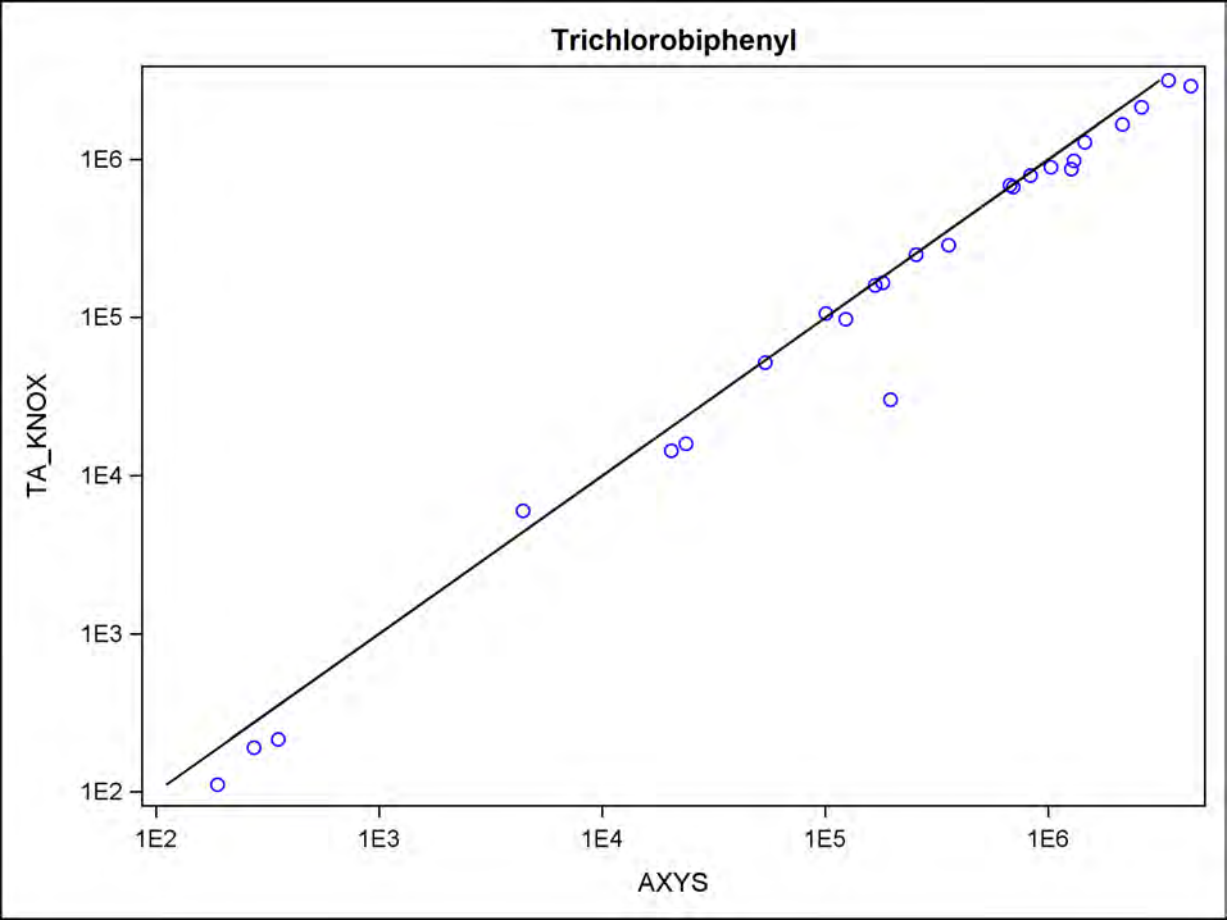

Pyrene
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS
Method
AXYS METHOD MLA-021 Rev 09
AXYS METHOD MLA-021 Rev 08

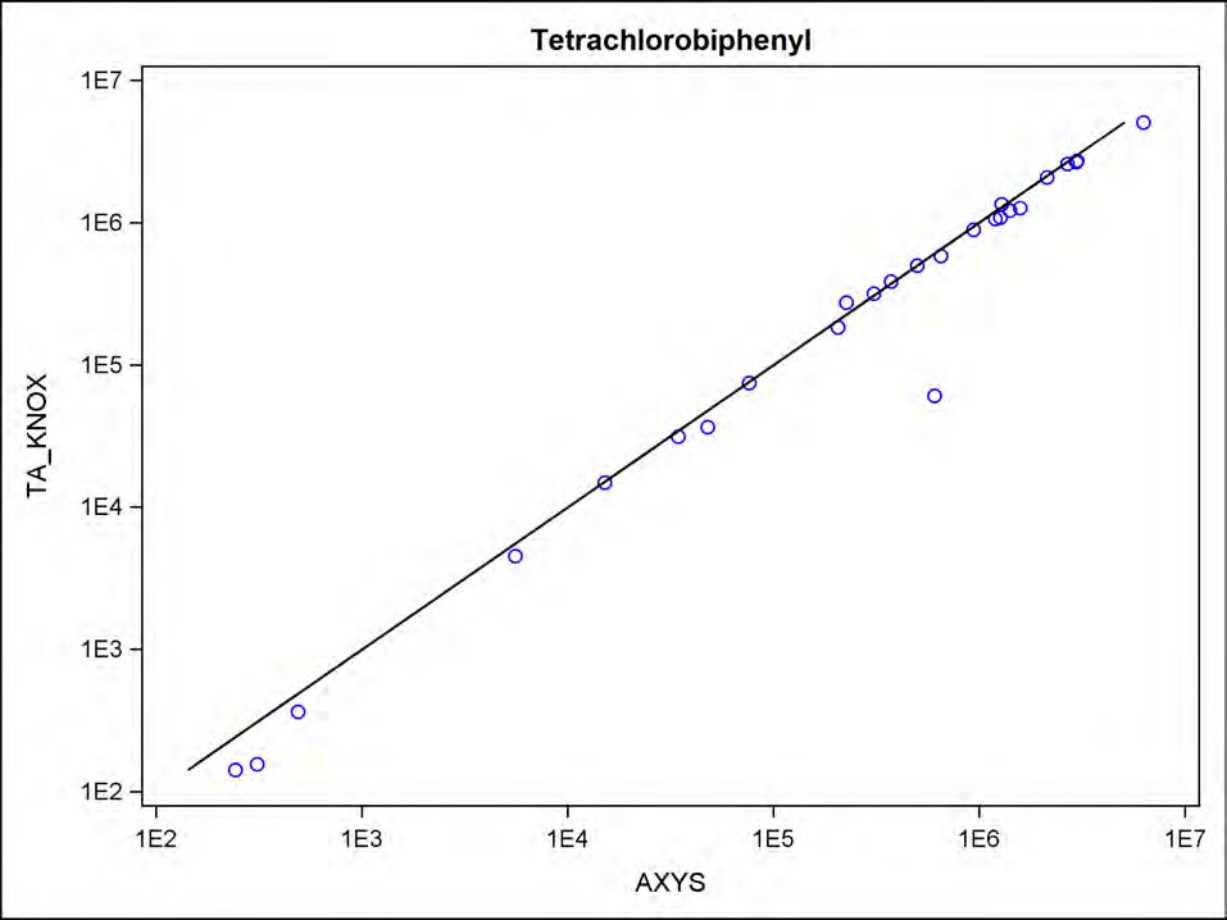
Attachment 2

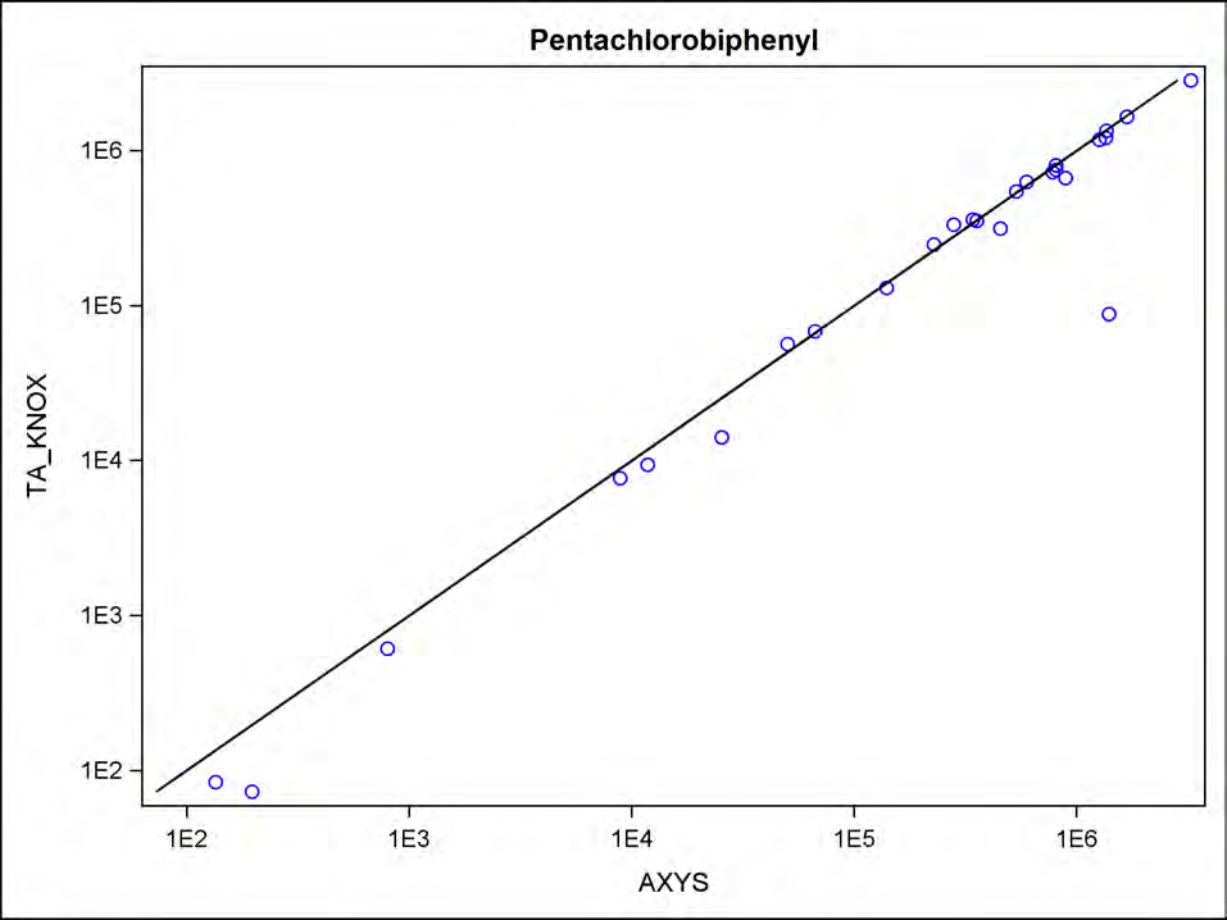
Log PCB Agreement Plots by Laboratory

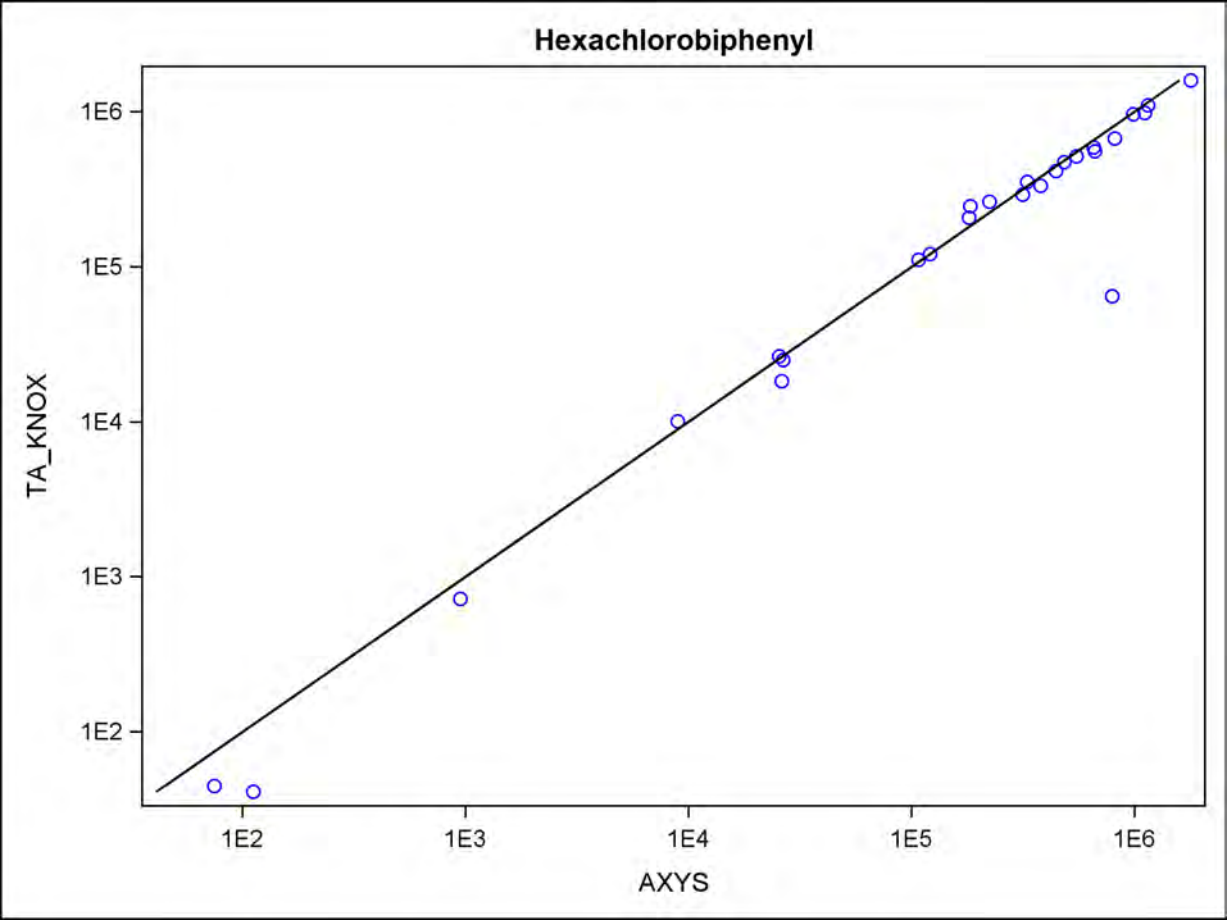

Monochlorobiphenyl
TA_KNOX
10000
1000
100
100
1000
10000
100000
AXYS

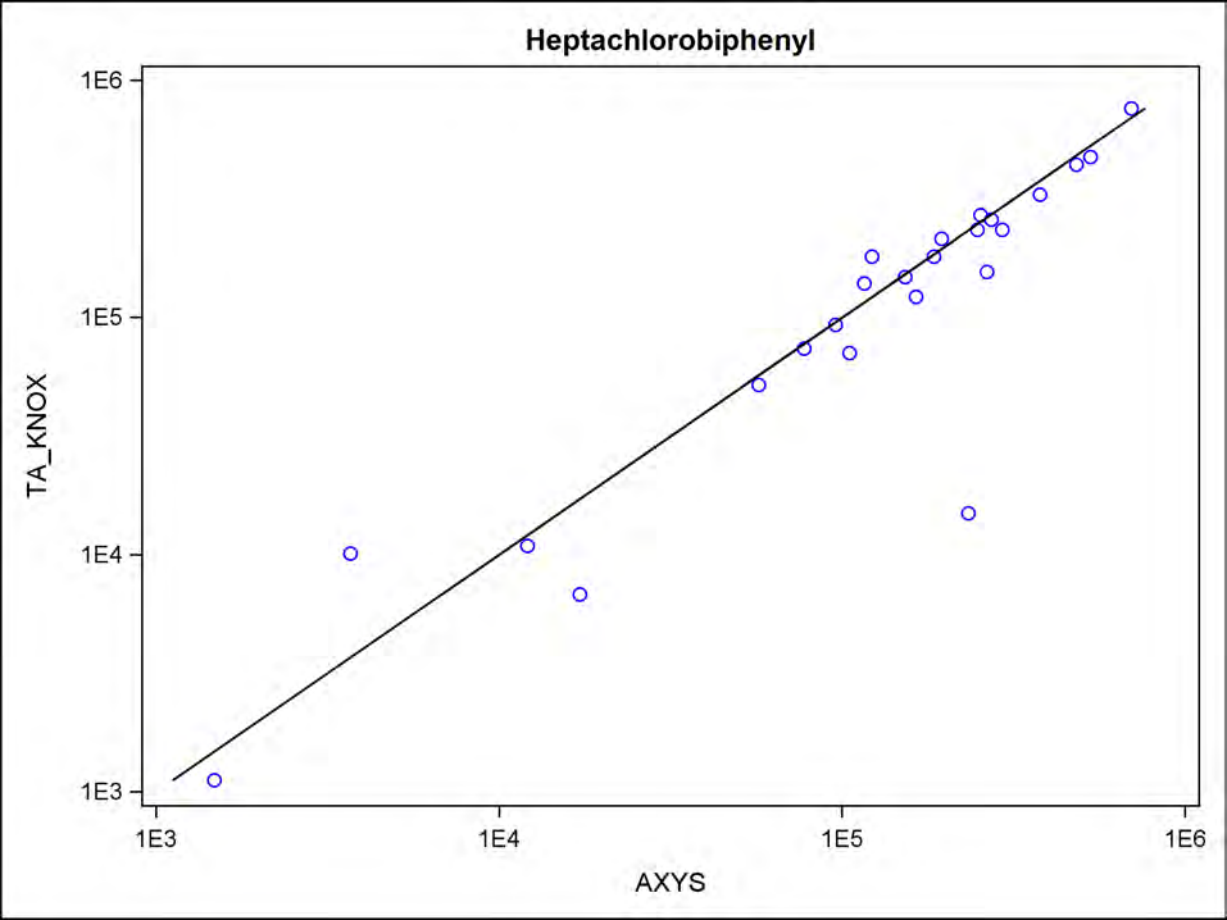

Dichlorobiphenyl
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6

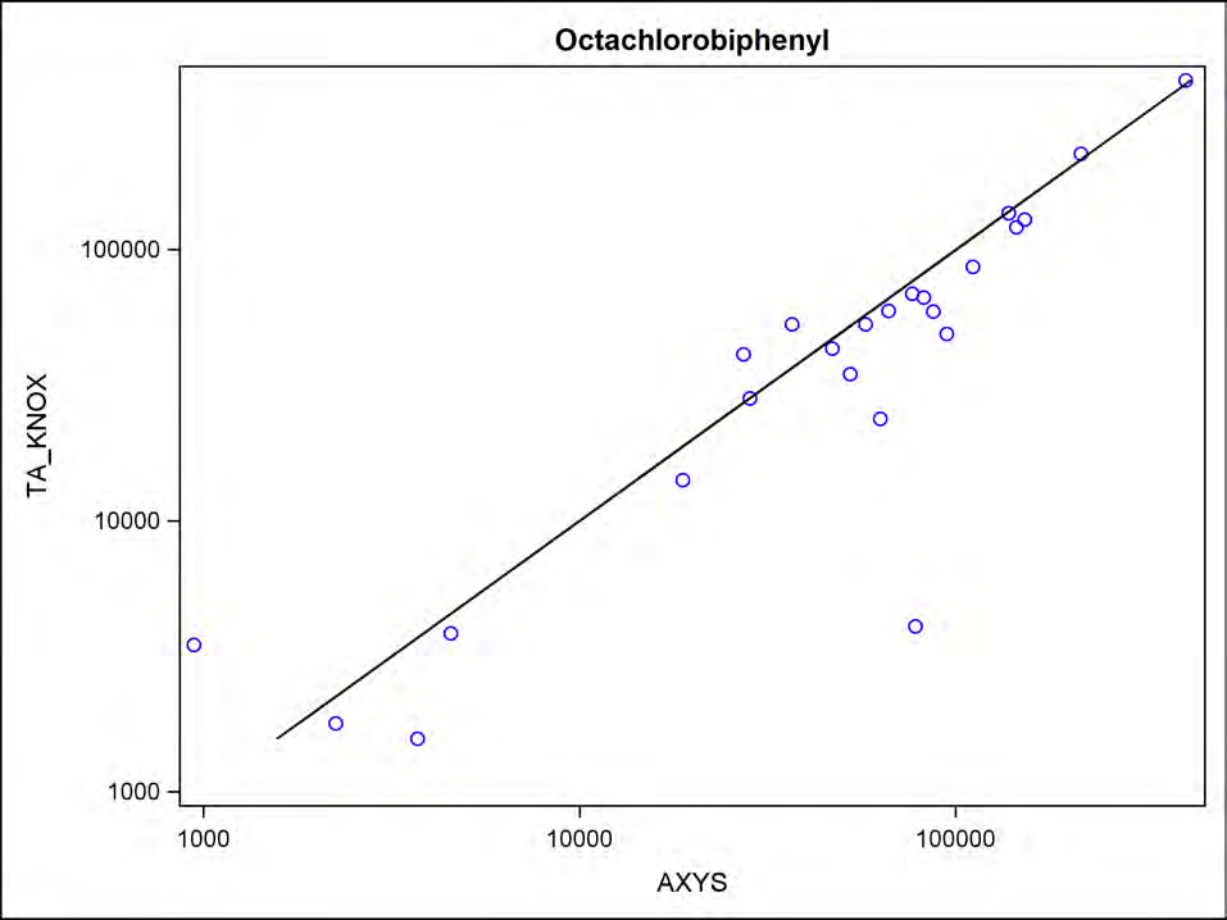

Trichlorobiphenyl
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6

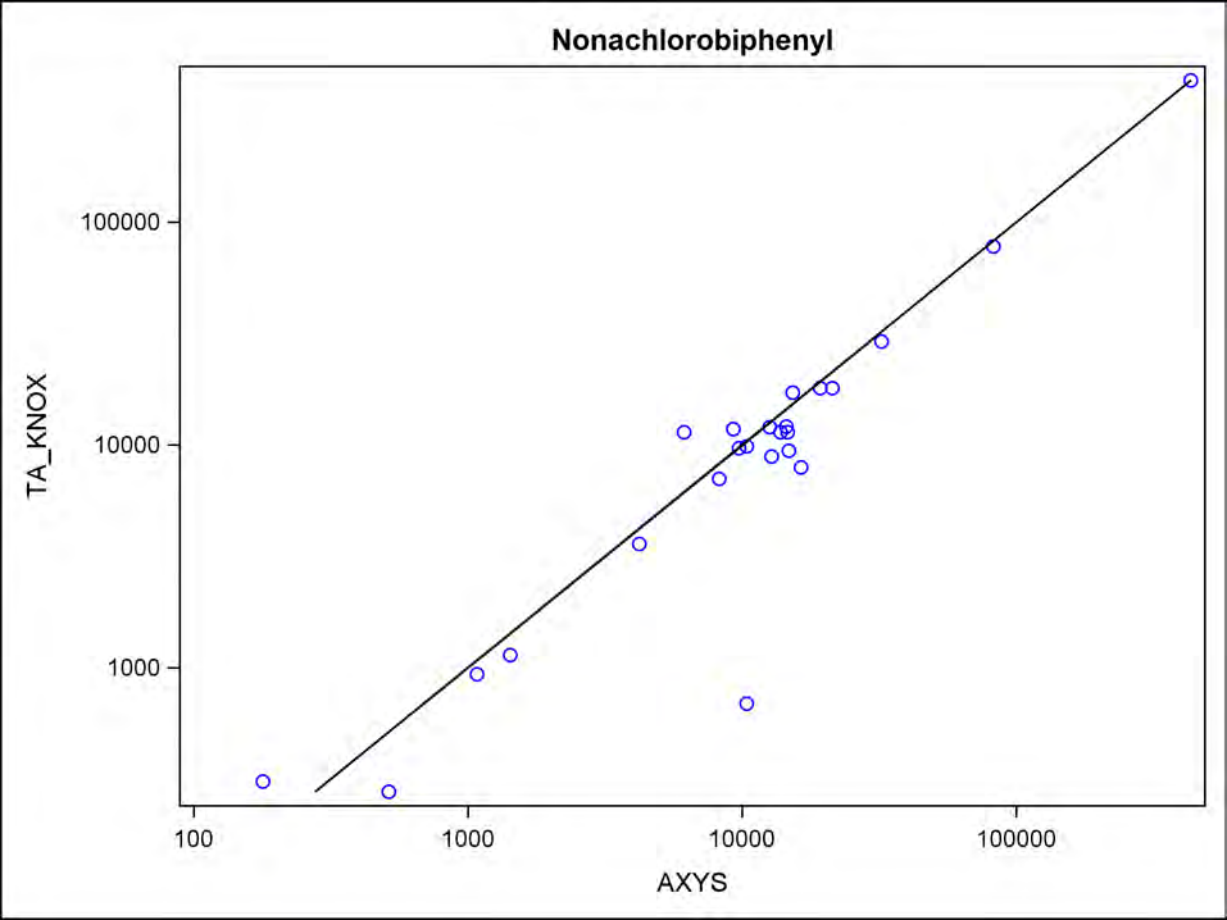

Tetrachlorobiphenyl
TA_KNOX
AXYS
1E7
1E6
1E5
1E4
1E3
1E2
1E2
1E3
1E4
1E5
1E6
1E7

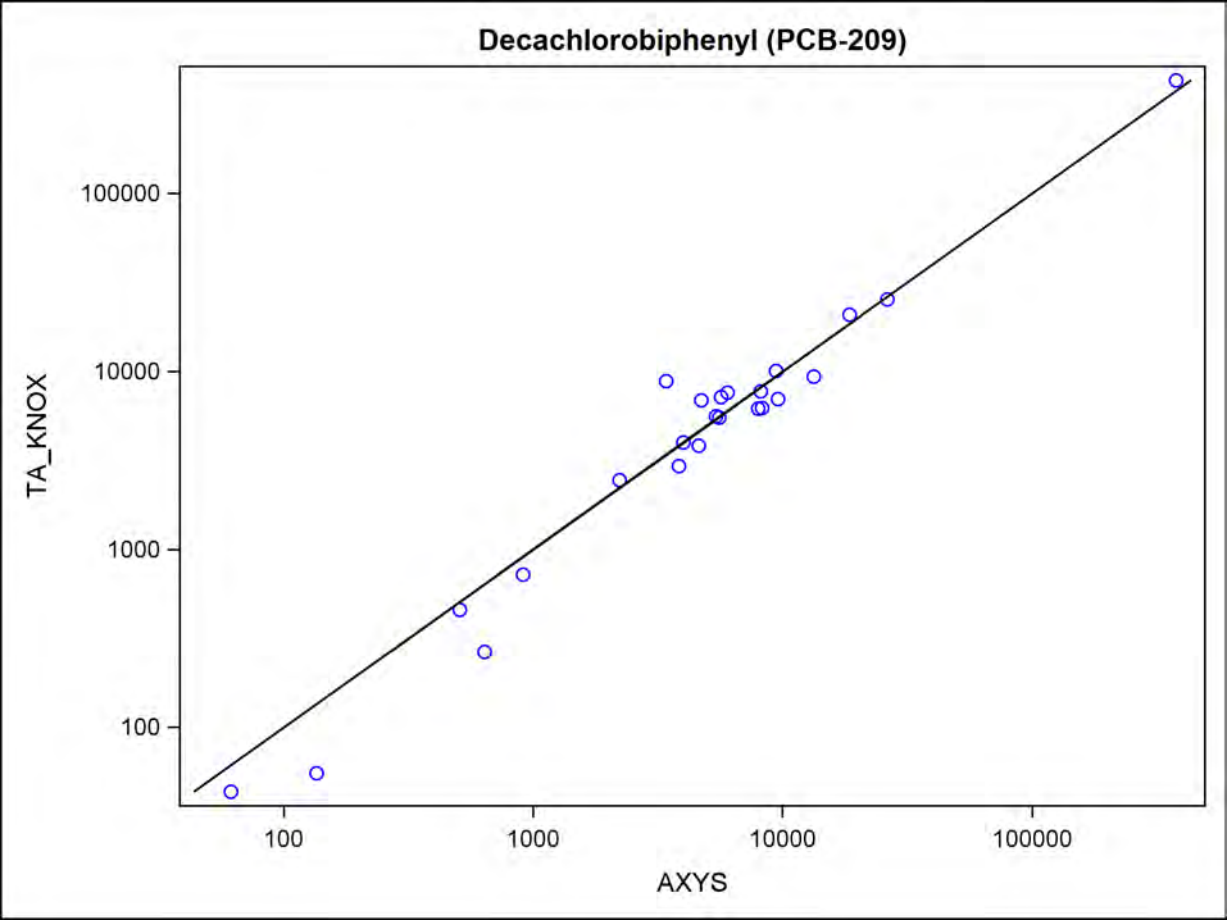

Pentachlorobiphenyl
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6
1E2
1E3
1E4
1E5
1E6

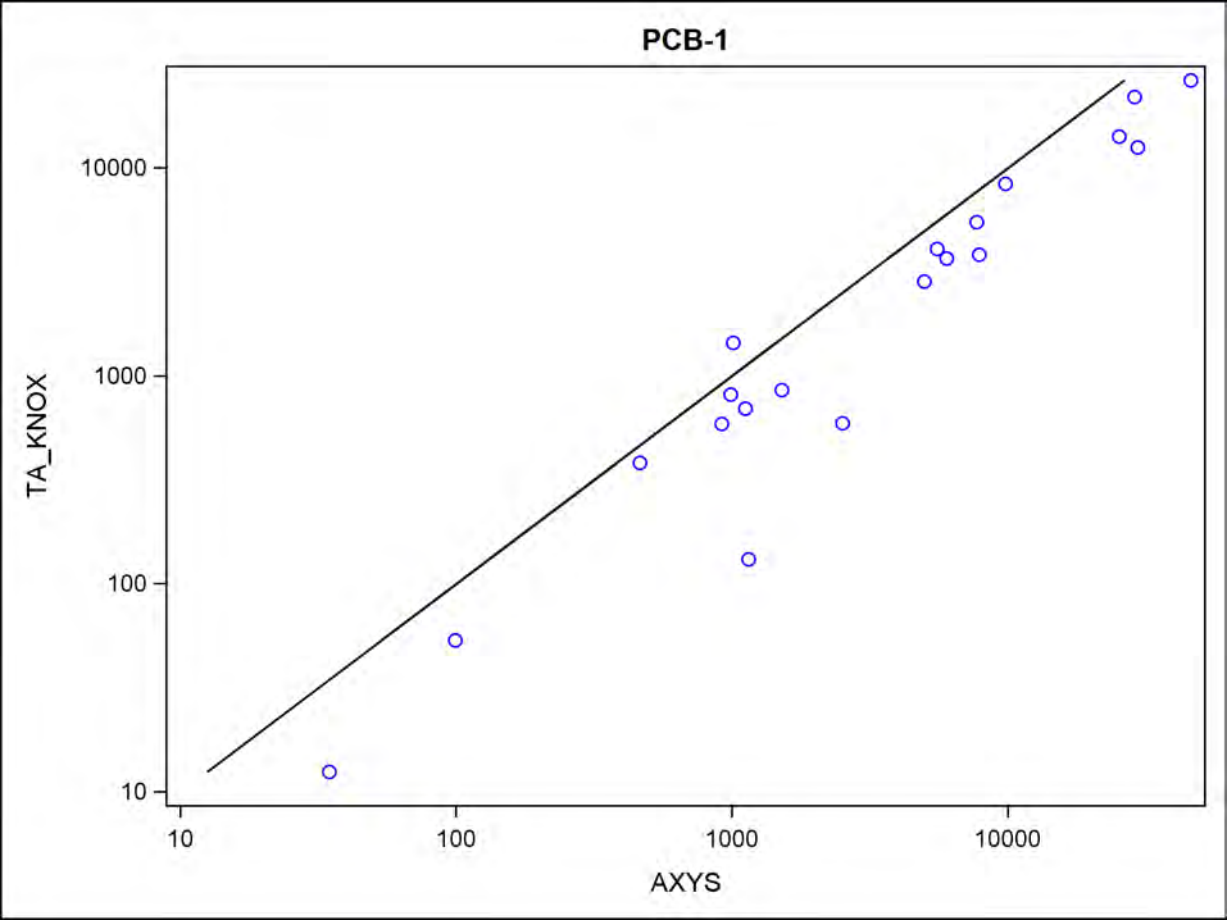

Hexachlorobiphenyl
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6
1E2
1E3
1E4
1E5
1E6

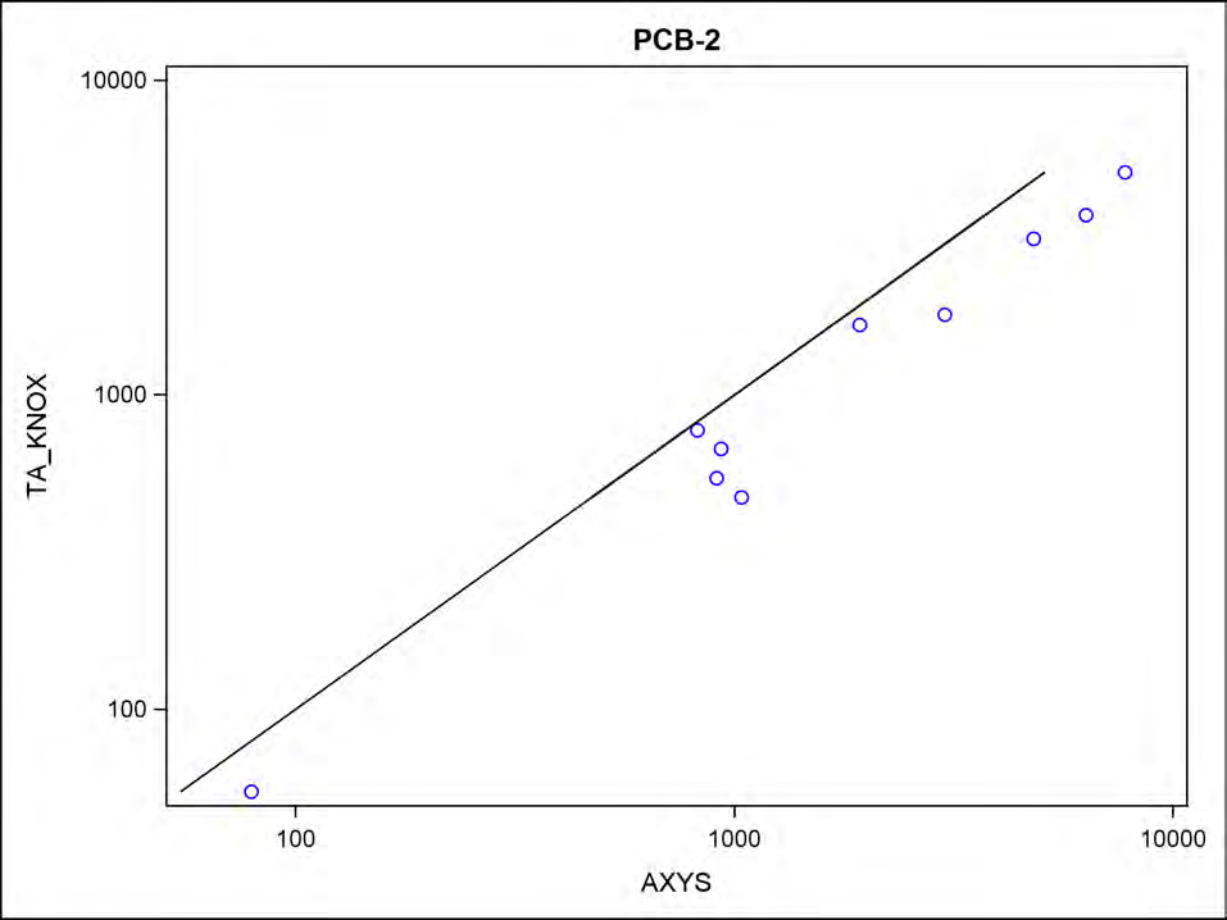

Heptachlorobiphenyl
TA_KNOX
AXYS
1E6
1E5
1E4
1E3
1E3
1E4
1E5
1E6

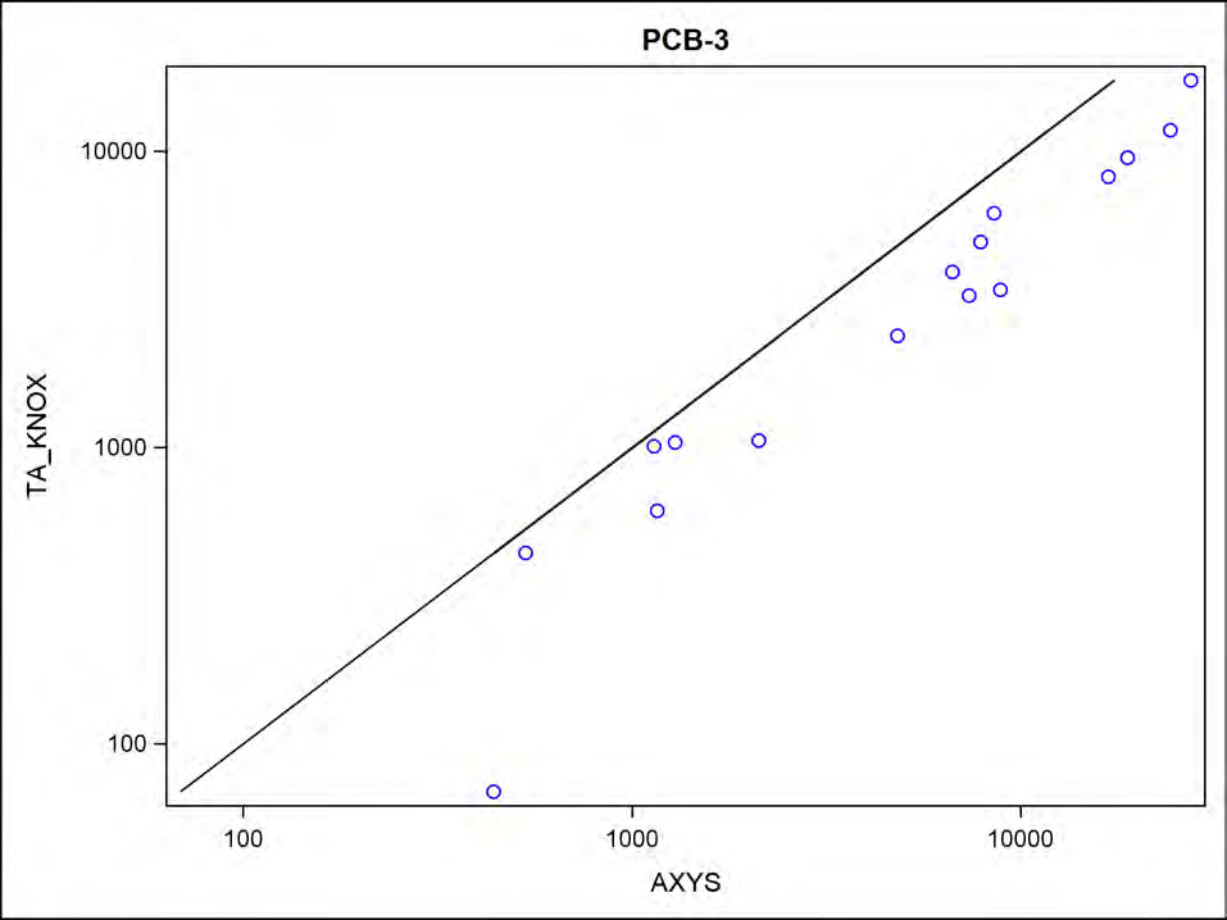

Octachlorobiphenyl
TA_KNOX
100000
10000
1000
1000
10000
100000
AXYS

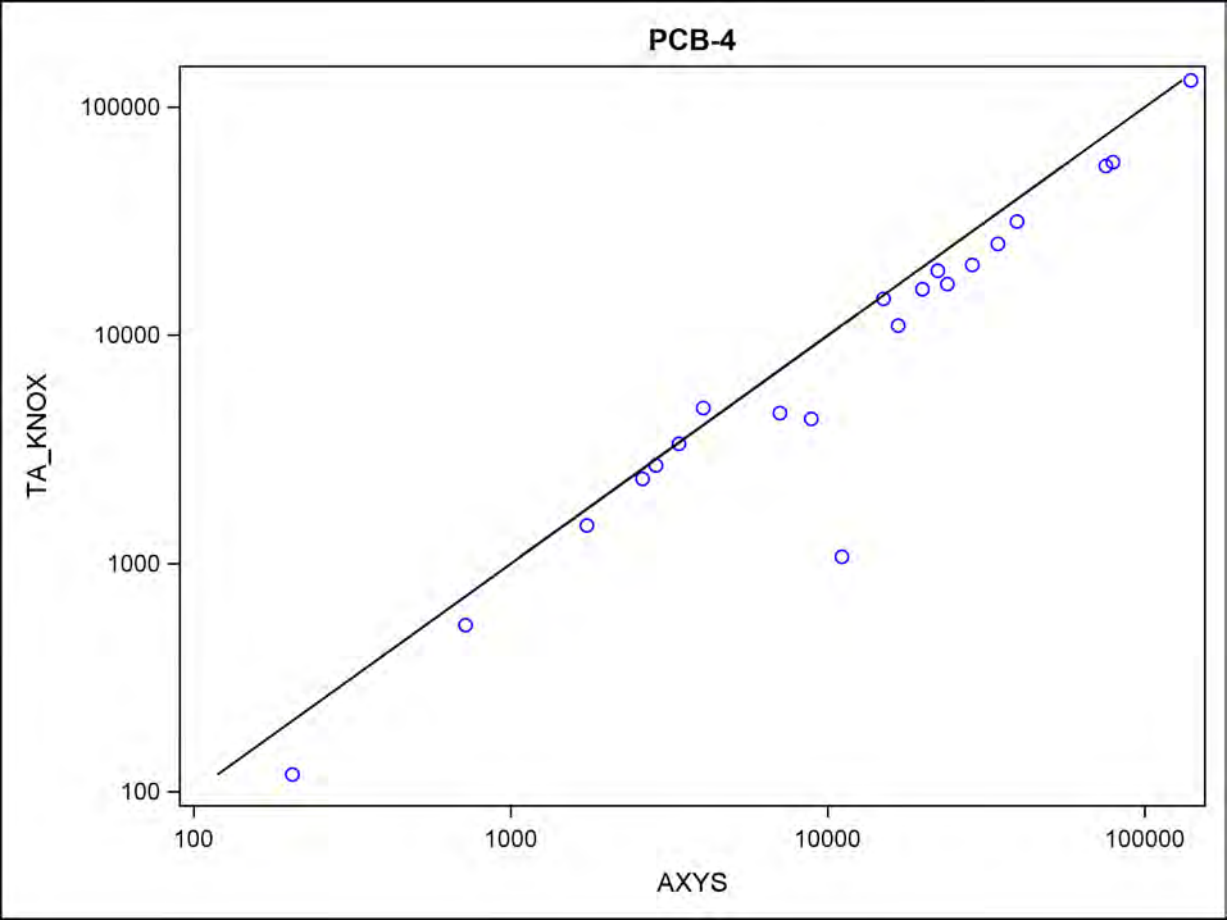

Nonachlorobiphenyl
TA_KNOX
100000
10000
1000
100
1000
10000
100000
AXYS

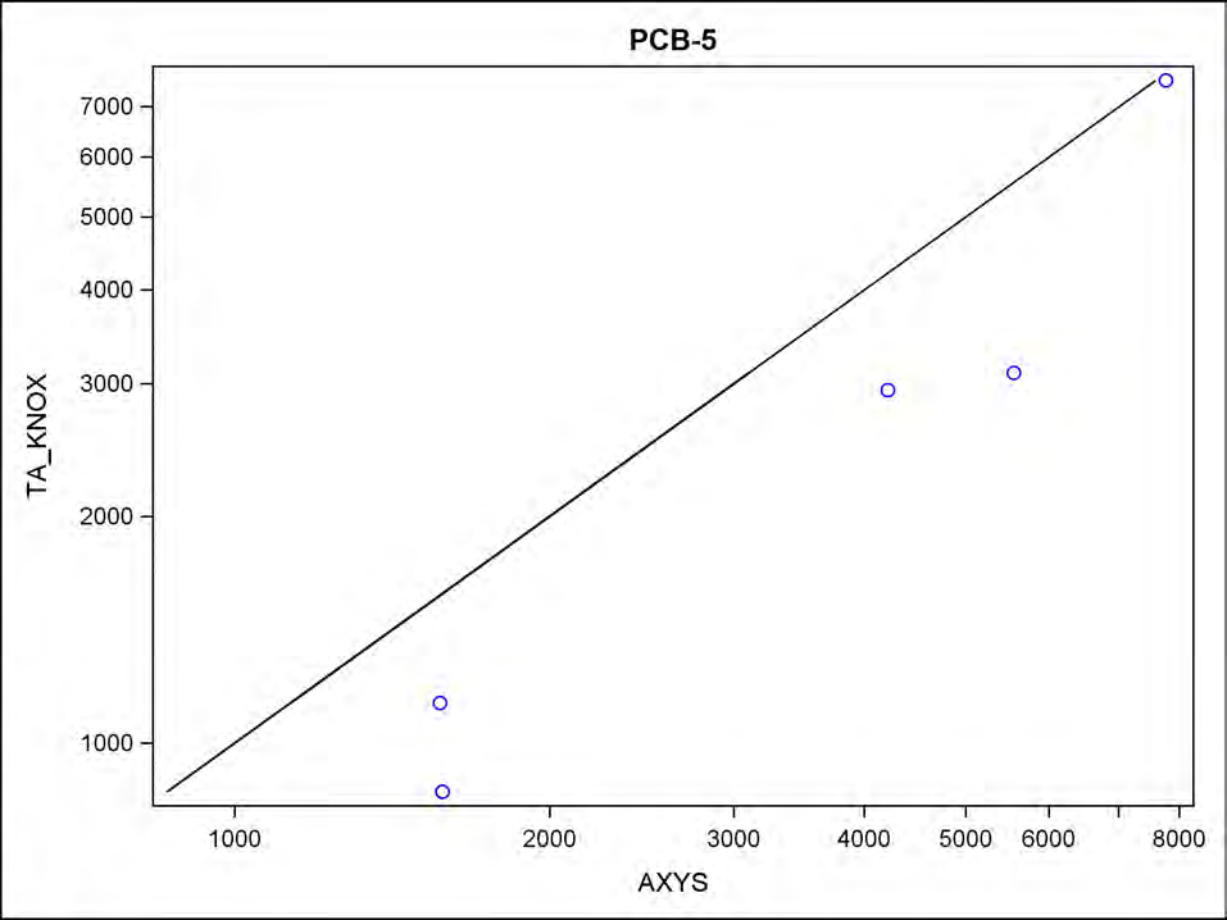

Decachlorobiphenyl (PCB-209)
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

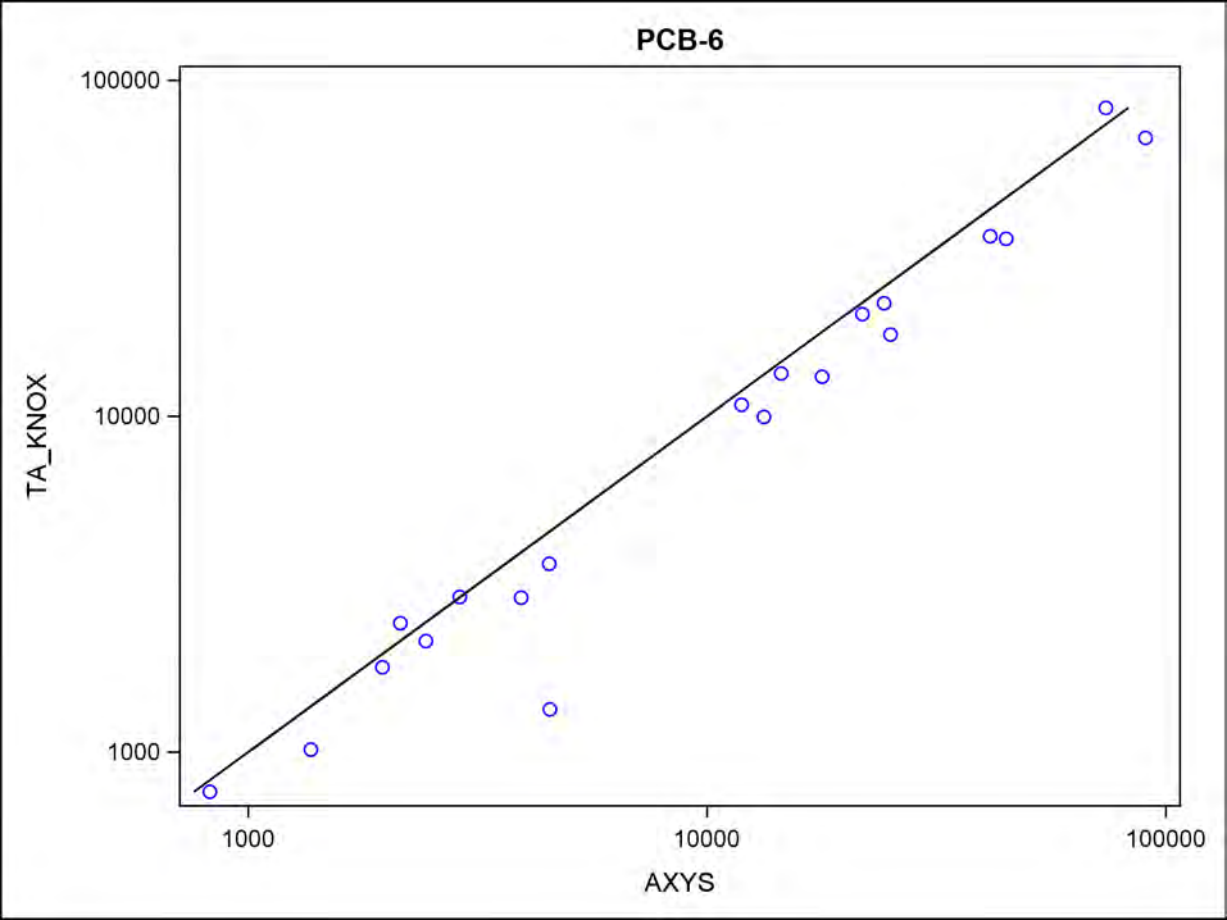

PCB-1
TA_KNOX
AXYS
10
100
1000
10000
10
100
1000
10000

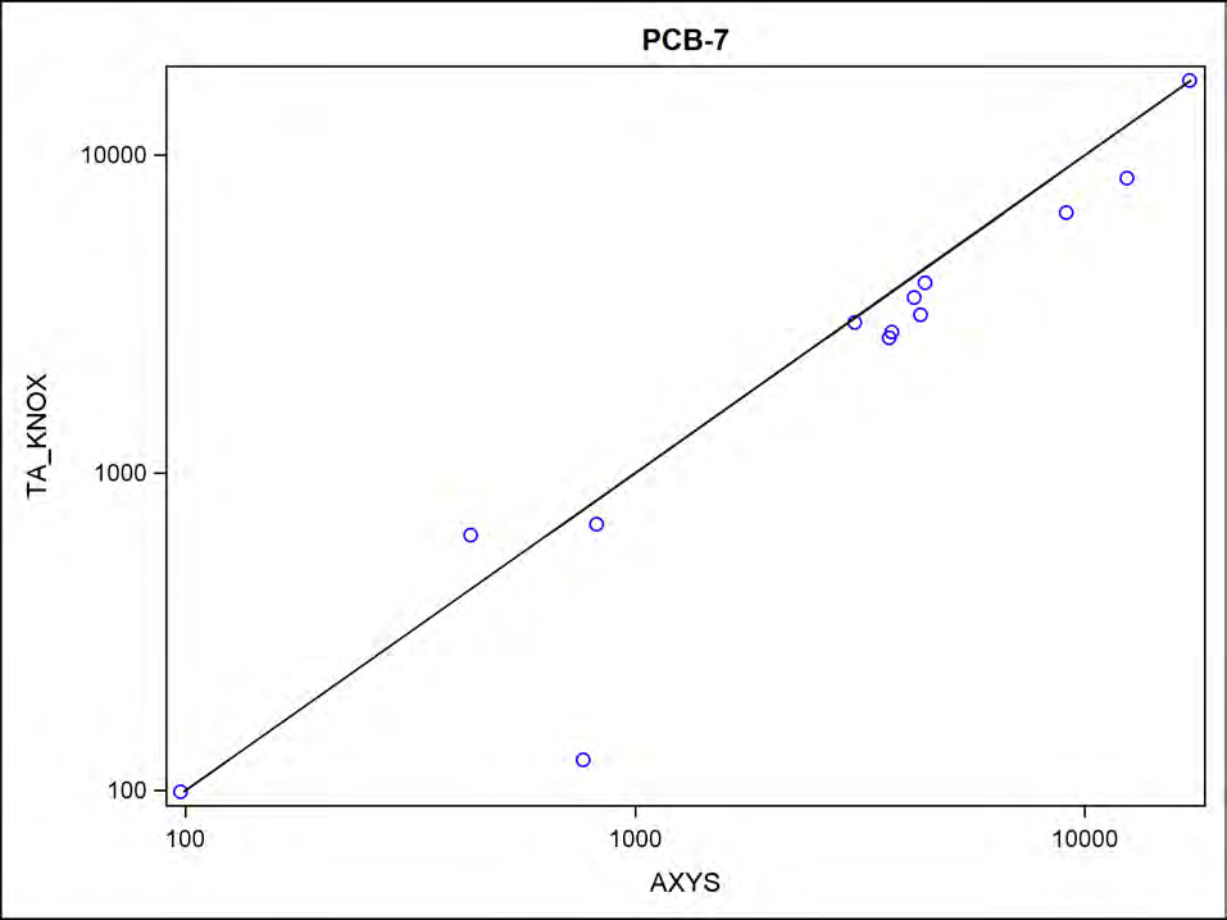

PCB-2
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

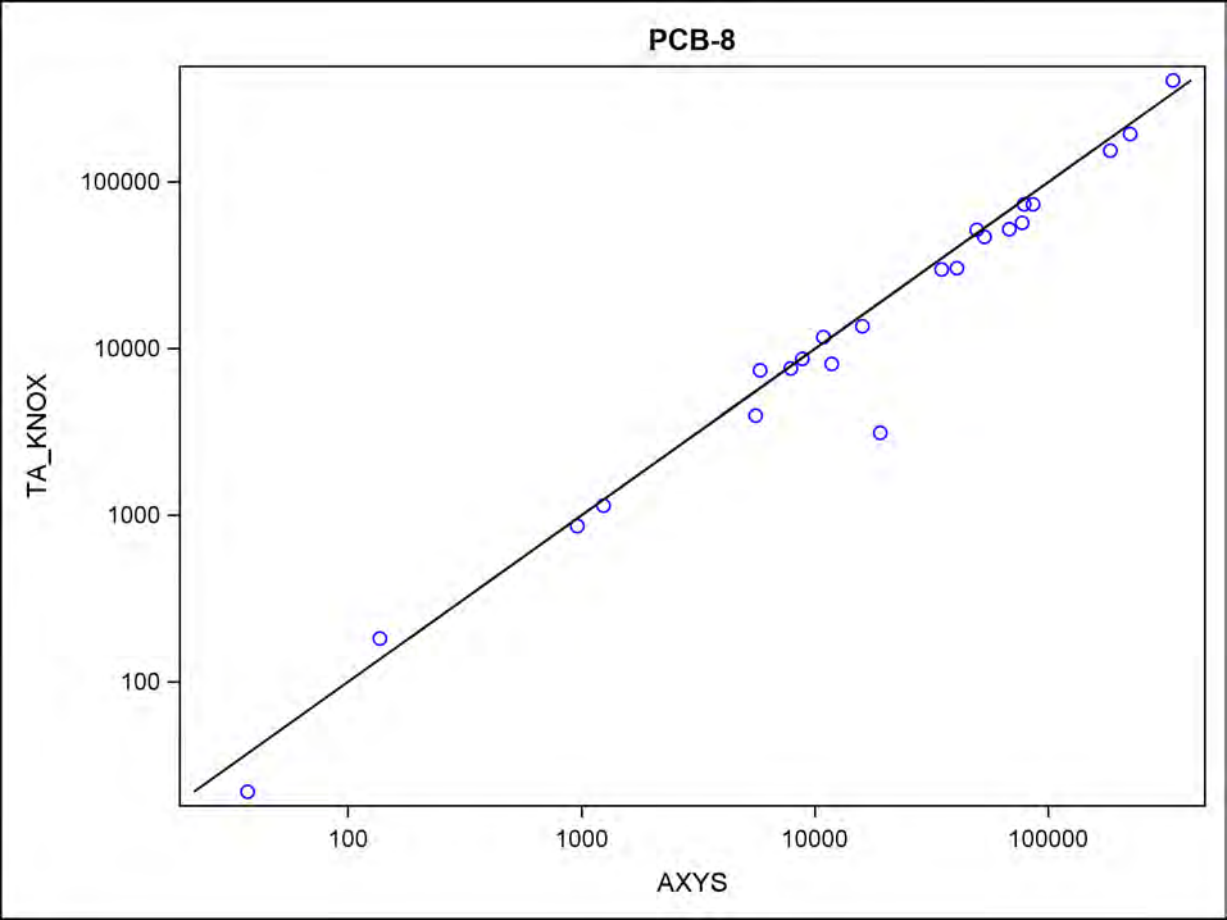

PCB-3
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

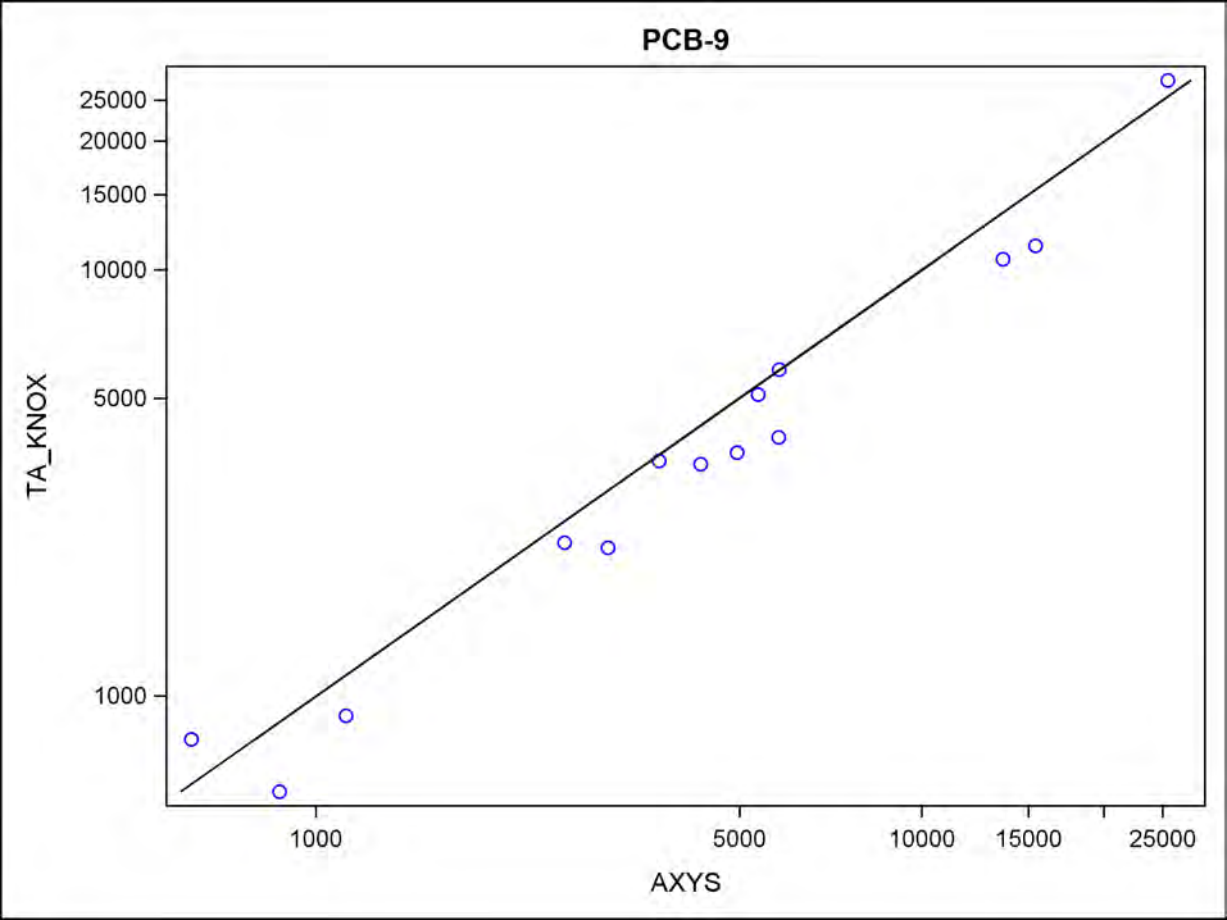

PCB-4
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

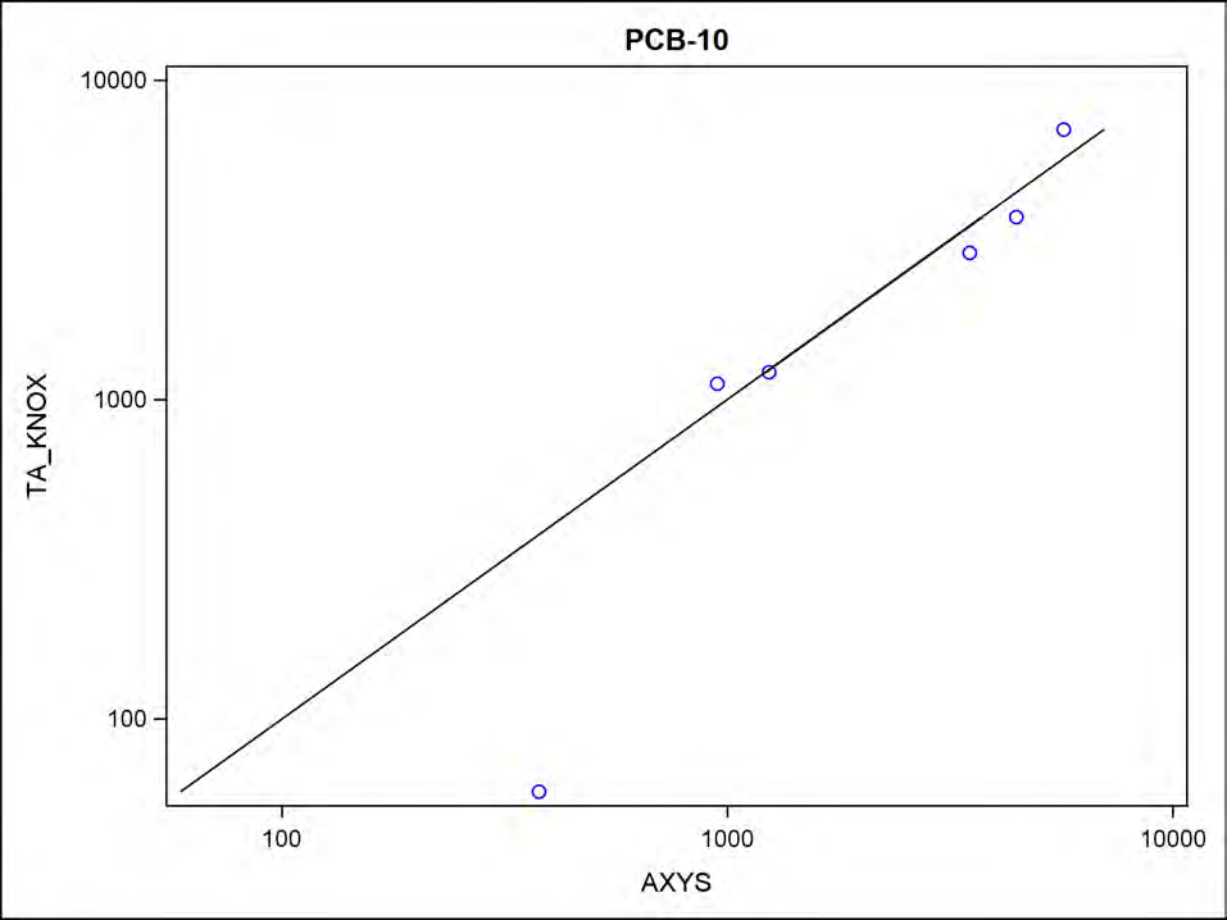

PCB-5
TA_KNOX
7000
6000
5000
4000
3000
2000
1000
1000
2000
3000
4000
5000
6000
8000
AXYS

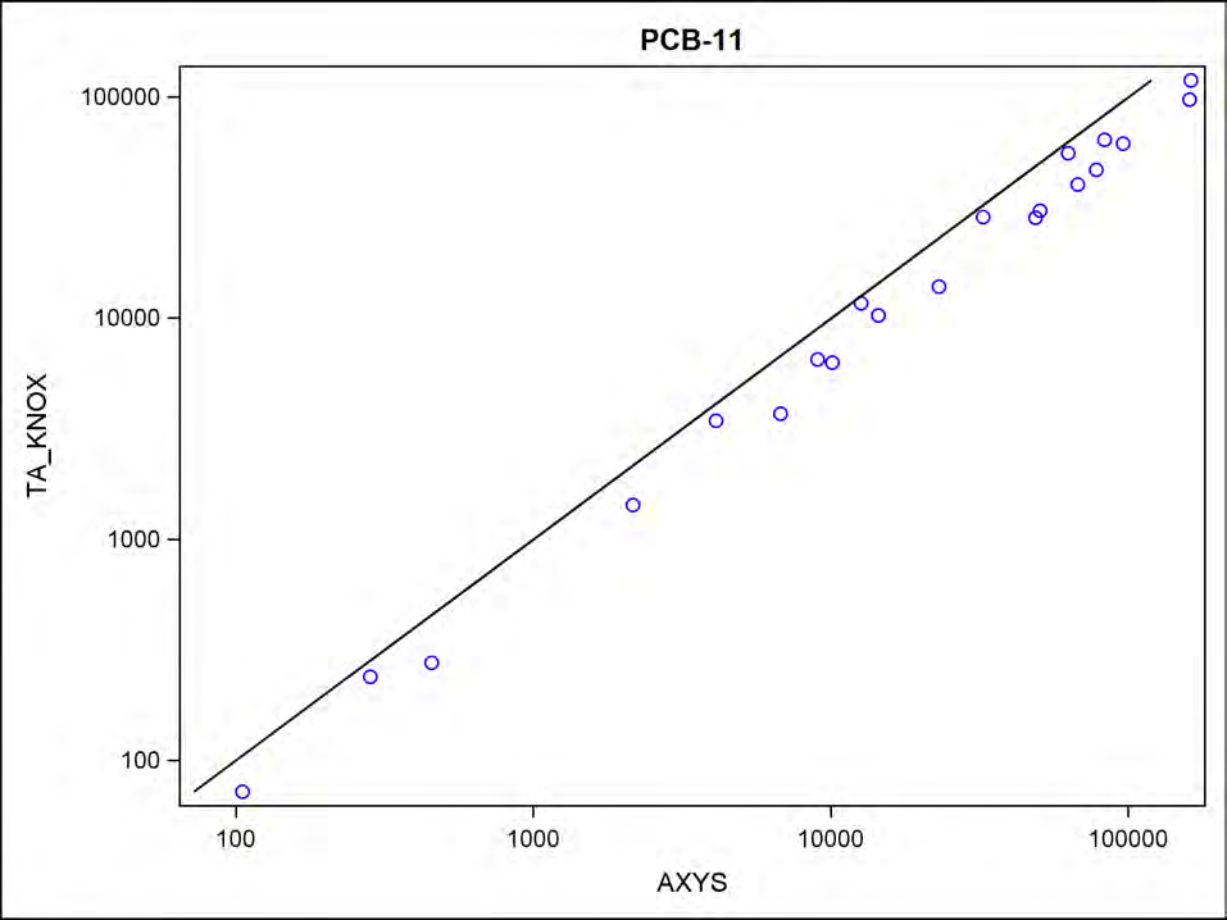

PCB-6
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

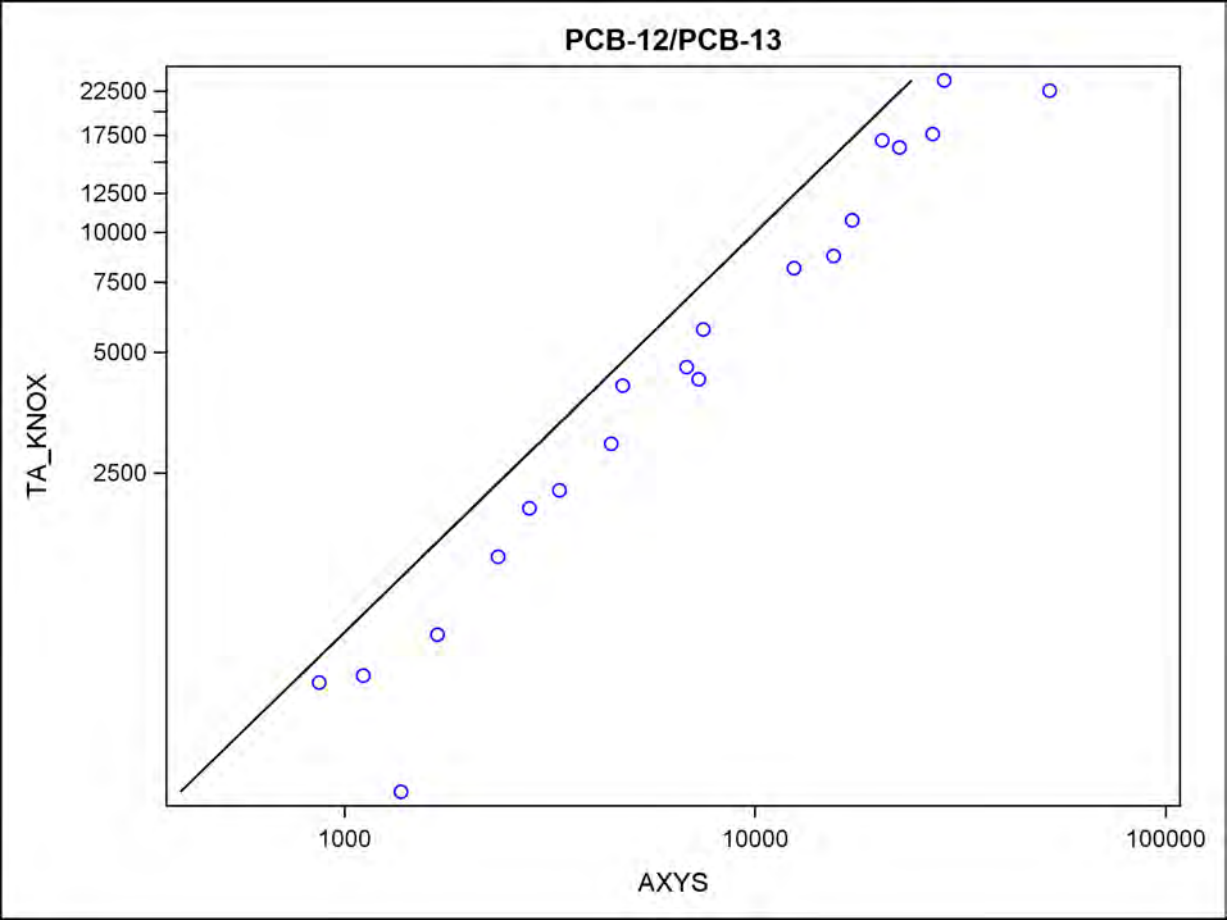

PCB-7
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

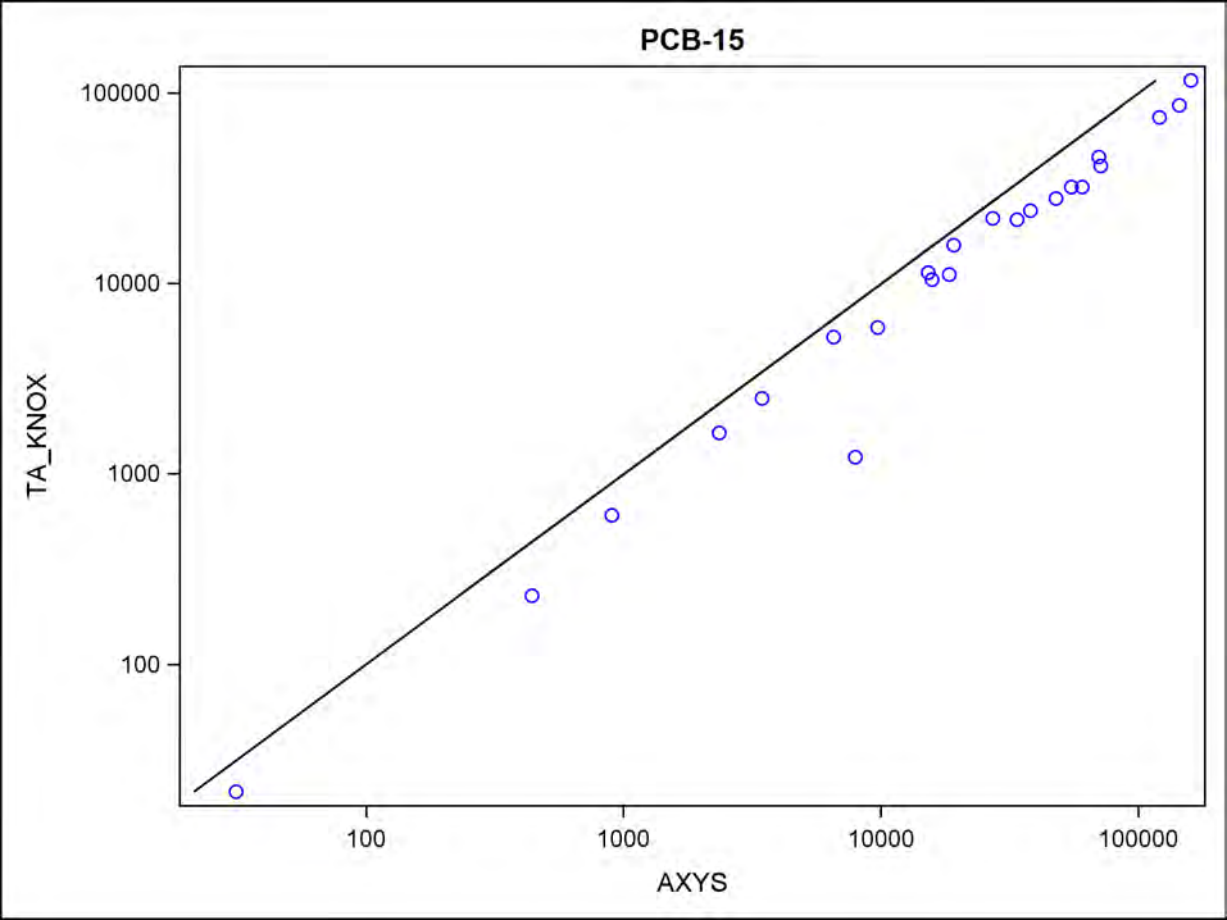

PCB-8
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS

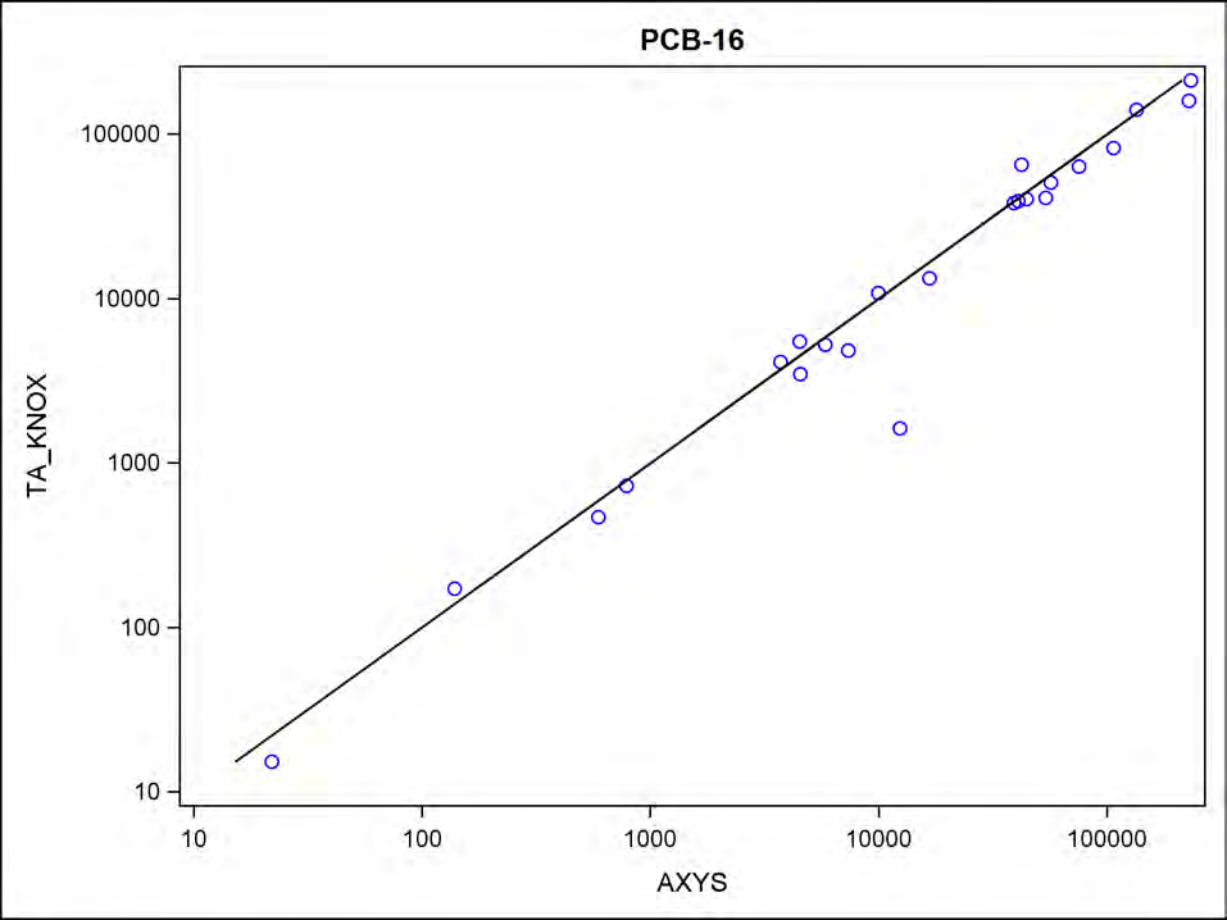

PCB-9
TA_KNOX
25000
20000
15000
10000
5000
1000
1000
5000
10000
15000
25000
AXYS

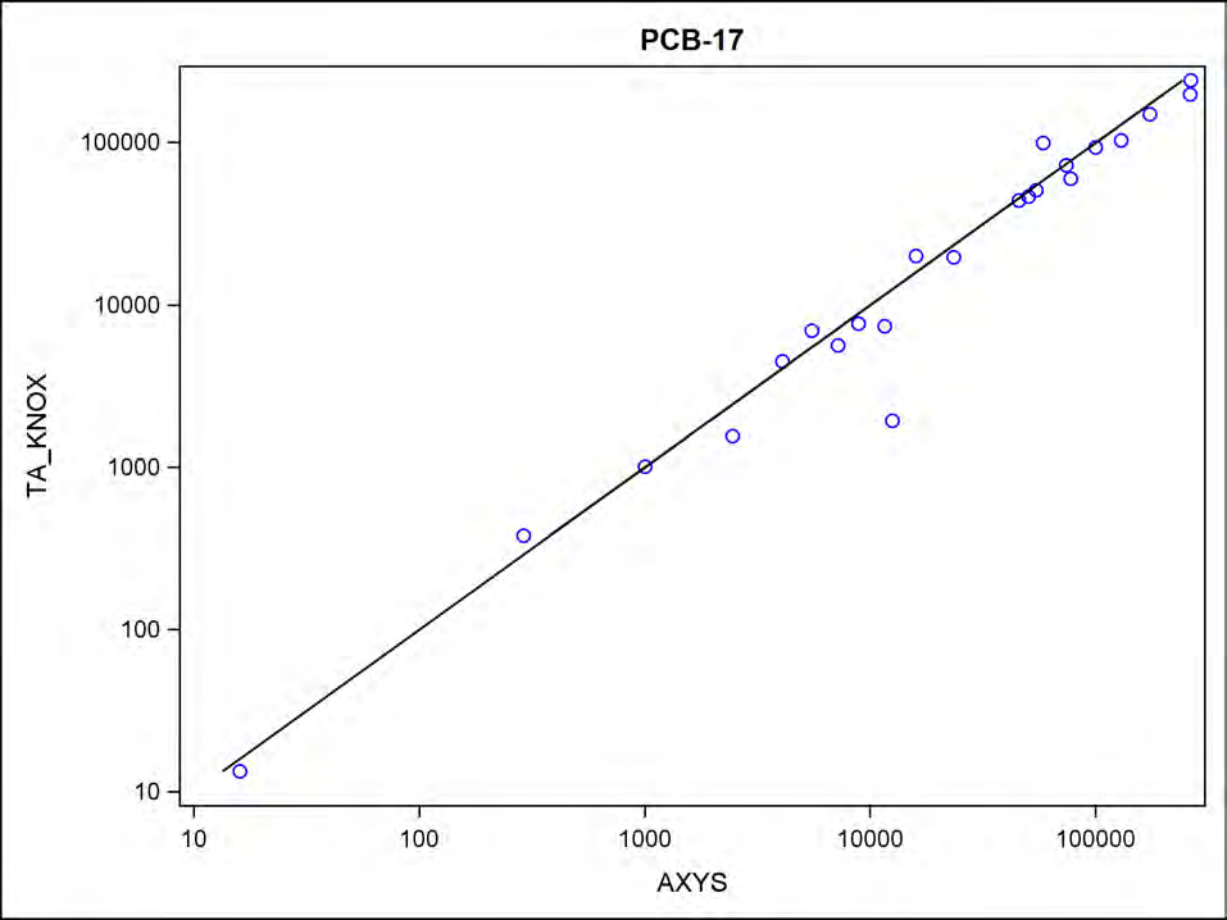

PCB-10
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

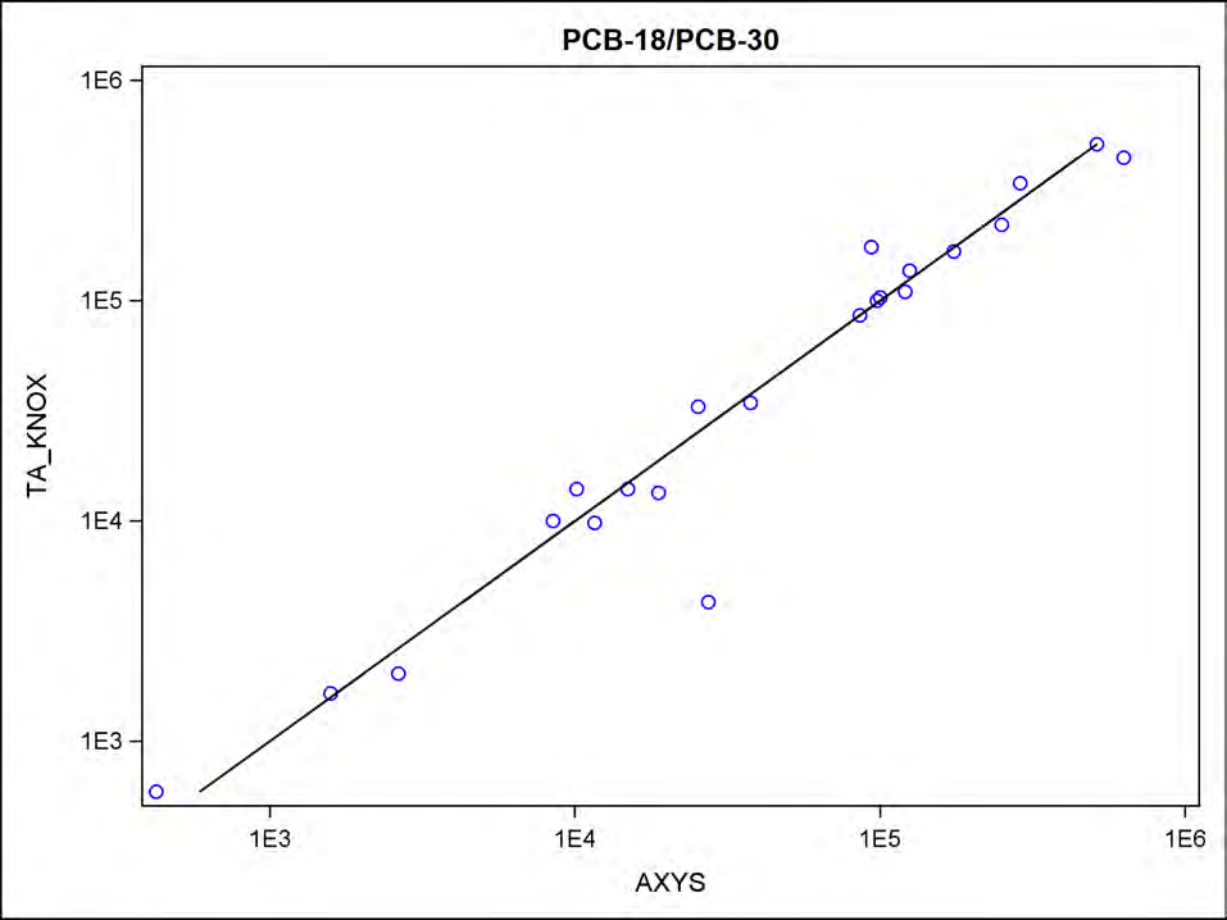

PCB-11
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

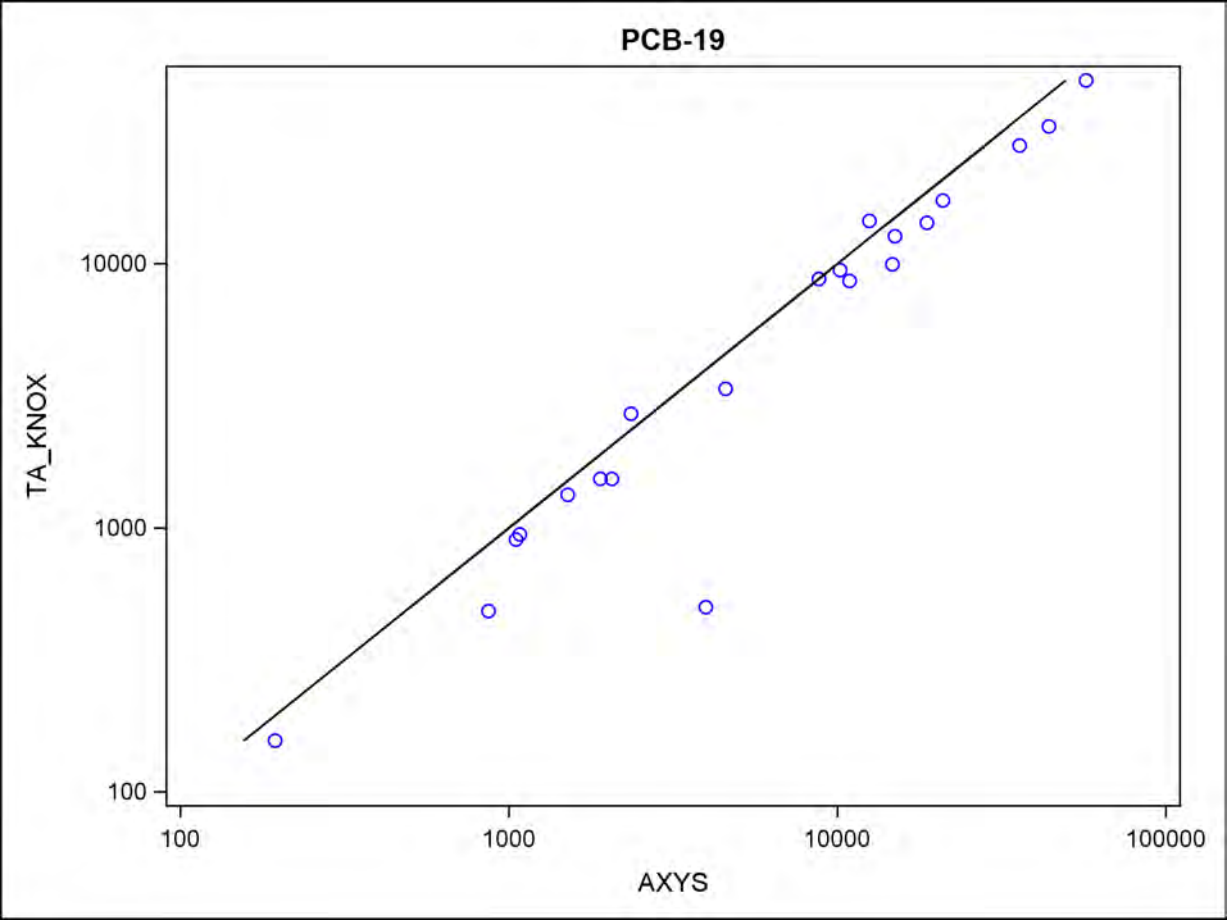

PCB-12/PCB-13
22500
17500
12500
10000
7500
5000
2500
TA_KNOX
1000
10000
100000
AXYS

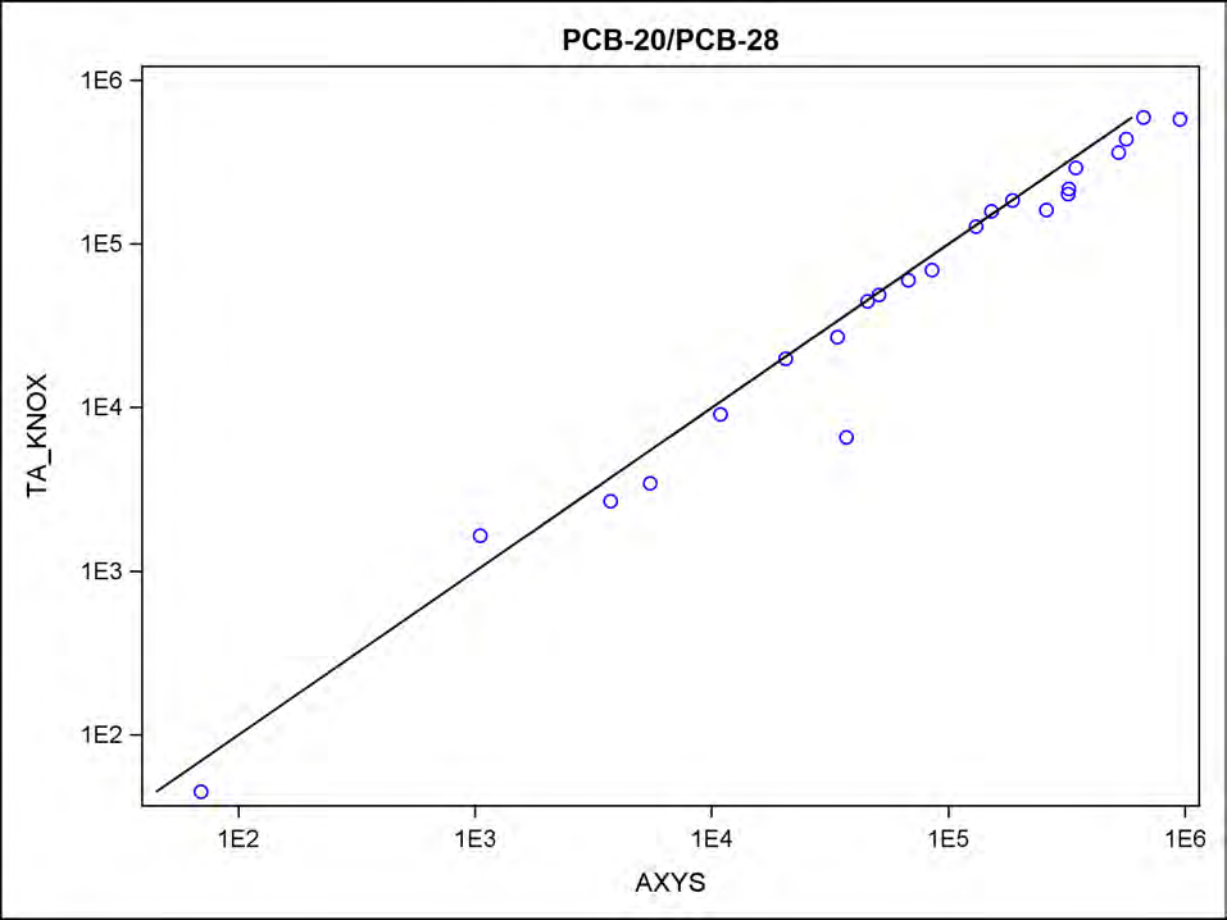

PCB-15
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

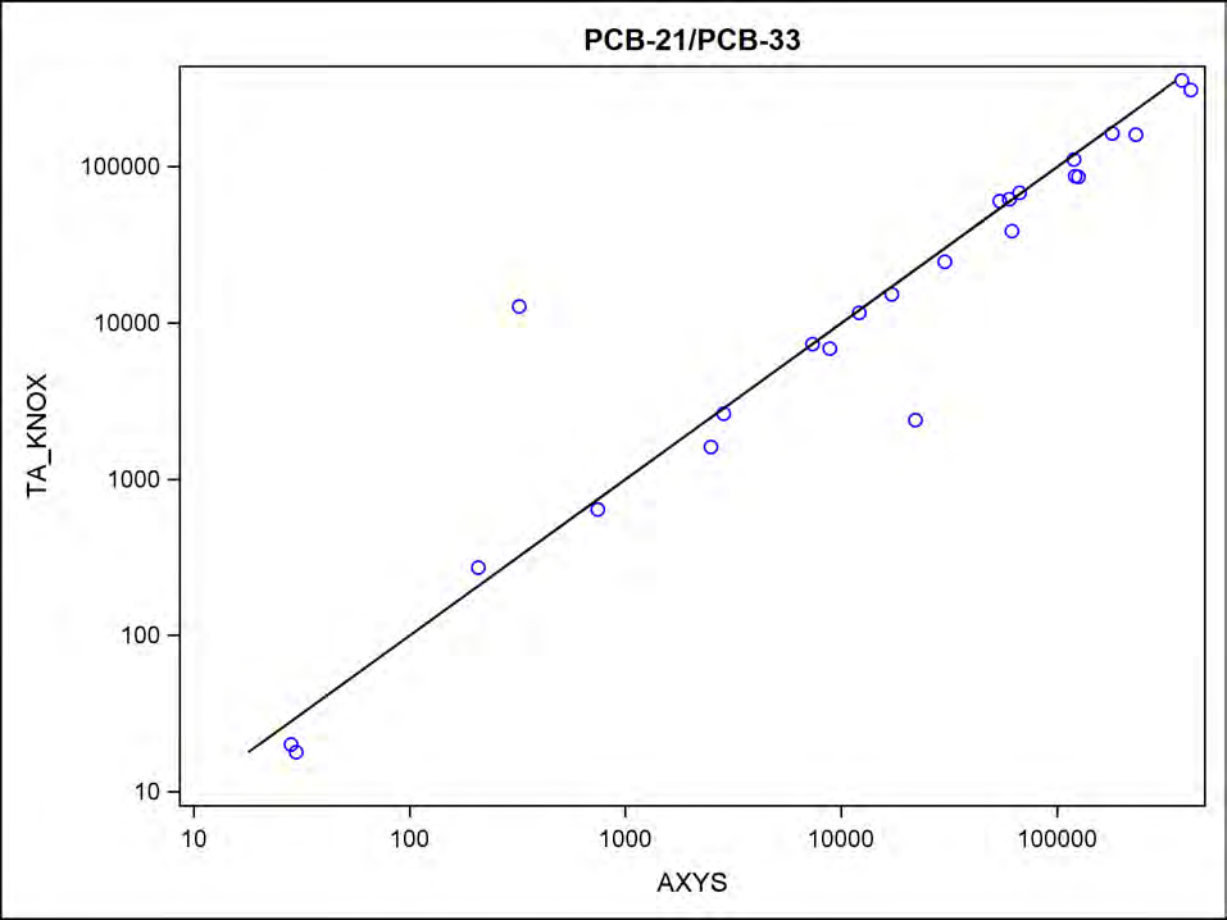

PCB-16
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

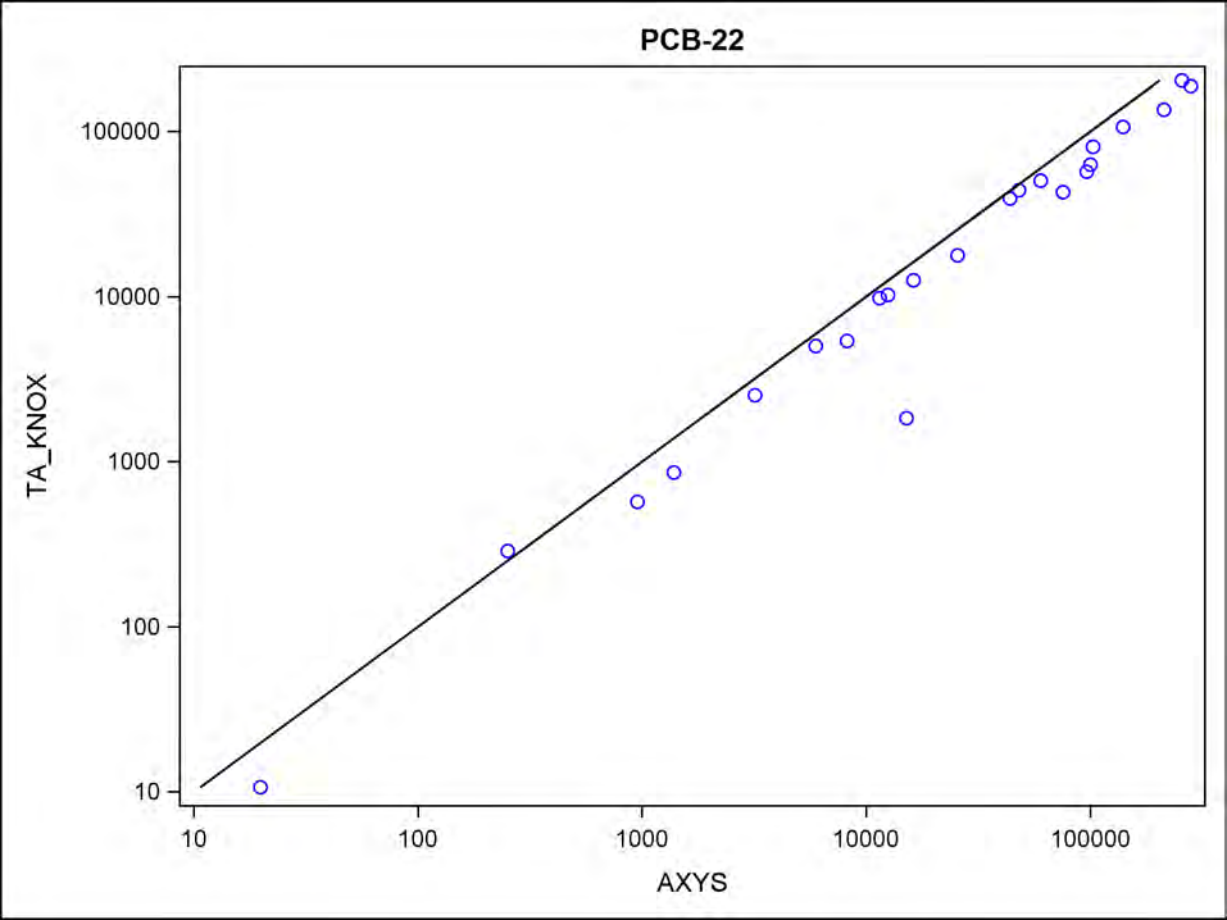

PCB-17
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

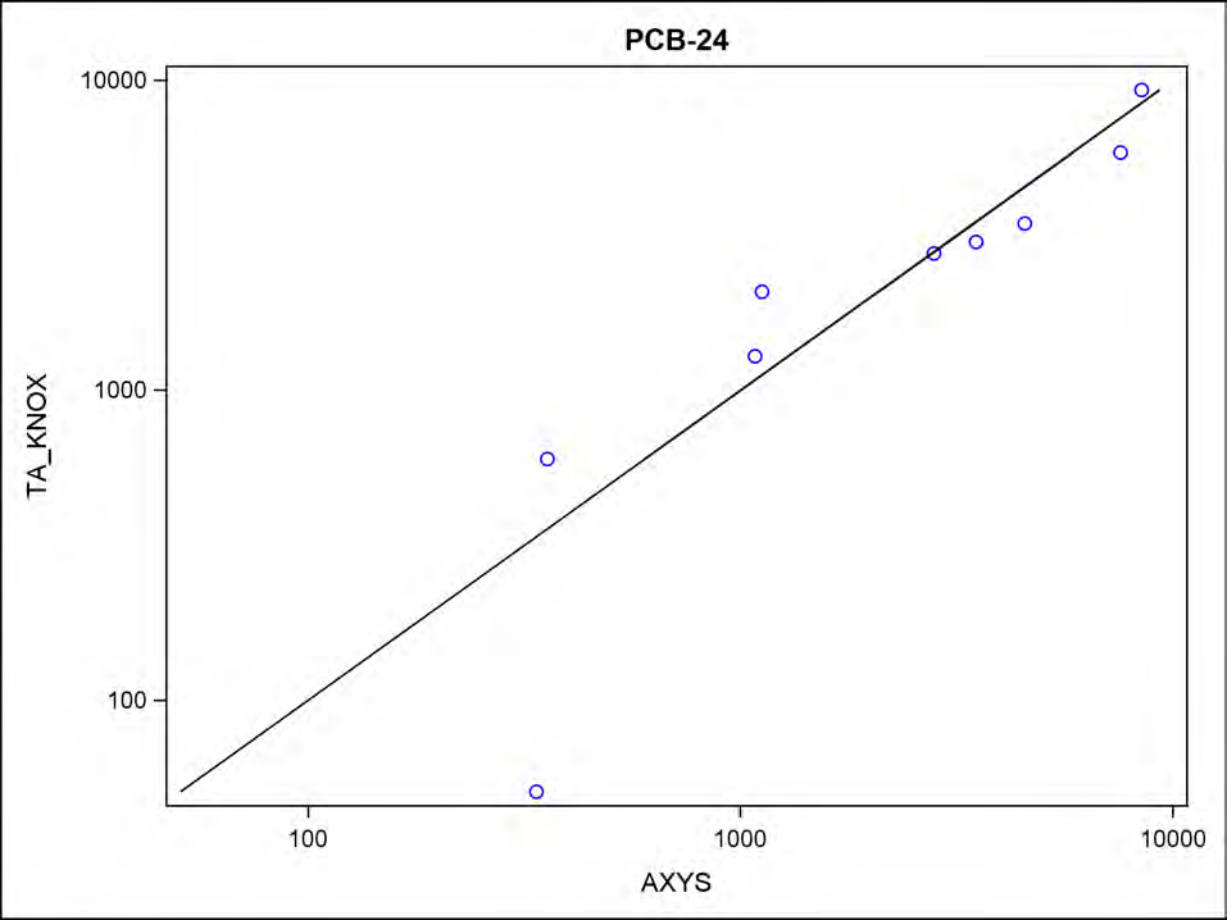

PCB-18/PCB-30
1E6
1E5
1E4
1E3
TA_KNOX
1E3
1E4
1E5
1E6
AXYS

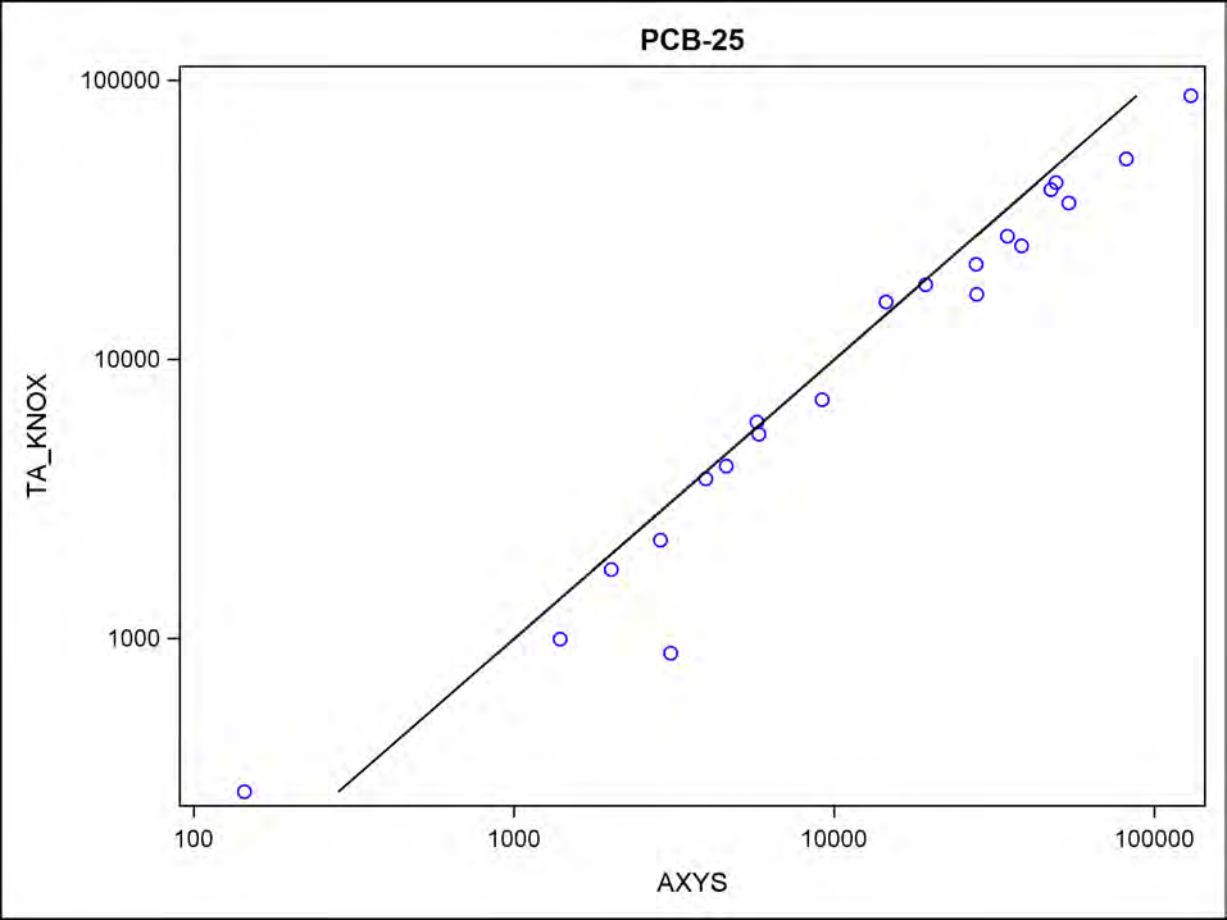

PCB-19
TA_KNOX
10000
1000
100
100
1000
10000
100000
AXYS

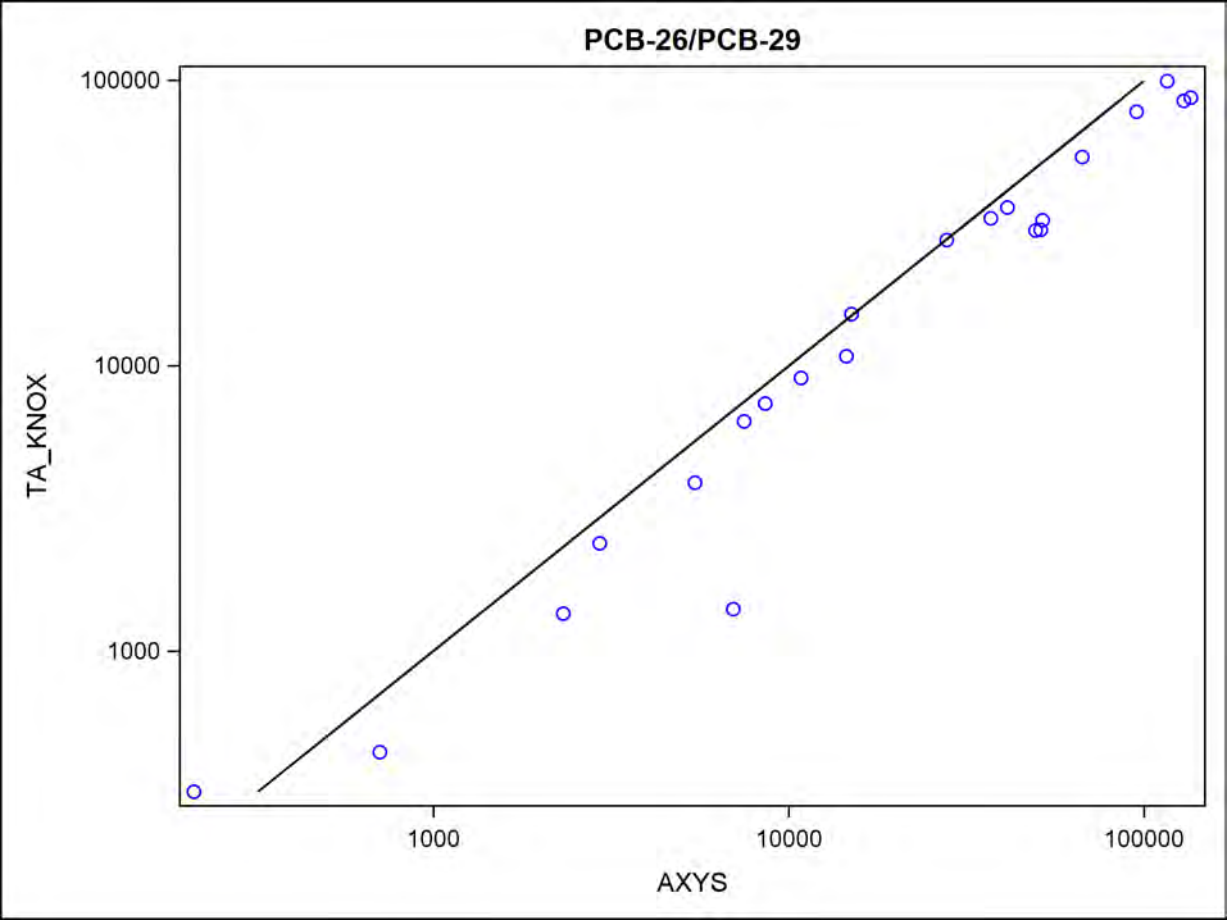

PCB-20/PCB-28
TA_KNOX
AXYS
1E6
1E5
1E4
1E3
1E2
1E2
1E3
1E4
1E5
1E6

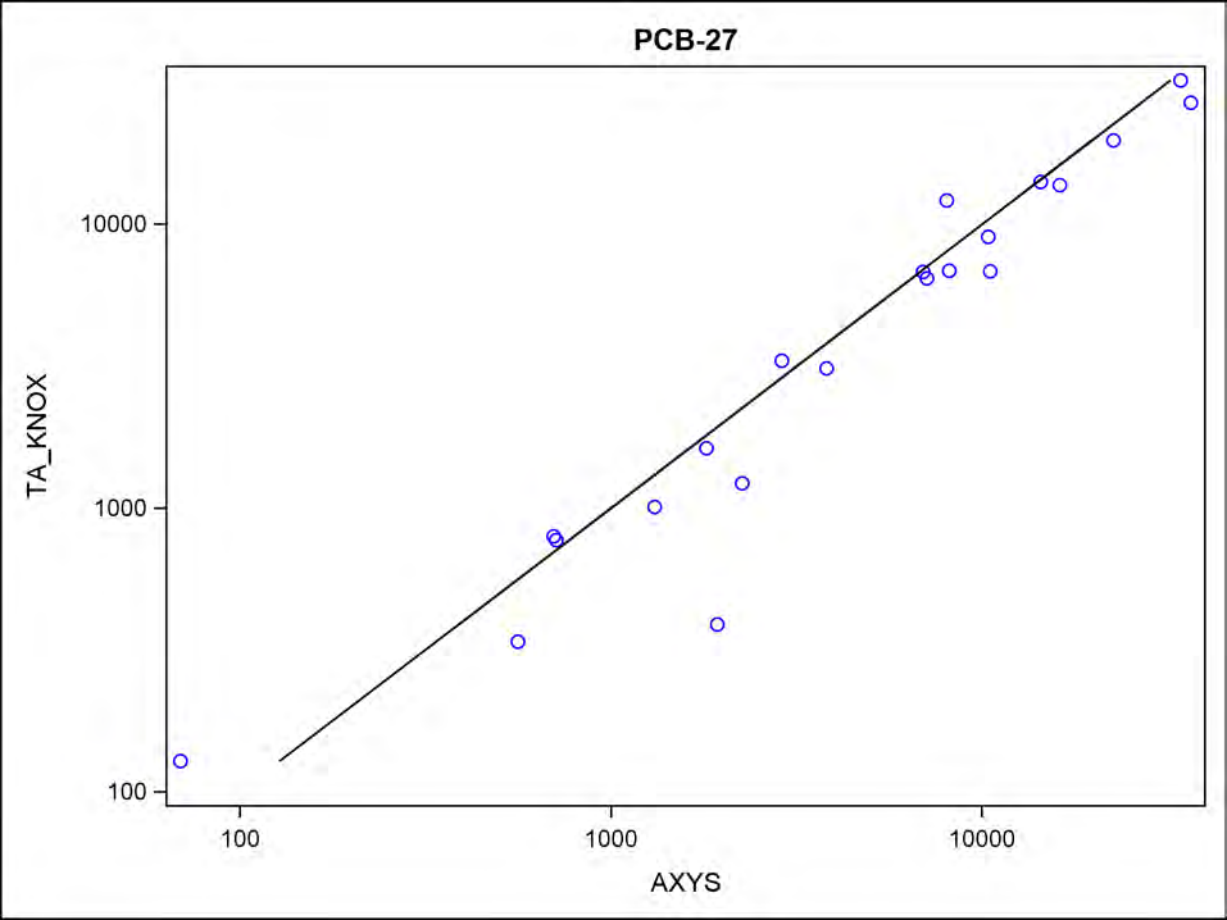

PCB-21/PCB-33
TA_KNOX
AXYS
10
100
1000
10000
100000
10
100
1000
10000
100000

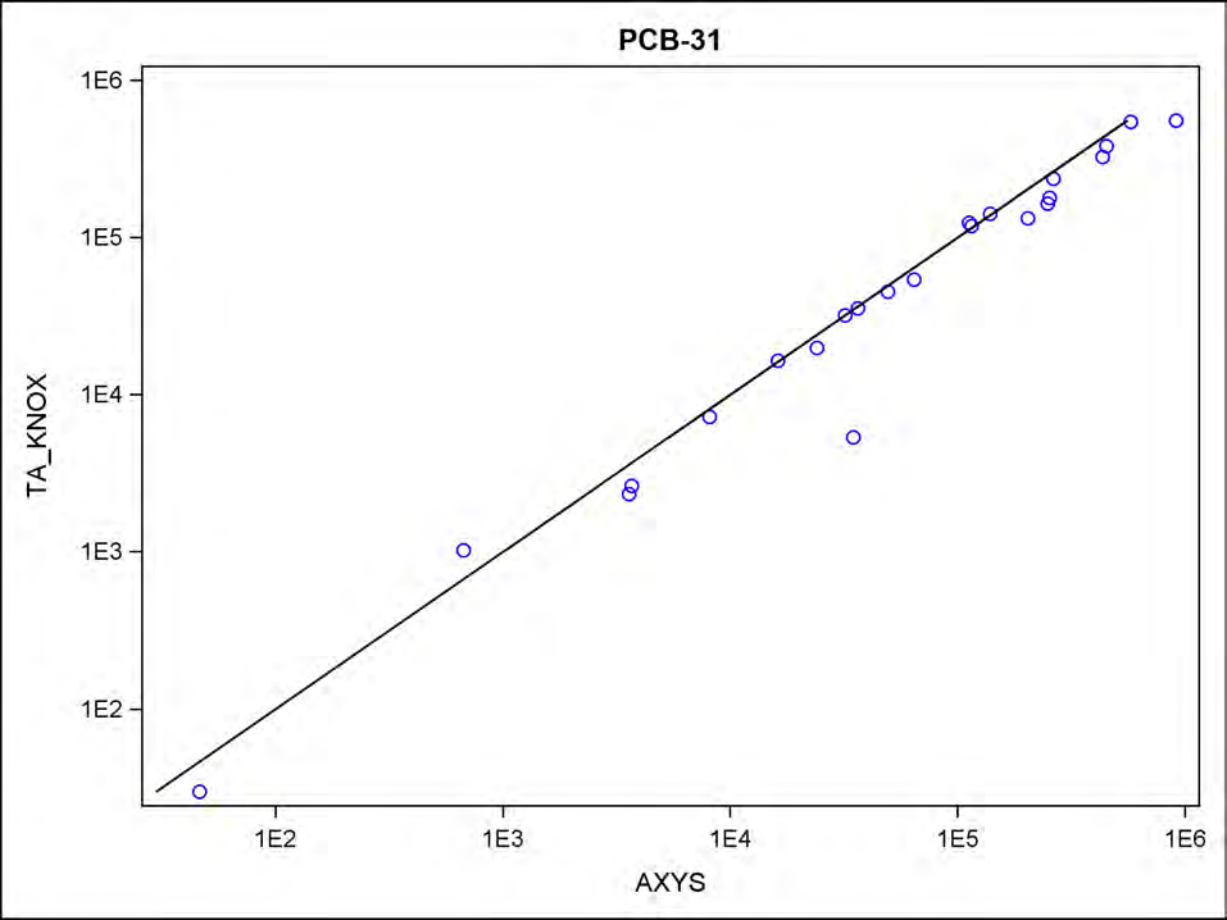

PCB-22
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

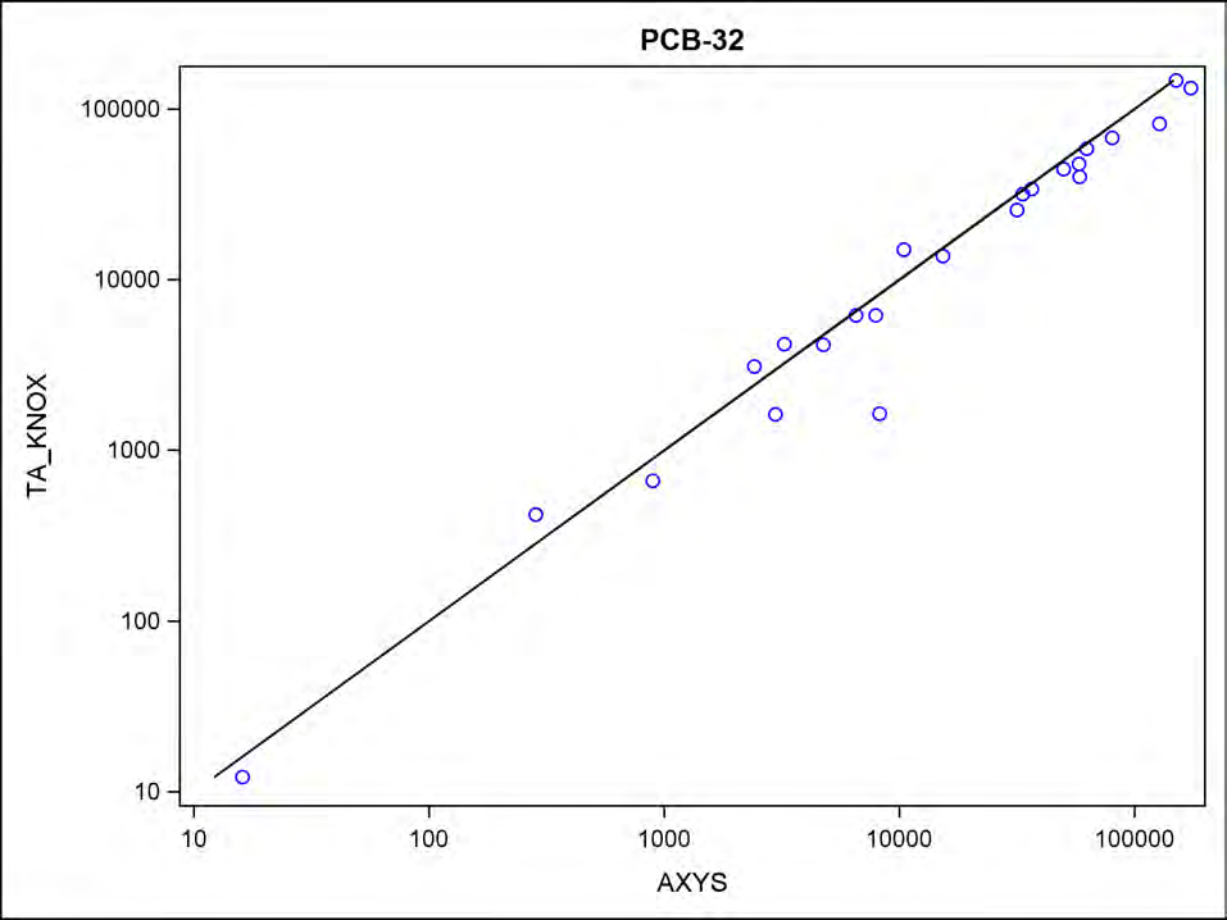

PCB-24
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

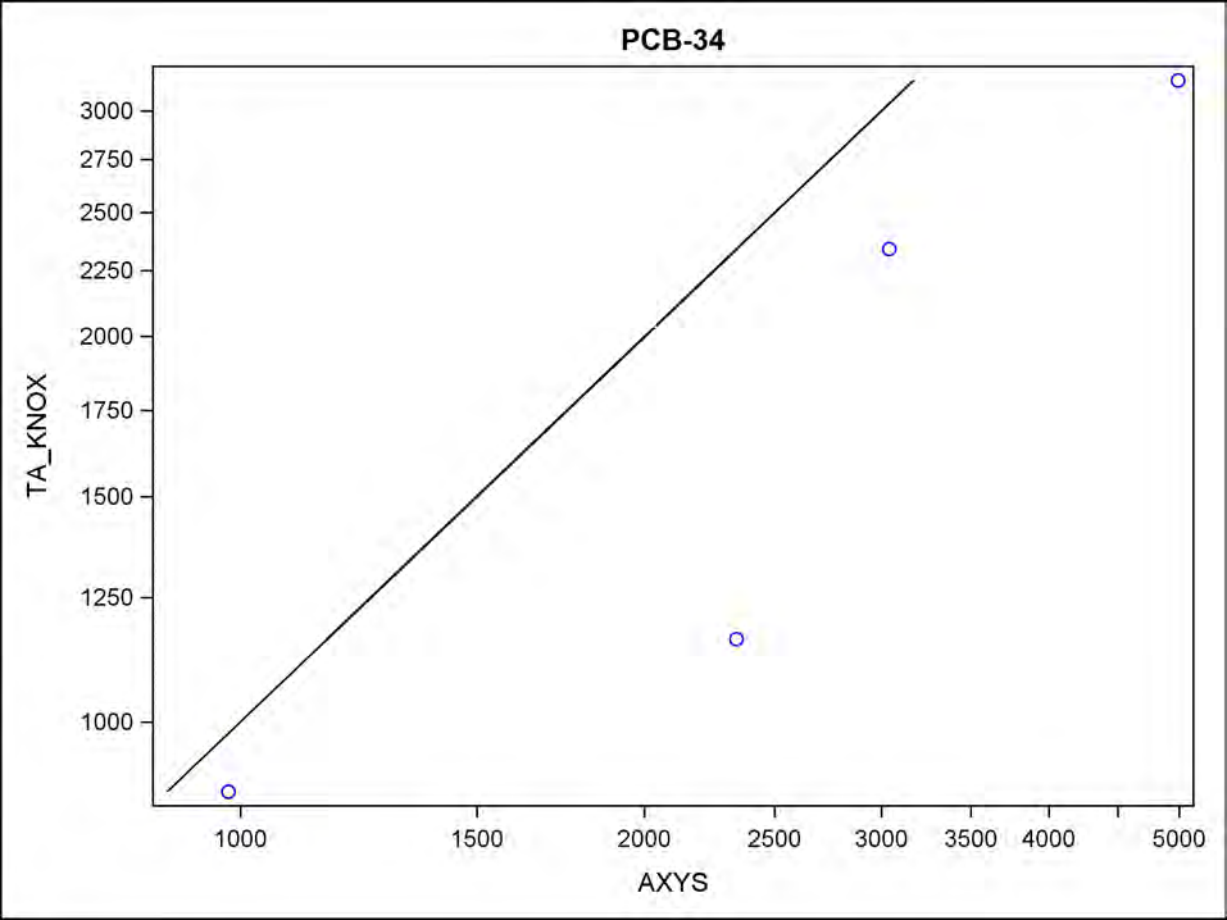

PCB-25
100000
10000
1000
TA_KNOX
100
1000
10000
100000
AXYS

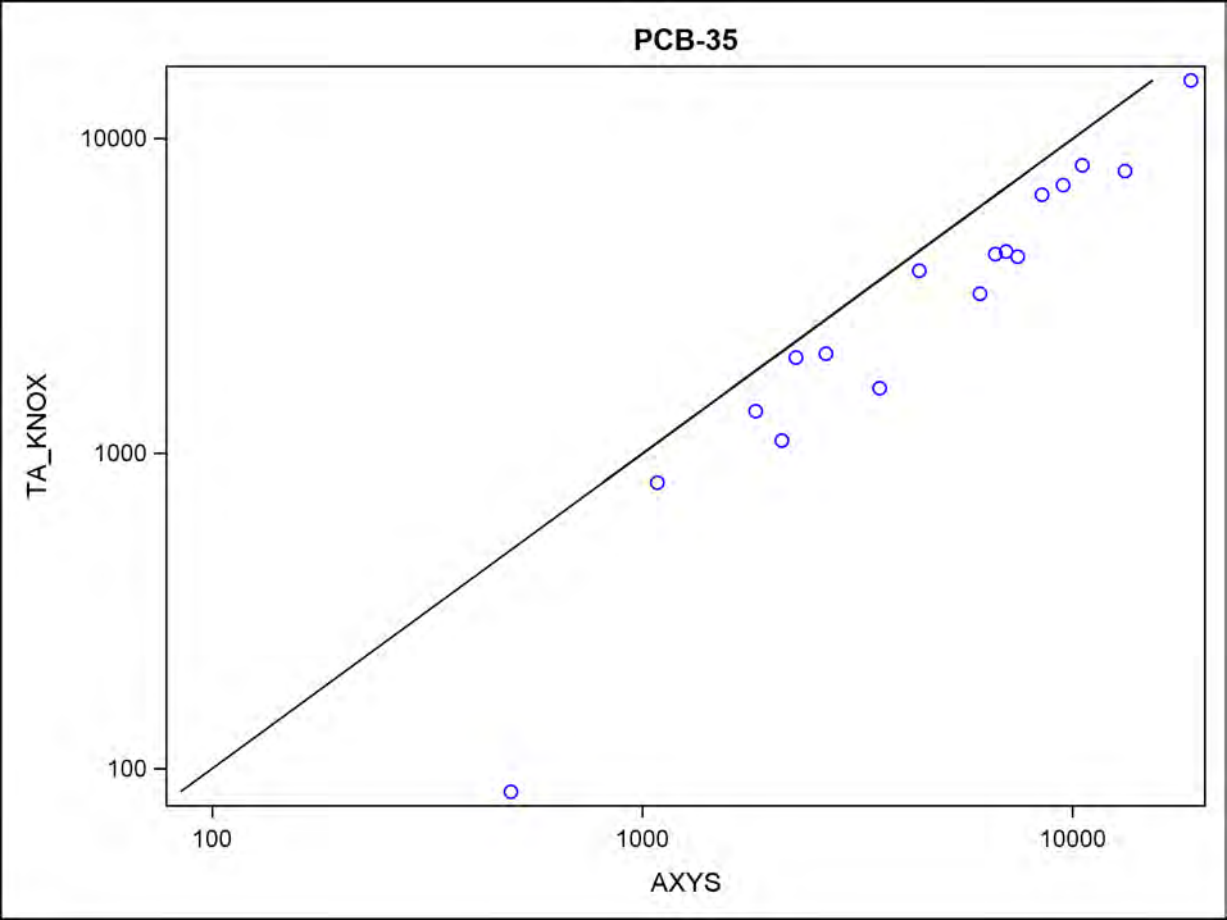

PCB-26/PCB-29
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

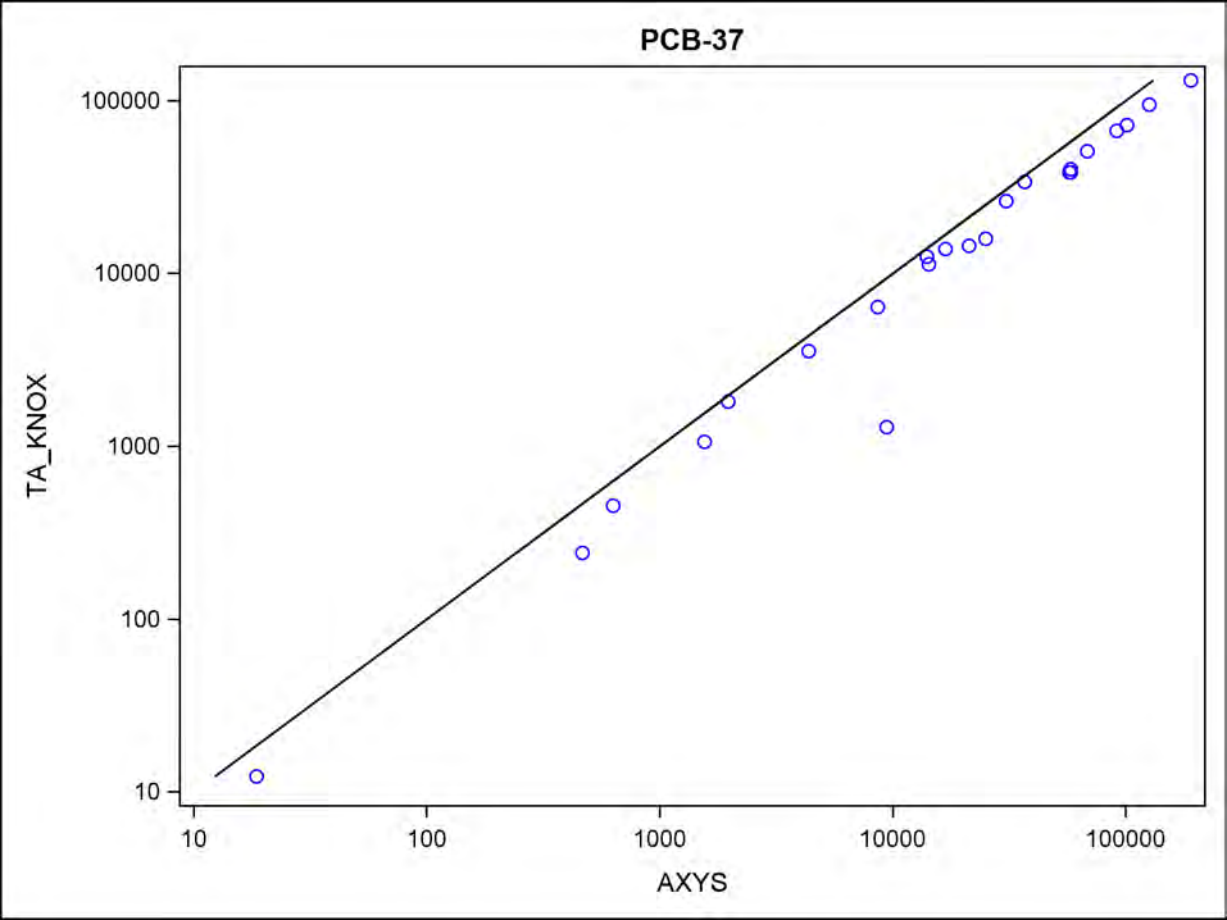

PCB-27
TA_KNOX
10000
1000
100
100
1000
10000
AXYS

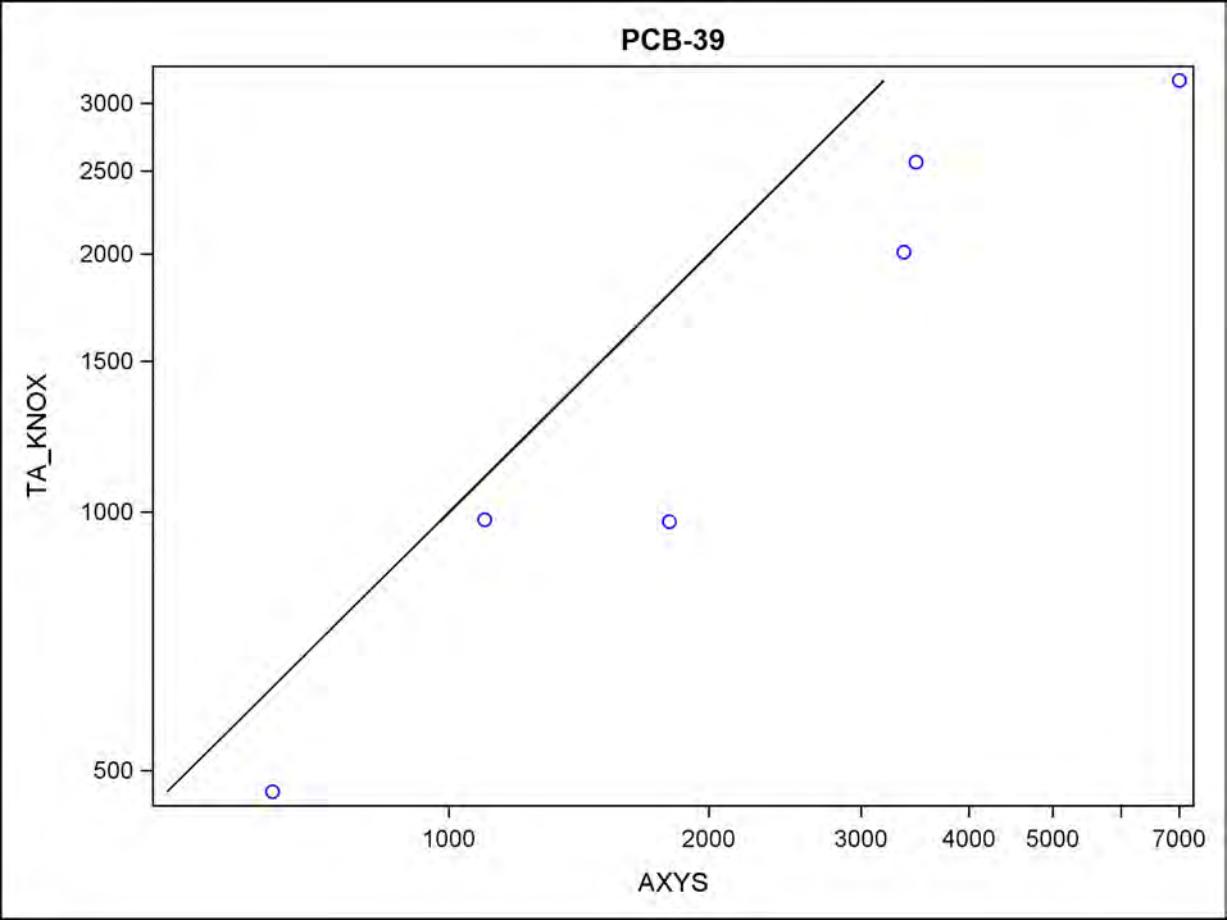

PCB-31
TA_KNOX
AXYS
1E6
1E5
1E4
1E3
1E2
1E2
1E3
1E4
1E5
1E6

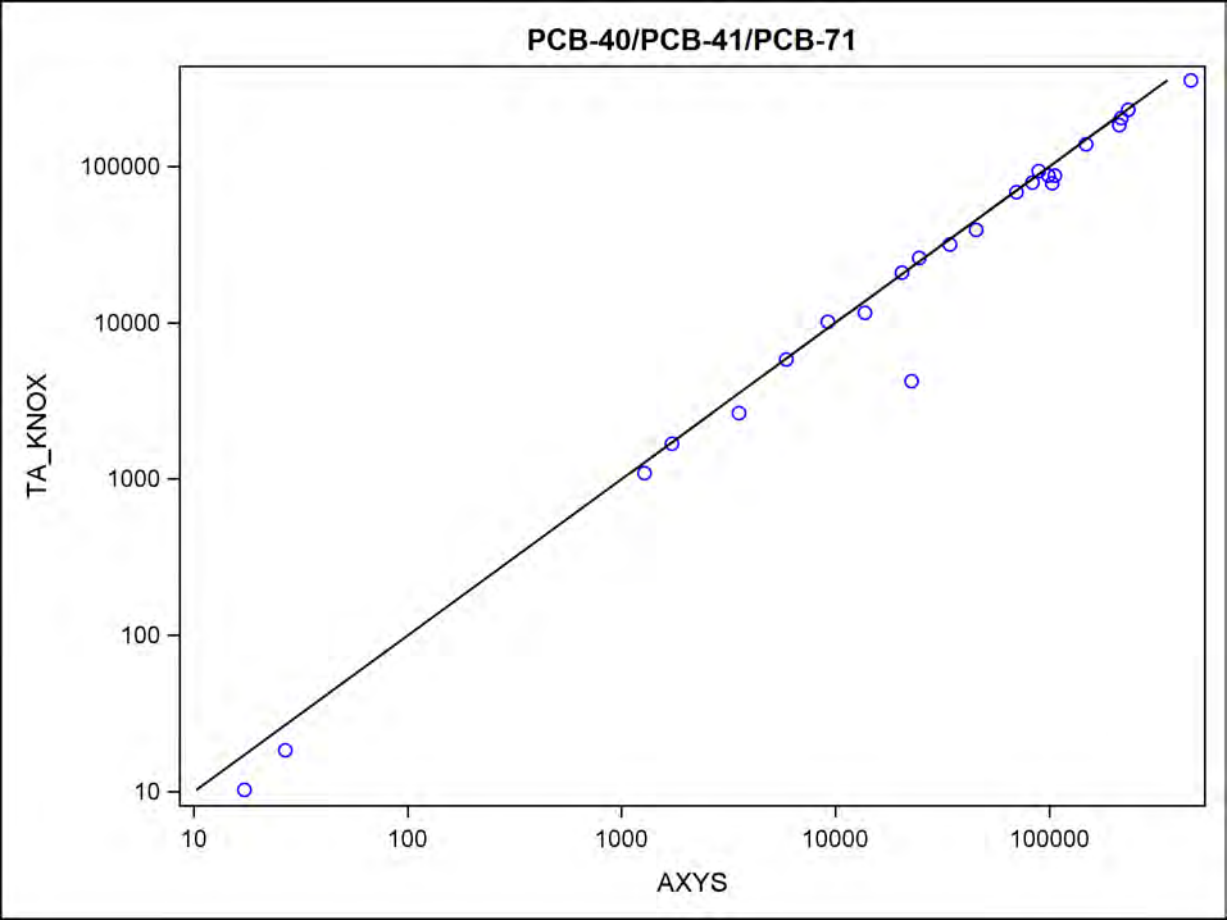

PCB-32
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

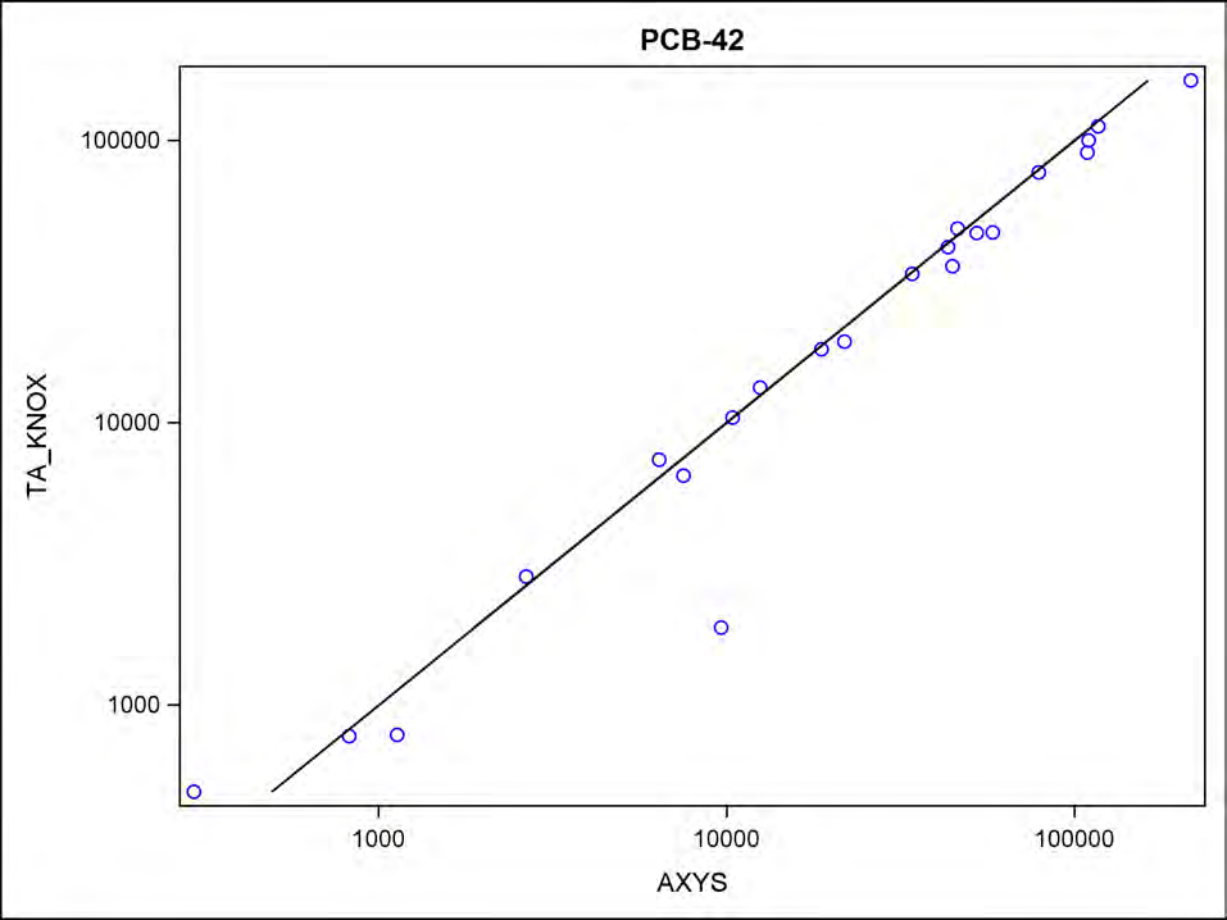

PCB-34
TA_KNOX
3000
2750
2500
2250
2000
1750
1500
1250
1000
1000
1500
2000
2500
3000
3500
4000
5000
AXYS

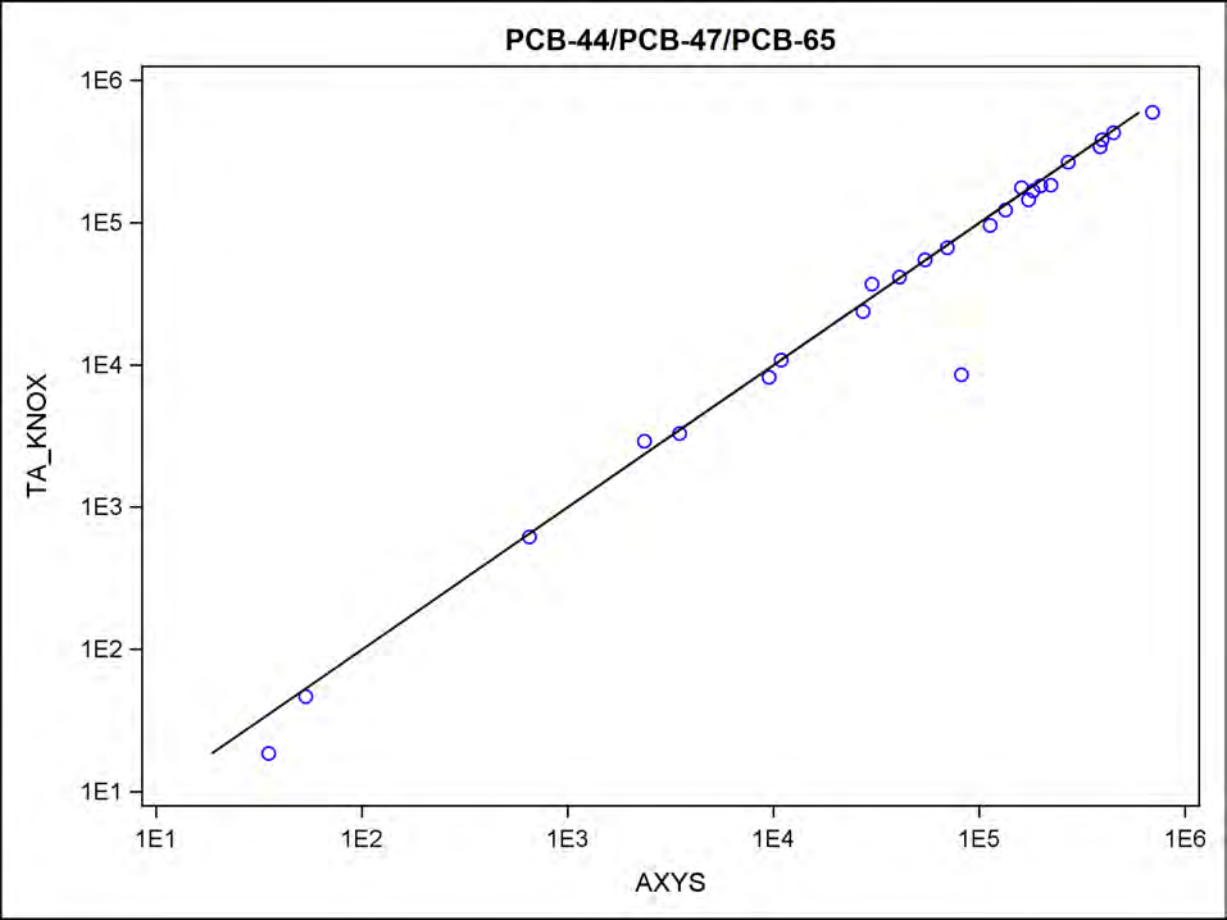

PCB-35
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

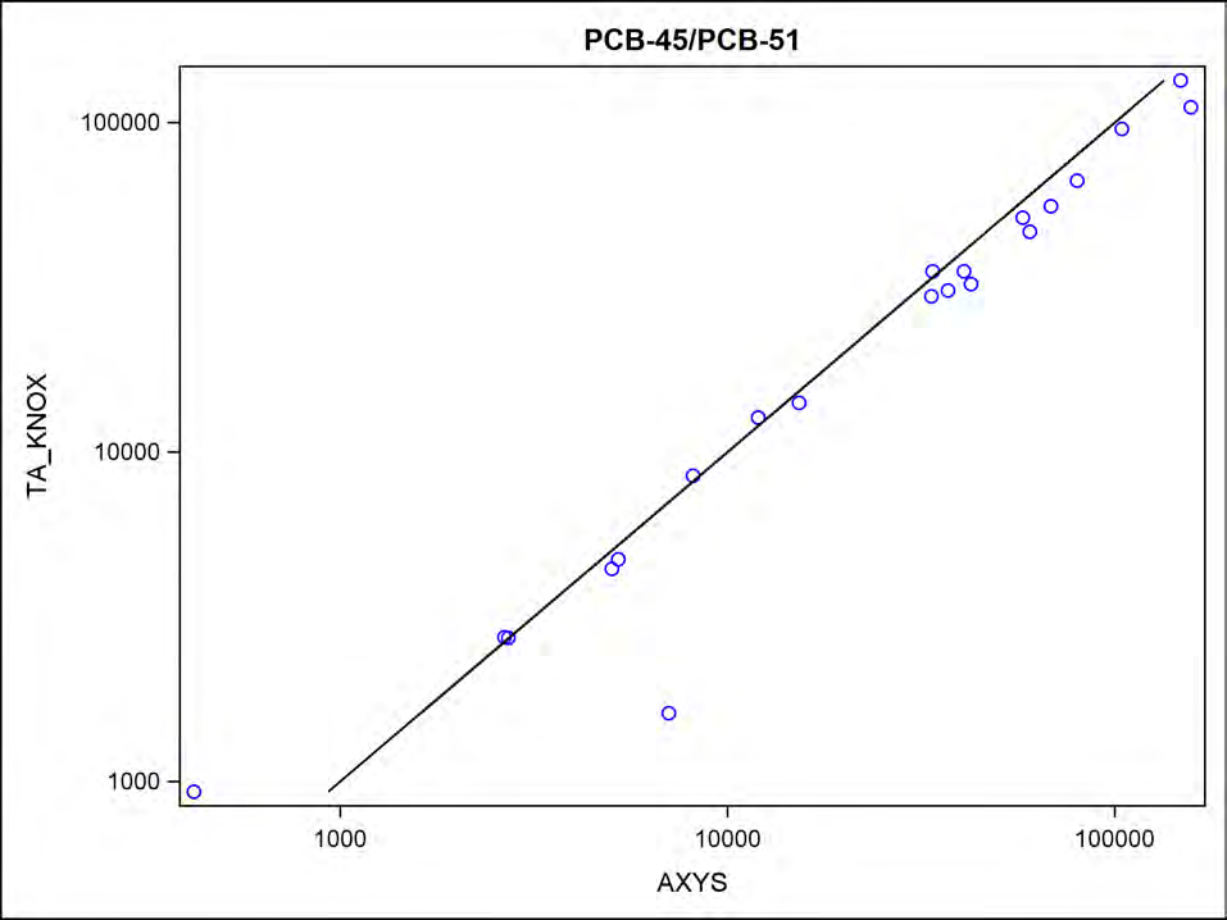

PCB-37
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

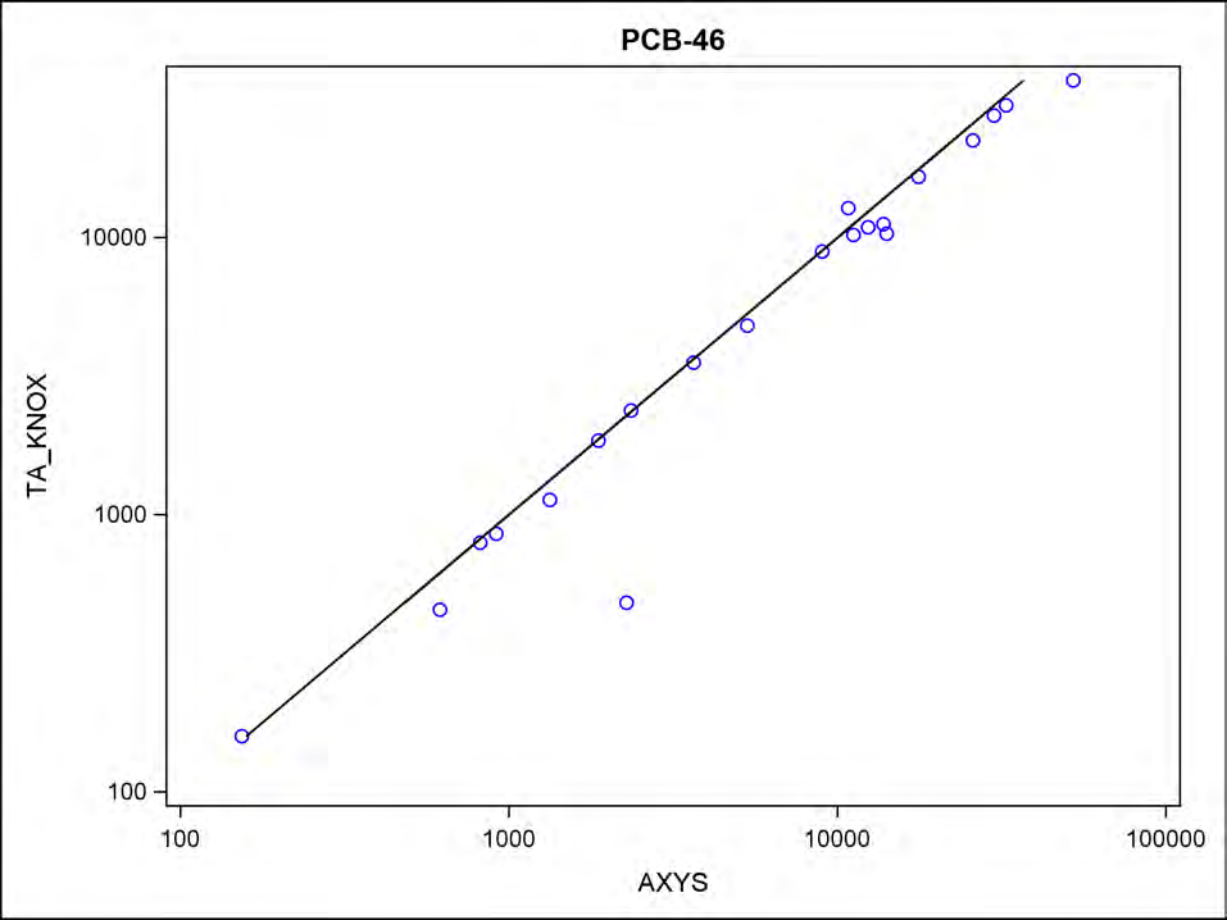

PCB-39
TA_KNOX
3000
2500
2000
1500
1000
500
1000
2000
3000
4000
5000
7000
AXYS

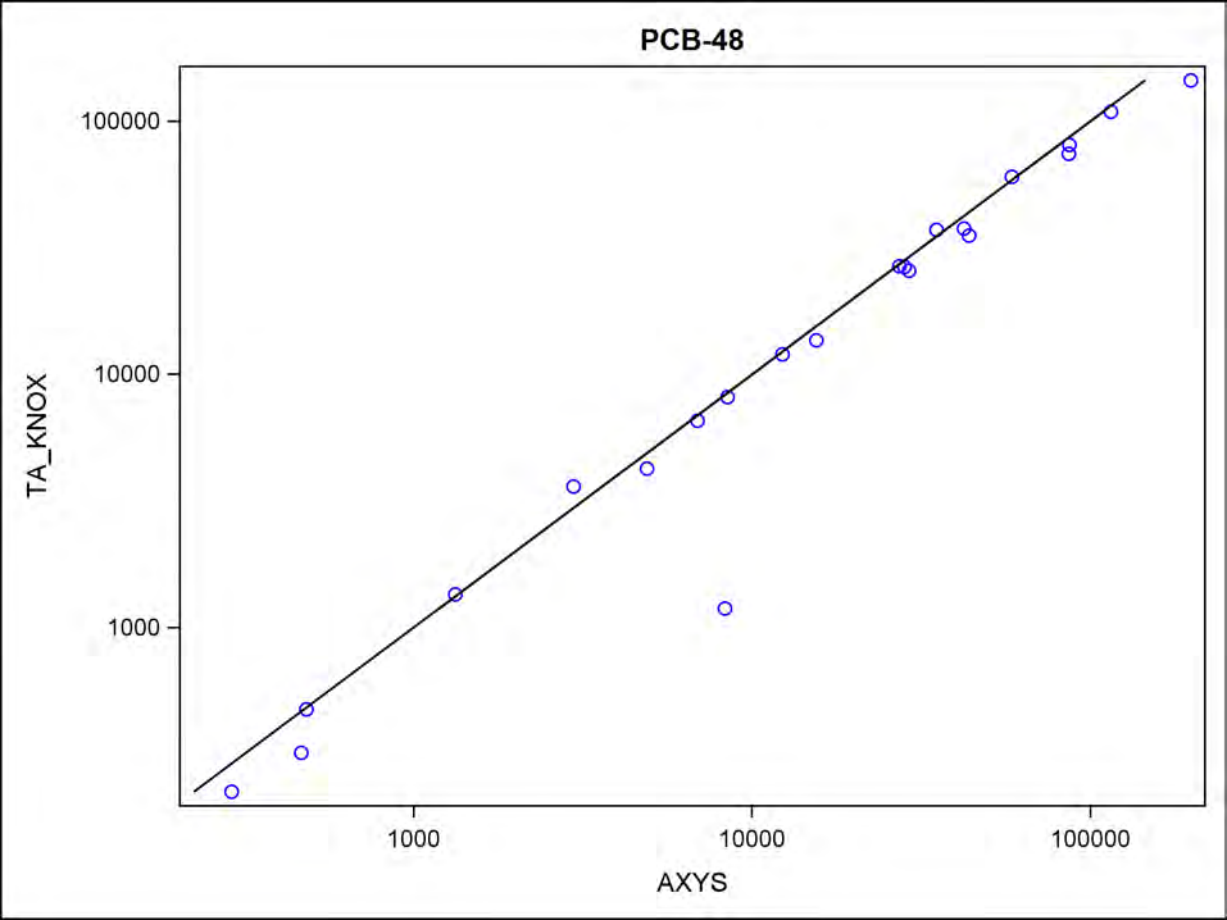

PCB-40/PCB-41/PCB-71
TA_KNOX
AXYS
10
100
1000
10000
100000

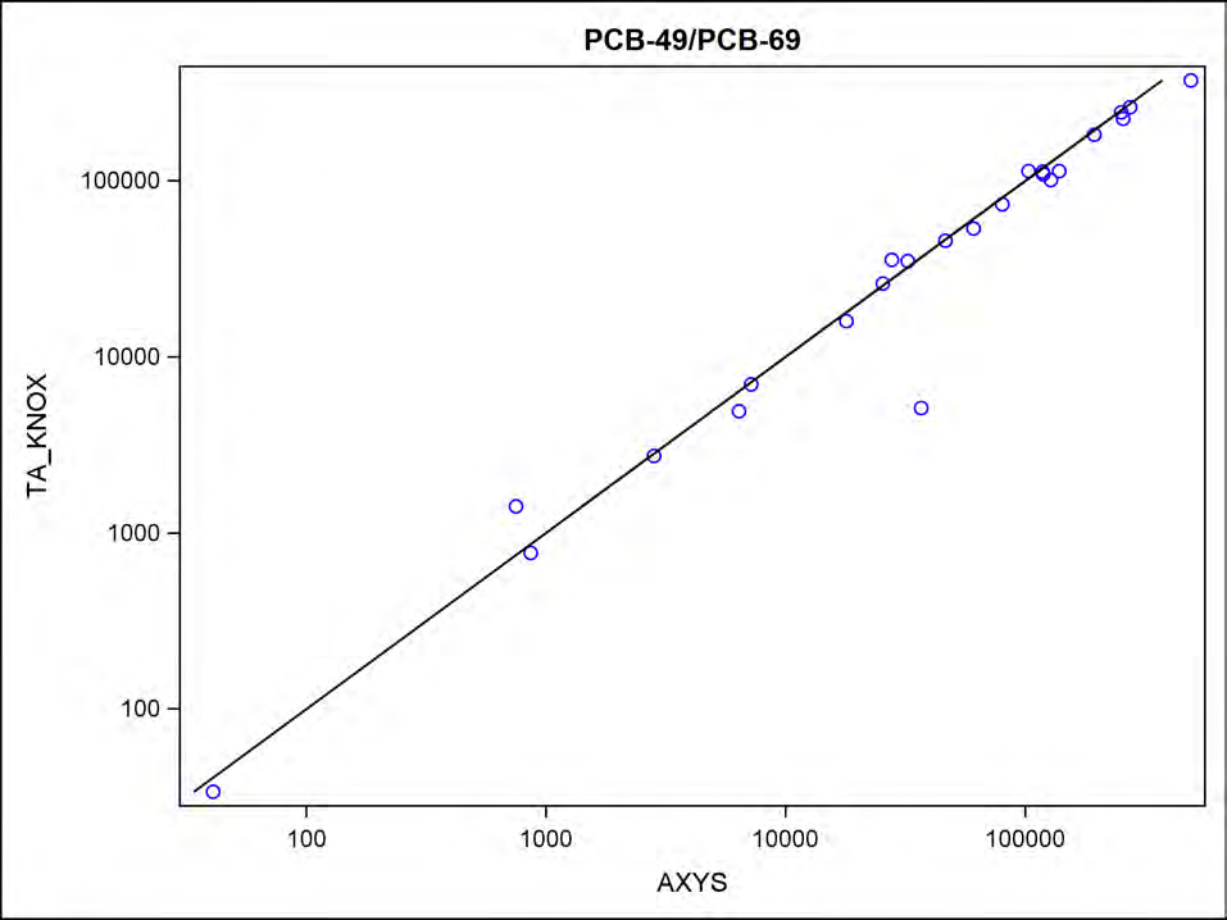

PCB-42
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

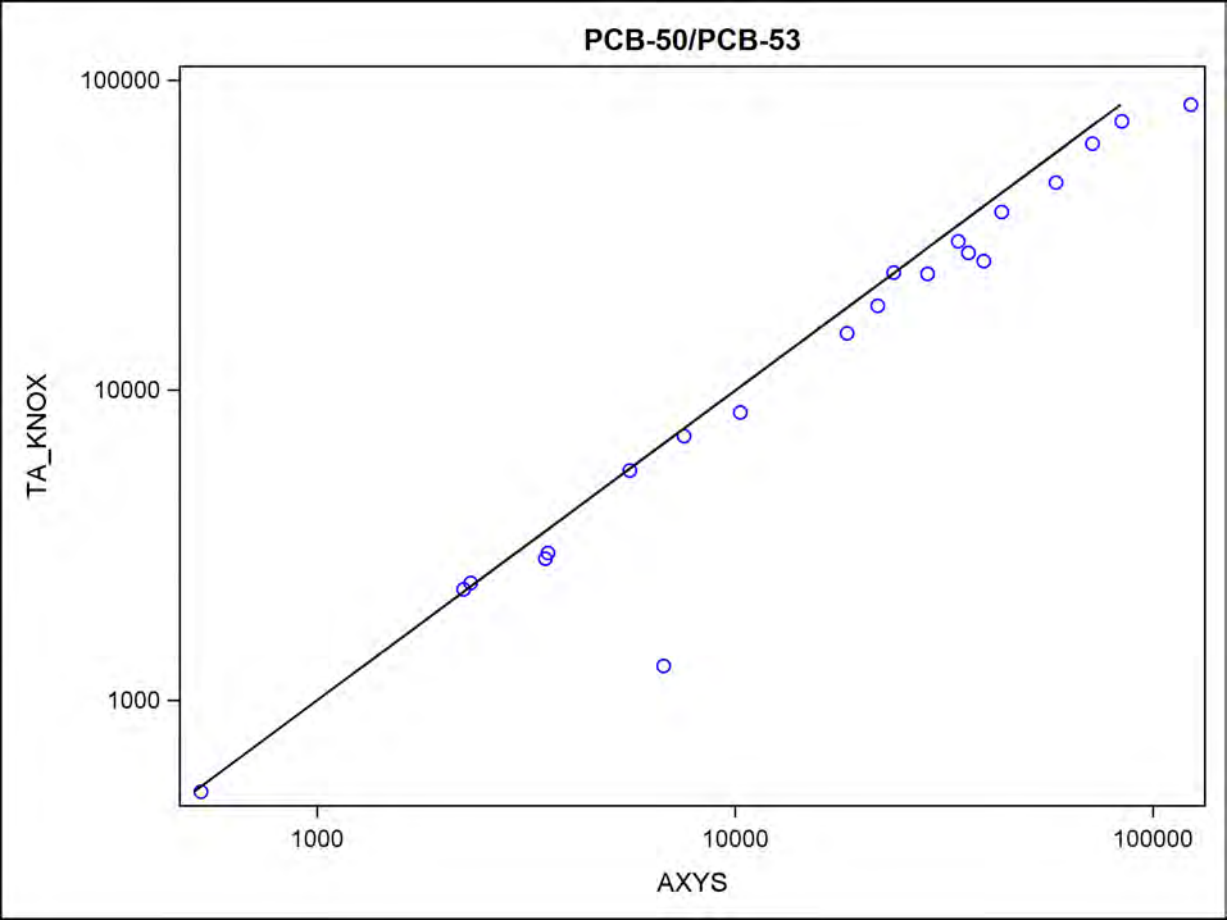

PCB-44/PCB-47/PCB-65
TA_KNOX
AXYS
1E1
1E2
1E3
1E4
1E5
1E6

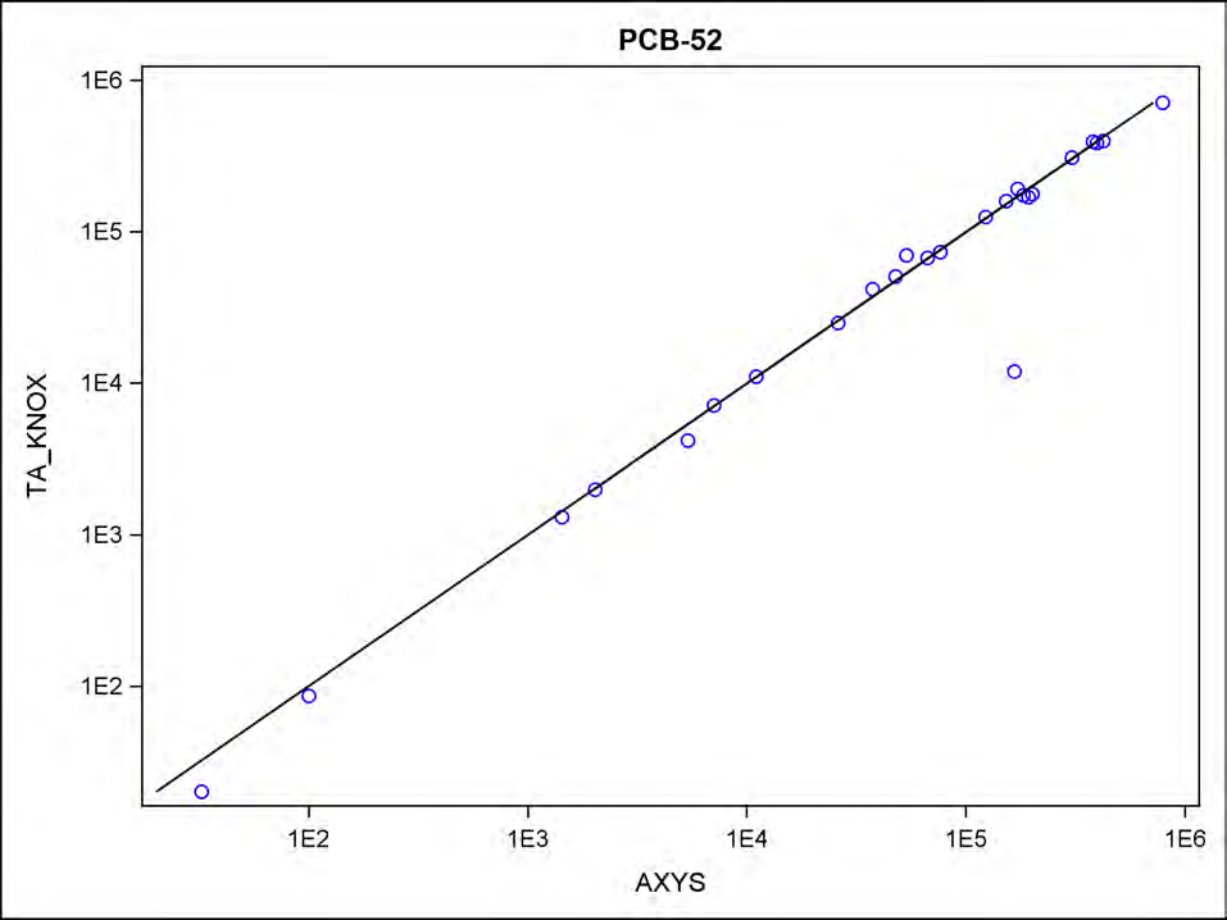

PCB-45/PCB-51
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

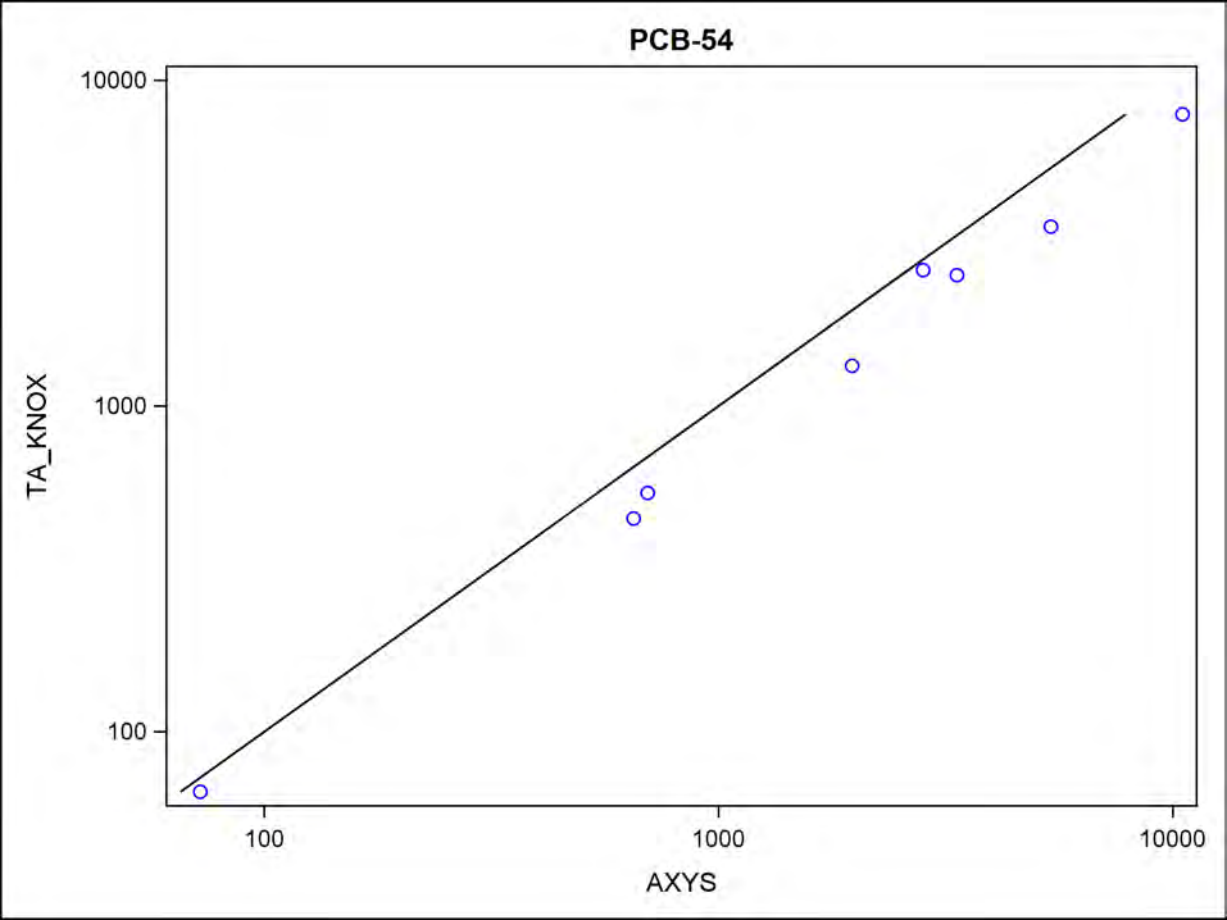

PCB-46
TA_KNOX
10000
1000
100
100
1000
10000
100000
AXYS

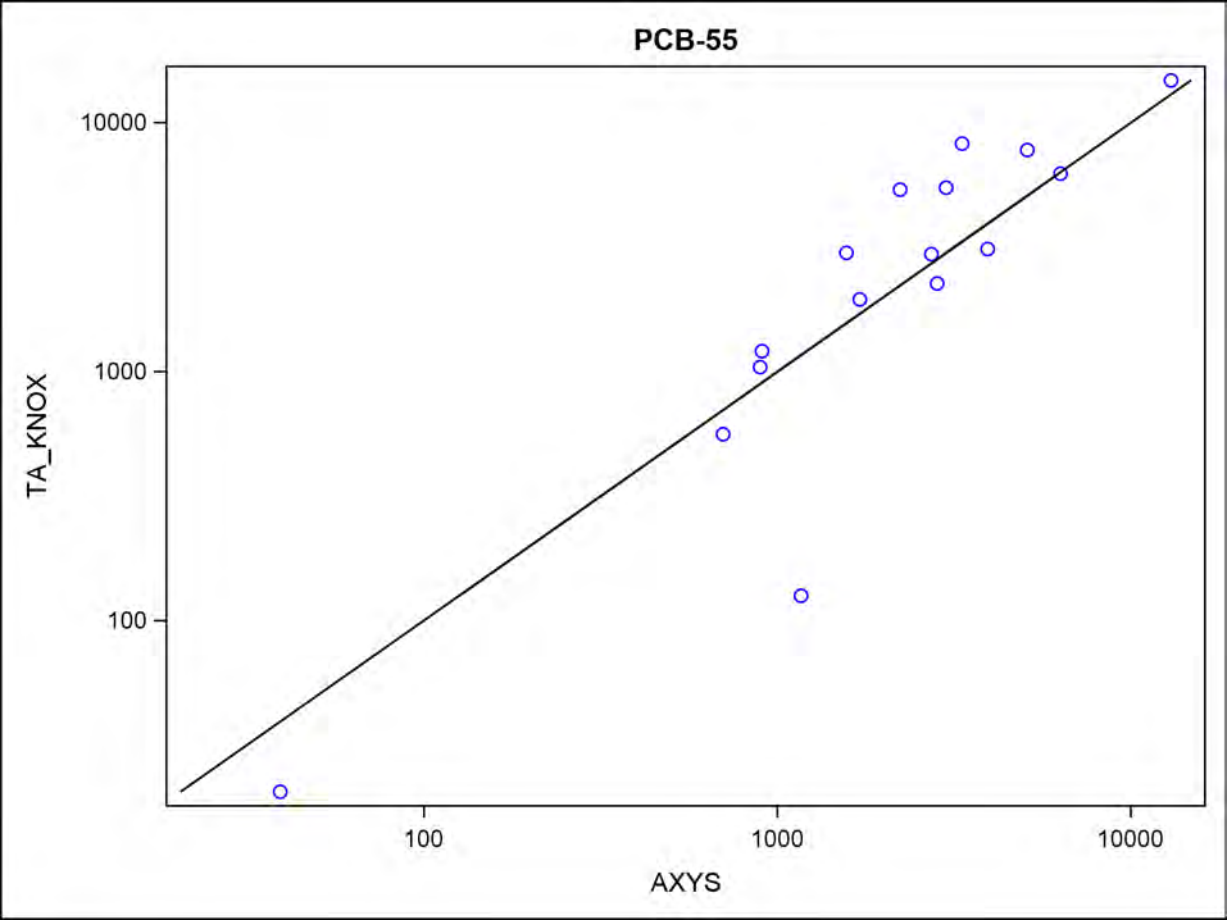

PCB-48
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

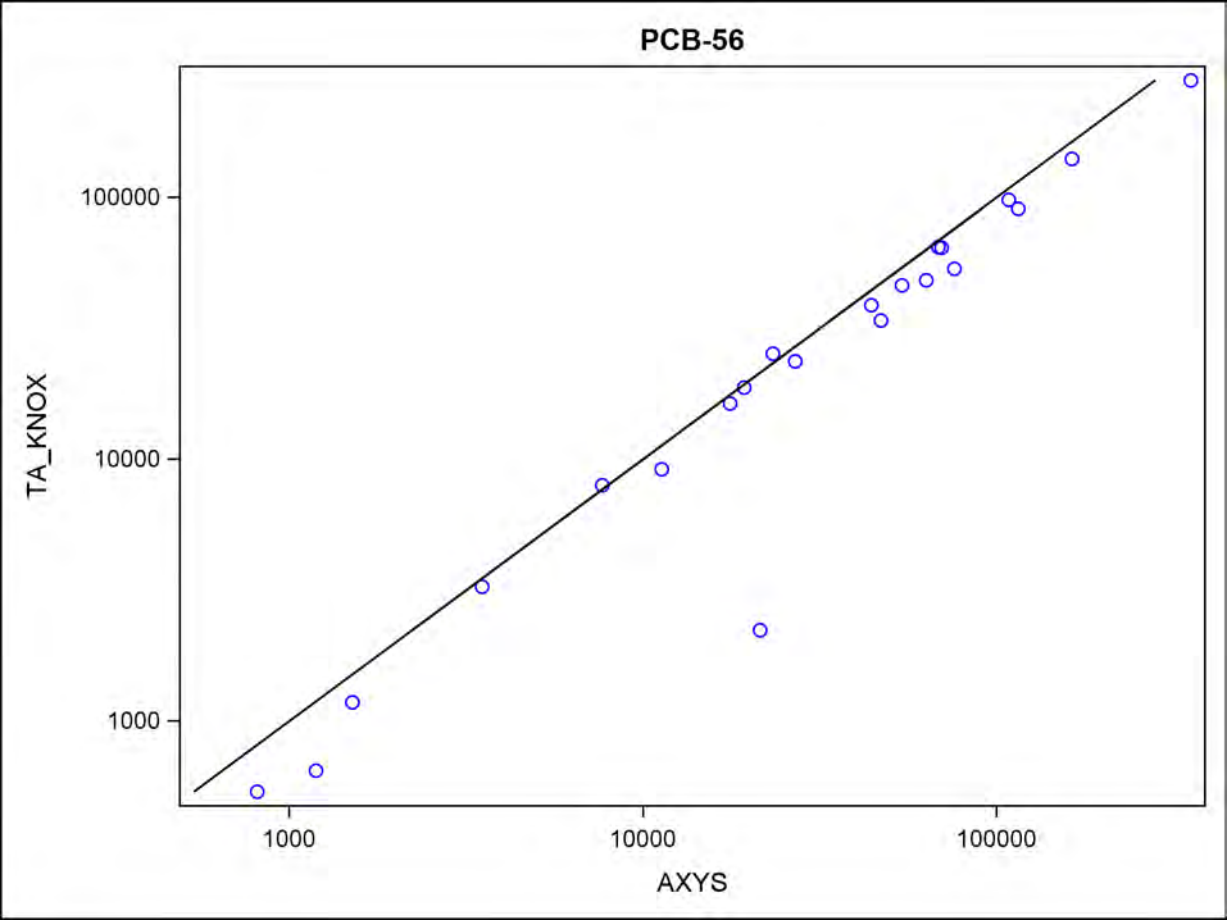

PCB-49/PCB-69
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

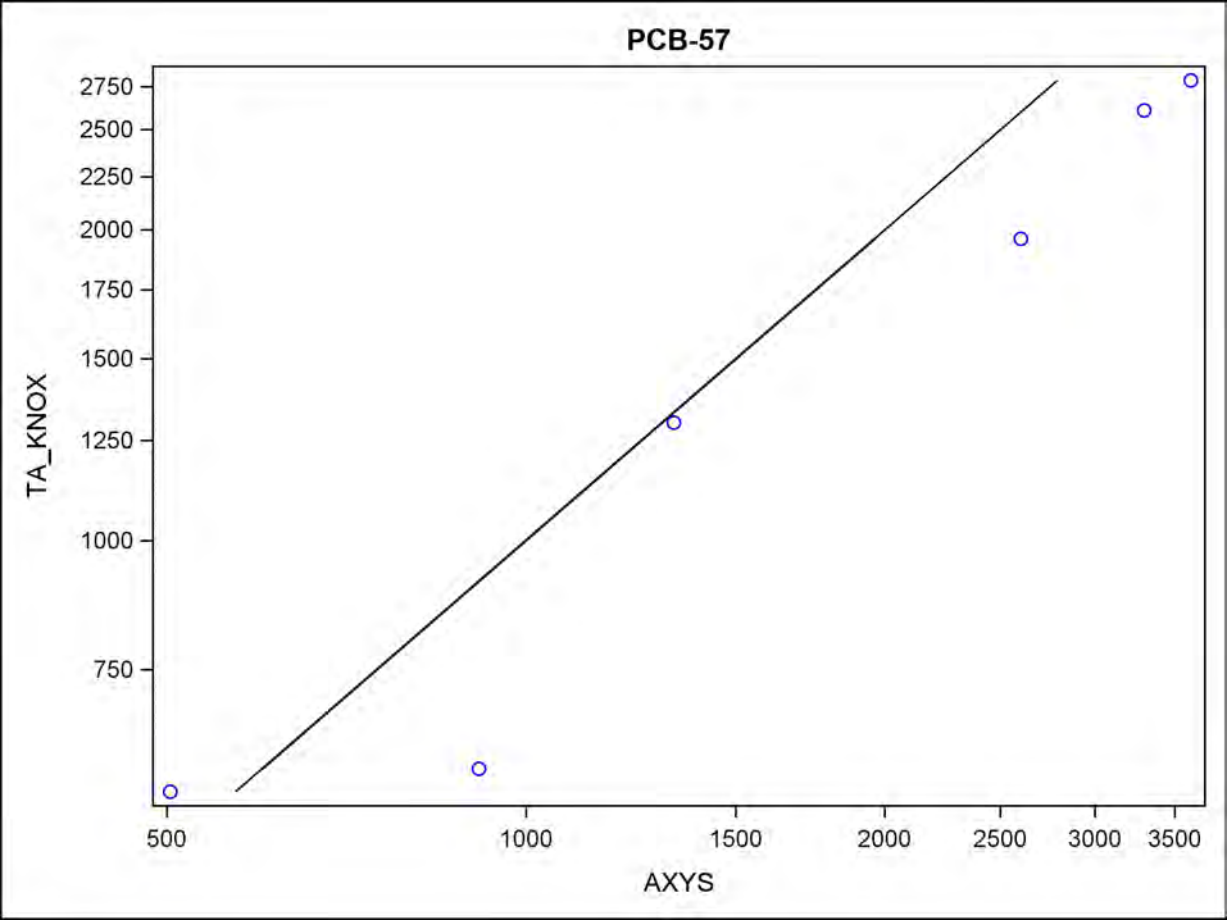

PCB-50/PCB-53
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

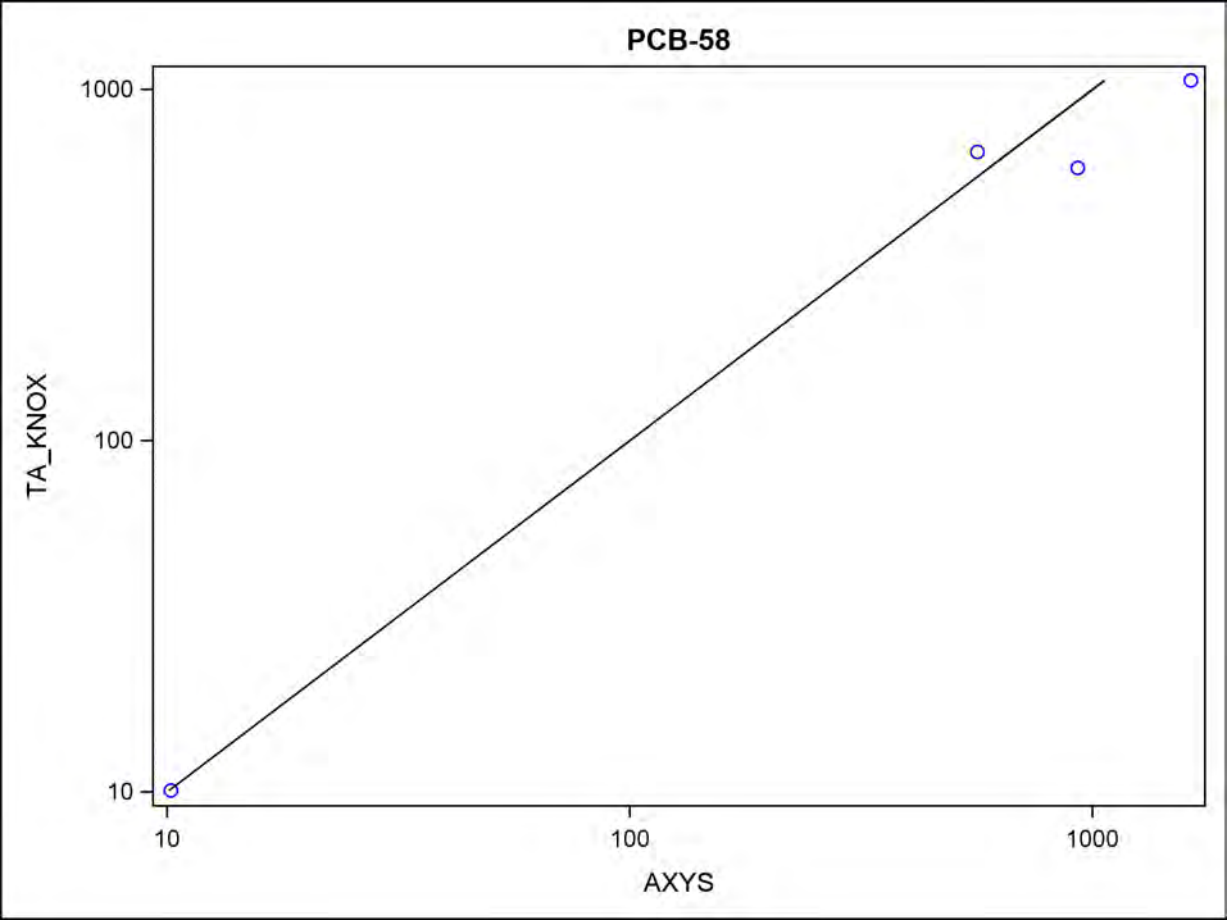

PCB-52
1E6
1E5
1E4
1E3
1E2
TA_KNOX
1E2
1E3
1E4
1E5
1E6
AXYS

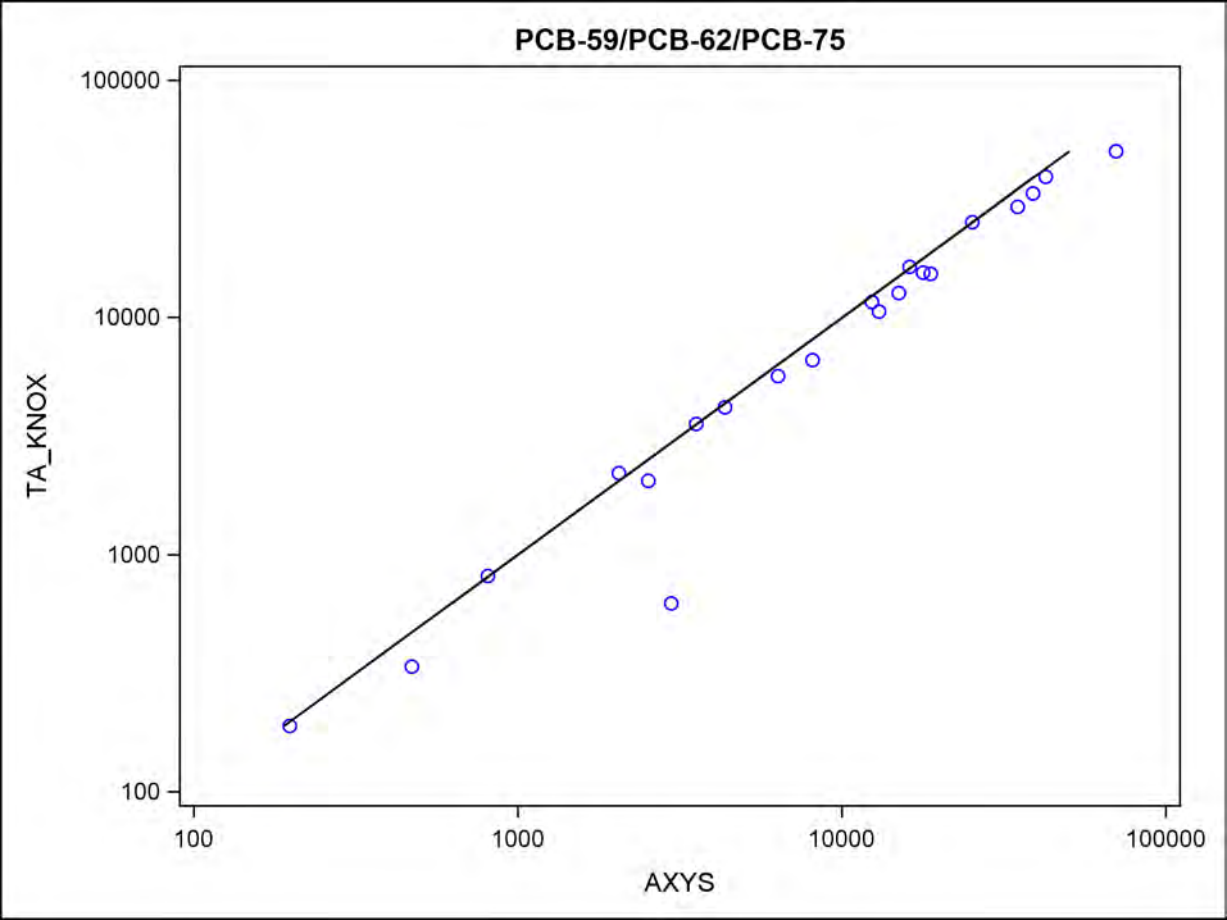

PCB-54
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

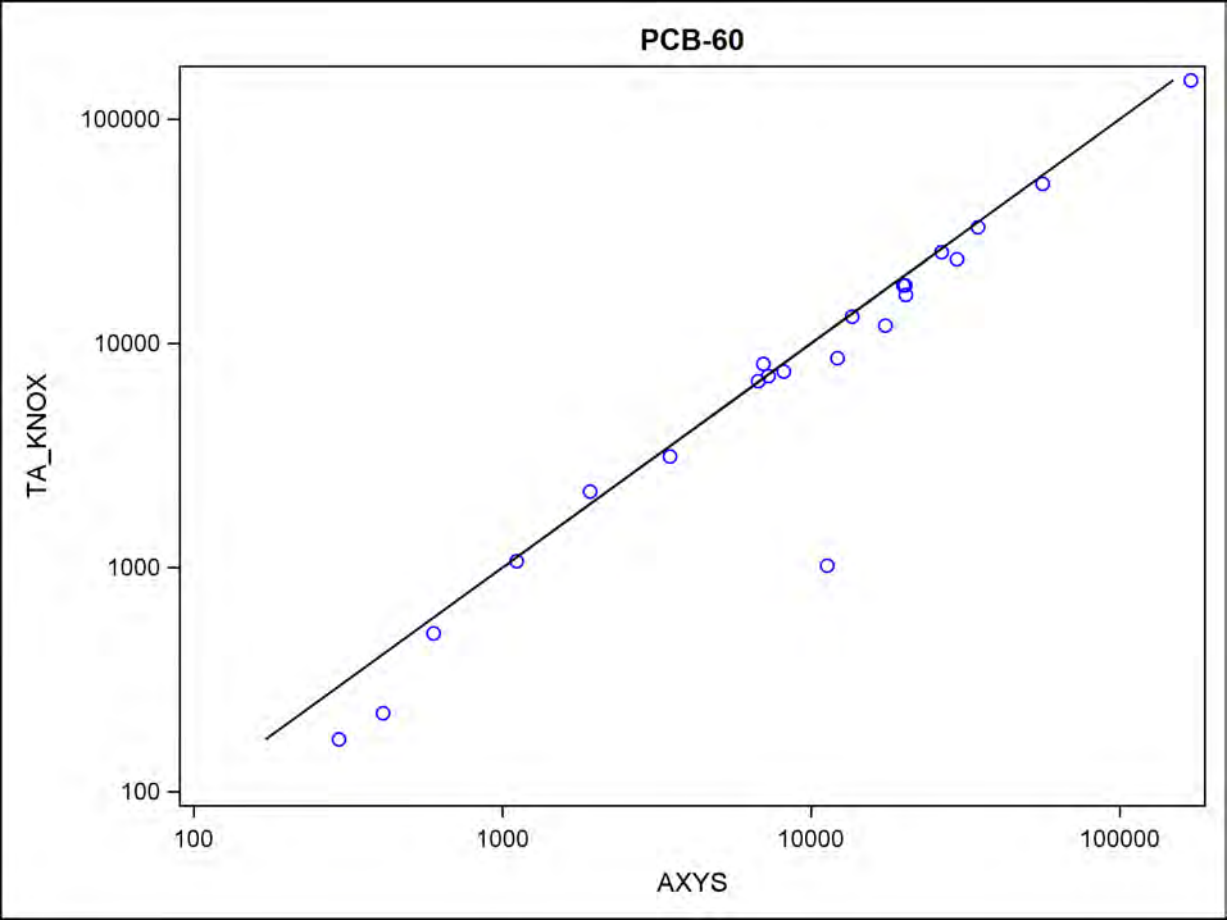

PCB-55
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

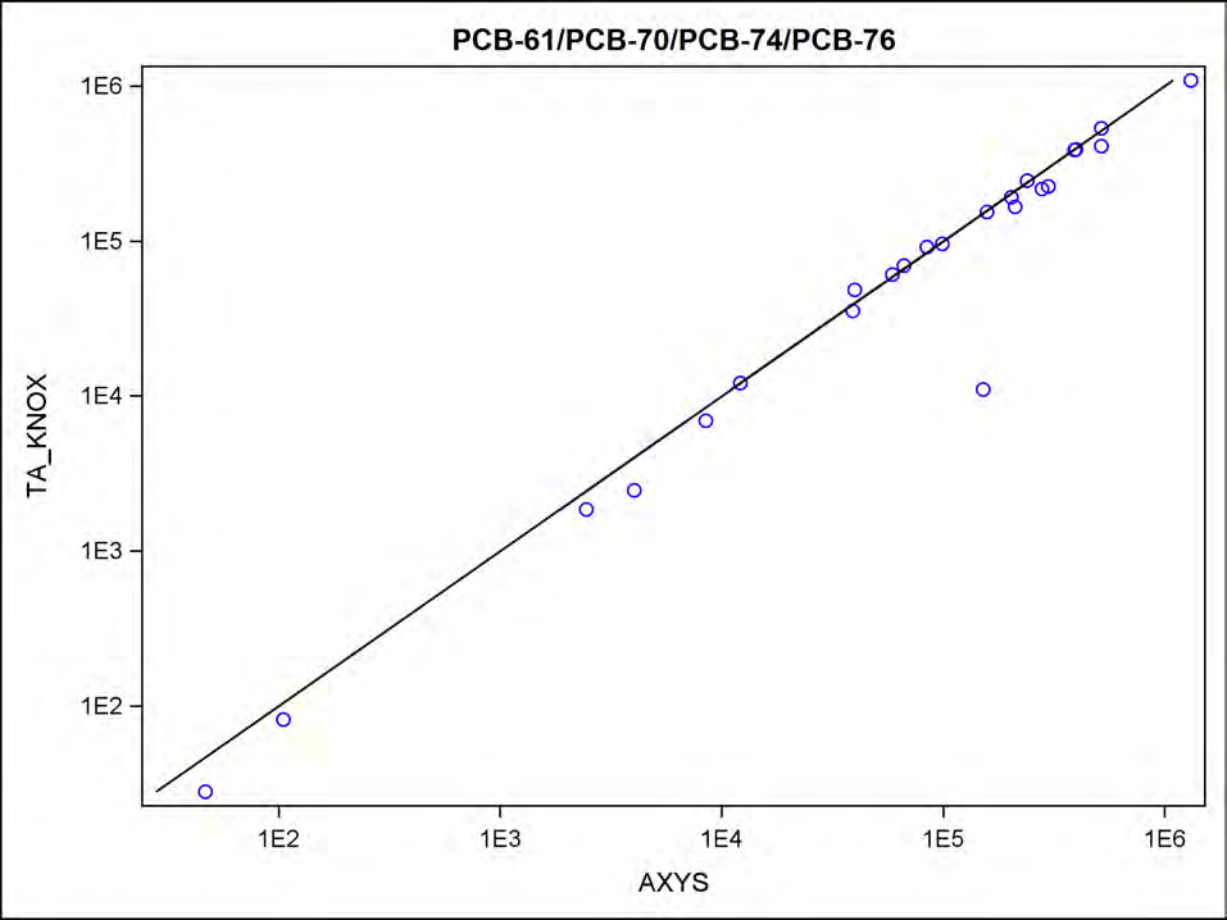

PCB-56
TA_KNOX
AXYS
100000
10000
1000
1000
10000
100000

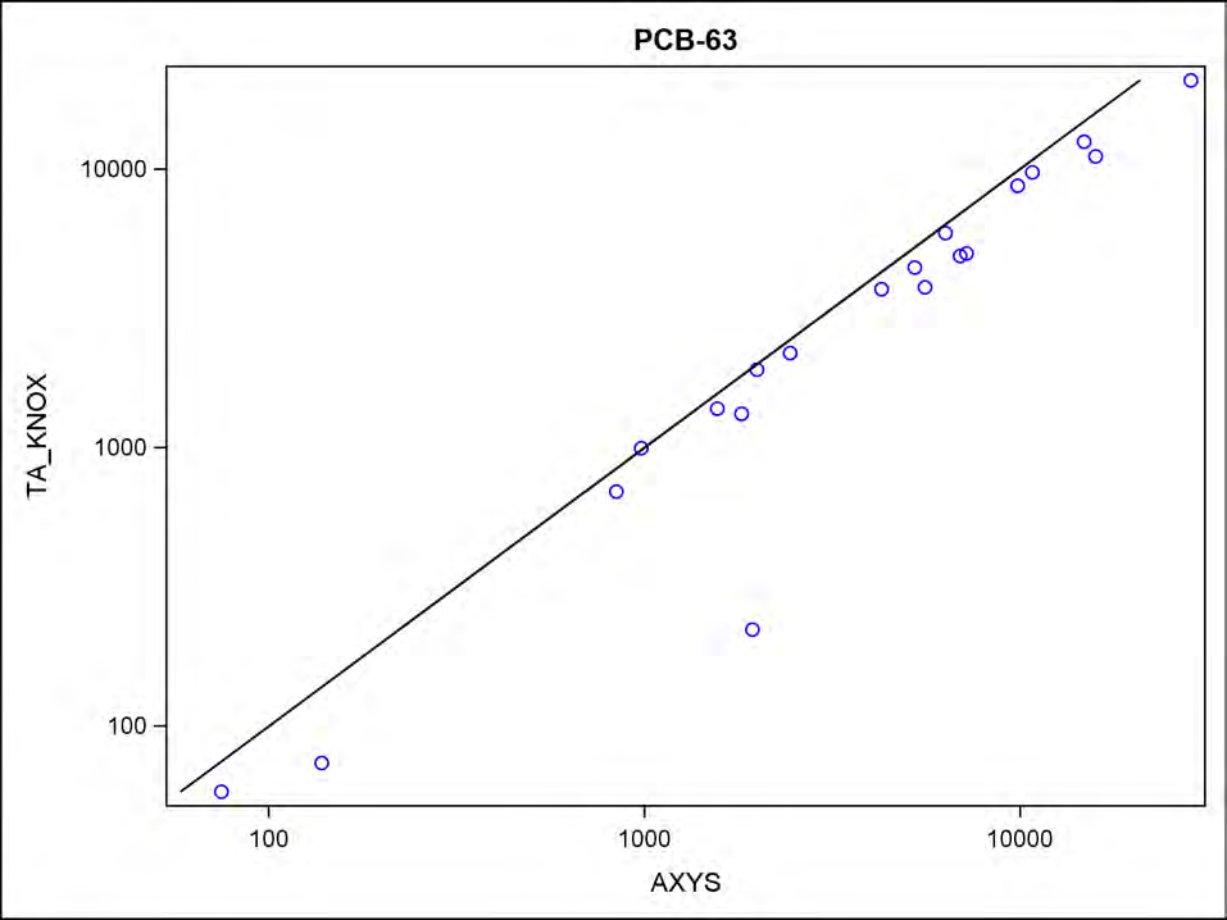

PCB-57
TA_KNOX
2750
2500
2250
2000
1750
1500
1250
1000
750
500
1000
1500
2000
2500
3000
3500
AXYS

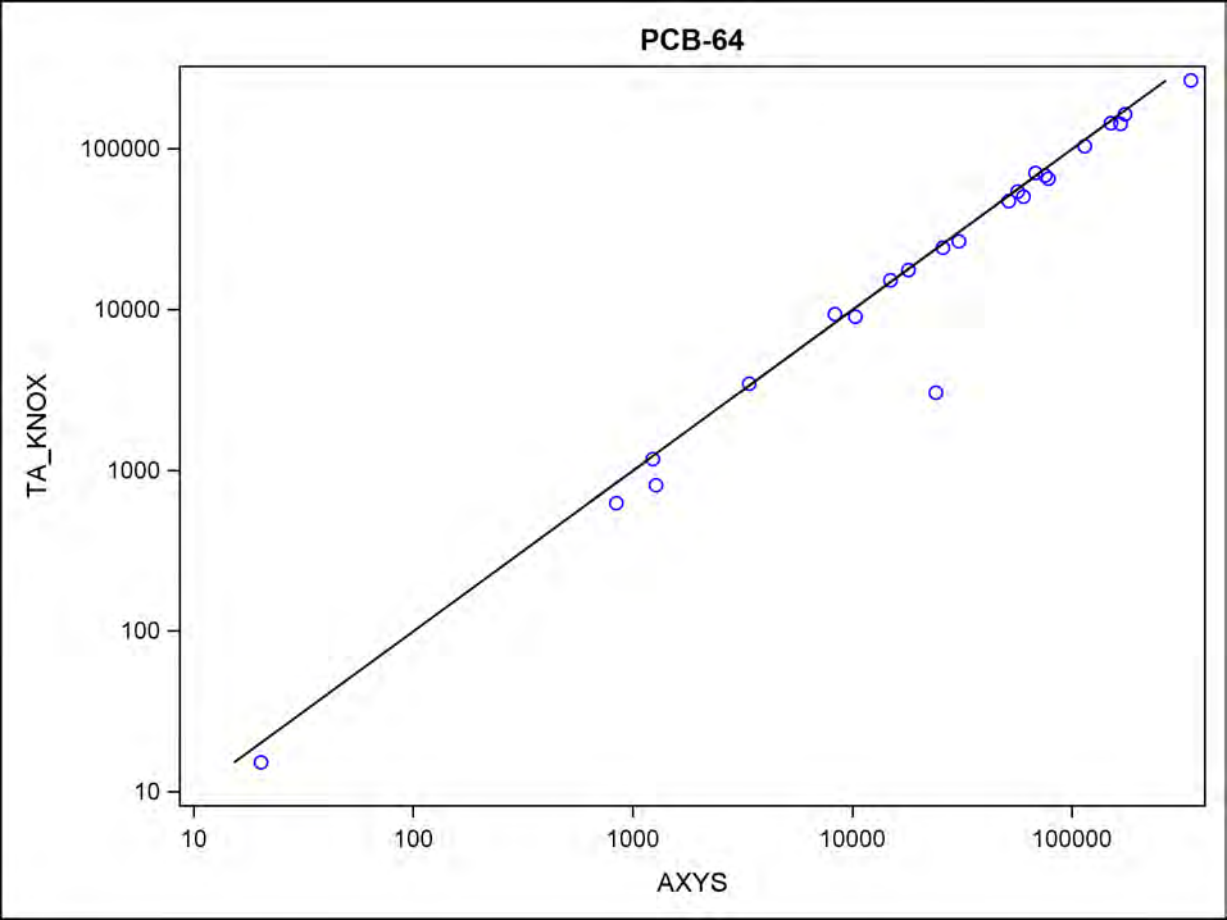

PCB-58
1000
100
10
TA_KNOX
10
100
1000
AXYS

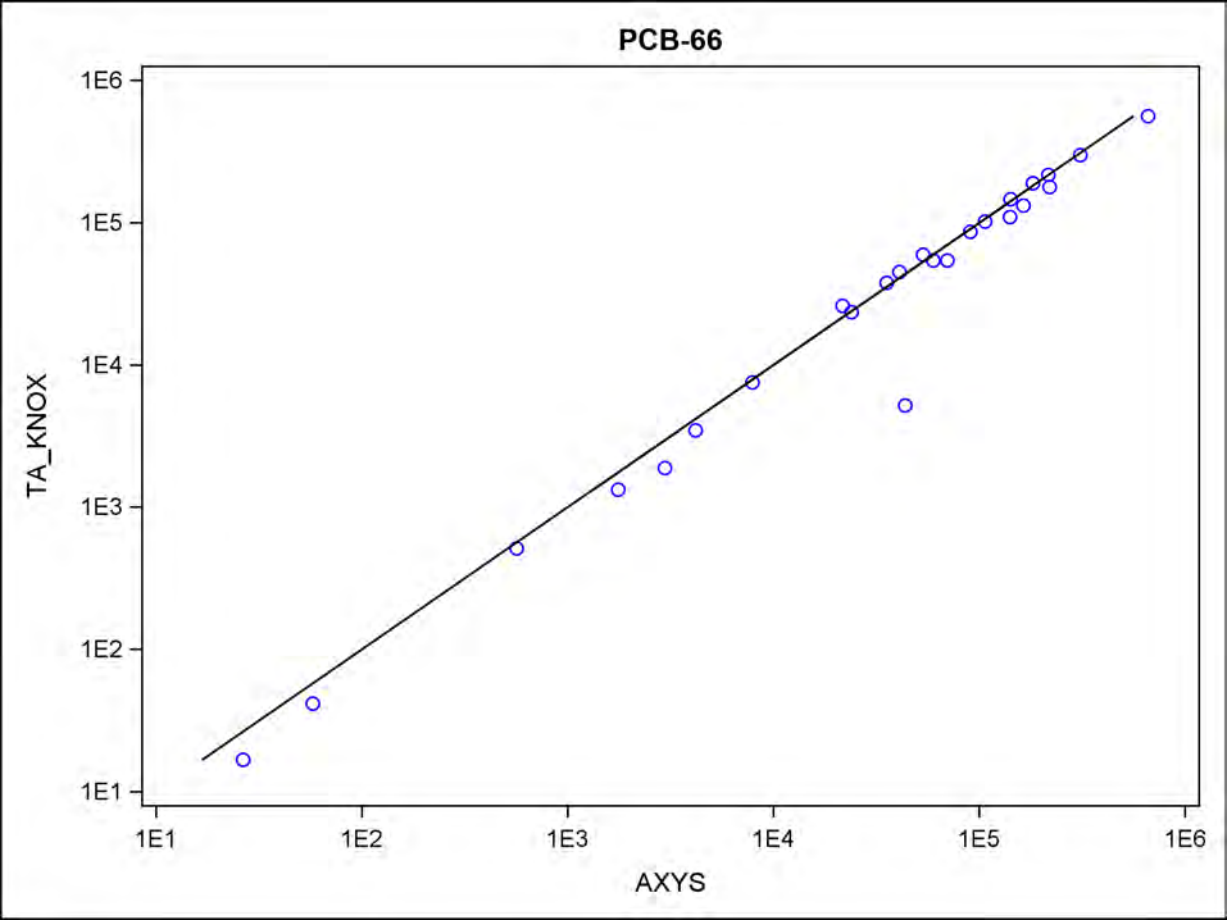

PCB-59/PCB-62/PCB-75
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

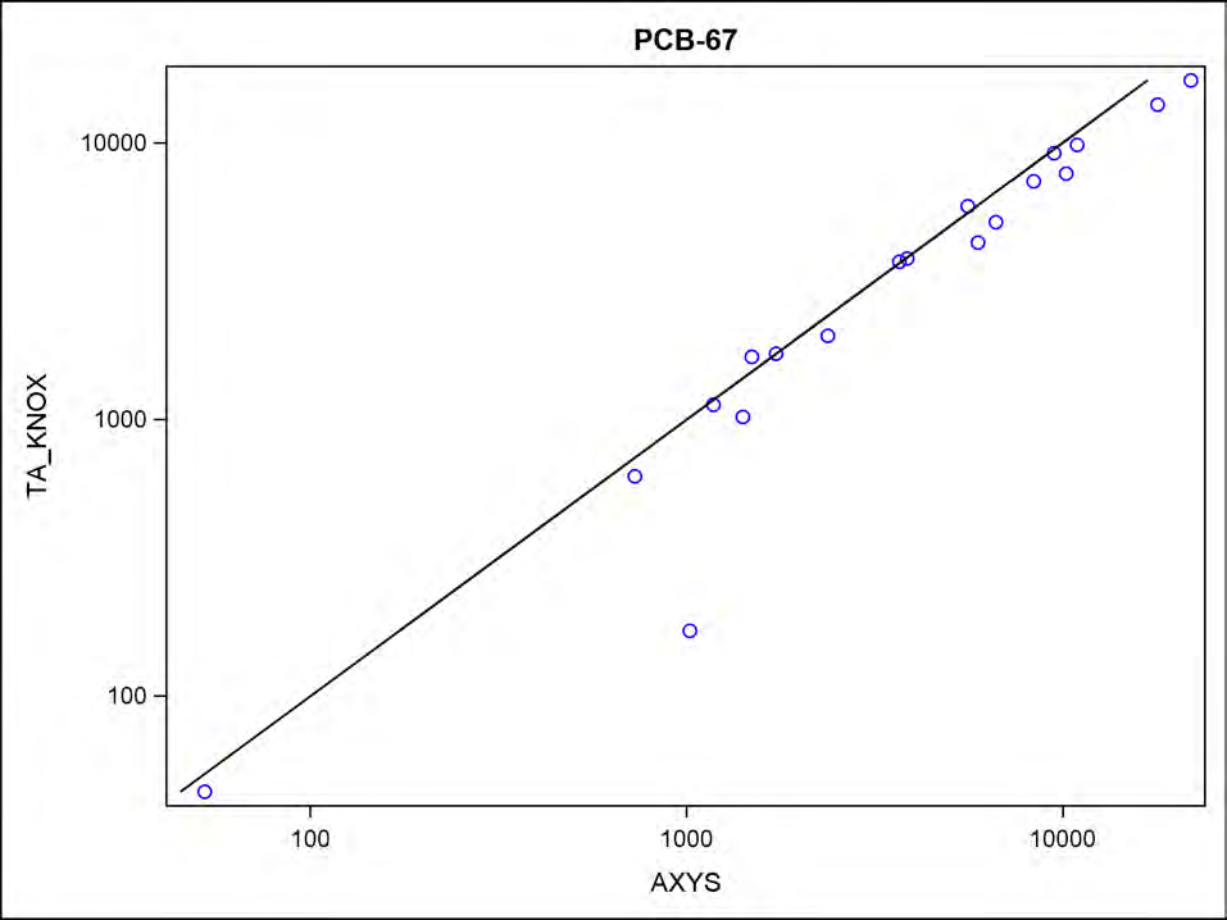

PCB-60
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

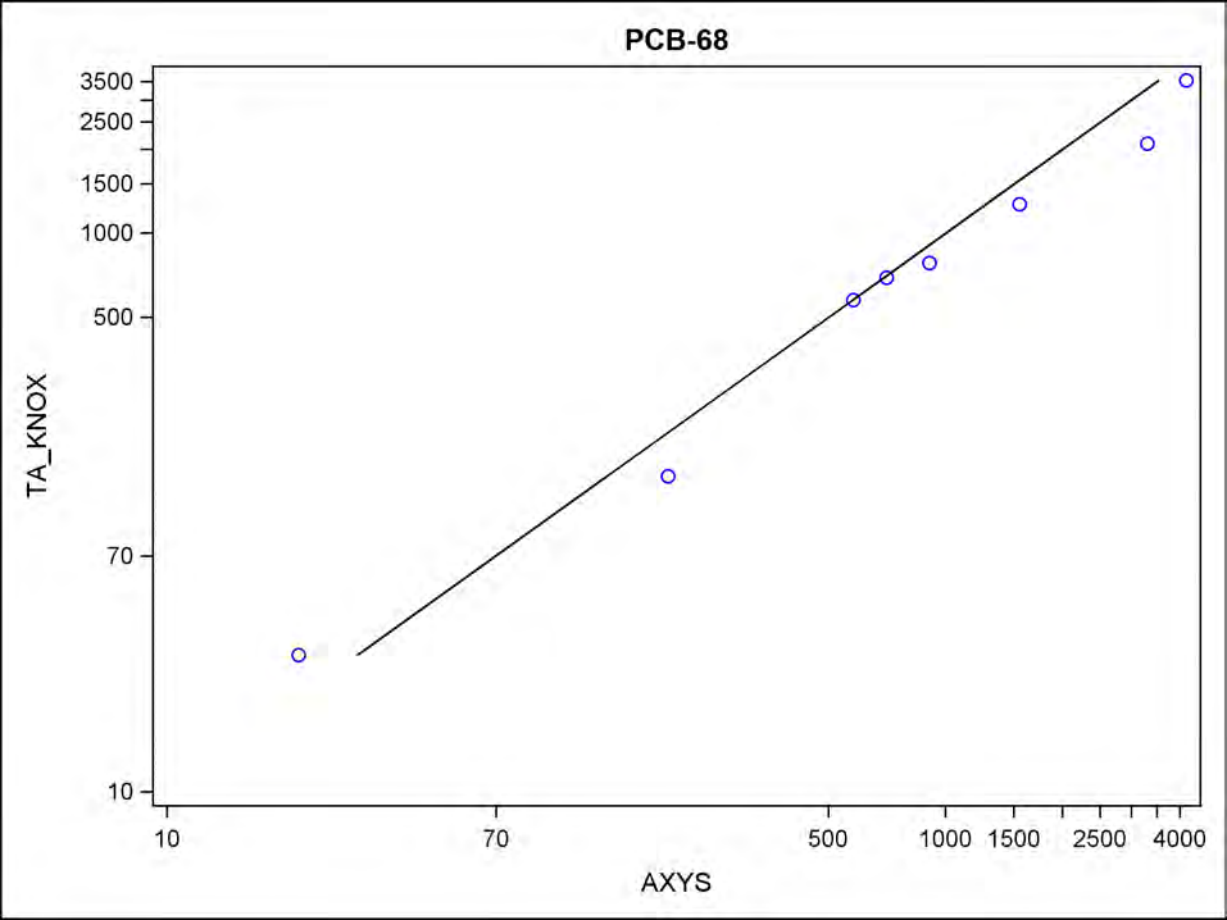

PCB-61/PCB-70/PCB-74/PCB-76
TA_KNOX
AXYS
1E2
1E3
1E4
1E5
1E6

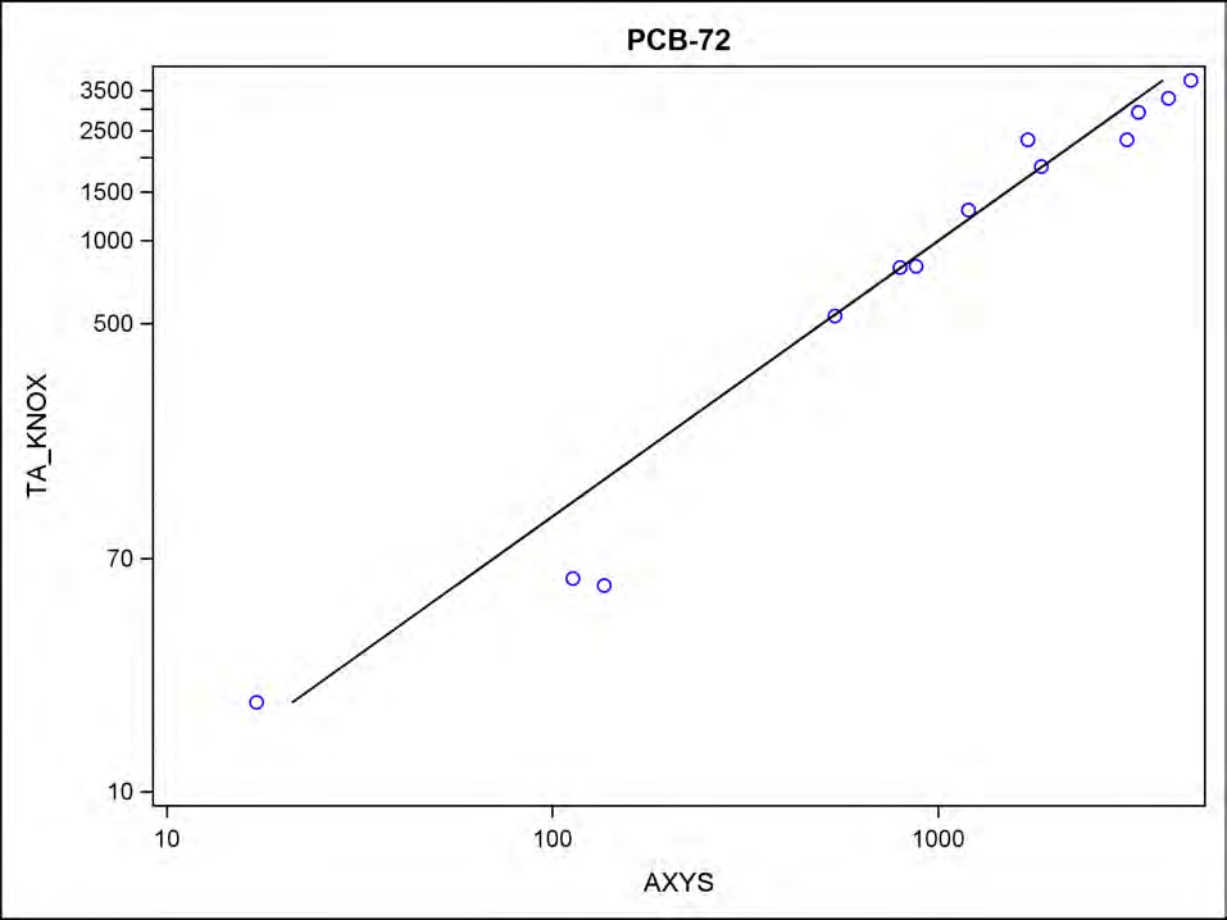

PCB-63
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

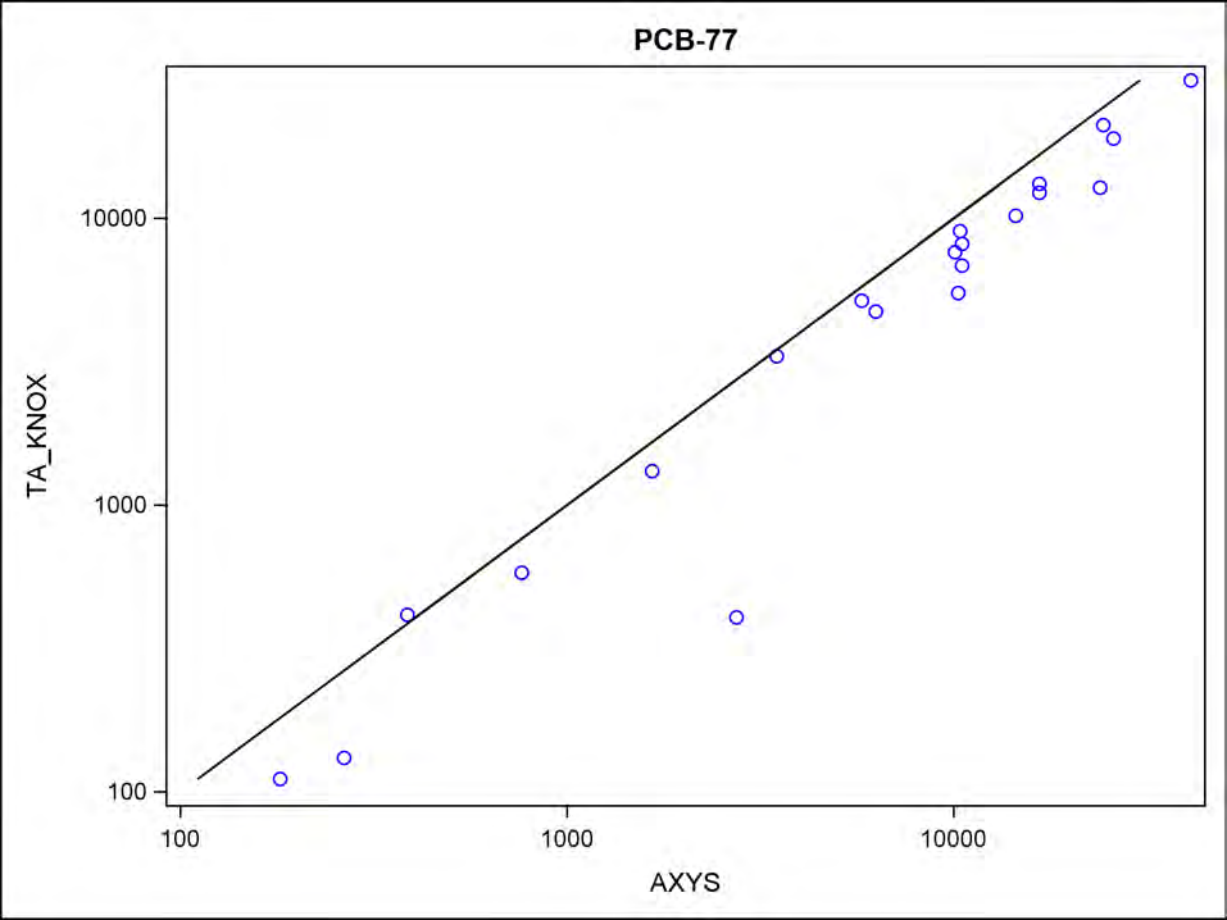

PCB-64
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

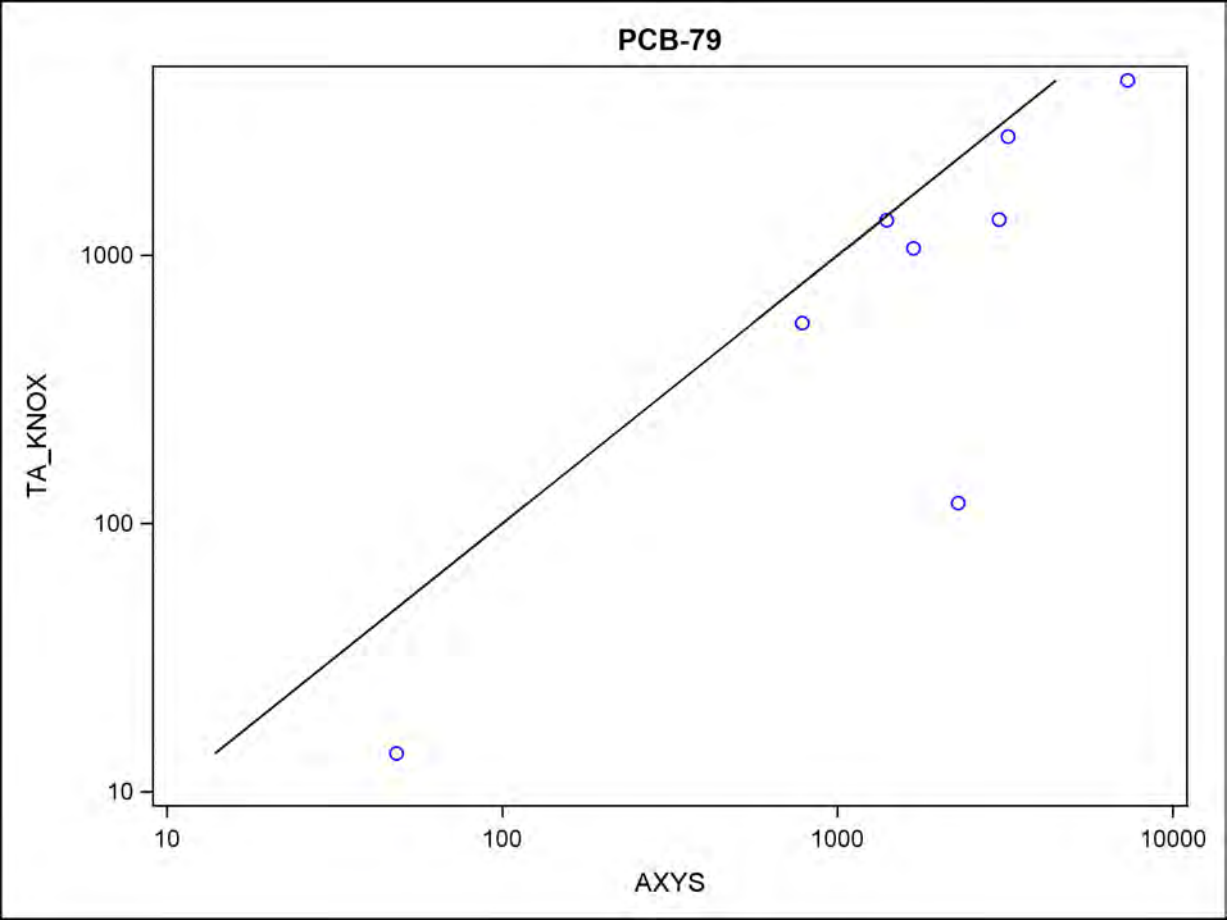

PCB-66
TA_KNOX
AXYS
1E1
1E2
1E3
1E4
1E5
1E6

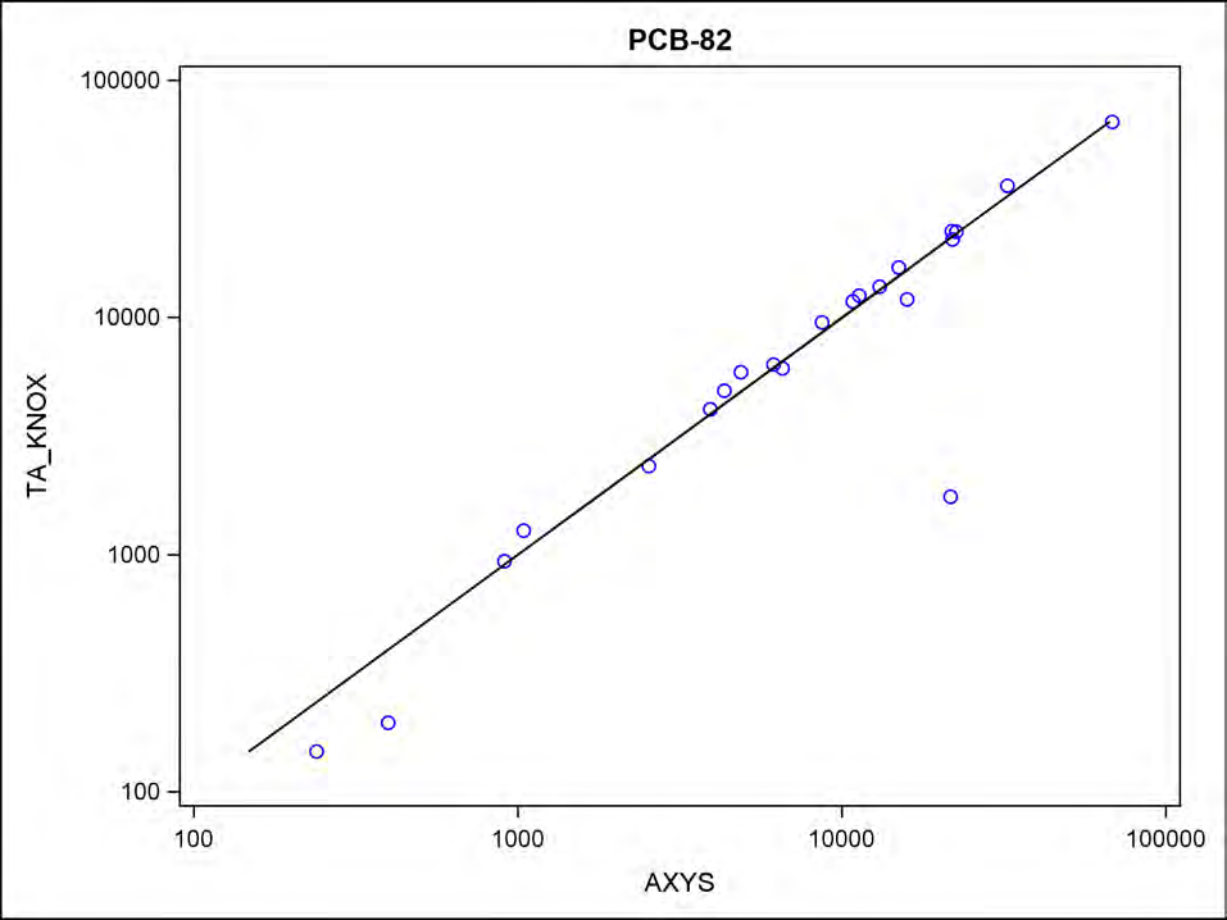

PCB-67
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

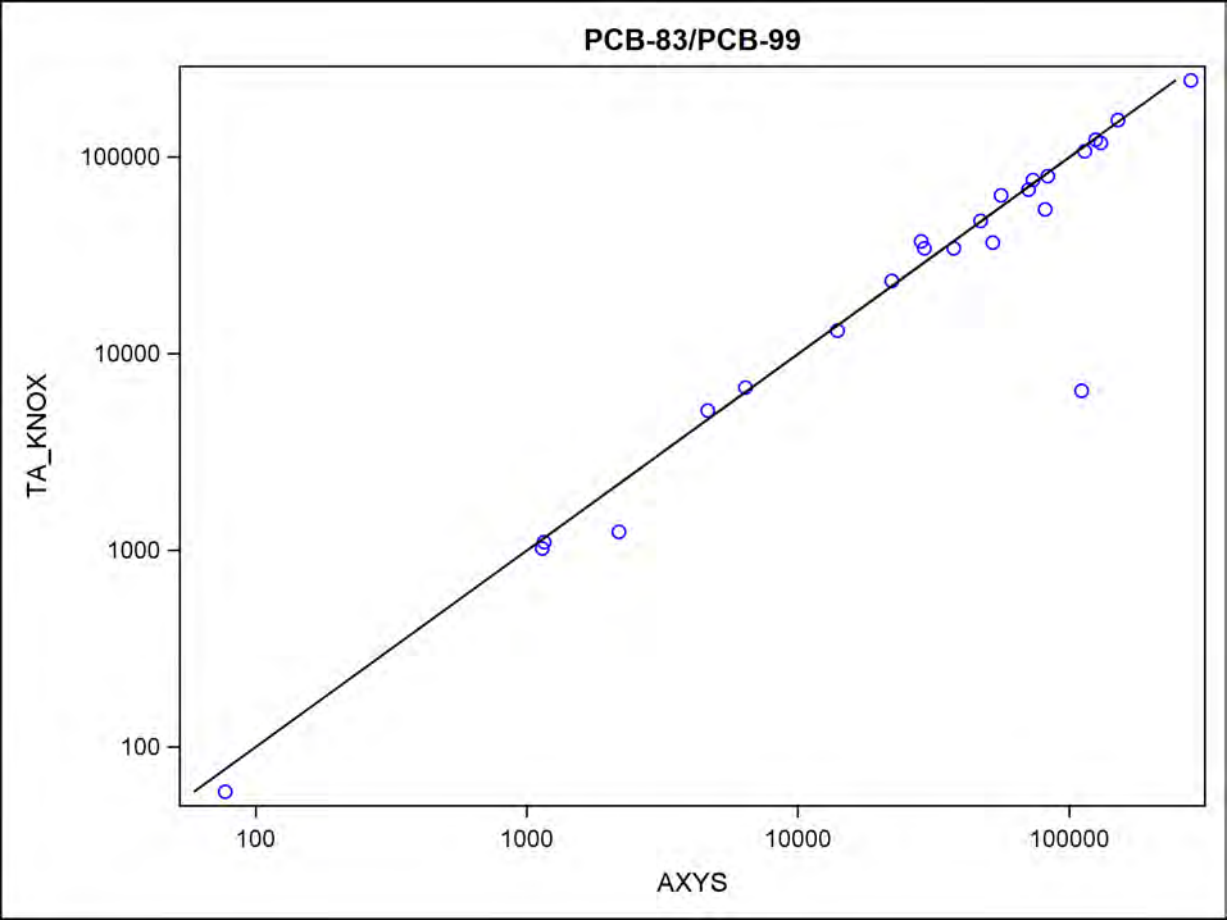

PCB-68
TA_KNOX
3500
2500
1500
1000
500
70
10
AXYS
10
70
500
1000
1500
2500
4000

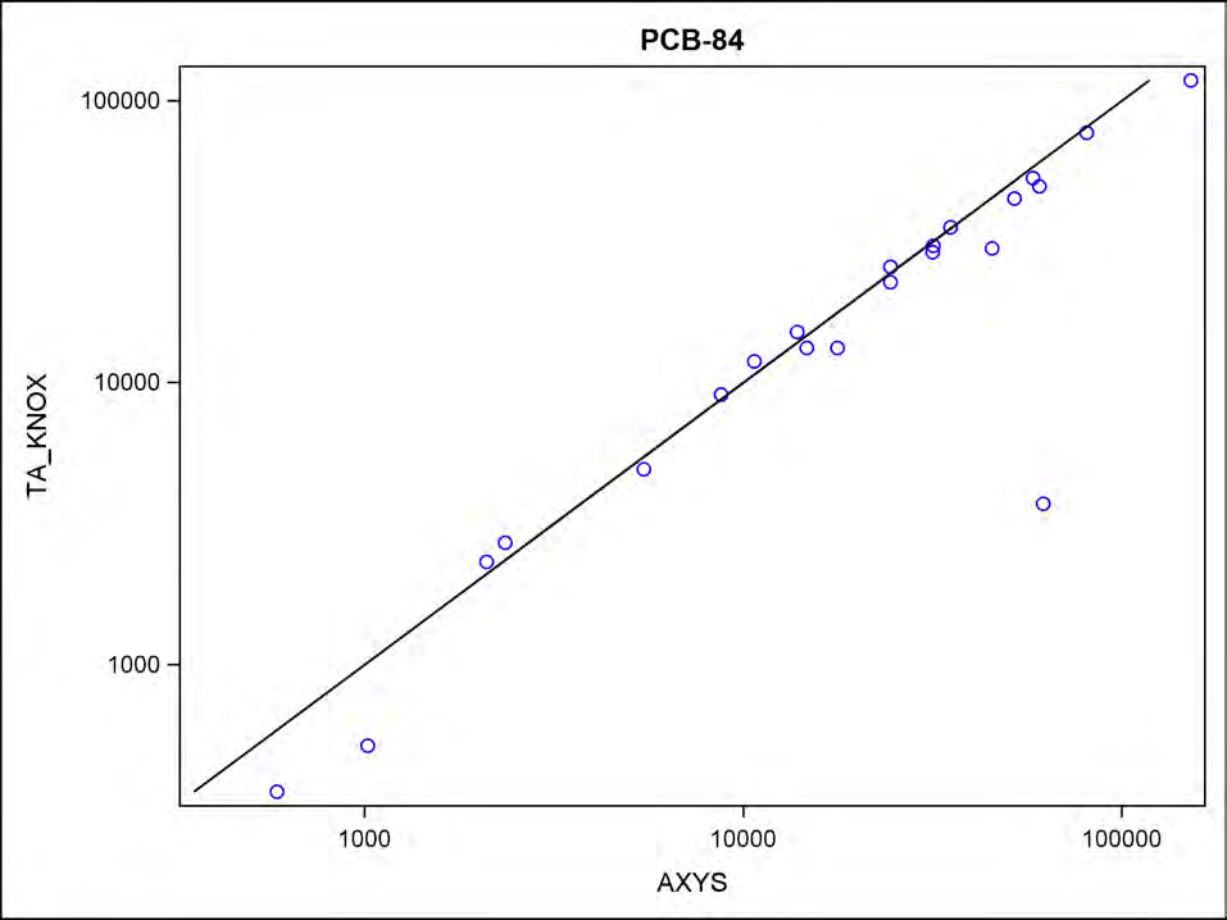

PCB-72
3500
2500
1500
1000
500
70
10
TA_KNOX
10
100
1000
AXYS

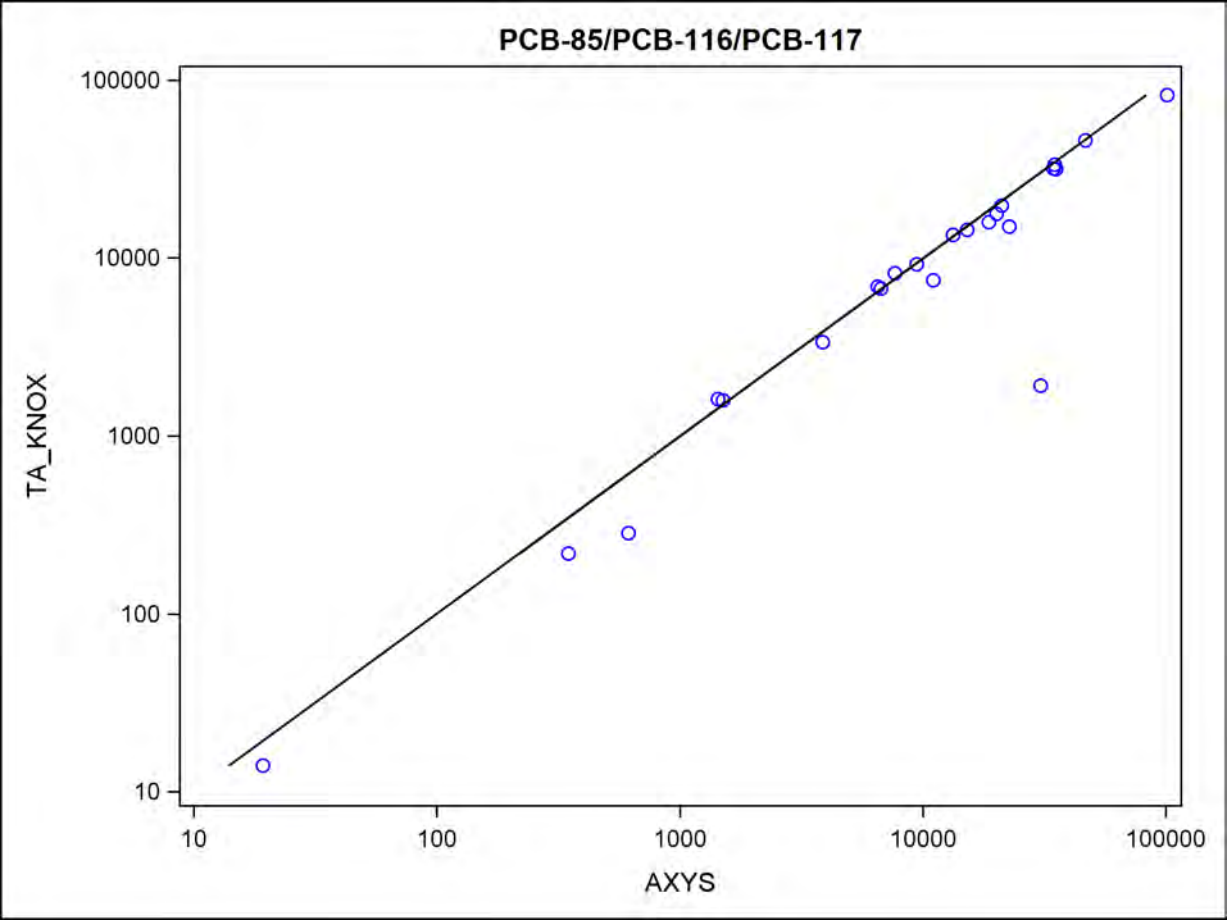

PCB-77
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

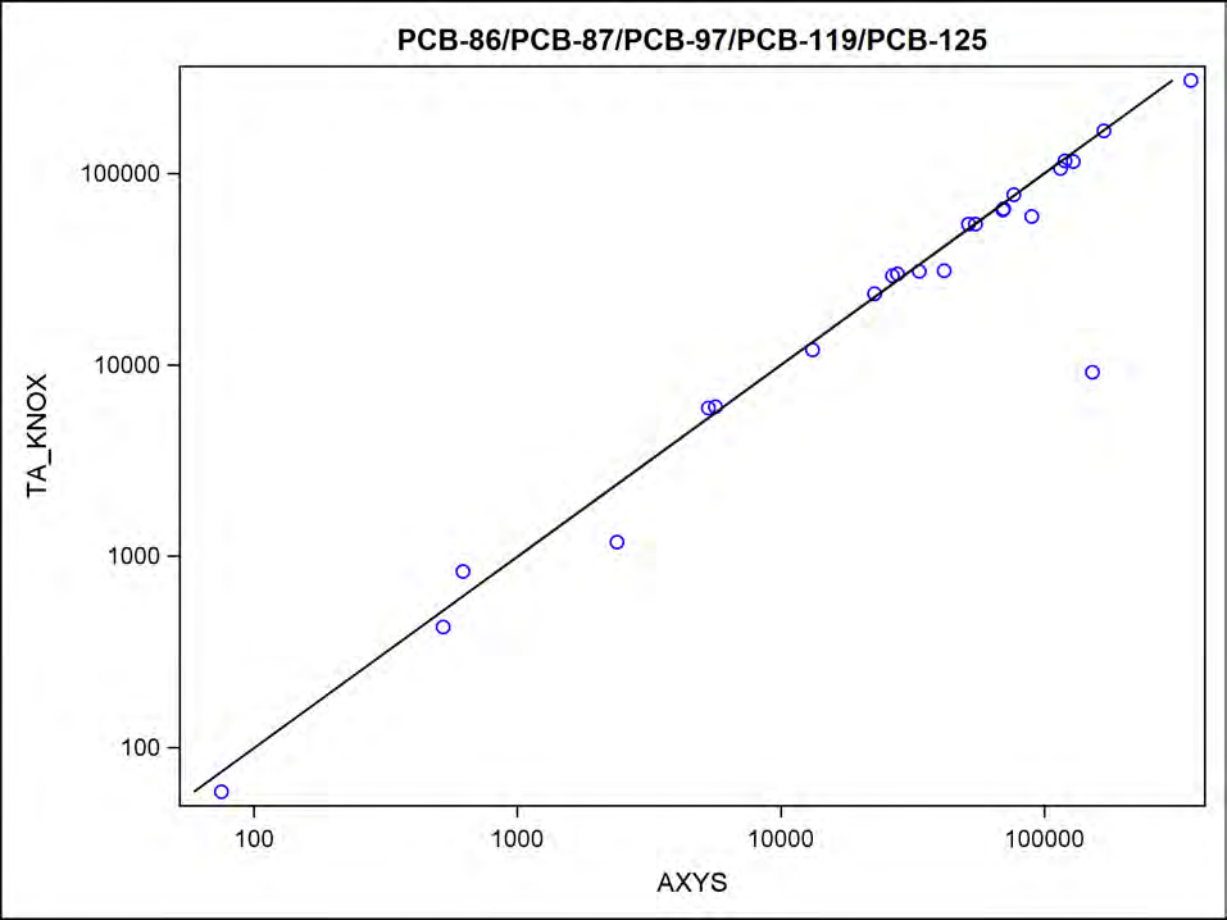

PCB-79
TA_KNOX
1000
100
10
10
100
1000
10000
AXYS

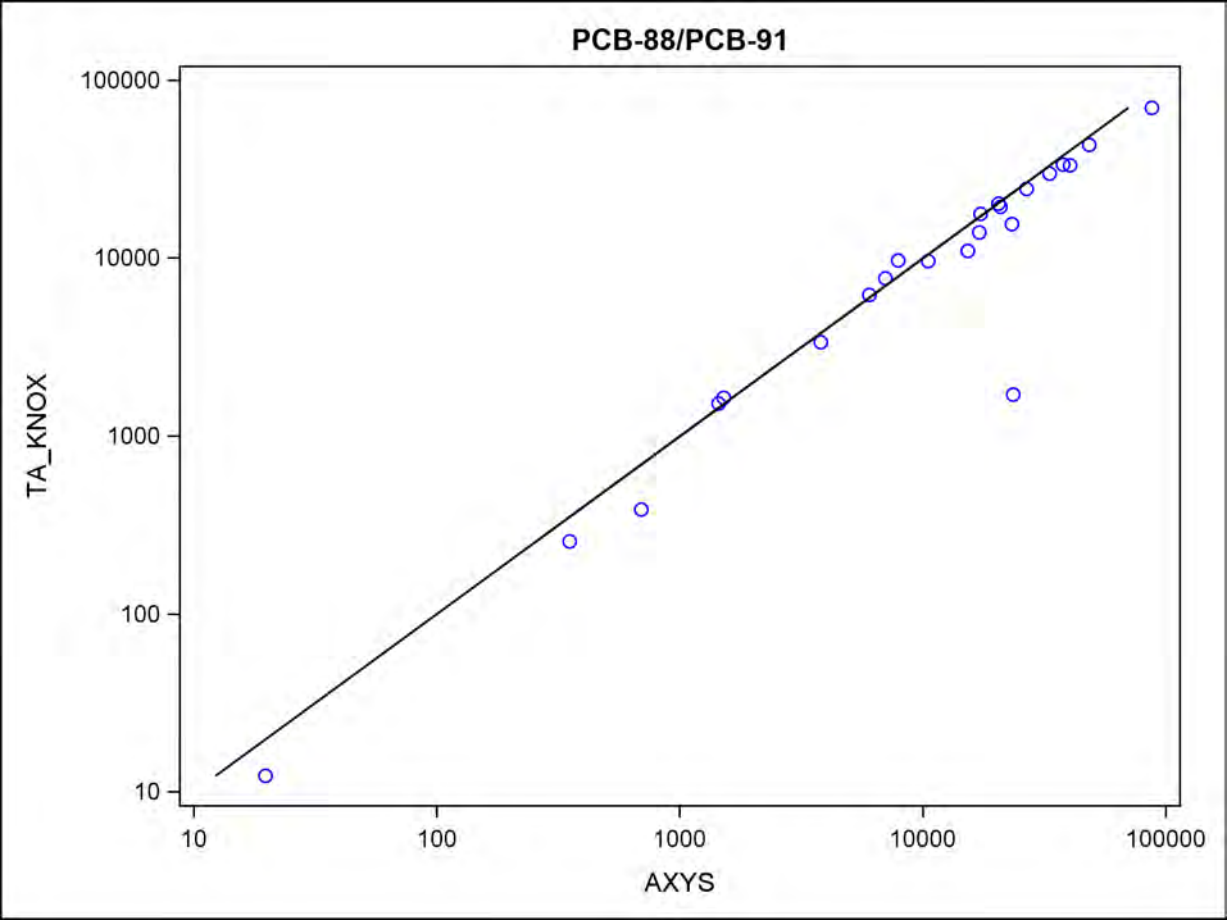

PCB-82
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

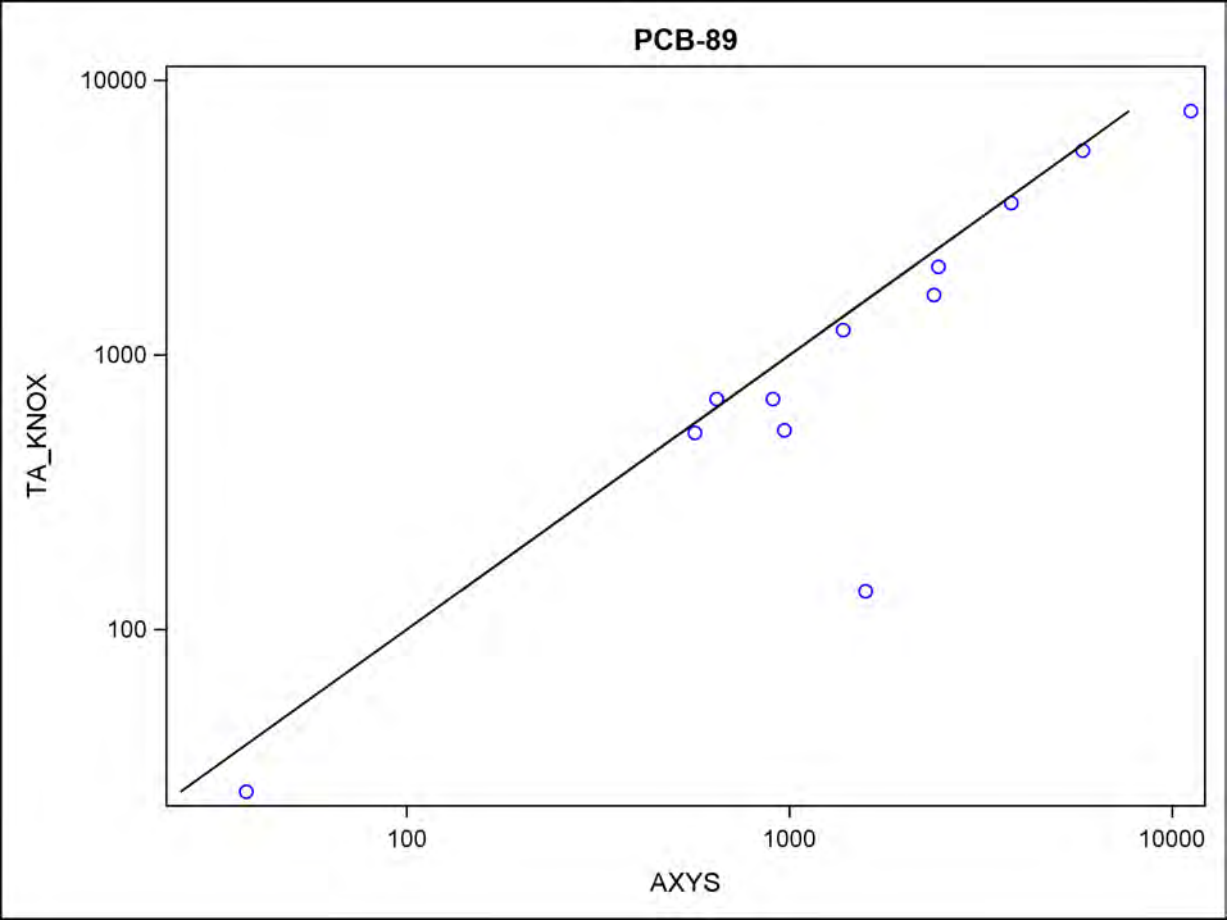

PCB-83/PCB-99
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

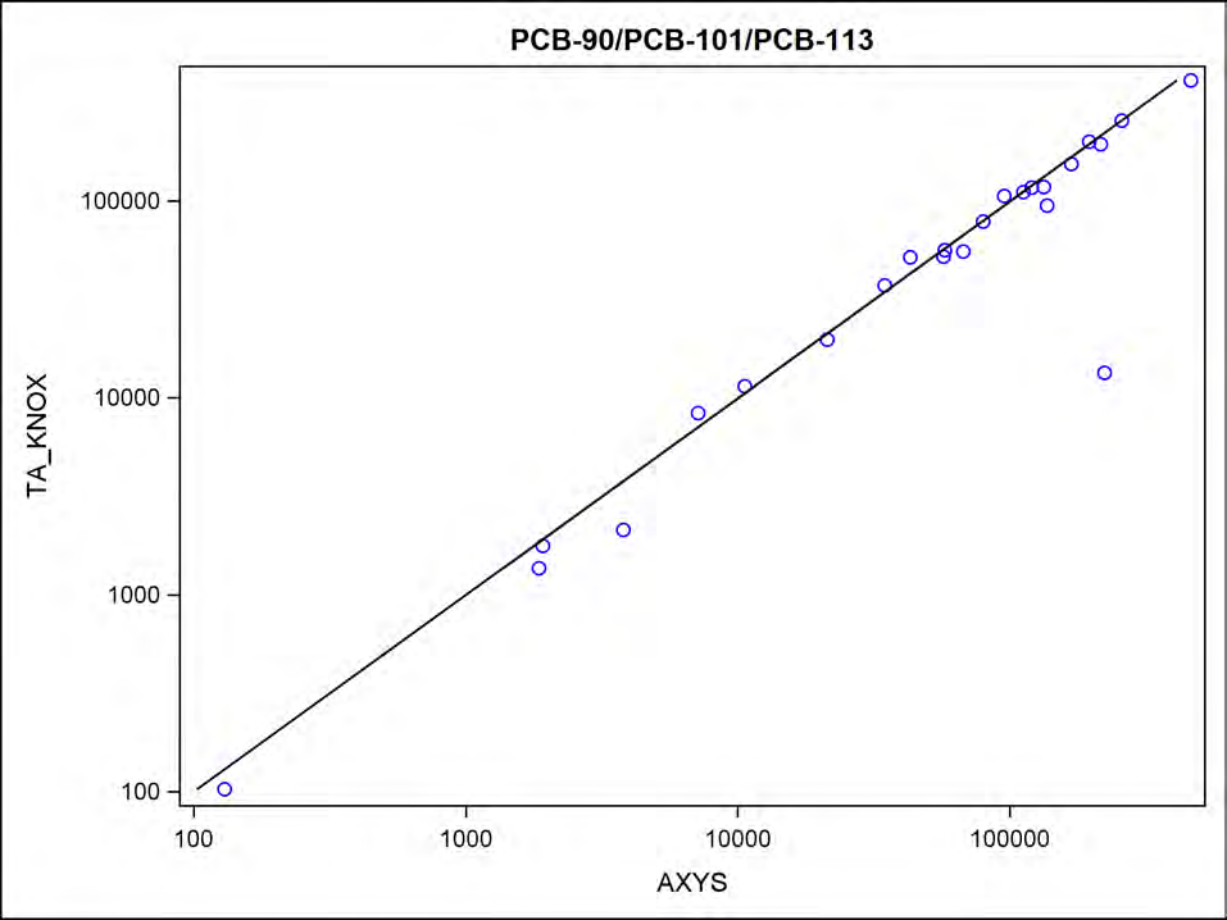

PCB-84
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

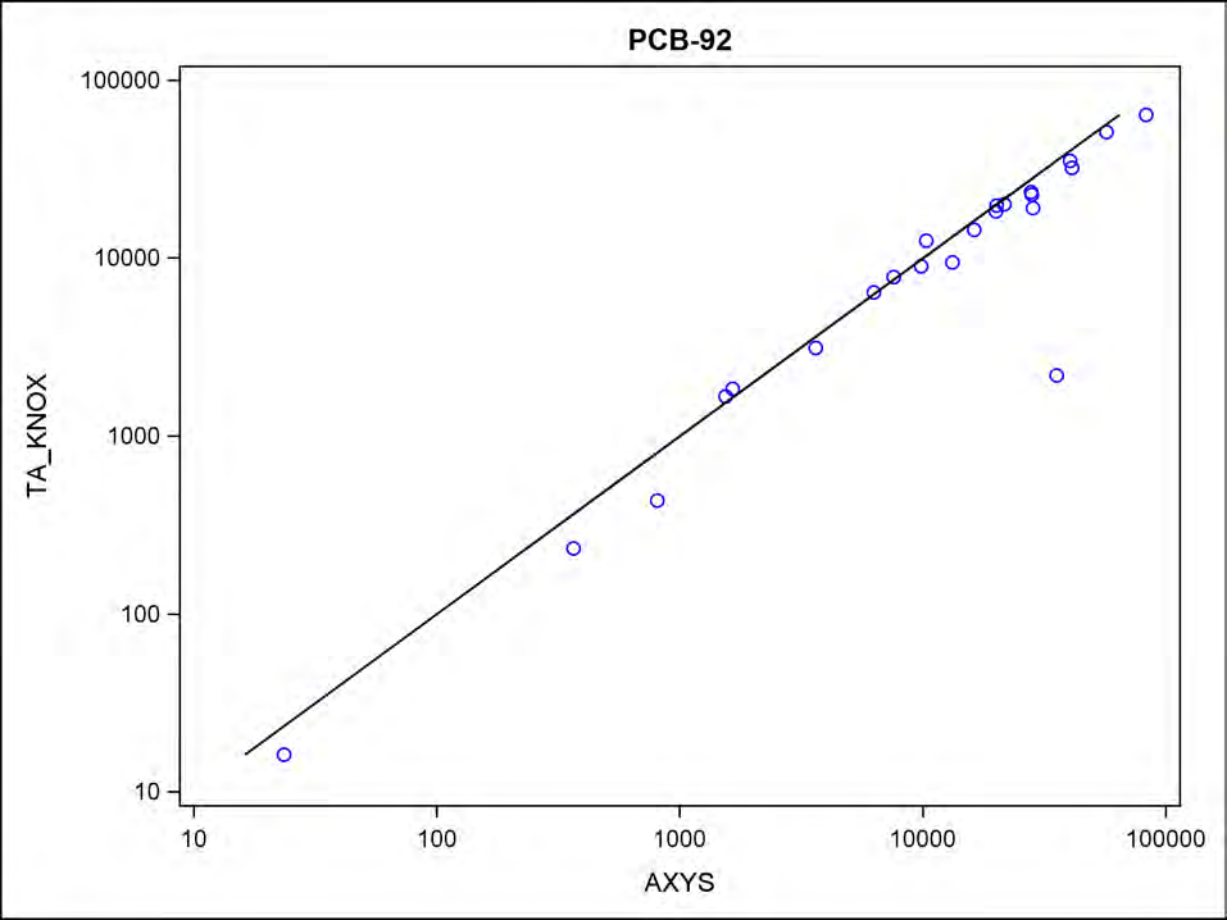

PCB-85/PCB-116/PCB-117
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

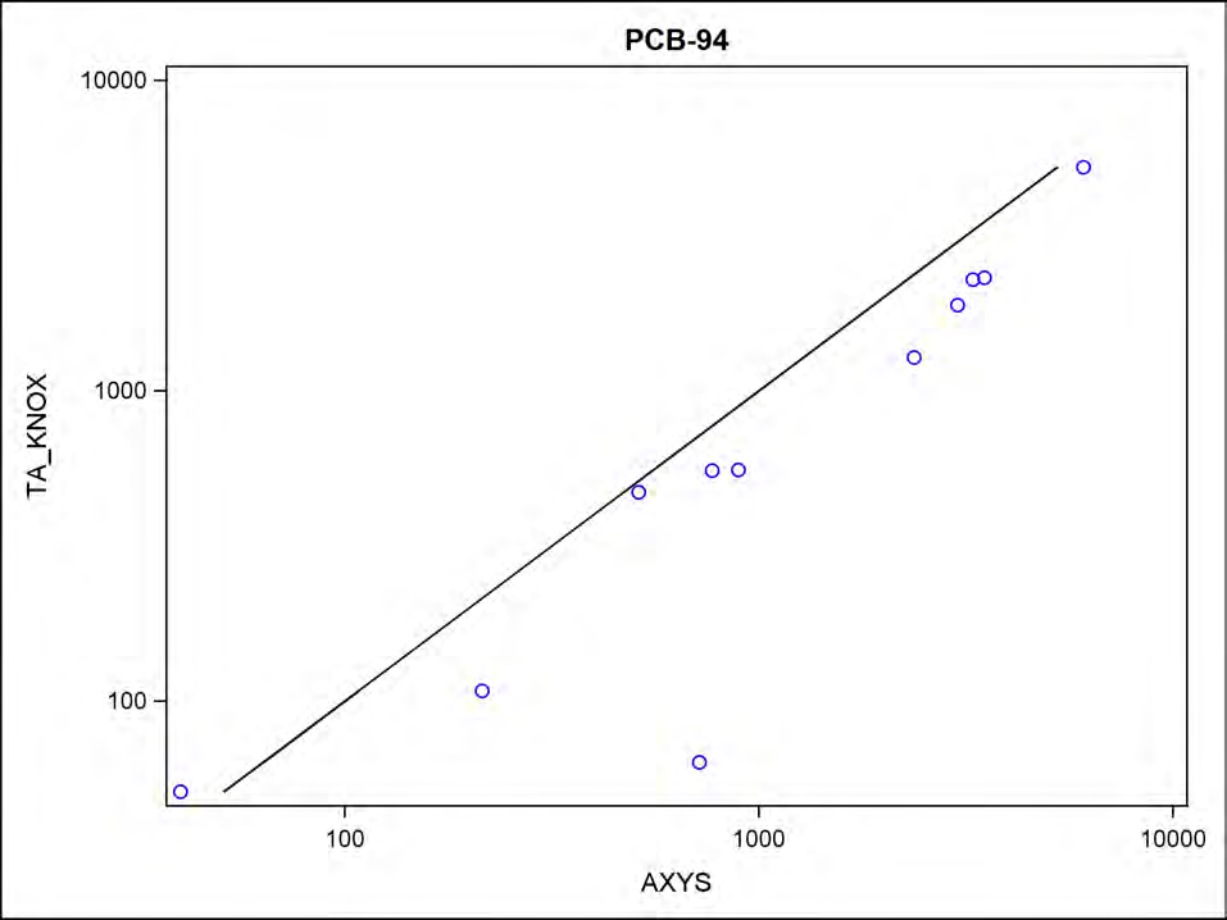

PCB-86/PCB-87/PCB-97/PCB-119/PCB-125
TA_KNOX
100000
10000
1000
100
100
1000
10000
100000
AXYS

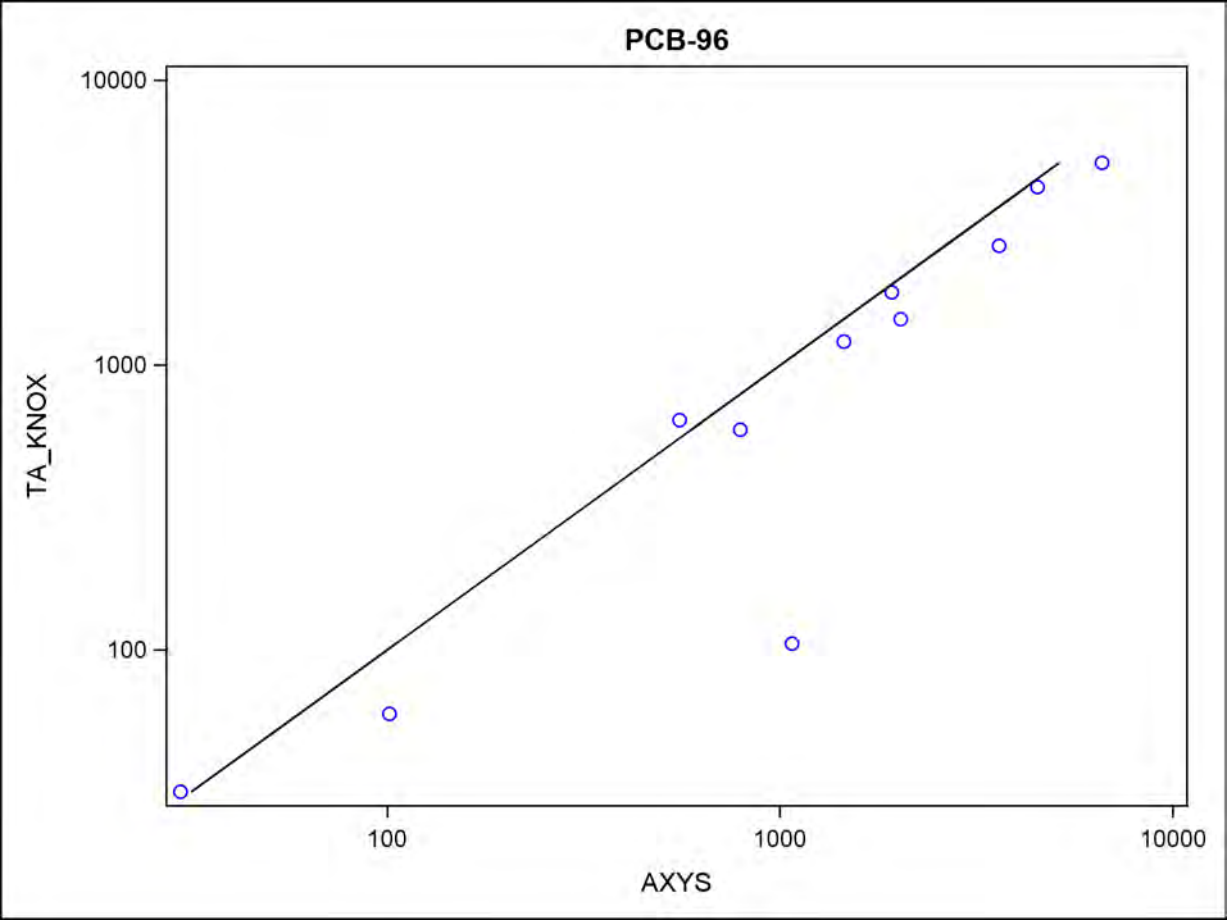

PCB-88/PCB-91
TA_KNOX
AXYS
100000
10000
1000
100
10
10
100
1000
10000
100000

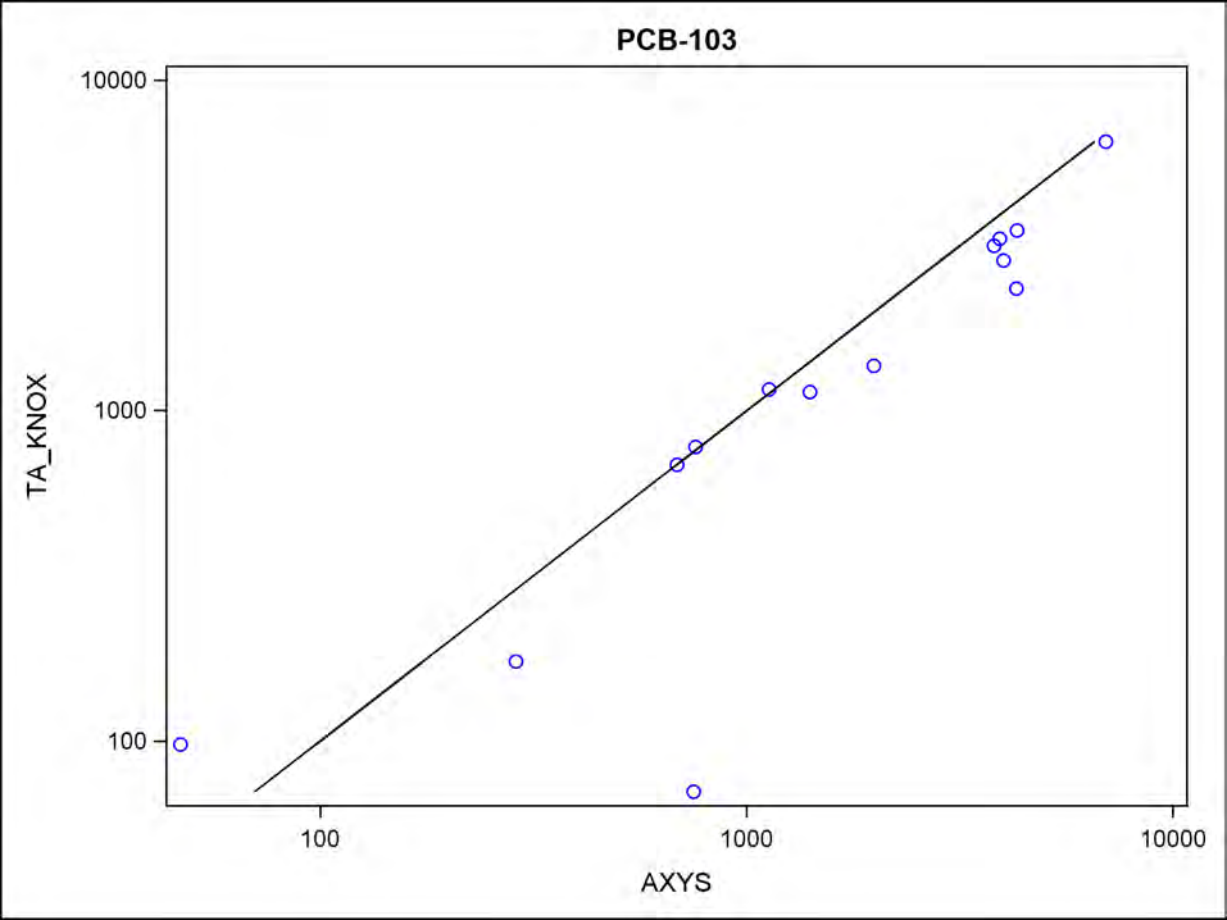

PCB-89
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

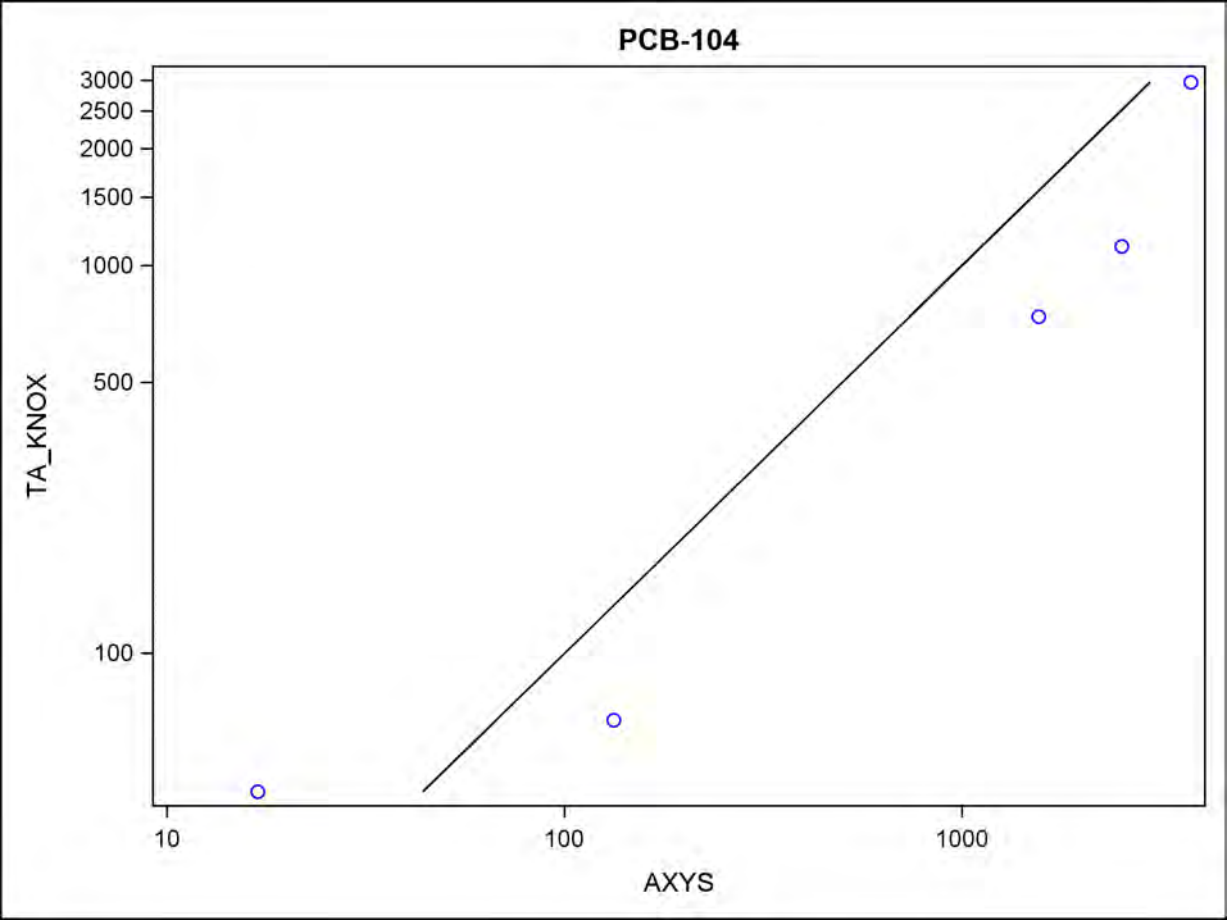

PCB-90/PCB-101/PCB-113
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

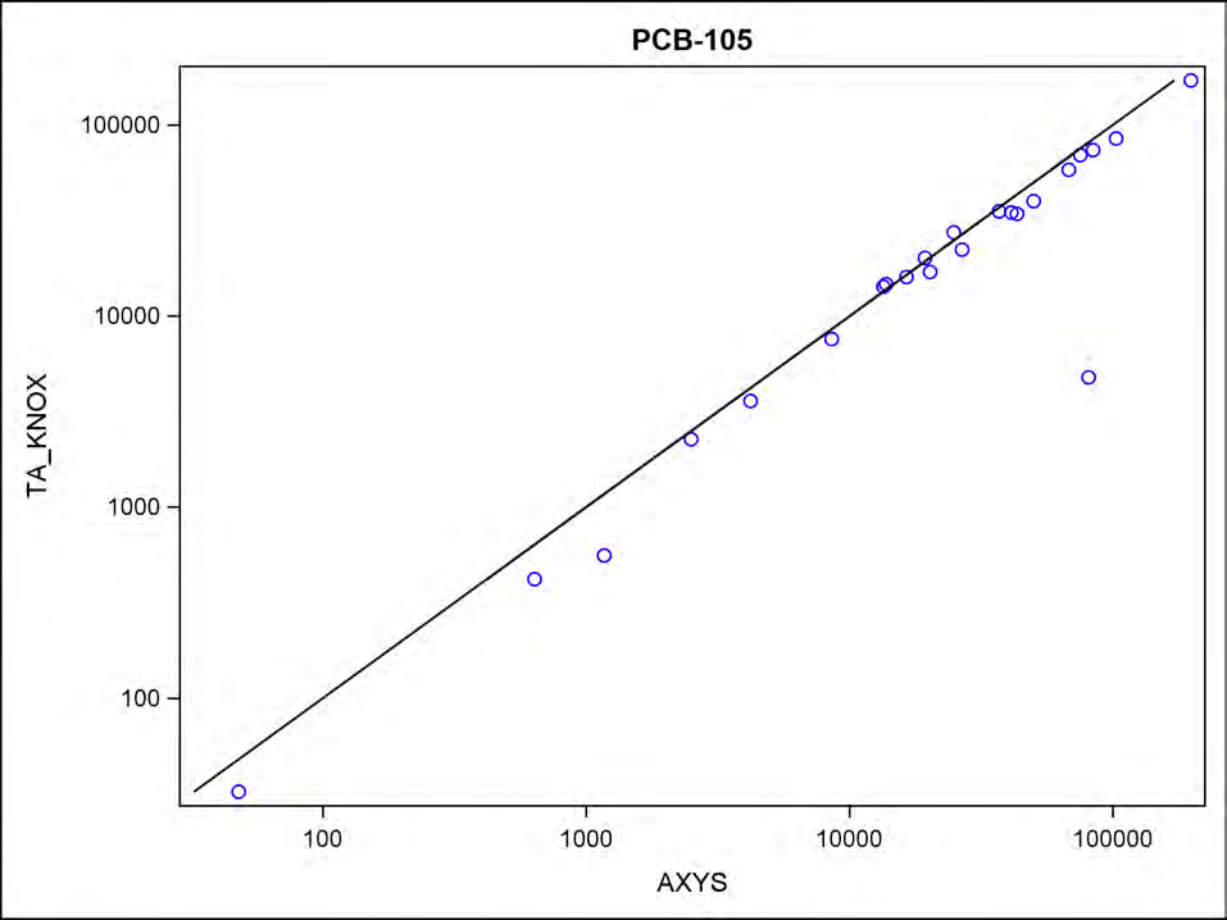

PCB-92
100000
10000
1000
100
10
TA_KNOX
10
100
1000
10000
100000
AXYS

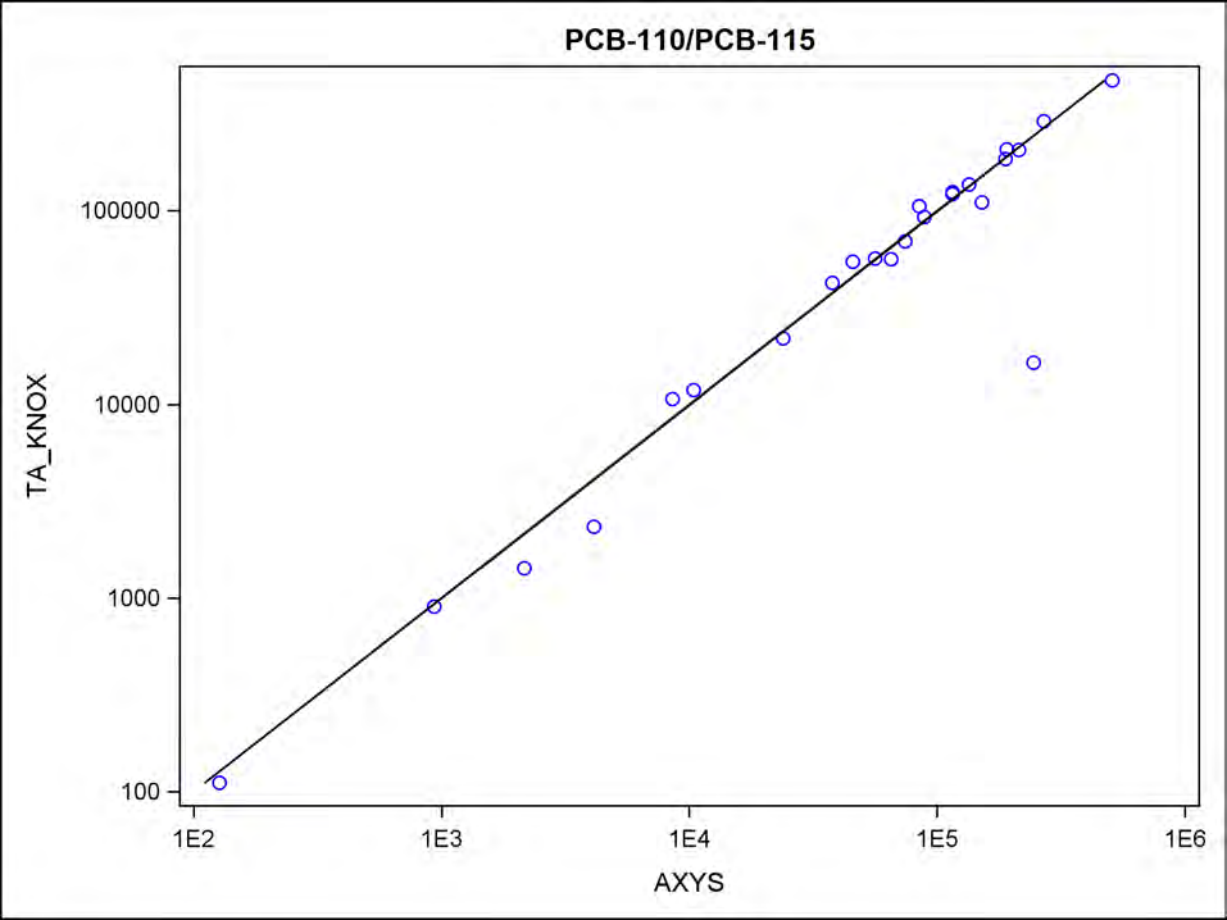

PCB-94
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

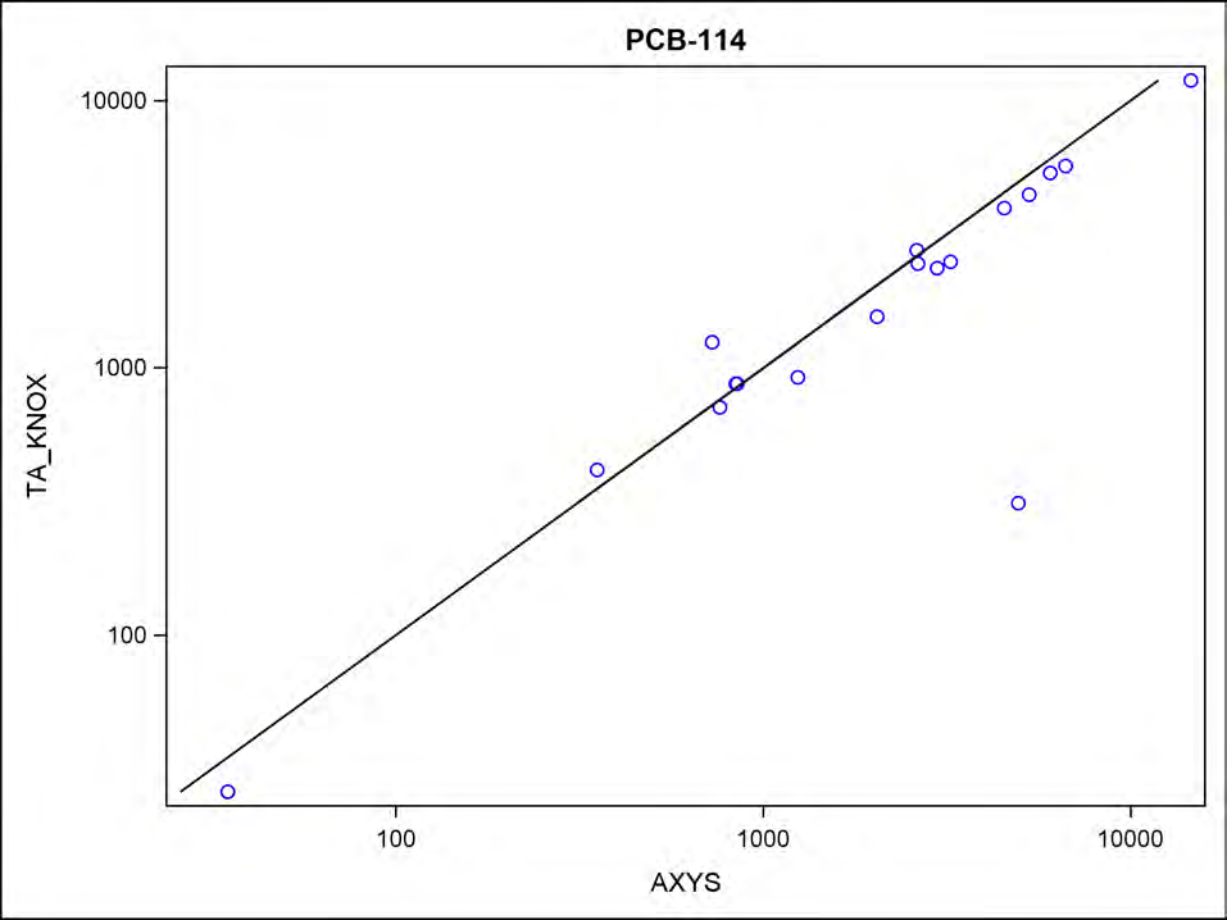

PCB-96
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

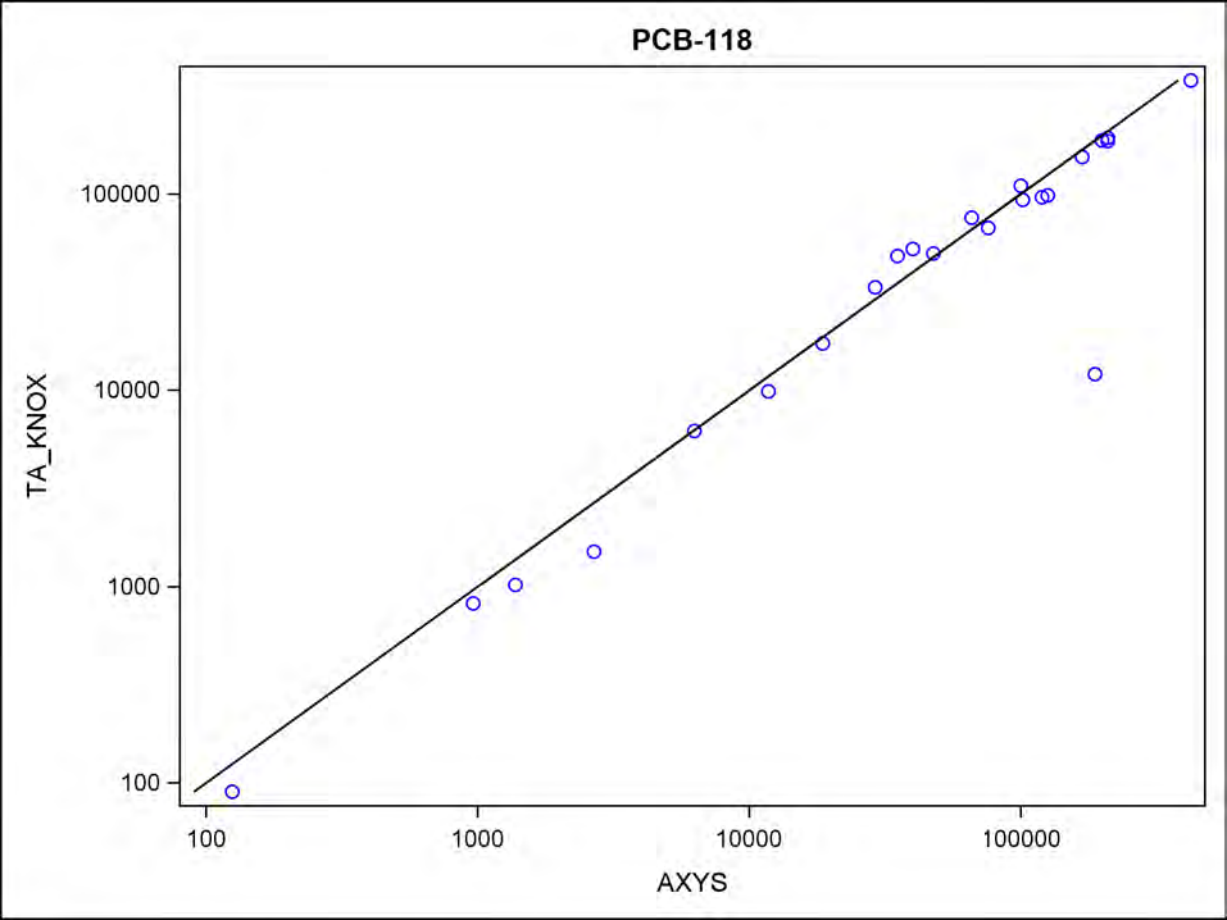

PCB-103
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

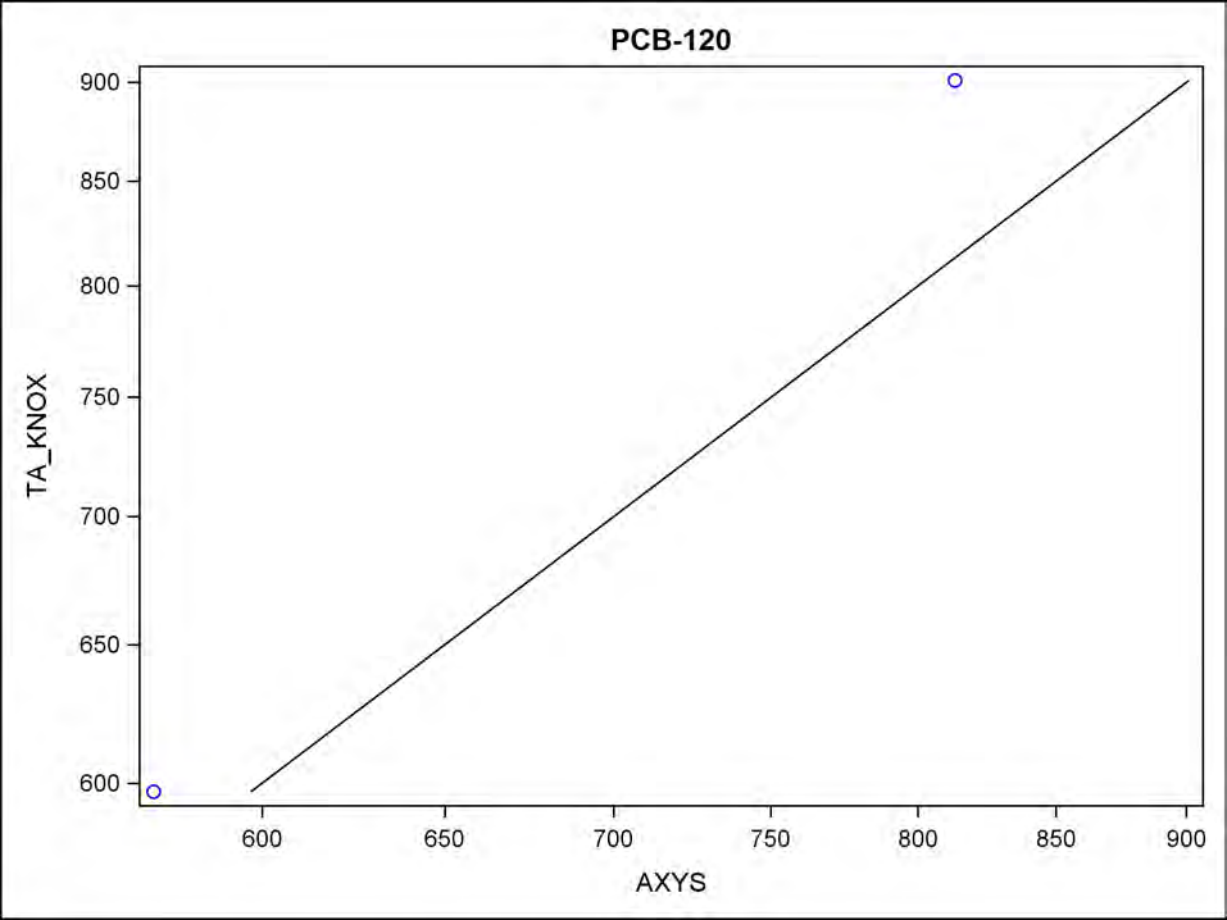

PCB-104
3000
2500
2000
1500
1000
500
100
TA_KNOX
10
100
1000
AXYS

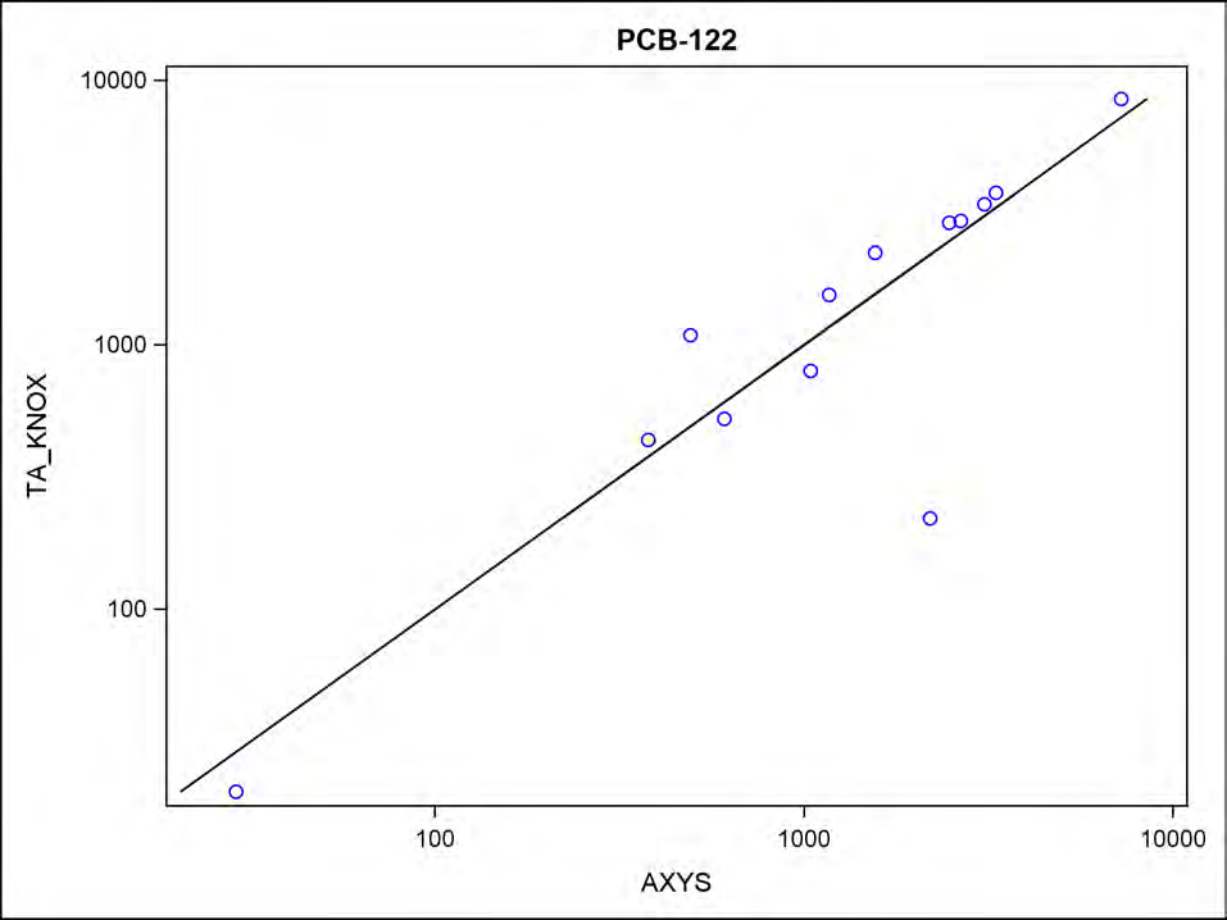

PCB-105
TA_KNOX
AXYS
100000
10000
1000
100
100
1000
10000
100000

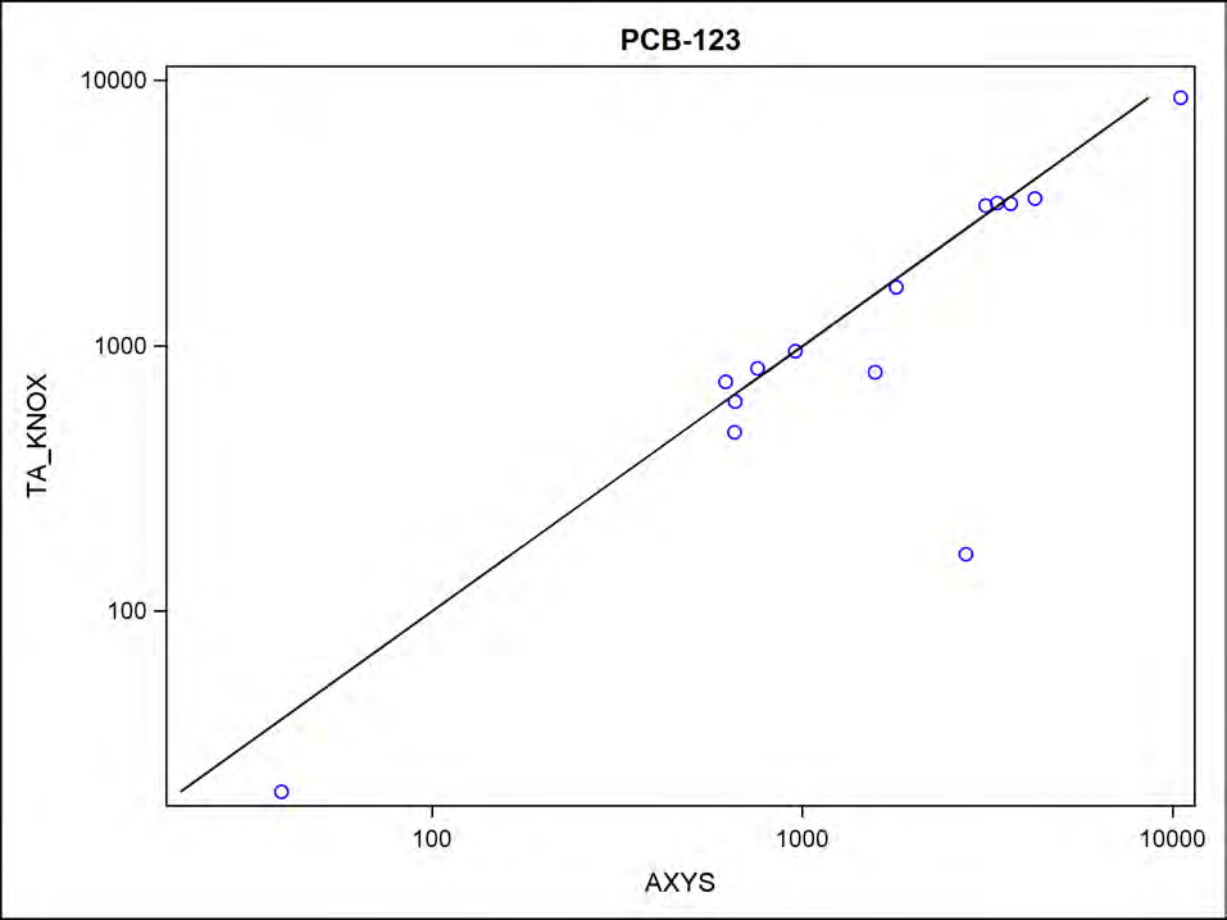

PCB-110/PCB-115
TA_KNOX
100000
10000
1000
100
1E2
1E3
1E4
1E5
1E6
AXYS

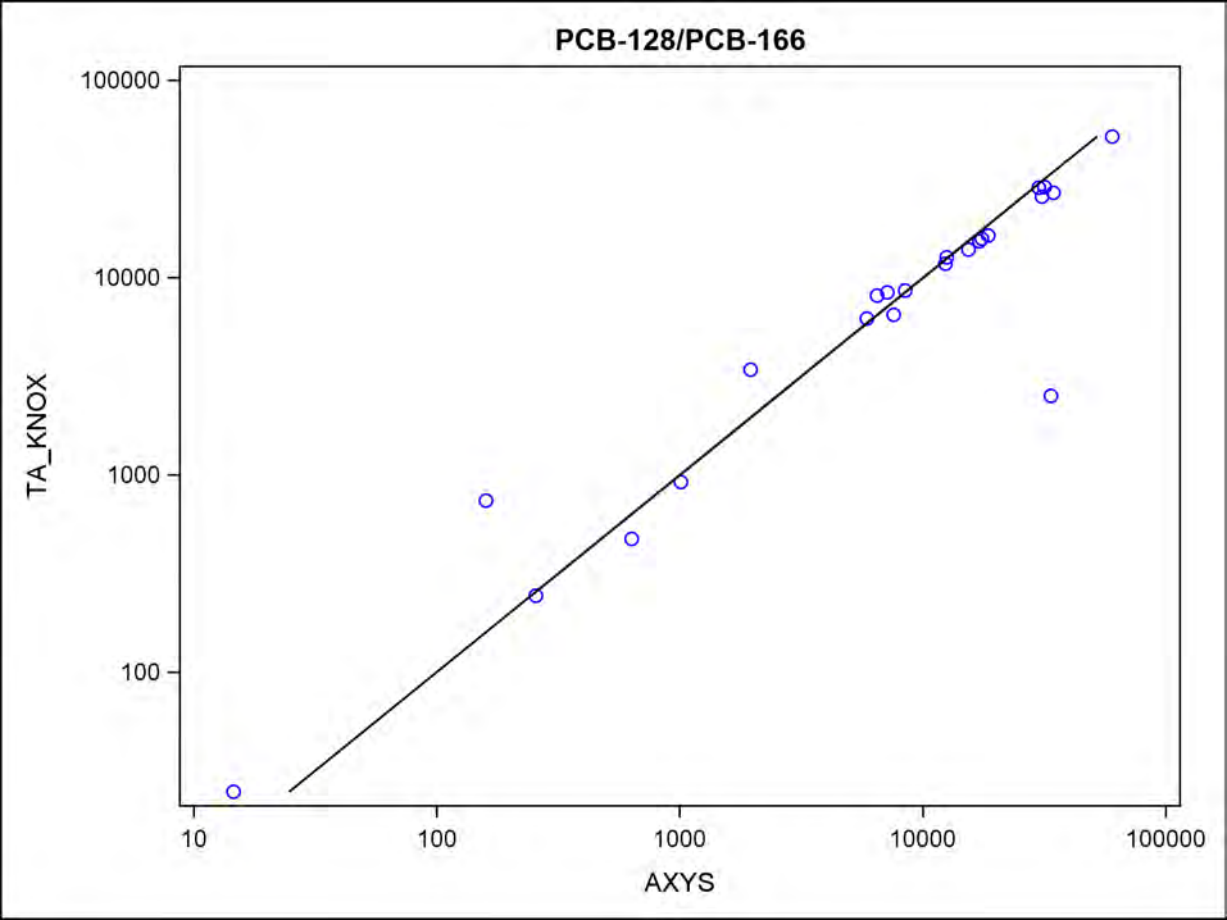

PCB-114
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

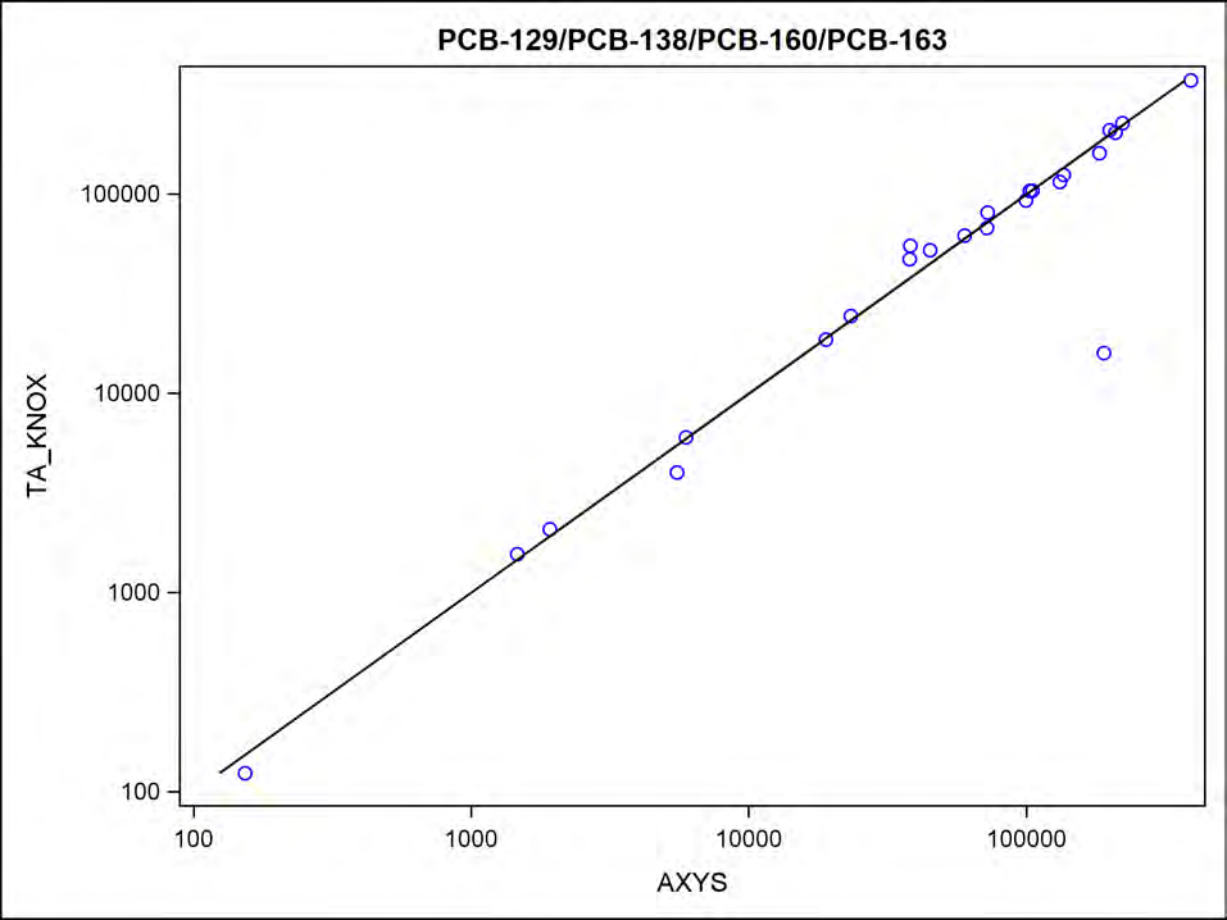

PCB-118
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

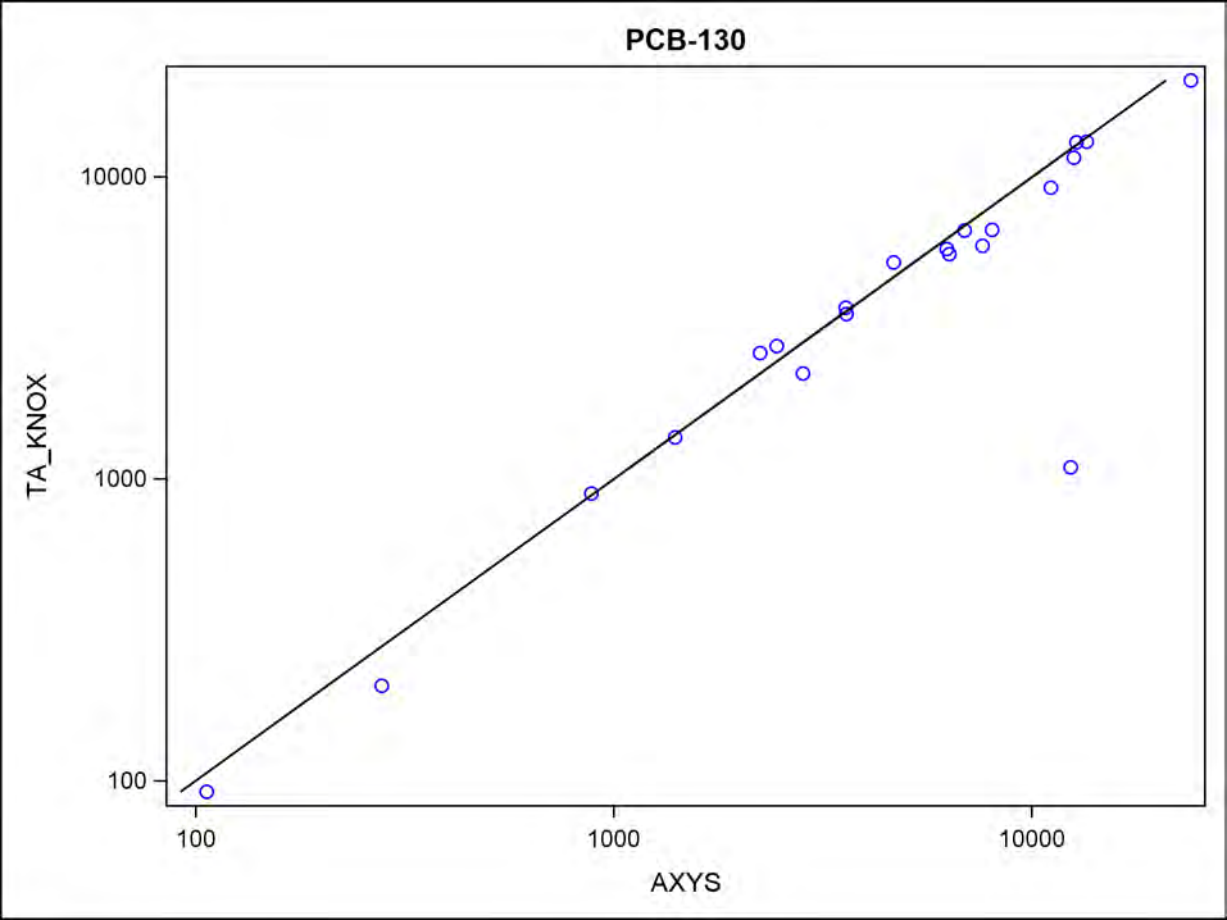

PCB-120
TA_KNOX
AXYS
900
850
800
750
700
650
600
600
650
700
750
800
850
900

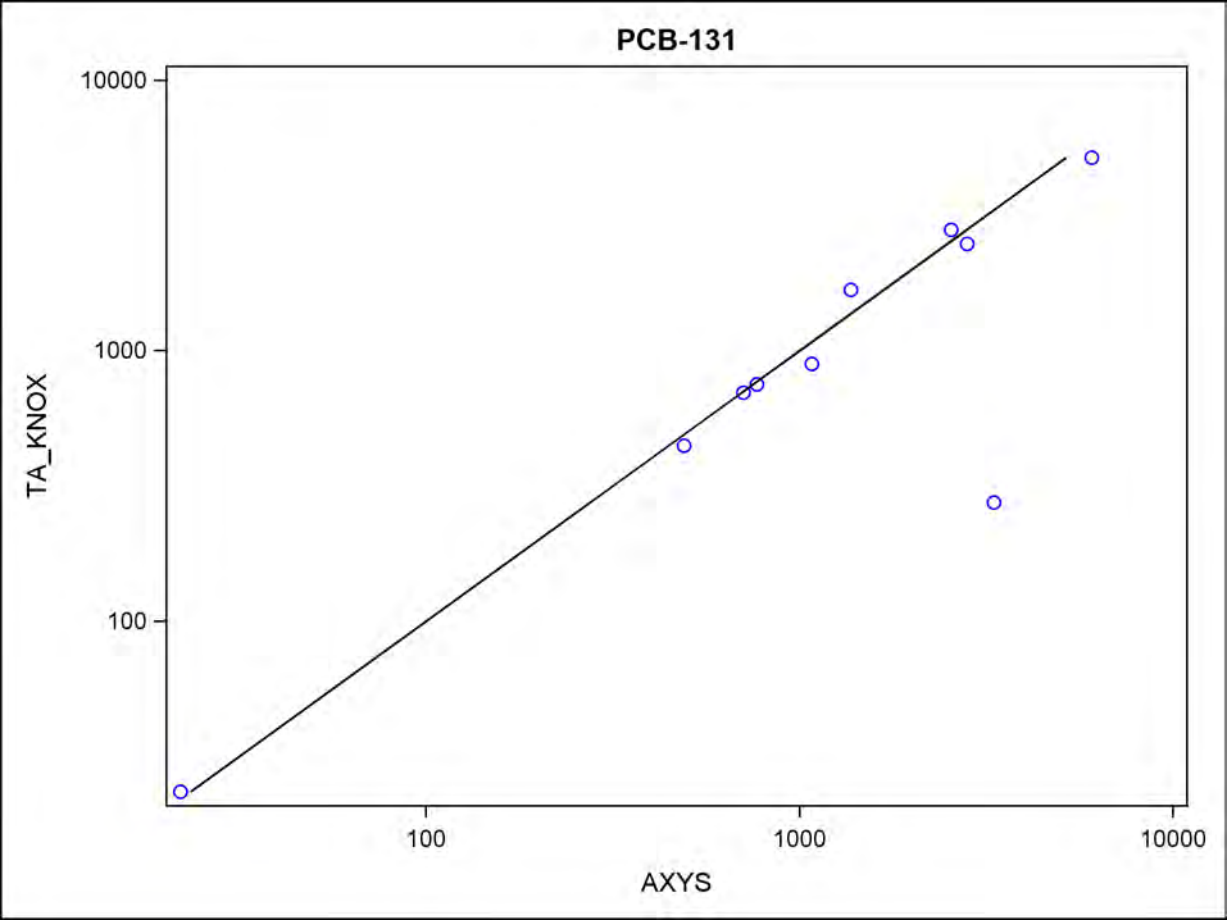

PCB-122
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

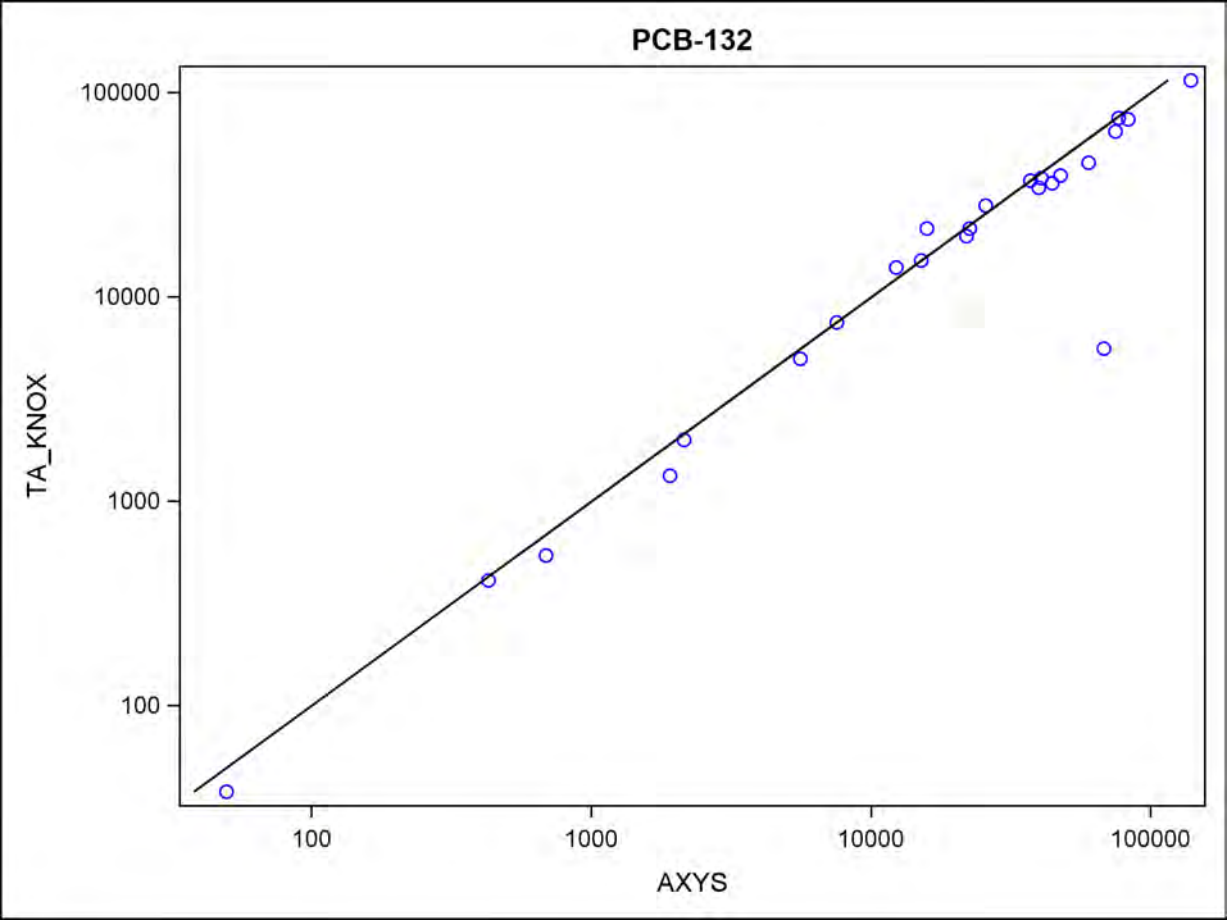

PCB-123
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

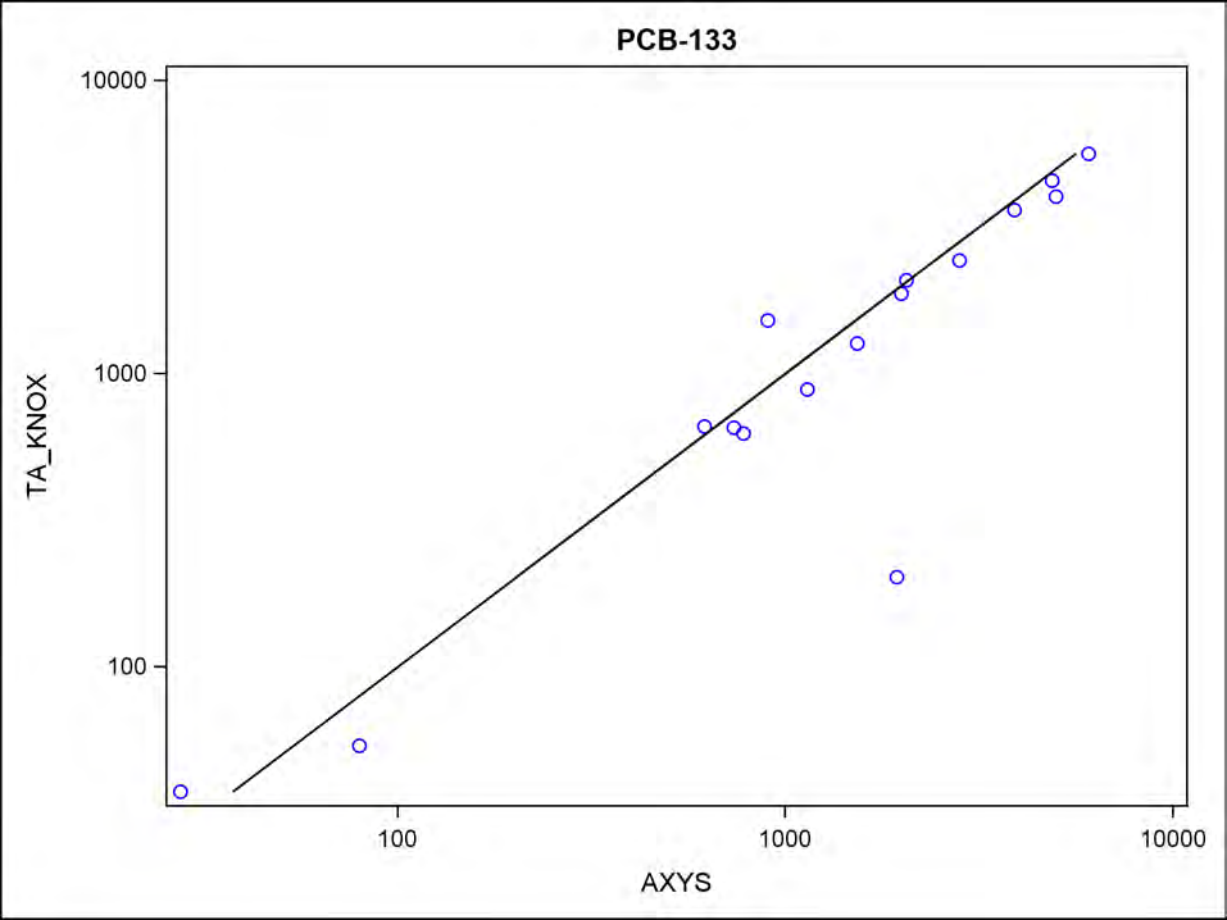

PCB-128/PCB-166
100000
10000
1000
100
TA_KNOX
10
100
1000
10000
100000
AXYS

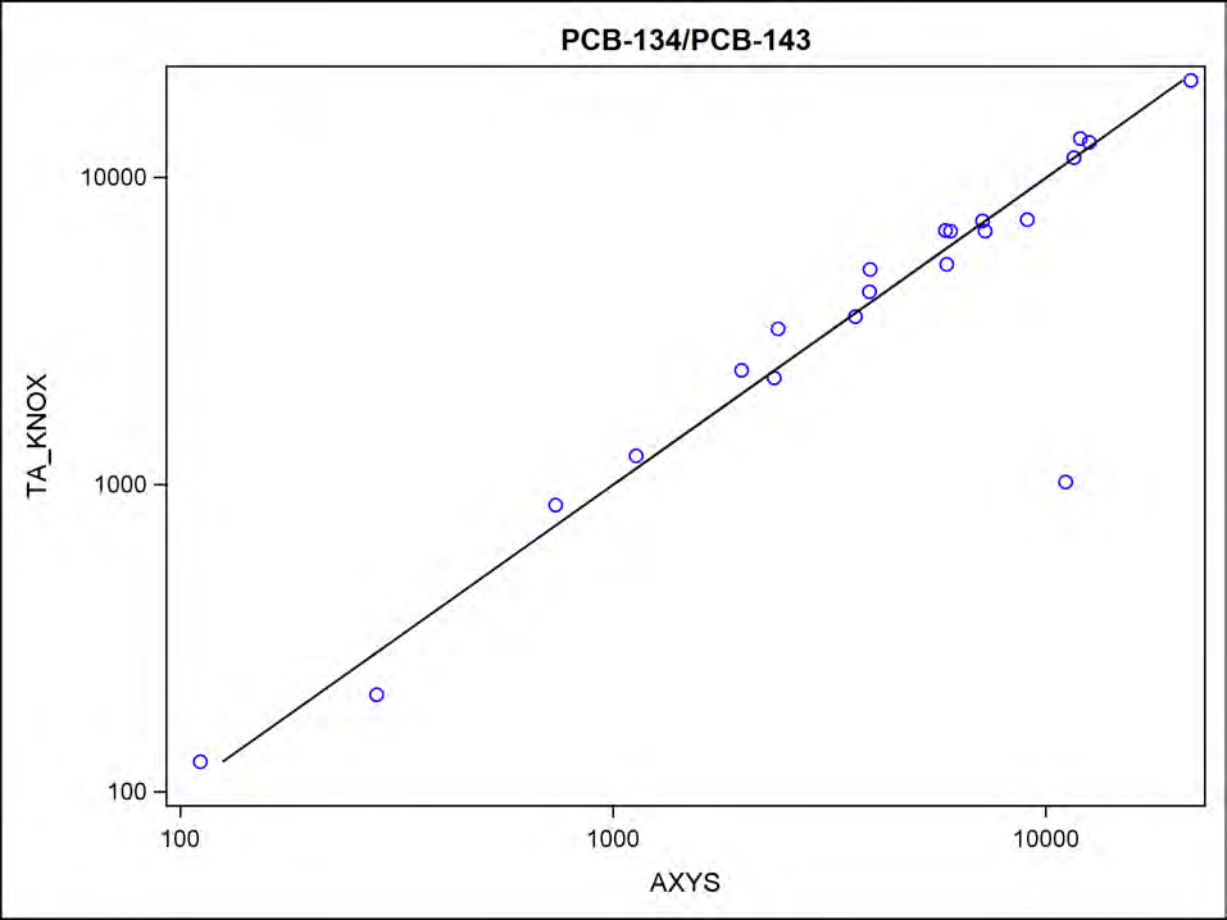

PCB-129/PCB-138/PCB-160/PCB-163
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

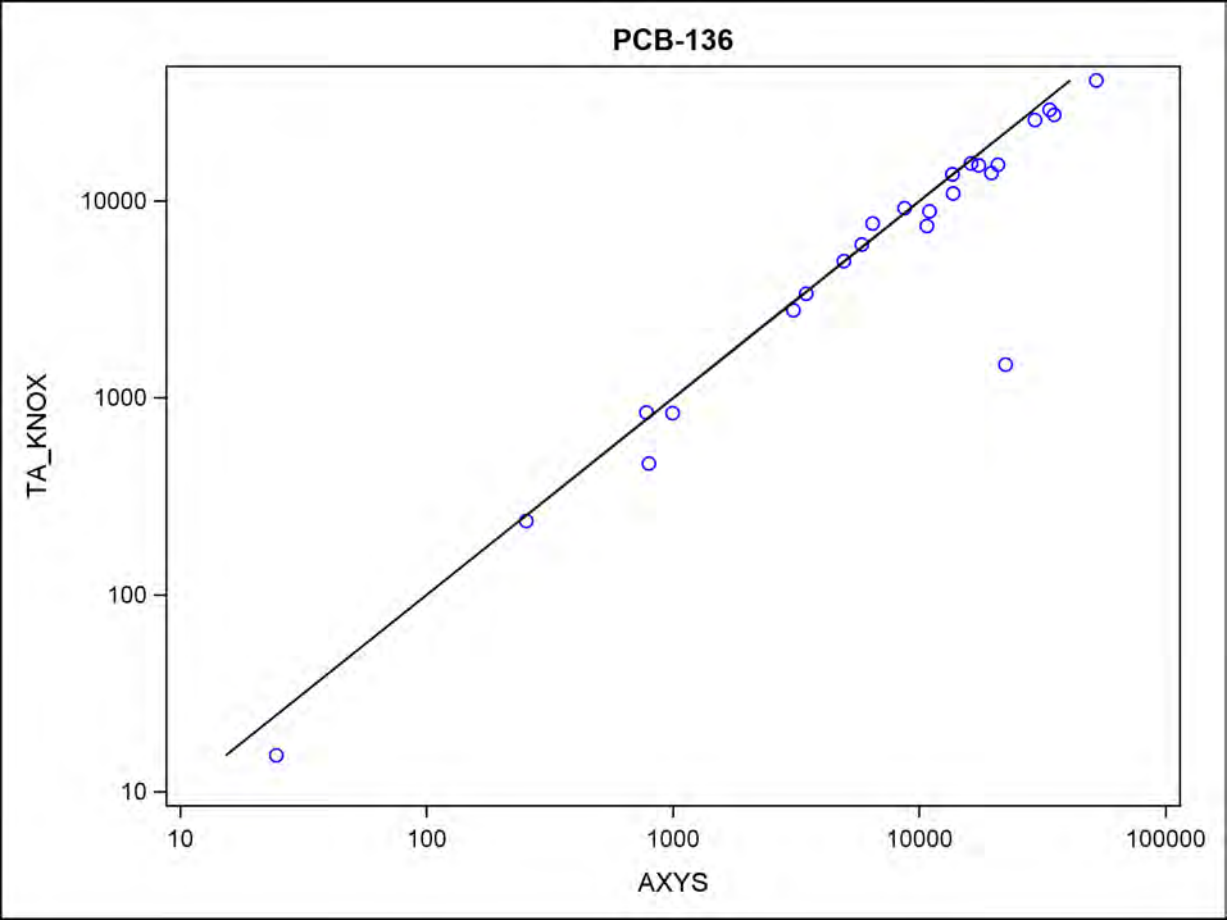

PCB-130
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

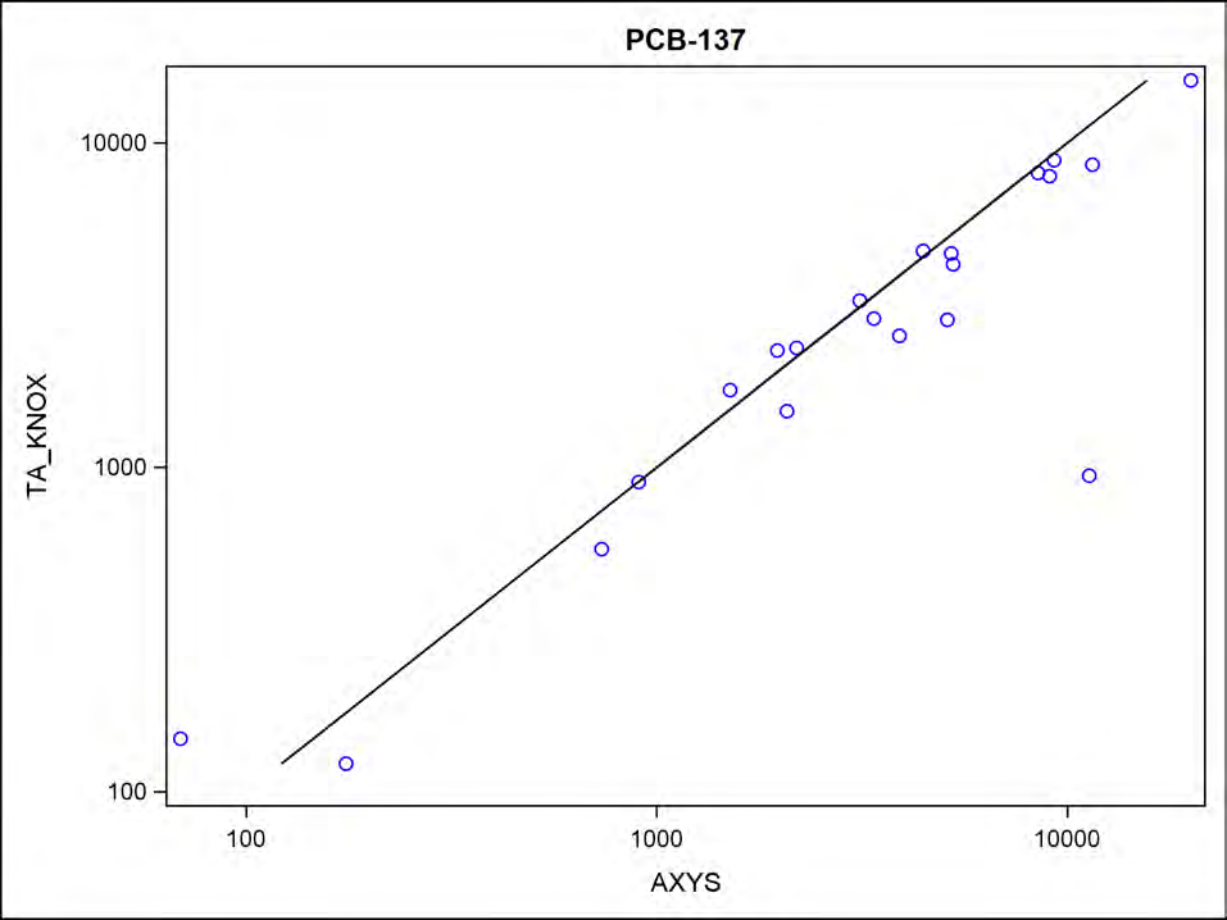

PCB-131
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

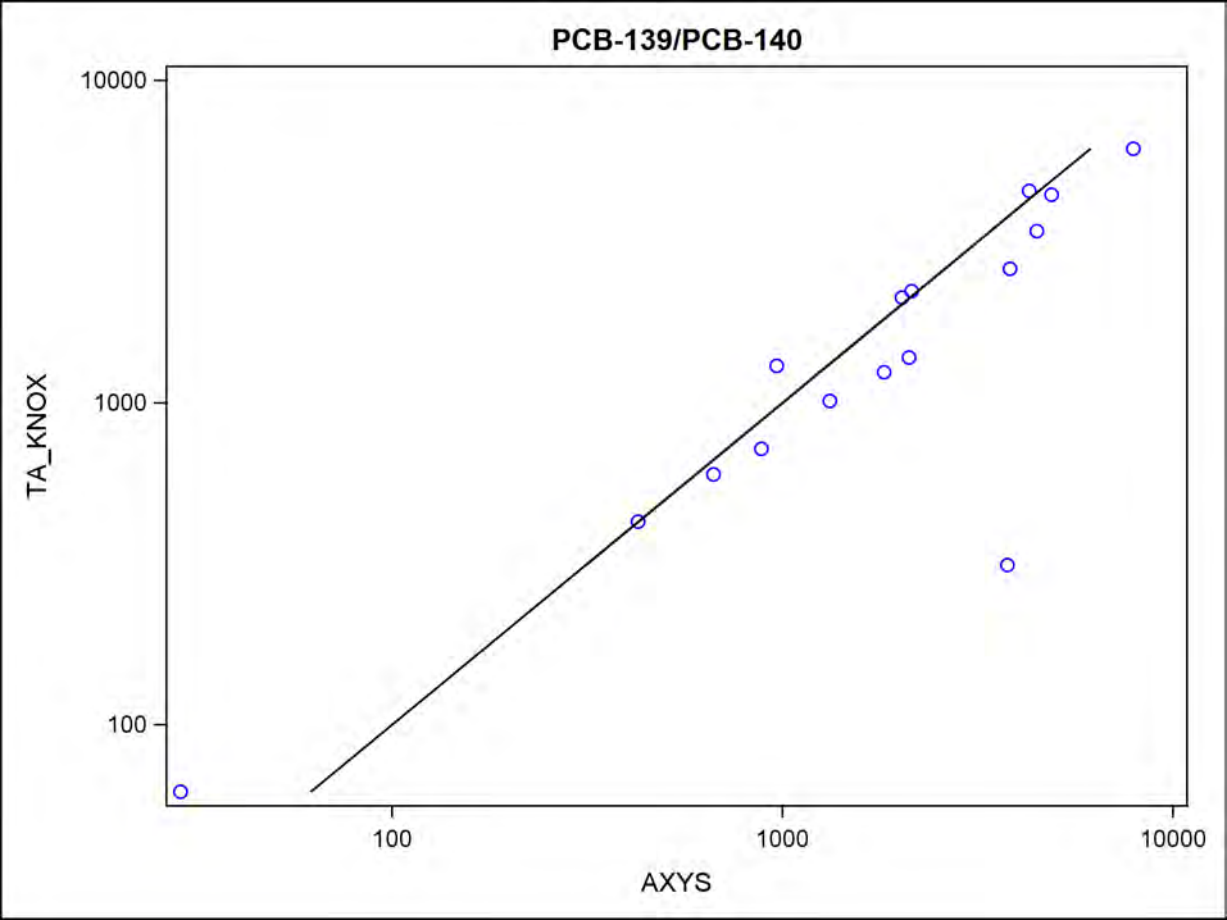

PCB-132
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

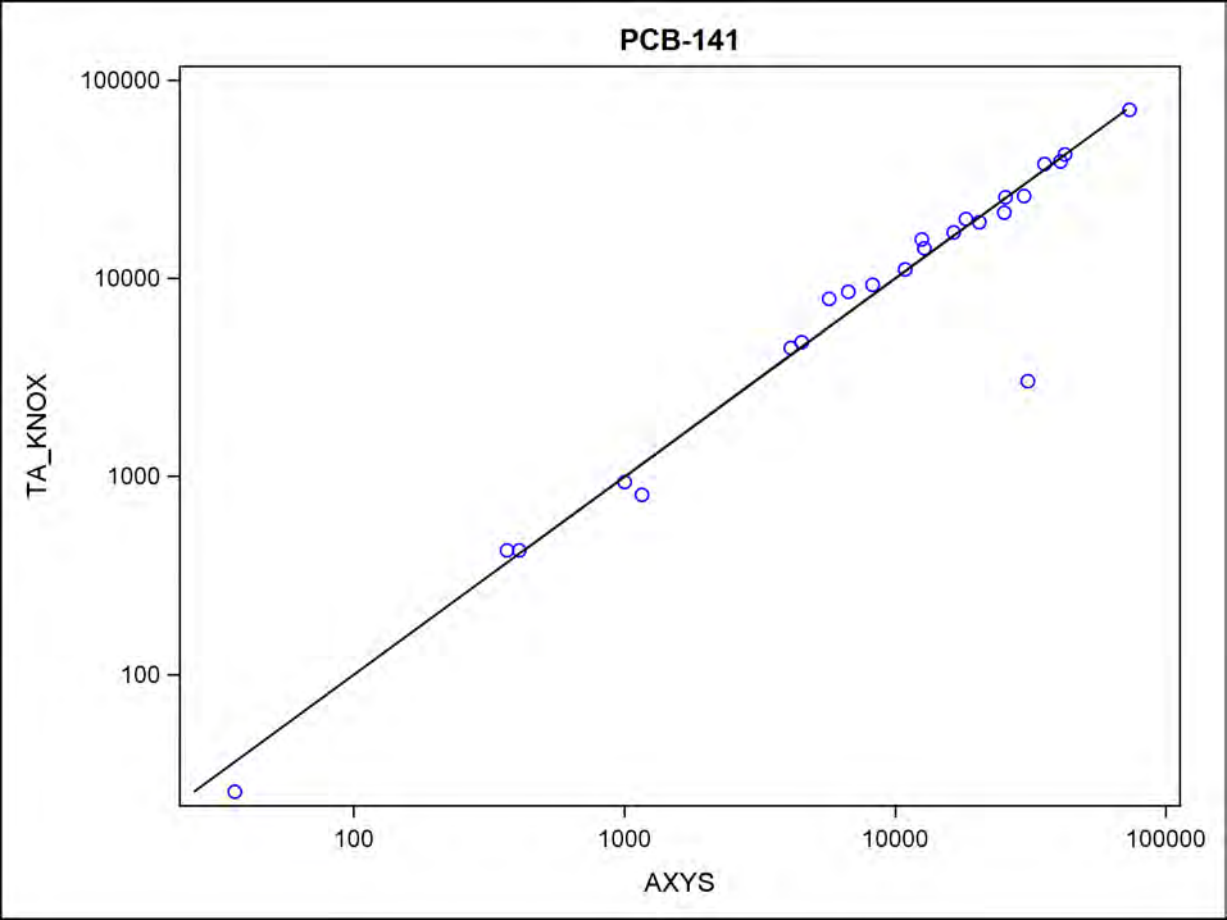

PCB-133
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

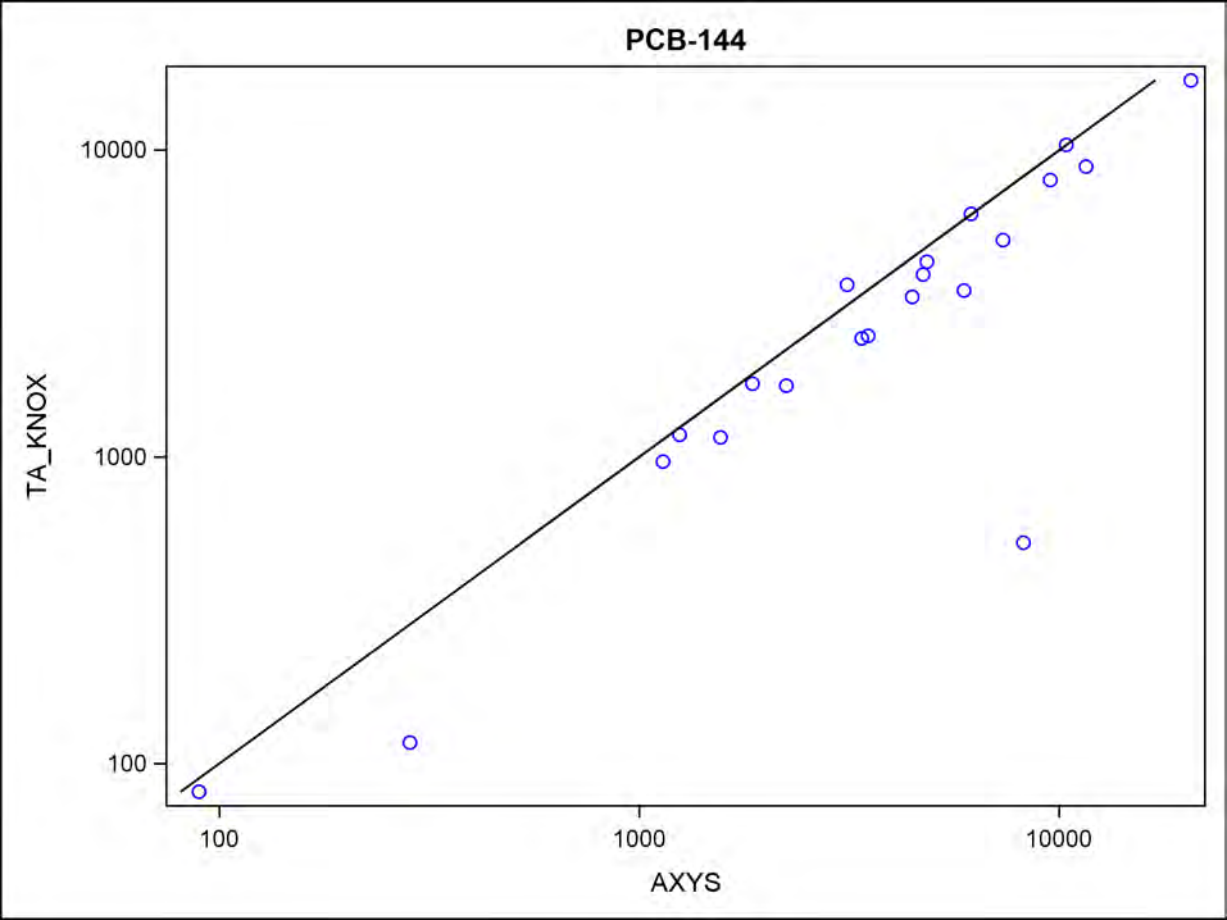

PCB-134/PCB-143
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

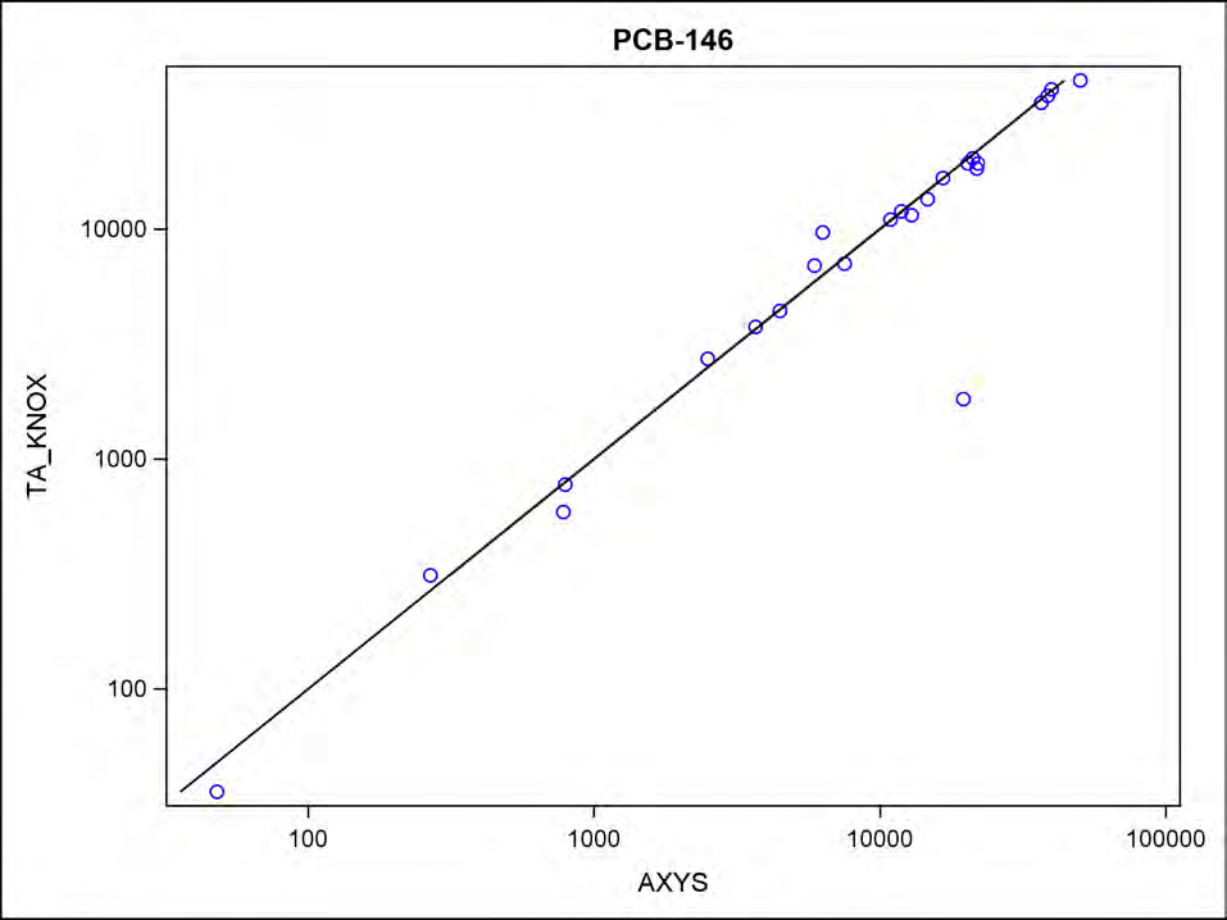

PCB-136
TA_KNOX
AXYS
10
100
1000
10000
100000

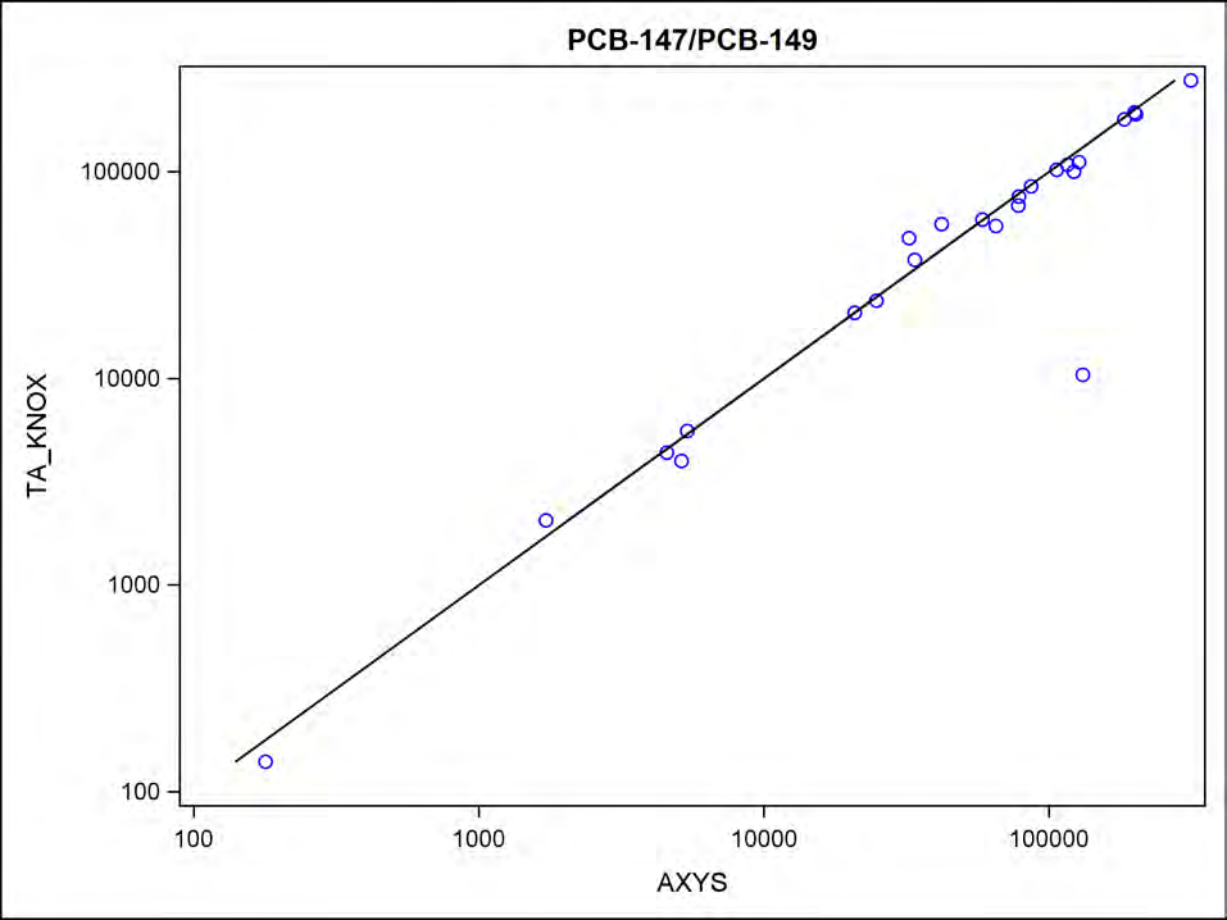

PCB-137
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

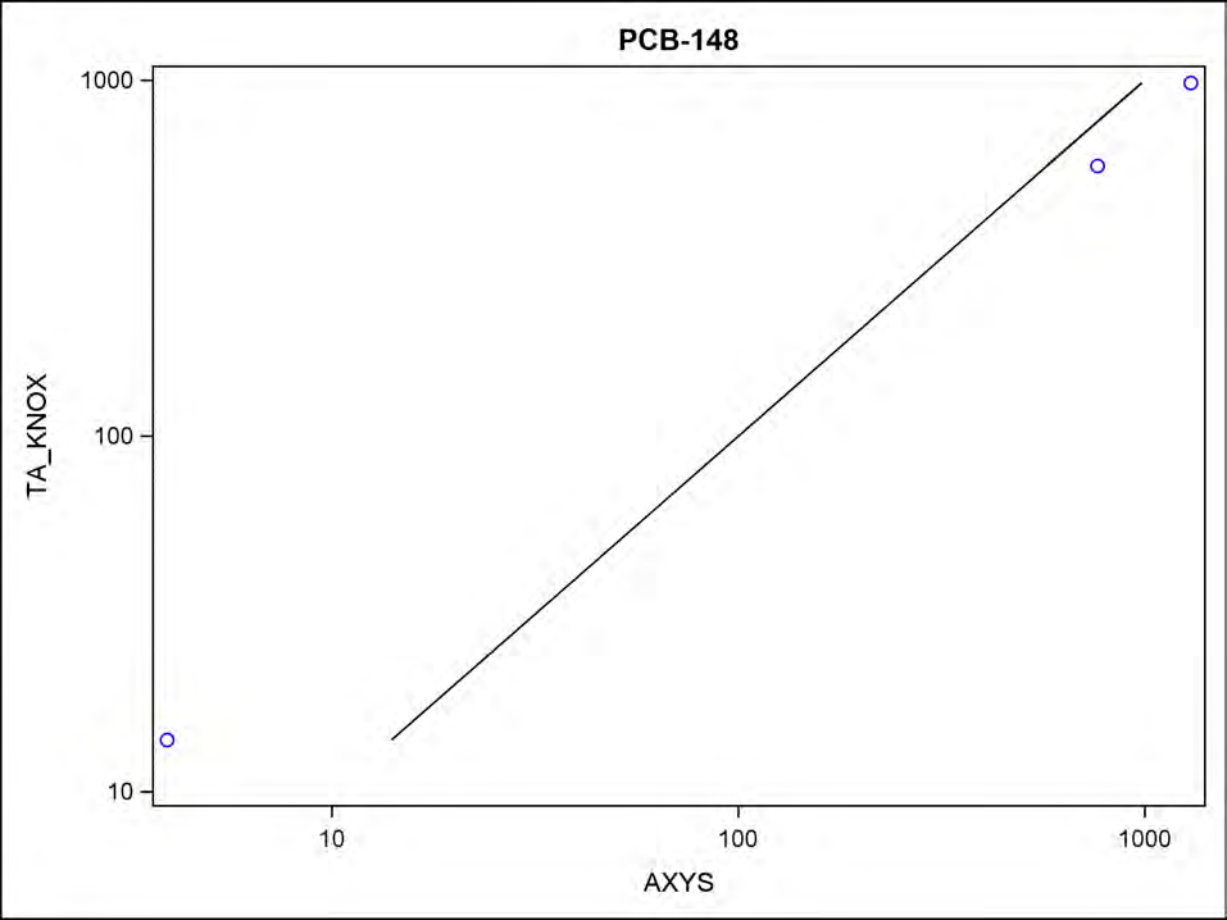

PCB-139/PCB-140
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

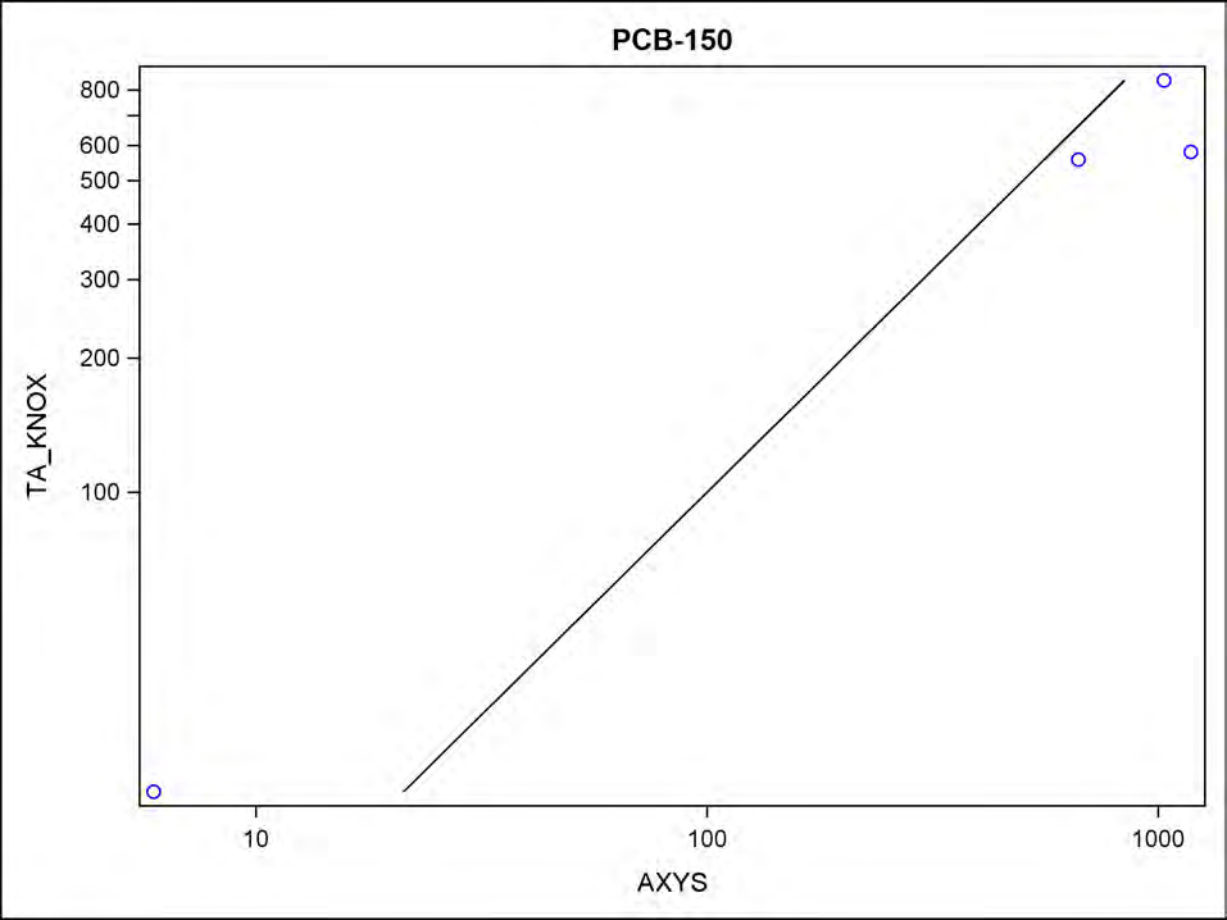

PCB-141
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

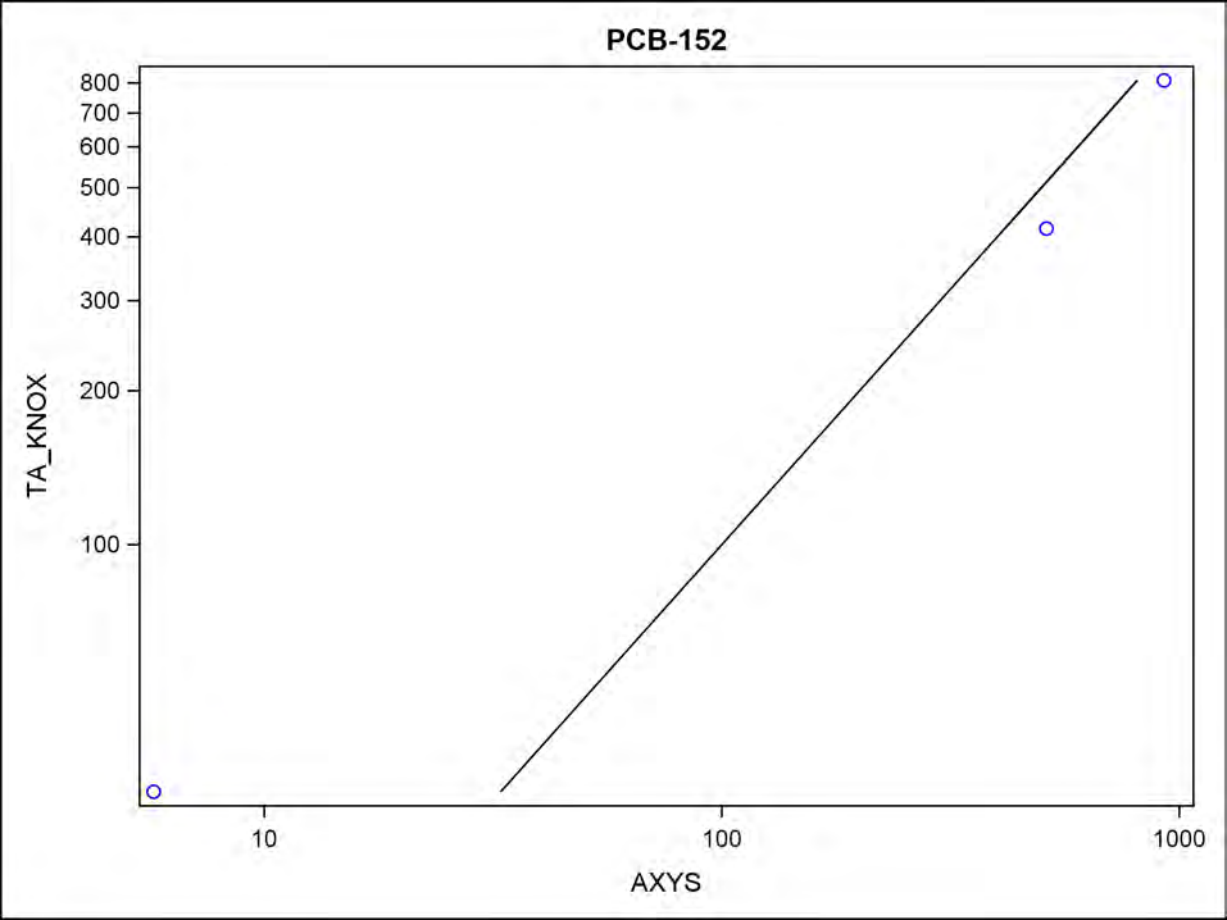

PCB-144
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

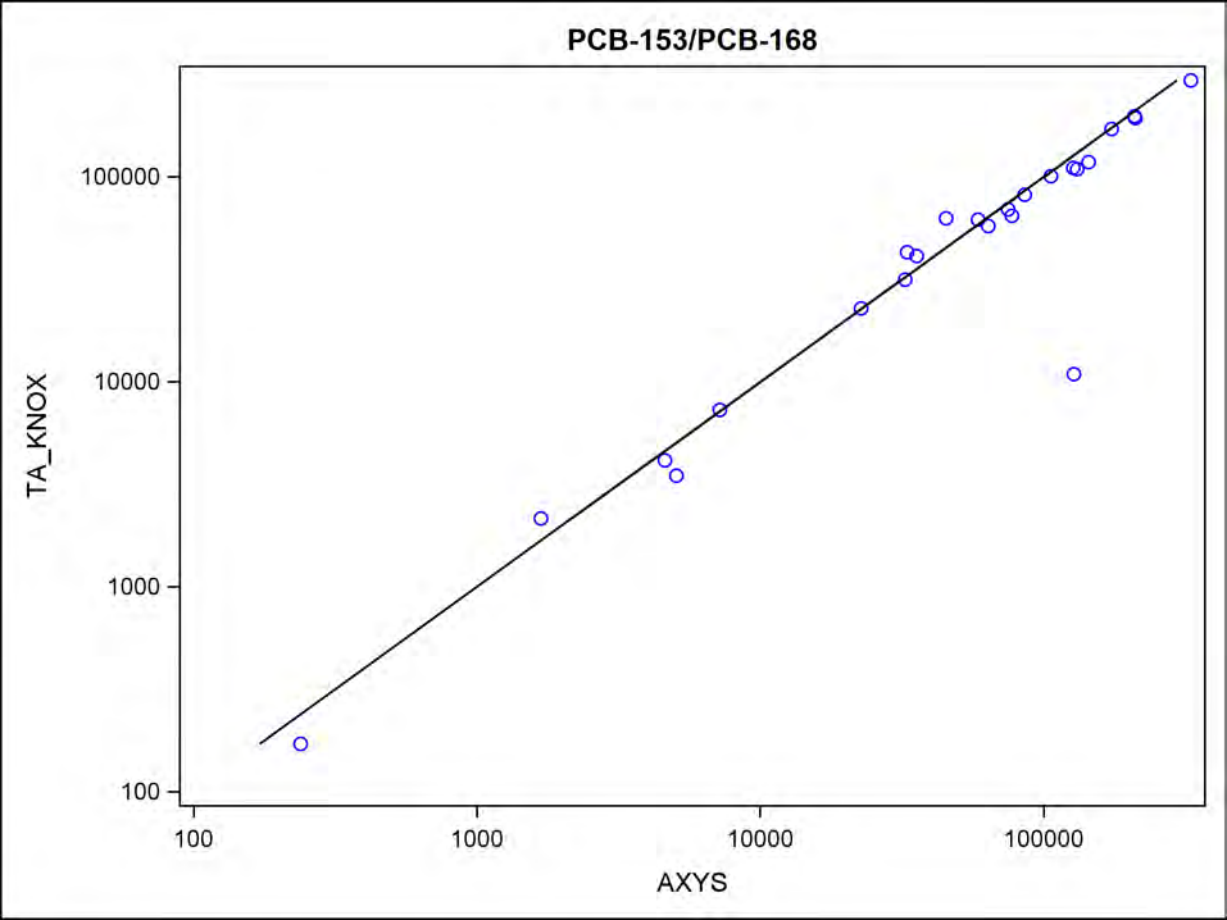

PCB-146
TA_KNOX
10000
1000
100
100
1000
10000
100000
AXYS

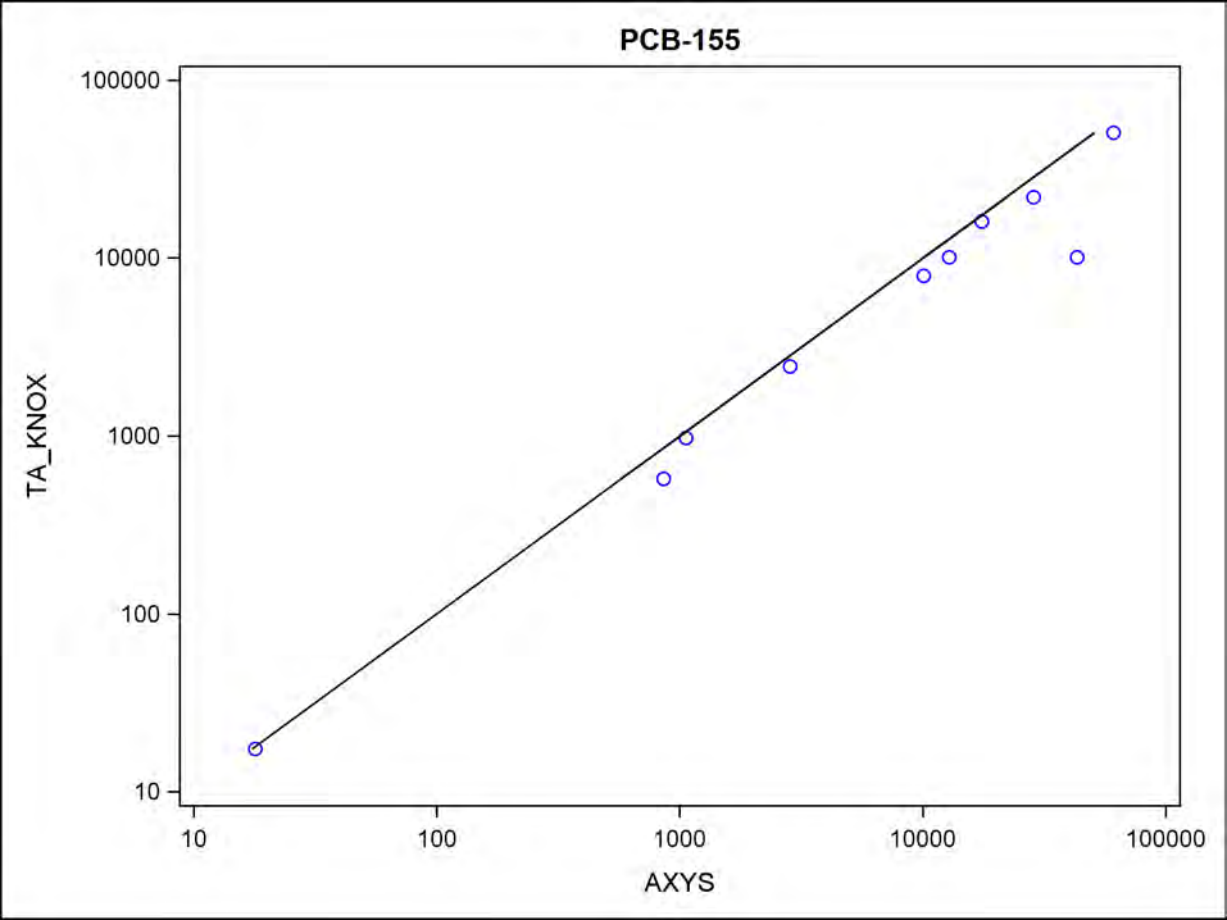

PCB-147/PCB-149
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

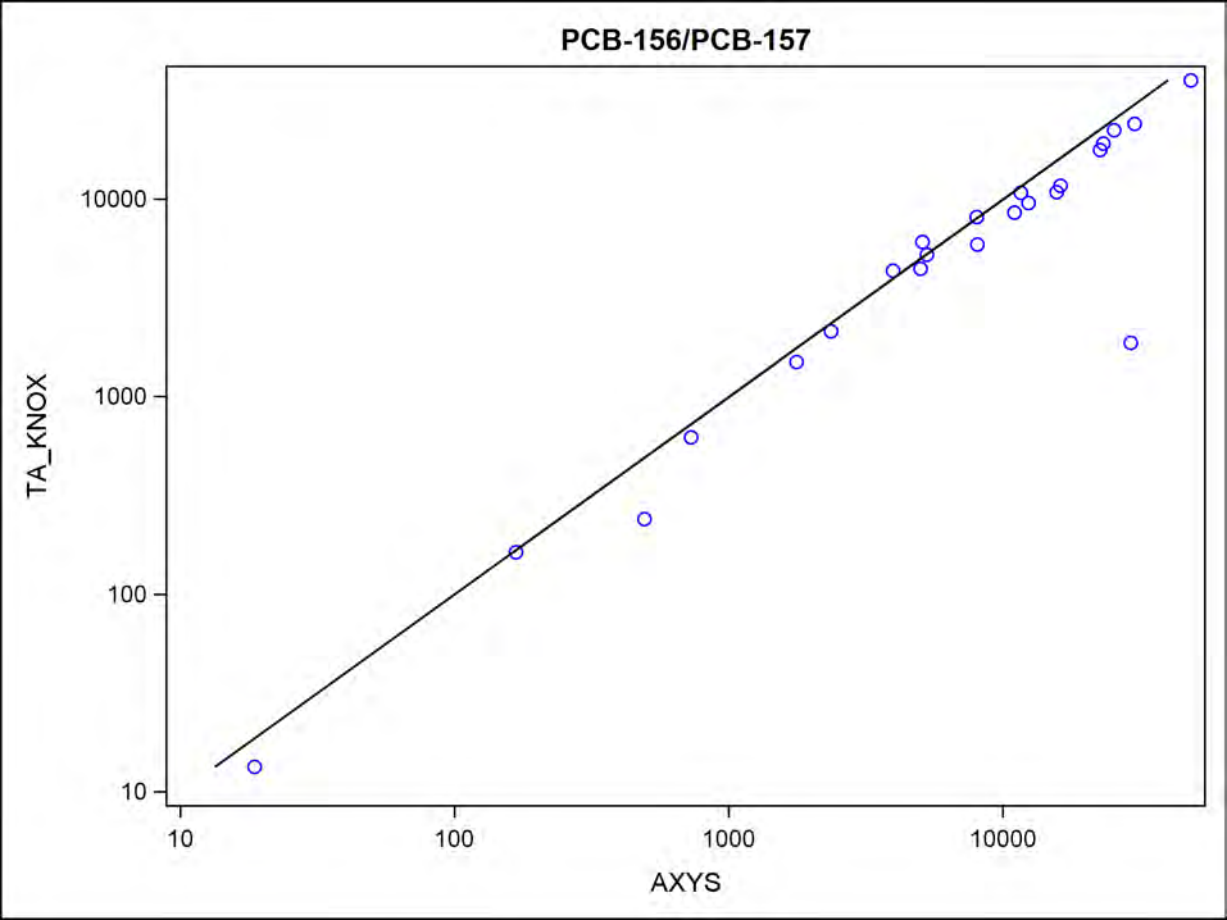

PCB-148
1000
100
10
TA_KNOX
10
100
1000
AXYS

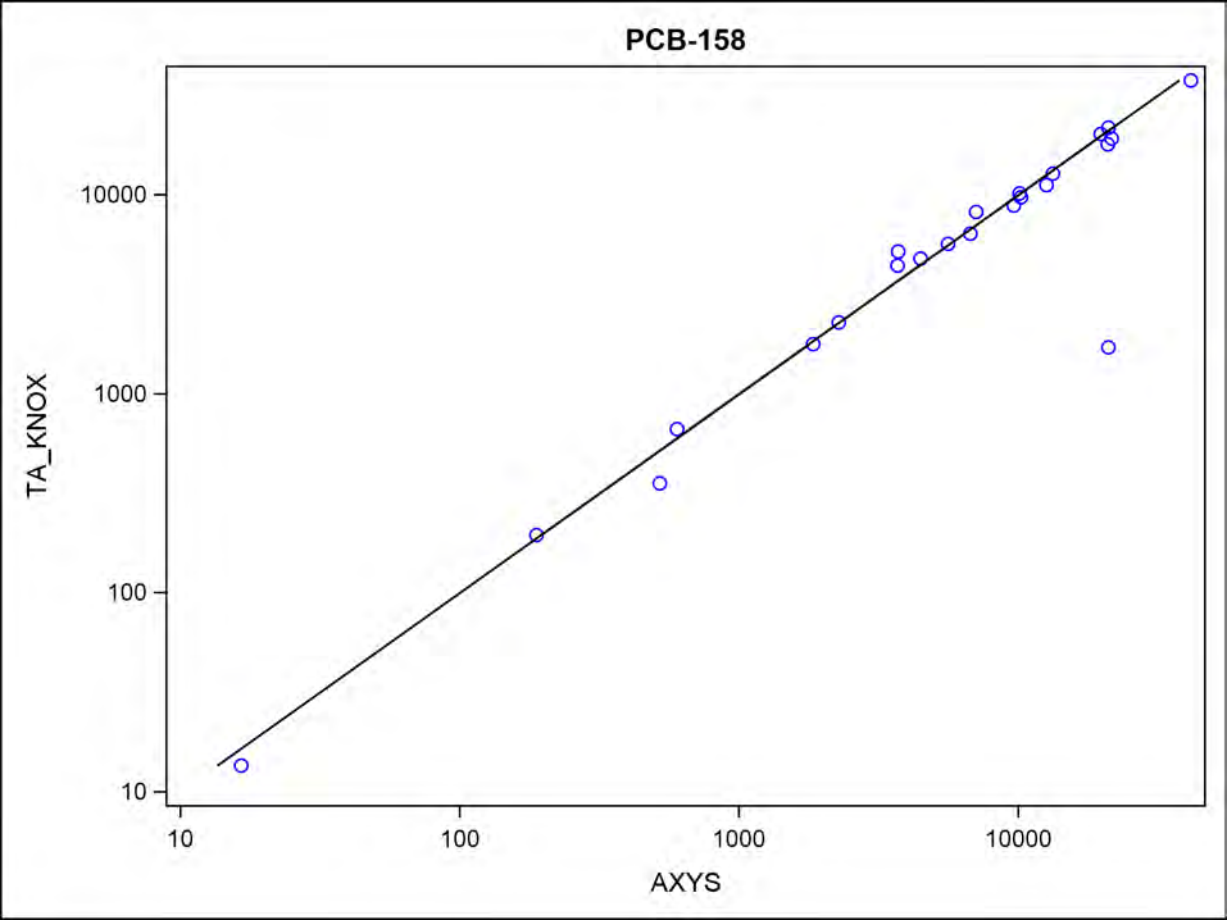

PCB-150
800
600
500
400
300
200
100
TA_KNOX
10
100
1000
AXYS

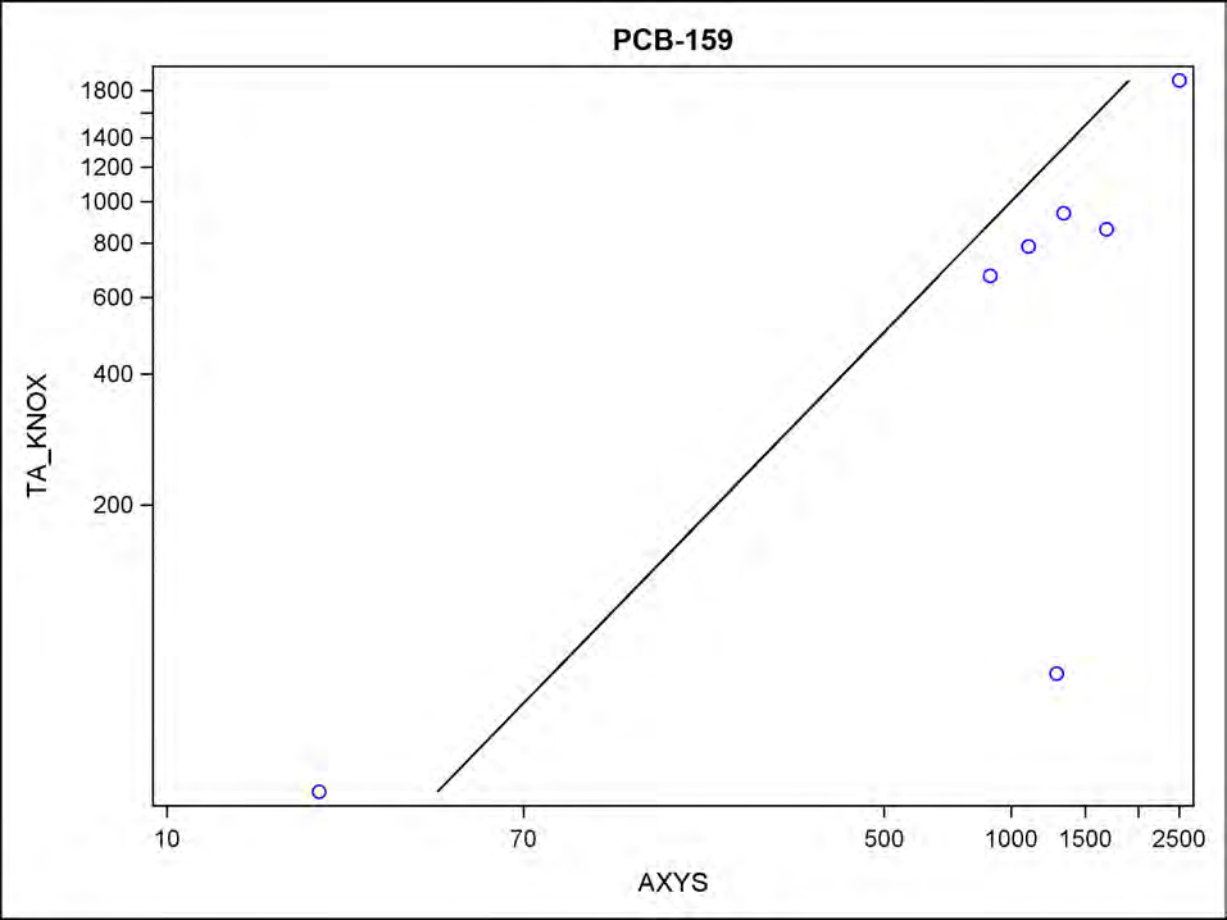

PCB-152
800
700
600
500
400
300
200
100
TA_KNOX
10
100
1000
AXYS

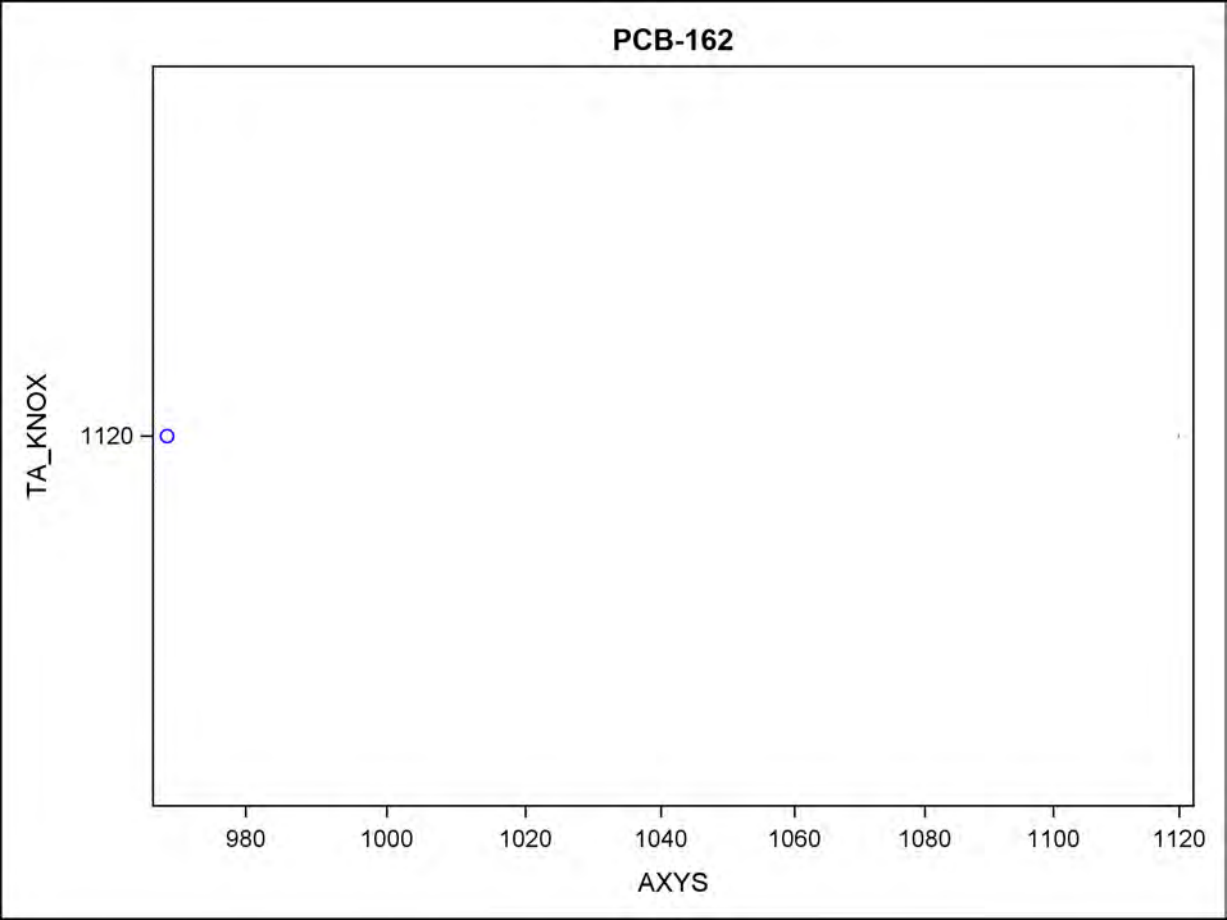

PCB-153/PCB-168
TA_KNOX
AXYS
100
1000
10000
100000
100
1000
10000
100000

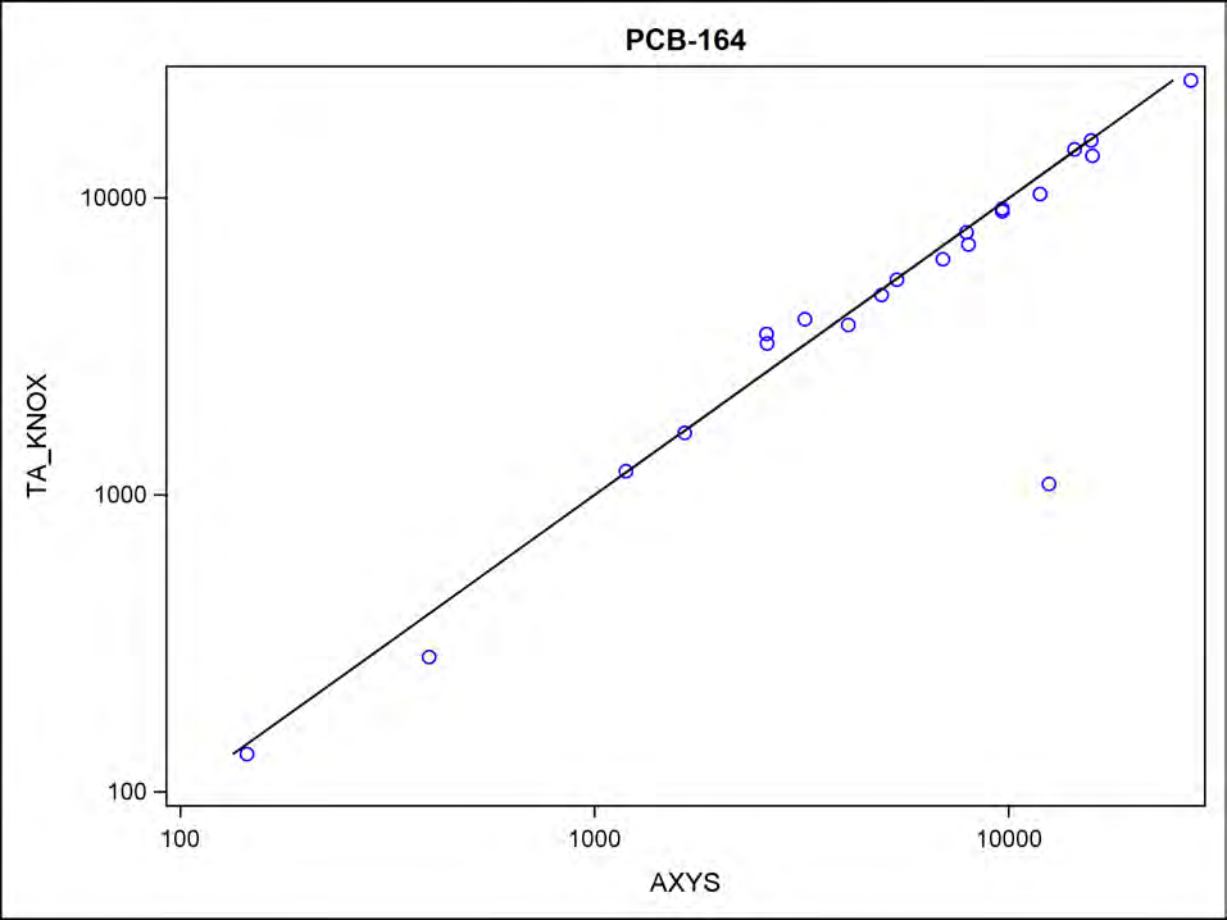

PCB-155
100000
10000
1000
100
10
TA_KNOX
10
100
1000
10000
100000
AXYS

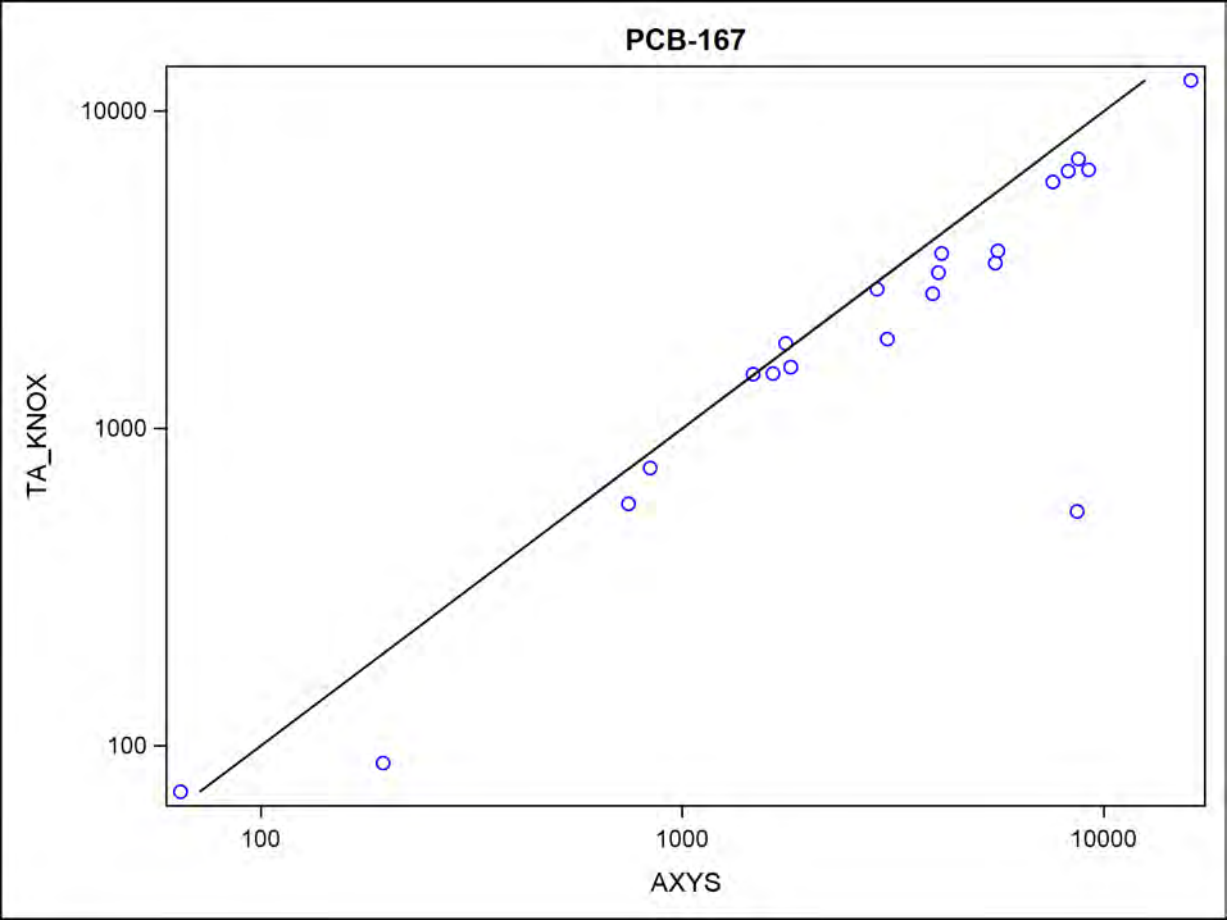

PCB-156/PCB-157
TA_KNOX
AXYS
10
100
1000
10000
10
100
1000
10000

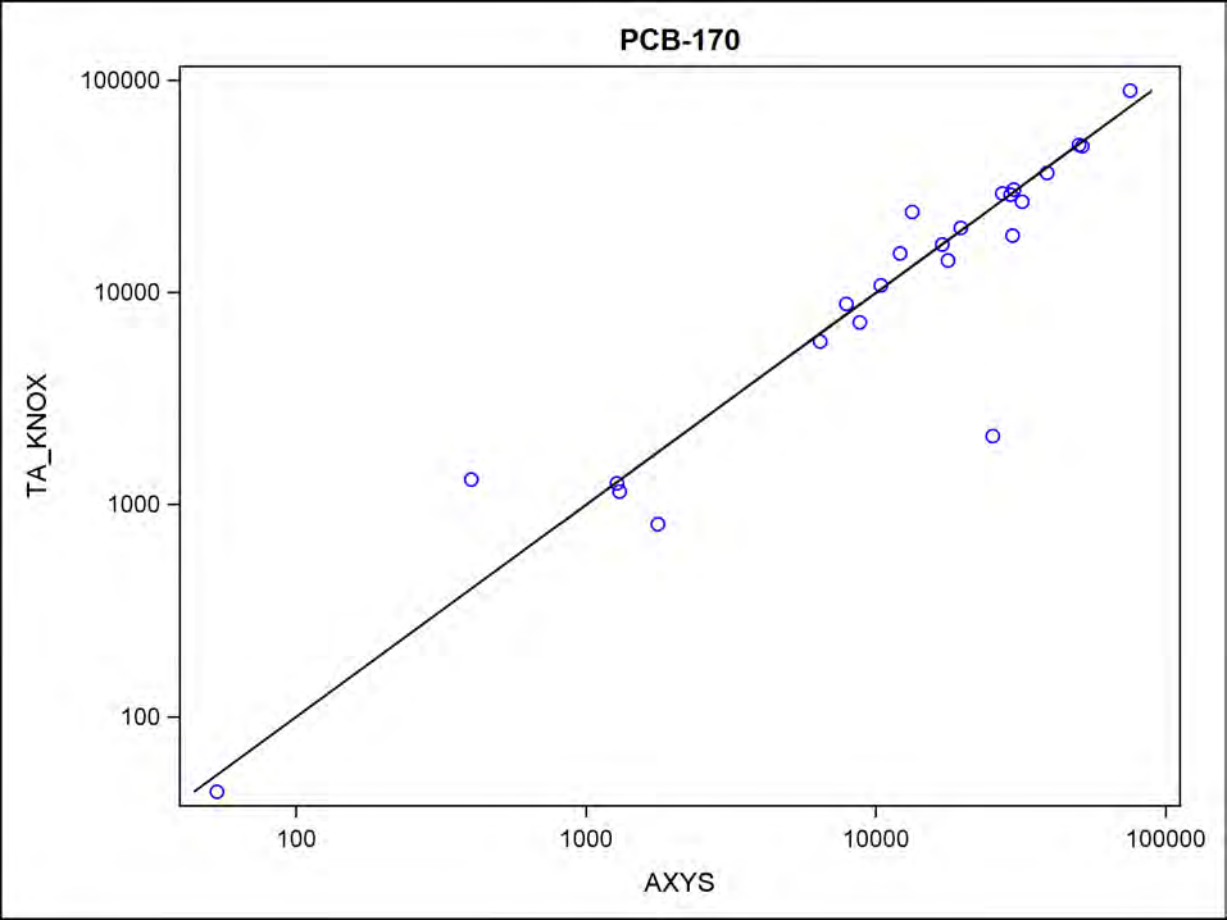

PCB-158
TA_KNOX
AXYS
10
100
1000
10000
10
100
1000
10000

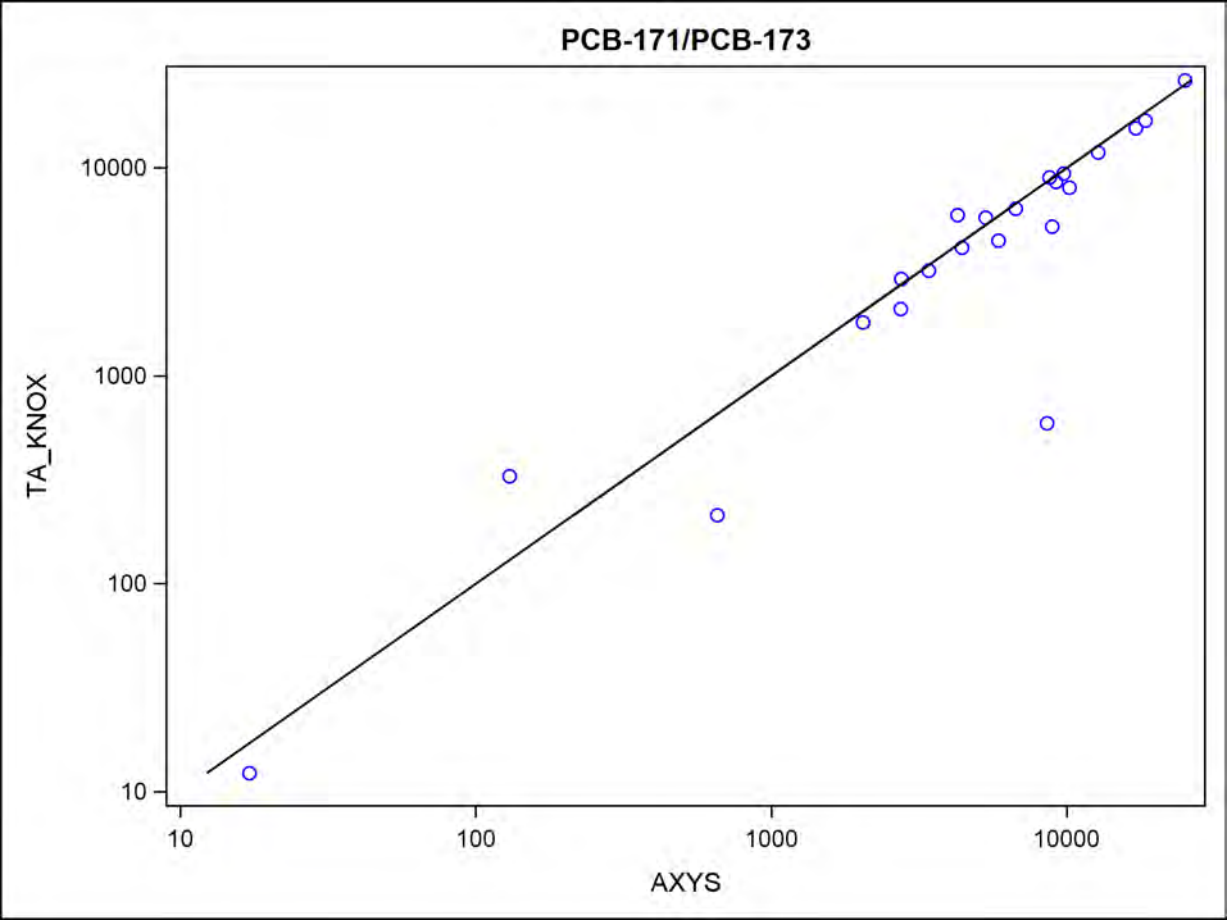

PCB-159
TA_KNOX
1800
1400
1200
1000
800
600
400
200
10
70
500
1000
1500
2500
AXYS

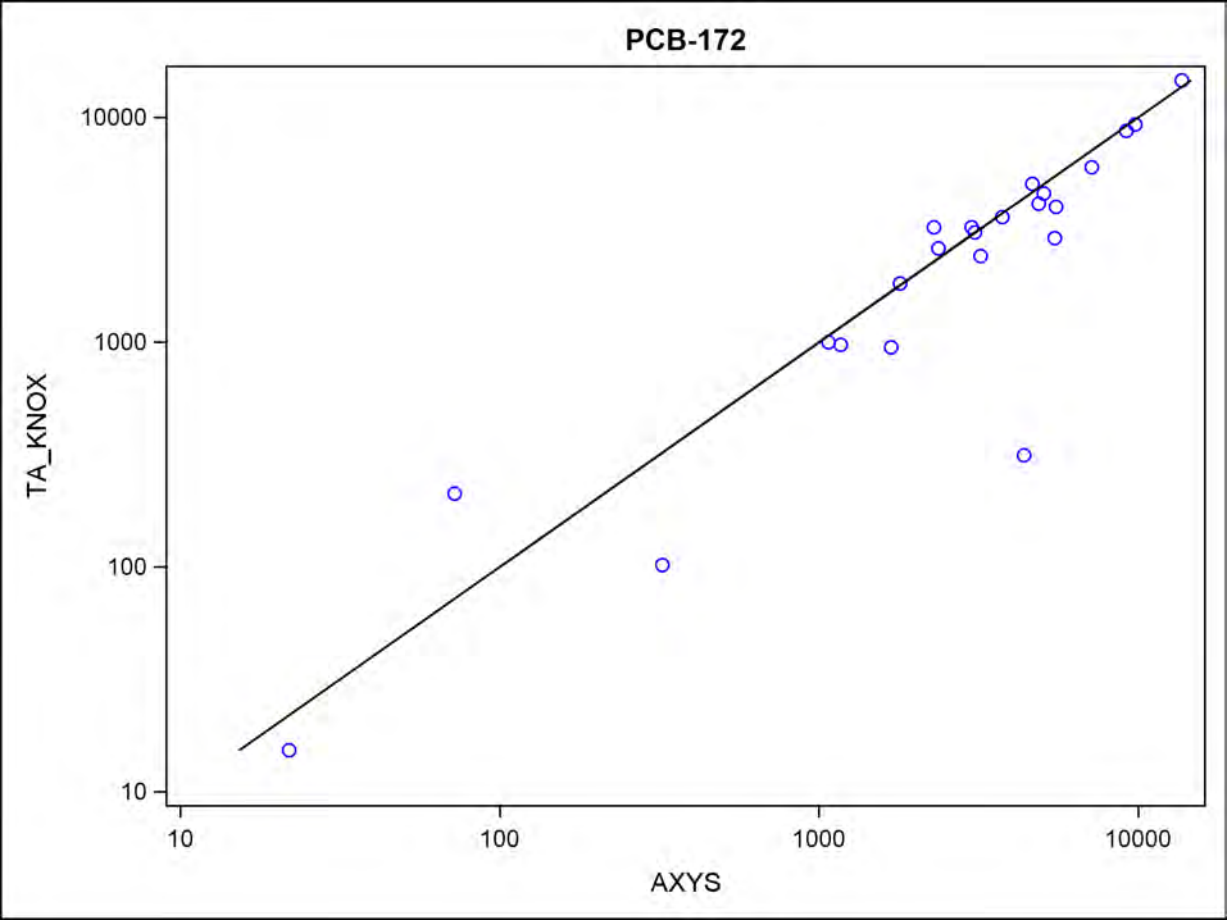

PCB-162
TA_KNOX
1120
980
1000
1020
1040
1060
1080
1100
1120
AXYS

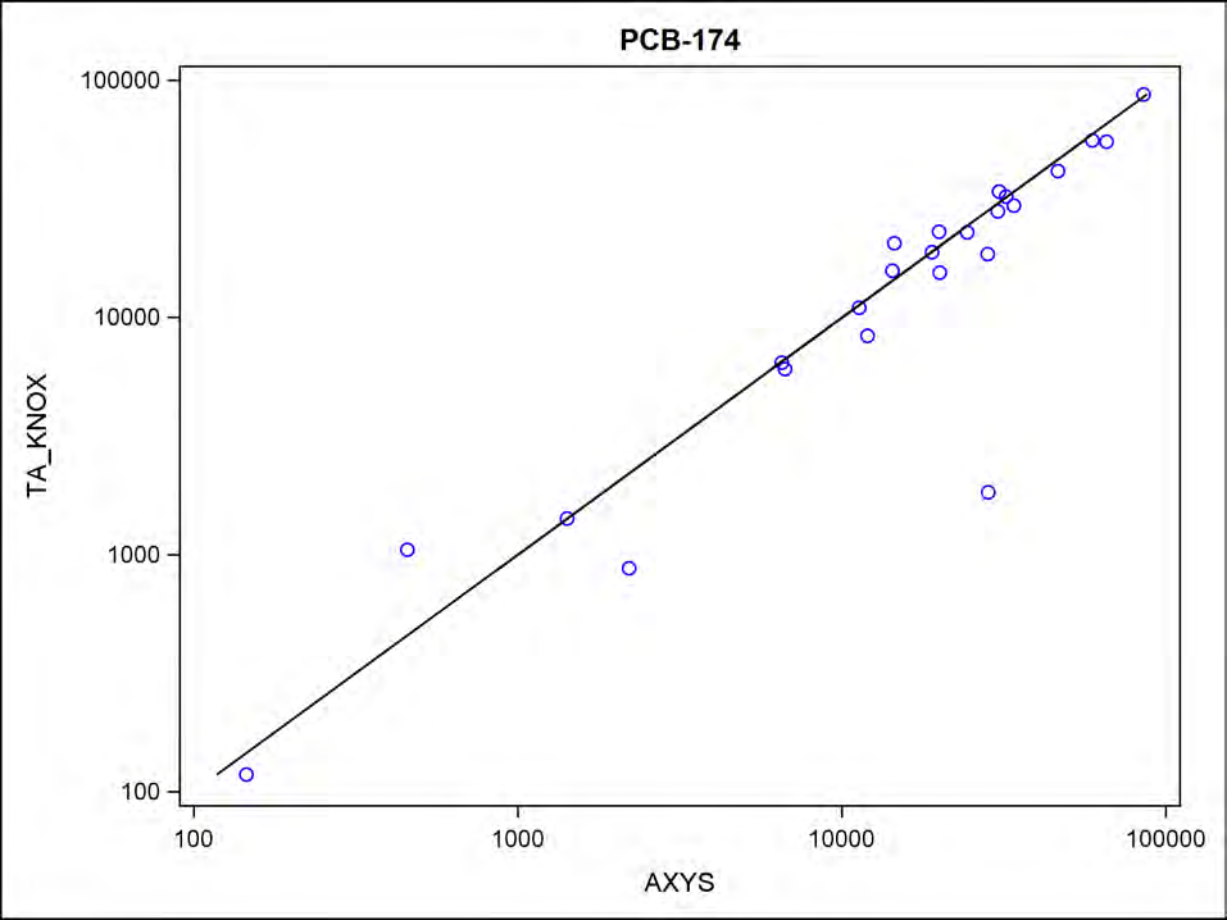

PCB-164
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

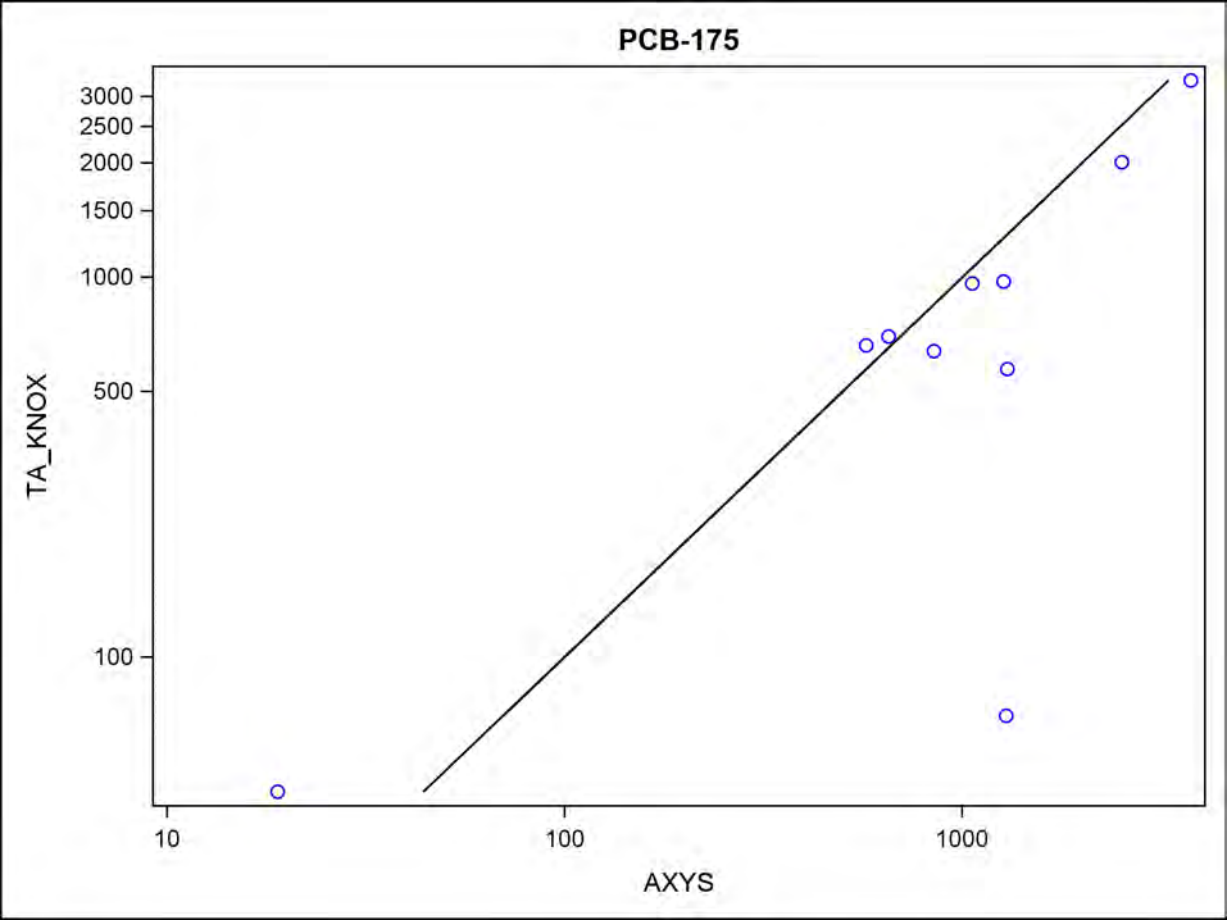

PCB-167
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

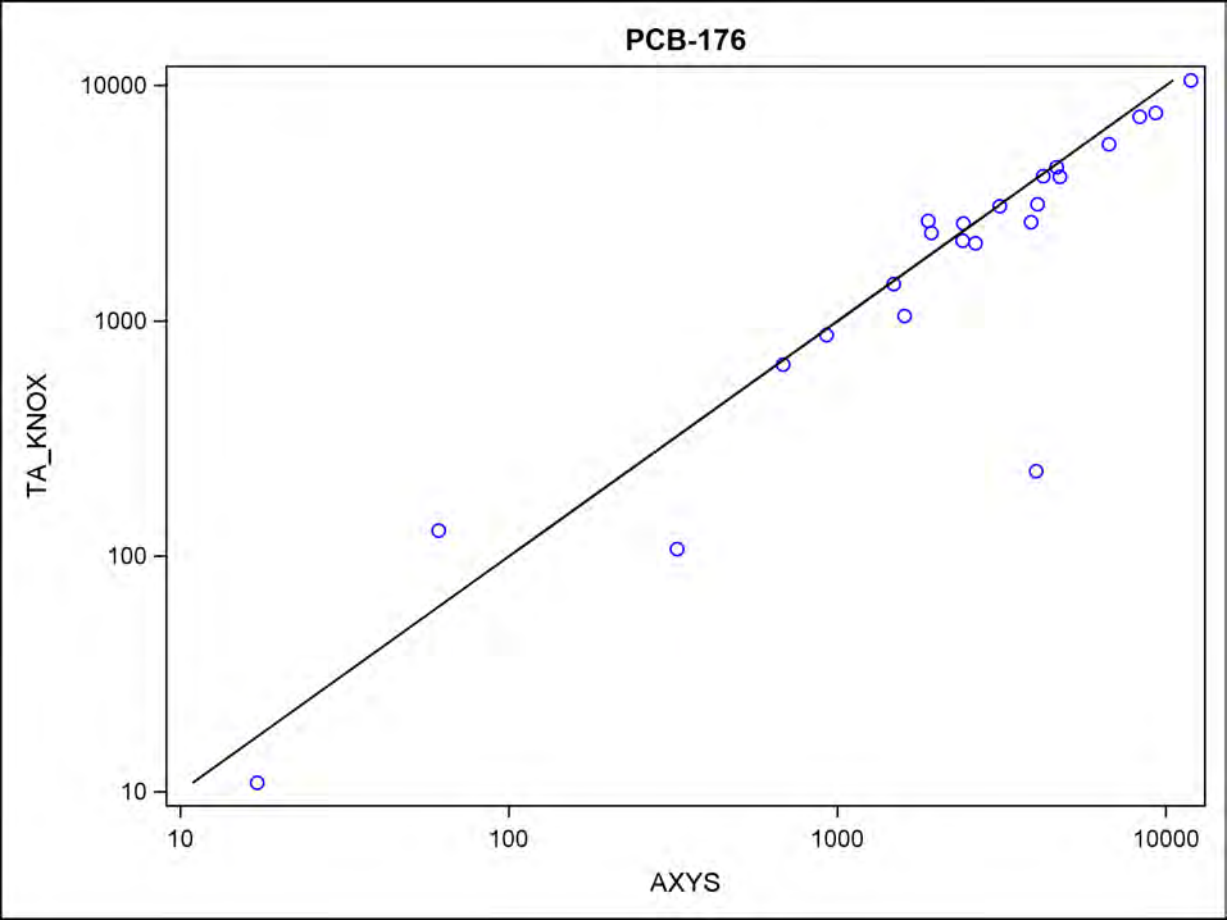

PCB-170
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

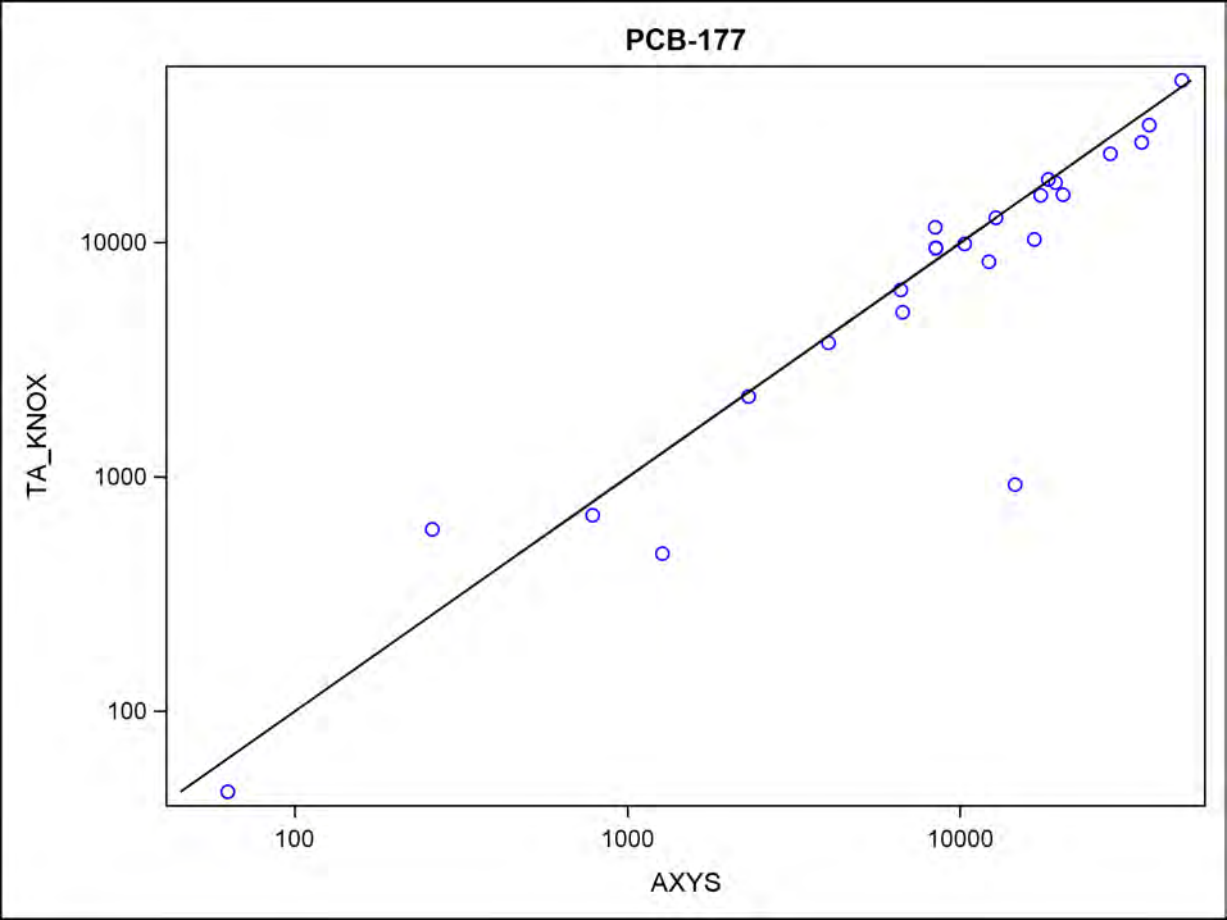

PCB-171/PCB-173
TA_KNOX
AXYS
10
100
1000
10000
10
100
1000
10000

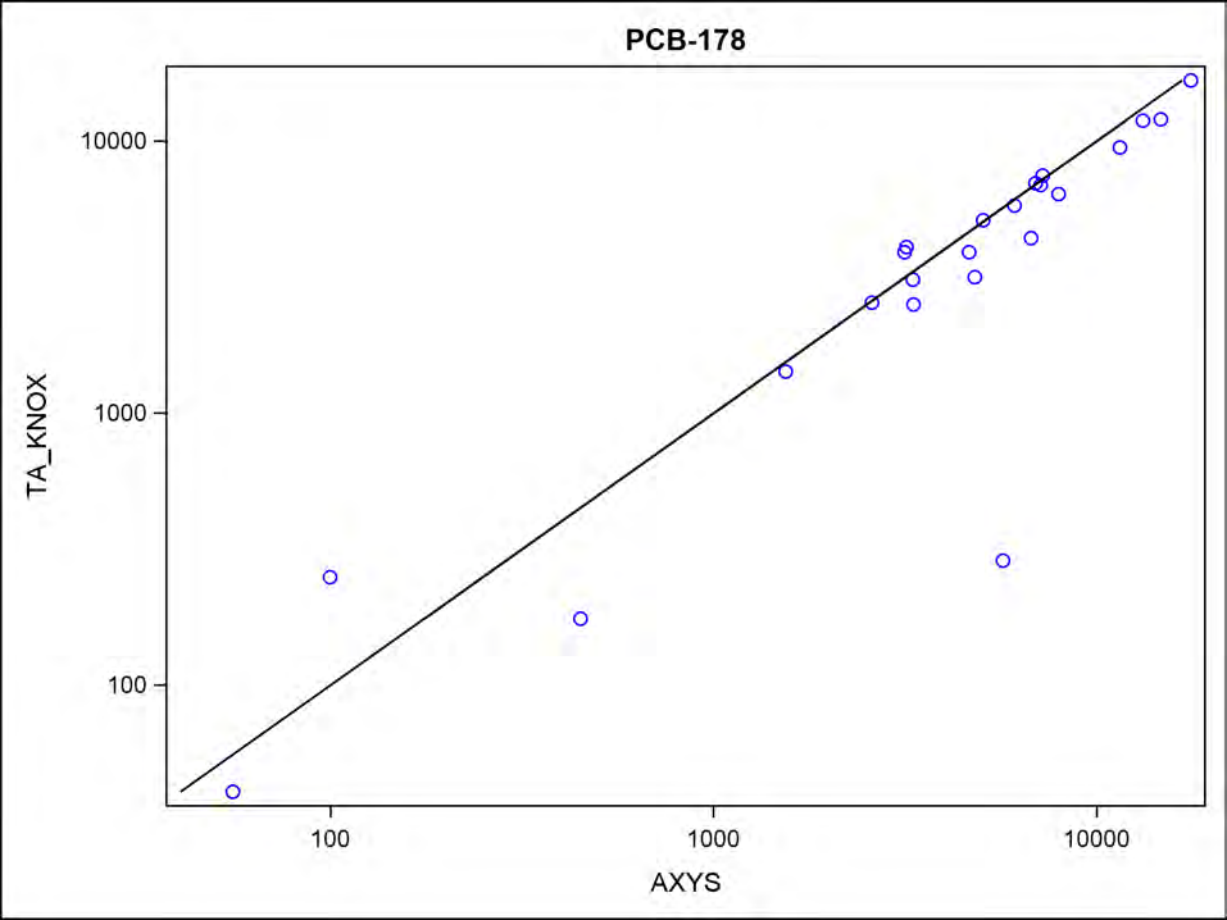

PCB-172
10000
1000
100
10
TA_KNOX
10
100
1000
10000
AXYS

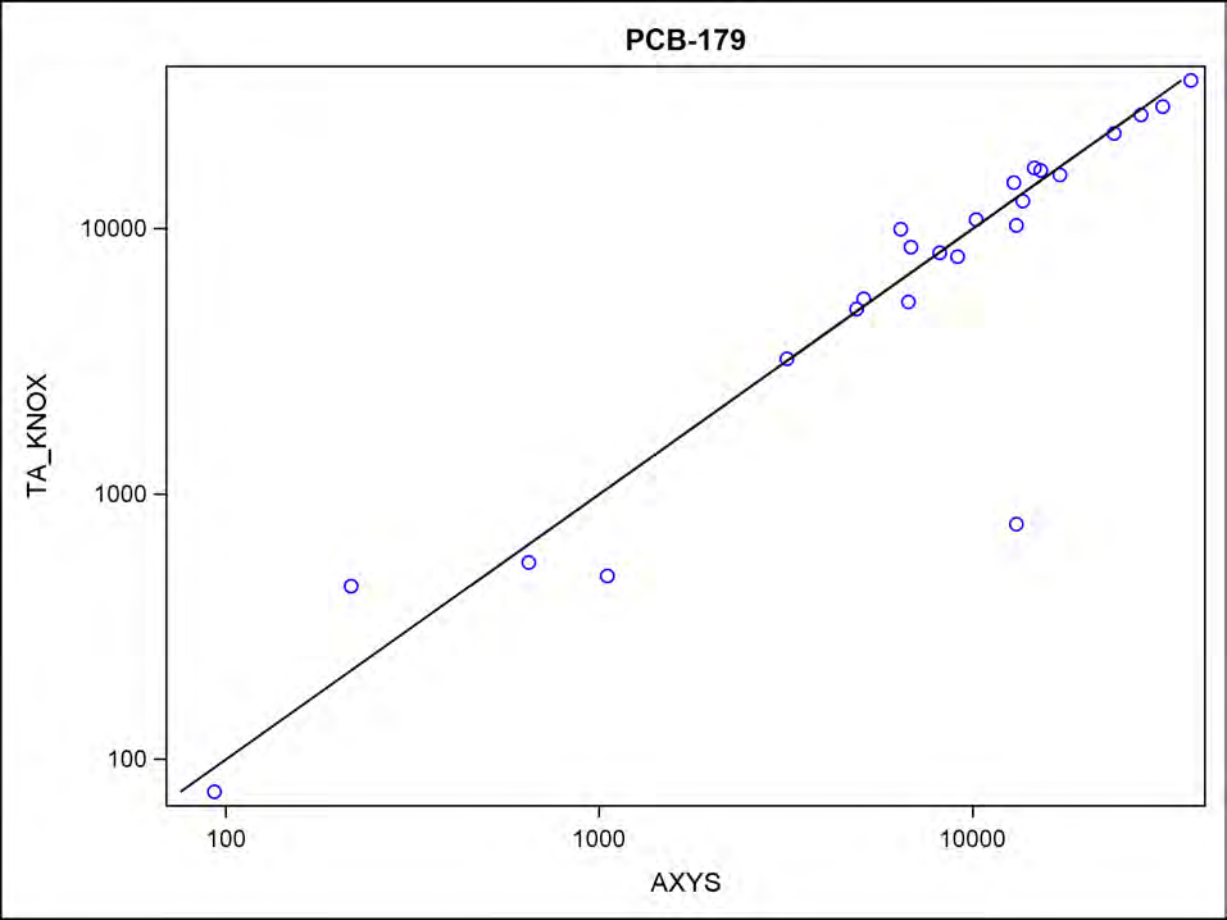

PCB-174
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

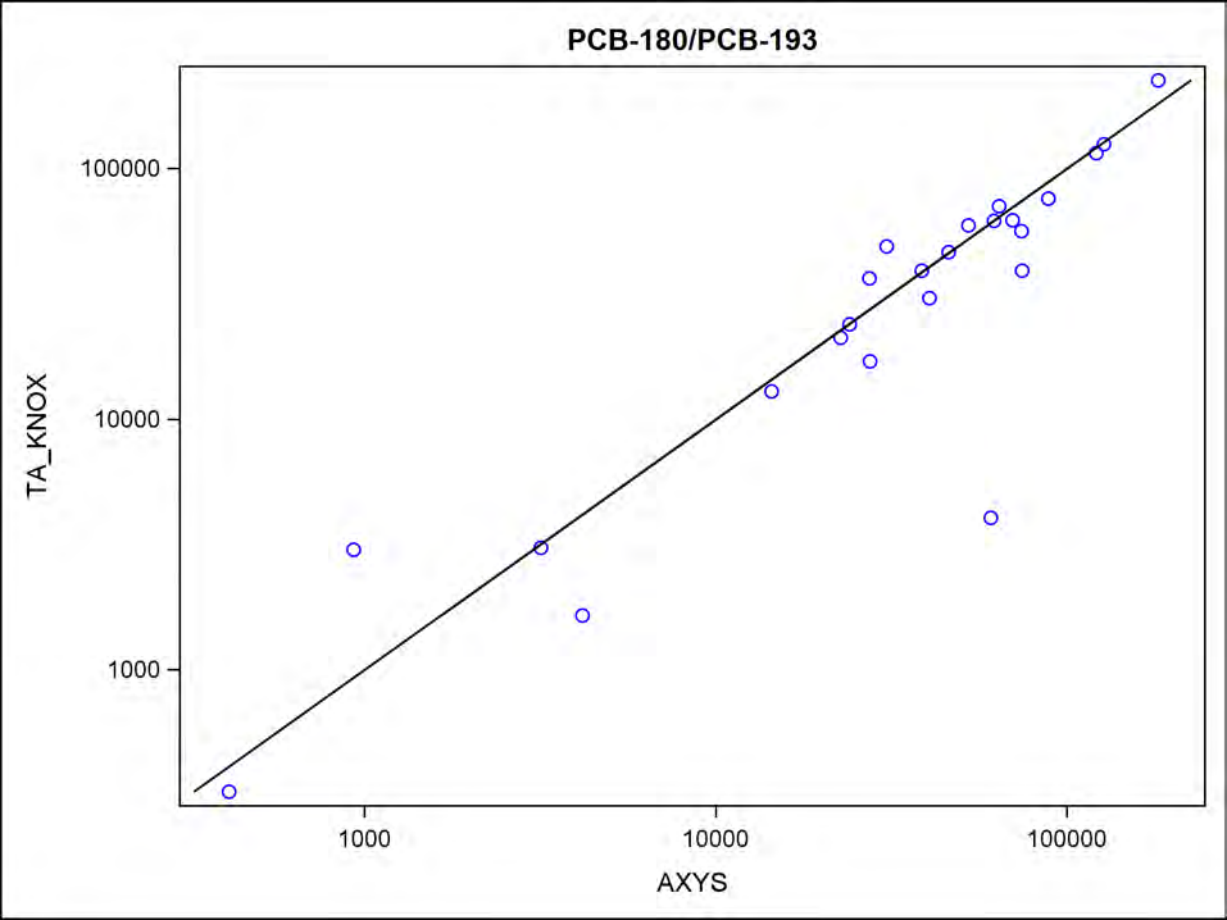

PCB-175
TA_KNOX
3000
2500
2000
1500
1000
500
100
10
100
1000
AXYS

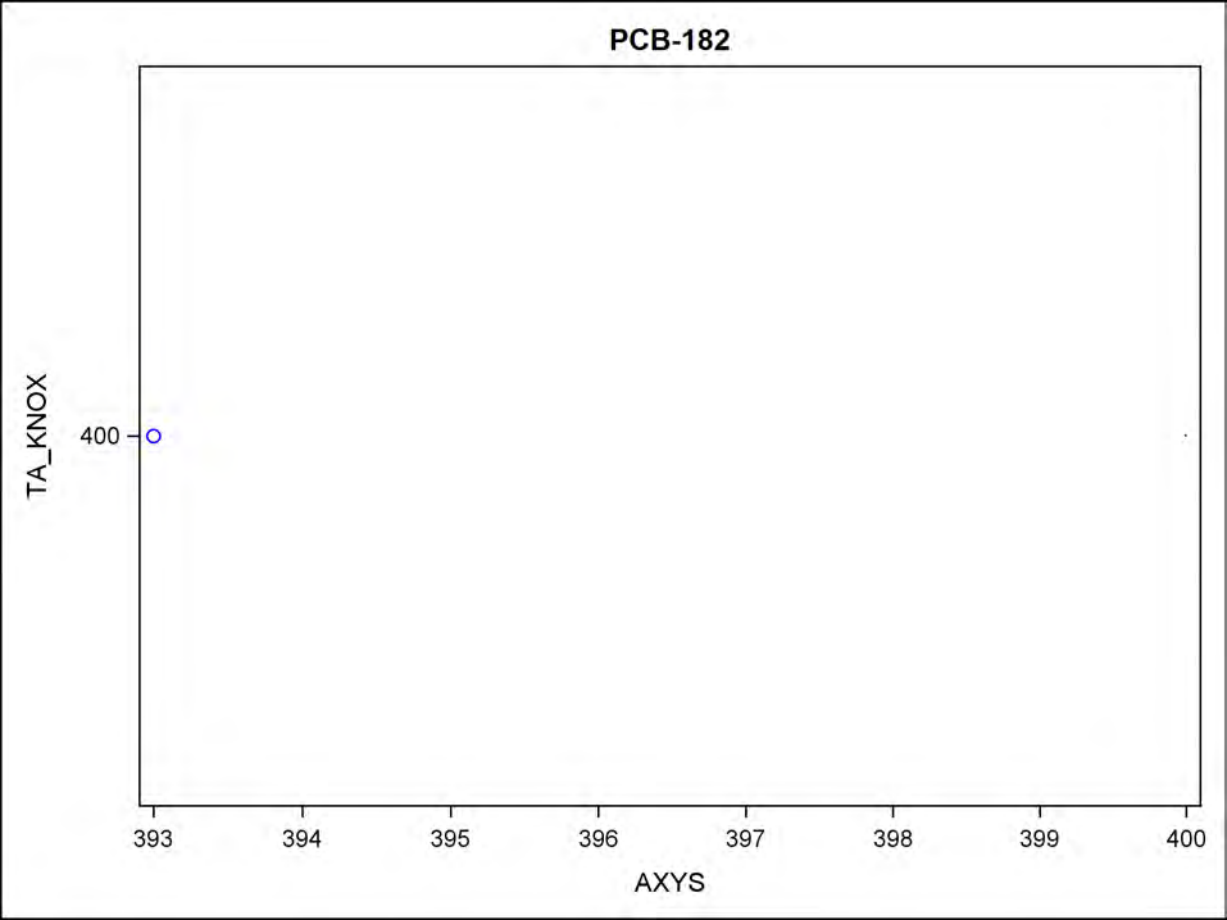

PCB-176
10000
1000
100
10
TA_KNOX
10
100
1000
10000
AXYS

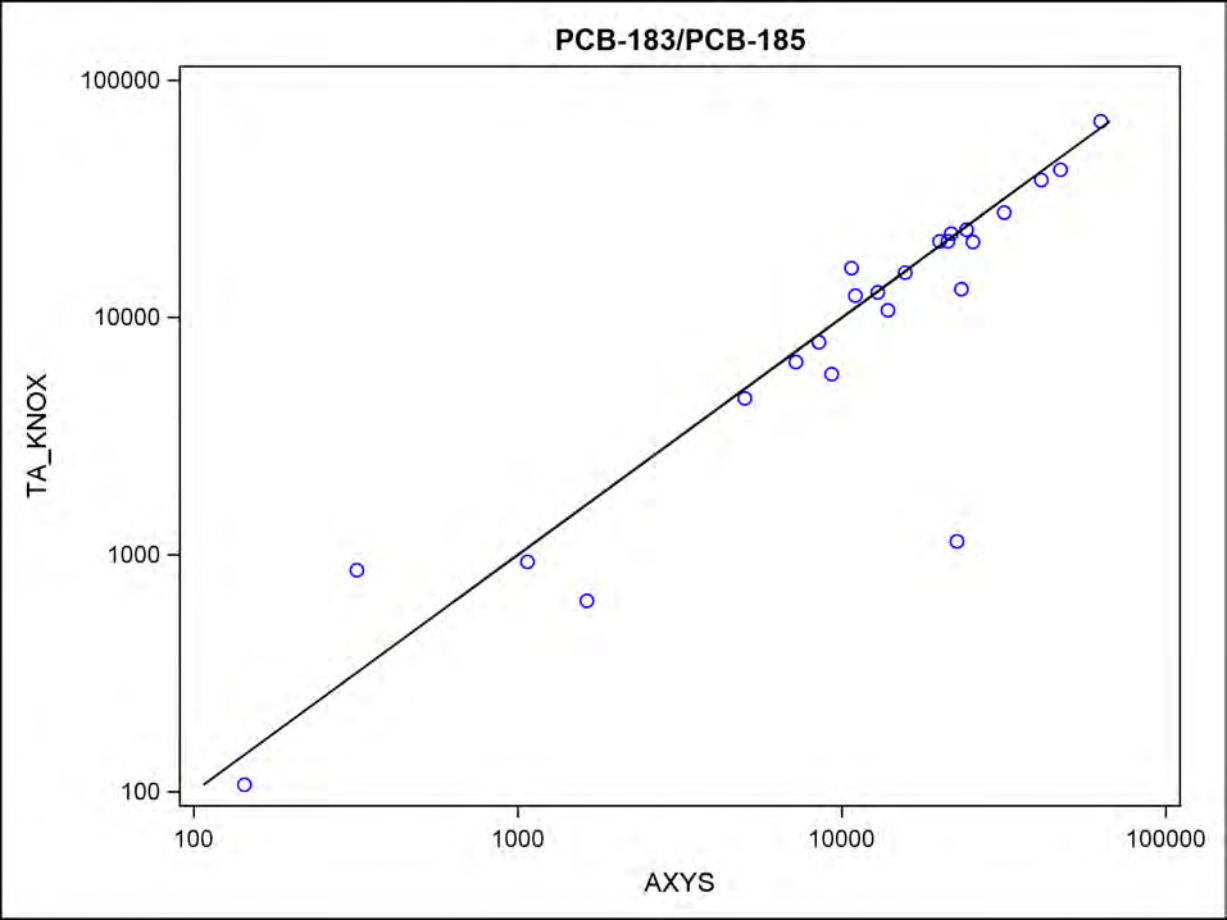

PCB-177
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

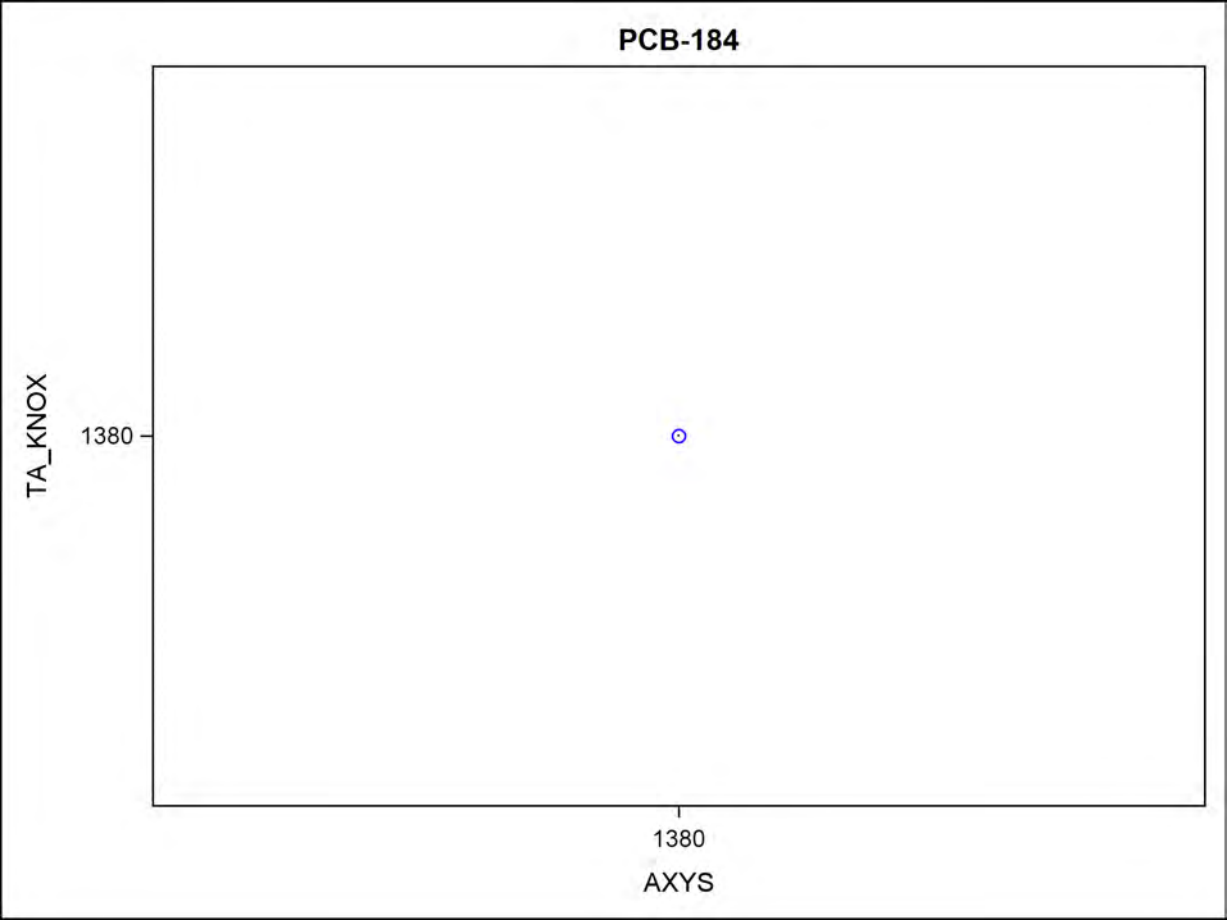

PCB-178
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

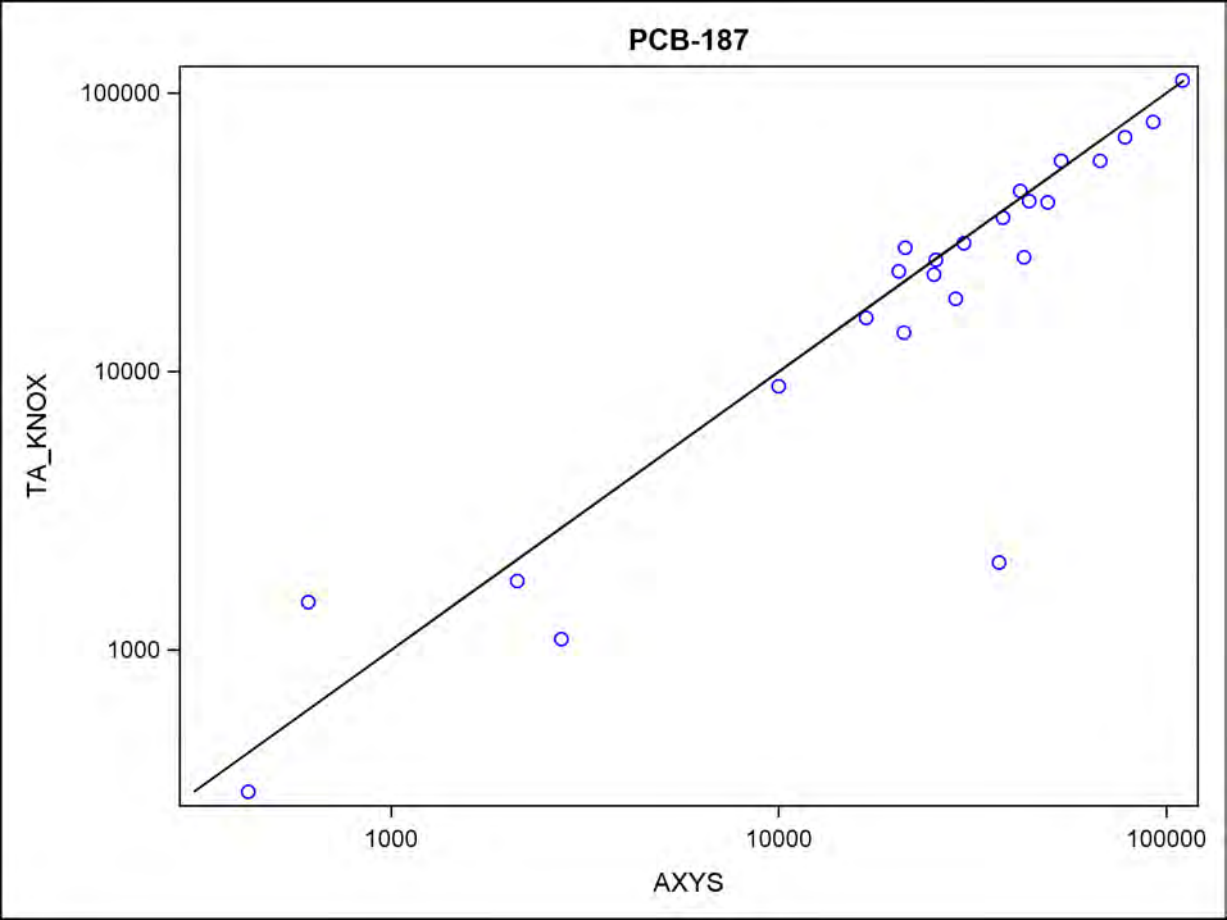

PCB-179
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

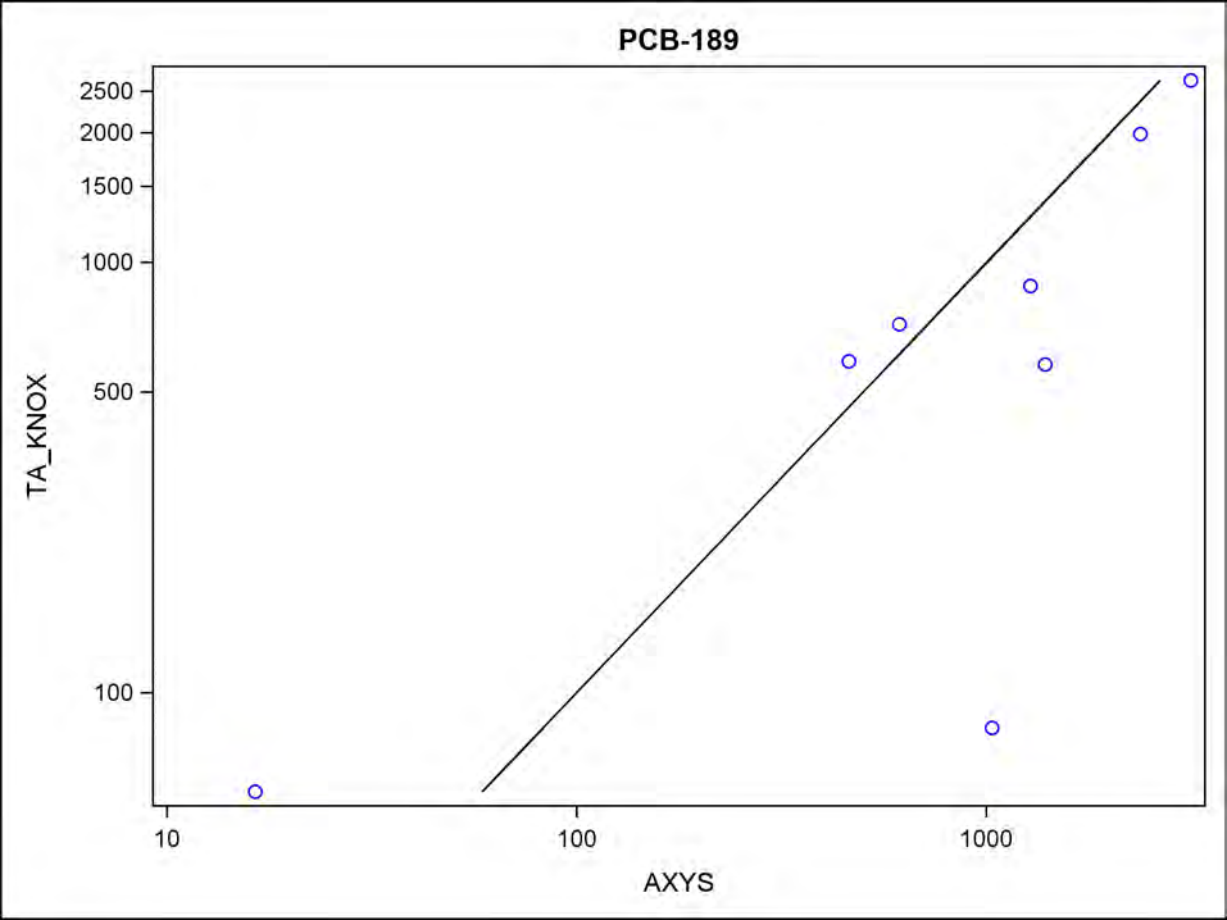

PCB-180/PCB-193
TA_KNOX
100000
10000
1000
1000
10000
100000
AXYS

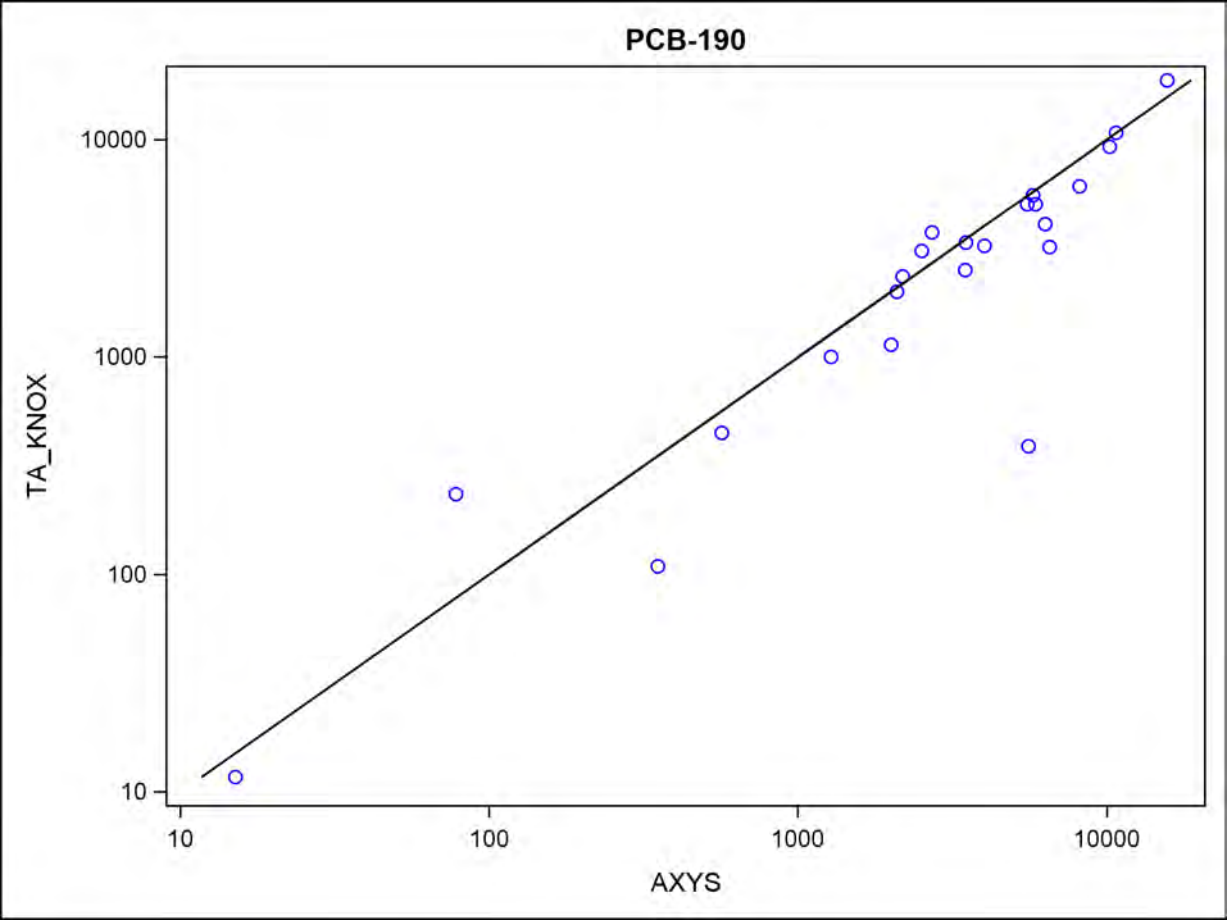

PCB-182
TA_KNOX
400
393
394
395
396
397
398
399
400
AXYS

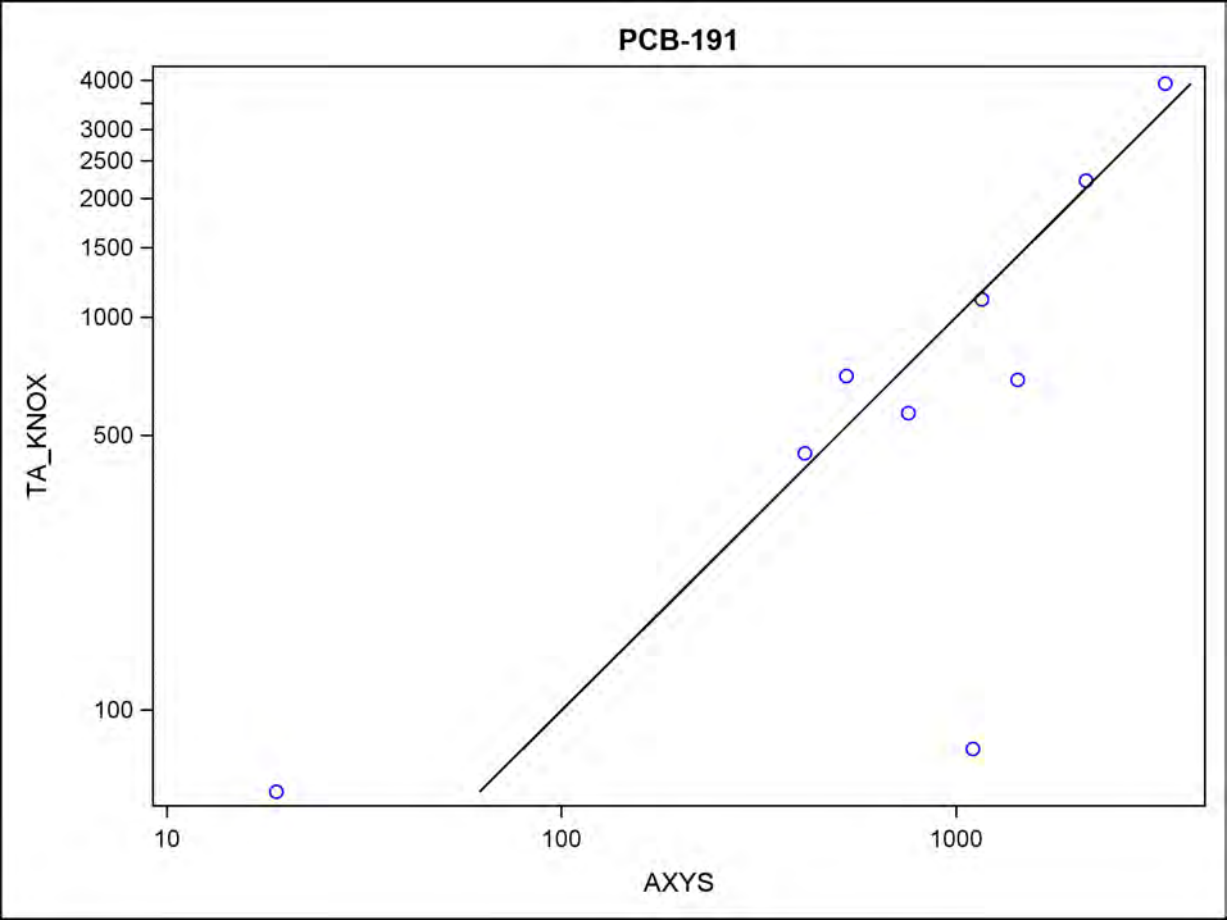

PCB-183/PCB-185
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

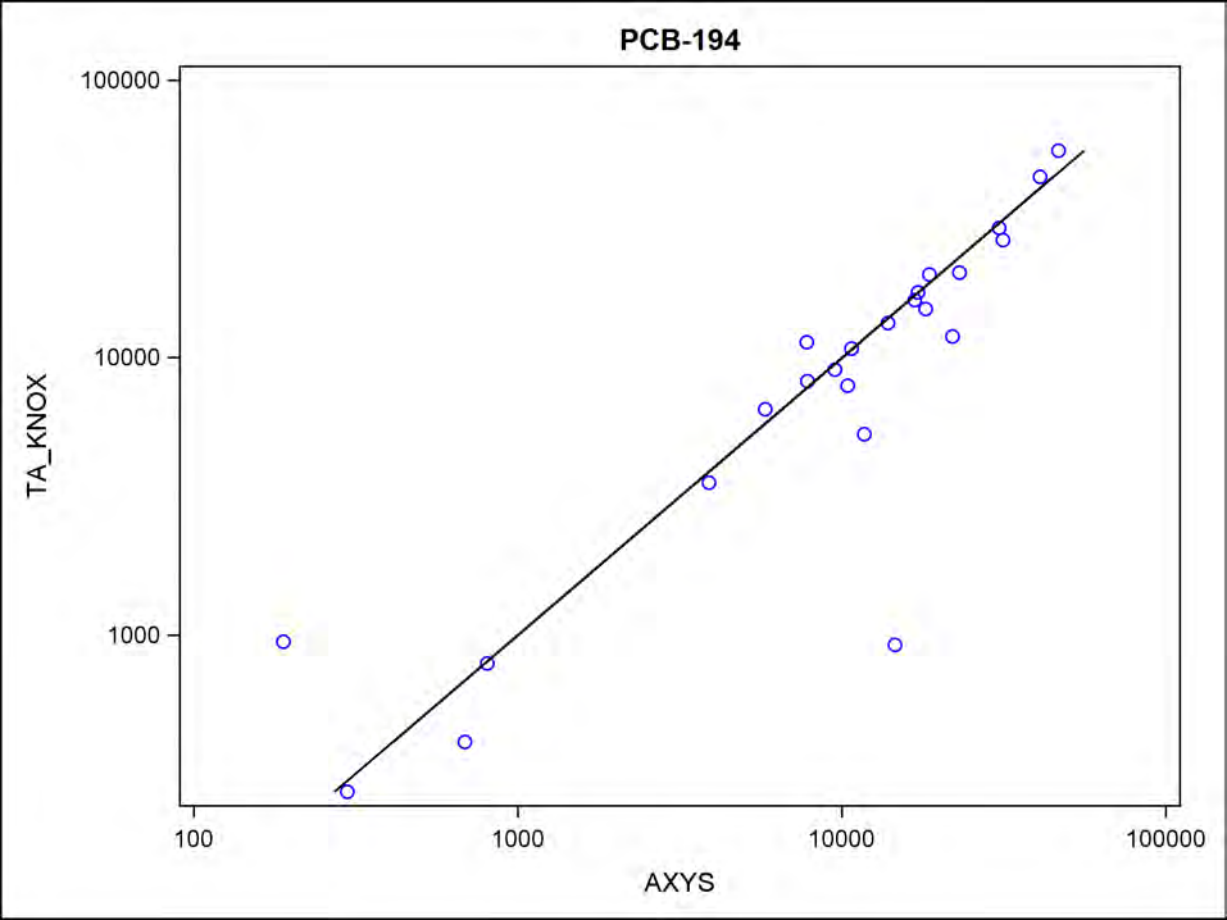

PCB-184
TA_KNOX
1380
1380
AXYS

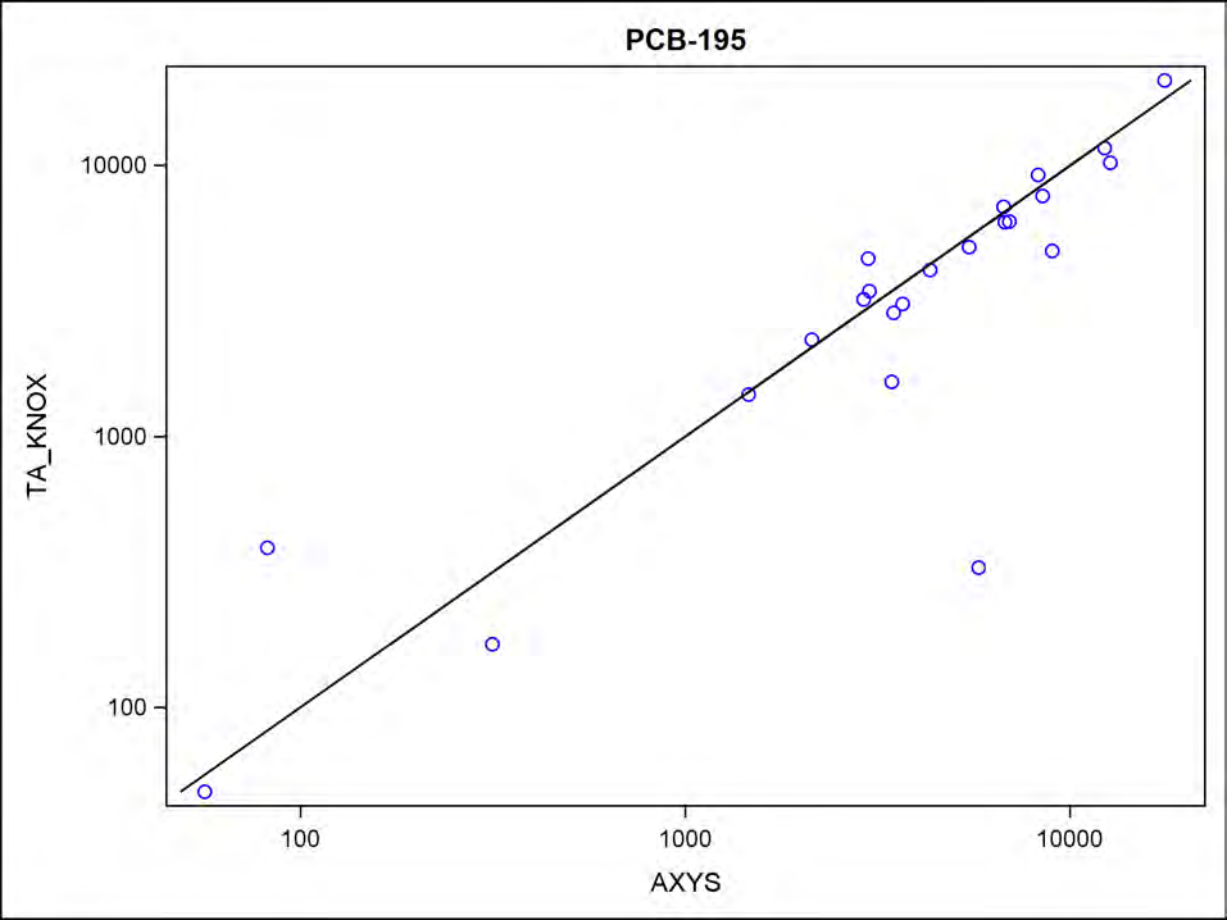

PCB-187
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

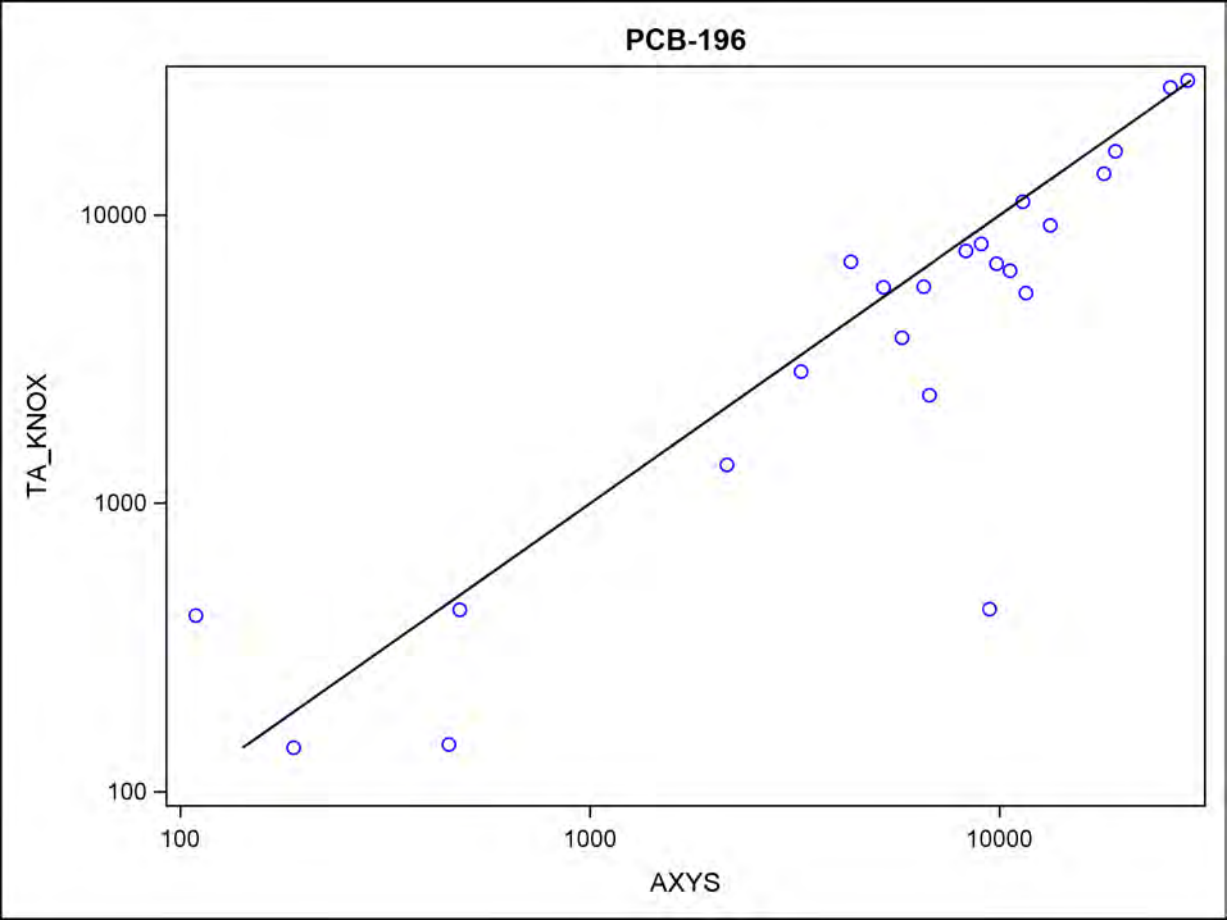

PCB-189
2500
2000
1500
1000
500
100
TA_KNOX
10
100
1000
AXYS

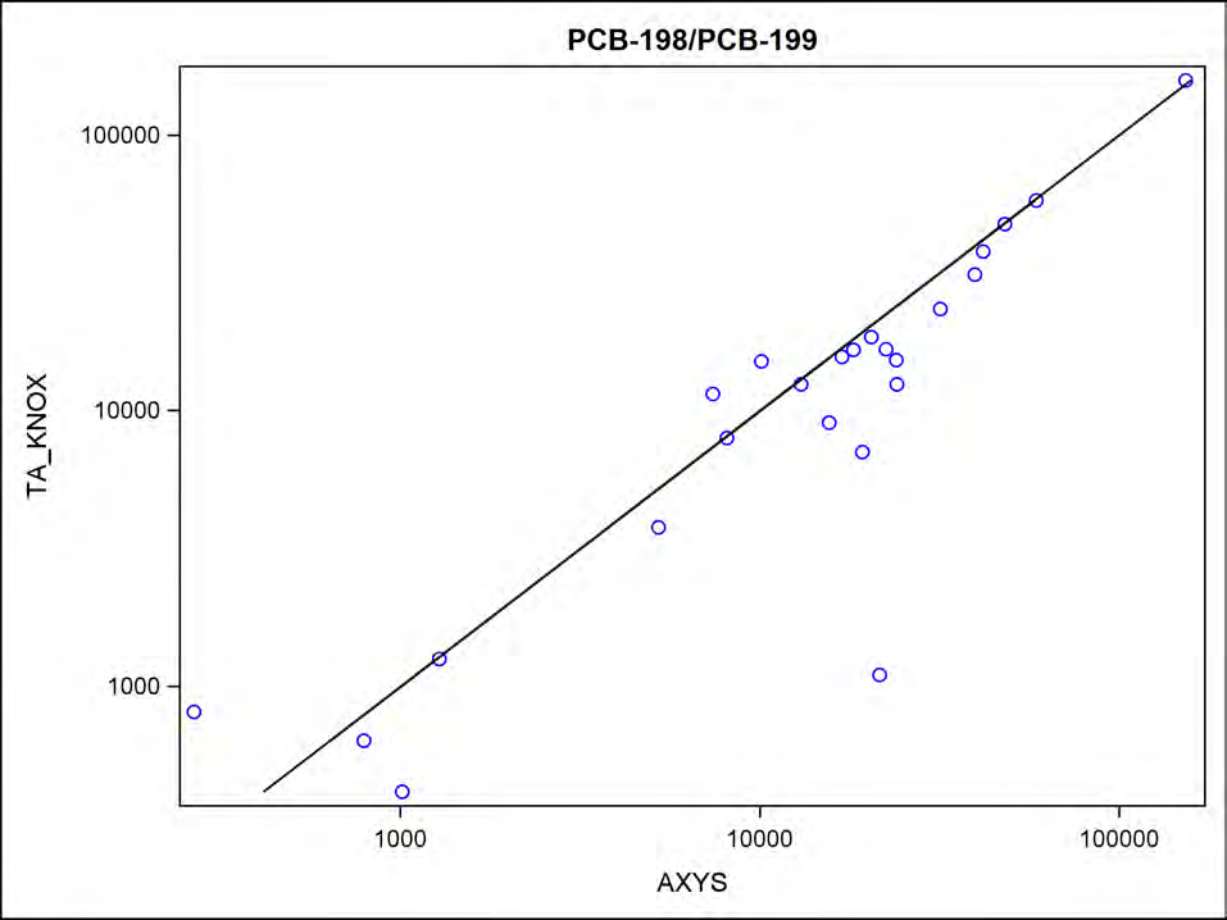

PCB-190
TA_KNOX
AXYS
10
100
1000
10000
10
100
1000
10000

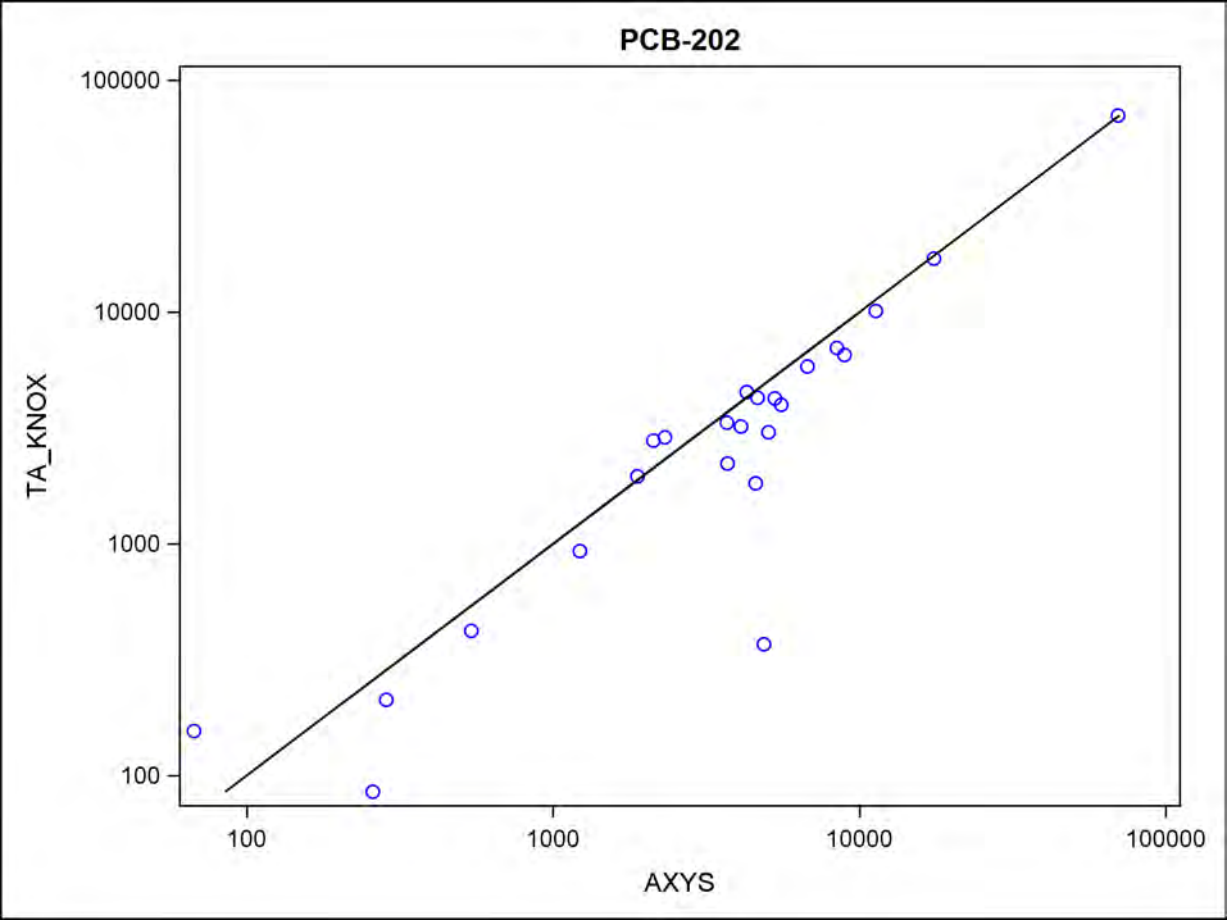

PCB-191
4000
3000
2500
2000
1500
1000
500
100
TA_KNOX
10
100
1000
AXYS

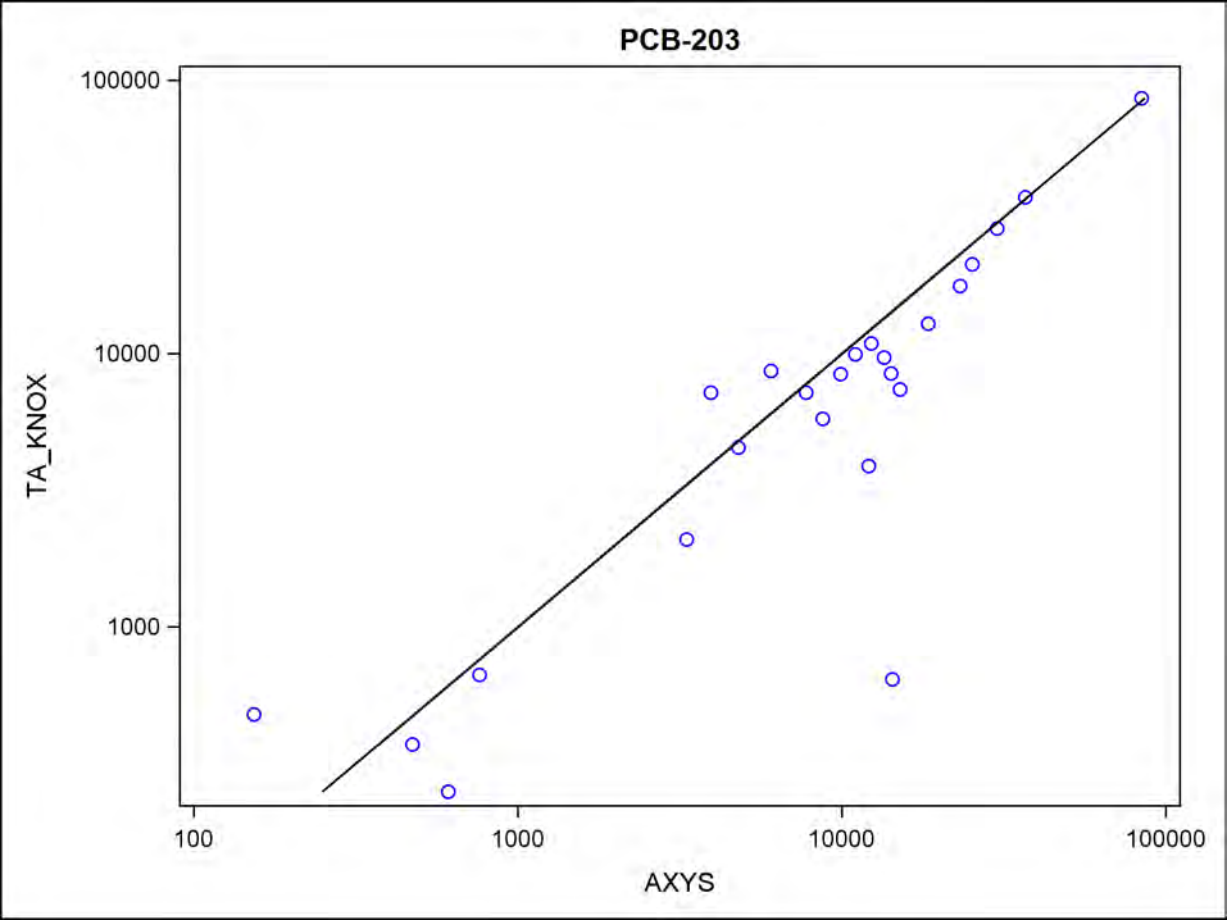

PCB-194
100000
10000
1000
TA_KNOX
100
1000
10000
100000
AXYS

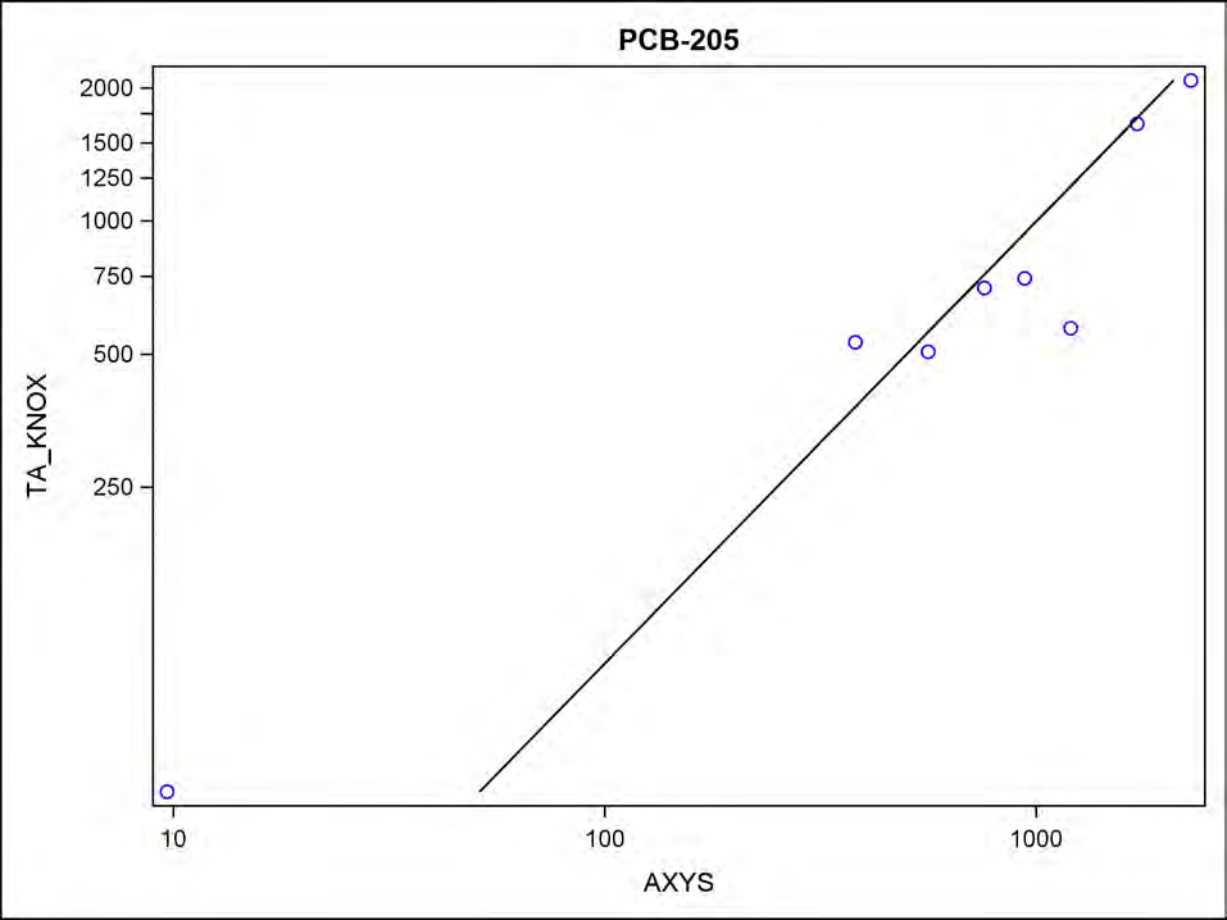

PCB-195
10000
1000
100
TA_KNOX
100
1000
10000
AXYS

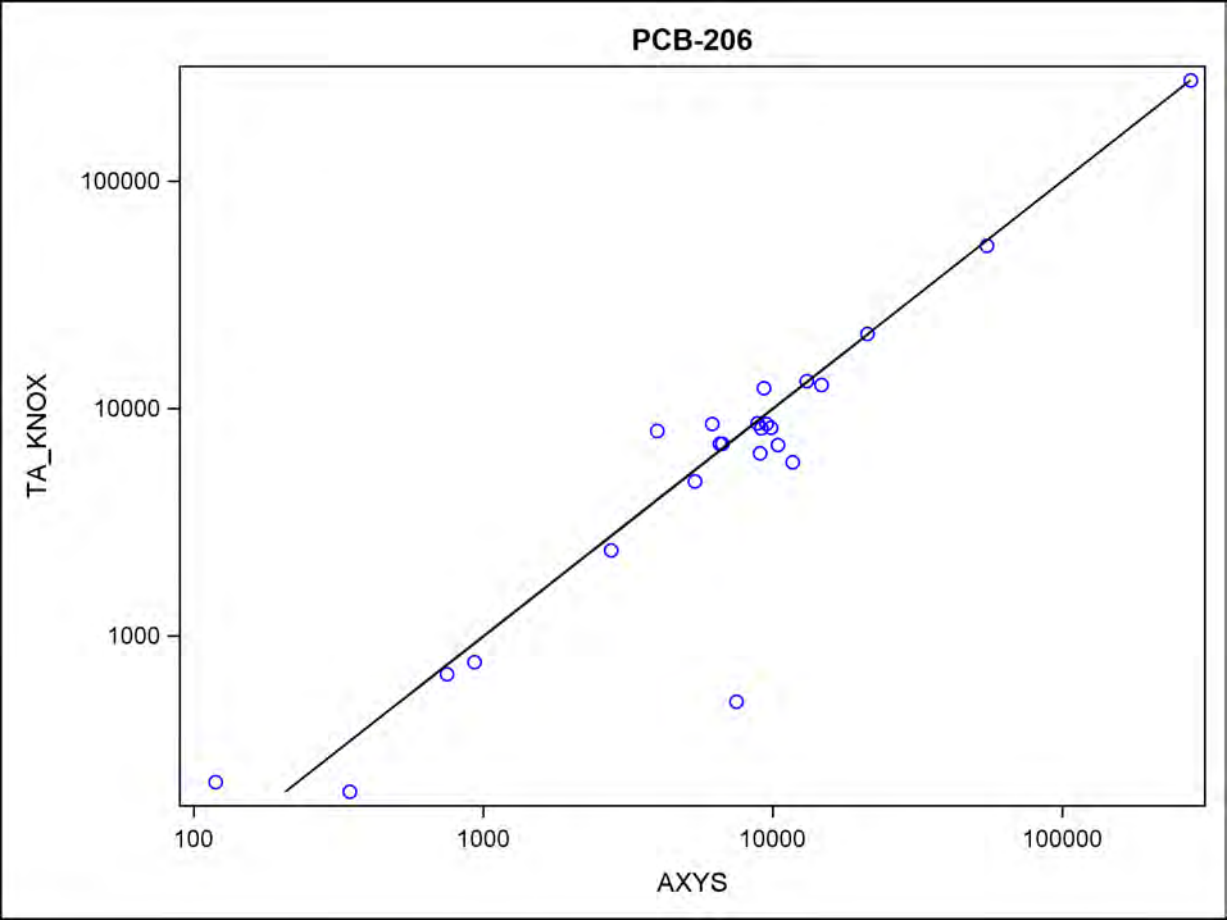

PCB-196
TA_KNOX
AXYS
10000
1000
100
100
1000
10000

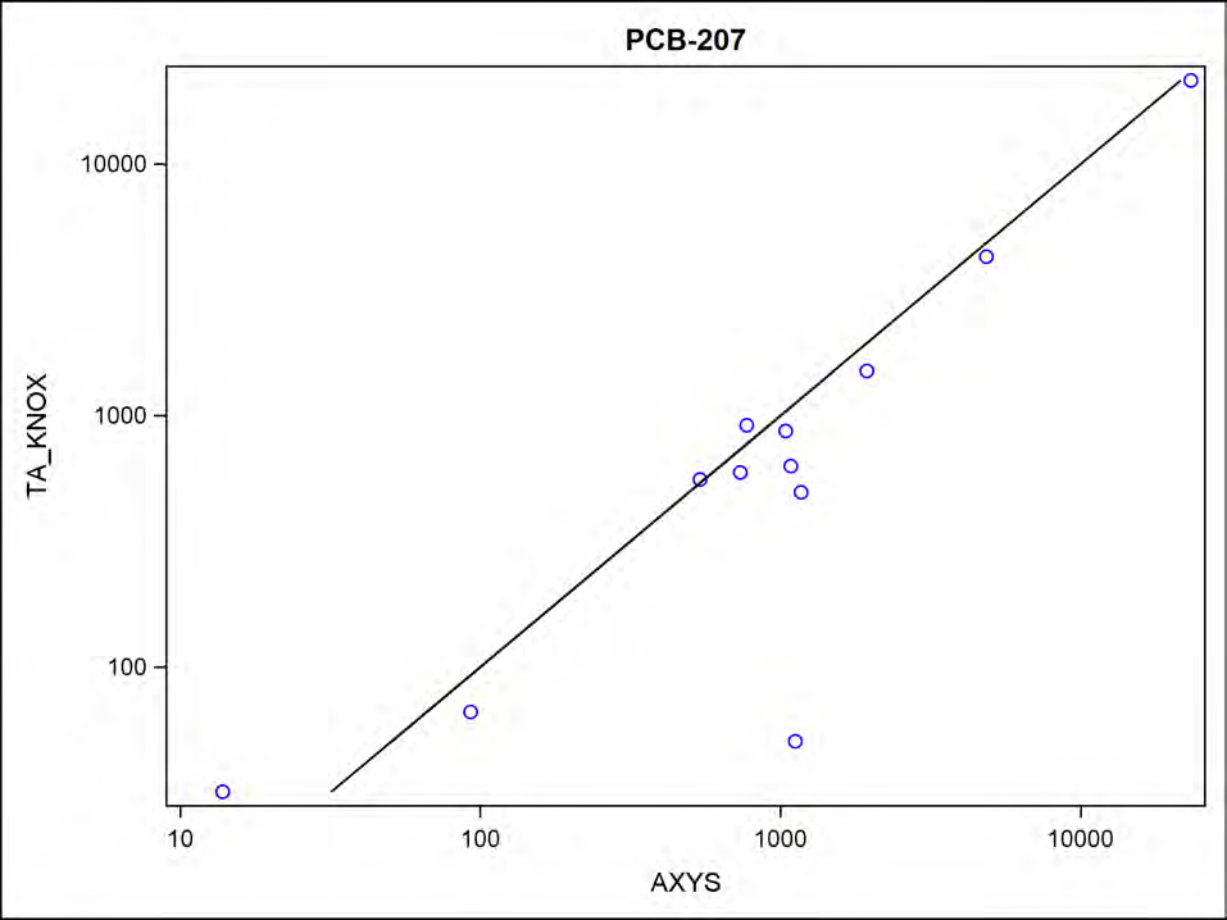

PCB-198/PCB-199
100000
10000
1000
TA_KNOX
1000
10000
100000
AXYS

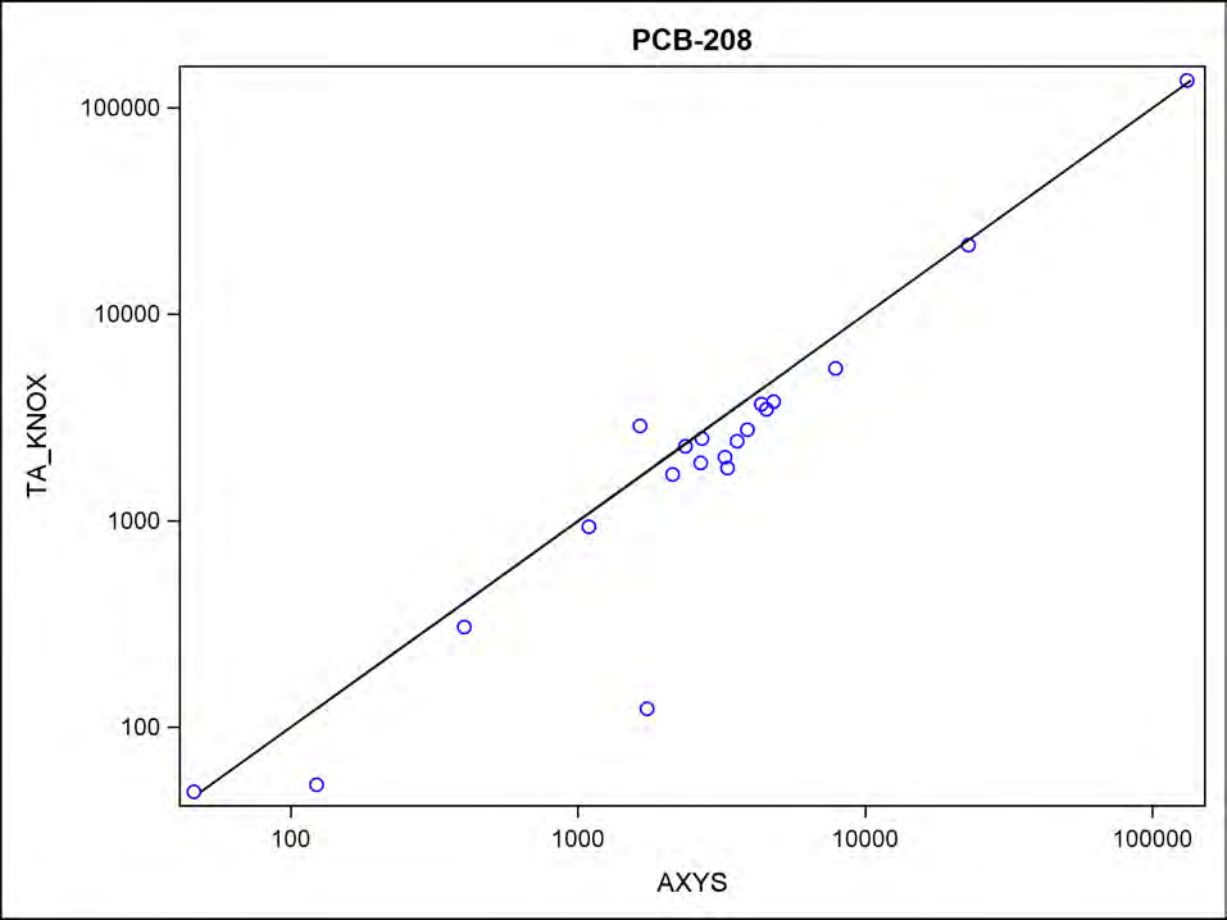

PCB-202
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS


PCB-203
100000
10000
1000
TA_KNOX
100
1000
10000
100000
AXYS


PCB-205
2000
1500
1250
1000
750
500
250
TA_KNOX
10
100
1000
AXYS


PCB-206
TA_KNOX
100000
10000
1000
100
1000
10000
100000
AXYS


PCB-207
TA_KNOX
AXYS
10000
1000
100
10
100
1000
10000


PCB-208
100000
10000
1000
100
TA_KNOX
100
1000
10000
100000
AXYS

ARCADIS

Attachment 4

ARCADIS U.S., Inc.
326 First Street
Suite 200
Annapolis
Maryland 21403
Tel 410 295 1205
Fax 410 295 1225

MEMO

To:
Clifford Firstenberg (Tierra)

Copies:
Alain Hebert (ARCADIS)
Emily Morrison (ARCADIS)
Shannon Dunn (ARCADIS)
Jacqueline Iannuzzi (ARCADIS)

From:
Timothy Iannuzzi
Melissa Beauchemin

Date:
August 14, 2014

ARCADIS Project No.:
B0009968.0000

Subject:
Evaluation of Potential Ecological Risks for the Lower Passaic River Study Area

---

1 Introduction

The Baseline Ecological Risk Assessment (BERA) presented as Appendix D of the Remedial Investigation Report (RIR; Louis Berger Group et al. 2014) for the Focused Feasibility Study (FFS) of the lower eight miles of the Passaic River (FFS Study Area) does not follow the Framework for Ecological Risk Assessment (U.S. Environmental Protection Agency [USEPA] 1992) or comply with Ecological Risk Assessment Guidance for Superfund (USEPA 1997, 1998, 1999) for conducting a BERA. The FFS BERA:

- Uses overly conservative assumptions and simplified data evaluations akin to a screening-level ERA, particularly in addressing potential risks to the benthic community
- Ignores much of the available site-specific information for the Lower Passaic River
- Does not accurately assess ecological conditions (i.e., Problem Formulation) in the FFS Study Area
- Does not provide a reasonable and realistic characterization of exposed organisms in the FFS Study Area, and includes mink as a receptor, despite the fact that neither mink nor mink habitat exist in the Lower Passaic River
- Does not include a thorough assessment of toxicity data and information from the scientific literature for the specific types of organisms present in the FFS Study Area.

Cumulatively, these shortcomings result in an FFS BERA that is flawed, by design, to be overly conservative. In addition, the high degree of uncertainty that results from the FFS BERA prevents any justifiable, scientifically-based risk management decisions from being made for the FFS Study Area.

In this memorandum, ARCADIS provides a focused alternative ERA that:

- Considers baseline habitat conditions and actual ecological exposures in the FFS Study Area through a Problem Formulation
- Evaluates benthic community conditions and risks in the context of the substantial site-specific data and information on chemistry, toxicity and biological communities
- Evaluates potential ecological risks to fish and piscivorous birds from 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and polychlorinated biphenyls (PCBs)[1], two of the chemicals identified as ecological risk-drivers in the FFS BERA.

The results of this alternative ERA indicate that there is no significant ecological risk from the chemicals in the FFS Study Area. This lack of ecological risk precludes the need to develop preliminary remediation goals (PRGs) for these chemicals, and this alternative ERA concludes that remediation of the lower eight miles of the Passaic River for ecological risk in isolation of the remedy to be selected through the larger RI/FS process for the entire 17-mile Lower Passaic River Study Area (LPRSA) is unnecessary.

2 Problem Formulation

The Problem Formulation sets the stage and ecological setting for the ERA. It provides documented evidence of the existence of ecological habitat (or lack thereof) in the FFS study area and describes the organisms that utilize the habitat(s). Specifically, it establishes the breadth and focus of the ERA, as well as assessment endpoints (USEPA 1997). An ecological conceptual site model (CSM) is developed based on the identified exposure pathways and ecological receptors present.

This section briefly discusses the results of bird, incidental mammal, and other wildlife surveys from more than 20 years of data and information on the Passaic River (e.g., Iannuzzi et al. 1996, Wolfskill and McNutt 1998; Iannuzzi and Ludwig 2000, Wallin et al. 2002, Iannuzzi et al. 2002, Iannuzzi and Ludwig 2004 and 2005, Ludwig and Iannuzzi 2005, Ludwig et al. 2010, and various reports prepared on behalf of the Cooperating Parties Group [CPG]). Substantive historical data and information exist from these studies (and others) which are used to provide an accurate and detailed characterization of the ecological setting of the

[1] Dioxin is evaluated as 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), the most toxic congener. Total PCBs are based on the sum of 209 individual PCB congeners.

FFS Study Area and overall ecological CSM that provides the basis for selecting appropriate site-specific receptors for evaluation in the ERA.

More than 150 years of urbanization and industrialization in the FFS Study Area have left little in the way of habitat for either aquatic or semi-aquatic organisms in the Lower Passaic River (Iannuzzi et al. 2002, 2004). By the mid-20th century, much of the habitat in the river was substantially degraded by dredging, sewage input, industrial pollution, and/or urban infrastructure (Ludwig and Iannuzzi 2005). Currently, the shoreline of the FFS Study Area is highly industrialized and much of the historical natural shoreline has been modified substantially. Iannuzzi et al. (2002) describes the documented loss of natural shorelines and wetlands along the lower Passaic River throughout the 20th century. Currently, less than 10% of the riverbanks in the lower eight miles of the river support any kind of natural features (wetlands or vegetative communities); the vast majority is occupied by bulkhead or riprap. Even the remaining vegetated areas are highly disturbed, remnant habitat consisting of the invasive common reed (*Phragmites australis*) and weedy plants typical of unmanaged, urban open spaces (Ludwig and Iannuzzi 2005). Mixed tree and scrub-shrub communities lay at higher elevations in some areas, consisting primarily of opportunistic species that colonize disturbed areas such as tree of heaven (*Ailanthus altissima*), mugworts (*Artemisia spp.*), and goldenrods (*Solidago spp.*).

What remains of the shoreline is a patchy network of bulkhead, riprap, and degraded intertidal mudflats. In fact, the majority of the shoreline consists of bulkhead and riprap, which are used to stabilize the shoreline and protect the industrial and urban properties that line the riverbanks. While riprap can provide refuge and attachment substrates for some organisms, its habitat quality is considered minimal. Bulkheads, which are typically built using either metal sheet piling or pressure-treated wood, provide no habitat value and often inhibit ecological colonization of the surrounding substrate. Shading impacts of shoreline structures on aquatic flora and fauna are increasingly being recognized in aquatic resource assessments. Recent research has documented fewer species, lower abundances, and fewer feeding opportunities beneath large over-water structures compared to open water, pile fields, or edge habitat (Able and Duffy-Anderson 2006).The large extent of bulkhead and riprap shoreline is a substantial limitation to the ecology of the area and signifies the continuing commitment of the river as an industrial waterway.

2.1 Aquatic Life

Aquatic life in the FFS Study Area consists of limited species of primarily pollutant-tolerant benthic infauna such as oligachates and polychaetes and various species of fish. Blue crabs (*Callinectes sapidus*) dominate the shellfish species in the estuarine zone (RM 0 to RM 10). In a recent fisheries survey conducted by Windward Environmental, LLC (Windward 2011a), the catch in the FFS study area was dominated by white perch (*Morone americana*), American eel (*Anguilla rostrata*), Atlantic menhaden (*Brevoortia tyrannus*), and white catfish (*Ameiurus catus*). Mummichog (*Fundulus heteroclitus*) dominated the forage fish catch. Data from a 1999 survey indicate similar species, with the catch dominated by mummichog, inland silverside (*Menidia beryllina*) and white perch (Iannuzzi and Ludwig 2004).

2.2 Wildlife

Birds are the predominant wildlife that utilize the Lower Passaic River. The lack of shoreline and wetland habitats along the river prevent substantial use of the river by other types of wildlife.

Waterbird species that utilize the Passaic River and Newark Bay region may be broadly categorized as waterfowl (ducks and geese), wading birds (herons and egrets), shorebirds (sandpipers, plovers, oystercatchers), seabirds (gulls, terns, cormorants), birds of prey (osprey), and terrestrial birds. Most of the water bird species found in the New York/New Jersey (NY/NJ) Harbor Estuary are migratory. The estuary is part of the Atlantic Flyway, a major north-south migration route (Elphick et al. 2001). Migrant species use the open waters and wetlands as seasonal stopovers, feeding and resting for a few days to a few weeks en route to northern breeding grounds or southern wintering areas.

On behalf of Tierra Solutions, Inc. (Tierra), ARCADIS conducted a site-specific characterization of bird occurrences in the lower Passaic River during a year-long bird survey from 1999-2000, as documented by Ludwig et al. (2010). The bird survey was designed and conducted to account for key environmental parameters that determine bird use of estuarine ecosystems, including time of day (Bibby et al. 1992), tidal stage (Hess et al. 2000), and the distribution of habitats (Burger 1984, Hancock and Kushlan 1984). A total of 49 different bird species were observed from three general areas of the river. The majority of birds that were observed included common terrestrial birds such as sparrows, pigeons, crows, and hawks; waterfowl such as ducks and geese; wading birds such as herons and egrets; and diving birds such as gulls and cormorants. The number of species observed is small compared to other areas of the NY/NJ Harbor Estuary, which showed a higher diversity and abundance of species (Ludwig et al. 2010).

The CPG conducted an avian study over four seasons from 2010 to 2011, the results of which are presented by Windward (2011b, 2012a). A total of 157 species and approximately 29,000 individuals of aquatic and semi-aquatic birds were observed and identified during the four seasonal avian community surveys conducted in summer and fall 2010 and winter and spring 2011 (Windward 2012a). Mallard (*Anas platyrhynchos*), Canada goose (*Branta canadensis*), and ring-billed gull (*Larus delawarensis*) were the dominant aquatic and semi-aquatic species during all four seasonal surveys. Herring gull (*Larus argentatus*), double-crested cormorant (*Phalacrocorax auritus*), and great black-backed gull (*Larus marinus*) were observed frequently during all surveys, but in lower numbers than the dominant aquatic species. Habitat uses recorded during the Tierra 1999-2000 surveys are generally consistent with the CPG 2010-2011 surveys—gulls were observed most often on man-made structures, waterfowl were typically on the water, shorebirds were usually on mudflats or the shoreline, and wading birds preferred the shoreline (Windward 2012a).

The intertidal mudflats represent the only truly functional habitat for aquatic and semi-aquatic birds in the Lower Passaic River. The isolated mudflats in the FFS Study Area primarily consist of cobble and/or gravel in the high intertidal zone, with finer sediment in the lower intertidal zone. Some mudflats are adjacent to vertical upland, bulkhead, and riprap shoreline, which has reduced value for foraging for some water bird

species (Kane et al. 1991, USEPA 1998). Habitat is a key determinant of bird community structure in this area, and all lines of evidence strongly support the conclusion that the lack of habitat in the FFS Study Area constrains bird use. Foraging by waterbirds, particularly wading birds, generally occurs along intertidal mudflats and tidal marshes throughout the estuary.

The selection of wildlife receptors of concern, especially for mammals, must consider the limited habitat along the riverbanks. Only squirrels, chipmunks, groundhogs (herbivores), and rats (omnivores) were periodically observed along the riverbanks during the CPG field investigation (Windward 2014a). None of these species are semi-aquatic or piscivorous. Other human-tolerant species, such as raccoons, that likely inhabit the FFS Study Area are also not primarily piscivorous. None of these species represent organisms that have substantial exposure to contaminated sediments nor do they prey upon fish from the river. As such, they should not be addressed in an ERA for the FFS Study Area.

American mink (*Neovison vison*) have never been documented within the Lower Passaic River; the only documented mink tracks were observed near Dundee Dam (Windward 2014a), more than 11 miles above the FFS Study Area. As such, this species should not be considered a receptor in the Lower Passaic River because it does not inhabit this area and therefore cannot be at risk.

3 Ecological Conceptual Site Model

The limited and generally poor habitat quality in the FFS Study Area substantially constrains the types of organisms that inhabit or utilize the area. The basic food web in the FFS Study Area is therefore limited. Various resident and migratory fish and shellfish (crabs, shrimp) comprise the primary aquatic community. Piscivorous waterbirds—mainly migratory species—are the primary upper-trophic wildlife species that utilize the FFS Study Area, though none of them breed there. These birds feed upon the fish and shellfish present in the FFS Study Area, which in turn are exposed to the benthic infauna, the algal/plankton communities, water and sediments. A representative ecological CSM (i.e., food web) for the FFS Study Area is provided in Figure 1. Although additional fish and bird species utilize the river, this CSM utilizes some of the most representative species to represent each trophic level of the food web.

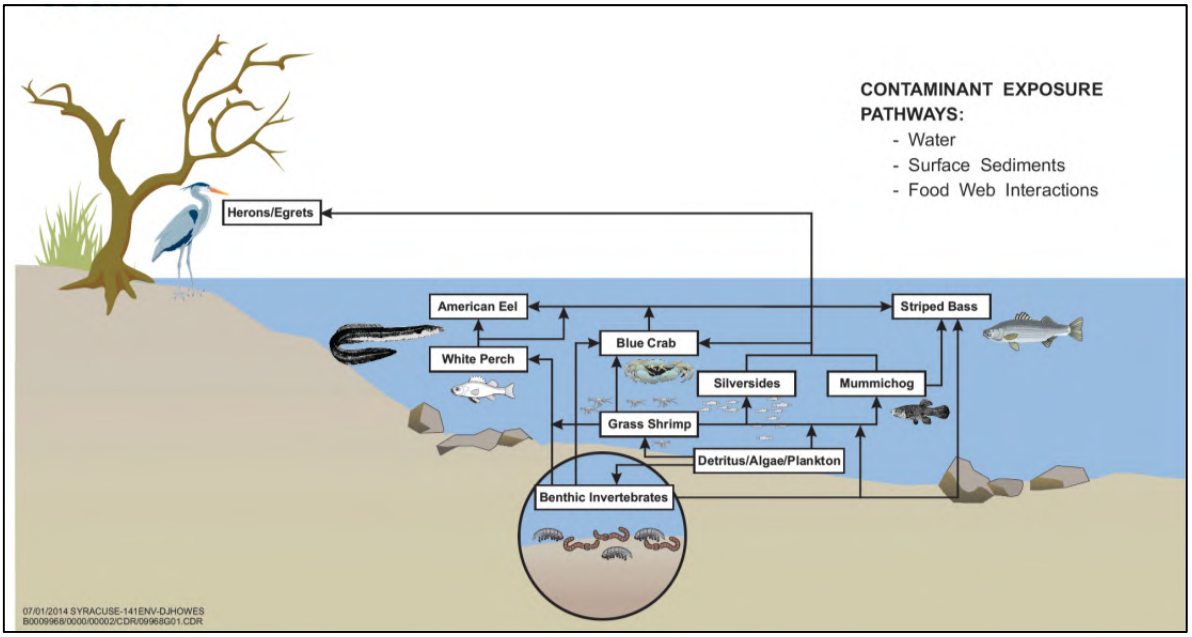


Figure 1. Representative Ecological Conceptual Site Model for the FFS Study Area.

4 Assessment and Measurement Endpoints

Based on the information provided above, along with the ecological setting description and Problem Formulation provided in the FFS BERA, three assessment endpoints require evaluation:

1. Benthic Invertebrate Community

2. Fish Community (i.e., different trophic levels)

3. Pisciviorous Waterbird Populations

Sections 4.1, 4.2, and 4.3 below describe each assessment endpoint, along with the various lines of evidence (i.e., measurement endpoints) used in this ERA.

4.1 Benthic Invertebrate Community

One of the major flaws of the benthic invertebrate evaluation in the FFS BERA is that the risks were evaluated solely by comparing sediment chemical data to literature-based sediment screening benchmarks or sediment quality guidelines (SQGs). This decision by Region 2 was particularly curious, given the fact that large sediment quality triad studies (i.e., synoptic collections of co-located sediment chemistry, toxicity and benthic community data) were conducted on two occasions in the FFS Study Area—by Tierra in 1999 (published in Iannuzzi et al. 2007) and by the CPG in 2009.

In 2009, the CPG conducted the first of three planned field investigations in the 17-mile stretch of the Lower Passaic River Study Area (LPRSA). Of the 101 sample stations, 47 were located in the lower eight miles of the river (i.e., the FFS Study Area). The results of that benthic field effort are documented in Windward

(2011c, 2011d, 2012b, 2014b) and compared (in these reports) to the work that Iannuzzi et al. (2007) performed at 15 stations in the lower six-mile section of the Passaic River in 1999 (i.e., within the FFS Study Area). Collectively, these studies can be used to provide an accurate appraisal of potential chemical risks to benthic communities, and provide perspectives on the potential for risk management to be successful in the urban habitats of the FFS Study Area.

4.1.1 Sediment Chemistry and Toxicity

In 1999, two standardized laboratory sediment toxicity tests were performed on bulk sediment samples from each station: amphipod survival was determined via the 10-day static *Ampelisca abdita* test and polychaete survival and growth were determined via the 28-day static *Neanthes arenaceodentata* test. Each sample was classified as “nontoxic,” “marginally toxic,” or “highly toxic” using a classification system employed by NOAA to evaluate similar types of test results for a nationwide survey of estuaries and marine bays (Long et al. 1996). Few samples were toxic to polychaetes; therefore, only amphipod results are used in this evaluation. Results indicate no discernable spatial gradient in amphipod toxicity throughout the lower six-mile portion of the river. Eight of 15 stations were classified as highly toxic, but these samples were scattered throughout the study area. The four nontoxic samples and three marginally toxic samples were also were scattered throughout the river with no apparent pattern (Iannuzzi et al. 2007).

Toxicity testing with *Hyallella azteca*, *Amelisca abdita,* and *Chironomus dilutus* was performed on surface (i.e., 0 to 15 centimeter [cm]) sediment samples collected during fall 2009 from the LPRSA (Windward 2011b). Only the *A. abdita* tests, conducted in the estuarine zone (RM 0 to 10) are considered appropriate for use in this evaluation of toxicity in the lower eight miles of river, as *Hyallella* and *Chironomus* are freshwater species that would not occur in this portion of the river. Results of the 2009 sediment toxicity tests for *A. abdita* are consistent with the findings from Iannuzzi et al. (2007) that there is no clear relationship between any individual chemical and *A. abdita* survival. Table 4-1 shows that the majority of 2009 sediment samples (n=19) are not considered toxic because they had *A. abdita* survival greater than 80%. A handful of sediment samples (n=5) had survival ranging from 50 to 80% per sample and can be considered “marginally toxic.” Only three samples had survival less than 50% and can be considered “toxic” (Table 4-1).

A large mix of individual chemicals is evident in the sediments; the concentrations of these chemicals generally increase as the sediments become more toxic. The sediments also vary in terms of physical factors such as sulfides and percent fines, which generally decrease as sediments become increasingly toxic (Table 4-1). There are no specific chemicals that are clearly associated with the trend in sediment toxicity. Instead, it is clear that the general urban conditions of these sediments drive such toxicity and limitations to the benthic community, and that a variety of chemicals as well as non-chemical factors (organic enrichment, substrate type, etc.) contribute to such conditions (Iannuzzi et al. 2007).

In the FFS BERA, Region 2 concludes that 2,3,7,8-TCDD is a primary chemical driver of risk and toxicity to benthic invertebrates. There is no basis for such a conclusion. A study by Barber et al. (1998) demonstrated no toxicity to *A. abdita* during a spiked sediment bioassay, with concentrations of 2,3,7,8-TCDD as high as

10 milligrams per kilogram (mg/kg), which is orders of magnitude higher than concentrations in surface sediment in the FFS Study Area. In fact, it has been shown that 2,3,7,8-TCDD does not elicit aryl hydrocarbon receptor (AhR) mediated responses in benthic organisms (e.g., amphipods, polychaetes, etc.) because they do not possess the cellular AhR that is associated with dioxin-like toxicity in higher-trophic level (i.e., vertebrate) organisms (Hahn 1998, 2002; USEPA 2008).

4.1.2 Benthic Community

In 1999, benthic taxonomic analyses were performed at each station along the six-mile study area (Iannuzzi et al. 2007). A multi-metric benthic index of biotic integrity (B-IBI) was calculated for each station using a method established for the NY/NJ Harbor Estuary (Weisberg et al. 1998). The benthic community composition data were evaluated to identify potential differences among stations in the lower six miles of the Passaic River. Several trends were discernable in the structure of the benthic community in 1999 (Iannuzzi et al. 2007). The total number of taxa per sample (richness) generally increased from upstream to downstream. The percentage of pollutant-tolerant taxa generally decreased from upstream to downstream, with these taxa dominating (93 to 100%) the five most upstream stations in the study area. Overall, the benthic community in the lower six miles of the Passaic River was dominated by three species: the polychaete *Laeonereis culveri* is well-adapted to the stressful conditions of intertidal environments and dominated the lower, more saline portion of the study area; and two pollutant-tolerant oligochates (*Limnodrilus sp. and Enchytraeus sp.*) dominated the upstream portion of the study area. Calculated B-IBI scores for the study area ranged from 1 to 2.5, indicating that the benthic community is highly-to-moderately impaired at all stations; however, scores at three reference area stations (2, 2.5, and 3.5) also indicate slight benthic impairment (Iannuzzi et al. 2007).

The CPG conducted a benthic community survey and associated analysis on the entire 17-mile portion of the Lower Passaic River in fall 2009 (Windward 2014b). Benthic community metrics were quantitatively evaluated and described using a variety of descriptive statistics and standardized metrics, including abundance per square meter, taxonomic richness (number of species [or higher order taxa, if not identified to species] in a sample), Shannon-Wiener diversity index, Pielou's evenness index, and Swartz's dominance index. The estuarine zone includes the brackish river segment and part of the transition river segment from approximately RM 0 to RM 8.5. The dominant taxon at all locations below RM 8.5 was either a polychaete (*Leitoscoloplos fragilis* or *Marenzellaria viridis*), an oligochaete (*Tubificoides heterochaetus* or *Limnodrilus hoffmeisteri*), or a crustacean (*Cyathura polita)*. Other dominant taxonomic groups included crustaceans (amphipods, decapods, isopods, and crustaceans), molluscs (bivalves and gastropods), and miscellaneous taxa (nemerteans, leeches, and flat worms).

The benthic invertebrate community in the lower 8.5 miles of the Passaic River generally consists of species commonly found in the brackish water zone of northeastern United States estuaries (USEPA 2003), as determined by the CPG and in the benthic community survey results from RM 1 to RM 7 conducted in 1999 by Iannuzzi et al. (2007). The two most dominant groups in both Lower Passaic River surveys were polychaetes and oligochaetes. Polychaetes were found in higher abundance closer to the mouth of the river

during both surveys, with oligochaetes increasing in abundance upriver and becoming the most dominant group by RM 4.5. One notable difference between the surveys was the greater abundance of mollusks in the lower portion of the Passaic River during fall 2009 compared to fall 1999. Mollusk species observed in 2009 included: *Macoma balthica, Mulinia lateralis, Sphaeriidae, Hydrobiidae,* and *Corbicula sp* (Windward 2014b). Overall, the benthic community composition and indices of diversity and abundance are within those for the urban background in the NY/NJ Harbor Estuary. The IBI and other relevant community indices fall within those from less impacted areas of the Estuary, most notably Jamaica Bay, which has been approved by Region 2 as a reference envelope for the marine/estuarine urban background for benthic communities for the 17-mile LPRSA draft BERA (Windward 2014c).

4.1.3 Bioaccumulation Data

The CPG conducted a laboratory bioaccumulation study in 2009 with surface sediment collected from locations throughout the LPRSA (Windward 2011c). Based on the interstitial water salinity of the sediment, one of two organisms was selected for a 28-day test. Five tests were conducted with an estuarine polychaete worm (*Nereis virens*) and 14 tests were conducted on the freshwater species, blackworm (*Lumbriculus variegatus*). At the conclusion of the 28-day test, polychaete tissue concentrations of 2,3,7,8-TCDD ranged from 2 to 19 nanograms per kilogram (ng/kg). Total PCBs ranged from 26,200 to 135,000 ng/kg (Table 4-2).

The CPG also conducted a caged bivalve study in the FFS Study Area (Windward 2012b). Caged ribbed mussels (*Geukensia demissa)* were deployed at seven locations between RM 0 and RM 10 during spring 2011 and were left in place for 60 days. Mortality was greater than 99% for mussels from cages placed between RM 6 and RM 10; therefore, tissue data are only available for mussels from stations between RM 0 and RM 4. According to Windward (2012b), the average 2,3,7,8-TCDD concentration was 0.66 ng/kg and ranged from 0.25 to 1.2 ng/kg; the average concentration of Total PCBs was 9,300 ng/kg and ranged from 2,600 to 18,000 ng/kg (Table 4-2).

4.1.4 Blue Crabs

Blue crabs dominate the larger macroinvertebrate crustaceans in the FSS Study Area. A total of 60 whole-body blue crabs were collected during the 1999/2000 and 2009 CPG studies. Concentrations of 2,3,7,8-TCDD in blue crabs ranged from 4 to 141 ng/kg with a mean of 57 ng/kg and concentrations of Total PCBs ranged from 75,700 to 786,000 ng/kg, with a mean concentration of 325,212 ng/kg (Table 4-2).

4.2 Fish Community

The fish community in the FFS Study Area includes small forage fish and large individual sportfish/ piscivorous fish species. Forage fish include several species and are defined as small fish (i.e., less than 16 cm) or juveniles that generally feed on detritus and the benthos and could be considered prey items for larger piscivorous fish, birds, and/or mammals. Forage fish datasets collected in 1999/2000 and 2009

consist of small whole-body fish that were composited together to form samples (Iannuzzi et al. 2004, Windward 2012c). A total of 93 samples were collected and include the following species: gizzard shad, mixed forage fish (e.g., silversides, darters, bass, shiners, mullet), mummichog, pumpkinseed, silver shiner, silverside, spottail shiner, and white perch. Forage fish tissue concentrations of 2,3,7,8-TCDD ranged from 2 to 828 ng/kg, with a mean of 63 ng/kg; Total PCB concentrations ranged from 172,000 to 1,850,000 ng/kg, with a mean of 533,367 ng/kg.

Other larger fish (including American eel, common carp, white perch, striped bass, Atlantic menhaden, bluefish, and brown bullhead) were collected during the 1999/2000 and 2009 field efforts as individual samples, either as whole-body organisms or as sportfish fillets, to evaluate human health risks (Iannuzzi et al. 2004, Windward 2011a). Tissue concentrations of 2,3,7,8-TCDD in whole-body fish ranged from 0.38 to 1400 ng/kg, with a mean of 156 ng/kg. Tissue concentrations of Total PCBs in whole-body fish ranged from 259,000 to 7,860,000 ng/kg, with a mean of 2,859,625 ng/kg. Table 4-2 provides summary statistics for the benthic invertebrate, fish, and crab tissue data used in this evaluation.

4.3 Piscivorous Waterbird Populations

4.3.1 Great Blue Heron

Upper trophic-level wildlife receptors evaluated in the FFS Study Area are piscivorous (i.e., fish-eating) birds, represented by the great blue heron (*Ardea herodias*), which is often observed foraging along the mudflats of the FFS Study Area (Ludwig et al. 2010, Windward 2014a). This section discusses the life history and exposure parameters of great blue heron.

Great blue heron are mostly gray with a yellow bill, white head, and black stripe over the eye that ends in a plume on the back of the head and neck. They have long legs and a long, curved neck. Males and females of this species look alike. An adult great blue heron is typically 97 to 137 cm (38.2 to 53.9 inches) long, with a potential wing span ranging from 167 to 201 cm (65.7 to 79.1 inches) (Cornell Lab of Ornithology 2011). Adult herons weigh an average of 2.34 kg (USEPA 1993).

Great blue heron are found along freshwater, estuarine, and marine shoreline habitats or wetlands (Cornell Lab of Ornithology 2011). Favored habitat consists of shorelines of lakes, rivers, ponds, and streams and they are sometimes found in grassy fields near surface water. Great blue heron are versatile in the types of habitats they use; availability of natural cover (i.e., vegetation) is not a limiting factor for use of habitat for foraging and nesting (Short and Cooper 1985). In South Dakota rivers and streams, great blue heron were observed to travel up to 24.4 kilometers (km) from the colony to forage; however, the mean distance was just 3.1 km (USEPA 1993). Fifteen to 20 km is the farthest distance that great blue heron regularly travel between foraging areas and colonies (USEPA 1993). Nests are usually located in tall trees near water, such as on islands or forested swamps. Great blue heron usually nest in isolated colonies; however, individual pairs may be found nesting as well. Nesting colonies are usually isolated from human disturbance and can have populations of hundreds of pairs of mixed heron species. Nests are large platforms made of sticks

mounted at heights of 3 to 9 meters (10 to 30 feet) and are lined with moss, dry grass, twigs, or pine needles. Nests from previous years are often reoccupied by heron pairs (Cornell Lab of Ornithology 2011, Short and Cooper 1985).

Adult herons of two years and older may mate and breed. Typical clutch size is three to four eggs and may be as many as seven eggs. Eggs are incubated for 28 days by both parents, and both parents also care for the nestlings. Fledging occurs at approximately 60 days old, but the fledglings will continue to return to the nest for feeding for several weeks after fledging (Cornell Lab of Ornithology 2011).

Great blue heron feed in shallow water during both night and day. Locating its prey by sight and stalking it, the great blue heron spears the prey with its long pointed beak and swallows it whole, head first. With legs longer than other herons, the great blue heron can exploit water that is deeper, giving it an advantage when it comes to feeding. Fishing requires water depths up to 0.5 meter with a firm substrate (Short and Cooper 1985).

Great blue heron diet consists of fish as well as other primarily aquatic animals including crustaceans, amphibians, and insects. Various studies cited by the USEPA (1993) and others (e.g., Short and Cooper 1985) about dietary composition consistently show a diet for great blue heron that is dominated by fish (94 to 100 percent). Great blue heron are assumed to consume fish ranging in size from 50 to 300 millimeters, based on an analysis by Henning et al. (1999). In addition to crustaceans and amphibians, other prey items reported include snakes, birds, and mammals. As a result, great blue heron in the FFS Study Area are assumed to consume a diet that consists of forage fish and blue crabs.

USEPA (1993) cites a dietary ingestion rate of 0.18 gram per gram per day (g/g-day) wet weight for both adult male and female great blue heron. USEPA (1993) estimates a water ingestion rate of 0.045 g/g-day for adult male and female great blue heron. No data on sediment ingestion rates of great blue herons were found in the literature, but sediment ingestion rates are likely to be low based on their foraging behavior. USEPA (1993) states that when fishing, great blue herons use two fishing techniques: standing still and waiting for fish to swim within striking distance and/or slow wading to catch more sedentary prey. Therefore, in order to capture prey, great blue heron require shallow water with a firm substrate and usually immerse larger prey before swallowing. Based on these foraging techniques, the best professional estimate for a sediment ingestion rate uses Beyer et al.'s (1994) conservative rate of 2% as well as information from Eckert and Karalus (1988). In addition, a sediment ingestion rate of 2% was assumed for the BERA for the Hudson River (USEPA 2000). Although incidental ingestion of sediment is considered negligible for the great blue heron, a conservative assumption of 2% appears reasonable. Selected dietary exposure parameters are provided in Table 4-3.

4.3.2 Double-Crested Cormorant

A large population of another piscivorous seabird species, the double-crested cormorant, inhabits the lower Passaic River, Newark Bay, and NY/NJ Harbor Estuary (Elbin et al. 2008). Parsons (2003) collected

double-crested cormorant eggs from Shooters Island, located in the southern portion of Newark Bay (approximately six miles south of the FFS Study Area), as well as from two other islands in the NY/NJ Harbor Estuary. Parsons (2003) compared tissue concentrations of chemicals in bird eggs (including 2,3,7,8-TCDD and PCBs) among the islands to evaluate whether the chemicals have an effect on the reproduction of cormorants. There was no conclusive evidence from this study that chemical concentrations correlated to reduced reproduction of cormorants (Parsons 2003).

Because cormorants have a foraging range of 30 to 40 km from their colony (Custer and Bunck 1992, Hatch and Weseloh 1999, Ainley and Boekelheide 1990), the population of cormorants on Shooters Island is representative of piscivorous birds that may forage on fish from the FFS Study Area. The tissue concentrations observed in the eggs on Shooters Island can be compared to appropriate literature-based tissue residue values to evaluate potential effects to avian embryos. Dioxin is known to have effects on early life stages, such as avian eggs (USEPA 2008). Non-lipid normalized 2,3,7,8-TCDD concentrations in cormorant eggs for the Shooters Island population range from 8.6 to 201 ng/kg, with a mean 2,3,7,8-TCCD concentration of 59.8 ng/kg and a mean 2,3,7,8-TCDD toxic equivalent (TEQ) of 92 ng/kg (Parsons 2003).

5 Ecological Effects Assessment – Toxicity Reference Values

Toxicity reference values (TRVs) for benthic invertebrates, fish, and birds were obtained from available scientific literature. The compilation of TRVs for 2,3,7,8-TCDD and PCBs was conducted in two steps. First, ARCADIS compiled TRVs from previous reports/investigations for the Lower Passaic River. These include:

- TRVs compiled by ARCADIS for preliminary risk assessment work previously conducted on behalf of Tierra for the lower six miles of the Passaic River
- The risk assessment portions of the Draft FFS for the lower eight miles of the Passaic River, prepared by Battelle on behalf of Region 2 (USEPA 2007)
- TRV reporting for the LPRSA prepared by Windward on behalf of the CPG (Windward 2012d).

As a second step, ARCADIS conducted a focused literature review to update/amend the TRV list for the FFS Study Area. The focus was on key toxicological studies that have been published since 2011 in the scientific literature, and the Hudson River and Tittabawassee River Superfund site investigations for which TRVs for 2,3,7,8-TCDD and/or PCBs have also been compiled.

For each of these sites, TRVs were compiled for various receptors from the literature, including both individual studies as well as known government databases (e.g., U.S. Army Corps of Engineers Environmental Residue Effects Database). TRVs were only selected from the studies that met specific criteria. For example, the following selection criteria were applied by Windward (2012d):

- TRVs were derived from controlled toxicity studies that used standardized and/or peer-reviewed experimental methods in which a clear concentration- or dose-response relationship was reported
- TRVs are based on the exposure of an organism to a single chemical or certain mixtures of related chemicals (i.e., consideration of appropriate mixtures of chemicals within the same class, such as PCBs and polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans)
- TRVs reflect an exposure route relevant to effects threshold type (e.g., ingestion exposure for dietary thresholds)[2]
- TRVs are not based on bioaccumulation studies that do not search for or report a toxic effect
- TRVs are based on LPRSA-specific receptors (e.g., heron, mummichog) when receptor-specific toxicity data are available
- For birds, TRVs are not based on reproductive endpoints in a domesticated species, such as chickens or Japanese quail, because these species are bred to have unnaturally high egg-laying rates and have very different toxicological reproductive sensitivities than wild bird species
- For invertebrate and fish tissue, thresholds are based on whole-body concentrations that are reported at the time that the effects were measured.

TRVs are presented as predicted tissue effect and/or no effect levels on the survival, growth, or reproduction of the receptor species (Tables 5-1 through 5-3). They are documented as no observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) and are presented in parts per trillion[3] for benthic invertebrates and fish. For birds, the TRVs are presented as parts per trillion of body weight per day (i.e., dose). While not all studies report both a NOAEL and a LOAEL, studies with both values are preferentially selected instead of studies with only one of the values. In some cases, a study will extrapolate a NOAEL value from a LOAEL value using an “uncertainty” factor of 10. The LOAEL value represents the upper threshold limit based on observed impacts or predictions that ecological impacts could occur (USEPA 1997).

---

[2] For dietary effect thresholds, if dietary ingestion-based thresholds are not available for a particular chemical, other exposure routes (e.g., gavage, injection) were considered.

[3] Parts per trillion (ppt) = picograms/gram (pg/g) or nanograms per kilogram (ng/kg)

For each receptor group, site-specific considerations were accounted for during species selection. For instance, species that have been documented in the FFS Study Area were selected over species unknown to inhabit the area or species that are reared solely for laboratory purposes (e.g., domestic chicken). The ranges of TRVs that were selected are provided in Table 5-4 and discussed by receptor group in the following sections.

5.1 Benthic Invertebrates

As shown on Table 5-1, tissue-based TRVs for 2,3,7,8-TCDD are not generally available for benthic invertebrates because invertebrates lack the cellular AhR that binds dioxin-like compounds and is responsible for expression of toxic effects (Hahn 1998, 2002; USEPA 2008). However, one study by Cooper and Wintermeyer (2009) report reproductive effects of 2,3,7,8-TCDD under laboratory exposures to softshell clams (*Mya arenaria*). The mechanism for these effects to occur are not clear from the study or, but to be consistent in the approach for TRV reporting, this value is included in the assessment.

Tissue-based TRVs for PCB effects are available for benthic invertebrates, which vary due to species-specific sensitivities. Shrimp (e.g., grass, pink, brown) and oysters appear to be the most sensitive species to PCBs, followed by amphipods and polychaetes. Blue crabs only have a NOAEL TRV for PCBs, from a single study: 2.9×10^7 ng/kg (Table 5-1).

5.2 Fish

Two categories of fish were evaluated for potential ecological risks: forage fish and all other fish. Each category has a range of TRVs (Table 5-2 and 5-4). Forage fish include mummichogs, minnows (sheepshead and fathead), spottail shiner, bluegill, Japanese medaka, and pumpkinseed. A range of TRVs is also presented for mummichogs alone (Table 5-4).

For the non-forage fish species, a range of TRVs was selected based on available values reported for all warm-water species (e.g., carp, perch, catfish, bass) (Table 5-4). Salmonid species (i.e., trout and salmon) values are reported, but were excluded from the TRV selection because they are cold-water species that do not (and cannot) occur in the FFS Study Area, and their sensitivities to 2,3,7,8-TCDD and PCBs are different substantially from warm-water and estuarine species (Elonen et al. 1998; Steevens et al. 2005).

5.3 Birds

Two sets of TRVs for birds were obtained from primary literature: one set is based on concentrations in the fish that they consume and acceptable dietary doses of 2,3,7,8-TCDD and PCBs in that fish; the other set is based upon toxicological studies involving injections of chemicals into bird eggs (Table 5-3).

Dietary dose-based TRVs are derived primarily from laboratory dosing/toxicity studies, and sometimes comparable field studies. The dietary dosing studies used to select TRVs for birds vary widely. Specifics of

the studies including duration of exposure, method of exposure, form of chemical, measured endpoints, and species used are highly variable among studies. Studies were separated based on dietary preference and habitat. Ranges of TRVs are based on those species that are likely to inhabit the Lower Passaic River and to have piscivorous diets (e.g., great blue heron, gulls, osprey, tern, kingfisher, bald eagle) (Table 5-3). This group excludes common terrestrial, non-piscivorous species such as kestrel, chicken, pheasant, owls, and doves, which are unlikely to feed on fish from the river. For comparison, a range of TRVs for all birds including the non-piscivorous species is presented in Table 5-4, and the overall values are similar to the group that excludes non-piscivorous species.

Additional TRVs were compiled for avian egg tissues. Dioxins are known to affect early life stages of organisms. Therefore, additional TRVs based on injected doses of 2,3,7,8-TCDD into avian eggs, specifically for piscivorous birds, are provided in Table 5-3.

6 Ecological Risk Characterization

6.1 Benthic Invertebrate Community

For benthic invertebrates, the maximum measured tissue concentrations from the CPG bioaccumulation study using polychaetes were compared to the range of TRVs selected. No TRVs exist for 2,3,7,8-TCDD in polychaetes as they lack the cellular Ah response necessary for dioxin-like toxicity as previously described. The average concentration of Total PCBs in polychaetes (54,300 ng/kg) is also below the TRVs for PCBs, which range from $3.6x10^7$ to $2x10^8$ (Rice et al. 2000, Fowler et al. 1978). Therefore, there are no apparent risks from Total PCBs to polychaetes in the FFS Study Area. An additional line of evidence of the lack of risk to polychaetes was observed in the results of the toxicity studies conducted in 1999. As described in Section 4 and by Iannuzzi et al. (2007), there was a lack of significant toxicity in any of the sediment samples used in the polychaete toxicity test.

Average 2,3,7,8-TCDD concentration in transplanted ribbed mussels from the CPG's caged bivalve study was 0.66 ng/kg and ranged from 0.25 to 1.2 ng/kg (Windward 2012b). The only LOAEL-based TRVs for 2,3,7,8-TCDD, based on a single reproductive study with softshell clams, range from 2 to 10 ng/kg (Cooper and Wintermeyer 2009). As such, there are no potential adverse ecological effects to any bivalves that may occur in the FFS Study Area.

For blue crabs, no TRVs exist for 2,3,7,8-TCDD. This is not surprising, given the lack of a cellular AhR response in invertebrates. Hence, it is widely accepted that 2,3,7,8-TCDD is not toxic to these animals. For Total PCBs, the average concentration of 325,212 ng/kg is well below the NOAEL for blue crabs ($2.3x10^7$) (Duke et al. 1970, Table 6-1).

Results from amphipod toxicity studies conducted in 1999 and 2009 indicate a low potential for risk/toxicity to this sensitive species, based on the low toxicity observed in only three of 27 samples in the FFS Study Area (see Section 4.1.1). Furthermore, although the *in-situ* benthic community remains dominated by

pollutant-tolerant organisms such as polychaetes and oligochates, the benthic community is similar to regional urban reference communities, such as Jamaica Bay, which was used as a reference area in the draft BERA for the estuarine portion of the 17-mile LPRSA by the CPG (Windward 2014c).

Overall, based on the lines of evidence described above, there are no ecological risks to the benthic invertebrate community from 2,3,7,8-TCDD and PCB concentrations in sediment in the FFS Study Area, and chemical risks in general are part of the larger urban condition that impacts and constrains community diversity and abundance. This situation cannot be managed through targeted sediment removal and capping, as previously discussed.

6.2 Fish Community

Overall, the comparison of site-specific fish tissue data to conservative residue-based TRVs indicate a low potential for ecological risk from 2,3,7,8-TCDD and Total PCB concentrations in sediment in the FFS Study Area (Table 6-1). For 2,3,7,8-TCDD, all of the observed mean tissue concentrations are below the minimum reported LOAEL-based TRV. For most species, the observed concentrations are below the NOAEL TRV as well. The exception is common carp for which a species-specific NOAEL TRV was not available; however, the observed mean concentration is within the NOAEL-based TRV range for all fish. For Total PCBs, all of the observed mean concentrations are below the maximum NOAEL TRV (Table 6-1).

6.3 Piscivorous Waterbird Populations

6.3.1 Great Blue Heron Food Web Modeling

Observed aquatic tissue concentrations were incorporated into a food web dose model to calculate an average daily dose (mg/kg bw-day) of dioxin and Total PCBs for great blue heron, as well as TEQ[4]-adjusted values. The food web model for the heron includes ingestion of prey items, which include forage fish and blue crabs. Forage fish are considered to comprise the majority of the heron's diet because they fit the appropriate size range of fish consumed by herons (see Section 4.3). Blue crab data were included as a conservative measure because it is possible for heron to be stabbing at, and consuming, blue crab tissue. The model also includes ingestion of surface water and mudflat sediment. Only mudflat sediment is included in the evaluation because wading birds such as herons would not be exposed to sediment within deeper parts of the river (e.g., channel). Summary statistics for the surface water and mudflat datasets are provided in Tables 6-2 and 6-3.

[4] TEQ = toxic equivalency quotient. The sum of individual dioxin and dioxin-like PCB congeners multiplied by their congener-specific toxic equivalency factor (TEF), which is based on their relative toxicity to 2,3,7,8-TCDD.

The average daily dose calculated from the food web model is then compared to the range of LOAEL-based TRVs described in Section 5 to determine if there is current ecological risk in the FFS Study Area. Because the LOAEL represents the upper threshold level for potential effects, it is more appropriate to use than the NOAEL. A range of LOAELs is provided, if available. If the resulting hazard quotient (HQ) is greater than 1, the potential exists for adverse effects to piscivorous birds from exposure to chemicals in the FFS Study Area. Results less than 1 indicate no potential ecological risks.

An inherent assumption of this risk equation and the application of TRVs is that forage fish and crab tissue from the Lower Passaic River are the only food sources for the receptor. Therefore, this approach and its results represent a conservative worst-case risk scenario. In fact, most piscivorous birds (including the heron) are migratory and will only spend a fraction of their time feeding in the Lower Passaic River, particularly given the limited habitat present in the FFS Study Area (Iannuzzi and Ludwig 2000). As a result, two potential scenarios were evaluated in the food web model:

1. *Average Assumptions*. Average mudflat sediment concentrations, average forage fish and blue crab tissue concentrations, and a site-specific use factor that accounts for the seasonality of great blue heron in the FFS Study Area.

2. *Conservative Assumptions*. The 95UCL[5] mudflat sediment concentrations, 95UCL forage fish and blue crab tissue concentrations, and an assumption that great blue heron are year-round residents in the FFS Study Area.

Concentrations of surface water, mudflat sediment, and tissue used as exposure point concentrations (average concentrations and 95UCLs) in the food web models are presented in Table 6-4.

Results of the dose model evaluation are presented in Tables 6-5 and 6-6. Results using reasonable estimates of average tissue, sediment, and surface water concentrations indicate a lack of any predicted adverse effects to populations of great blue heron foraging along the mudflats of the FFS Study Area (Table 6-5). Only the HQ for total TEQ using the lowest LOAEL slightly exceeds 1 (HQ = 2). HQs using higher LOAELs are not exceeded for 2,3,7,8-TCDD, Total PCBs, or TEQs.

HQs that result from the analysis using more conservative assumptions (i.e., 95UCLs and assuming great blue heron forage at the site year-round) indicate that the lowest LOAELTRVs are exceeded for 2,3,7,8-TCDD, Total PCBs, and TEQs but only slightly exceed the threshold value of 1 (HQ $LOAEL_{low}$ = 1.8 to 4.1). Using the higher range of LOAEL TRVs, only Total PCBs exceeds an HQ of 1 (HQ $LOAEL_{high}$ = 1.8) (Table 6-6).

---

[5] 95UCL = 95th upper confidence limit of the mean of the data; calculated using ProUCL version 5.0.

Overall, the modeling results suggest a lack of ecological risk to piscivorous waterbird populations from exposure to mudflat sediment, surface water, and forage and blue crab tissues, even using conservative assumptions.

6.3.2 Avian Eggs

To evaluate potential ecological risk to sensitive early life stages of piscivorous waterbirds (i.e., avian eggs) from dioxin-life effects, 2,3,7,8-TCDD concentrations in cormorant egg tissue data from a local population on Shooters Island are compared to the avian egg TRVs identified in Section 6 (Table 6-7). According to Parsons (2003), non-lipid normalized 2,3,7,8-TCDD concentrations in cormorant eggs for the Shooters Island population range from 8.6 to 201 ng/kg, with a mean 2,3,7,8-TCCD concentration of 59.8 ng/kg and a mean TEQ of 92 ng/kg. These values are well below the established literature-based TRVs for avian eggs, specifically cormorant 2,3,7,8-TCDD concentrations, with NOAELs that range from 1,000 to 3,000 ng/kg and LOAELs that range from 4,000 to 10,000 ng/kg (Powell et al. 1997, 1998; Sanderson and Bellward 1995) Thus, there is no potential for adverse effects to avian eggs from exposure to 2,3,7,8-TCDD (Table 6-7).

Non-lipid normalized Total PCB concentrations in cormorant eggs for the Shooters Island population range from1,980,000 to 40,400,000 ng/kg, with a mean concentration of 13,900,000 ng/kg Total PCBs and a mean TEQ of 322 ng/kg (Parsons 2003). NOAELs for PCBs range from 7,000 to 20,000 ng/kg and LOAELs range from 40,000 to 180,000 ng/kg (Powell et al. 1997, 1998). As such, the potential for risk exists to avian eggs from exposure to PCBs in fish from the FFS Study Area (Table 6-7). However, the measures of egg hatching, growth and survival that were conducted by Parsons (2003) did not show an effect on the cormorants, despite these chemical exposures.

7 Summary and Conclusions

Habitat constraints of the FFS Study Area include an overall lack of natural shoreline vegetation, bulkhead, and large quantities of chemical inputs that have occurred for decades. Collectively, the urban conditions in this river constrain its ecology to a limited food web.

In this memorandum, ARCADIS provides a focused alternative ERA that:

- Considered baseline habitat conditions and actual ecological exposures in the FFS Study Area through a Problem Formulation
- Evaluated benthic community conditions and risks in the context of the substantial site-specific data and information on chemistry, toxicity and biological communities
- Evaluated potential ecological risks to fish and piscivorous birds from 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and polychlorinated biphenyls (PCBs), two of the chemicals identified as ecological risk-drivers in the FFS BERA.

Several lines of evidence were evaluated for the benthic community including the results of toxicity tests with amphipods and polychaetes, bioaccumulation data for polychaetes and ribbed mussels, blue crab tissue concentrations, and *in-situ* biological community information. The results of all of these analyses indicate no ecological risk to any of the benthic invertebrate species. Rather, the low toxicity observed to amphipods in only three sediment samples is likely due to the mix of chemical inputs to the system, which is also affecting the diversity of the *in-situ* benthic invertebrate communities that are dominated by pollutant-tolerant species.

Tissue concentrations of 2,3,7,8-TCDD and PCBs in forage fish and other large piscivorous fish were compared to literature-based TRVs (i.e., tissue concentrations shown to have an adverse effect on the survival, growth, or reproduction of the organisms [LOAELs]). Of the TRVs available for the specific species or the community as a whole, none of the site-specific tissue concentrations exceed the highest ranges of the TRVs. As a result, there are no ecological effects to the fish community.

Piscivorous waterbirds were evaluated using a food web dose model for a wading bird, the great blue heron. Inputs to the food web model included concentrations of 2,3,7,8-TCDD and Total PCBs in sediment, surface water, and prey tissue items. The average daily dose calculated from this model was compared to literature-based TRVs with known affect levels (i.e., LOAELs). There are no potential ecological risks using average concentrations and site-specific exposure frequency. For the model used with more conservative assumptions, including 95UCLs and assuming that great blue heron forage in the FFS Study Area year-round, an extremely low potential exists for ecological risk from PCBs (HQ = 1.8, which is just slightly above the threshold value of 1).

Because dioxin and dioxin-like compounds are known to be sensitive to early life stages of organisms (USEPA 2008), an additional evaluation was conducted using cormorant egg tissue concentrations collected from nearby Shooters Island and comparing them to literature-based residue values for piscivorous eggs. Concentrations of 2,3,7,8-TCDD are well below any of the reported residue effects levels for cormorants. Although concentrations of Total PCBs are above the range of reported residue effects levels, no associated reproductive or growth effects on cormorants were reported by Parsons (2003).

The results of this alternative ERA indicate that there is no significant ecological risk from the chemicals in the FFS Study Area. This lack of ecological risk precludes the need to develop PRGs for these chemicals and concludes that remediation of the lower eight miles of the Passaic River for ecological risk in isolation of the remedy to be selected through the larger RI/FS process for the entire 17-mile LPRSA is unnecessary.

8 References

Able, K.W. and J.T. Duffy-Anderson. 2006. Impacts of piers on juvenile fishes in the Lower Hudson River. Pages 428-440 in Levinton, J.S., and J.R. Waldman, editors. The Hudson River Estuary. Cambridge University Press, Cambridge, New York.

Ainley, D.G. and R.J. Boekelheide. 1990. Seabirds of the Farallon Islands. Stanford Univ. Press, Stanford, CA.

Barber, T.R., D.J. Chappie, K.J. Duda, P.C. Fuchsman, and B.L. Finley. 1998. Using a spiked sediment bioassay to establish a no-effect concentration for dioxin exposure to the amphipod *Ampelisca abdita*. *Environ. Toxicol. Chem.* 17(3):420-424.

Beyer, W.N, E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *Journal of Wildlife Management* 58(2):375-382.

Bibby, C.J., N.D. Burgess, and D.A. Hill. 1992. *Bird Census Techniques*. Academy Press, New York, NY, USA.

Burger, J. 1984. Shorebirds as marine animals. In: Burger J and Olla BL (eds), *Shorebirds: Breeding Behavior and Populations*, pp 17–81. Plenum Press, New York, NY, USA.

Cooper, K.R. and M. Wintermyer. 2009. A Critical Review: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) Effects on Gonad Development in Bivalve Mollusks. *J. Env. Sci. Health* Part C 27: 226-245.

Cornell Lab of Ornithology. 2011. All About Birds: Great Blue Heron. Accessed at http://www.allaboutbirds.org/guide/Great_Blue_Heron/lifehistory on July 10, 2011.

Custer, T.W. and C. Bunck. 1992. Feeding flights of breeding Double-crested Cormorants at two Wisconsin colonies. *J. Field Ornithol*. 63:203-211.

Duke, T.W., J.I. Lowe, and A.J. Wilson, Jr. 1970. A polychlorinated biphenyl (Aroclor 1254) in the water, sediment, and biota of Escambia Bay, Florida. *Bulletin of Environmental Contamination & Toxicology* 5(2):171–180.

Eckert, A.W. and K.E. Karalus. 1983. *The Wading Birds of North America: North of Mexico*. Weathervane Books, New York, New York. 226 pp.

Elbin, S., E. Craig, and K. Ruskin. 2008. Double-crested Cormorants of the New York Harbor 2008 Field Season. NYC Audubon Society. Presentation to the Greater New York/New Jersey Harbor Colonial Waterbirds Working Group. Lyndhurst, NJ. December 11, 2008.

Elonen, G.E., R.L. Spehar, G.W. Holcombe, R.D. Johnson, J.D. Fernandez, R.J. Erickson, J.E. Tietge, and P.M. Cook. 1998. Comparative toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin to seven freshwater fish species during early life stage development. *Environ. Toxicol. Chem*. 17:472-483.

Elphick, C., J.B. Dunning, and D.A. Sibley (eds). 2001. *The Sibley Guide to Bird Life and Behavior*. Alfred A. Knopf, NY.

Fowler, S. W., G. G. Polikarpov, D. L. Elder, P. Parsi, and J.P. Villeneuve. 1978. Polychlorinated biphenyls: accumulation from contaminated sediments and water by the polychaete *Nereis diversicolor*. *Marine Biology* 48:303-309.

Hahn, M.E. 1998. The Aryl Hydrocarbon Receptor: A Comparative Perspective. *Comp. Biochem. Physiol.* 121C(3):23-53.

Hahn, M.E. 2002. Aryl hydrocarbon receptors: diversity and evolution. *Chemico-Biological Interactions*. 141:131-160.

Hancock, J. and J. Kushlan. 1984. *The Herons Handbook*. Croom Helm, London, UK.

Hatch, J. J. and D.V. Weseloh. 1999. Double-crested Cormorant (*Phalacrocorax auritus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/441.

Henning, M.H., N.M. Shear Weinberg, N.D. Wilson, and T.J. Iannuzzi. 1999. Distributions for key exposure factors controlling the uptake of xenobiotic chemicals by great blue herons (*Ardea herodius*) through ingestion of fish. *Human Ecol. Risk Assess.* 5(1):125-144.

Hess, G.K., R.L. West, and M.V. Barnhill, III. 2000. *Birds of Delaware.* University of Pittsburgh Press, Pittsburgh, PA, USA.

Iannuzzi, T.J., N.W. Harrington, N.M. Shear, C.L. Curry, H. Carlson-Lynch, M.H. Henning, S.H. Su, and D.E. Rabbe. 1996. Distributions of key exposure controlling the uptake of xenobiotic chemicals in an estuarine food web. *Environ. Toxicol. Chem.* 15(11):1979-1992.

Iannuzzi, T.J., D.F. Ludwig, J.C. Kinnell, J.M. Wallin, W.H. Desvousges, and R.W. Dunford. 2002. *A Common Tragedy: History of an Urban River*. Amherst, Massachusetts, USA. Amherst Scientific.

Iannuzzi, T.J., T.N. Armstrong, J.B. Thelen, D.F. Ludwig, and C.E. Firstenberg. 2004. Chemical Contamination of Aquatic Organisms from an Urbanized River in the New York/New Jersey Harbor Estuary. *Hum. Ecol. Risk Assess.* 10: 389-413.

Iannuzzi, T.J., T.N. Armstrong, E.R. Long, J. Iannuzzi, and D.F. Ludwig. 2007. Sediment quality triad assessment of an industrialized estuary of the northeastern USA. *Environ. Monit. Assess.* 139(1-3):257-275.

Iannuzzi, T.J. and D.F. Ludwig. 2000. The role of food web models in the environmental management of bioaccumulation chemicals. *Soil Sediment Contam.* 9(3):181-195.

Iannuzzi, T.J. and D.F. Ludwig. 2004. Historical and current ecology of the lower Passaic River. *Urban Habitats* 2(1).

Iannuzzi, T.J. and D.F. Ludwig. 2005. An interdisciplinary investigation of ecological history and environmental restoration objectives in an urban landscape. *Ecol. Restoration* 22(3):157-166.

Kane, R., P. Kerlinger, and R. Radis. 1991. Birds of the Arthur Kill Tributaries, 1990. Records of N.J. Birds. 17: 22-33.

Long, E.R., A. Robertson, D.A. Wolfe, J. Hameedi, and G.M. Sloane. 1996. Estimates of the spatial extent of sediment toxicity in major U. S. estuaries. *Environmental Science & Technology*, 30(12).

Louis Berger Group, Inc., Battelle, and Hydroqual. 2014. Remedial Investigation Report for the Focused Feasibility Study of the Lower Eight Miles of the Lower Passaic River. Prepared for USEPA Region 2 and USACE, Kansas City District.

Ludwig, D.F. and T.J. Iannuzzi. 2005. Incremental ecological exposure risks from contaminated sediments in an urban estuarine river. *Integr. Environ. Assess. Manag.* 1(4):1-17.

Ludwig D.F., J. Iannuzzi, T.J. Iannuzzi, and J.K. Shisler. 2010. Spatial and Temporal Habitat Use Patterns by Water Birds in an Urban Estuarine Ecosystem: Implications for Ecosystem Management and Restoration. *Hum. Ecol. Risk Assess.: An International Journal* 16(1):163-184.

Parsons, K.C. 2003. Chemical Residues in Cormorants from New York Harbor and Control Location. Final Report submitted to New York State Department of Environmental Conservation, Division of Fish, Wildlife and Marine Resources. Prepared by Manomet Center for Conservation Sciences, Manomet, Massachusetts. Contract No. C003858. February 28.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, J.F. Powell, J.C. Restum, K.L. Stromborg, and J.P. Giesy. 1997. Effects of 3,3',4,4',5-pentachlorobiphenyl (PCB 126), 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), or an extract derived from field-collected cormorant eggs injected into double-crested cormorant (*Phalacrocorax auritus*) eggs. E*nviron. Toxicol. Chem*., vol. 16, no. 7, pp. 1450-1455.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, M.E. Kelly, K.L. Stromborg, M.J. Melancon, S.D. Fitzgerald, and S.J. Bursian. 1998. Effects of 3,3',4,4',5-pentachlorobiphenyl and 2,3,7,8-tetrachlorodibenzo-p-dioxin injected into the yolks of double-crested cormorant (*Phalacrocorax auritus*) eggs prior to incubation. *Environ. Toxicol. Chem*., vol. 17, no. 10, pp. 2035-2040.

Rice, C.A., M.S. Myers, M.L. Willis, B.L. French, and E. Casillas. 2000. From sediment bioassay to fish biomarker - connecting the dots using simple trophic relationships. *Mar Environ Res* 50:527-533.

Sanderson, J.T. and G.D. Bellward. 1995. Hepatic microsomal ethoxyresorufin O-deethylase-inducing potency in ovo and cytosolic Ah receptor binding affinity of 2,3,7,8-tetrachlorodibenzo-p-dioxin: comparison of four avian species. *Toxicol Appl Pharmacol* 132: 131-145.

Short, H.L. and R.J. Cooper. 1985. Habitat Suitability Index Models: Great Blue Heron. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C. Biological Report 82(10.99). July 1985.

Steevens, J.A., M.R. Reiss, and A.V. Pawlisz. 2005. A methodology for deriving tissue residue benchmarks for aquatic biota: A case study for fish exposed to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin and equivalents. *Integr. Environ. Assess. Manag*. 1(2):142-151.

USEPA. 1992. Framework for Ecological Risk Assessment. Risk Assessment Forum. Washington, DC. EPA/630/R-92/001. February.

USEPA. 1993. Wildlife Exposure Factors Handbook. Volumes I and II. EPA/600/R-93/187a&b. Washington, DC.

USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. EPA 540-R-97-006. Office of Solid Waste and Emergency Response. June.

USEPA. 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. EPA/630/R-95/002F. April.

USEPA. 1999. Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites. Memorandum from Stephen D. Luftig, Director. OSWER Directive 9285.7-28 P.

USEPA. 2000. Phase 2 Report. Further Site Characterization and Analysis. Volume 2E – Revised Baseline Ecological Risk Assessment. Hudson River PCBs Reassessment. Prepared by TAMS Consultants, Inc. and Menzie-Cura & Associates, Inc.

USEPA. 2003. Sediment Quality of the NY/NJ Harbor System: A 5-year revisit (1993/1994 – 1998). EPA/902-R-03-002. USEPA Region II, Edison, New Jersey.

USEPA. 2007. Source Control Early Action Focused Feasibility Study. DRAFT. Prepared by Malcolm Pirnie, Inc. In conjunction with Battelle and HydroQual, Inc.

USEPA. 2008. Framework for Application of the Toxicity Equivalence Methodology for Polychlorinated Dioxins, Furans, and Biphenyls in Ecological Risk Assessment. Office of the Science Advisor. EPA 100/R-08/004. June.

Wallin, J.M., M.D. Hattersley, D.F. Ludwig, and T.J. Iannuzzi. 2002. Historical assessment of the impacts of chemical contaminants in sediments on benthic invertebrates in the tidal Passaic River, New Jersey. *Human Ecol. Risk Assess.* 8(5):1155-1176.

Weisberg, S. B., Ranasinghe, J. A., O'Connor, J. S., and D.A. Adams. 1998. A Benthic Index of Biotic Integrity (B-IBI) for the New York/New Jersey Harbor. Appendix C in Sediment Quality of the NY/NJ Harbor System: An Investigation Under the Regional Environmental Monitoring and Assessment Program (REMAP). EPA/902-R-98-001.

Wenning, R.J., N.L. Bonnevie, and S.L. Huntley. 1994. Accumulation of metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons in sediments from the lower Passaic River, New Jersey. *Arch. Environ. Con. Toxicol.* 27:64-81.

Windward. 2011a. Final Fish Community Survey and Tissue Collection Data Report for the Lower Passaic River Study Area. 2010 Field Efforts. July 20.

Windward. 2011b. Avian Community Survey Data Report for the Lower Passaic River Study Area Summer and Fall 2010. Prepared for Cooperating Parties Group. August 8.

Windward. 2011c. 2009 Bioaccumulation Tissue Chemistry Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. September 19.

Windward. 2011d. Sediment Toxicity Test Data Report for the Lower Passaic River Study Area Fall 2009 Investigation. Prepared for Cooperating Parties Group. February 28.

Windward. 2012a. Avian Community Survey Data Report for the Lower Passaic River Study Area Winter and Spring 2011. Prepared for Cooperating Parties Group. July 17.

Windward. 2012b. 2011 Caged Bivalve Study Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. July 18.

Windward. 2012c. 2010 Small Forage Fish Tissue Chemistry Data for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. July 18.

Windward. 2012d. Revised Risk Analysis and Risk Characterization Plan for the Lower Passaic River Study Area. Draft. Prepared for Cooperating Parties Group by Windward Environmental, LLC and AECOM. April 13.

Windward. 2014a. Final Habitat Identification Survey Data Report for the Lower Passaic River Study Area Fall 2010 Field Effort. Prepared on behalf of the Cooperating Parties Group. January 6.

Windward. 2014b. Final Fall 2009 Benthic Invertebrate Community Survey and Benthic Field Data Collection for the Lower Passaic River Study Area. Prepared on behalf of the Cooperating Parties Group. January 6.

Windward. 2014c. Draft. Lower Passaic River Study Area Baseline Ecological Risk Assessment. Prepared for Cooperating Parties Group. June 13.

Wolfskill, L.A. and R.P. McNutt. 1998. An environmental study of the Passaic River and its estuary. *Seton Hall Law Review* 29(1):7-59.

Tables

ARCADIS

List of Attached Tables

Table 4-1. Select Mean Chemical Concentrations for *Ampelisca abdita* Survival Ranges

Table 4-2. Tissue Summary Statistics (1999/2000 and 2009 Whole Body Data)

Table 4-3. Dietary Exposure Parameters for Great Blue Heron

Table 5-1. Toxicity Reference Values for Benthic Invertebrates (Whole BodyTissue Residues)

Table 5-2. Toxicity Reference Values for Fish (Whole BodyTissue Residues)

Table 5-3. Toxicity Reference Values for Birds (dietary-based TRVs, unless noted as egg which are tissue-based)

Table 5-4. Range of Toxicity Reference Values for Benthic Invertebrates, Fish, and Birds

Table 6-1. Benthic Invertebrate and Fish Tissue Residue Evaluation

Table 6-2. Surface Water Summary Statistics for River Miles 0 to 10.2 (2011-2013)

Table 6-3. Summary Statistics for Mudflat Data

Table 6-4. Exposure Point Concentrations for Great Blue Heron Food Web Model

Table 6-5. Food Web Dietary Dose Model for Great Blue Heron (Average Assumptions[a])

Table 6-6. Food Web Dietary Dose Model for Great Blue Heron (Conservative Assumptions[a])

Table 6-7. Avian Egg Evaluation

Table 4-1
Select Mean Chemical Concentrations for Ampelisca abdita Survival Ranges

***A. abdita* % survival (normalized to control)**	**>80%**	**50-80%**	**<50%**
Number of Samples	**19**	**5**	**3**
Select Mean Chemical Concentrations			
Chromium (mg/kg)	96	95	178
Copper (mg/kg)	138	139	280
Lead (mg/kg)	160	191	246
Mercury (µg/kg)	1635	1680	2900
Zinc (mg/kg)	361	401	577
Bis(2-ethylhexyl)phthalate (µg/kg)	6371	7320	11,467
Total 2,2' and 4,4'-DDT (ug/kg)	87	124	89
2,3,7,8-TCDD (ng/kg)	198	198	1990
Total PAHs SVOC (µg/kg)	25,288	27,000	54,333
Total HMW PAHs SVOC (µg/kg)	22,846	24,600	42,333
Total LMW PAHs SVOC (µg/kg)	2427	2480	12,707
Total PCB Congeners (209) (ng/kg)	817,090	857,263	3,388,809
Total WHO Dioxin TEQ Bird (ng/kg)	284	305	2127
Total WHO Dioxin TEQ Fish (ng/kg)	253	268	2073
Total WHO Dioxin TEQ Human/Mammal (ng/kg)	253	266	2076
Mean Physical Parameters			
Percent fines (%)	70	62	48
Sulfide (mg/kg)	926	966	222

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
TEQ = toxic equivalent
WHO = World Health Organization
µg/kg = micrograms per kilogram
% = percent
Not all chemicals analyzed for are shown in this table.
Data reported by Windward. 2011b. Sediment Toxicity Test Data Report for the Lower Passaic River Study Area Fall 2009 Investigation. Prepared for Cooperating Parties Group. February 28.

Table 4-2
Tissue Summary Statistics (1999/2000 and 2009 Whole Body Data)

Species (Whole Body)	Chemical (ng/kg)	Number of Samples	Number of Detections	Min Detect	Max Detect	Mean	Standard Deviation
Benthic Invertebrates							
Polychaeta	2,3,7,8-TCDD	5	5	2	16	6	7
	Total PCB Congeners (209)	5	5	26200	135000	54300	45419
Ribbed mussels	2,3,7,8-TCDD	3	3	0.25	1.2	0.66	0.49
	Total PCB Congeners (209)	3	3	2.6	18	9.3	7.9
Blue crab	2,3,7,8-TCDD	60	60	4	141	57.34	27.53
	Total PCB Congeners (209)	41	41	75700	786000	325212	135332
Fish							
Forage fish	2,3,7,8-TCDD	93	93	2.4	828	63.09	100.24
	Total PCB Congeners (209)	30	30	172000	1850000	533367	317824
Adult striped bass	2,3,7,8-TCDD	6	6	4.14	100.05	70.83	35.72
American eel	2,3,7,8-TCDD	25	24	0.38	47	17.05	13.68
	Total PCB Congeners (209)	19	19	419000	5690000	1536632	1219942
Atlantic menhaden	2,3,7,8-TCDD	6	6	25	79.1	45.45	24.51
Bluefish	2,3,7,8-TCDD	2	2	37.8	66.7	52.25	20.44
Brown bullhead	2,3,7,8-TCDD	6	6	7.8	190	91.3	70.72
	Total PCB Congeners (209)	6	6	259000	1700000	878667	621157
Common carp	2,3,7,8-TCDD	12	12	5.2	1400	409.18	380.11
	Total PCB Congeners (209)	12	12	1520000	7860000	4133333	2020555
Juvenile striped bass	2,3,7,8-TCDD	3	3	75.2	95.9	82.8	11.39
White perch	2,3,7,8-TCDD	37	37	18	352	169.38	86.2
	Total PCB Congeners (209)	19	19	289000	5140000	2175474	1193440

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
ng/kg = nanograms per kilogram
PCB = polychlorinated biphenyl

Table 4-3
Dietary Exposure Parameters for Great Blue Heron

Parameter	Abbreviation	Value	Units	Reference	Note
Sediment ingestion rate	IR_{sed}	0.008424	kg/d	Beyer et al. 1994	a
Tissue ingestion rate	IR_{tissue}	0.4212	kg/d	USEPA 1993	b
Site use factor	SUF	0.75	unitless	USEPA 1993	c
Water ingestion rate	IR_{water}	0.1	L/day	USEPA 1993	d
Body weight	BW	2.34	kg	USEPA 1993	

Notes:
a. Estimated to be 2% based on blue-winged teal and duck.
b. Based on ingestion rate of 0.18 gram per gram per day (g/g-day).
c. Most migrating herons leave their breeding grounds by October or November and return between February and April. Conservatively assumed that herons only migrate between November and February.
d. Based on ingestion rate of 0.045 g/g-day.

kg = kilograms
kg/d = kilograms per day
L/day = liters per day
USEPA = U.S. Environmental Protection Agency

Table 5-1
Toxicity Reference Values for Benthic Invertebrates (Whole Body Tissue Residues)

Species	TRVs (pptr)					
	2,3,7,8-TCDD			Total PCBs		
	NOAEL	LOAEL	Reference	NOAEL	LOAEL	Reference
Grass shrimp				**4.2E+05**	**1.1E+06**	**Hansen et al. 1974**
Grass Shrimp				1.8E+07	2.7E+07	Nimmo et al. 1974
Grass Shrimp				5.4E+06	6.5E+07	Nimmo et al. 1974
Pink shrimp				1.3E+06	3.9E+06	Duke et al. 1970
Pink shrimp					1.6E+07	Duke et al. 1970
Pink shrimp					3.3E+07	Duke et al. 1970
Brown shrimp				3.8E+06	4.2E+07	Hansen et al. 1974
American oyster				4.0E+06	3.2E+07	Hansen et al. 1974
Eastern oyster				8.1E+06	3.3E+07	Duke et al. 1970
Eastern oyster				1.0E+08	1.2E+08	Lowe et al. 1972
Eastern oyster					3.5E+04	Wintermyer and Cooper 2003
Blue mussel				1.4E+06	1.4E+06	Velduizen-Tsoerkan et al. 1991
Blue mussel				3.7E+06		Eertman et al. 1996
Blue mussel				1.5E+05		Krishnakumar et al. 1999
Blue mussel					2.0E+04	Einsporn and Koehler 2008
Scallop					5.0E+01	Liu et al. 2009
Bent nose clam				1.7E+06		Boese et al. 1995
Soft shell clam		2 - 10	Cooper and Wintermeyer 2009			
Cladoceran					1.2E+07	Kwon and Fisher 2006 (unpub)
Blue crab				2.3E+07		Duke et al. 1970
Amphipod				2.9E+07		Borgmann et al. 1990
Amphipod					7.6E+07	Nebeker and Puglisi 1974
Amphipod				1.3E+08	5.5E+08	Nebeker and Puglisi 1974
Polychaete					3.6E+07	Rice et al. 2000
Polychaete					2.0E+08	Fowler et al. 1978
Midge					8.9E+07	Kwon and Fisher 2006 (unpub)

Notes: see notes after Table 5-3.

Table 5-2
Toxicity Reference Values for Fish (Whole Body Tissue Residues)

	TRVs (pptr)					
	2,3,7,8-TCDD			Total PCBs		
Species	**NOAEL**	**LOAEL**	**Reference**	**NOAEL**	**LOAEL**	**Reference**
Mummichog	300		Salomon 1994			
Mummichog	122	300	Salomon 1994	1.5E+07		Matta et al. 2001
Mummichog				7.6E+05	3.8E+06	Black et al. 1998
Sheepshead minnow				1.9E+06	9.3E+06	Hansen et al. 1974b
Sheepshead minnow				7.7E+07	2.0E+08	Hansen et al. 1975
Minnow (*Phoxinus phoxinus*)					2.5E+07	Bengtsson 1980
Fathead minnow		69000	Adams et al. 1986	5.3E+06	1.4E+07	Dillon 1988
Fathead minnow				3.6E+08		DeFoe et al. 1978
Fathead minnow					5.0E+07	DeFoe et al. 1978
Fathead minnow				196000000 (males) 429000000 (females)	1.0E+09	Nebeker et al. 1974
Spottail shiner	5400	103000	Olivieri and Cooper 1997	1.5E+07	1.7E+08	Bengtsson 1980
Bluegill	5000	25000	Kleeman et al. 1988			
Bluegill	1000	5000	Kleeman et al. 1988			
Pumpkinseed				1.5E+06	1.7E+07	Bengtsson 1980
Pumpkinseed	290	600	Walker et al. 1994	5.0E+05		Adams et al. 1989, 1990, 1992
Japanese medaka	2400	2410	Schmieder et al. 1995			
Yellow perch	290	600	Walker et al. 1994	1.5E+06	1.7E+07	Bengtsson 1980
Yellow perch	143		Kleeman et al. 1986			
Yellow perch	129		Kleeman et al. 1986			
Yellow perch	1000	5000	Kleeman et al. 1988			
Yellow perch	1000	5000	Spitsbergen et al. 1988a			
White perch	290	600	Walker et al. 1994	1.5E+06	1.7E+07	Bengtsson 1980
White perch				3.1E+06		Westin et al. 1983
Common carp		2200	Cook et al. 1991			
Channel catfish				3.2E+07		Mayer et al. 1977
Channel catfish				1.3E+07		Mayer et al. 1977
Channel catfish				2.1E+07		Mayer et al. 1977
Brown bullhead	8000	18000	Elonen et al. 1998	1.5E+06	1.7E+07	Bengtsson 1980
Lake whitefish	**46**	**85**	**Fisk et al. 1997**			
Largemouth bass	290	600	Walker et al. 1994	1.5E+06	1.7E+07	Bengtsson 1980
Largemouth bass	5000	25000	Kleeman et al. 1988	5.0E+05		Adams et al. 1989, 1990, 1992
Striped bass	290	600	Walker et al. 1994	1.5E+06	1.7E+07	Bengtsson 1980
Striped bass				3.1E+06		Westin et al. 1983
Striped bass				4.4E+06		Westin et al., 1983
Shortnose sturgeon	290	600	Walker et al. 1994	1.5E+06	1.7E+07	Bengtsson 1980
Pinfish						Hansen et al. 1971
Pinfish					1.1E+08	Hansen et al. 1974b
Pinfish				1.7E+07		Duke et al. 1970
Common barbel				**5.2E+05**	**2.6E+06**	**Hugla and Thome 1999**
Spot				2.7E+07	4.6E+07	Hansen et al. 1971
Goldfish					2.5E+08	Hattula and Karlog 1972
Zebrafish				1.1E+06	2.7E+06	Orn et al. 1998
Rainbow trout	72	150	Fisk et al. 1997	8.2E+06		Lieb et al. 1974
Rainbow trout		780	Branson et al. 1985	1.2E+08		Mayer et al. 1985
Rainbow trout		650	Branson et al. 1985			
Rainbow trout		980	Mehrle et al. 1988	7.0E+07	1.2E+08	Mayer et al. 1985
Rainbow trout		990	Mehrle et al. 1988	8.0E+07		Nestel and Budd 1975
Rainbow trout	2500	11900	Mehrle et al. 1988			
Rainbow trout	1570	1380000	Hawkes and Norris 1977			
Rainbow trout	1000	5000	Kleeman et al. 1988			
Rainbow trout	250		Kleeman et al. 1988			
Rainbow trout	1000	5000	Spitsbergen et al. 1988b			
Rainbow trout	1000	5000	van der Weiden et al. 1990			
Brook trout	1486		Tietge et al. 1998	3.1E+07	7.1E+07	Mauck et al. 1978
Brook trout	150	300	Tietge et al. 1998, Johnson et al. 1998	7.1E+07	1.3E+08	Mauck et al. 1978
Lake trout				1.8E+06	2.4E+06	Mac and Seelye 1981b
Lake trout				7.3E+06	7.3E+06	Mac and Seelye 1981a
Lake trout					1.5E+06	Berlin et al. 1981
Coho salmon	125	2170	Miller et al. 1979	3.9E+06	6.5E+08	Mayer et al. 1977
Coho salmon	125	478	Miller et al. 1979	1.0E+06	4.0E+06	Gruger et al. 1976
Chinook salmon				9.8E+05		Powell et al. 2003
Chinook salmon				6.0E+07		Powell et al. 2003

Notes: see notes after Table 5-3.

Table 5-3
Toxicity Reference Values for Birds (dietary-based TRVs, unless noted as egg which are tissue-based)

	TRVs (pptr)					
	2,3,7,8-TCDD			Total PCBs		
Species	**NOAEL**	**LOAEL**	**Reference**	**NOAEL**	**LOAEL**	**Reference**
Cormorant	3700	11000	lab data - USEPA (2003)	2.5E+07		Parsons 2003
Cormorant	3670	11090	lab data - USEPA (2003)	7.3E+06	7.3E+06	Yamashita et al. 1993
Cormorant		350	field data - USEPA (2003)		7.3E+06	Larson et al. 1996
Cormorant (egg)	1000	4000	Powell et al. 1997	2.0E+04	4.0E+04	Powell et al. 1997
Cormorant (egg)	1300	5400	Powell et al. 1998	7.0E+03	1.8E+04	Powell et al. 1998
Cormorant (egg)	3000	10000	Sanderson and Bellward 1995			
Cormorant		134.2	Larson et al. 1996			
Herring gull	50000		lab data - USEPA (2003)		1.4E+07	Grasman et al. 1996
Black-headed gull	50000		lab data - USEPA (2003)			
Mallard	35000		lab data - USEPA (2003)	2.6E+05	2.6E+06	Custer and Heinz 1980
Mallard				3.9E+06		Risebrough and Anderson 1975
Mallard					1.5E+07	Haseltine and Prouty 1980
Mallard				2.5E+06		Custer and Heinz 1980
Wood duck	5	20	field data - USEPA (2003)			
Great blue heron	13	100	field data - USEPA (2003)			
Great blue heron	1.4	14	Nosek et al. 1992	1.0E+04	7.0E+04	Scott 1977
Great blue heron (egg)	220	360	Elliot et al. 2001			
Osprey	140		field data - USEPA (2003)			
Common tern		4400	lab data - USEPA (2003)			
Common tern		4400	Hoffman et al. 1998			
Forster's tern	350		field data - USEPA (2003)			
Caspian tern	1440	1420	field data - USEPA (2003)			
Bald eagle	2.8		Elliot and Normstrom 1998			
Kingfisher	1.4	14	Nosek et al. 1992	1.0E+04	7.0E+04	Scott 1977
Chicken				1.0E+05	4.0E+05	Chapman 2003
American kestrel					7.0E+06	Fernie et al. 2003a
American kestrel					9.5E+06	Bird et al. 1983
American kestrel						Fernie et al. 2000, 2001, 2003a, 2003b
Ring-necked pheasant	**14.3**	**143**	**Nosek et al. 1992**	6.0E+05	1.8E+06	Dahlgren et al. 1972
Ring-necked pheasant	710	7940	Fredericks et al. 2011			
White leghorn, cockerels	1000		Schwetz et al. 1973			
White leghorn, cockerels	100	1000	Schwetz et al. 1973			
White leghorn chickens				2.9E+05	2.9E+06	Platonow and Reinhart 1973
White leghorn males				5.4E+04		Ahmed et al. 1978
Screech owl				**4.9E+05**		**McLane and Hughes 1980**
Ringed turtle-dove					**1.4E+06**	**Peakall et al. 1972; Peakall and Peakall 1973**
Mourning dove					1.6E+06	Tori and Peterle 1983

Notes: see notes after Table 5-3.

Notes:

Bold TRVs are the TRVs recommended by the Cooperating Parties Group.
LOAEL = lowest observed adverse effects level
NOAEL = no observed adverse effects level
PCB = polychlorinated biphenyl
pptr = parts per trillion (picograms per gram or nanograms per kilogram)
TRV = Toxicity Reference Value

References:

Adams, W.J., Degraeve, G.M., Sabourin, T.D., Cooney, J.D., and Mosher, G.M. 1986. Toxicity and bioconcentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin to fathead minnows (Pimephales promelas). Chemosphere, 15:1503-11

Adams, S.M., K.L. Shepard, M.S. Greeley Jr., B.D. Jimenez, M.G. Ryon, L.R. Shugart, and J.F. McCarthy. 1989. The use of bioindicators for assessing the effects of pollutant stress on fish.Marine Environmental Research. 28:459-464.

Adams, S.M., L.R. Shugart, G.R. Southworth and D.E. Hinton. 1990. Application of bioindicators in assessing the health of fish populations experiencing contaminant stress. In: J.F. McCarthy and L.R. Shugart, eds., Biomarkers of Environmental Contamination. Lewis Publishers, Boca Raton, FL. Pp. 333-353.

Adams, S.M., W.D. Crumby, M.S. Greeley, Jr., M.G. Ryon, and E.M. Schilling. 1992. Relationships between physiological and fish population responses in a contaminated stream. Environmental Toxicology and Chemistry. 11:1549-1557.

Ahmed T., G.H. Arscott, and I.J. Tinsley. 1978. Effect of chlorinated hydrocarbons on reproductive performance of adult white leghorn male chickens. Poult Sci 57:1594-1598.

Bengtsson, B.E. 1980. Long-term effects of PCB (Clophen A50) on growth, reproduction and swimming performance in the minnow, Phoxinus phoxinus. Water Research, Vol. 1, pp. 681-687.

Berlin, W.H., R.J. Hesselberg, and M.J. Mac. 1981. Growth and mortality of fry of Lake Michigan lake trout during chronic exposure to PCBs and DDE. U.S. FWS Technical Paper No. 105. U.S. Fish & Wildlife Service, Washington, DC.

Bird, P.H., P.H. Tucker, G.A. Fox, and P.C. Lague. 1983. Synergistic effects of Aroclor 1254 and Mirex on the semen characteristics of American Kestrels. Arch. Environ. Contam. Toxicol. 12:633–640.

Black, D.E., R. Gutjahr-Gobell, R.J. Pruell, B. Bergen, and A.E. McElroy. 1998. Effects of a mixture of nonortho-and mono-ortho-polychlorinated biphenyls on reproduction in Fundulus heteroclitus (Linnaeus). Environmental Toxicology & Chemistry 17(7):1396–1404.

Boese, B.L., M. Winsor, H. Lee Li, S. Echols, J. Pelletier and R. Randall. 1995. Environ Tox & Chem 14:303-310

Borgmann, U., Norwood, W.P., Ralph, K.M., 1990. Chronic toxicity and bioaccumulation of 2,5,20,50-tetrachlorobiphenyl and 3,4,30,40-tetrachlorobiphenyl and aroclor 1242 in the amphipod Hyalella-azteca. Arch. Environ. Contam. Toxicol. 19, 558–564.

Branson, D.R., I.T. Takahashi, W.M. Parker, and G.E. Blau. 1985. Bioconcentration kinetics of 2,3,7,8-tetrachlorodibenzo-p-dioxin in rainbow trout. Environmental Toxicology & Chemistry 4:779–788.

Cheung, C.C.C., G.J. Zheng, P.K.S. Lam, and B.J. Richardson. 2002. Mar pollut Bull 45:181-191

Cook, P.M., D.W. Kuehl, M.K. Walker, and R.E. Peterson. 1991. Bioaccumulation and toxicity of TCDD and related compounds in aquatic ecosystems. p. 1-18, In M.A. Gallo, R.J. Scheuplein and K.A. Van Der Heijden, eds. Biological basis for risk assessment of dioxins and related compounds. Banbury Report 35. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY.

Cooper, K.R. and M. Wintermyer. 2009. A Critical Review: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) Effects on Gonad Development in Bivalve Mollusks. J. Env. Sci. Health Part C 27: 226-245.

Custer, T.W., and G.H. Heinz. 1980. Reproductive success and nest attentiveness of mallard ducks fed Aroclor 1254. Environmental Pollution (Series A) 21:313–318.

Dahlgren, R.B., R.L. Linder, and C.W. Carlson. 1972. Polychlorinated biphenyls: their effects on penned pheasants. Environmental Health Perspectives 1:89–101.

DeFoe, D.L., G.D. Veith, and R.W. Carlson. 1978. Effects of Aroclor 1248 and 1260 on the fathead minnow (Pimephales promelas). Journal of the Fisheries Research Board of Canada 35:997–1002.

Dillon, T.M. 1988. Environmental effects of dredging. Technical notes. Relationship between PCB tissue residues and reproductive success of fathead minnows. EEDP-01-13. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Duke, T.W., J.I. Lowe, and A.J. Wilson, Jr. 1970. A polychlorinated biphenyl (Aroclor 1254) in the water, sediment, and biota of Escambia Bay, Florida. Bulletin of Environmental Contamination & Toxicology5(2):171–180

Eertman, R.H.M., W. Zurburg, C.A. Schipper, B. Sandee, and A.C. Smaal. 1996. Comp Biochem Physiol 113C:267-272

Einsporn, S., and A. Koehler. 2008. Mar Environ Res. 66: 185-186

Elliott, J.E. and R.J. Norstrom. 1998. Chlorinated hydrocarbon contaminants and productivity of bald eagle populations on the Pacific coast of Canada, Environ. Toxicol. Chem. 17: 1142-1153.

Elliott, J.E., M.L. Harris, L.K. Wilson, P.E. Whitehead, and R.J. Norstrom. 2001. Monitoring temporal and spatial trends in polychlorinated dibenzo-pdioxins (PCDDs) and dibenzofurans (PCDFs) in eggs of great blue heron (Ardea herodias) on the coast of British Columbia, Canada, 1983- 1998. Ambio 30:416–428.

Elonen, G.E., R.L. Spehar, G.W. Holcombe, R.D. Johnson, J.D. Fernandex, R.J. Erickson, J.E. Tietge, and P.M. Cook. 1998. Comparative toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin to seven freshwater fish species during early life-stage development. Environmental Toxicology and Chemistry. 17:3, pp 472-483.

Faria, M. L. Carrasco, S. Diaz, M.C. Riva, J.M. Bayona, and C. Barata. 2009. Comp. Biochem. Phys Part C: 149-281-288.

Health A 60:291–303.

Fernie, K. J., Bortolotti, G. R., Smits, J. E., Wilson, J., Drouillard, K. G., and Bird, D. M. 2000. Changes in egg composition of American kestrels exposed to dietary polychlorinated biphenyls. J. Toxicol. Environ. Health A 60:291–303

Fernie, K.J., J.E. Smits, G.R. Bortolotti, and D.M. Bird. 2001a. In ovo exposure to polychlorinated biphenyls: reproductive effects on second-generation American kestrels. Archives of Environmental Contamination & Toxicology 40:544–550.

Fernie, K.J., J.E. Smits, G.R. Bortolotti, and D.M. Bird. 2001b. Reproductive success of American kestrels exposed to dietary polychlorinated biphenyls. Environ. Toxicol. Chem. 20:776–781.

Fernie K.J., J.E. Smits, and G.R. Bortolotti. 2003a. Developmental toxicity of in ovo exposure to polychlorinated biphenyls. I. Immediate and subsequent effects on first generation nestling American kestrels (Falco sparverius). Environ Toxicol Chem 22:554–560.

Fernie, K., G. Bortolotti, and J. Smits. 2003b. Reproductive abnormalities, teratogenicity, and developmental problems in American kestrels (Falco sparverius) exposed to polychlorinated biphenyls. Journal of Toxicology and Environmental Health-Part A 66(22):2089-2103.

Fisk A.T., A.L. Yarechewski, D.A. Metner, R.E. Evans, W.L. Lockhart, and D.C.G. Muir. 1997. Accumulation, depuration and hepatic mixed-function oxidase enzyme induction in juvenile rainbow trout and lake whitefish exposed to dietary 2,3,7,8-tetrachlorodibenzo-p-dioxin. Aquat Toxicol 37:201-220.

Fowler, S. W. , G. G. Polikarpov, D. L. Elder, P. Parsi, and J.P. Villeneuve. 1978. Polychlorinated biphenyls: Accumulation from contaminated sediments and water by the polychaete Nereis diversicolor. Marine Biology 48:303-309.

Fredericks, T.B. M.J. Zwiernik, R.M. Seston, S.J. Coefield, D.L. Tazelaar, S.A. Roark, D.P. Kay, J.L. Newsted, and J.P. Giesy. 2011. Effects on tree swallows exposed to dioxin-like compounds associated with the Tittabawassee River and floodplain near Midland, Michigan, USA. Environmental Toxicology and Chemistry 30:1354-1365.

Galbraith Environmental Sciences, LLC. 2003. Tittabawassee River Aquatic Ecological Risk Assessment. Michigan Department of Environmental Quality, Remediation and Redevelopment Division, Saginaw Bay District.

Grasman, K.A. G.A. Fox, P.F. Scanlon, and J.P. Ludwig. 1996. Organochlorine-associated immunosuppresin in prefledgling Caspian terns and herring gulls from the Great Lakes: An ecoepidemiological perspective. Environmental Health Perspectives 104: 829-84

Gruger, E.H., Jr., M.M. Wekell, and P.A. Robisch. 1976. Effects of chlorinated biphenyls and petroleum hydrocarbons on the activity of hepatic aryl hydrocarbon hydroxylase of coho salmon (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha). Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms, Seattle, WA. 1977. D.A. Wolfe (ed.). Pergamon Press, pp. 323–331.

Hansen, D.J., P.R. Parrish, J.I. Lowe, A.J. Wilson, Jr., and P.D. Wilson. 1971. Chronic toxicity, uptake, and retention of Aroclor 1254 in two estuarine fishes. Bulletin of Environmental Contamination & Toxicology 6(2):113–119.

Hansen D., P. Parrish, J. Forester. 1974a. Aroclor 1016: Toxicity to and uptake by estuarine animals. ENVIRON RES 01/1974; 7(3):363-373.

Hansen, D.J., S.C. Schimmel, and J. Forester. 1974b. Aroclor 1254 in eggs of sheepshead minnows: effect on fertilization success and survival of embryos and fry. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm., pp. 420–426.

Hansen, D.J., S.C. Schimmel, and E. Matthews. 1974c. Avoidance of Aroclor 1254 by shrimp and fishes, Bull. of Environ. Contam. and Toxicol. 12(2):253-293.

Hansen, D. J., S.C. Schimmel, and J. Forester. 1975. Effects of Aroclor 1016 on embryos, fry, juveniles and adults of sheepshead minnows(Cyprinodon variegatus). — Trans. Am. Fish. Soc.104, 584–588

Haseltine, S.D., L. Sileo, D.J. Hoffman, and B.D. Mulhern. 1985. Effects of chromium on reproduction and growth in black ducks. Unpublished. Not seen as cited in ORNL 1996.

Haseltine, S.D., and R.M. Prouty. 1980. Aroclor 1242 and reproductive success of adult mallards (Anas platyrhynchos). Environmental Research. 23:29-34.

Hattula, M.L., and O. Karlong. 1972. Toxicity of polychlorinated biphenyls (PCB) to goldfish. Acta Pharmacologica et Toxicological 31: 238-240.

Hoffman, D.J., M.J. Melancon, P. N. Klein, J.D. Eisemann, and J.W. Spann. 1998. Comparative developmental toxicity of planar polychlorinated biphenyl congeners in chickens, American kestrels, and common terns. Environ. Toxicol. Chem., 17:747-757.

Hugla, J.L., and J.P. Thome. 1999. Effects of polychlorinated biphenyls on liver ultrastructure, hepatic monooxygenases, and reproductive success in the barbel. Ecotox Environ Saf 42:265-273

Johnson, R.D., J. Tietge, K. Jensen, J. Fernandez, A.L. Linnum, D. Lothenbach, G.W. Holcombe, P.M. Cook, S.A. Christ, D.L. Lattier, and D.A. Gordon. 1998. Toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin to early life stage brook trout (Salvelinus fontinalis) following parental dietary exposure. Environmental Toxicology & Chemistry 17(12):2408–2412.

Kleeman, J.M., J.R. Olson, and R.E. Peterson. 1988. Species differences in 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity and biotransformation in fish. Fundamental & Applied Toxicology 10:206–213.

Kleeman, J.M., J.R. Olson, S.M. Chen, and R.E. Peterson. 1986. 2,3,7,8-tetrachlorodibenzo-p-dioxin metabolism and disposition in yellow perch. Toxicology & Applied Pharmacology 83:402–411.

Krishnakumar, P.K., E. Casillas, R.G. Snider, A.N. Kagley, and U. Varanasi. 1999. J Invert. Path. 73: 135-146.

Larson, J.M., W.H. Karasov, L. Sileo, K.L. Stromborg, B.A. Hanbidge, J.P. Giesy, P.D. Jones, D.E. Tillitt, and D.A. 1996. Verbrugge. Reproductive success, developmental anomolies, and environmental contaminants in double-crested cormorants (Phalacrocorax auritas). Environmental Toxicology and Chemistry 15: 553-559.

Lieb, A.J., D.D. Bills, and R.O. Sinnhuber. 1974. Accumulation of dietary polychlorinated biphenyls (Aroclor 1254) by rainbow trout. J. Agric. Food Chem. 22(4):638–642.

Liu-Qing, P, L. Zhang, J. Miao, and J. Wang. 2009. Fish Shellfish Imm. 26: 422-428

Livingston, D.R., C. Nasci, M. Sole, L. Da Ros, S.C.M. O'Hara, L.D. Peters, V. Fossato, A.N. Wootton, and P.S. Goldfarb. 1997. Aquat Toxicol 38:205-224

Lowe, J.I., P.R. Parrish, J.M. Patrick Jr., and J. Forester 1972. Effects of the polychlorinated biphenyl Aroclor® 1254 on the American oyster Crassostrea virginica. Marine Biology 17:209-214.

Mac, M.J., and J.G. Seelye. 1981a. Patterns of PCB accumulation by fry of lake trout. Bull. Environ. Contam. Toxicol., 27: 368-375.

Mac, M.J., and J.G. Seelye. 1981b. Potential influence of acetone in aquatic bioassays testing the dynamics and effects of PCBs. Bulletin of Environmental Contamination & Toxicology 27:359–367.

Matta, M.B., J. Linse, C. Cairncross, L. Francendese, and R.M. Kocan. 2001. Reproductive and transgenerational effects of methylmercury or Aroclor 1268 on Fundulus heteroclitus. Environmental Toxicology & Chemistry 20(2):327–335.

Mauck, W.L., P.M. Mehrle, and F.L. Mayer. 1978. Effects of the polychlorinated biphenyls Aroclor 1254 on growth, survival, and bone development in brook trout (Salvelinus fontinalis). Journal of the Fisheries Research Board of Canada 35:1084–1088.

Mayer, F.L., P.M. Mehrle, and H.O. Sanders. 1977. Residue dynamics and biological effects of polychlorinated biphenyls in aquatic organisms. Archives of Environmental Contamination & Toxicology 5:501–511.

Mayer, K.S., F.L. Mayer, and A. Witt. 1985. Waste transformer oil and PCB toxicity to rainbow trout. Trans Am Fish Soc 114: 869–886.

McLane, M.A., and D.L. Hughes. 1980. Reproductive success of screech owls fed Aroclor 1248. Archives of Environmental Contamination & Toxicology 9:661–665.

Mehrle, P.M., D.R. Buckler, E.E. Little, L.M. Smith, J.D. Petty, P.H. Peterman, D.L. Stalling, G.M. de Graeve, J.J. Coyle, and W.J. Adams. 1988. Toxicity and bioconcentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2,3,7,8-tetrachlorodibenzofuran in rainbow trout. Environmental Toxicology & Chemistry 7:47–62.

Miller, R.A., L.A. Norris, and B.R. Loper. 1979. The response of coho salmon and guppies to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in water. Transactions of the American Fisheries Society 108:401–407.

Nebeker, A.V., F.A. Puglisi, and D.L. DeFoe. 1974. Effect of polychlorinated biphenyl compounds on survival and reproduction of the fathead minnow and flagfish. Transactions of the American Fisheries Society 103(3):562–568.

Nebeker, A.V., and F.A. Puglisi. 1974. Effect of polychlorinated biphenyls (PCBs) on survival and reproduction of daphnia, gammarus, and tanytarsus, Trans. Am. Fish. Soc. 103(4):722-728.

Nestel, H., and J. Budd. 1975. Chronic oral exposure of rainbow trout (Salmo gairdneri) to a polychlorinated biphenyl (Aroclor 1254): pathological effects. Canadian Journal of Comparative Medicine 39:208-215.

Nimmo, D.R., J. Forester, P.T. Heitmuller, and G.H. Cook. 1974. Accumulation of Aroclor 1254 in grass shrimp (Palaemonetes pugio) in laboratory and field exposures. Bulletin of Environmental Contamination & Toxicology 11(4):303–308.

Nosek, J.A., S.R. Craven, J.R. Sullivan, S.S. Hurley, and R.E. Peterson. 1992. Toxicity and reproductive effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin in ring-necked pheasant hens. Journal of Toxicology and Environmental Health 35:187–198.

Olivieri, C.E., and K.R. Cooper. 1997. Toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in embryos and larvae of the fathead minnow (Pimephales promelas). Chemosphere 34(5-7):1139-1150.

Orn, S., P.L. Andersson, L. Forlin, M. Tysklind, and L. Norrgren. 1998. The impact on reproduction of an orally administered mixture of selected PCBs in zebrafish (Danio rerio). Archives of Environmental Contamination & Toxicology 35(1):52–57.

Parsons, K.C. 2003. Chemical resides in cormorants from New York Harbor and control locations. NY State Dept. of Environmental Conservation

Peakall, D.B., J.L. Lincer, and S.E. Bloom. 1972. Embryonic mortality and chromosomal alterations caused by Aroclor 1254 in ring doves. Environmental Health Perspectives(April):103–104.

Peakall, D.B., and M.L. Peakall. 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. Journal of Applied Ecology 10:863–868.

Platanow, N.S., and B.S. Reinhart. 1973. The effects of polychlorinated biphenyls (Aroclor 1254) on chicken egg production, fertility and hatchability. Can. J. Comp. Med. 37:341-346.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, J.F. Powell, J.C. Restum, K.L. Stromborg, and J.P. Giesy. 1997. Effects of 3,3',4,4',5-pentachlorobiphenyl (PCB 126), 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), or an extract derived from field-collected cormorant eggs injected into double-crested cormorant (Phalacrocorax auritus) eggs. Environ. Toxicol. Chem., vol. 16, no. 7, pp. 1450-1455.

Powell, D.C., R.J. Aulerich, J.C. Meadows, D.E. Tillitt, M.E. Kelly, K.L. Stromborg, M.J. Melancon, S.D. Fitzgerald, and S.J. Bursian. 1998. Effects of 3,3',4,4',5-pentachlorobiphenyl and 2,3,7,8-tetrachlorodibenzo-p-dioxin injected into the yolks of double-crested cormorant (Phalacrocorax auritus) eggs prior to incubation. Environ. Toxicol. Chem., vol. 17, no. 10, pp. 2035-2040.

Powell, D.B., R.C. Palm Jr., A. Skillman, and K. Godtgredsen. 2003. Immunocompetence of juvenile Chinook salmon against Listonella anguillarum following dietary exposure to Aroclor® 1254. Environmental Toxicology and Chemistry 22: 285-295.

Rice, C.A., M.S. Myers, M.L. Willis, B.L. French, and E. Casillas. 2000. From sediment bioassay to fish biomarker – connecting the dots using simple trophic relationships. Mar Environ Res 50:527-533.

Risebrough, R.W., and D.W. Anderson. 1975. Some effects of DDE and PCB on mallards and their eggs. Journal of Wildlife Management 39(3):508–513.

Salomon, K.S. 1994. Dietary uptake of 2,3,7,8-tetrachlorodibenzo-p-dioxin and its effects on reproduction in the common mummichog (Fundulus heteroclitus). Master's Thesis, University of Rhode Island, Kingston, RI.

Sanders, H.O., and J.H. Chandler. 1972. Biological magnification of a polychlorinated biphenyl (Aroclor 1254) from water by aquatic invertebrates. Bulletin of Environmental Contamination & Toxicology 7/8:257–263.

Sanderson, J.T., and G.D. Bellward. 1995. Hepatic microsomal ethoxyresorufin O-deethylase-inducing potency in ovo and cytosolic Ah receptor binding affinity of 2,3,7,8-tetrachlorodibenzo-p-dioxin: comparison of four avian species. Toxicol Appl Pharmacol 132: 1

Schmieder, P., D. Lothenbach, J. Tietge, R. Erickson, and R. Johnson. 1995. [3H]-2,3,7,8-TCDD uptake and elimination kinetics of medaka (Oryzias latipes). Environmental Toxicology and Chemistry 14: 1735-1743.

Schwetz, B.A., J.M. Morris, G.L. Sparschu, V.K. Rowe, P.J. Gehring, J.L. Emerson, and C.G. Gerbig. 1973. Toxicology of chlorinated dibenzo-p-dioxins. Environmental Health Perspectives 5:87–99.

Scott, M.L. 1977. Effects of PCBs, DT, and mercury compounds in chickens and Japanese quail. Federation Proceed. 36:1888-1893.

Spitsbergen, J.M., J.M. Kleeman, and R.E. Peterson. 1988a. 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity in yellow perch (Perca flavescens). Journal of Toxicology and Environmental Health 23:359–383.

Spitsbergen, J.M., J.M. Kleeman, and R.E. Peterson. 1988b. Morphologic lesions and acute toxicity in rainbow trout (Salmo gairdneri) treated with 2,3,7,8-tetrachlorodibenzo-p-dioxin. Journal of Toxicology and Environmental Health 23:333–358.

Tietge, J.E., R.D. Johnson, K. Jensen, P.M. Cook, G. Elonen, J. Fernandez, G.W. Holcombe, D. Lothenbach, and J.W. Nichols. 1998. Reproductive toxicity and disposition of 2,3,7,8-tetrachlorodibenzo-p-dioxin in adult brook trout (Salvelinus fontinalis) following a dietary exposure. Environmental Toxicology & Chemistry 17(12):2395–2407

Tori, G.M., and T.J. Peterle. 1983. Effects of PCBs on mourning dove courtship behavior. Bull. Environ. Contam. Toxicol. 30:44-49.

USEPA. 2003. Analyses of laboratory and field studies of reproductive toxicity in birds exposed to dioxin-like compounds for use in ecological risk assessment. EPA/600/R-03/114F. National Center for Environmental Assessment, US Environmental Protection Agency, Cincinnati, OH.

van der Weiden, M.E.J., J. van der Kolk, A.H. Penninks, W. Seinen, and M. van den Berg. 1990. A dose/response study with 2,3,7,8-TCDD in the rainbow trout (Oncorhynchus mykiss). Chemosphere 20(7–9):1053–1058.

Veldluizen-Tsoerkan, M.B., D.A. Holwerda, and D.I. Zandee. 1991. Arch Environ Contam Toxicol 20:259-265

Walker, M.K., P.M. Cook, A.R. Batterman, B.C. Buttworth, C.Berini, J.J. Libal, L.C. Hufnagle, and R.E. Peterson. 1994. Translocation of 2,3,7,8-tetrachlorodibenzo-p-dioxin from adult female lake trout (Salvelinus namaycush) to oocytes: effects on early life stage development and sac fry survival. Can. J. Fish. Aquat. Sci. 51:1410-1419.

Westin, D.T., C.E. Olney, and B.A. Rogers. 1983. Effects of parental and dietary PCBs and survival, growth, and body burdens of larval striped bass. Bull. Environ. Contam. Toxicol. 30:50-57.

Wintermyer, M. and K.R. Cooper. 2003. J Shellfish Research 22: 737-746.

Yamashita, N., S. Tanabe, J.P. Ludwig, H. Kurita, M.E. Ludwig, and R. Tatsukawa. 1993. Embryonic abnormalities and organochlorine contamination in double-crested cormorants (Phalacrocorax auritas) and Caspian terns (Hydroprogne caspia) from the Upper Great Lakes in 1988. Environmental Pollution 79: 163-173.

Table 5-4
Range of Toxicity Reference Values for Benthic Invertebrates, Fish, and Birds

Receptors	2,3,7,8-TCDD (pptr)				Total PCBs (pptr)			
	NOAEL		LOAEL		NOAEL		LOAEL	
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum
Benthic invertebrates (all)					1.50E+05	1.27E+08	5.00E+01	5.52E+08
Shrimp[a]					4.20E+05	1.80E+07	1.10E+06	6.50E+07
Amphipods					2.89E+07	1.27E+08	7.60E+07	5.50E+08
Oyster					4.00E+06	1.01E+08	3.53E+04	1.19E+08
Mussel					1.50E+05	3.72E+06	2.00E+04	3.32E+06
Clam			2	10	1.70E+06			
Blue crab					2.30E+07			
Forage fish (all)	122	5400	300	103,000	5.00E+05	3.60E+08	3.80E+06	9.99E+08
Mummichog	122	300			7.60E+05	1.50E+07	3.80E+06	
Other fish (all)	46	8000	85	1380000	5.00E+05	1.20E+08	1.53E+06	6.45E+08
Other fish (excluding salmonids)[b]	46	8000	85	25,000	5.00E+05	3.20E+07	2.64E+06	2.50E+08
Birds (all)	1.4	50,000	14	11,090	7.00E+03	2.47E+07	1.75E+04	1.50E+07
Birds (excluding non-piscivorous species)[c]	1.4	50,000	14	11,090	7.00E+03	2.47E+07	1.75E+04	1.50E+07

Notes:
a. Shrimp include brown, pink, and grass shrimp.
b. Other fish (excluding salmonids) excludes trout and salmon.
c. Birds (excluding non-piscivorous species) excludes kestrel, chicken, pheasant, owls, and doves.

LOAEL = lowest observed adverse effects level
NOAEL = no observed adverse effects level
PCB = polychlorinated biphenyl
pptr = parts per trillion (pg/g or ng/kg)

Table 6-1
Benthic Invertebrate and Fish Tissue Residue Evaluation

Chemical	Species	Average Whole Body Concentration (ng/kg)	TRV NOAEL Range	TRV LOAEL Range
2,3,7,8-TCDD	Polychaetes	6	300	3000
	Blue crab	57	300	3000
	Forage fish	63	122 - 5,400	300 - 103,000
	American eel	17	46 - 8,000	85 - 138,000
	Common carp	409	46 - 8,000	2,200
	White perch	169	290	600
Total PCBs	Polychaetes	54,300	-	36,000,000 - 200,000,000
	Blue crab	325,212	23,000,000	-
	Forage fish	533,367	500,000 - 360,000,000	3,800,000 - 999,000,000
	American eel	1,536,632	500,000 - 32,000,000	2,600,000 - 250,000,000
	Common carp	4,133,333	500,000 - 32,000,000	2,600,000 - 250,000,000
	White perch	2,175,474	1500000 - 3,100,000	17,000,000

Notes:
a. In the absence of a species-specific value, the TRV is the range for all species of fish.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
LOAEL = Lowest observed adverse effects level
NOAEL = No observed adverse effects level
PCB = polychlorinated biphenyl
TRV = Toxicity Reference Value

Table 6-2
Surface Water Summary Statistics for River Miles 0 to 10.2 (2011-2013)

Chemical Name	Sample Type	Unit	LPRSA River Mile	Sample Size	Number of Detections	Minimum Detection	Maximum Detection	Mean	Standard Deviation
2,3,7,8-TCDD	Total	pg/L	0	56	35	0.4	5.63	1.57	1.25
2,3,7,8-TCDD	Total	pg/L	1.4	56	46	0.48	15.4	3.73	3.66
2,3,7,8-TCDD	Total	pg/L	2.2 - 4.2	48	46	0.77	56	8.71	10.6
2,3,7,8-TCDD	Total	pg/L	4.2	8	6	0.7	13.6	4.27	4.42
2,3,7,8-TCDD	Total	pg/L	3 - 6.7	48	47	0.41	1870	91	371
2,3,7,8-TCDD	Total	pg/L	6.7	8	5	0.45	12.9	3.87	4.11
2,3,7,8-TCDD	Total	pg/L	10.2	57	49	0.07	81.3	7.61	13.9
Total PCB Congeners (209)	Total	ng/L	0	24	24	5.77	39.6	11.4	7.01
Total PCB Congeners (209)	Total	ng/L	1.4	24	24	6.76	43.1	15.8	8.5
Total PCB Congeners (209)	Total	ng/L	2.2 - 4.2	24	24	11.1	102	34.7	28
Total PCB Congeners (209)	Total	ng/L	3 - 6.7	24	24	11.4	71.3	26.9	17.6
Total PCB Congeners (209)	Total	ng/L	10.2	24	24	1.96	29.4	11.6	7.74

Notes:

a. Summary of surface water data collected by the Cooperating Parties Group from August 2011 through March 2013.

b. Field duplicates averaged.

c. One-half of the detection limit substituted for nondetects.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

LPRSA = Lower Passaic River Study Area

ng/L = nanograms per liter

PCB = polychlorinated biphenyl

pg/L = picograms per liter

Table 6-3
Summary Statistics for Mudflat Data

Chemical (ng/kg)	Number of Samples	Number of Detections	Minimum Detection	Maximum Detection	Mean	Standard Deviation
2,3,7,8-TCDD	17	16	32.3	7130	705	1679
Total PCB Congeners (209)	17	16	356000	18900000	1912608	4388286
Total PCB TEQ (bird)	17	16	44.5	3640	438	830
Total PCB TEQ (fish)	17	16	0.24	18.5	2.37	4.18
Total PCB TEQ (human/mammal)	17	16	2.88	230	28.8	52.2
Total TEQ (bird)	17	16	123	11000	1253	2539
Total TEQ (fish)	17	16	39.4	7290	777	1704
Total TEQ (human/mammal)	17	16	63	7500	804	1751
Total WHO Dioxin TEQ (bird)	17	16	43	7370	815	1716
Total WHO Dioxin TEQ (fish)	17	16	38.2	7270	775	1700
Total WHO Dioxin TEQ (human/mammal)	17	16	38.6	7270	775	1700

Notes:
a. Field duplicates averaged.
b. CPG data averaged by location.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ng/kg = nanograms per kilogram
PCB = polychlorinated biphenyl
TEQ = toxic equivalent
WHO = World Health Organization

Table 6-4
Exposure Point Concentrations for Great Blue Heron Food Web Model

Chemical	Sediment[a]		Tissue[b]		Surface Water[c]	
	Average (mg/kg)	95UCL (mg/kg)	Average (mg/kg)	95UCL (mg/kg)	Average (mg/L)	95UCL (mg/L)
2,3,7,8-TCDD	0.0007054	0.00248	0.00006853	0.0001045	1.846E-08	5.408E-08
Total PCB Congeners (209)	1.912608	6.551852	0.478625	0.557795	0.00002296	0.00002555
Total PCB TEQ (bird)	0.0004384	0.001315	0.0001399	0.0001542	1.846E-08	5.408E-08
Total TEQ (bird)	0.001253	0.003937	0.0002184	0.0002378	1.846E-08	5.408E-08
Total WHO Dioxin TEQ (bird)	0.0008153	0.00263	0.00007864	0.0001153	1.846E-08	5.408E-08

Notes:

Nondetects assume a value of one-half the detection limit.
5.0.

a. Mudflat sediment.

b. Forage fish and blue crab.

c. Concentrations of 2,3,7,8-TCDD in surface water used in lieu of TEQs.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
95UCL = 95 percent upper confidence limit
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
PCB = polychlorinated biphenyl
TEQ = toxic equivalent
WHO = World Health Organization

Table 6-5
Food Web Dietary Dose Model for Great Blue Heron (Average Assumptionsa)

Parameter	Value	Units
Sediment ingestion rate	0.008424	kg/d
Tissue ingestion rate	0.4212	kg/d
Site use factor	0.75	unitless
Water ingestion rate	0.1	L/day
Body weight	2.34	kg

Chemical	Average EPC_{sed} (mg/kg)	Average EPC_{tissue} (mg/kg ww)	Average EPC_{water} (mg/L)	Dose (mg/kg-day)	Range of TRVs for Piscivorous Birds (mg/kg-day)		Range of Hazard Quotients	
					$LOAEL_{low}$	$LOAEL_{high}$	$LOAEL_{low}$	$LOAEL_{high}$
2,3,7,8-TCDD	7.05E-04	6.85E-05	1.85E-08	1.12E-05	0.000014	0.01109	0.8	0.001
Total PCB Congeners (209)	1.91E+00	4.79E-01	2.30E-05	6.98E-02	0.07	0.07	1.0	1.0
Total PCB TEQ (bird)	4.38E-04	1.40E-04	1.85E-08	2.01E-05	0.000014	0.01109	1.4	0.002
Total TEQ (bird)	1.25E-03	2.18E-04	1.85E-08	3.29E-05	0.000014	0.01109	**2**	0.003
Total WHO Dioxin TEQ (bird)	8.15E-04	7.86E-05	1.85E-05	1.34E-05	0.000014	0.01109	1.0	0.001

Notes:
a. Average assumptions include:
Average tissue, water, and sediment concentrations
Migration period from November to February
Bold values indicate HQ>1

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
kg = kilogram
kg/d = kilograms per day
L/day = liters per day
mg/kg = milligrams per kilogram
mg/kg-day = milligrams per kilogram per day
mg/L = milligrams per liter
PCB = polychlorinated biphenyl
TEQ = toxic equivalent
TRV = Toxicity Reference Value
WHO = World Health Organization
ww = wet weight

Table 6-6
Food Web Dietary Dose Model for Great Blue Heron (Conservative Assumptionsa)

Parameter	Value	Units
Sediment ingestion rate	0.008424	kg/d
Tissue ingestion rate	0.4212	kg/d
Site use factor	1	unitless
Water ingestion rate	0.1	L/day
Body weight	2.34	kg

Chemical	95UCL EPC_{sed} (mg/kg)	95UCL EPC_{tissue} (mg/kg ww)	95UCL EPC_{water} (mg/L)	Dose (mg/kg-day)	Range of TRVs for Piscivorous Birds (mg/kg-day)		Range of Hazard Quotients	
					$LOAEL_{low}$	$LOAEL_{high}$	$LOAEL_{low}$	$LOAEL_{high}$
2,3,7,8-TCDD	2.48E-03	1.05E-04	5.41E-08	2.77E-05	0.000014	0.01109	**2.0**	0.003
Total PCB Congeners (209)	6.55E+00	5.58E-01	2.56E-05	1.24E-01	0.07	0.07	**1.8**	**1.8**
Total PCB TEQ (bird)	1.32E-03	1.54E-04	5.41E-08	3.25E-05	0.000014	0.01109	**2.3**	0.003
Total TEQ (bird)	3.94E-03	2.38E-04	5.41E-08	5.70E-05	0.000014	0.01109	**4.1**	0.005
Total WHO Dioxin TEQ (bird)	2.63E-03	1.15E-04	5.41E-08	3.02E-05	0.000014	0.01109	**2.2**	0.003

Notes:
a. Conservative assumptions include:
95UCLs for tissue, water, sediment
100% site use factor; no migratory period
Bold values indicate HQ>1

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
95UCL = 95 percent upper confidence limit
kg = kilogram
kg/d = kilograms per day
L/day = liters per day
mg/kg = milligrams per kilogram
mg/kg-day = milligrams per kilogram per day
mg/L = milligrams per liter
PCB = polychlorinated biphenyl
TEQ = toxic equivalent
TRV = Toxicity Reference Value
WHO = World Health Organization
ww = wet weight

Table 6-7
Avian Egg Evaluation

Chemical	Cormorant Egg Chemical Concentrations from Shooters Island (Parsons 2003) (ng/kg wet weight)			Cormorant Egg Tissue-Based TRVs (ng/kg in eggs)				
	Mean (Mean TEQ)	Min	Max	NOAEL		LOAEL		References
				Min	Max	Min	Max	
2,3,7,8-TCDD	59.8 (92)	8.6	201	1,000	3,000	4,000	10,000	Powell et al. 1997, Sanderson and Bellward 1995
Total PCB	13,900,000 (322)	1,980,000	40,400,000	7,000	20,000	40,000	180,000	Powell et al. 1997 and 1998

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
LOAEL = lowest observed adverse effect level
Max = maximum
Min = minimum
ng/kg = nanograms per kilogram
NOAEL = no observed adverse effect level
PCB = polychlorinated biphenyl
TEQ = toxic equivalent
TRV = Toxicity Reference Value

Timothy Iannuzzi

Principal Ecologist/Senior Vice President
Arcadis

SUMMARY

Mr. Iannuzzi is a scientist with more than 25 years of research and consulting experience and is the Chief Ecologist and Technical Knowledge and Innovation Leader for the Integrated Environmental Sciences and Technology (IES&T) Group and the Natural Resources Damage Assessment (NRDA) Practice within ARCADIS. His project work and management experience ranges from screening-level environmental assessments to multimillion-dollar, risk-based investigations of ecological and human health, NRDAs, environmental impact evaluations and ecological restoration. Mr. Iannuzzi also teaches courses in ecological risk and impact assessment in scientific conference/short-course forums and currently as a credited course at the University of Maryland.

Mr. Iannuzzi is currently managing a range of projects related to sediment contamination of industrialized waterways, NRD assessments/settlements, and ecological impact and restoration analyses for a variety of ecosystems. His responsibilities on these projects are broad-based and include developing technical strategies, designing studies, participating in regulatory negotiations and publishing and presenting scientific investigations, as well as managing staff and budgets. In addition, Mr. Iannuzzi is continuously involved in research into key areas related to estuarine and freshwater ecology, risk/impact assessment, NRDA and historical ecology. His publications includes more than 35 technical papers in peer review journals, two book chapters and senior authorship on a book entitled *A Common Tragedy, History of an Urban River* (Amherst Press, 2002) which chronicles the problems and challenge related to the NRD process and restoration of urban watersheds.

Mr. Iannuzzi is senior technical advisor and/or reviewer for several environmental risk assessment projects being performed throughout the United States. He has also led ecological risk assessments for numerous U.S. Environmental Protection Agency (USEPA) CERCLA (Superfund) projects, and been retained as a testifying expert for legacy contaminant-related cases. His technical experience includes performing remedial investigations/feasibility studies (RI/FSs) and NRDAs for a wide range of hazardous waste sites including Superfund sites, RCRA sites, oil/chemical spills, mining sites, and industrial manufacturing facilities.

Mr. Iannuzzi has particular risk-related expertise in polychlorinated dibenzo-p-dioxins/furans, polychlorinated biphenys (PCBs) and polycyclic aromatic hydrocarbons (PAHs). He has been working for more than 20 years on the Passaic River Superfund site in Newark, New Jersey where he has been evaluating the effects of dioxins/furans and related compounds on aquatic and wetlands organisms.

EDUCATION

SUNY Oneonta, Oneonta, NY	Biology	M.S.	1990
SUNY Oneonta, Oneonta, NY	Biology	B.S.	1987
SUNY Morrisville, Morrisville, NY	Natural Resource Conservation	A.A.S.	1984

YEARS OF EXPERIENCE

- Total - 25
- With ARCADIS - 14

PROFESSIONAL ASSOCIATIONS

- Atlantic Estuarine Research Society
- Coastal and Estuarine Research Federation
- Society for Environmental Toxicology and Chemistry
- Society of Ecological Restoration

LOWER PASSAIC RIVER AND NEWARK BAY PROJECT EXPERIENCE

Currently managing risk, environmental impact, and restoration assessments for the Lower Passaic River and Newark Bay, two large Superfund sites located in the New York/New Jersey Harbor Estuary. A key focus has been remedial investigation/feasibility study (RI/FS) risk assessments for sediment contamination. Contaminants of concern include PCDD/PCDFs, PCBs, PAHs, pesticides and metals. Participates in regulatory negotiations, designs and implements work plans and field sampling investigations, manages budgets and personnel and provides technical oversight. Conducted human health and ecological risk characterizations, sediment toxicity assessments, ecological investigations, combined sewer investigations and chemical fingerprinting evaluations. Prepared peer-reviewed manuscripts for applicable work assignments. Lead author on a book that chronicles the ecological, sociological and environmental impact history in the Passaic River/Newark Bay region, and broadly describes key NRD-related considerations in such waterways.

KEY PUBLICATIONS AND PRESENTATIONS

- Iannuzzi, J., M. Butcher, and **T. J. Iannuzzi** (2011). Evaluation of potential relationships between chemical contaminants in sediments and aquatic organisms from the lower Passaic River, New Jersey, USA. *Environ. Toxicol. Chem.* 30(7):1721-1728.
- **Iannuzzi, T. J.**, T. N. Armstrong, E. R. Long, J. Iannuzzi, and D. F. Ludwig (2008). Sediment quality triad assessment of an industrialized estuary of the northeastern USA. *Environ. Monit. Assess.* 139: 257-275.
- Kay, D. P., J. L. Newsted, M. T. BenKinney, **T. J. Iannuzzi**, and J. P. Giesy (2007). Passaic River interstitial porewater phase 1 toxicity identification evaluation. *Chemosphere* 70: 1737-1747.
- Ludwig, D. F. and **T. J. Iannuzzi** (2005). Incremental ecological exposure risks from contaminated sediments in an urban estuarine river. *Integrated Environ. Assess. Manag.* 1(4): 1-17.
- **Iannuzzi, T. J.**, D. F. Ludwig, J. C. Kinnell, J. M. Wallin, W. H. Desvousges, and R. W. Dunford (2002). *A Common Tragedy: History of An Urban Waterway*. Amherst Scientific Publishers, Amherst, Massachusetts.
- Ludwig, D. F. and **T. J. Iannuzzi** (2001). Incremental chemical risks and damages in urban estuaries: spatial and historical ecosystem analysis. *Coastal and Estuarine Risk Assessment*, eds. M. C. Newman, M. H. Roberts, Jr., and R. C. Hale. Boca Raton, Florida: Lewis Publishers.

Jacqueline Iannuzzi

Senior Scientist/Statistician
Arcadis

SUMMARY

Ms. Iannuzzi is a Senior Statistician and Scientist in ARCADIS. She has conducted a variety of statistical and other quantitative evaluations for site investigations, epidemiological and occupational health studies, human and ecological risk assessments, environmental forensic studies, and natural resource damage assessments (NRDA). Ms. Iannuzzi has provided statistical, quantitative, and sample design support on a variety of projects and her experience includes: evaluation of sediment toxicity from organic and inorganic contaminants to benthic invertebrates; sediment quality triad sampling design and analysis; sediment bioaccumulation studies; assessment of effects of exposure to dioxins/furans (PCDD/Fs) and polychlorinated biphenyls (PCBs) to birds; spatial analyses of contaminant exposure data in soils, water, sediments, and biota; fingerprint and source identification analysis (dioxins and PCBs); wildlife abundance and diversity studies (aquatic invertebrates, fish, birds) and associated techniques (nonmetric multi-dimensional scaling analysis, cluster analysis;); Bayesian modeling of population count data; habitat equivalency analysis (HEA); reliability analysis; Monte Carlo simulation; kriging and spatial simulation of contaminant concentrations; laboratory method comparison studies; development of site specific cleanup levels using dose response models; and database design. Ms. Iannuzzi has authored or co-authored a number of publications in peer reviewed scientific journals, co-authored a book chapter on estimating dose-response curves, and developed related presentations for scientific conferences. Ms. Iannuzzi is proficient in several statistical software programs (SAS, SPSS, Systat).

In addition to her career in environmental consulting, Ms. Iannuzzi has worked as a biostatistician and programmer for industry and in a university research hospital where she has performed analyses in support of occupational health assessments, clinical trials, longitudinal studies and behavioral research. Projects include a longitudinal study to identify risk factors for child abuse and neglect, clinical trials to determine the effects of interventions (e.g., exercise, diet) on health outcomes in gerontological research, evaluation of confounders in breast cancer research, reliability assessment of screening tests to predict probability of disease in beryllium-exposed workers, meta-analysis of occupational lead exposure and cognitive effect studies, reliability and validity analysis of psychometric questionnaires; and design and maintenance of large databases.

Ms. Iannuzzi also has a background in hydrogeology focused on soil and groundwater sampling, hydrogeological assessments, and groundwater modeling. She has designed, implemented, and managed site investigations at hazardous waste sites for governmental and industrial clients and in support of Superfund Remedial Investigation/Feasibility Studies (RI/FS).

EDUCATION

University of Southern Maine, Portland, ME	Statistics	M.A.	2000
Stockton State College, Pomona, NJ	Geology	B.S.	1985

YEARS OF EXPERIENCE

- Total - 20
- With ARCADIS - 9

PASSAIC RIVER AND NEWARK BAY PROJECT EXPERIENCE

Provide support for risk assessment for the Lower Passaic River (LPR) and Newark Bay, two large Superfund sites located in the New York/New Jersey Harbor Estuary. Evaluated relationships between sediment and biota tissue concentrations and developed a tool to predict bioaccumulation in aquatic organisms. Compared concentrations of chemicals within sediments using linear modeling. Evaluated the relevance and application of empirical models for predicting the uptake of contaminants within the systems' food web, the results of which were published in a scientific journal. Performed statistical

analyses and research in support of a bird abundance study, the results of which were published in a peer review journal. Performed research and multivariate statistical analyses in support of a sediment quality triad assessment, the results of which were published in a peer review journal. Reviewed various regulatory guidance documents for applicability to site contaminants and ecological risk assessment. Performed statistical analysis (ANOVA, ANCOVA) of sediment data in the LPR and Newark Bay. Provided sampling design support for a proposed ecological risk assessment in Newark Bay.

KEY PUBLICATIONS AND PRESENTATIONS

- **Iannuzzi, J.**, Butcher, M., and Iannuzzi, T. (2011). Evaluation of potential relationships between chemical contaminants in sediments and aquatic organisms from the lower Passaic River, New Jersey, USA. *Environmental Toxicology and Chemistry*, 30: 1721-1728.
- Ludwig, D. F., **J. Iannuzzi**, T. J. Iannuzzi, and J. K. Shisler (2010). Spatial and temporal habitat use patterns by water birds in an urban estuarine ecosystem: Implications for ecosystem management and restoration. *Human and Ecological Risk Assessment* 139: 257-275.
- Iannuzzi, T. J., T. N. Armstrong, E. R. Long, **J. Iannuzzi**, and D. F. Ludwig (2008). Sediment quality triad assessment of an industrialized estuary of the northeastern USA. *Environmental Monitoring and Assessment* 139: 257-275.
- Iannuzzi, T. J., M. Butcher, and **J. Iannuzzi** (2009). Limitations on the scientific credibility of empirical models for remedial decision-making: a case study of the biota-sediment accumulation factor (BSAF) for an urban river. Presentation at the *19th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) Europe Meeting*, Goteborg, Sweden, June.
- Ludwig, D. F., T. J. Iannuzzi, J. K. Shisler, J. M. Gonzalez, and **J. Iannuzzi** (2006). Time, space, and site-specific exposure factors for birds in urban estuaries. Presentation at the *27th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC)*, Montreal, Canada, November.

Melissa A. Beauchemin

Senior Environmental Scientist
Arcadis

SUMMARY

Ms. Beauchemin has over 13 years of experience as an environmental scientist, specializing in marine/aquatic ecology, sediment investigations, and ecological risk assessments. She uses a broad background in biology, aquatic toxicology, policy, and chemistry to assist clients in environmental decision-making.

Ms. Beauchemin serves as project/task manager for which she develops work plans, field sampling plans, quality assurance project plans, and assists with the design and implementation of the overall projects. She provides technical support for the interpretation of data, preparation, review, and production of reports. She is knowledgeable of analytical procedures for water, sediment, and biota and has served as the Principal Investigator for acute and chronic toxicity studies using benthic and aquatic invertebrates.

Ms. Beauchemin evaluates ecological risks to aquatic and terrestrial receptors from persistent environmental contaminants such as polychlorinated biphenyls (PCBs), dioxins/furans, polycyclic aromatic hydrocarbons (PAHs), pesticides (e.g., DDT), explosives and metals. Sites range in size from small landfills and streams to large rivers and 1200-acre upland habitats. They range from the local to international scale with major clients including chemical companies, wood-treating facilities, oil and gas, and pharmaceutical manufacturers.

EDUCATION

University of Massachusetts	Environmental Science/Policy, Coastal and Ocean Sciences	M.S.	2002
Stonehill College	Biology	B.S.	1998

YEARS OF EXPERIENCE

- Total - 13
- With ARCADIS – 6

PROFESSIONAL ASSOCIATIONS

- Society for Environmental Toxicology and Chemistry
- Environmental Business Council of New England

LOWER PASSAIC RIVER AND NEWARK BAY PROJECT EXPERIENCE

Project manager/ecological risk assessor for the preparation of the baseline ecological risk assessment, being performed as part of the overall Remedial Investigation for Newark Bay and its tributaries. The work is being conducted under the Superfund program, led by USEPA Region 2. Coordinates and works directly with the client and technical team, including outside consultants. Responsible for devising the important programmatic and strategic design of the ecological risk assessment, including designing the sampling and analysis of sediment and tissue for over 200 chemical constituents. Specific activities include:

- Coordinated a two-day workshop to discuss, among agencies and consultants, the strategic elements of the baseline ecological and human health risk assessments. Developed pre-meeting documents and post-meeting minutes.
- Conducted an offshore Reconnaissance Survey of Newark Bay and documented significant ecological habitats and land and human use areas along the shoreline.
- Responsible for the preparation and delivery of major planning documents related to the risk assessments including the Conceptual Site Model, Problem Formulation, Crab and Clam Sampling and Analysis Quality Assurance Project Plan, Reconnaissance Survey Report, and Bird Egg Sampling and Analysis Quality Assurance Project Plan.

Task leader for the preparation of various reports to support the ongoing Remedial Investigation for the Hackensack River Study Area. Prepared a revised Remedial Investigation Report and a Supplemental Work Plan that included proposed efforts for conducting the baseline ecological risk assessment.

PUBLICATIONS AND PRESENTATIONS

- **M. Beauchemin** (2014). Development of Site-specific Uptake Factors for Metals. Platform presentation at *North Atlantic Chapter Meeting of SETAC*. University of Massachusetts, Amherst. June 10-11, 2014.
- N. Bonnevie, **M. Beauchemin**, A. Stojak, D. Buys, and D. Jones (2014). Weight of Evidence for Evaluating Effects of Residual Coal Fly Ash on the Benthic Invertebrate Community. Submitted to *Integrated Environmental Assessment and Management. Special Series*. March 7.
- **M. Beauchemin**, P. Anderson, T. Iannuzzi, N. Bonnevie (2013). Absence of Predicted Toxicity from Creosote-derived PAHs in Sediments. Platform presentation at *SETAC North America*. Nashville, TN. November.
- S. Dunn, T. Iannuzzi, **M. Beauchemin**, E. Denkenberger, P. J. Bluestein (2013). Bird Deterrence on the Lower Passaic River. Poster presentation at *Battelle Sediments Conference*. Dallas, TX. February 2013.
- A. Dunster, K. Baker, H. Hayward, P. Hamer, **M. Beauchemin**, N. Bonnevie (2013). Assessment of Volatile Organic Compounds and Active Pharmaceutical Ingredients in a Sediment and Surface Water System in England. Presented at *AquaConSoil. Barcelona*, Spain. April 2013.

Comments on EPA's Focused Feasibility Study for the Lower Eight Miles of the Lower Passaic River

August 9, 2014

Prepared for:

Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared by:

Matthew F. Bingham
Jason C. Kinnell
Dawn M. Woodard
Sara G. Hickman
Grant S. Crownfield

1851 Evans Road
Cary, NC 27513

Office: 919.677.8787
Fax: 919.677.8331

VERITAS
Economic Consulting
VeritasEconomics.com

Table of Contents

Section **Page**

Comment Summary 1

Exposure Assessment 1

Other Human Use Components 2

1. The "weight of evidence" approach EPA Region 2 employed to estimate fish and crab consumption rates is inconsistent with USEPA's Risk Assessment Guidance for Superfund; it should be rejected and replaced by a strength of evidence approach that uses the extensive site-specific and Expert Panel-reviewed data and analysis 4

2. Region 2 ignored data and models that are consistent with RAGS; these depict much lower fish consumption rates that Region 2 should use for the Risk Assessment 13

3. EPA Region 2's "weight of evidence" approach does not account for structural uncertainties, parametric uncertainties, or sampling uncertainties; it should be rejected and replaced by a more modern technique that uses the site-specific data and can consider uncertainties to generate informed estimates of baseline and future risk. 23

4. Results from Connelly et al. (1992) that comprise 50% of the "weight of evidence" approach should not be transferred to the Lower Passaic; these results should be excluded from any "strength of science" approach; the Connelly results could be correctly adjusted and incorporated into a "weight of evidence" approach that includes the extensive site-specific, Expert-Panel-reviewed, peer-review-published information 29

4.1 An exposure assessment identifies specific points on a statistical distribution of ingestion which the Connelly study does not. 29

4.2 Exposure assessments measure ingestion at one particular site whereas the Connelly study measures ingestion across all sites covered by the study. 30

4.3 Exposure assessments are to measure the affected population—the Connelly study evaluates licensed anglers from all of New York State. 32

4.4 Exposure assessments are intended to measure baseline, current and future exposure—the Connelly study reflects behaviors that are decades old. 33

4.5 A Reasonably Similar Exposure assessment should consider the major pathway, which is white perch. The Connelly study has a different mix of species. 33

5. Results from Burger (2002) that comprise 50% of the "weight of evidence" come from an on-site study that was not intended to measure the consumption frequencies required for risk assessment; they should be excluded from a "strength of science" approach; the Burger results could be correctly adjusted and incorporated into a "weight of evidence" approach that includes the extensive site-specific, Expert-Panel-reviewed, peer-review-published information 36

6. The social costs from quality of life impacts are expected to be higher under the off-site disposal scenario than the confined aquatic disposal (CAD) scenario 38

7. EPA's preferred alternative is unlikely to affect development related to the Passaic River's navigational shipping channel 41

7.1 General Comments 41

7.2 EPA's Characterization of Past Maintenance Dredging Activities is Inconsistent with Actual Dredging Activities in Miles 0–8 42

7.3 Economic reasoning is inconsistent with the economic history of both the Passaic River and the Port of Newark's development 43

7.4 Economic reasoning ignores the benefit-cost analysis the USACE must undertake to evaluate any project and justify it relative to the net benefits of competing projects 46

7.5 Survey responses regarding hypothetical future behaviors do not appear to be credible 47

8. EPA's preferred alternative will do little, if anything, to change the fishable water-quality condition of the River, will have done nothing to change the River's boatable and swimmable water-quality condition, and should be rejected 52

9. References 53

Appendix A Selected Catch-and-Release Rates in the U.S. 58

Comment Summary

This document presents the comments that Veritas Economic Consulting (Veritas) has prepared on Region 2's Focused Feasibility Study (FFS) for the Lower Eight Miles of the Lower Passaic River Study Area (LPRSA or FFS Study Area). Veritas herein presents comments on two major topics covered in the FFS: the exposure assessment component of Region 2's Human Health Risk Assessment and other human-use components. The following text summarizes the seven themes that Veritas has developed on these two topics.

Exposure Assessment

1. The exposure assessment component of Region 2's baseline risk assessment is invalid and should not be used as the basis for making a $1,700,000,000 site-specific, policy decision. This is supported by the fact that EPA's exposure assessment does not follow the exposure assessment guidance in Chapter 6 of the EPA's Risk Assessment Guidance for Superfund (RAGS). EPA's exposure assessment does not determine current populations, identify at risk groups, characterize the exposure setting, nor identify important physical characteristics (USEPA 1989). Without this information, EPA is unable to properly characterize exposure under current, future, or baseline conditions, all of which are required for the baseline risk assessment.

2. Region 2's exposure assessment ignores extensive site-specific information that not only satisfies the requirements of USEPA's Risk Assessment Guidance for Superfund, but that also provides quantitative estimates of baseline-risk fish ingestion, estimates that are 4 to 30 times lower than Region 2's estimate.

3. Instead of using the extensive site-specific data and baseline-risk, fish-ingestion estimates, Region 2 characterizes exposure by using ingestion rates from two studies conducted outside the Lower Passaic River Study Area: Connelly et al. (1992) and Burger (2002). Despite the fact that it should have used site-specific, baseline-risk, fish-ingestion estimates as are required by RAGS and presented in Kinnell and Bingham (2014), Region 2 incorrectly applied the data and results from Connelly et al. (1992) and Burger (2002) to develop its baseline-risk, fish-ingestion estimates. For example,

   - Connelly et al. (1992) reports data collected from a survey of anglers in 1990. Fishing and fish-consuming behavior have changed in the last quarter century. Applying those behavioral changes to the Connelly et al. (1992) data would result in a downward adjustment of Region 2's fish-ingestion estimate.

   - Consumption estimates from Connelly et al. (1992) are estimated across *all contaminated sites* contained in the data set, not for a single site as is required for the Lower Passaic River's baseline risk assessment. Simulations of trip diary data from the 2000 New Jersey Outdoor Recreation Survey presented in Bingham et al. (2011), which places anglers' trips to the Lower Passaic River Study Area in the context of all the trips they take to sites in New Jersey, indicates that scaling the Connelly et al. (1992) to reflect single site consumption frequencies would result in a downward adjustment to EPA's fish-ingestion estimate.

- The high frequency consumers in the Connelly et al. (1992) data are predominately from rural areas and predominately white. Those are not the characteristics of the population consuming fish from the Lower Passaic River Study Area. Adjusting the Connelly et al. (1992) data so that it is more representative of the Lower Passaic River fish consuming population would result in a downward adjustment of Region 2's fish-ingestion estimate.

- The survey reported in Connelly et al. (1992) was of licensed anglers. Passaic River anglers are a mixture of licensed and unlicensed anglers. Adjusting the Connelly et al. (1992) data so that it is representative of the behaviors of licensed and unlicensed anglers would result in a downward adjustment of EPA's fish-ingestion estimate.

- Burger (2002) reports the results of an on-site survey that is apparently not weighted for the anglers' visitation frequency. Weighting the Burger (2002) data to account for the anglers' visitation frequency would result in a downward adjustment of EPA's fish-ingestion estimate.

4. Region 2's *Technical Memorandum Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment* (EPA 2012) is not a peer-reviewed document; it did not undergo an independent Expert Panel review process that follows USEPA's guidance for conducting Expert Panel review (USEPA 2006); it does not use data from studies that underwent an Expert Panel review process; and its "weight-of-evidence approach" was not developed following an Expert Panel review process. In comparison, the baseline-risk, fish-ingestion estimates presented in Kinnell and Bingham (2014) were developed by

   - following the recommendations of an independent, Expert Panel convened to identify the steps necessary to develop baseline-risk, fish-ingestion estimates (Law 2011) given existing studies published in peer-reviewed journals (Bingham et al. 2011; Kinnell et al. 2007; Ray et al. 2007a, 2007b; Kinnell et al. 2006);

   - using data from two site-specific, creel-angler surveys that underwent Expert Panel review: the 2010–2011 Passaic River Creel/Angler Survey (Law 2011) and the 2000–01 Passaic River Creel/Anglers Survey (Finley et al. 2003); and

   - using data and analysis of fishing preferences developed from anglers residing in Essex, Hudson, Passaic, Bergen, and Union counties—the five counties that border the Lower Passaic River Study Area (Bingham et al. 2011). The anglers residing in these five counties are most likely to fish in the LPRSA or have the LPRSA in their choice set of relevant fishing alternatives.

Other Human Use Components

5. The social costs from expected quality of life impacts are expected to be higher under the Off-Site Disposal scenario than the Confined Aquatic Disposal (CAD) scenario.

6. Region 2's preferred alternative will not guarantee any future development goals for the lower two miles of the Lower Passaic River's navigational shipping channel.

   USACE's survey of commercial property owners does not provide an economically sound representation of activities that are likely to occur under future development goals of the Passaic River's navigation channel. Moreover, Region 2's chosen

scenario does not guarantee that the USACE will receive funding to undertake future maintenance dredging of the navigational channel. As the USACE's 2010 report suggests, not only do the costs and benefits of any future maintenance dredging projects have to be assessed for Miles 0–2, but they also have to be compared against the costs and benefits of other competing navigation channel dredging projects. Given the proximity of Miles 0–2 to the Port Newark-Elizabeth Marine Terminal, it seems unlikely that the net benefits (benefits minus costs) of any maintenance dredging for the Passaic River's navigational channel will exceed those of the Port Newark-Elizabeth Marine Terminal. This is born out in the historical maintenance dredging decisions for the Passaic River compared with the development decisions for the Port Newark-Elizabeth Marine Terminal.

7. Region 2's preferred alternative will have done little, and potentially nothing, to change the fishable water-quality criteria of the River and will have done nothing to change the river's boatable and swimmable water-quality criteria:

   - Do Not Eat fish consumption advisories for all species are most likely to remain in place into the future.
   - The river is currently boatable.
   - The river will not be swimmable because of the input of continued, on-going pathogen sources from Combined Sewer Overflows.

The following sections present the specific comments that Veritas has developed on each of these themes.

1. The "weight of evidence" approach EPA Region 2 employed to estimate fish and crab consumption rates is inconsistent with USEPA's Risk Assessment Guidance for Superfund; it should be rejected and replaced by a <u>strength of evidence</u> approach that uses the extensive site-specific and Expert Panel-reviewed data and analysis

According to USEPA (2001), "Weight-of-evidence generally refers to the quantity of science, while strength of evidence generally refers to the quality of science." In its "Technical Memorandum Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment," Region 2 of the Environmental Protection Agency (hereafter referred to as Region 2) employs a "weight of evidence" approach to identify fish ingestion rates from the Lower Passaic River (EPA Region 2 2012). Region 2 presents its "weight of evidence" approach as part of the exposure assessment component of the Human Health Risk Assessment that underlies the selection of its preferred alternative in the Focused Feasibility Study (FFS). However, the "weight of evidence" approach Region 2 used to identify fish ingestion rates for Miles 0–8 of the Lower Passaic River Study Area (LPRSA) is not consistent with the United States Environmental Protection Agency's (USEPA) Risk Assessment Guidance for Superfund (RAGS) and, therefore, cannot inform a valid regulatory risk assessment (USEPA 1989, 2001).

The document's failure of adherence to RAGS occurs in a number of areas (USEPA 1989). Of most concern is the "weight of evidence" approach's inability to be able to

- identify affected populations and subpopulations at special risk (pp. 6-6, 6-7, 6-8)
- characterize physical characteristics of exposure setting (pp. 6-2, 6-3, 6-4)
- characterize future land uses (p. 6-7).

These omissions result in a flawed exposure assessment as it is not reasonably possible to consider baseline, current, and future conditions without this information.

Considering the identification of groups that could be affected, RAGS instructs that exposure assessments "determine (the) location of current populations relative to the site (USEPA 1989)." This information could include "distance and direction of potentially exposed populations" and identification of "those populations that are closest to or actually living on the site" (USEPA 1989). RAGS advises that this information could be collected during a site visit, as other information is gathered as part of the site investigation, during the initial stages of the remedial investigation, or from population surveys conducted near the site (USEPA 1989, p. 6-6).

RAGS further instructs that risk assessments should "identify subpopulations of potential concern" including those who exhibit "behavior patterns that may result in high exposure" (USEPA 1989, p. 6-7). Exposure by consumption can occur from frozen or gifted fish; however, the primary fish consumption pathway is anglers who eat fresh, self-caught fish. Given this general population, a subpopulation of special concern consists of consuming anglers who fish frequently and are also effective (i.e., high catch rate) anglers catching fish they enjoy eating. The subpopulation of frequent anglers is by its nature easier to locate than less-frequent anglers because frequent anglers are the anglers who are most likely to be intercepted in an on-site survey. Despite the ease of identifying this subpopulation at particular risk, EPA made no effort to identify this group or to determine what species the most successful angling fish consumers generally target and catch for consumption.

RAGS also advises that analysts "characterize the exposure setting with respect to the general physical characteristics of the site (USEPA 1989, p. 6-5)." The exposure setting refers to consuming anglers fishing from the Lower Passaic River. Even a cursory inspection of the banks of the Passaic River indicates that in many areas, access to the Lower Passaic River is limited due to typical urban obstacles. As a result, perhaps the most important "general physical characteristic" of the Lower Passaic River that underlies exposure via fish contamination is the amount, type, and location of access to the River for fishing. However, Region 2 provides no discussion of where anglers fish along the Passaic, how much fishing takes place at parks or less official access points, whether anglers are highly concentrated or dispersed, or any other of the access features that underlie exposure.

With respect to assessing future risk, RAGS also guides that exposure assessments should "determine future land use," advising that future land use should be determined if "any activities associated with a current land use are likely to be different under an alternate future land use" (USEPA 1989, p. 6-7). It then specifically advises to "determine if land use of the site itself could change in the future. For example, if a site is currently classified as industrial, determine if it could possibly be used for residential or recreational purposes in the future" (USEPA 1989, p. 6-7). EPA's failure to collect any of this information means it has neither site-specific, current estimates nor the ability to develop any meaningful, quantitative characterization of baseline or future exposure.

In comparison, contrasting changes in land use and observed angling activity that occurred in two Lower Passaic River Creel/Angler Surveys (CAS) illustrates what is lacking from EPA's approach. The 2000–2001 and 2011–2012 Lower Passaic River CAS adhered to RAGS guidance and were developed specifically to evaluate fish consumption from the Lower Passaic

River. The 2000–2001 CAS estimates a population of 177 to 486 anglers taking 2,248 trips to all the sites in River Miles 1–7 of the LPRSA (Kinnell et al. 2007 and Ray et al. 2007b).

This study also revealed a consistent concentration of anglers at a particular site in Harrison, New Jersey. In 2000–01, this site accounted for nearly 70 percent of all the fishing activity in Miles 1–7 and had more than five times as many trips as the site with the second-highest number of trips (Kinnell et al. 2007). In addition, it had much higher rates of repeat visitation than other sites. This site had a number of features attractive to anglers. For example, the site contained a concrete structure (henceforth referred to as the abandoned bulkhead) along the shoreline that had open access to the River (i.e., there was no fence between the abandoned bulkhead and the River and there was no vegetation along the shoreline). Some anglers may find such structures easier and more productive than bank/shore fishing.[1] Figure 1 depicts the conditions at this site during 2000 and 2001. The building in the background of Figure 1 is a Hess Gas Station with a convenience store providing food, drinks, cigarettes, and other sundries.

Figure 1: Abandoned Bulkhead Adjacent to the Hess Gas Station: 2000-2001

[1] For example, bottom snags and casting snags may be less likely from an abandoned bulkhead than from a vegetated shoreline. Greater deep-water coverage is typically available with a given casting radius from an abandoned bulkhead than from a vegetated shoreline. By comparison, the other sites with notable trip levels from the 2000–2001 Passaic River CAS had vegetated shorelines (Riverbank Park Ironbound and Riverbank Kearny) or had fences or railings adjacent to the shoreline (i.e., the shoreline behind the Pathmark Grocery Store).

Considering access to the site, there is foot access from a number of nearby neighborhoods. Also, as Figure 2 shows, in addition to street parking, in 2000–01, the property adjacent to the Hess Gas Station was an abandoned lot that supported parking.

Figure 2: Aerial View of the Hess Gas Station and Adjacent Property: 2000—2001

When driving, there is easy access to the site as it is located near the intersection of Harrison and Passaic Avenues. Because Harrison Avenue connects to Interstate 280, there is easy access from more distant locations. The site is on the east bank of the River; however, access from the west bank of the River via McCarter Highway (Highway 21) is easy, as the Bridge Street Bridge crosses the Passaic River and connects McCarter Highway to the intersection of Harrison and Passaic Avenues at the Hess Gas Station.

In 2000–2001 this was an informal fishing spot without regular police presence or game wardens. Anglers did not need a license to fish at this location. Based on observations, traditional risky behaviors (smoking and public drinking) occurred frequently at this site (Kinnell 2014). Perhaps not coincidentally, the abandoned bulkhead at the Hess Gas Station was an important location for fish consumption in Miles 1–7 during the 2000–01 CAS; fully half of the fish-consuming anglers identified during the year-long study were at this site, making the Hess Gas Station bulkhead a critical exposure "hotspot" for Miles 1–7 during 2000–01.

Subsequent to the 2000–01 CAS, the vacant lot that contained the abandoned bulkhead and the adjacent Brownfield site was re-developed as a new Hampton Inn Suites hotel—which opened in 2006. This resulted in the shoreline and aerial transformations depicted in Figures 3 and 4.

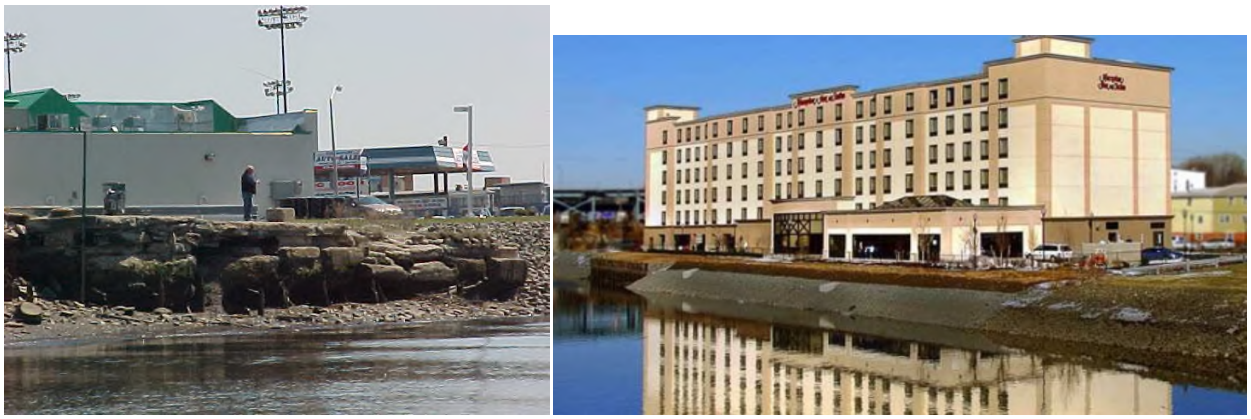


Figure 3: Brownfield Shoreline in 2000-01 versus Re-developed Shoreline in 2006

Figure 4: Changes to the Abandoned Bulkhead between 2000 and 2006
The arrow in each image identifies the location of the abandoned bulkhead.

Unfortunately, no primary data is available about behavior at this site for the decade that encompassed site development. However, a second Passaic River CAS was conducted in 2011–2012 to support a site-specific, baseline risk assessment for the LPRSA (Kinnell and Bingham 2014; Law 2011). The 2011–12 CAS documents no fishing activity at that site throughout the entire year-long study (Kinnell and Bingham 2014). Perhaps a less anticipated result is that there was no offsetting increase in trips to other access points in Miles 0–8:

- The 2011–12 CAS estimates 972 trips to all the sites in River Miles 0–8 (Kinnell and Bingham 2014).
- The 2000–01 CAS estimates 2,248 trips to all the sites in River Miles 0–8 (Kinnell et al. 2007 and Ray et al. 2007b).

Apparently, the loss of the abandoned bulkhead site resulted in a greater than 50 percent reduction in total trips.[2] An even more important conclusion is that there was a much lower concomitant reduction in the total number of anglers who were responsible for 90 percent of the total fish-consuming activity during 2000–2001. The clear implication is that the transition of the abandoned bulkhead is responsible for much of the risk reduction observed over the 2000–2001 and 2011–2012 studies.

This result underscores the importance of following RAGS guidance when assessing current, baseline, and future risk. Specifically, when assessing current exposure via fish consumption at a particular site, it is important to know something about the behaviors of people who actually fish at that site. This is the case for the entire waterbody; however, given the RAGS focus on upper percentiles of exposure, it is particularly important to understand the existence of, and behaviors at, exposure hotspots like the bulkhead behind the Hess Gas Station. This is important because that is where risk is concentrated and because information can be cost-effectively collected there.

Another important aspect that changes in this site inform is the baseline-risk, fish ingestion rate. The regulatory-baseline-risk, fish-ingestion rate intends to capture fish ingestion without institutional controls. For the Lower Passaic, the relevant institutional control is the Do Not Eat fish consumption advisory on all species. Baseline-risk consumption is the level of fish consumption that would occur without the Do Not Eat Fish Consumption Advisory being in force, but all other site conditions remaining constant. Here again, understanding behaviors at exposure hotspots like the abandoned bulkhead is important. Because the population fishing at

[2] As described in other comments, total trips are among the easiest quantities to estimate; the methods for estimating them were similar across the 2000–2001 and 2011–2012 creel/angler surveys, and both studies employed extensive coverage of the study area with a boat-based survey team identifying and counting the number of anglers on the river for nearly 40 percent of the days in each annual survey.

the Hess Gas Station had the highest consumption rates under current conditions, it is also likely to have had the highest consumption rates under baseline conditions. Specifically, under the baseline risk conditions, increases in the 90th percentile of ingestion are likely to come from either current, high-frequency-angling, high-frequency consumers eating even more Passaic River fish (via trip increases) or from current, high-frequency angling, moderate-frequency consumers increasing their consumption frequency. Because new anglers to the Lower Passaic River would actually be expected to reduce the (regulatory) risk metric, understanding how the behaviors of current consumers are affected by the advisory is critical to understanding baseline.

Kinnell and Bingham (2014) describe how these behaviors will affect the baseline risk metric; however, the studies that EPA used in its "weight of evidence" approach also illustrate these points. For example, Connelly et al. (1992) says that 46% of consumers did not make changes in consumption due to advisories and the most commonly stated reason was that they already were consuming below the limit. Connelly et al. (1992) also notes that, "of those aware of the health advisory, women and those living in large cities were less likely than other groups to make any change in their fishing and fish-eating behaviors in response to advisories." A major result from Burger (2002) is that people do not pay much attention to advisories, so their consumption should not increase much if one were not present.

The changes in shoreline conditions at the Hess Gas Station underscore the importance of current/past land use and associated behaviors in understanding future exposure conditions for the Lower Passaic River. For example, in 2000–2001 exposure was geographically concentrated at the Hess Gas Station. Connelly et al. (1992) notes that a group of consuming anglers consumed contaminated fish because they participated in other behaviors that were more risky than consuming contaminated fish. Consistent with what was observed in the Connelly study, the Hess Gas Station had particular features that could make it attractive to people who are likely to engage in risky behaviors generally. For example, because of the height of the bulkhead, the site is not accessible by water-borne law enforcement. Open containers were common at the site and a quick can drop into the riverside trashcan or into the River would be an easy way to avoid a public drinking citation from law enforcement approaching by land.

Importantly, the Hampton Inn was the first of what is expected to be increased development in Harrison. Because the hotel, as constructed, eliminated access to cast a line into the River, in 2011–2012, this site was no longer available for fishing. However, according to the 2011–2012 results, no new high-exposure site replaced it (Kinnell and Bingham 2014;

Law 2011). This is critical for understanding future exposure. For example, considering Harrison, improvements in rail access to Manhattan are planned via a $256 million upgrade to the Harrison Path Station. Nine developers intend to spend $650 million over the next ten years on Harrison, which is expected to, "transform 275 acres of abandoned, deteriorating manufacturing buildings into the next outpost on New Jersey's Gold Coast … adding 3,000 units of housing to a town with 14,500 residents (Kaysen 2012)."

The *Amended Harrison Waterfront Redevelopment Plan 2012* describes significant changes to the formerly industrial riverfront during recent years. Harrison occupies 1.2 miles of Lower Passaic riverbank. Industrial sites have been cleaned up, demolished, and replaced with a soccer stadium, Hampton Inn hotel, mixed use commercial and residential projects, major capital investments and upgrades to the PATH station, and other improvements that help transform the area into a "mixed use Transit Oriented Development (Town of Harrison 2012)." Future development will include additional, similar projects (Town of Harrison 2012).

Harrison's redevelopment plan "provides significant opportunities for enhancement of the changing social needs of [Harrison's] citizens," describing intended waterfront amenities, such as a waterfront walkway and park. Thus far, the walkway has been completed along the River frontage adjacent to the Hampton Inn. The Town of Harrison notes that the "public has not had access to the waterfront for several generations" (Town of Harrison 2012).

Understanding what is expected to happen in Harrison is important for understanding future risk. Clearly, new people are expected in Harrison, as is development. Behaviors at abandoned manufacturing sites are likely to be much different than at new parks and apartment buildings. This means that understanding future exposure can be enhanced by understanding the relationship between current site conditions and current exposure, then characterizing future land uses and drawing appropriate conclusions about future exposure. In this case, because development has occurred at an important exposure hotspot, there is an opportunity to evaluate that effect; however, Region 2 undertook no such efforts.

Region 2 took none of the basic steps described in Chapter 6 of RAGS that addresses exposure assessment. Moreover, Region 2's consideration of such factors is limited to a discussion in which Region 2 asserts that the information it obtained from peer-reviewed, published consumption surveys is "from areas with geography, population groups, and climatic conditions similar to those of the Lower Passaic River" (EPA 2014c).

The "weight of evidence" approach EPA Region 2 employed to estimate fish and crab consumption rates is inconsistent with USEPA's Risk Assessment Guidance for Superfund and

should be rejected. According to USEPA (2001), "Weight-of-evidence generally refers to the quantity of science, while strength of evidence generally refers to the quality of science." Region 2 ignored extensive site-specific LPRSA data and models that are consistent with RAGS. In ignoring the existing data, Region 2 is not using the full quantity of available information, and it is intentionally omitting quality scientific data and analysis. The data Region 2 chose to omit is from site-specific surveys that have been reviewed by independent Expert Panels and/or published in peer-reviewed journals (Bingham et al., 2011; Law 2011; Kinnell et al., 2007; Ray et al., 2007a; Ray et al., 2007b; Kinnell et al., 2006; Finley 2003). Therefore, not only does Region 2's weight-of-evidence approach not follow USEPA's (2001) description of what a weight-of-evidence approach is intended to be, it is also the incorrect approach. Region 2 should utilize a strength-of-evidence approach that uses the extensive site-specific, Expert-Panel-reviewed, peer-review-published information as described in Kinnell and Bingham (2014).

2. Region 2 ignored data and models that are consistent with RAGS; these depict much lower fish consumption rates that Region 2 should use for the Risk Assessment

Region 2 has placed a large emphasis on supporting its chosen remedy based on the impact it will have on the risk that anglers face from consuming fish from the lower eight miles of the Passaic River. For example, Region 2:

> "This FFS builds on the results of the Remedial Investigation (RI) that…established the existence of unacceptable human health cancer risks and non-cancer health hazards from exposure to contaminants in fish and crabs…(p. ES-1 USEPA's FFS)."

Region 2 then states that its first Remedial Action Objective for the FFS Study Area is to

> "Reduce cancer risks and non-cancer health hazards for people eating fish and shellfish by reducing the concentrations of chemicals of potential concern (COPCs) in the sediments of the FFS Study Area (p. ES-2 USEPA's FFS)."

Region 2's estimate of risk and basis for the change in risk that will occur as a result of its preferred remedy is based, in part, on its estimation of the baseline risk level of fish consumption: 34.6 grams per day for the reasonably maximally exposed (RME) individual. EPA notes that this estimate was

> "developed from a detailed evaluation of LPRSA-pertinent angler and creel surveys and related literature, which was documented in the USEPA Region 2 Technical Memorandum, "Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment" (USEPA Region 2, 2012). This analysis provided a weight-of-evidence approach for evaluating consumption for the RME individual (p. 3-19 USEPA FFS, Appendix D Human Health Risk Assessment)."

Region 2 notes further that

> "To minimize uncertainty in the calculated risks, exposure assumptions and parameters for these receptors were obtained from published literature sources (*e.g.*, creel surveys) for the Lower Passaic River or surrounding areas. The fish ingestion rate (IR) is based on the only two published surveys conducted in the New York/New Jersey Harbor estuary with enough information to calculate statistical distributions of IRs. Those surveys use different sampling methods (*i.e.*, intercept and licensed angler survey), yet result in comparable consumption rates. The surveys also represent large angling populations from coastal New York and New Jersey watersheds. The fish IR is consistent with rates calculated from other surveys conducted within USEPA Region 2 and nationally."

Despite the large emphasis that Region 2 has placed on the effect that its chosen remedy will have on fish consumption, Region 2 has not used the extensive site-specific data that exist for the FFS Study Area. Nor has Region 2 used state-of-the-art techniques to analyze

angler behavior and site specific fish consumption data to develop its baseline risk fish consumption estimates. Region 2's statement that the analysis is conducted for the human health risk assessment "provides a weight-of-evidence approach for evaluating consumption for the RME individual" ignores all of the evidence contained in the following seven studies on Passaic River fishing and fish consumption that Veritas has developed and/or published in the peer-reviewed literature:

- Kinnell and Bingham (2014)—Estimates of Current and Baseline Fish Ingestion for the Lower Passaic River Study Area
- Bingham et al. (2011)—An Application of Behavioral Modeling to Characterize Urban Angling Decisions and Values
- Kinnell et al. (2007)—A Survey Methodology for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1)
- Ray et al. (2007a)—A Statistical Method for Analyzing Data Collected by a Creel/Angler Survey (Part 2)
- Ray et al. (2007b)—Human Health Exposure Factor Estimates Based Upon a Creel/Angler Survey of the Lower Passaic River (Part 3)
- Kinnell et al. (2006)—Estimating Site-Choice Decisions for Urban Recreators
- Finley et al. (2003)—The Passaic River Creel/Angler Survey: Expert Panel Review, Findings, and Recommendations.

In the past, Region 2 has claimed that it will not rely on the results of these studies because they were conducted on the River in the presence of a fish-consumption advisory and therefore cannot be used to estimate baseline risk. By comparison, Region 2 uses studies conducted outside the LPRSA to develop its fish consumption rate. The EPA estimates are therefore, by definition, not site specific.

RAGS requires that a baseline risk assessment characterize risk in the absence of any site-related controls that might reduce exposure. At 40 *CFR* 300.430(d)(4), the National Contingency Plan (NCP) specifies that the "…lead agency shall conduct a site-specific baseline risk assessment to characterize the current and potential threats to human health and the environment." As the preamble to the NCP [55 *FR* 8711] explains, "…one specific objective of the risk assessment is to provide an analysis of baseline risk (i.e., the risks that exist if no remedial action or institutional controls are applied to a site)."[3]

Fish consumption advisories are considered a form of institutional control (USEPA 2010). Because institutional controls can reduce or preclude exposure while not actively

[3] The National Contingency Plan provides the blueprint for CERCLA implementation.

remediating a site, the USEPA considers that their presence ***does not*** represent the baseline risk situation.

To assess baseline risk in the FFS Study Area, the baseline risk assessment must characterize what the fish consumption rate would likely be if the site-specific, Do Not Eat fish consumption advisory were not in force, but all other site conditions were the same.[4] Specifically, what is the likely angling and consumption behavior, assuming that the site-specific, institutional control of an advisory warning anglers not to consume any fish or crabs is not in force, but all other current site conditions remain, including the urbanized site setting, access, and degraded water and sediment quality?

Because current consumption can be observed, current consumption (and regulatory risk under CERCLA) can be evaluated using traditional on-site survey techniques. In contrast, baseline risk (and consumption) refers to conditions that would exist in the absence of institutional controls that may reduce risk. The implication for sites with fish consumption advisories (such as the FFS Study Area) is that quantifying baseline regulatory risk requires estimating what fish consumption would be if the relevant fish consumption advisories did not exist.

Unlike current fish consumption, baseline fish consumption is not directly observable; this complicates the identification of baseline risk. Region 2 has avoided this complication by ignoring the presence of the extensive and sophisticated site-specific data listed above. However, in so doing, Region 2 has also ignored the vast set of site-specific information and analysis that shows that the baseline level of fish consumption is not 34.6 g/day, but is more-properly estimated as 0.88 g/day for all anglers fishing in the lower eight miles and 6.23 g/day for consuming anglers—estimates that are unlikely to support its preferred remedial alternative.

Kinnell and Bingham (2014) developed estimates of baseline fish consumption for the Lower Passaic River Study Area, including the lower eight miles. The baseline-risk, fish-ingestion estimates presented in Kinnell and Bingham (2014) were developed by

- following the recommendations of an independent, Expert Panel convened to identify the steps necessary to develop baseline-risk, fish-ingestion estimates (Law 2011) given existing studies published in peer-reviewed journals (Bingham et al. 2011; Kinnell et al. 2007; Ray et al. 2007a, 2007b; Kinnell et al. 2006)

[4] By not in force we mean that a posted sign is not present on site and/or published materials warning anglers about risks from consuming site fish and crab are not available, but all other site conditions remain under their Current conditions.

- using data from two site-specific, creel-angler surveys that underwent Expert Panel review: the 2010–2011 Passaic River Creel/Angler Survey (Law 2011) and the 2000–2001 Passaic River Creel/Anglers Survey (Finley et al. 2003)
- using data and analysis of fishing preferences developed from anglers residing in Essex, Hudson, Passaic, Bergen, and Union counties—the five counties that border the Lower Passaic River Study Area (Bingham et al. 2011). The anglers residing in these five counties are most likely to fish in the FFS Study Area or to have the FFS Study Area in their choice set of relevant fishing alternatives.

Kinnell and Bingham (2014) link current trip taking and consumption to baseline trip taking and consumption via a behavioral model of anglers' fish trip and consumption decisions. The analysis builds on all of the site-specific, Expert-Panel reviewed, and peer-review-published work conducted on the LPRSA angling population over the last 14 years (Bingham et al. 2011; Kinnell et. al. 2007; Ray et al. 2007a, 2007b; Kinnell et al. 2006; and Finley et al. 2003). It also includes data and analysis from a survey conducted in 2013, at the direction of the Expert Panel, to evaluate the specific impact that the Passaic River's fish consumption advisory has on anglers' fishing and consumption decisions. That survey, along with the behavioral model Kinnell and Bingham (2014) developed to estimate baseline risk fish consumption, was conducted under an intensive Expert Panel, peer-review process (Law 2011), leading to robust and reliable results. A critical part of this process was the development of a Fish Consumption Simulation Model (FCSM) that characterizes FFS Study Area angling population, fishing pressure at numerous LPRSA sites, and fish consumption rates under current and baseline conditions.

Region 2 ignored data and models that are consistent with RAGS; these calculate much lower fish consumption rates and should be used for the Risk Assessment. Region 2 improperly used a "weight of evidence" approach in developing its fish-ingestion estimates (EPA Region 2 2012). As USEPA (2001) describes, a "weight-of-evidence generally refers to the quantity of science." In ignoring the existing data, Region 2 is not using the full quantity of available information. More importantly, the data Region 2 chose to ignore is from site-specific creel/angler surveys that have been reviewed by independent Expert Panels and published in peer-reviewed journals. Therefore, not only does Region 2's weight-of-evidence approach not follow USEPA's (2001) description of what a weight-of-evidence approach is intended to be, it is also the incorrect approach. Region 2 should utilize or employ a strength-of-evidence approach that uses the extensive site-specific, Expert-Panel-reviewed, peer-review-published information.

Region 2 claims that Burger (2002) and Connelly et al (1992) are the only two published surveys conducted in the New York/New Jersey Harbor estuary that contain enough information to calculate statistical distributions for the ingestion rates (USEPA 2012, p. 3-41 FFS, Appendix D Human Health Risk Assessment). This assertion is inaccurate. The consumption behaviors of LPRSA anglers have been studied extensively since 2000 (Finley et al., 2003; Kinnell et al., 2007; Ray et al., 2007a; Ray et al., 2007b; Law 2011). These studies were reviewed by expert panels of peer reviewers who concluded the studies were designed properly and implemented in accordance with their designs, producing reliable data essential to develop accurate consumption rates to inform the human health risk assessment (Finley et al., 2003; Law 2011).

Throughout the RI/FS process, Region 2 has steadfastly refused to accept that any sort of angler studies of the Passaic River will yield useful risk information. In 2001, an Expert Panel was convened and this panel's advice was adhered to in constructing the 2000-2001 Passaic River Creel/Angler Survey to estimate fish ingestion from the Lower Passaic River. In addition, the 2000-2001 Passaic River Creel/Angler Survey incorporated a number of features specifically requested by Region 2 such as expanding the survey's coverage to include night angling; using interviewers who were fluent in English, Portuguese, and/or Spanish; translating the On-Site Interview forms into Portuguese and Spanish; and having a cellular phone translation service available to administer the survey in eleven languages in addition to English, Spanish, and Portuguese (Firstenberg 2001; Kinnell et al., 2007). The results from the 2000-2001 Creel/Angler Survey demonstrated that incorporating these components into the study did not affect the quantitative results. For example, during the year-long survey, no anglers were observed night fishing and no interview was conducted in Portuguese.

Region 2 states that the 2000-2001 Passaic River Creel/Angler Survey, "and its results may not be used in the LPRSA risk assessment without caveat," because, "the workplan for the survey described in Ray et al. (2007b) was submitted to EPA for review and was not approved, because it was inconsistent with EPA guidance in planning, implementation, and analysis (EPA 2012)." Region 2's statement is completely inconsistent with the comments provided by the independent Expert Panel convened to review the workplan for the survey described in Ray et al. (2007b). For example, in response to the following charge question,

> Question #2: Is the proposed CAS workplan sufficient to characterize local fish consumption behavior for risk assessment purposes? (Finley et al., 2003, p. 849).

The Expert Panel stated that,

> The study design does an excellent job of identifying the catch of each angler at all interview sites on survey dates, and these data are much better than those available from existing fish consumption studies. Existing studies, using diaries or mail surveys, are subject to response and recall biases that likely overstate consumption rates. There is no significant bias in the direct observation of the size and composition of the catch.

In addition,

> The panel believes that the CAS for the Passaic River study area represents a valuable and detailed investigation which goes well beyond any previous studies of its type in terms of scope and completeness. The CAS is a major step forward in how fish consumption studies are designed and conducted in support of site specific risk assessments, and will significantly contribute to the Passaic River Study Area risk assessment (Finley et al., 2003 p. 850).

When the panel states that the data from the 2000-2001 Passaic River Creel/Angler Survey,

> are much better than those available from existing fish consumption studies. Existing studies, using diaries or mail surveys, are subject to response and recall biases that likely overstate consumption rates.

they are referring to studies such as Connelly et al. (1992) and Burger (2002), the two studies that EPA relies on to develop its 34.6 grams/day ingestion estimate (EPA 2012, p. 10). The surveys that generate the data used in both of these studies were conducted prior to the 2000-2001 Passaic River Creel/Angler survey, use a mail or diary format (i.e., in this context of the Expert Panel's comments that they do not collect data on anglers actual observed catch from an individual site), and were available as background material for the Expert Panel's review and consideration.

Region 2 also notes that in developing a 95th percentile fish consumption rate of 1.8 grams per day, Ray et al. (2007b) included non-consuming anglers that they believe, "should not have been included in the calculation of a fish ingestion rate for the RME individual (EPA 2012, p. 1)." However, when Region 2 cites information from Ray et al. (2007b) on rates for consuming anglers, they ignore their own guidance as to why those rates are not relevant for the reasonably maximally exposed (RME) individual estimate. For example, Region 2 states that Risk Assessment Guidelines for Superfund (RAGS) Part A, "defines the RME as the maximum exposure that is reasonably expected to occur under baseline conditions and is not a worst-case exposure scenario (EPA 2012 p. 2)." Region 2 goes on to cite the guidance documents further noting that RAGS Part A recommends calculating an ingestion rate that, "…reflects the amount of contaminated medium contacted per unit time or event. If statistical data are available for a contact [ingestion] rate, use the 95th percentile value for this variable

(EPA 1989, p.6-22)." Region 2 notes further that RAGS Part A states that, "the 90th percentile value can be used if the 95th percentile value is not available (EPA 2012, p. 2)."

Region 2 ignores this guidance when it says that the two values of 23.95 and 28 grams per day in Ray et al. (2007b) are comparable to the 26 grams per day consumption rate for anglers recommended in EPA's 1997 Exposure Factors Handbook. That comparison is irrelevant, as Region 2's own citation of Ray et al. (2007b) and EPA guidance points out. As Region 2 cites, the 23.95 and 28 grams per day estimates in Ray et al. (2007b) are neither the 90th nor the 95th percentile that the guidance documents recommend should be used. They are the maximum reported and maximum estimated values from the 2000-2001 Passaic River Creel/Angler Survey data. By definition, they are not the RME estimate because they are not the, "maximum exposure that is reasonably expected to occur under baseline conditions (EPA 2012, p. 2)." Rather, by definition, they are the maximum amount that was estimated to occur under current conditions; they are the, "worst-case exposure scenario (EPA 2012, p. 2)," exactly the estimate that Region 2 points out that RAGS Part A defines that the RME is not supposed to be. Ironically, the estimate that Region 2 uses in its analysis (34.6 grams per day) is higher than the worst case exposure scenario observed from the 2000-2001 Passaic River Creel/Angler Survey data.

The other statement that Region 2 uses to exclude the LPRSA's site-specific angler and fish-consumption data is that, "RAGS Part A guidance (EPA 1989) further indicates that current and future exposure are evaluated in the absences of Institutional Controls such as the health advisories for fish and crab consumption that are in effect on the Lower Passaic River (EPA 2012, p. 2)." EPA made a similar statement in an April 14, 2011 letter to the Cooperating Parties Group (CPG) regarding the development and administration of the 2011-2012 Lower Passaic River Study Area (LPRSA) Creel/Angler Survey in which EPA expressed concern that because of the current presence of the fish consumption advisory, a CAS conducted on the LPRSA will, "yield highly uncertain results and not accurately characterize exposure to the Reasonably Maximally Exposed Individual (Law 2011)."

To address EPA's concern, a methodology was developed to incorporate all the available site-specific LPRSA data and analysis to develop baseline-risk fish ingestion estimates. The description of how that analysis would be undertaken was included in the workplan for the 2011-2012 LPRSA Creel/Angler Survey, reviewed by the Expert Panel, provided to EPA for review, and requested that, "…the final CAS work plan, and peer review comments and other CAS correspondence and documents be incorporated into the Administrative Record for Operable Unit 2 of the Diamond Alkali Superfund Site (Law 2011, p. 1)."

As part of developing these comments, the Expert Panel's recommendations on the analysis were implemented so that all of the LPRSA's site-specific data could be used to develop fish-ingestion estimates under baseline-risk conditions (i.e., the level of ingestion without the LPRSA's Do Not Eat fish consumption advisory being in force, but all other site conditions remaining constant).[5] The baseline-risk, fish-ingestion estimates are developed to inform the baseline-risk human health risk assessment, for as Law (2011) notes, "Absent such site-specific data, it will be impossible to prepare an accurate, site-specific baseline human-health risk assessment (HHRA), which is key to development of an effective remedy for the entire LPRSA (p. 2)." Kinnell and Bingham 2014 present the methodology and results of implementing the Expert Panel's recommendations and using all the LPRSA's site-specific data to develop baseline-risk, fish-ingestion estimates.

Table 1 presents a comparison of Kinnell and Bingham 2014, Connelly et al. (1992), and Burger (2002). As Table 1 demonstrates, Kinnell and Bingham 2014 is superior to the Connelly and Burger studies for evaluating the statistical distributions of baseline-risk, fish ingestion from the LPRSA in every way.

Table 1
Comparison of Studies

Characteristics	Kinnell and Bingham 2014	Connelly et al. (1992)	Burger (2002)
Created to calculate ingestion distributions	Yes	No	No
Reviewed by expert panel	Yes	No	No
Surveys licensed and unlicensed anglers	Yes	No	Yes
Includes a population survey	Yes	Yes	No
Includes an on-site survey	Yes	No	Yes
Population survey is of affected anglers	Yes	No	No
On-site survey is at affected sites	Yes	No	No
Employs boat counts	Yes	No	No
Decomposes consuming angler types	Yes	No	No
Considers anglers' behaviors/advisory response	Yes	No	No

Most importantly, Region 2's standing objection to any scientific, site-specific approach is invalidated by the Expert Panel-approved survey referenced in Law 2011 and the modeling

[5] By not in force we mean that a posted sign is not present on site and/or published materials warning anglers about risks from consuming site fish and crab are not available, but all other site conditions remain under their Current conditions.

approach for developing baseline-risk, fish-ingestion estimates employed in Kinnell and Bingham 2014. Specifically, Region 2 has objected to any sort of site-specific study for measuring baseline fish ingestion, claiming that baseline ingestion cannot be estimated for the LPRSA. This position underlies Region 2's rejection of proposals to scientifically measure behaviors on the Passaic River. It also allows Region 2 the latitude of selecting studies to transfer to the LPRSA that are driven by remedy preference rather than a scientific process.

Transfer studies are essentially current consumption rates estimated at sites with either no or a lower fish consumption advisory than at the site being evaluated. Unlike current fish consumption, regulatory baseline fish consumption is not directly observable; this complicates the identification of regulatory baseline risk. A common solution is to use default rates or transfers of fish consumption from other sites. Although default rates or transfers are straightforward to conduct, fishing sites and angler behaviors can differ greatly in ways other than those related to consumption advisories. Considering the LPRSA, there are important differentiators from sites used to generate default values including the population that is affected, access, water quality, and species availability (Kinnell et al., 2007). As a result, it can be inappropriate to transfer values to a specific study area. In addition, a number of U.S. Environmental Protection Agency (U.S. EPA) guidance documents encourage risk assessors to collect site specific data in determining risk estimates (U.S. EPA, 1989, 1998a, 1998b, 2001). The agency notes specifically that states should "use results from fish intake rates … that are likely to most closely represent the defined populations being addressed. Generally, the more specific the data are to the individuals who use the water body of interest, the better the data are considered to be for estimating accurate fish intake rates" (U.S. EPA, 1998b).

The other important aspect of deciding whether a study can be reliably transferred from one site to another is the quality of the science underlying the transferred study. As Table 1 summarizes, and comments 4 and 5 address in greater detail, Kinnell and Bingham 2014 provide higher quality, site-specific analysis than either Connelly et al. (1992) or Burger (2002). Comments 4 and 5 present specific details of why Connelly et al. (1992) and Burger (2002) are not appropriate transfers for the LPRSA.

As Kinnell and Bingham (2014) shows, Region 2's position that baseline risk cannot be measured by studying behaviors of LPRSA anglers is incorrect. Moreover, the assumption that fish ingestion will be higher under baseline-risk conditions than under current-risk conditions is incorrect. As Kinnell and Bingham (2014) show, when consuming anglers are the relevant population being evaluated, it is possible for the *regulatory* risk metric (i.e., grams per day for 90th percentile of consuming anglers) to *decrease* under the baseline-risk conditions. This

would occur whenever new LPRSA anglers consume at a rate that is less than the current LPRSA anglers and would be magnified by large trip changes. For example, with a population of 100 anglers, consumption of the top ten defines the 90th percentile. The addition of 100 new anglers under baseline-risk conditions would increase the population to 200 anglers, and consumers at and above the 90th percentile would be the top 20 consumers. If the new consumers consume less than the top ten do under current-risk conditions, the 90th percentile will be lower under the baseline risk conditions. Another possibility is that the risk metric would remain relatively unchanged. This could occur if new anglers consume at the same rate as existing anglers. It could also occur if existing anglers consumed more, but that the additional consumption was driven by anglers who are below the 90th percentile under current conditions (see Kinnell and Bingham 2014 for a complete description of the theoretical construct for developing baseline-risk, fish-ingestion estimates and the results for the LPRSA).

Finally, Burger (2002) indicates that current angling behaviors are important in understanding baseline angling behaviors. The objective of Burger (2002) is to understand why people do not follow advisories and notes that "…since some people do not follow consumption advisories, it is of public health policy interest to understand why people fish and what they eat."

3. EPA Region 2's "weight of evidence" approach does not account for structural uncertainties, parametric uncertainties, or sampling uncertainties; it should be rejected and replaced by a more modern technique that uses the site-specific data and can consider uncertainties to generate informed estimates of baseline and future risk.

There is inherent uncertainty in anglers' fishing behaviors, behaviors which ultimately underlie the risk metric of grams per day of consumed, self-caught fish. Examples include the annual trip frequencies of LPRSA anglers, their catch rate per trip, the type and size of species that they keep, and the parts of their kept catch that they consume. In addition, while these uncertainties address current angling and consumption behaviors, it is necessary to understand how these behaviors may change under the baseline risk conditions and how those changes would affect the baseline risk fish ingestion estimates and ultimately the baseline human-health risk assessment. EPA's "weight of evidence" approach is a transfer-based, point estimate that can neither account for how all of these uncertainties affect current consumption estimates, nor how they would change under the baseline risk conditions.

In comparison, integrating all of the site-specific data available for the Lower Passaic River Study Area into a model of anglers' behavior produces estimates for every percentile of angler consumption behavior (as opposed to a single point estimate), evaluates the effect that uncertainties in anglers' trip and consumption behaviors have on each percentile estimate, and identifies how the effect of those uncertainties change under different scenarios, including the baseline risk scenario (Kinnell and Bingham 2014). Table 2 summarizes the implications that the inclusion of all the uncertain components in angler behavior and fish consumption that are captured by the site-specific LPRSA data have for the uncertainty in consumption rates. As the table shows, these estimates are not just a single point estimate of an individual percentile identified in isolation (i.e., there is no context for EPA's 34.6 g/day estimate—there is no other percentile, no mean, no population of anglers and total trips this number is collected from), they reflect estimates for different percentiles, are estimated with uncertainty, and across a number of varying scenarios including each of the following:

- Geography – River Miles 0-8, 8-17, and the entire LPRSA (Table 2 presents the results for Miles 0-8 of the LPRSA and Kinnell and Bingham 2014 present additional results for the entire 17-mile LPRSA as well as miles 8-17 for comparison).[6]

[6] Moreover, because Kinnell and Bingham 2014 include trips to all of the sites anglers have been observed visiting in the LPRSA, the modeling of the extensive site-specific data can evaluate consumption for any defined geography.

- Population – All anglers versus fish-consuming anglers.
- Risk Conditions – current and baseline.
- Species – Estimates of consumption by species (Table 2 present the results across all species and Kinnell and Bingham 2014 present the results by species).

As Table 2 shows, EPA's point estimate of 34.6 g/day is higher than the mean estimate of the 90th, 95th, and 99th percentile of any scenario evaluated using all the site-specific data. In addition, EPA's point estimate is outside the range of the confidence intervals estimated for the 90th and 95th percentiles. For example, the mean of 3.76 grams per day for the 95th percentile of consuming anglers under current risk conditions has a 90-percent confidence interval that ranges from 1.00 to 9.50 grams per day. When these uncertainties are evaluated under the baseline-risk conditions, EPA's 34.6 grams per day estimate falls outside the 90-percent confidence interval of 1.30 to 13.60 grams per day. Finally, EPA's point estimate falls outside the range of the confidence intervals estimated for all but one of the 99th percentile estimates.

Table 2
Consumption Estimates by Scenario – All Species [a]

Geographic Scenario	Angling Population Scenario	Risk Estimate Scenario	Consumption (g/day)				
			Mean	Median	90th	95th	99th
River Miles 0–8	All Anglers	Baseline	0.29 (0.08-0.74)	0.00 (0.00-0.00)	0.49 (0.10-1.30)	1.38 (0.30-3.60)	5.64 (1.40-15.00)
		Current	0.13 (0.04-0.32)	0.00 (0.00-0.00)	0.13 (0.10-0.30)	0.55 (0.10-1.40)	2.74 (0.70-6.90)
	Consuming Anglers	Baseline	1.33 (0.36-3.39)	0.39 (0.10-1.00)	3.14 (0.70-8.40)	5.19 (1.30-13.60)	15.13 (3.80-38.71)
		Current	0.92 (0.28-2.28)	0.31 (0.10-0.80)	2.06 (0.50-5.20)	3.76 (1.00-9.50)	9.71 (2.50-25.41)

[a] LPRSA species include American eel, blue crab, carp, catfish, striped bass, and white perch.

The construct of Table 2 also separates the uncertainty evaluation into two components:

1. The effect that varying scenarios have on the ingestion estimates (e.g., the effect of evaluating consumption for the entire angling population versus only the fish-consuming population or the effect of evaluating ingestion under current-risk conditions versus baseline-risk conditions), and

2. The effect that the uncertainty in all the parameter inputs have on the ingestion estimate develop for each scenario—identified by the confidence interval on each parameter under each scenario specification.

In statistical analysis, the term *uncertainty* refers to the statistical reliability of estimates. Ingestion estimates are most useful when the causes of uncertainty are clearly identified and quantified. There are numerous sources of uncertainty that may lead to imprecision or bias in consumption estimates. Following Finkel (1990), EPA classifies uncertainty into two general types (EPA 2011):

- structural uncertainty—which reflects limited understanding of the appropriate model and relationships among model parameters, and
- parameter uncertainty—which reflects imprecision in the specific numeric values of model parameters.

Structural uncertainties will generally lead to inaccuracies, rather than imprecision, in consumption estimates. The analysis that develops the results presented in Table 2 (Kinnell and Bingham 2014) accounts for structural uncertainty by building a behavioral model that matches the structural aspects of how anglers make decisions that influence fish consumption (e.g., how many trips anglers decide to take, where angler decide to take those trips—LPRSA versus substitute sites, the amount of fish they keep, the types of fish they keep, the parts they consume, and how their behaviors across each of these would change under baseline-risk conditions).

To address parameter uncertainty, the model that generates Table 2's results includes a Monte Carlo component that quantifies and incorporates the effects of uncertainty in each input parameter on the overall uncertainty in consumption estimates under each evaluated scenario. The Monte Carlo analysis combines uncertainty in input parameters within the structural behavioral model to quantify uncertainty in consumption. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates within the framework of the consumption estimation. The resulting combination of the various inputs creates an estimate of consumption under each scenario.

The Monte Carlo analysis repeats this process of drawing from the various input distributions numerous times, each time drawing randomly from the designated ranges of values for calculating consumption. Each repetition produces a different estimate of consumption. The resulting distribution of outcomes from the repeated draws produces the range of potential consumption estimates that explicitly addresses uncertainty.

EPA's "weight-of-evidence" approach cannot account for either structural or parameter uncertainty. In addition, there are other uncertainties that affect consumption estimates that EPA's "weight-of-evidence" approach cannot account for. For example, between the 2000-2001 and 2011-2012 creel/angler surveys there were substantial changes in access in River Miles 1-7. Most notably, the single most popular site from the 2000-2001 creel/angler survey, the bulkhead behind the Hess Gas Station which had nearly five times as many anglers as any other site in the lower six miles, underwent substantial physical changes beginning in 2006 and did not have any observed angling activity during the 2011-2012 CAS administration. The site is now a hotel with a well-lit, brick walkway along the river that has a fence blocking direct access to the river.

During the 2000-01 CAS anglers fishing at the bulkhead behind the Hess Gas Station were also observed to smoke and drink alcohol in public at the site while they fished, risky behaviors that have been documented to be correlated with consuming fish from sites with a fish consumption advisory (Connelly et al., 1992). Thus, the characteristics of the bulkhead may have attracted individuals who are more likely to engage in risky behaviors. Moreover, when the site was turned into a hotel with a brick, well-lit pathway adjacent to the river, its characteristics may have changed to one that does not lend itself to supporting public acts of risky behavior like smoking and drinking in public.

The population estimates that Kinnell and Bingham (2014) developed for Miles 0-8 of the LPRSA show that the average number of trips per angler dropped from approximately 5 in 2000-2001 to 2 in 2011-2012. This means that the high-visitation, fish-consuming anglers observed during the 2000-2001 study are not taking trips to other sites in Miles 0-8 (e.g., Riverbank Park Ironbound, Riverbank Park Kearny, or the Pathmark Pier), or, if they are, they are not taking them with the same frequency as they did in 2000-2001. Figures 5 and 6 present the annual trip frequencies estimated from the site-specific fishing trip data collected during the 2000-2001 and 2011-2012 creel/angler surveys.

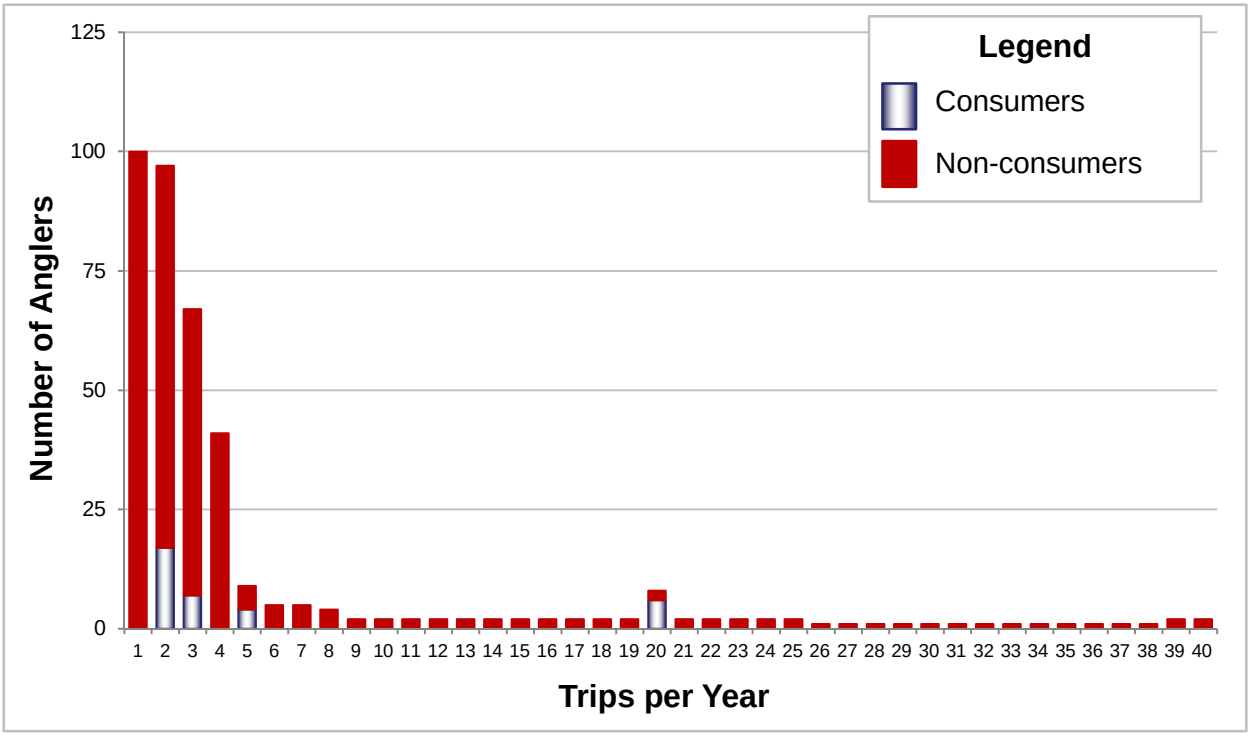


Figure 5: Annual Trip Frequency Histogram Using Data on Anglers Observed Trips in Miles 1-7 of the LPRSA during 2000-2001

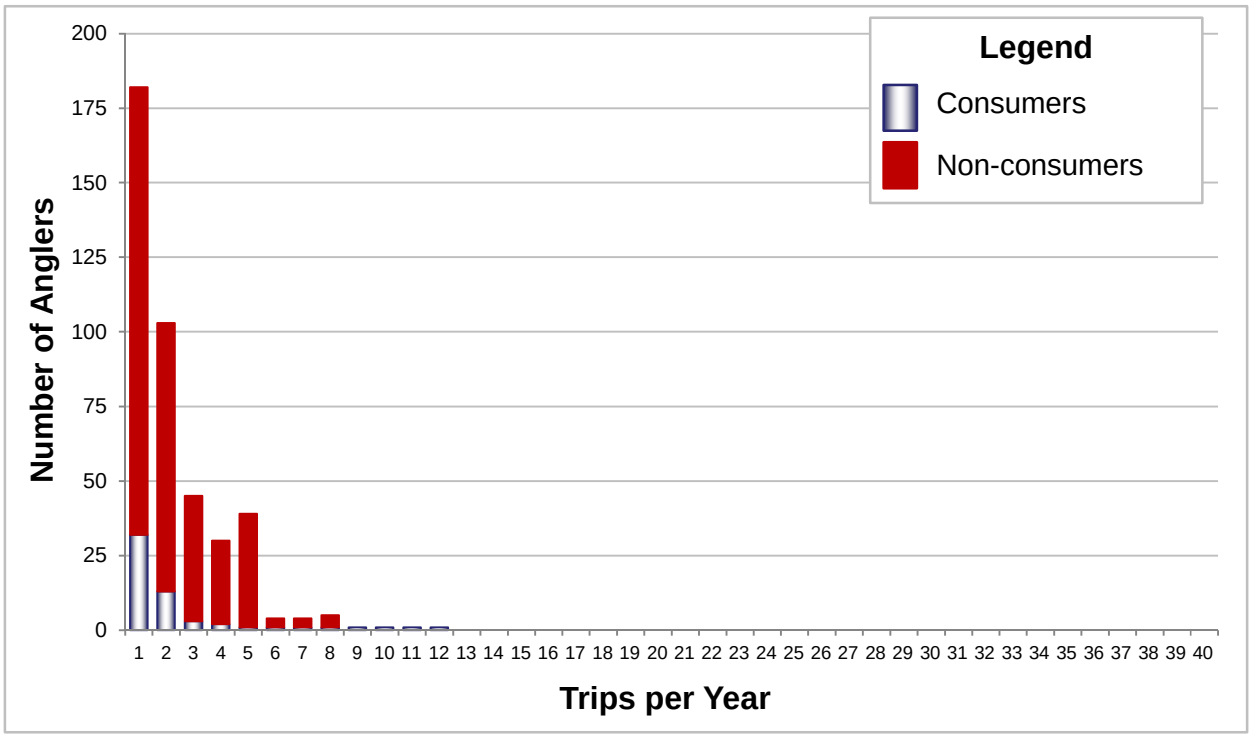


Figure 6: Annual Trip Frequency Histogram Using Data on Anglers Observed Trips in Miles 0-8 of the LPRSA during 2011-2012

The shape of the two frequency histograms is different. There were more high-frequency-trip anglers in 2000-2001 than in 2011-2012 (indicated by the longer right tail in Figure 5 than 6), there were fewer low-frequency-trip anglers in 2000-2001 than in 2011-2012 (indicated by the lower height of 1 and 2 trip angles in Figure 5 than 6), and a greater percentage of the high-frequency-trip anglers in 2000-2001 were consuming anglers (i.e., indicated by the percentage of consuming anglers taking 20 trips per year in Figure 5). Those were the anglers observed fishing at the bulkhead that existed behind the Hess Gas Station in 2000-2001 that did not exist in 2011-2012. The comparison between Figure 5 and 6 shows that these anglers did not show up at another site in River Mile 0-8 during the 2011-2012 study.

In addition, the decrease in trip frequencies produces lower ingestion rates when evaluated across the two time periods: the lost access at the Hess Gas Station and lower visitation frequency has decreased the 95th percentile estimate of current fish ingestion from 1.8 grams per day in 2000-2001 (Ray et al., 2007b) to 0.55 grams per day in 2011-2012. These results hold across both the consuming angler scenario and the baseline risk scenario as summarized in Table 3.

Table 3
Consumption Estimates by Scenario – All Species [a]

Geographic Scenario	Angling Population Scenario	Risk Estimate Scenario	Ingestion Rate for the 95th Percentile: Under 2000-2001 Conditions with the Access Behind the Hess Gas Station	Ingestion Rate for the 95th Percentile: Under 2011-2012 Conditions with Changed Access Behind the Hess Gas Station
Miles 0-8	All Anglers	Baseline	2.50	1.38
		Current	1.80	0.55
	Consuming Anglers	Baseline	12.52	5.19
		Current	11.96	3.76

[a] LPRSA species include American eel, blue crab, carp, catfish, striped bass, and white perch.

Because EPA has not used any of the LPRSA's site-specific data, nor based its evaluation on angler behavior, it cannot account for any of these uncertainties in its analysis. Its weight of evidence approach should therefore be rejected and replaced by a more modern technique, such as described in Kinnell and Bingham (2014), that uses the extensive site-specific, Expert-Panel reviewed, peer-review-published data and can consider uncertainties to generate informed estimates of baseline and future risk.

4. Results from Connelly et al. (1992) that comprise 50% of the "weight of evidence" approach should not be transferred to the Lower Passaic; these results should be excluded from any "strength of science" approach; the Connelly results could be correctly adjusted and incorporated into a "weight of evidence" approach that includes the extensive site-specific, Expert-Panel-reviewed, peer-review-published information

In its weight of evidence approach to calculate exposure, EPA transfers results from Connelly et al. (1992) that reports results from a survey that is intended to "identify effects of the updated advisory and general changes over time." A RAGS-consistent exposure assessment that could be transferred to the Lower Passaic would be a very different sort of study over a number of dimensions as described below.

1. An exposure assessment identifies specific points on a statistical distribution of ingestion which the Connelly study does not.
2. Exposure assessments measure ingestion at one particular site whereas the Connelly study measures ingestion across all sites covered by the study.
3. Exposure assessments are to measure the affected population the Connelly study evaluates licensed anglers from all of New York.
4. Exposure assessments are intended to measure baseline, current and future exposure, the Connelly study reflects behaviors that are decades old.
5. Exposure assessment should consider the major pathway, which is white perch. The Connelly study addresses a different mix of species.

For all these reasons which are described further below, the Connelly study does not constitute an exposure assessment.

4.1 An exposure assessment identifies specific points on a statistical distribution of ingestion which the Connelly study does not.

As described in RAGS, exposure assessments are to identify the "reasonably maximally exposed individual". This is often taken as the 90th percentile of consumption in grams per day. However, the Connelly study never mentions the concept of the reasonably maximally exposed individual. Nor does it identify the 90th percentile of ingestion. Rather, it contains a mix of descriptive quantitative statements about ingestion such as:

- "one-quarter of respondents did not eat sport caught fish"
- "two-thirds consumed within the limits"
- "8% of respondents exceeded the recommended number of fish meals per year"

- "about ¼ of respondents fished waters with advisories but did not eat listed species"
- "4% ate listed fish within the limits of the advisory"
- "7% ate up to 3 times over the recommended limit"
- "7% or respondents ate more than 3 times the recommended limit"

In referencing that the 90th percentile of fish consumption from the Connelly study was 31.9 grams per day, the Region 2 "exposure assessment" references a document that does contain the 31.9 grams per day estimate (TAMS). However, this document, an exposure assessment for the Upper Hudson, is not clear about the origin of the 31.9 grams per day estimate; the most specific related statement reads

> "Based on the 1991 New York survey of fish consumption by licensed anglers, (Connelly et al. 1992), the central tendency of the fish ingestion rate was determined to be 4.0 grams per day, or about six half-pound meals per year and the RME fish ingestion rate was determined to be 31.9 grams per day, or about 51 half-pound meals per year for adults."

No information is available to directly reconstruct the 31.9 estimate. One possibility is that the analysts relied on the statement, "8% of respondents exceeded the recommended number of fish meals per year."

Combined with the "recommended limit" of one meal per week (52 per year) this could potentially be extended as follows: if 8% exceed 52 meals per year, it could be speculated that approximately 10% exceed 51 meals per year. In this case, the 90th percentile of meals is 51 meals per year. At ½ pound per meal, this leads to 25.5 pounds per year, the equivalent of 31.7 grams per day (11,566.596 grams per year/ 365 days per year) which is close to 31.9 grams per day.

4.2 Exposure assessments measure ingestion at one particular site whereas the Connelly study measures ingestion across all sites covered by the study.

As described in RAGS, risk assessments are to take place at contaminated water bodies that are "large enough to produce a consistent supply of edible-sized fish over the anticipated exposure period" (USEPA 1989). Clearly, RAGS is referring to individual waterbodies. The resulting implication is that risk metrics such as the 90th percentile of ingestion should also be based on ingestion from individual waterbodies.

However, the Connelly et al. (1992) ingestion rates appear to refer to consumption of contaminated fish from <u>every</u> site. For example, Table 16 in the Connelly et al. (1992) report lists the mean number of sport-caught fish meals from all waterbodies for respondents in three

categories (advisory awareness, behavioral change, and behavioral intention) and their sub-categories. The report does not list the waterbodies where respondents caught fish nor does it identify the number of meals of fish eaten from any individual waterbodies.

It is the nature of exposure that exposure from all sources (here sites) is higher than exposure from any particular site. For example, if a person eats ten meals of contaminated fish per year, that person's total meals per year is 10/365. If that person eats from two different sites, the consumption from each of those sites is less than 10/365 (e.g. 2/365 and 8/365). This means that if the Connelly study were to be employed in the (misguided) weight of evidence approach, its numbers should be adjusted. Adjusting for this factor would lead to substantially reduced consumption frequencies that would be more appropriate for transferring to the Passaic.

The Connelly data are not available to make this adjustment. However, the 2000 New Jersey Outdoor Recreation Survey was a population-based survey that collected trip diary information to all fishing sites in New Jersey visited by anglers in the five counties surrounding the LPRSA: Essex, Hudson, Bergen, Passaic, and Union (Bingham et al. 2011). To evaluate the likely reduction, we looked at this trip data and identified repeat trip taking. Specifically responses to the consumption frequency question "How many meals from all…" were simulated by identifying individual anglers' frequency distribution for trips to all sites with advisories. The cumulative frequency distribution for trips is depicted below.

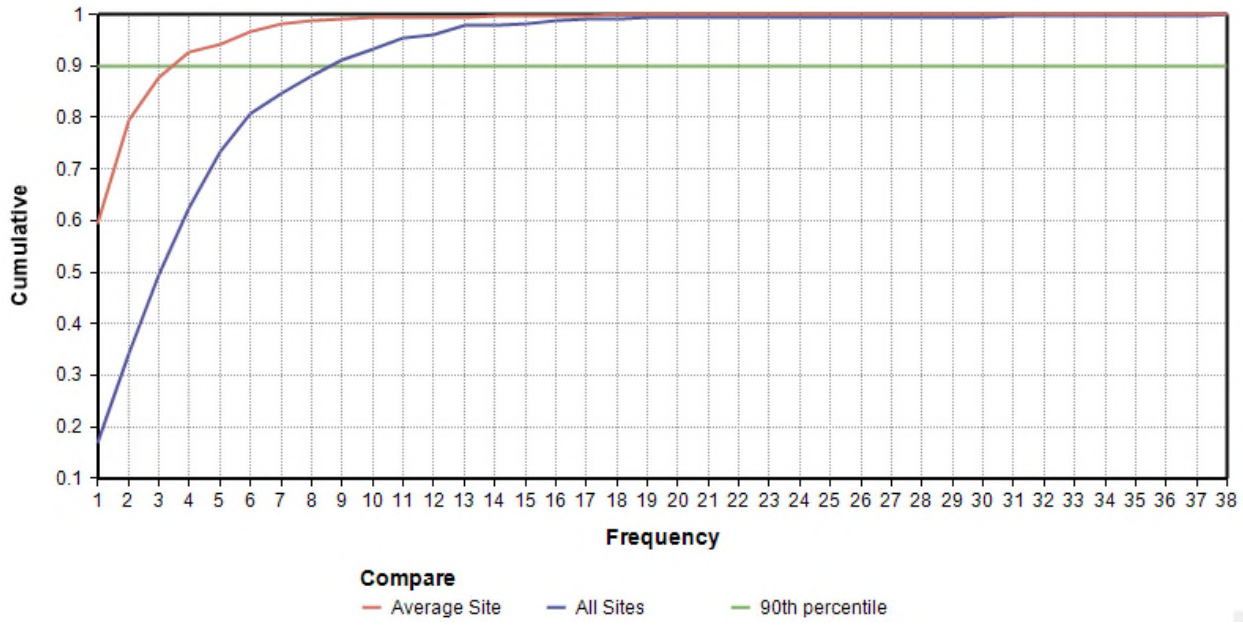


Figure 7: Cumulative Frequency Distribution for Trips

The blue cumulative density function (cdf) is for all sites. This indicates a 90th percentile of between eight and nine trips per year. The more appropriate values are for the average site indicated by the red cdf which indicates a 90th percentile of between two and three trips.

These data covered three months rather than a year. Also, although trips and success underlie consumption, they are not consumption. Nevertheless, the results are instructive: in the three month case using a population survey, the 90th percentile of trips anglers take to individual sites is less than a third of the 90th percentile taken to all sites.

An implication of this difference is that the Connelly et al., 1992 exposures are for consumption of contaminated fish from every site included in the study which substantially overstates ingestion from an individual site such as the Lower Passaic River. Like the survey employed by Connelly et al. (1992), the 2000 New Jersey Outdoor Recreation Survey reported in Bingham et al. (2011) is a population survey. Adjusting Bingham et al. (2011) so that the multiple-site frequencies are single-site frequencies requires reducing the multiple-site frequencies by 59%. Applying this 59% reduction to the ingestion estimates from Connelly et al. (1992) would result in a reduction from 31.9 to 13.1 grams per day.

4.3 Exposure assessments are to measure the affected population—the Connelly study evaluates licensed anglers from all of New York State.

Under RAGS exposure assessments are expected to consider the population that is actually being exposed to the contaminant. RAGS specifies that risk assessments should "identify subpopulations of potential concern" including those who exhibit "behavior patterns that may result in high exposure" (USEPA 2001). RAGS advises that exposure assessments must "determine (the) location of current populations relative to the site (USEPA 2001)." This information could include, "distance and direction of potentially exposed populations and identification of those populations that are closest to or actually living on the site (USEPA 2001)."

As described earlier, Region 2 did none of this. Rather Region 2 performed a sort of weighted transfer. A major problem with this is that the Connelly study, which comprises 50% of the weighted transfer, covers a very different geography and population of anglers. For example, the Connelly study is the population of the entire State of New York. No apparent corrections are made to adjust for the difference in the population of or fishing choices available to Lower Passaic River anglers. As a result, there is incongruence between the two. For example, the studies conducted on the River indicate that high consumers are urban and non-

white. Yet the study Region 2 chose to transfer specifically notes that "anglers who ate above the recommended limit were predominantly male, white, and came from a rural area."

4.4 Exposure assessments are intended to measure baseline, current and future exposure—the Connelly study reflects behaviors that are decades old.

An exposure assessment that is reasonably transferrable should consider current practices. Yet the Connelly study reflects behaviors that are nearly 25 years old. An important potential change is the rise in U.S. recreational anglers practicing catch-and-release fishing. In the early decades of the 20th century, articles in outdoor magazines often mentioned releasing legally harvestable gamefish (Quinn 1996). Currently, federal and state agencies impose size limits, bag limits, seasonal closures, or rarely, a complete moratorium on the harvest of a particular species. State fisheries experts respond to angler preferences when recommending catch-and-release regulations (Jersey Coast Anglers Association 2001; Quinn 1996).

This combination of voluntary effort and regulatory action has induced recreational anglers to reduce harvest rates of the fish they catch by releasing the fish alive. In some fisheries, voluntary release rates now approach 100 percent (Cooke and Suski 2005). Table A.1 in Appendix A estimates catch-and-lease rates for U.S. waterbodies. Where data are available over time for taxa in the same waterbodies, the table shows that catch-and-release fishing increases. For example, angler release of trout into New Jersey rivers and streams increased from 2003 to 2012.

Because of lack of information, it is difficult to make direct comparisons. However, it is clear that catch-and-release has increased, implying a decline in consumption. The National Oceanic and Atmospheric Administration (2008) reported that 51 percent of anglers caught and released fish in 1993. By 2013, New York anglers released as much as 99 percent of some species that they caught (Great Lakes Sport Fishing Council 2011). An implication is that this is another factor that requires consideration in transferring the results from the Connelly study to the LPRSA. Incorporating this factor into the transfer could easily result in a reduction of up to 30% in the ingestion rate reported in Connelly et al. (1992).

4.5 A Reasonably Similar Exposure assessment should consider the major pathway, which is white perch. The Connelly study has a different mix of species.

The Connelly study covers behaviors from all over New York State. These naturally cover a variety of waterbodies and species. The Lower Passaic is a degraded waterbody, with fish populations that reside in degraded water quality. An implication is that consumption in the

Passaic River will be very different from consumption at the sites covered by the Connelly study. The Connelly study collected, but did not report species data.

According to the two CAS's of the Lower Passaic, white perch is the most caught and consumed species (Kinnell and Bingham 2014; Kinnell et al. 2007). Crouse, Jacobsen, and Boriek (undated), New Jersey Division of Fish and Wildlife employees, reported that "white perch are plentiful" in the Passaic River below Dundee Dam. Anglers discuss fishing for white perch in the Passaic River on message boards and other sites (including those from RM 8-17):

- *Kayak Fishing Magazine* (2013) includes remarks from a Passaic River angler stating that hundreds of white perch could be caught at dusk.
- Fishing Facts (2005) listed several locations on the Passaic River where white perch can be caught.
- Carp.com (2006) included comments from people fishing the Passaic River, such as "What are you using to catch the white perch?"

Along with their reports, some anglers post photographs of white perch caught from the Passaic River.

Table 4 lists the fish from Table 25 in Connelly et al. (1992) and the percentage of respondents stating that they did not eat the fish before learning about fish-consumption advisories. Given the difference between species consumed generally across the entire State of New York, and the species that are available to consume only from the Lower Passaic River, transferring the all-species results from the Connelly study to the consumption rate calculations of Lower Passaic River consumption significantly and improperly skews the results (USEPA 1989, pp. 4-11, 6-30, 6-31, 6-43). The difference in consumption across species that are known as table fare such as trout, salmonids, and walleye and those that are available in the Passaic such as white perch, eel, and carp is an important unadjusted effect in transferring the Connelly et al. (1992) results to the LPRSA. Accounting for this effect in the transfer implies a downward adjustment of up to 50% in the Connelly et al. (1992) ingestion rate.

Table 4
Connelly Report: Percentage of New York Anglers Who Did Not Eat Fish

Fish Listed in Table 25 Connelly et al. (1992)	Percentage of Respondents Who Did Not Eat the Fish
American eel	91.8
Brown bullhead	55.5
Brown trout	33.9
Carp	93.9
Channel catfish	80.0
Chinook salmon	60.5
Coho salmon	58.3
Crappie	56.3
Lake trout	43.7
Largemouth bass	32.2
Muskellunge	87.8
Pickerel or pike	54.3
Rainbow trout	27.8
Smallmouth bass	31.6
Sunfish	51.0
Walleye	45.5
White perch	63.5
White sucker	93.1
Yellow perch	36.9

In using Connelly et al. (1992) in its weight of evidence approach, Region 2 employs a study that is not designed for estimating the 90th percentile of consumption. Connelly et al. (1992) should therefore not be used for this purpose. If Region 2 is going to transfer Connelly et al. (1992) to the LPRSA, it must be adjusted across a number of areas. Many of these adjustments by themselves support reductions of up to 50% in the ingestion rates, resulting in estimates that provide external validity to the scientifically developed, site-specific ingestion estimates presented in Kinnell and Bingham 2014.

5. Results from Burger (2002) that comprise 50% of the "weight of evidence" come from an on-site study that was not intended to measure the consumption frequencies required for risk assessment; they should be excluded from a "strength of science" approach; the Burger results could be correctly adjusted and incorporated into a "weight of evidence" approach that includes the extensive site-specific, Expert-Panel-reviewed, peer-review-published information

EPA also employed results from Burger (2002) in its weight of evidence approach. The Burger study was an on-site study, conducted in nearby Newark Bay. Thus the area and population bears some resemblance to the Lower Passaic River. However, as explained in earlier comments, consumption can be very site-specific and driven by idiosyncrasies over small areas like the Lower Passaic—this tends to invalidate transfers from even very similar sites.

Given that a transfer was attempted, important considerations were ignored. For example, Region 2 notes "all of the papers provided below were published in the peer-reviewed literature". The Burger study falls into this category; however, results regarding the important risk metrics (mean and 90th percentile) do not appear in the paper. The FFS implies that the paper is technically peer-reviewed, but results, as described below, regarding consumption percentiles that are employed in the risk assessment are not peer-reviewed; describing their status as such is misleading.

A particularly important flaw with employing the Burger study and data to develop ingestion rates for the Passaic River is how the data are weighted. There is no discussion of weighting; in fact, the paper states,

> "Although the results of the study clearly represent those interviewed, there is no reason to assume that this does not represent the fishing public using this area because we interviewed nearly everyone present and sampled at all times of day, on both weekends and holiday (Burger 2002)."

Actually, certain results are not representative of the population when evaluating unweighted on-site data; this results from avidity bias, and trip frequency weighting is required to remove it so the results can be representative of the population. Without trip-frequency weights, conclusions about frequency-based behaviors such as fish consumption are invalid. Adjusting to reflect trip-frequency leads to substantially reduced consumption estimates. This process is very recognized and is described in Ebert et al. (2011); Stern, Korn, and Ruppel (1996); Sechena et al. (2003); Imm et al. (2005); Williams et al. (2000); Leggett et al. (2012); and Ray et al. (2007a, 2007b).

The problems with not weighting by trip frequency can be demonstrated by example as well. A current effort by Industrial Economics to conduct a risk assessment on the Upper Columbia River describes the issue and also points out that contractors for other USEPA regions commonly use the proper approach in other venues (Leggett et al. (2012)).

> "Consider a simple example involving day trips to a hypothetical beach. Suppose 500 of the visitors are "Type A" visitors and visit three times a year, while 500 of the visitors are "Type B" visitors and visit only once a year. Clearly, when averaging across the entire population of 1,000 visitors, the average annual trips to the beach is two visits per year. However, as Type A visitors contribute three times as many trips as Type B visitors, Type A visitors would be three times as likely to be selected in a typical on-site sample. That is, in a typical on-site sample of 100 visitors, approximately 75 would be Type A visitors and approximately 25 would be Type B visitors. The average annual trips calculated from this sample would be 2.5 trips per year: 2.5 = (75 * 3 + 25 * 1)/(75 + 25). Thus, in the absence of weighting, the sample average provides an estimate of the population mean that is biased toward avid visitors.
>
> However, if each respondent in this example is weighted by the inverse of his or her probability of selection, an unbiased estimate of average annual trips can be obtained. Let p represent the probability of selection for a Type B visitor, so that the sampling weight for Type B visitors is 1/p. The probability of selection for a Type A visitor (who takes three times as many trips) would then be 3p, with a sampling weight equal to 1/(3p). For the typical sample of 100 visitors described above, the weighted average annual trips would be equal to 2.0 trips per year: 2.0 = (1/(3p) * 75 * 3 + (1/p) * 25 * 1)/(1/(3p) * 75 + (1/p) * 25)."

Because meals per time period are tied to frequency of fishing for each time period, correctly calculating ingestion requires frequency weighting. If frequency weighting is not conducted, a substantial overestimate will result. This means that data from Burger (2002) cannot be transferred to the LPRSA without substantial downward adjustment. The example above implies a downward adjustment on the mean of 20% (1 - 2.0/2.5). Because the effects of not weighting are magnified for higher frequency anglers, it is possible that a downward adjustment of 50% or more is appropriate for the 90th percentile ingestion estimate from Burger (2002).

In using Burger (2002) in its weight of evidence approach, Region 2 employs a study that is not designed for estimating the 90th percentile of consumption. Burger (2002) should therefore not be used for this purpose. If Region 2 is going to transfer Burger (2002) to the LPRSA, it must be adjusted across a number of areas, including frequency weighting. This single adjustment by itself supports reductions of up to 50% in the ingestion rates, resulting in estimates that provide external validity to the scientifically developed, site-specific ingestion estimates presented in Kinnell and Bingham 2014.

6. The social costs from quality of life impacts are expected to be higher under the off-site disposal scenario than the confined aquatic disposal (CAD) scenario

The Off-site Disposal's higher social costs are expected to result from the over-land transportation of hazardous substances; siting, construction, and operation of the hazardous substance handling and wastewater treatment facility; and greater energy consumption from the off-site disposal than the CAD. Unlike the costs of either scenario, these quality of life changes are not priced in markets, so they do not have a traditional market value, nor are they typically included as a quantitative cost estimate. However, because their effects can decrease the well-being of residents located in areas within, or adjacent to, the project area, their effects should, at a minimum, be identified to understand the explicit, even if unquantified, tradeoffs that exist between scenarios. Quantifying the impacts that these quality of life changes have on society's well-being produces what economists refer to as the social costs of each scenario.

Under the CAD scenario, 4,304,000 cubic yards of sediment would be removed from Miles 0–8 and placed in the CAD, which would then be capped. Barges would carry the sediment from the Lower Passaic River to the CAD. The barge transportation would generate social costs associated with expending energy for transportation (e.g., the human-health and ecological impacts from increased carbon dioxide (CO_2), unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter emissions).

In addition, traffic and navigation may be affected. Land-based traffic may be affected by increased operation of mechanical bridges. Navigation traffic may be affected by the increased barge traffic on the Passaic River and in Newark Bay. Traffic increases would cause social costs as residents and businesses would spend more time in traffic and have less time for labor and leisure activities.

The CAD itself consists of two cells in Newark Bay, with a total area of 80 acres, and an excavation depth of 60 feet below mean low water (MLW). The CAD excavation would require energy, which would produce a social cost. In addition, the CAD could potentially make certain parts of Newark Bay inaccessible, which could produce a social cost.

The Off-site Disposal scenario involves moving 4,304,000 cubic yards of sediment from the river's bottom to a dewatering facility. From there, 180,000 tons of dewatered materials are transported out of state to thermal treatment facilities in Texas, Utah, Nebraska, or potentially Canada. In addition to the 180,000 tons transported to thermal facilities, 2,460,000 tons of dewatered materials would be disposed at Subtitle C landfills in Louisiana, Oklahoma, or Idaho.

Major actions generating social costs include constructing and operating the sediment handling and wastewater treatment facility as well as getting sediment to, and removing it from, the facility.

The facility would be up to 26 acres in size and would be located near the waterfront and transportation resources. Because it would handle hazardous substances, its siting, construction, and operation has the potential to reduce nearby property values, which would be a social cost. This is a social cost that is not expected to occur under the CAD scenario, or if it does occur, to not be as large in the CAD scenario. The facility would also use energy for de-watering. This would have social costs of energy use. Also, lights and noise could have social costs if the facility is located near a residential area.

Sediment would have to be dredged, pumped, and/or transported to the facility, which will use energy and produce social costs (e.g., the human-health and ecological impacts from increased carbon dioxide (CO_2), unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter emissions). The energy expended for this scenario is expected to be higher than the dredging component of the CAD scenario, producing higher social costs from the Off-Site Disposal scenario than the CAD scenario.

Finally, dredged material would be removed from the facility and temporarily stored on-site before being loaded onto dedicated rail cars for transport to facilities licensed for treatment and disposal of hazardous substances. This would have the social costs of that transportation including noise, congestion, air pollution, and accident risk.

Table 5 provides a summary of the social costs that would be present under the CAD and Off-Site Disposal scenarios and indicates whether the social cost component is expected to be higher under one scenario than the other. The Off-Site Disposal scenario has higher expected social costs than the CAD scenario.

As Table 5 describes, both scenarios will experience land-based traffic from increased operations of mechanical bridges and navigation traffic caused by increased barge traffic. These social costs result from transporting the sediment from the Lower Passaic River to either the CAD or the upland sediment processing facility (under the Off-Site Disposal scenario). The social costs associated with expending energy and decreases in property values are expected to be higher under the Off-Site Disposal scenario than the CAD scenario. The Off-Site Disposal scenario is also expected to have a land-based increase in accident risk from increases in rail traffic of treated sediment enroute to off-site landfills, light impact from the upland sediment processing facility, and noise impacts from the upland sediment processing facility's operations.

Table 5
Economic Impacts and Social Cost Comparison by Scenario.

Potential Quality of Life Impacts/Social Costs	Off-Site Disposal	CAD Cell
Social costs associated with expending energy	●	•
Barge transportation of sediment to CAD		•
CAD excavation		•
Barge transportation of sediment to upland sediment processing facility (USPF)	•	
Pumping sediment at USPF	•	
Dewatering of sediment at USPF	•	
Energy consumed from rail transportation of sediment to off-site landfills	•	
Land-based traffic from increased operation of mechanical bridges	•	•
Land-based traffic/accident risk from increased rail traffic to off-site landfills	•	
Navigation traffic caused by the increased barge traffic	•	•
Parts of Newark Bay becoming inaccessible		•
Decrease in property values	●	•
USPF that handles hazardous substances, siting, construction, & operation	●	
Presence of CAD in Newark Bay		•
Light impacts from USPF	•	
Noise from USPF and increased rail traffic to off-site landfills	•	

Legend

A dot in the cell identifies that the disposal option will have the individual quality of life impact and social cost.

The size of the dot corresponds to the relative size of the impact and social cost.

● The larger dots anticipate higher relative quality of life impacts and social costs for that category than the smaller dots.

• The larger dots anticipate higher relative quality of life impacts and social costs for that category than the smaller dots.

7. EPA's preferred alternative is unlikely to affect development related to the Passaic River's navigational shipping channel

USACE's survey of commercial property owners does not provide an economically sound representation of activities that are likely to occur under future commercial use of the Passaic River's navigation channel. Moreover, EPA's chosen scenario does not guarantee that the USACE will receive funding to undertake future maintenance dredging of the navigational channel. As the USACE's 2010 report suggests, not only do the costs and benefits of any future maintenance dredging projects have to be assessed for Miles 0–2, but they also must be compared against the costs and benefits of other competing navigation channel dredging projects. Given the proximity of Miles 0–2 to the Port Newark-Elizabeth Marine Terminal, it seems unlikely that the net benefits (benefits minus costs) of any maintenance dredging for the Passaic River's navigational channel will exceed those of the Port Newark-Elizabeth Marine Terminal. This is borne out in the historical maintenance dredging decisions for the Passaic River compared with the development decisions for the Port Newark-Elizabeth Marine Terminal.

7.1 General Comments

In the FFS press release, Judith A. Enck, EPA Regional Administrator, states that "The EPA's proposed cleanup plan will result in a cleaner river that protects people's health and increases the productive use of one of New Jersey's most important natural resources…" (EPA 2014a). Commercial shipping is one of the productive uses that EPA claims will be increased following completion of its preferred alternative. For example, EPA notes in its Fact Sheet for the FFS that "In most cases, navigational dredging has ceased altogether in the Lower Passaic, in part because contaminant levels in the sediment made treatment and disposal of dredged materials prohibitively expensive (EPA 2014b, page 1)."

EPA's technical justification that its preferred alternative has the possibility of supporting the future development goals of the Passaic River's navigational channel is based on

- a characterization of past maintenance dredging activities that is inconsistent with actual past activities
- economic reasoning that
    1. is inconsistent with the economic history of both the Passaic River and the Port of Newark's development
    2. ignores the benefit-cost analysis the USACE must undertake to evaluate any project and justify it relative to the net benefits of competing projects

- relies on survey responses regarding hypothetical future behaviors that do not appear to be credible given current actual behavior and the maintenance dredging conditions in Miles 0–2 over the last 30 years.

7.2 EPA's Characterization of Past Maintenance Dredging Activities is Inconsistent with Actual Dredging Activities in Miles 0–8

Under the heading of "The Causes of Pollution in the Lower Passaic River," EPA notes the following in its Fact Sheet on the Passaic River's Polluted Past:

> "The Lower Passaic River has a federally authorized navigation channel, which was constructed at the end of the 19th century, then sporadically maintained in various portions of the river through 1983. As maintenance dredging declined and stopped, the artificially deep navigation channel filled with sediment. At the same time, industrial activities along the river grew, and industries and municipalities disposed of wastewater in the river. The coincidence of disposal in the river of large quantities of chemicals that bond with sediment particles, along with the filling-in of the navigation channel, created an ideal situation for the accumulation of contaminated sediment in the river bottom…When maintenance dredging was largely stopped in the 1950s in most of the lower eight miles, sediment filling rates were relatively high (approximately four inches per year) and coincided with a period when industrial discharges were most active, so the deepest sediment is the most highly contaminated. (EPA 2014b, page 4)."

EPA appears to base a number of its commercial shipping claims and analysis of the navigation channel on the analysis that US Army Corps of Engineers conducted and summarized in its 2010 report *Lower Passaic River Commercial Navigation Analysis* (USACE 2010). However, a number of statements in the USACE's report contradict the claims EPA is making on commercial shipping and maintenance of the navigational channel in its Fact Sheet (EPA 2014b). First, the USACE notes that

> "The first thirty foot deepening project was constructed in 1932 from Newark Bay to RM 2.6, just above the Lincoln Highway Bridge (Figure 3), removing nearly 1.5 million cubic yards of material … No further new construction was authorized after 1932, but the channel was regularly maintained for nearly fifty more years. The entire length of the new thirty foot project was first maintained in 1933, one year after construction and again in 1941 and 1946. During the 1940s the river was busy with traffic as the height of industrialization and manufacturing industries on the Passaic River coincided with World War II. Post-war, the project was regularly maintained. However, maintenance typically focused only on the first two miles. Portions of the thirty foot project were maintained in 1951, 1953, 1957, 1962, 1965, 1971, 1972, 1977 and 1983. The last maintenance dredging project was completed by USACE in 1983 when just over 500,000 cubic yards were removed from the lower 1.9 miles of the federal project area (USACE 2010)."

As the penultimate sentence of this quote notes, maintenance dredging in the lower two miles not only continued after 1950, it was conducted in nine separate events from 1951 to

1983. In addition, the amount of material dredged in 1983 was nearly one third of the total material removed in the channel's initial construction in 1932. These facts from the USACE dredging maintenance records directly contradict EPA's statements that "maintenance dredging was largely stopped in the 1950s in most of the lower eight miles" (EPA 2014b, page 1) and that the federally authorized navigation channel as "sporadically maintained in various portions of the river through 1983" (EPA 2014b, page 4).

In addition, the USACE's maintenance dredging records for all the reaches of the Lower Passaic River's navigation channel indicate that the USACE stopped its maintenance dredging of the Harrison Reach (River Miles 2.6 through 4.6) in 1937 (Table 1, page 6 USACE 2010). At a minimum, this is 13 years prior to the date EPA contends that "maintenance dredging largely stopped in the 1950s in most of the lower eight miles" (EPA 2014b). The disparity between EPA's characterization of maintenance dredging in the lower eight miles and the USACE's maintenance dredging records calls into question on the validity of EPA's statement that, "In most cases, navigational dredging has ceased altogether in the Lower Passaic, in part because contaminant levels in the sediment made treatment and disposal of dredged materials prohibitively expensive (EPA 2014b, page 1)." The more likely explanation is that the economics of maintenance dredging of the Lower Passaic River's navigational channel could not compete with the macroeconomic forces at work in international shipping in the late 1970's and early 1980's.

7.3 Economic reasoning is inconsistent with the economic history of both the Passaic River and the Port of Newark's development

Regional economic conditions and global shipping trends contributed to the decline in commercial shipping in the Passaic River and the recent increase in shipping in Newark Bay. As the USACE notes, "During the 1940s the river was busy with traffic as the height of industrialization and manufacturing industries on the Passaic River coincided with World War II. Post-war, the project was regularly maintained (USACE 2010, page 8)." However, not long after World War II there was a general decline in commercial shipping activity on both the Passaic River and in Newark Bay (Iannuzzi et al. 2002). As Figure 8 illustrates, this decline continued throughout the early 1990s until commercial shipping activity began to increase again in Newark Bay. As Figure 8 illustrates, this decline continues through the early 1990's until commercial shipping activity begins to increase again on Newark Bay.

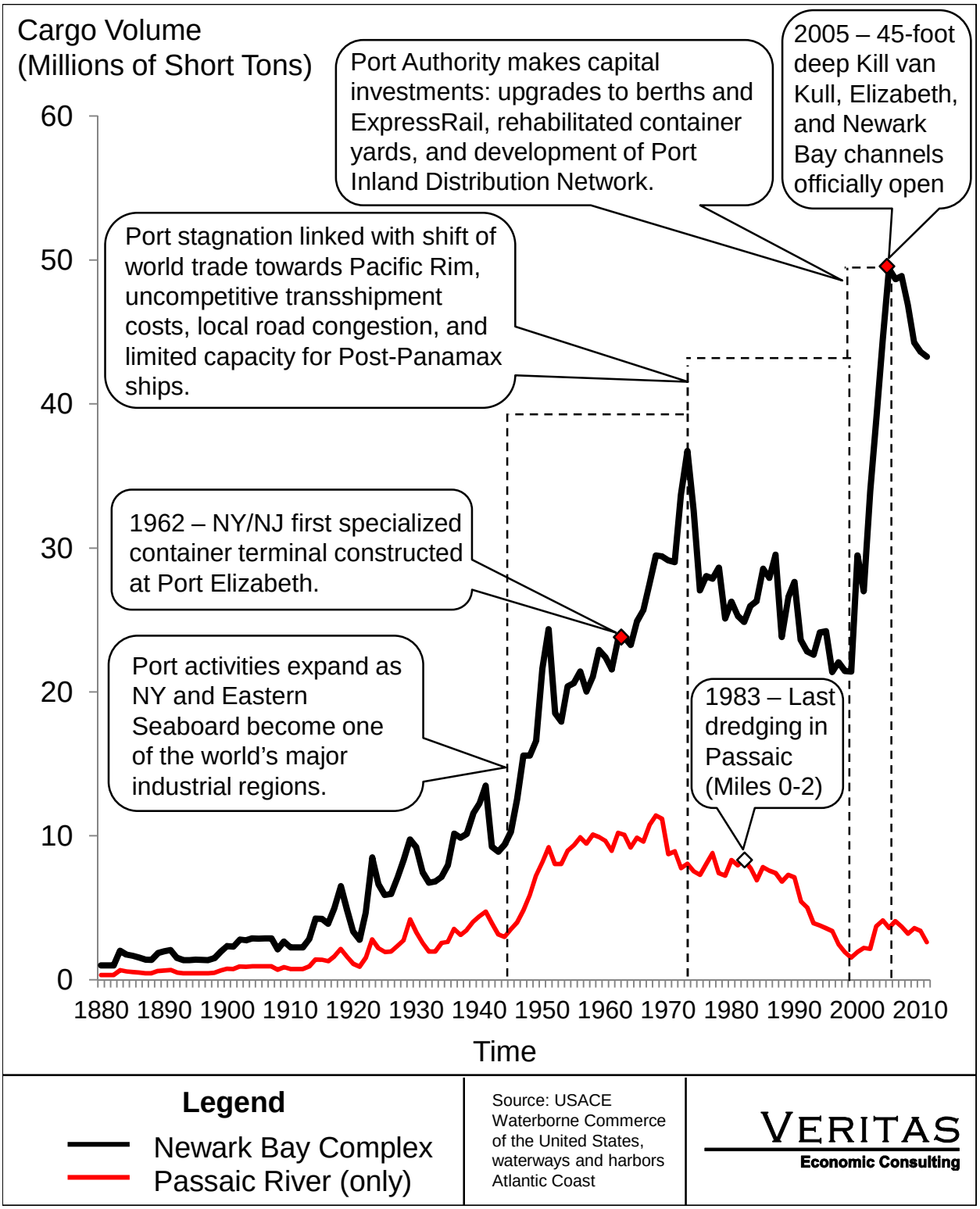


Figure 8: Commercial Shipping Volumes for Newark Bay: 1880–2010

Figure 8 summarizes how the economic conditions and regional trends affected commercial shipping in Newark Bay and the Passaic River. After World War II through the early 1970s, activities at the New York/New Jersey port (the Port) expanded as New York and the eastern seaboard became one of the world's main industrial regions. During this period, the Port Authority of New York and New Jersey (Port Authority) opened the world's first container port: Port Elizabeth. Following the opening of Port Elizabeth in 1962, Newark Bay experienced a sharp increase in container traffic and cargo volume.

However, from the 1970s through the mid-1990s, the Port and the Passaic River saw stagnation in cargo volume. This stagnation is linked with a shift of world trade to Pacific Rim ports such as Singapore and Hong Kong and the contemporaneous rise of U.S. Pacific Coast ports including Los Angeles and Long Beach (Rodrigue 2004). The container volume at these ports rose and topped the New York/New Jersey Port. In addition to exogenous factors like the global shift in trade, local factors such as inadequate intermodal rail access and high labor costs played significantly in its [the Port's] decline (Warf and Kleyn 1989). At the time, the channel depth of 40 feet could not accommodate post-Panamax containerships, which require a channel depth between 42 and 52 feet. During this time of the changing nature of global shipping, in 1983 the USACE conducted its last maintenance dredging for Miles 0-2 of the Passaic River.

Following this period of stagnation, the Port again saw an increase in cargo volumes. From the mid-1990s through the 2000s, the Port Authority made significant capital investments. The Port Authority upgraded the berths and container yards at Port Newark, adding additional acreage and cranes that could accommodate larger ships. The Port Authority also upgraded an intermodal rail facility so that it could handle more containers. The Port Authority created the Port Inland Distribution Network (PIDN) to reduce the local traffic congestion and improve air quality. The PIDN moves "containerized cargo by barge or rail between marine terminal facilities in the New York-New Jersey area and regional terminals in New York, New Jersey and three other Northeast states" (Port Authority of New York and New Jersey 2002). In addition to capital improvements, the world's largest container shipper, Maersk-Sealand, renewed its contract in 1999 with the Port Authority, keeping the Port as its East Coast hub. Two additional container shippers renewed their leases with the Port Authority in 2000.

In 2005, USACE completed and officially opened 45-foot deep Kill van Kull, Elizabeth, and Newark Bay channels. These deeper channels accommodate ships that carry more than 4,500 TEUs (twenty foot equivalent containers). The USACE, in conjunction with the Port Authority, are currently near completion of a 50-foot channel deepening project in the main navigational channels in the Port area, including the Kill van Kull, main Newark Bay, and Port

Elizabeth channels. With only the channel deepening project, Post-Panamax ships would not be able to navigate to the Port because they could not clear the Bayonne Bridge. In 2010, the Port Authority announced it would raise the Bayonne Bridge an additional 64 feet, which will allow for post-Panamax ships to cross beneath the bridge and make their way to the marine terminals in Newark Bay.

As Rodrigue (2004) describes, the reason for this initial decline and then resurgence in Newark Bay shipping has more to do with global shipping trends and the investment decisions that the Port of Newark made in the 1980s than the costs of maintenance dredging alleged by EPA). By switching to containerization, switching activity from New York Harbor to Newark Bay, and expanding the Newark Bay channels, the New York/New Jersey Port Authority was able to increase the amount of shipping activity in Newark Bay (Rodrigue 2004).

7.4 Economic reasoning ignores the benefit-cost analysis the USACE must undertake to evaluate any project and justify it relative to the net benefits of competing projects

Along with the disparity in facts calling into question that "navigational dredging has ceased altogether in the Lower Passaic, in part because of contaminant levels", EPA's preferred alternative does not guarantee that the USACE will receive funding to undertake future maintenance dredging of the navigational channel. As the USACE notes in its navigational analysis of the Lower Passaic River, maintenance dredging investment decisions are not made without considering the opportunity costs of other Federal investment alternatives. Specifically the USACE notes, "Future maintenance dredging by the USACE would require economic justification of project costs to obtain federal funding (USACE 2010, page 8)." Comparisons of the economic justification of maintenance dredging in Newark Bay versus the lower two miles of the Passaic River provide a direct opportunity cost comparison and one that is likely to have been winning out since the investment decisions for expanding Newark Bay's containerized shipping capabilities were evaluated and made more than 30 years ago (Rodrigue 2004).

As the USACE's 2010 report suggests, not only do the costs and benefits of any future maintenance dredging projects have to be assessed for Miles 0–2, but they also have to be compared against the costs and benefits of other competing navigation channel dredging projects. Given the proximity of Miles 0–2 to the Port Newark-Elizabeth Marine Terminal, it seems unlikely that the net benefits (benefits minus costs) of any maintenance dredging for the Passaic River's navigational channel will exceed those of the Port Newark-Elizabeth Marine Terminal. This is borne out in the historical maintenance dredging decisions for the Passaic River compared with the development decisions for the Port Newark-Elizabeth Marine Terminal.

7.5 Survey responses regarding hypothetical future behaviors do not appear to be credible

In addition to having to obtain economic justification for federal funding to support future maintenance dredging, the USACE further notes that

> "Economic analysis of maintenance dredging would be reevaluated in the future given changes in commercial usage and sediment conditions post- remediation. In addition, the decision to maintain the navigational channel would be further influenced by a commitment from the users to maintain their berths (USACE p. 8)"

To understand the "changes in commercial usage and sediment conditions post-remediation," the USACE conducted a survey asking current commercial shipping users of the lower Passaic River to identify what their likely future use would be post-remediation (USACE 2010). The USACE's survey of commercial property owners in Miles 0–8 is non-scientific and does not provide an economically sound representation of activities that are likely to occur under future development of the Passaic River's navigation channel.

Table 6 lists the 24 entities with berths on the Lower Passaic River since 1997. Of these, 8 organizations, comprising 29 percent of total shipping between 1997 and 2006, attended an August 27, 2009 meeting with USEPA, USACE, and NJDEP and responded to USACE's survey (USACE 2010). Minutes of this meeting are unavailable; however, the agenda for the meeting began with an overview of the Lower Passaic River Clean Up and the alternatives for the Focused Feasibility Study (USACE 2012). The USACE then reviewed its 2008 Commercial Navigation Analysis with the meeting participants. The remainder of the meeting was focused on an open discussion regarding the following questions:

- How are you currently using the Passaic River navigation channel?
    - Discuss any physical constraints that limit how you are operating.
- How do you expect to operate in the future?
    - How would you operate if conditions stayed the same as they are now?
    - How would you operate if the channel were deeper?
    - Are there facility/infrastructure changes, operational modifications or other investments you would need to make in order to operate in a deeper channel?
    - If so, how likely is it that you will be able to make these investments in the short term (2-5 years)? In the long term (5+ years)?

Table 6
Shipping History and Survey Response Status of Companies with Berths on the Passaic River, Miles 0–8

Berths	River Mile	Tons Transported on LPR 1997–2006	% Tons Transported	Responded to Survey
Amerada Hess, Delancey Street Terminal	0.0	3,600,000	17%	No
Motiva Enterprises	0.0	6,500,000	31%	No
Apex Oil Company at Center Point Terminal	0.1	1,700,000	8%	No
Passaic Valley Sewerage Commissioners Wharf	0.4	500,000	2%	Yes
Darling International	0.6	750,000	4%	Yes
Cardolite Corporation	0.7	10,000	0%	No
Sunoco Logistics Partners, L.P.	0.9	2,900,000	14%	No
General Chemical	1.1	35,000	0%	No
Nimco Shredding Company Wharf	1.2	0	0%	No
George Harms Construction	1.4	250,000	1%	Yes
Amerada Hess, Newark Terminal Wharf	1.5	0	0%	No
Getty Petroleum Marketing	1.6–1.7	4,500,000	21%	Yes
Disch Construction	1.9	N/A	N/A	Yes
Clean Earth of New Jersey (CENJ)	2.2	N/A	N/A	Yes
PSE&G Co, Essex Generating Station Wharf	2.3	50,000	0%	No
City of Newark Municipal Dock	4.8	N/A	N/A	No
Colonial Concrete Company	4.8	1,000	0%	No
PSE&G Co, Harrison Gas Plant Wharf	5.5	0	0%	No
Linde-Griffith Construction Company Wharf	6.5	0	0%	No
Innovation Fuels	6.5	150,000	1%	Yes
Newark Asphalt Corp. Wharf (Napp-Grecco Wharf)	7.0	0	0%	Yes
Q Facility Petroleum Wharf	7.4	0	0%	No
Linonetti Oil Recovery Service Company Wharf	7.5	2,500	0%	No
Riverbank Petroleum Company Wharf	8.1	1,500	0%	No

As depicted in Table 7, two of the eight responding berth owners (Innovation Fuels and Newark Asphalt Corp.) appear unlikely to benefit from EPA's preferred remedy because depths will not be sufficient. For three other berth owners, it is unclear whether there would be a benefit. Darling International provided no relevant information and Disch Construction provided contradictory information about the drafts of their boats and berth depths. Clean Earth International is an entity that hopes to build a facility for handling contaminated sediment from Passaic River clean-up activities. This means that Clean Earth International receiving any benefit is contingent upon remediation activities.

In all cases, it appears that EPA unduly influenced the survey results. For example, the most meaningful potential impact is reported by Getty Oil. However, Getty's response arises from EPA's prodding: "Your feedback was not detailed enough for us to use it in our evaluation of how deep a navigation channel we should build into any potential future Superfund clean-up of the Passaic River." Although the depth of the federally authorized navigation channel is at issue and its berth is on the south side of the river, Disch Construction apparently requires remediation that is "bank to bank with a sand cap" to support its planned activities. Of most concern is the response from George Harms construction. This response (discussed in detail elsewhere) indicates a complete misunderstanding about the history of dredging the navigational channel.

Table 7
Respondents' Likelihood of Benefiting from Preferred Remedy

Berths	Shipping Benefit from Preferred Alternative	Other Comments
Passaic Valley Sewerage Commissioners Wharf	Yes	Spectraserv operates two barges to remove sludge. The Maria (draft 14'11) and Lisa (draft 18'4) must be short loaded due to draft issues.
Darling International	No/unclear	No operational information was provided.
George Harms Construction	No/unclear	Response was judged unreliable (see specific comment).
Getty Petroleum Marketing	Yes	Current draft limitations; with 25 feet of draft, would switch from 27K BBL barge to 78K BBL barge.
Disch Construction	No/unclear	Receiving benefit of deeper channel depth requires dredging, disposal, and sand capping from federal channel limit line to pier and bulkhead line. Implies that barges are currently light-loaded. Lists equipment with drafts much deeper than facility operating depths (i.e., 16' vs 8').
Clean Earth of New Jersey (CENJ)	No/unclear	Group hopes to create contaminated dredge material management facility to serve PRPs. With current depths could receive 2–3 barges drawing 14'. Goal is 2–3 scows drawing 17'. Viability of facility appears linked to selection of remedy.
Innovation Fuels	No	Would like to bring in 25K BBL barges versus 10–15K BBL barges brought in now; depths associated with preferred alternative in this section of the river (10') would not help this company.
Newark Asphalt Corp.	No	The standard stone transportation scows this company would like to use have a draft of 10', requiring a controlling depth of 12'. Depths associated with preferred alternative in this section of the river (10') would not help this company.

The survey also suffers from a number of the attendant problems associated with asking respondents hypothetical questions in which they bear no responsibility for the costs that would

be incurred. A review of one of the responses to the USACE's survey provides keen insights into these problems (the USACE's questions from its survey are in bold):

1. **How are you currently using the Passaic Navigation channel? Discuss any physical constraints that limit how you are operating. Please include any specific information about the vessels you are bringing in, including size draft, and the name of the vessel.**

   "…we purchased the property in February 2009. We have only recently started our permitting and site plan approval process and have had limited used of the property. Even with our limited use, to date, we have been hampered by the shallow water depths and have had to work around the tides due to the draft of our tugs. The main physical constraint that limits our operation is the depth of water. Depending on what the USACE does or does not do to the Passaic River channel, they could have a major impact on our operation…"

2. **How do you expect to operate in the future?**

   We expect to operate as a marine service provider and a loading and off loading location for our construction work, as well as servicing others needing access to the water for the loading and unloading of material, equipment, and other related services. One of our plans is to bring construction aggregates in on ships to be loaded and off loaded at our location, as well as using our location as a distribution point for these aggregates. We also have plans on using the location as a staging site for off shore and coastal water work in the tri-state area. We plan to establish an onsite precast concrete products plant for supply and shipping of precast products by barge from the property.

a. **How would you operate if the conditions stayed the same as they are now (no maintenance)?**

   We would be forced to operate around the tides for loading and off-loading. It would severely limit the activities we could perform at the site thereby limiting our volume of business and our ability to generate employment and trade opportunities.

   The fact that the current conditions could possibly worsen, if not addressed, is an issue that the USACE should also be considering.

b. **How would you operate if the channel were deeper and/or maintained at its authorized depth?**

   We are taken back by the possibility that the USACE may not maintain the depths of the channel. We fully anticipated, when we purchased the property, that the channel depths would be provided and maintained, based on the past history of the dredging in the lower Passaic River.

   Although maintenance dredging to maintain the channel depth is a necessity, we fell the channel need only be maintained at a 25 foot depth to operate efficiently.

As the responses indicate, there are some inconsistencies between the planned activities this respondent reports to be expecting to undertake in the future and his expectation that, "We full[y] anticipated, when we purchased the property [in February 2009], that the

channel depths would be provided and maintained, based on the past history of the dredging in the Lower Passaic River [last maintenance dredging performed in 1983]." It is difficult to say what expectations the respondent is basing his investment decisions upon when 26 years transpired between the last maintenance dredging on the River (1983) and his purchase of the property (2009). The respondent indicates that he has extensive plans for the site and claims the realization of those plans would be based on the continued maintenance of the shipping channel, maintenance that has not taken place in over 30 years. Given the absurdity of these statements, it is difficult to believe that these responses can be taken seriously, let alone that they can be considered credible.

8. EPA's preferred alternative will do little, if anything, to change the fishable water-quality condition of the River, will have done nothing to change the River's boatable and swimmable water-quality condition, and should be rejected

As established through environmental economic studies, understanding the value of natural resources requires understanding the intersection between ecological systems and meaningful economic endpoints (Boyd and Krupnick 2009). As defined in the Clean Water Act, an important determinant of the value that people hold for waterbodies is their usefulness for boating, fishing, and swimming. These form the "water quality" ladder that has been employed in many economic studies subsequent to the Clean Water Act. These terms are somewhat vague and are typically further defined in economic studies. For example, in an early application a survey described "boatable" as safe to fall into briefly and "fishable" as able to support gamefish such as bass (Mitchell and Carson 1989).

Billions of gallons of raw sewage and other pollutants go into New Jersey's rivers and bays each year. The amount varies from year to year based on rainfall and storms (O'Neill 2013). After Hurricane Sandy, about 840 million gallons of raw sewage was discharged into the waters of New Jersey, leading the USEPA to report that bacteria levels were high in samples taken from the LPRSA (USEPA 2013; EPA Region 2 2012).

The 73 combined sewer overflows (CSOs) that discharge into the Passaic River account for the high bacteria levels as well as other contaminants (Donovan et al. 2008). As little as one inch of rainfall can cause the discharges and within 24 to 48 hours can result in an estimated 125 million gallons of combined storm water and sanitary sewage to discharge directly into the Passaic River. These discharges result in the low dissolved oxygen and higher nutrient levels of the Lower Passaic.

Remedial action of the sort envisioned by EPA's preferred alternative will do nothing to change the river's boatable and swimmable water-quality conditions because the River is currently boatable; the River will not be swimmable because of continued, on-going pathogen sources from CSOs. These overflows will also continue to affect fish populations, with the river supporting gamefish such as bass, but with most of the catch dominated by species that thrive in low quality water, such as white perch. Moreover, the Do Not Eat fish consumption advisories for all species are most likely to remain in place well into the future.

9. References

Bingham, Matthew F., Zhimin Li, Kristy E. Mathews, Colleen M. Spagnardi, Jennifer S. Whaley, Sara G. Veale, and Jason C. Kinnell. 2011. "An Application of Behavioral Modeling to Characterize Urban Angling Decisions and Values." *North American Journal of Fisheries Management* 31:257–268.

Boyd, James, and Alan Krupnick. 2009. "The Definition and Choice of Environmental Commodities for Nonmarket Valuation." Discussion Paper RFF DP 09-35. Washington, DC: Resources for the Future.

Burger, Joanna. 2002. "Consumption Patterns and Why People Fish." *Environmental Research* 90(2):125–135.

Carp.com. 2006. "Passaic River, NJ." Available at http://www.carp.com/topic/66-passaic-river-nj/. Retrieved On May 28, 2014.

Connelly, Nancy A., Barbara A. Knuth, and Carole A. Bisogni. 1992. *Effects of the Health Advisory and Advisory Changes on Fishing Habits and Fish Consumption in New York Sport Fisheries*. Report for New York Sea Grant Institute Project No. R/FHD-2-PD. Ithaca, NY: Human Dimension Research Unit, Department of Natural Resources, New York State College of Agriculture and Life Sciences, Fernow Hall, Cornell University.

Cooke, Steven J., and Cory D. Suski. 2005. "Do We Need Species-Specific Guidelines for Catch-and-Release Recreational Angling to Effectively Conserve Diverse Fishery Resources?" *Biodiversity and Conservation* 14:1195–1209.

Crouse, Shawn, Ron Jacobsen, and Mark Boriek. Undated. "River Fishing Opportunities Not to Be Overlooked." Available at http://www.eregulations.com/newjersey/fishing/freshwater/river-fishing-opportunities-not-to-be-overlooked/. Retrieved On May 28, 2014.

Donovan, Ellen, Ken Unice, Jennifer D. Roberts, Mark Harris, and Brent Finley. 2008. "Risk of Gastrointestinal Disease Associated with Exposure to Pathogens in the Water of the Lower Passaic River." *Applied and Environmental Microbiology* 74(4):994–1003.

Ebert, Ellen S., Natalie Wilson, Mitch Wacksman, John R. Loper, John D. Schell, and Alan Fowler. 2011. "Utilization Survey of a Rural Creek Fishery in Central Alabama." *Risk Analysis* DOI: 10.1111/j.1539-6924.2011.01678.x.

Environmental Protection Agency, Region 2. 2012. "Technical Memorandum: Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment." February.

Environmental Protection Agency, Region 2. 2014a. "EPA Proposes Plan to Remove Toxic Sediment from the Passaic River; Largest Cleanup in EPA History Will Protect People's Health and Create Jobs." Retrieved on April 11, 2014. Available at http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/cf9f96c6f99f225b85257cb700635826!OpenDocument.

Environmental Protection Agency, Region 2. 2014b. "The Passaic River's Polluted Past." Retrieved on May 20, 2014. Available at http://www.epa.gov/region02/passaicriver/pdf/pollution_problems_overview_fact_sheet__english_may_2014.pdf.

Environmental Protection Agency, Region 2. 2014c. *Appendix D Risk Assessment: Lower Eight Miles of the Lower Passaic River Risk Assessment*. Available at http://passaic.sharepointspace.com/Public%20Documents/2014-02-20%20Appendix%20D%20Risk%20Assessment.pdf. Retrieved on April 15, 2014.

Finkel, A.M. 1990. "A Simple Formula for Calculating the 'Mass Density' of a Lognormally Distributed Characteristic: Applications to Risk Analysis." *Risk Analysis* 10(2):291–301.

Finley, Brent L., Timothy J. Iannuzzi, Natalie D. Wilson, Jason C. Kinnell, Valerie A. Craven, Stanley Lemeshow, Christopher M. Teaf, Edward J. Calabrese, and Paul T. Kostecki. 2003. "The Passaic River Creel/Angler Survey: Expert Panel Review, Findings, and Recommendations." *Human and Ecological Risk Assessment* 9(3):829–855.

Fishing Facts. 2005. "New Jersey Fishing." Available at http://www.fishingfacts.info/angler/new_jersey_fishing.htm. Retrieved On May 28, 2014.

Great Lakes Sport Fishing Council. 2011. "Lake Ontario Black Bass Fishery using Cooperator Angler Diaries." Available at http://www.strikezonecharters.ca/Docs/2011_Lake_Ontario_Report.pdf. Retrieved on August 7, 2014.

Iannuzzi, T.J., D.F. Ludwig, J.C. Kinnell, J.M. Wallin, W.H. Desvousges, and R.W. Dunford. 2002. *A Common Tragedy: History of an Urban River*. Amherst, MA: Amherst Scientific Publishers.

Imm, Pamela, Lynda Knobeloch, Henry A. Anderson, and the Great Lakes Sport Fish Consortium. 2005. "Fish Consumption and Advisory Awareness in the Great Lakes Basin." *Environmental Health Perspectives* 113(10):1325–1329.

Jersey Coast Anglers Association. 2001. "Recreational Fishing Alliance Position Paper: Too Much of a Good Thing." Available at http://www.jcaa.org/JCNL0101/RFA.htm. Retrieved on May 28, 2014.

Kayak Fishing Magazine. 2013. "Passaic River Pacu." Available at http://www.kayakfishingmagazine.net/forum/tri-state-area/4112-passaic-river-pacu.html. Retrieved On May 28, 2014.

Kaysen, Rhonda. 2012. "Just Outside the City, and Building Bedrooms." *The New York Times*, 30 October 2012, B7.

Kinnell, Jason C. and Matthew F. Bingham. 2014. "Developing Baseline Risk Fish Ingestion Estimates for Baseline Human Health Risk Assessments." Technical Working Paper. Veritas Economic Consulting. Cary, NC. Available at http://www.VeritasEconomics.com.

Kinnell, Jason C., Matthew F. Bingham, Elizabeth A. Hastings, Rose Ray, Valerie Craven, and Miranda Freeman. 2007. "A Survey Methodology for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1)." *Journal of Toxicology and Environmental Health, Part A* 70:477–495.

Kinnell, Jason C., Matthew F. Bingham, Ateesha F. Mohamed, William H. Desvousges, Thomas B. Kiler, Elizabeth K. Hastings, and Karen T. Kuhns. 2006. "Estimating Site Choice Decisions for Urban Recreators." *Land Economics* 82(2):257–272.

Law, Robert H. 2011. Letter to Stephanie Vaughn, Remedial Project Manager, USEPA Region 2 Regarding Final Creel/Angler Survey Work Plan and Expert Review Panel Comments—Lower Passaic River Study Area (LPRSA), CERCLA Docket No. 02-2007-2009. Clinton, NJ: de maximis, inc.

Leggett, Chris, Nora Scherer, Mark Curry, and Ryan Bailey. 2012. *Recreational Consumption and Resource Use Survey for the Upper Columbia River Site Human Health Risk Assessment and Remedial Investigation/Feasibility Study*. Cambridge, MA: Industrial Economics, Incorporated.

Leontief, W. 1986. *Input-Output Economics*. New York: Oxford University Press.

Mitchell, Robert Cameron, and Richard T. Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington DC: Resources for the Future, Inc.

New Jersey Division of Fish and Wildlife. 2014. "New Jersey Freshwater Fishing Digest." Available at http://www.nj.gov/dep/fgw/pdf/2014/digfsh14.pdf. Retrieved On May 28, 2014.

National Oceanic and Atmospheric Administration. 2008. "Recreational Catch Down Slightly, Remains Second Highest Catch in Decade." Available at http://webarchive.library.unt.edu/eot2008/20080917134056/http://www.noaanews.noaa.gov/stories2008/20080717_catchdown.html. Retrieved on August 7, 2014.

O'Neill, James M. 2013. "Staggering Cost of Repairs Allows Sewage to Foul N.J. Waterways." *The Record*, 5 January 2013. Available at http://www.northjersey.com/news/staggering-cost-of-repairs-allows-sewage-to-foul-n-j-waterways-1.454229. Retrieved on June 2, 2014.

Port Authority of New York and New Jersey. 2002. "Port Authority Launches Unique Cargo Distribution System by Establishing First Regional Port in Upstate New York." Available at http://www.panynj.gov/press-room/press-item-print.cfm?headLine_id=251. Retrieved on June 25, 2014.

Quinn, Steve. 1996. "Trends in Regulatory and Voluntary Catch-and-Release Fishing." *American Fisheries Society Symposium* 16:152–162.

Ray, Rose, Valerie Craven, Jason Kinnell, Matthew Bingham, Miranda Freeman, and Brent Finley. 2007a. "A Statistical Method for Analyzing Data Collected by a Creel/Angler Survey (Part 2)." *Journal of Toxicology and Environmental Health, Part A* 70:496–511.

Ray, Rose, Valerie Craven, Matthew Bingham, Jason Kinnell, Elizabeth Hastings, and Brent Finley. 2007b. "Human Health Exposure Factor Estimates Based Upon a Creel/Angler Survey of the Lower Passaic River (Part 3)." *Journal of Toxicology and Environmental Health, Part A* 70:512–528.

Rodrigue, Jean-Paul. 2004. "The Port Authority of New York and New Jersey: Global Changes, Regional Gains and Local Challenges in Port Development." Les Cahiers Scientifiques du Transport 44: 55–75. Available at http://people.hofstra.edu/jean-paul_rodrigue/downloads/PANYNJ_CST.pdf. Retrieved on April 10, 2014.

Sechena, Ruth, Shiquan Liao, Roseanne Lorenzana, Connie Nakano, Nayak Polissar, and Richard Fenske. 2003. "Asian American and Pacific Islander Seafood Consumption—A Community-Based Study in King County, Washington." *Journal of Exposure Analysis and Environmental Epidemiology* 13:256–266.

Stern, A.H., L.R. Korn, and B.E. Ruppel. 1996. "Estimation of Fish Consumption and Methylmercury Intake in the New Jersey Population." *Journal of Exposure Analysis and Environmental Epidemiology* 6(4):503–525.

Town of Harrison, New Jersey. 2012. *Amended Harrison Waterfront Redevelopment Plan 2012 DRAFT*. Available at http://www.panynj.gov/path/pdf/amended_harrison_waterfront_redevelopment_plan_2012_draft.pdf. Retrieved on May 30, 2014.

U.S. Army Corps of Engineers. 2010. Lower Passaic River Commercial Navigation Analysis. New York District. Retrieved on April 10, 2014. Available at http://passaic.sharepointspace.com/Public%20Documents/2010-07-29%20USACE%20Lower%20Passaic%20River%20Commercial%20Navigation%20Analysis.pdf

U.S. Environmental Protection Agency. 1989. *Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual*. EPA-503-8-89-002. Washington, DC: U.S. EPA.

U.S. Environmental Protection Agency. 1992. *Guidelines for Exposure Assessment*. EPA/600/Z-92/001. Available at http://www.epa.gov/raf/publications/pdfs/GUIDELINES_EXPOSURE_ASSESSMENT.PDF. Retrieved on June 10, 2014.

U.S. Environmental Protection Agency. 1998a. *Guidance for Conducting Fish and Wildlife Consumption Surveys*. EPA-823-B-98-007. Washington, DC: U.S. EPA.

U.S. Environmental Protection Agency. 1998b. *Ambient Water Quality Criteria Derivation Methodology: Human Health, Technical Support Document—Final Draft*. EPA-822-B-98-005. Washington, DC: U.S. EPA.

U.S. Environmental Protection Agency. 2010. *Guidelines for Preparing Economic Analyses*. Report Number EPA 240-R-10-001. December. Washington, DC: U.S. EPA. Available at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf. Retrieved on June 19, 2013.

U.S. Environmental Protection Agency. 2011. *Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule*. EPA 821-R-11-002. Available at http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/upload/environbenefits.pdf. Retrieved on June 19, 2013.

U.S. Environmental Protection Agency. 2012. "Ironbound Residential/Passaic River Sampling Event." Available at http://www.epa.gov/region02/passaicriver/pdf/ironbound_sampling_detect.pdf. Retrieved on June 2, 2014.

U.S. Environmental Protection Agency. 2013. "Hurricane Sandy Response Efforts: Ironbound/Passaic River Sampling." Available at http://www.epa.gov/sandy/response_12-18-12.html. Retrieved on June 2, 2014.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. 1989 (updated 2010). *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)*. Available at http://epa.gov/oswer/riskassessment/ragsa/pdf/rags_a.pdf. Retrieved on May 21, 2014.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. 2001. *Risk Assessment Guidance for Superfund: Volume III—Part A, Process for Conducting Probabilistic Risk Assessment*. EPA 540-R-02-002, OSWER 9285.7-45, PB2002 963302. Available at http://www.epa.gov/oswer/riskassessment/rags3adt/pdf/rags3adt_complete.pdf. Retrieved on May 21, 2014.

U.S. Environmental Protection Agency Science Policy Council, Peer Review Advisory Group. 2006. *U.S. Environmental Protection Agency Peer Review Handbook 3rd Edition*. EPA/100/B-06/002. Available at http://www.epa.gov/peerreview/pdfs/peer_review_handbook_2012.pdf. Retrieved on January 24, 2013.

Warf, Barney, and Louis Kleyn. 1989. "Competitive Status of US Ports in the Mid-1980s." *Maritime Policy & Management* 16(2):157–172.

Williams, Rebecca L., Joseph T. O'Leary, Amy L. Sheaffer, and Doran Mason. 2000. "An Examination of Fish Consumption by Indiana Recreational Anglers: An On-Site Survey." Technical Report 99-D-HDFW-2. Available at http://fn.cfs.purdue.edu/fish4health/indiana/assets/INOnsite.pdf. Retrieved on May 28, 2014.

Appendix A
Selected Catch-and-Release Rates in the U.S.

Table A.1
Selected Release Rates among Recreational Anglers in the U.S.

Year	Taxa	Waterbody	Release Rate	Source of Estimate
1984	Coho salmon	Tributaries of Lake Ontario, New York	23%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2011	Coho salmon	Tributaries of Lake Ontario, New York	66%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
1986	Blass bass	Connecticut	40%	Quinn (1996)
1988	Blass bass	Connecticut	60%	Quinn (1996)
1990s	Blass bass	Connecticut	≈80%	Quinn (1996)
1996	Blass bass	Kerr Reservoir, Virginia	88%	Quinn (1996)
1996	Blass bass	Smith Mountain Lake, Virginia	94%	Quinn (1996)
1996	Largemouth and smallmouth bass	Lake Winnipesaukee, New Hampshire	>85%	Quinn (1996)
2007	Bass	Point A Reservoir, Alabama	95.6%	Weathers, Holley, and McCarter (2007)
1986	Largemouth bass	Several New York lakes	56%	Quinn (1996)
2011	Largemouth bass	Tributaries of Lake Ontario, New York	96%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2011	Largemouth bass	Northern Wisconsin lakes	96.9%	Gaeta et al. (2013)
1996	Largemouth bass	Iowa impoundment	≈100%	Quinn (1996)
1986	Smallmouth bass	Several New York lakes	18%	Quinn (1996)
2011	Smallmouth bass	Northern Wisconsin lakes	96.6%	Gaeta et al. (2013)
2011	Muskellunge (targeted)	Northern Wisconsin lakes	99.3%	Gaeta et al. (2013)
2011	Muskellunge (not targeted)	Northern Wisconsin lakes	100%	Gaeta et al. (2013)
2003	Trout	Streams and rivers in New Jersey	54%	Shramko (2014)
2010	Trout	Streams and rivers in New Jersey	60%	Shramko (2014)
2012	Trout	Streams and rivers in New Jersey	65%	Shramko (2014)
2006	Brown trout	Tributaries of Lake Ontario, New York	74%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2011	Brown trout	Tributaries of Lake Ontario, New York	84%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
1985–2006	Rainbow trout	Tributaries of Lake Ontario, New York	30.3%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2012	Rainbow trout	Tributaries of Lake Ontario, New York	61.7%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2011	Steelhead	Tributaries of Lake Ontario, New York	91%	Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit (2013)
2003	Walleye	Lake Sharpe, South Dakota	79.5%	Lott, Hanten, and Potter (2004)
2011	Walleye	Northern Wisconsin lakes	66%	Gaeta et al. (2013)

Table A.1, continued

Year	Taxa	Waterbody	Release Rate	Source of Estimate
2013	Walleye	Maumee River, Ohio	40.4%	Lake Erie Fisheries Units (2014)
2013	Walleye	Sandusky River, Ohio	67%	Lake Erie Fisheries Units (2014)
2010	All [freshwater] taxa	Loup Power Canal, Lake Babcock, and Lake North, Nebraska	57.7%	Loup River Public Power District (2011)
2007	Crappie	Point A Reservoir, Alabama	60%	Weathers, Holley, and McCarter (2007)
2011	Panfish	Northern Wisconsin lakes	66%	Gaeta et al. (2013)
1998	Bluefish	Atlantic Ocean, U.S. East Coast	55%	NOAA (2000)
1998	Atlantic croaker	Atlantic Ocean, U.S. East Coast	56%	NOAA (2000)
1998	Red drum	Atlantic Ocean, U.S. East Coast	72%	NOAA (2000)
2000	Red drum	Neuse River Estuary, North Carolina	80%	Aguilar, Rand, and Beckwith, Jr. (2002)
1998	Spotted sea trout	Atlantic Ocean, U.S. East Coast	66%	NOAA (2000)
1998	Summer flounder	Atlantic Ocean, U.S. East Coast	68%	NOAA (2000)
1998	Striped bass	Atlantic Ocean, U.S. East Coast	91%	NOAA (2000)
2007	Marine taxa	Coastal waters of the U.S.	58%	NOAA (2008)
2011	Marine taxa	Coastal waters of the U.S.	60%	NOAA Fisheries (2013a)
2013	Sharks	U.S. oceans	96%	NOAA Fisheries (2013b)

References

Aguilar, Robert, Peter S. Rand, and George H. Beckwith, Jr. 2002. "Quantifying the Catch-and-Release Mortality Rate of Adult Red Drum in the Neuse River Estuary." Available at http://www.ncsu.edu/ncsu/CIL/sea_grant/FRG/PDF/01FEG07.PDF. Retrieved on May 23, 2014.

Arlinghaus, Robert, Steven J. Cooke, Jon Lyman, David Policansky, Alexander Schwab, Cory Suski, Stephen G. Sutton, and Eva B. Thorstad. 2007. "Understanding the Complexity of Catch-and-Release in Recreational Fishing: An Integrative Synthesis of Global Knowledge from Historical, Ethical, Social, and Biological Perspectives." *Reviews in Fisheries Science* 15:75–167.

Cooke, Steven J., and Cory D. Suski. 2005. "Do We Need Species-Specific Guidelines for Catch-and-Release Recreational Angling to Effectively Conserve Diverse Fishery Resources?" *Biodiversity and Conservation* 14:1195–1209.

Gaeta, Jereme W., Ben Beardmore, Alexander W. Latzka, Bill Provencher, and Stephen R. Carpenter. 2013. "Catch-and-Release Rates of Sport Fishes in Northern Wisconsin from an Angler Diary Survey." *North American Journal of Fisheries Management* 33:3:606–614.

Ebert, Ellen S., Paul S. Price, and Russell E. Keenan. 1994. "Selection of Fish Consumption Estimates for Use in the Regulatory Process." *Journal of Exposure Analysis and Environmental Epidemiology* 4(3):373–393.

Ebert, Ellen S., Steave H. Su, Timothy J. Berry, Michael N. Gray, and Natalie W. Harrington. 1996. "Estimated Rates of Fish Consumption by Anglers Participating in the Connecticut Housatonic River Creel Survey." *North American Journal of Fisheries Management* 16:81–89.

Ebert, Ellen S., Natalie Wilson, Mitch Wacksman, John R. Loper, John D. Schell, and Alan Fowler. 2011. "Utilization Survey of a Rural Creek Fishery in Central Alabama." *Risk Analysis* 32(3):416–432. DOI: 10.1111/j.1539-6924.2011.01678.x.

Hickley, Phil. 1998. "Recreational Fisheries—Social, Economic and Management Aspects." Available at http://www.pescaricreativa.org/docs/No.%2066%20-%20Recfish%20book%20chapter.pdf. Retrieved on May 23, 2014.

Imm, Pamela, Lynda Knobeloch, Henry A. Anderson, and the Great Lakes Sport Fish Consortium. 2005. "Fish Consumption and Advisory Awareness in the Great Lakes Basin." *Environmental Health Perspectives* 113(10):1325–1329.

Jersey Coast Anglers Association. 2001. "Recreational Fishing Alliance Position Paper: Too Much of a Good Thing." Available at http://www.jcaa.org/JCNL0101/RFA.htm. Retrieved on May 28, 2014.

Lake Erie Fisheries Units. 2014. *Ohio's Lake Erie Fisheries 2013.* Available at http://wildlife.ohiodnr.gov/portals/wildlife/pdfs/fishing/Lake%20ErieStatus2013.pdf. Retrieved on May 23, 2014.

Leggett, Chris, Nora Scherer, Mark Curry, and Ryan Bailey. 2012. *Recreational Consumption and Resource Use Survey for the Upper Columbia River Site Human Health Risk Assessment and Remedial Investigation/Feasibility Study: Final Report*. Prepared for U.S. Department of the Interior, National Park Service, Lake Roosevelt National Recreation Area. Cambridge, MA: Industrial Economics, Incorporated.

Lott, John, Robert Hanten, and Kyle Potter. 2004. "Annual Fish Population and Angler Use, Harvest and Preference Surveys on Lake Sharpe, South Dakota, 2003." Available at http://www.outdoorrecreationdata.com/Stats/SD_lakesharpe_03.pdf. Retrieved on May 23, 2014.

Loup River Public Power District. 2011. "Creel Survey Report Appendix F2." Available at http://www.loup.com/relicense/html/documents/SISR/1256_SISR_F2_08_Creel_Survey_110211.pdf. Retrieved on May 23, 2014.

Mayfield, David. B., Sue Robinson, and Jim Simmonds. 2007. "Survey of Fish Consumption Patterns of King County (Washington) Recreational Anglers." *Journal of Exposure Science and Environmental Epidemiolog*y 17:604–612.

National Oceanic and Atmospheric Administration. 2000. "Conservation Efforts Increase in Recreational Fishing Community." Available at http://www.publicaffairs.noaa.gov/releases2000/feb00/noaa00r106.html. Retrieved on May 23, 2014.

National Oceanic and Atmospheric Administration. 2008. "Recreational Catch Down Slightly, Remains Second Highest Catch in Decade." Available at http://www.pierandsurf.com/fishing-forum/archive/index.php/t-54683.html. Retrieved on May 22, 2014.

National Oceanic and Atmospheric Administration Fisheries. 2013a. "Economy: Recreational Fishing—An American Pastime." Available at http://stateofthecoast.noaa.gov/rec_fishing/welcome.html. Retrieved on May 28, 2014.

National Oceanic and Atmospheric Administration Fisheries. 2013b. "Recreational Shark Fishing—Healthy Catch & Release." Available at http://www.nmfs.noaa.gov/stories/2013/08/best_fishing_practices_sharks.html. Retrieved on May 22, 2014.

Quinn, Steve. 1996. "Trends in Regulatory and Voluntary Catch-and-Release Fishing." *American Fisheries Society Symposium* 16:152–162.

Ray, Rose, Valerie Craven, Jason Kinnell, Matthew Bingham, Miranda Freeman, and Brent Finley. 2007. "A Statistical Method for Analyzing Data Collected by a Creel/Angler Survey (Part 2)." *Journal of Toxicology and Environmental Health, Part A* 70:496–511.

Ray, Rose, Valerie Craven, Matthew Bingham, Jason Kinnell, Elizabeth Hastings, and Brent Finley. 2007. "Human Health Exposure Factor Estimates Based Upon a Creel/Angler Survey of the Lower Passaic River (Part 3)." *Journal of Toxicology and Environmental Health, Part A* 70:512–528.

Sechena, Ruth, Shiquan Liao, Roseanne Lorenzana, Connie Nakano, Nayak Polissar, and Richard Fenske. 2003. "Asian American and Pacific Islander Seafood Consumption—A Community-Based Study in King County, Washington." *Journal of Exposure Analysis and Environmental Epidemiology* 13:256–266.

Shramko, Ross. 2014. "Trout Angler Survey Results." *New Jersey Freshwater Fishing Digest* January:42–43.

Stern, A.H., L.R. Korn, and B.E. Ruppel. 1996. "Estimation of Fish Consumption and Methylmercury Intake in the New Jersey Population." *Journal of Exposure Analysis and Environmental Epidemiology* 6(4):503–525.

Weathers, Kenneth C., Michael P. Holley, and Rob McCarter. 2007. "Point A Reservoir Management Report Spring 2007." Available at http://outdooralabama.com/fishing/freshwater/where/reservoirs/gantt/ganttcreel.pdf. Retrieved on May 23, 2014.

West, Patrick C., J. Mark Fly, Robert Marans, Frances Larkin, and Dorrie Rosenblatt. 1993. *1991–92 Michigan Sport Anglers Fish Consumption Study*. Final report to the Michigan Great Lakes Protection Fund. Technical Report #6. Ann Arbor, MI: University of Michigan School of Natural Resources, Natural Resources Sociology Research Lab.

Williams, Rebecca L., Joseph T. O'Leary, Amy L. Sheaffer, and Doran Mason. 2000. "An Examination of Fish Consumption by Indiana Recreational Anglers: An On-Site Survey." Technical Report 99-D-HDFW-2. Available at http://fn.cfs.purdue.edu/fish4health/indiana/assets/INOnsite.pdf. Retrieved on May 28, 2014.

Matthew F. Bingham

Principal Economist
Veritas Economic Consulting, LLC
1851 Evans Road, Cary, NC 27513

SUMMARY

Mr. Bingham is a Principal Economist and Founding Partner of Veritas Economic Consulting (Veritas). Mr. Bingham has led Veritas' custom modeling design and development efforts to evaluate and address complex market and non-market valuation questions. Mr. Bingham's specific experience includes leading the design and development of complex models to evaluate natural resource damages and the benefits of alternative restoration projects at sites throughout the United States. Mr. Bingham has also led Veritas' development of commercial and recreational fishing models for North Atlantic and Mid-Atlantic Coastal, Great Lakes, California Coast, and numerous U.S. inland fisheries. Mr. Bingham has more than 15 years of experience applying microeconomic theory, econometrics, statistics, and bioeconomic modeling to natural resource damage assessment and restoration evaluation and planning.

Mr. Bingham has provided and/or presented the results of his models for policy analysis, regulatory impact analysis, regulatory compliance, expert testimony, or litigation support. The results of Mr. Bingham's custom models have been used by and/or provided and presented to the United States Environmental Protection Agency (USEPA), the National Oceanic and Atmospheric Administration (NOAA), the United States Fish and Wildlife Service (USFWS), the U.S. Department of the Interior (DOI), the United States Army Corps of Engineers (USACE), the California Regional Water Quality Control Board, Pennsylvania Department of Environmental Protection (PADEP), Texas Commission on Environmental Quality (TCEQ), Texas Parks & Wildlife, and the Michigan Department of Natural Resources (MDNR) the Electric Power Research Institute (EPRI), and the North American Electricity Reliability Corporation (NERC).

EDUCATION

Univ. of North Carolina at Chapel Hill	Economics	M.S.	1996
North Carolina State Univ., Raleigh	Economics	B.A.	1992

PRACTICE AREAS

- NRDA
- Fisheries Economics
- 316(a)&(b) Compliance
- Regulatory Impact Analysis
- Policy Analysis
- Exposure Assessment

EXPERTISE

- Mathematical Modeling
- Bioeconomic Analysis
- Statistical Analysis
- Market & Nonmarket Valuation

KEY PROJECTS

- Developed random utility model from interviews of recreators for the 2007 San Francisco Bay oil spill. Prepared a thorough technical evaluation of the Trustees' model for the PRP.
- Confidential NRDA in the Southwest: created sophisticated hedonic property value model for the area surrounding the Superfund site and helped estimate the groundwater damages from alleged chemical releases.
- Spearheaded a technical team tasked with evaluating a prior NRDA settlement for a confidential Great Lakes site.

- Fox River Natural Resource Damage Assessment.
- Confidential NRDA for a river in the Midwest.
- Economic evaluation of commercial and recreational fishery impacts associated with current and future power plant operations in 13 states.

EXPERIENCE

2006-present	Veritas Economic Consulting – Principal Economist and Founding Partner
2000-2006	Triangle Economic Research, Durham, NC, Senior Economist
1997-2000	Triangle Economic Research, Durham, NC, Economist
1997	Walt Disney Attractions, Hong Kong—Risk Analyst
1995-1997	Environmental Controls Technology, Raleigh, NC—Head Statistician
1996	University of North Carolina, Chapel Hill, NC, Course Developer
1991-1995	University of North Carolina, Chapel Hill, NC, Economics Instructor

RECENT PUBLICATIONS

- Johnson, F. R., **M. F. Bingham**, and B. Kanninen (2006). "Experimental Design for Stated Choice Experiments" in *Valuing Environmental Amenities Using Stated Choice Studies: A Common Sense Approach to Theory and Practice*, ed. Barbara Kanninen. Dordecht, The Netherlands: Springer.
- Kinnell, J. C., **M. F. Bingham**, E. A. Hastings, R. Ray, V. Craven, and M. Freeman (2007). "A Survey Methodology for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1)." *Journal of Toxicology and Environmental Health*, Part A 70:477–495.

PUBLICATIONS

- **Bingham, Matthew F.**, Zhimin Li, Kristy E. Mathews, Colleen M. Spagnardi, Jennifer S. Whaley, Sara G. Veale, and Jason C. Kinnell (2011). "An Application of Behavioral Modeling to Characterize Urban Angling Decisions and Values." *North American Journal of Fisheries Management* 31:257–268.
- Johnson, F. R., **M. F. Bingham**, and B. Kanninen (2006). "Experimental Design for Stated Choice Experiments" in *Valuing Environmental Amenities Using Stated Choice Studies: A Common Sense Approach to Theory and Practice*, ed. Barbara Kanninen. Dordecht, The Netherlands: Springer.
- **Bingham, M. F.**, J. P. Prestemon, D. J. MacNair, and R. Abt (2003). "Market Structure in U.S. Southern Pine Roundwood." *Journal of Forest Economics* 9(2):1–21.
- Hauber, A. B., F. R. Johnson, and **M. F. Bingham** (2001). "Measuring Stated Preferences for Medical Interventions." *ISPOR News* 7(5):5–6.
- **Bingham, M. F.**, F. R. Johnson, and D. Miller (2001). "Modeling Choice Behavior for New Pharmaceutical Products." *Value in Health* 4(1):32–44.
- **Bingham, M. F.**, and G. Smith (2001). "The Role of Health State Experience in Longitudinal Conjoint Analysis of Patient Preferences." *Value in Health* 4(2):194–195.
- **Bingham, M. F.** and F. R. Johnson (2001). "Evaluating the Validity of Stated-Preference Estimates of Health Values." *Swiss Journal of Economics and Statistics* 137(1):49–64.
- Smith, G., **M. F. Bingham**, F. R. Johnson, and B. Bolinder (2001). "Does Patient Experience Matter? Type II Diabetes Patients' Stated Preferences for Insulin Therapies." *Value in Health* 4(2):115–116.
- **Bingham, M. F.**, F. R. Johnson, and L. Bell (1998). "Vox Populi: Stated Preferences for Pharmaceutical Innovations." *Value in Health* 1(1):76.

SELECTED REPORTS

- **Bingham, M. F.**, S. G. Veale, Z. Li, G. S. Crownfield, D. M. Woodard, and J. C. Kinnell (2014). "Integrating Revealed and Stated Preference Data to Improve the Estimation of Baseline Risk Fish Ingestion." Working Paper No. 2014-03. Available at http://www.veritaseconomics.com/Working%20Papers/Bingham.et.al.2014.Integrating.RP.and.SP.Data.to.Improve.Estimation.of.Baseline.Risk.Fish.Ingestion.pdf
- **Bingham, M. F.**, J. S. Kinnell, D. A. Santoianni, D. M. Woodard, and S. G. Veale (2011). "An Economic Assessment of Net Employment Impacts from Regulating Coal Combustion Residuals." Prepared for Utility Solid Waste Activities Group. Cary, NC: Veritas Economic Consulting.

Jason C. Kinnell

Principal Economist
Veritas Economic Consulting, LLC
1851 Evans Road, Cary, NC 27513

SUMMARY

Mr. Kinnell specializes in applying economic analysis to natural resource damage assessments (NRDA), exposure assessments, restoration planning and evaluation, regulatory and policy analysis, and regulatory compliance. His NRDA experience includes estimating human-use and ecological damages resulting from hazardous substance releases and oil spills as well as the benefits of alternative compensatory restoration projects at sites throughout the United States. As part of these efforts he has performed scoping-level assessments of potential damages based on existing public data; conducted detailed assessments of relevant baseline issues; evaluated alternative compensatory restoration efforts to identify the type, location, and amount of restoration necessary to offset potential human-use and ecological losses; developed and evaluated habitat equivalency analyses (HEAs); designed, implemented, and evaluated several original studies to collect data for developing site-specific damage and restoration-benefit estimates; and reviewed and critiqued assessments of potential nonuse damages.

The results of Mr. Kinnell's research have been used by and/or presented and submitted to the U.S. House of Representatives, USEPA, NOAA, USDOI, USFWS, USACE, FERC, the Electric Power Research Institute (EPRI), the CA Regional Water Quality Control Board, the FL Dept. of Environmental Projection (FADEP), MI Dept. of Natural Resources (MDNR), the NJ Dept. of Environmental Protection (NJDEP), the NJ Office of Maritime Resources (NJOMR), the PA Dept. of Environmental Protection (PADEP), the RI Dept. of Environmental Management (RIDEM), the TX Commission on Environmental Quality (TCEQ), the TX Parks & Wildlife Dept., and the WI Dept. of Natural Resources (WDNR).

EDUCATION

The Pennsylvania State University, University Park, PA	Economics, Dept. of Agricultural, Environmental, and Development Economics	M.S.	1997
Hampden-Sydney College, VA	Economics	B.A.	1993

PRACTICE AREAS

- NRDA
- Exposure Assessment
- Restoration Evaluation and Planning
- Regulatory Impact Analysis
- Regulatory Compliance
- Policy Analysis
- Fisheries Economics
- Water Resource Economics

EXPERTISE

- Nonmarket Valuation
- Benefit-Cost Analysis
- Statistical Analysis
- Survey Design and Administration

KEY PROJECTS AND EXPERIENCE

- Project Manager for the 2000-2001 Passaic River Creel/Angler Survey; supported the design, administration, and analysis of the 2011-2012 Lower Passaic River Study Area Creel/Angler Survey.
- Passaic River Cooperative NRDA.
- Fox River NRDA.
- NRDA for confidential Mid-Western Lakes and River Site, a Southeastern River site, and a confidential Lake and River Site.
- Confidential Great Lakes Site – Evaluated a prior NRDA settlement and developed rigorous models that resulted in reduced settlement payments.
- Developed benefit estimates of alternative ecological and human-use compensatory restoration projects for a Confidential River Site.

EXPERIENCE

2006-present	Veritas Economic Consulting – Principal Economist & Founding Partner.
1998-2000	Triangle Economic Research (TER) – Senior Economist 2000 to 2006 Economist.
1995-1998	Department of Agricultural, Environmental, and Development Economics, The Pennsylvania State University – Instructor and Graduate Asst.
1993-1995	Burlington Industries, Clarksville, VA – Assistant Administrative Manager.

RECENT PUBLICATIONS

- Deason, Jonathan P., G. Edward Dickey, **Jason C. Kinnell**, and Leonard A. Shabman (2010). "An Integrated Planning Framework for Urban River Rehabilitation." *Journal of Water Resource Planning and Management* 136(6):678–687.
- Kinnell, J.C., M.F. Bingham, A.F. Mohamed, W.H. Desvousges, T.B. Kiler, E.K. Hastings, and K.T. Kuhns. (2006). "Estimating Site-Choice Decisions for Urban Recreators." *Land Economics* 82(2):257–272.

SELECTED PUBLICATIONS

- Bingham, M. F. and **J. C. Kinnell** (2012). "The Role of Socioeconomic and Behavioral Modeling in an Integrated, Multidisciplinary Dam-Management Study: Case Study of the Boardman River Dams." In *Environmental Land Use Planning*, Seth Appiah-Opoku, ed. ISBN 978-953-51-0832-0. Rijeka, Croatia: InTech. Available at http://www.intechopen.com/articles/show/title/the-role-of-socioeconomic-and-behavioral-modeling-in-an-integrated-multidisciplinary-dam-management-.
- Deason, Jonathan P., G. Edward Dickey, **Jason C. Kinnell**, and Leonard A. Shabman (2010). "An Integrated Planning Framework for Urban River Rehabilitation." *Journal of Water Resource Planning and Management*, 136(6):678–687.
- **Kinnell, J. C.**, M. F. Bingham, E. A. Hastings, R. Ray, V. Craven, and M. Freeman (2007). "A Survey Methodology for Collecting Fish Consumption Data in Urban and Industrial Water Bodies (Part 1)." *Journal of Toxicology and Environmental Health*, Part A 70:477–495.
- Ray, R., V. Craven, **J. Kinnell**, M. Bingham, M. Freeman, and B. Finley (2007a). "A Statistical Method for Analyzing Data Collected by a Creel/Angler Survey (Part 2)." *Journal of Toxicology and Environmental Health*, Part A 70:496–511.
- Ray, R., V. Craven, M. Bingham, **J. Kinnell**, E. Hastings, and B. Finley (2007b). "Human Health Exposure Factor Estimates Based Upon a Creel/Angler Survey of the Lower Passaic River (Part 3)." *Journal of Toxicology and Environmental Health*, Part A 70:512–528.
- **Kinnell, J. C.**, M. F. Bingham, A. F. Mohamed, W. H. Desvousges, T. B. Kiler, E. K. Hastings, and K. T. Kuhns (2006). "Estimating Site-Choice Decisions for Urban Recreators." *Land Economics* 82(2):257–272.
- Finley, B., T. Iannuzzi, N. Wilson, **J. Kinnell**, V. Craven, S. Lemeshow, C. Teaf, E. Calabrese, and P. Kostecki (2003). "The Passaic River Creel/Angler Survey: Expert Panel Review, Findings, and Recommendations." *Journal of Human and Ecological Risk Assessment* 9(3):829–856.
- Iannuzzi, T. J., D. F. Ludwig, **J. C. Kinnell**, J. M. Wallin, W. H. Desvousges, and R. W. Dunford (2002). *A Common Tragedy: History of an Urban River*. Amherst, MA: Amherst Scientific Publishers.

SELECTED REPORTS

- **Kinnell, Jason C.** and Matthew F. Bingham (2014). "Developing Baseline Risk Fish Ingestion Estimates for Baseline Human Health Risk Assessments." Technical Working Paper. Veritas Economic Consulting. Cary, NC. Available at http://www.veritaseconomics.com/Working%20Papers/Kinnell.and.Bingham.2014.Developing.Baseline.Risk.Fish.Ingestion.Estimates.pdf
- Electric Power Research Institute (2011). *Comments on the Environmental Protection Agency's Information Collection Request (ICR) for a Willingness to Pay Survey for §316(b) Existing Facilities Cooling Water Intake Structures: Instrument, Pre-Test, and Implementation (EPA ICR No. 2402.01, OMB Control No. 2040-NEW)*. Palo Alto, CA: Electric Power Research Institute. Principal Investigators: M. F. Bingham, **J. C. Kinnell**.

Comments on the Lower Eight Miles of the Lower Passaic River Focused Feasibility Study Report

August 15, 2014

Prepared for:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared by:
Mark Harris, Ph.D.
Daniele Wikoff, Ph.D.
Jon Urban, Ph.D.
Camarie Perry, M.S.
Liz Abraham, M.S.

ToxStrategies

Innovative solutions
Sound science

© 2008 ToxStrategies, Inc. All rights reserved.

Table of Contents

SECTION 1: Summary of Comments 1

SECTION 2: Comments on the Region 2 FFS HHRA 10

Comment 2-1: Hazard and Risk Calculation and Reporting Errors 10
Comment 2-2: Use of Outdated Statistical Software 12
Comment 2-3: Region 2 did not use an adequate number of fish and crabs to characterize the Site 12
Comment 2-4: Region 2 did not evaluate all complete exposure pathways at the site 14
Comment 2-5: By focusing on fish and crab ingestion and ignoring direct sediment contact, Region 2 failed to identify PAHs as a significant risk driver 18
Comment 2-6: Region 2 should have evaluated the health risks from pathogens arising from the ongoing and government-sanctioned discharge of raw sewage into the Passaic River 19
Comment 2-7: Region 2 ignored site-specific data and OSWER directive 9200.1-120 21
Comment 2-8: Region 2 did not utilize the extensive site-specific information collected as part of a multi-year Creel Angler Survey (CAS) 22
Comment 2-9: Region 2 should not use a Fraction Ingestion (FI) value of 1 27
Comment 2-10: Region 2 made several errors associated with the cooking loss variable in the HHRA calculations 28
Comment 2-11: Region 2 applied default exposure assumptions that are not consistent with OSWER directive 9200.1-120 30
Comment 2-12: Region 2 used an out-of-date cancer slope factor for TCDD 31
Comment 2-13: Region 2 incorrectly assumes that TCDD acts via a mutagenic mode of action 33
Comment 2-14: TCDD has not been shown to be a human carcinogen 35
Comment 2-15: The Reference Dose (RfD) for TCDD is flawed and should not be used in the FFS HHRA 37
Comment 2-16: Region 2 should use the JECFA TDI to evaluate the TCDD noncancer hazard 39
Comment 2-17: Region 2 should use the best available science for TCDD toxicity criteria 41
Comment 2-18: The dose of TCDD alleged to be received by anglers in the FFS HHRA is less than what an infant receives from breastfeeding 43
Comment 2-19: Region 2 should calculate the excess cancer population risk for the anglers using the Passaic River 46
Comment 2-20: Region 2 did not follow USEPA guidance regarding the conduct of a TEF Sensitivity Analysis 47
Comment 2-21: Region 2 does not sufficiently address uncertainty associated with TEFs 49
Comment 2-22: Region 2 should use proper nomenclature to describe dioxin-like compounds. 51
Comment 2-23: Region 2 compounded conservatism in the FFS HHRA 51
Comment 2-24: Remedy Proposed by Region 2 does not achieve acceptable risk and hazards even after the expenditure of billions of dollars 52
Comment 2-25: Instead of citing Wikipedia, Region 2 should be citing peer-reviewed papers to provide scientific support for the LPR FFS methods and analysis 54

SECTION 3: State-of-the-Science HHRA 55
Comment 3-1: State-of-the-Science Deterministic Risk Assessment (DRA) 55
Comment 3-2: TEF Uncertainty Analysis 73
Comment 3-3: State-of-the-Science Probabilistic Risk Assessment (PRA) 76

SECTION 4: Comments on PRGs (Appendix E) Prepared by Region 2 80
Comment 4-1: Region 2 derived PRGs for Total PCBs using inaccurate measures of PCBs, resulting in PRGs that underestimate Total PCB exposures, Total PCB cancer risk, and Total PCB noncancer hazard 80
Comment 4-2: Region 2 underestimated background cancer risk and hazards based on sediment COPC levels measured above the Dundee Dam 81
Comment 4-3: Region 2 PRGs are unnecessarily conservative 83
Comment 4-4: PRG Calculation Errors and Ambiguity 84
Comment 4-5: Lack of rationale and information regarding interim PRGs. 86

SECTION 5: State-of-the-Science Evaluation of PRGs 87
Comment 5-1: Removing surface sediment containing TCDD at 1 ppb and greater from the LPR will achieve acceptable risk and hazard values for ingestion of fish and crab 87
Comment 5-2: Spatial analyses conducted using a state-of-the-science approach indicate that only 9% of the Study Area should be remediated based on TCDD. 90

SECTION 6. References 94

APPENDIX A: State-of-the-Science DRA Exposure Parameters and Toxicity Factors . 103

APPENDIX B: State-of-the-Science PRA Distributions 109

APPENDIX C: State-of-the-Science PRG Methods and Supporting Information 114

SECTION 1: Summary of Comments

This document contains ToxStrategies' comments on Region 2's Human Health Risk Assessment (HHRA) contained within the Focused Feasibility Study. Our comments are organized in five key sections:

1. Summary of comments (which serves as an executive summary).
2. Comments on the FFS HHRA prepared by Region 2
3. State-of-the-science HHRA
4. Comments on the FFS PRGs prepared by Region 2
5. State-of-the-science Evaluation of PRGs

Presented below is a summary of the comments from Sections 2-5 of this document.

SECTION 2: Comments on the FFS HHRA prepared by Region 2

The Region 2 HHRA was conducted in a manner that was not consistent with federal guidance (USEPA 1989a,b, 2001, 2010). It lacks use of site-specific data, omits complete exposure pathways, and selectively excludes chemicals of concern. The HHRA does not represent state-of-the-science risk assessment with respect to both the approach and the technical input. It is fraught with errors and flawed assumptions, and lacks transparency. As a result, the proposed billion-dollar remedial action is without robust scientific support – this is particularly notable given that under the conditions of the Region 2 HHRA, even the proposed remedial action does not result in acceptable hazard or risk. The HHRA should be revised to reflect the state-of-the-science described in the comments in this section.

Comment 2-1: Inconsistent, erroneous, and non-standard risk calculations cast doubt on the results of Region 2's HHRA. In an effort to confirm the results of Region 2's HHRA, the calculations were reconstructed. The following examples demonstrate inconsistencies in Region 2's approach, errors (albeit small) in the results, and the use of non-standard risk calculations that are not compliant with guidance. Since the erroneous results cannot be attributed to rounding errors or similar acceptable causes of mathematical differences, the results of the HHRA conducted by Region 2 are questionable. At a minimum, Region 2 needs to re-do the risk assessment and include a complete and transparent report of methods, assumptions, calculations, results and conclusions.

Comment 2-2: Region 2 utilized outdated statistical software for the calculation of exposure point concentrations (EPCs) for fish and crabs, which dramatically impacts the estimated EPC for dioxin-like (DL) PCBs in fish. Using the current version of ProUCL (version 5) results in a 40% increase in the EPC for DL-PCBs in fish over that reported by ProUCL version 4.1. Region 2 should utilize the most current version of ProUCL for the calculation of EPCs.

Comment 2-3: In the 2014 LPR FFS HHRA, Region 2 relied on only 39 fish samples in calculating the EPCs for all contaminants of concern, which represents only a fraction of the more than 100 available fish samples with analytical data that have been collected over the past two decades, and which is a significantly smaller sample size than used for other large sediment Superfund sites. Given the magnitude of the remedy Region 2 has proposed, all available data should be utilized to characterize the site. Region 2 should incorporate all available LPRSA fish and crab tissue data in the HHRA and recalculate risk and hazard.

Comment 2-4: Region 2 did not follow USEPA guidance in selecting appropriate receptors and exposure pathways to evaluate risk and hazard, despite acknowledging the existence of exposures beyond those experienced by anglers consuming fish and crab. Region 2 should revise the assessment to include all complete pathways that can be evaluated quantitatively, and in doing so, examine all chemicals of potential concern (COPCs) associated with each pathway and receptor.

Comment 2-5. The Region 2 LPR HHRA did not account for direct sediment exposure, which represents a significant contribution to overall cancer risk when critical exposure and toxicity parameters (e.g., age-specific sediment adhesion factor, chemical-specific dermal absorption factors, high PAH concentrations in LPR sediment, and age-dependent adjustment factors accounting for PAH mutagenicity) are included in the assessment. Region 2 should revise the HHRA to include direct sediment exposure (dermal exposure and incidental oral ingestion) so that all relevant chemical exposures are accounted for in this risk assessment.

Comment 2-6: Region 2 focused the LPR HHRA exclusively on chemical risk and hazard to LPR anglers. The presence of several pathogens arising from raw sewage routinely discharged into the LPR has already been well documented and currently presents a potentially serious public health threat to LPR anglers and other receptors. Therefore, pathogen risks should be integrated with results of the CERCLA baseline risk assessment to provide a more comprehensive understanding of overall risks at LPR.

Comment 2-7: In developing risk and hazard estimates for the latest LPR FFS, Region 2 ignores site-specific information pertaining to potential receptor exposures; the LPR HHRA does not comport with USEPA guidance on risk assessment (including the recent OSWER directive 9200.1-120) and should be revised to do so.

Comment 2-8: The fish and crab ingestion rates used by Region 2 in the LPR HHRA are not specific to the FFS Study Area, assume accessibility and angler avidity reflective of other regional fishing areas, and therefore lead to an overestimation of angler ingestion and hazard/risk; as such, they should be replaced with fish and crab ingestion rates derived from a robust and comprehensive LPR creel angler survey analysis of LPR river miles 0-8 (Kinnell et al., 2013).

Comment 2-9: Region 2 did not follow USEPA guidance when justifying the assumption that 100% of the fish and crab consumed by LPR anglers came from LPR (i.e., Fraction

Ingestion = 1.0). As a general matter, this assumption is unfounded, and logically can only be assumed in the HHRA if utilizing fish and crab ingestion rates derived from site-specific angler activity. Therefore, at a minimum Region 2 should adjust FI to some value less than 1.0. However, the correct solution is for Region 2 to update the LPR FFS risk/hazard estimates by applying the fish and crab ingestion rates specific to the LPRSA derived by Kinnell et al. (2013).

Comment 2-10: The FFS HHRA assumes no cooking loss for Reasonable Maximum Exposure (RME) exposure scenarios, an assumption that better approximates the consumption of raw, unprepared fish or crab and therefore is an improper assumption for the RME individual. Additionally, Region 2 applied incorrect cooking loss values for TCDD and PCBs in its Central Tendancy Exposure (CTE) exposure scenario. Therefore, Region 2 should update the HHRA using proper cooking loss values for the RME individuals (e.g., 10th percentile cooking loss), and correct the CTE exposure estimates by replacing the erroneous TCDD and PCB cooking loss values with the correct values derived from the USEPA's own 2000 Guidance for Assessing Chemical Contaminant Data for Use in Fish.

Comment 2-11: In addition to not being site-specific, several default exposure parameters applied by Region 2 in the HHRA are not consistent with the most recent 2014 USEPA OSWER Directive. Region 2 should refer to the Directive and update the HHRA with the relevant parameters.

Comment 2-12: Region 2 utilized a cancer slope factor for TCDD that was developed almost thirty years ago, thereby ignoring updated pathology classifications from the National Toxicology Program; Region 2 should utilize the CSF of 9,700 $(mg/kg\text{-}day)^{-1}$ based on the updated pathology classification that is reported in the peer reviewed literature.

Comment 2-13: Because a CSF for TCDD was used in the HHRA, Region 2 asserts that TCDD acts via mutagenic mode of action. This is incorrect; the consensus within the scientific community is that TCDD acts via a receptor based mode of action. Because Region 2 used the CSF, the cancer risks determined in the HHRA are grossly inflated and not scientifically defensible. Region 2 should revise the HHRA to incorporate a threshold-based mode of action for TCDD (e.g., Oral Reference Dose (RfD) protective of both cancer and noncancer effects) – doing so will greatly impact the risk estimates for TCDD.

Comment 2-14: The TCDD cancer slope factor used by Region 2 in the FFS HHRA is based on animal data and is not reflective of what has been observed in high-exposure occupational human studies. The TCDD exposures reconstructed in the NIOSH occupational cohort do not demonstrate an increase in mortality due to specific cancer types, nor are they likely to be associated with mortality due to all cancer types combined given confounding exposures to other chemical carcinogens, and therefore do not implicate TCDD as a human carcinogen. Region 2 should re-examine the evidence

supporting TCDD being a low-dose human carcinogen rather than utilize an animal-based oral cancer slope factor for the FFS cancer risk estimates.

Comment 2-15: The TCDD RfD used by Region 2 in the HHRA is based on two studies of a single high-exposure incident that evaluated health endpoints of questionable relevance and that contains several critical flaws; the use of this RfD resulted in unreasonable estimates of noncancer hazard due to LPR fish or crab ingestion. Noncancer hazard should be recalculated using the JECFA Acceptable Daily Intake (ADI).

Comment 2-16: Region 2 should use a noncancer toxicity value for TCDD that represents the best available science instead of using the highly-flawed reference dose in the FFS. Noncancer hazard should be recalculated using JECFA ADI.

Comment 2-17: Region 2 utilized noncancer and cancer-based toxicity values for TCDD that do not represent the best available science. Region 2 should evaluate risk based upon the best scientific judgment, and in doing so, use toxicity factors that are generally accepted as the current state-of-the-science.

Comment 2-18: The estimated intake (dose) of Dioxin-Like Compounds (DLCs) from ingestion of fish or crab from the LPR is less than that received by nursing infants, yet breastfeeding is recommended by state and federal agencies. It is unreasonable to propose/require massive sediment remediation to address a dose of DLCs from the ingestion of fish or crab from the LPR that is similar to or less than what an infant receives on a daily basis in the first months of life from breast milk. How can ingestion of LPR fish and crab pose an unacceptable hazard when infants receive similar or larger doses from breastfeeding? Based on this issue, Region 2 should withdraw the draft FFS HHRA.

Comment 2-19: The cancer risk estimates calculated by Region 2 for the HHRA actually apply to a very small population. When the cancer risk estimates are put into the context of the LPR angling population, the population excess risk is 2.1 (i.e., approximately two excess cancers are expected among LPR anglers due to consumption of LPR fish and crab). The population risk reflects the overly conservative assumptions integrated into the HHRA as described in the comments above, and the population risk falls below 1 when site-specific exposure assumptions and more scientifically defensible toxicity factors are used to calculate excess cancer risk. Region 2 should update their risk calculations and include population risk estimates to provide appropriate context for the cancer risk estimates for the small LPR angler population and justify the proposed remediation expenditure of over $850 million per excess cancer prevented.

Comment 2-20: Region 2 cited, but did not follow, USEPA guidance regarding the conduct of sensitivity analyses to illustrate the impact of TEFs (USEPA, 2010). This is a critical oversight by Region 2 because the LPR sediment contains large concentrations of dioxin-like PCBs and failure to understand the uncertainty associated with the TEFs (and thus the risk and hazard) can leave risk managers with incomplete information. A TEF sensitivity analysis should be conducted.

Comment 2-21: The discussion related to TEF uncertainty in the draft FFS is wholly insufficient; Region 2 should review and address the many uncertainties related to TEFs as discussed in USEPA guidance (USEPA, 2010).

Comment 2-22: Region 2 utilized a non-standard nomenclature for dioxin-like compounds; the nomenclature should be revised to be consistent with USEPA TEF guidance (USEPA, 2010).

Comment 2-23: The LPR FFS risk and hazard estimates used by Region 2 to inform remediation decisions are the deterministic products of compounded conservatism as each is based on exposure parameter values on the high end of their respective distributions, as well as toxicity values calculated using conservative assumptions. Region 2 should include a probabilistic risk assessment to characterize the impact of the compounded conservatism reflected in its risk and hazard estimates.

Comment 2-24: Based on the future risk estimates for LPR anglers modeled by Region 2, its proposed $1.7 billion dollar remediation alternative does not achieve acceptable cancer risk or hazard for LPR anglers. Also, there is no analysis of physical risks posed by the proposed remedy (e.g., likelihood of a truck or train accident). A single death or serious injury sustained while conducting the remediation will be far worse than choosing the no action alternative with regard to overall impact to human health. In addition, the model used by Region 2 to predict future sediment COPC levels (and by extension, future fish and crab COPC concentrations) likely underestimated future COPC concentrations, and therefore risk, suggesting even higher unacceptable risks after the proposed remedy is complete. Region 2 should re-evaluate the remedial alternatives in the context of revised risk and hazard estimates based on scientifically defensible exposure factors and toxicity factors.

Comment 2-25: Region 2 cited a Wikipedia webpage in support of a statistical method applied in the LPR FFS. This is an unacceptable reference source. In addition to revising its HHRA with the peer-reviewed and scientifically valid approaches described in the comments above, Region 2 should review the LPR FFS to remove any scientifically unacceptable references, such as Wikipedia citations.

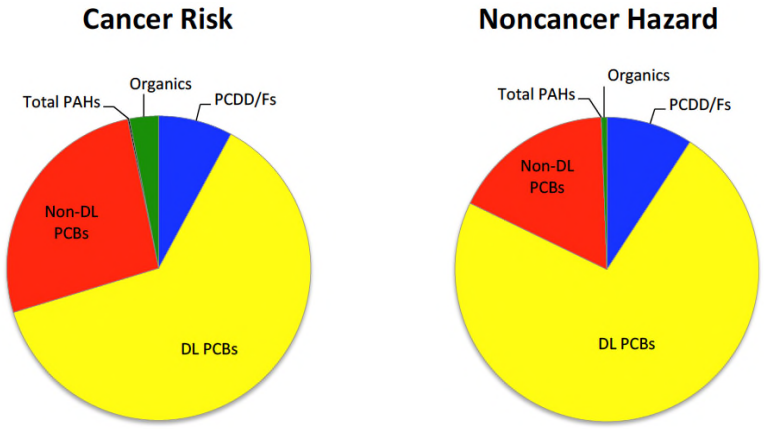
SECTION 3: State-of-the Science HHRA

In this section, we present both a deterministic HHRA (DRA) as well as a probabilistic HHRA (PRA) that represents state-of-the science approaches and technical input for site-specific risk assessments. Most notably, both the DRA and the PRA demonstrate that PCBs (both dioxin-like and non-dioxin-like) and PAHs significantly contribute to hazard and risk in the LPR – and their contributions are greater than the hazards and risks associated with TCDD. These analyses demonstrate the impact of the shortcomings in Region 2's overly simplistic, biased HHRA, and by extension, demonstrate that the billion-dollar remedy proposed in the FFS lacks robust scientific support.

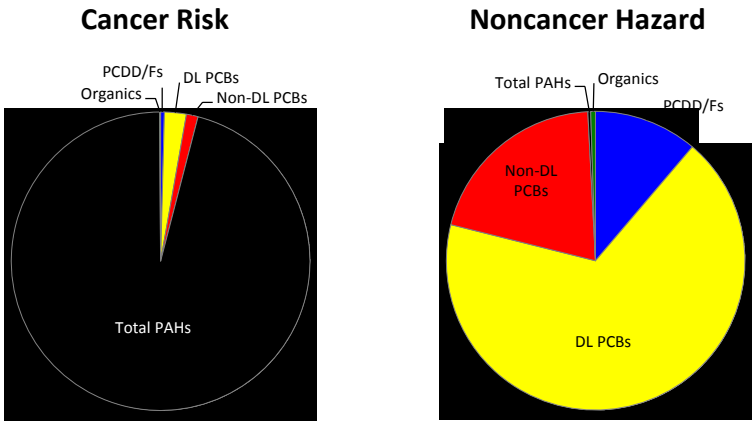
Comment 3-1: To address the significant shortcomings of the HHRA conducted by Region 2, ToxStrategies performed a deterministic HHRA using site-specific data and toxicity criteria that better represent the state-of-the-science, as well as exposure pathways and COPCs relevant to the LPR. These results demonstrate the significance of Region 2's failure to conduct an HHRA consistent with USPEA guidance. Region 2 has significantly overestimated the risk and hazard posed by human ingestion of LPR fish and crab. This state-of-the-science DRA demonstrates that there is no excess cancer risk that exceeds the 1×10^{-4} benchmark and that hazard estimates are dramatically lower than Region 2 contends. Region 2 should revise the FFS HHRA by using site-specific exposure data and scientifically-defensible toxicity criteria.

Comment 3-2: The failure of Region 2 to conduct a TEF Uncertainty Analysis as provided in USEPA TEF document (2010) was a critical oversight given that the LPR sediment contains large concentrations of dioxin-like PCBs and failure to understand the uncertainty associated with the TEFs (and thus the risk and hazard) will leave risk managers with incomplete information. Conduct of a TEF Uncertainty Analysis for the state-of-the-science DRA performed by ToxStrategies demonstrated that DL-PCBs are likely large contributors to the hazard and risk from ingesting LPR fish, a finding similar to that observed with a TEF sensitivity analysis conducted using Region 2 data.

Comment 3-3: Due to the failure of Region 2 to conduct a probabilistic risk assessment (PRA) as specified in USEPA guidance (USEPA 2001), ToxStrategies performed a PRA using site-specific data and toxicity criteria that represent the state-of-the-science approach. In addition, ToxStrategies' PRA evaluated additional exposure pathways and COPCs relevant to the LPR. The findings uniformly demonstrate that PCBs and PAHs present significant risk and hazard (**see pie charts below**), thus highlighting the impact of the errors, bias, and omissions in the Region 2 HHRA, and supporting the request that Region 2 withdraw the FFS HHRA and conduct a proper HHRA in accordance with USEPA guidance.



LPR Probabilistic Risk Assessment Results for Fish and Crab Ingestion in Child Receptor (95%ile): *A PRA for LPR fish and crab ingestion, properly conducted according to Agency guidance, demonstrates that DL-PCBs are the drivers of cancer risk and noncancer hazard for this pathway, followed by non-DL-PCBs.*



LPR PRA Results for All Relevant Exposure Pathways in Child Receptor (95%ile): *A PRA for LPR fish and crab ingestion, incidental sediment ingestion, and direct sediment contact, conducted according to Agency guidance, demonstrates that Total PAHs are the primary drivers of cancer risk, while PCBs (DL- and non-DL-PCBs) are the drivers of noncancer hazard.*

SECTION 4: Comments on FFS PRGs Prepared by Region 2

The preliminary remediation goals (PRGs) for LPR RM0-8 sediments presented by Region 2 were developed using similar deterministic methods and exposure assumptions employed in its HHRA, a derivation inconsistent with USEPA guidance. Like the LPR FFS HHRA, the LPR FFS PRGs do not represent the state-of-the-science in either derivation methodology or parameter input. In addition to ignoring site-specific data on fish and crab consumption, Region 2 applied inaccurate measures of PCBs that underestimated Total PCB exposures, resulting in PCB PRGs that may not lead to acceptable risk and hazard. Similarly, Region 2 prepared a background risk assessment that used inaccurate measures of COPCs, thereby underestimating background risk and hazard estimates. Furthermore, there are significant errors in some of the sediment PRG calculations. As a result, the PRGs and background risk assessment presented by Region 2 are inadequate to support scientifically-defensible remedial decisions. The PRGs should be corrected and revised to reflect the state-of-the-science as described in the comments in this section.

Comment 4-1: Region 2 calculated PRGs for PCBs using modeled fish and crab tissue COPC concentration estimates based on Aroclor sediment data. This approach has two shortcomings: a) it likely underestimates the actual Total PCB sediment and (by extension) fish and crab tissue concentrations, and b) it precludes an accurate analysis of Total PCBs risk consistent with USEPA guidance, whereby the risk and hazard of both dioxin-like and non-dioxin-like PCBs is calculated. Ultimately, the effect of these shortcomings is the derivation of PCB PRGs that are not protective of exposures to Total

PCBs (i.e., non-dioxin-like and dioxin-like PCBs). Region 2 should update their PCB PRG calculations to accurately and completely account for risk and hazard from Total PCBs.

Comment 4-2: Region 2 calculated background risk and hazard estimates based solely on concentrations of TCDD and non-dioxin-like PCBs in sediments collected at River Mile 17.4 in the Upper Passaic River. These data represent only a fraction of all dioxins and furans (PCDD/Fs) and Total PCBs (non-dioxin-like and dioxin-like). Furthermore, the impact of background sediment PAHs on risk was not addressed. Since the background risk and hazard is estimated to help risk managers put the LPR FFS Study Area risk and hazard estimates into context, ignoring these critical COPCs results in considerable underestimates of the background risks. Region 2 should revise its background site analysis to include PAHs, all dioxins, furans, and DL-PCBs so that the risks and hazards reported in the LPR FFS provide sufficient understanding to inform risk managers.

Comment 4-3: Contrary to USEPA guidance, Region 2 did not utilize the most relevant site-specific exposure parameter data (based on empirical data from comprehensive LPR creel angler surveys), or when site-specific data were not available, the most current USEPA OSWER default assumptions, in the development of the sediment PRGs for the LPR RM0-8. Furthermore, Region 2 did not apply the most scientifically defensible cancer risk or noncancer hazard toxicity factors in deriving PRGs for dioxin-like compounds. As a result, Region 2 PRGs do not accurately reflect the LPR FFS Study Area conditions or the best science, and thus should not be used to make risk management decisions. Region 2 should revise its PRG values using the site-specific exposure data and most current USEPA OSWER default exposure parameters.

Comment 4-4: Region 2 developed sediment PRGs based on incorrect assumptions and erroneous calculations and did not present a clear methodology. Importantly, it appears that the sediment PRG calculated for TCDD TEQ by Region 2 is incorrect by a factor of 2 (7.1 pg/g vs. 14 pg/g for fish consumption, using the methods described in Region 2's LPR FFS PRG document). Region 2 should revise its PRG using the correct calculations.

Comment 4-5: Region 2 does not adequately explain the derivation, utility, or plan associated with the interim biota tissue PRGs. Such discussion must be significantly more robust, including specific information as to why this is useful in the context of the FFS.

SECTION 5: State-of-the-Science Evaluation of PRGs

Region 2 derived its sediment preliminary remediation goals (PRGs) for the LPR FFS Study Area in a deterministic manner using default fish/crab ingestion rates that are not reflective of the Passaic River angling community. ToxStrategies employed a state-of-the-science approach to determine health-protective PRGs for TCDD and PCBs. Specifically, a model was used to assess whether sediment concentrations were protective of hazard and risks associated with exposure to TCDD and PCBs via fish and crab consumption. These data were then evaluated spatially to determine the location and volume of sediment that would be subject to remedial action in order to achieve the health-

protective sediment concentrations. The results demonstrated that a TCDD sediment PRG of 1 ppb was protective of both cancer risk and noncancer hazard. This sediment PRG resulted in only 9% of sediment area from RM0-8 requiring remedial action. In contrast, acceptable PCB risk and hazard was not achieved even if the TCDD PRG were decreased to 0.5 ppb, resulting in remedial action for 12% of the LPR sediment. For the current sediment condition, PCBs account for 74% of the noncancer hazard associated with fish ingestion using TEF distributions in the calculations. Conducting a similar analysis but focusing on PCB-containing sediments, the PRG analysis for consuming anglers shows a Total PCB PRG of 0.7ppm is health protective, which corresponds to remedial action for 71% of the LPR RM0-8 area. These calculations demonstrate that Region 2 can obtain acceptable risk and hazard for TCDD with much less remedial work than that proposed in the FFS. Region 2 should withdraw its proposed remedial options, conduct its PRG determination using the approach described herein, and thereafter revise its proposed remedial options consistent with the new information. These analyses further demonstrate that PCBs are widely distributed in the sediment of LPR at elevated concentrations and pose much more of a risk/hazard to human health than does TCDD – a fact that was overlooked repeatedly by Region 2.

Comment 5-1: In an effort to improve on the overly simplistic approach utilized by Region 2 to derive PRGs, ToxStrategies derived health-protective PRGs using a state-of-the-science approach. The series of iterative analyses demonstrated that a PRG of 1ppb TCDD is protective for cancer risks and noncancer hazards associated with fish and crab consumption. Additonally, for consuming anglers, a PCB sediment PRG of 0.7ppm was found to be protective for cancer risks and noncancer hazards associated with PCB and all DLC (which includes TCDD as well as PCB congeners PCB-118 and PCB-126).

Comment 5-2: An independent spatial analysis revealed that a sediment remediation scenario based on a PRG of 1 ppb TCDD would require remediation of only 9% of the sediment area from RM0-8, which is only a small portion of the area Region 2 has proposed be subject to remedial action in the FFS as a result of its flawed and biased HHRA and PRG evaluation. This analysis demonstrates that the impact of Region 2's compounded conservatism and series of actions that are not supported by scientific data are associated with overly burdensome remedial actions (and thus cause undue waste of financial resources and unnecessary inconveniences to area residents).

SECTION 2: Comments on the Region 2 FFS HHRA

The Region 2 HHRA was conducted in a manner that was not consistent with USEPA guidance (USEPA 1989a,b, 2001, 2010). It lacks use of site-specific data, omits complete exposure pathways, and selectively excludes chemicals of concern. The HHRA does not represent state-of-the-science risk assessment (cite) with respect to both the approach and technical input. It is fraught with errors and flawed assumptions, and lacks transparency. As a result, the proposed billion-dollar remedy is without robust scientific support – this is particularly notable given that under the conditions of the Region 2 HHRA, even the proposed remedies do not result in acceptable hazard or risk. The HHRA should be revised to reflect the state-of-the-science as described in the comments in this section.

Comment 2-1: Hazard and Risk Calculation Errors

Inconsistent, erroneous, and non-standard risk calculations cast doubt on the results of Region 2's HHRA.

In an effort to confirm the results of Region 2's HHRA, the calculations were reconstructed. The following examples demonstrate inconsistencies in Region 2's approach, errors (albeit small) in the results, and the use of non-standard risk calculations that are not compliant with guidance. Since the erroneous results cannot be attributed to rounding errors or similar acceptable causes of mathematical differences, the results of the HHRA conducted by Region 2 are questionable. At a minimum, Region 2 needs to re-do the risk assessment and include a complete and transparent report of methods, assumptions, calculations, results, and conclusions.

Region 2 made errors in conducting and reporting the human health risk and hazard calculations as presented in the FFS Appendix D – Risk Assessment. These include:

1. Table 3-4 (Summary of Baseline Risks Associated with Fish and Crab Consumption) appears to provide an incorrect value for the fish CTE Hazard Index (HI). Table 3-4 lists this HI as 13, while the RAGS D Table 4-24 (Child, CTE) in Attachment 4 shows a child HI of 14, which is the value that appears to be utilized in the assessment. As such, there is a clear discrepancy between the information provided in the summary tables of risk assessment relative to the tables provided in the attachments. This discrepancy should be addressed and the tables updated to be consistent.
2. Some of the intakes, risks and hazards presented in various tables throughout Appendix D cannot be exactly replicated. While most of the receptor-specific intakes, risks and hazards on the individual RAGS D tables could be exactly replicated, ToxStrategies calculates an intake of 4.8E-11 mg/kg-day instead of Region 2's 4.9E-11 mg/kg-day for TCDD TEQ (PCBs), adult (Table 4-19). Also, while some values for the future no action scenario could be exactly replicated using the various EPCs provided, for the child RME scenario, several could not. We calculated a HQ of 66, 49 and 46 for TCDD TEQ (D/F), TCDD TEQ (PCBs) and Total PCBs, respectively. Region 2 calculated HQs of 65, 50 and 45 for these

chemicals. ToxStrategies calculated a total HI of 164, while Region 2's calculation was 163. Further, we were unable to replicate several of the fish CTE summary risks/hazards and percent contribution values reported in Tables 3-6 and 3-7. For example, Table 3-6 reports that TCDD TEQ (D/F) contribute to 70% of total CTE risk, and Table 3-7 indicates that TCDD TEQ (D/F) contribute to 49% of the hazard. We were unable to replicate these values. Similarly, we were unable to replicate the adult, adolescent and child risks listed in Table 3-6 for total PCBs, as well as the 10% contribution for PCBs. We were unable to replicate the adult, adolescent and child hazards listed in Table 3-7 for TCDD TEQ (PCBs), as well as the 8% contribution for TCDD TEQ (PCBs). We were unable to replicate the total HI values for adult and child. Region 2 appears to have used an inconsistent method in reporting the data, and presumably in the calculations, with respect to the numbers of significant figures between EPCs for the various COCs. This inconsistency was observed, in particular, between fish and crab EPCs. In an effort to replicate these numbers, a "hybrid" approach combining values from different tables was necessary to replicate some of the numbers (though EPCs could still not be replicated for all COPCs).

3. Region 2 reported that a 30% cooking loss was assumed for PCBs in fish for the CTE scenario in Table 3-4 of Appendix D, Risk Assessment. The risk and hazard calculations could not be replicated with this value. However, rearranging the equations and solving for cooking loss, a value of 20% was determined. As such, it appears that Region 2 either incorrectly reported the value for cooking loss, or meant to use 30% and did not correctly input the values.
4. Although it is difficult to know what Region 2 actually did with target-organ specific noncancer HI calculations, it is clear that it did not follow USEPA risk assessment guidance (see inset from USEPA 1989a). Page 3-33 of Appendix D, Risk Assessment, states, "Noncancer HIs segregated by effect/target organ also are shown on Table 3-7." Table 3-7 presents hazards for each chemical and lists the target organ(s) corresponding to each chemical, but no HIs for chemicals having the same target organ were calculated. As shown in USEPA 2001 RAGS D, target-organ specific HIs are the summed hazard estimates across all chemicals associated with each target organ. USEPA acknowledges the appropriateness of the target-organ specific HI. In its Technology Transfer Network Air Toxics2005 National-Scale Air Toxics Assessment website (http://www.epa.gov/ttn/atw/natamain/gloss1.html):

> *Ideally, HQs should be combined for pollutants that cause adverse effects by the same toxic mechanism. However, because detailed information on toxic mechanisms was not available for most of the substances in this assessment, EPA aggregates the effects when they affect the same target organ regardless of the mechanism.*

PROCEDURE FOR SEGREGATION OF HAZARD INDICES BY EFFECT

Segregation of hazard indices requires identification of the major effects of each chemical, including those seen at higher doses than the critical effect (e.g., the chemical may cause liver damage at a dose of 100 mg/kg-day and neurotoxicity at a dose of 250 mg/kg-day). Major effect categories include neurotoxicity, developmental toxicity, reproductive toxicity, immunotoxicity, and adverse effects by target organ (i.e., hepatic, renal, respiratory, cardiovascular, gastrointestinal, hematological, musculoskeletal, and dermal/ocular effects). Although higher exposure levels may be required to produce adverse health effects other than the critical effect, the RfD can be used as the toxicity value for each effect category as a conservative and simplifying step.

These inconsistencies, errors, and disregard for standard USEPA guidance in risk assessment cast doubt on the accuracy of the HHRA conducted by Region 2. Consistent and accurate reporting of actual values used in the caclulations (e.g., EPCs, cooking loss for PCBs) are essential for providing necessary clarity in the steps performed to determine risks and hazards. At a minimum, Region 2 needs to re-do the risk assessment and include a complete and transparent report of methods, assumptions, calculations, results and conclusions.

Comment 2-2: Use of Outdated Statistical Software

Region 2 utilized outdated statistical software for the calculation of EPCs for fish and crabs which dramatically impacts the estimated EPC for dioxin-like (DL) PCBs in fish. Using the current version of ProUCL (version 5) results in a 40% increase in the EPC for DL-PCBs in fish over that reported by ProUCL version 4.1. Region 2 should utilize the most current version of ProUCL for the calculation of EPCs.

Region 2 utilized ProUCL version 4.1 for the determination of EPCs in fish and crab for the FFS HHRA. ProUCL Version 4.1 was replaced by ProUCL version 5.0 on September 19, 2013 (USEPA 2014). For most chemicals evaluated in the FFS HHRA, there is no significant difference in the EPC (95th UCL of the mean) for fish and crab reported by ProUCL versions 4.1 and 5.0. However, there is a substantial difference in the output for DL-PCBs for fish. ProUCL 5.0 reports a 40% larger EPC (95th UCL of the mean) for DL-PCBs in fish than does ProUCL 4.1. Specifically, the EPC for DL-PCBs in fish should be 22.86 ppt and not 16.3 ppt as reported by Region 2. Clearly, Region 2 should be using the most recent version of ProUCL and it is unclear why Region 2 elected to utilize outdated statistical software for the FFS HHRA (ProUCL version 5 has been available since September 2013). This error impacts risk and hazard estimates in the HHRA. Region 2 should recalculate the EPCs for the HHRA using ProUCL version 5.0 and utilize such to estimate both hazard and risk for DL-PCBs.

Comment 2-3: Region 2 did not use an adequate number of fish and crabs to characterize the Site

In the 2014 LPR FFS HHRA, Region 2 relied on only 39 fish samples in calculating the exposure point concentrations (EPCs) for all contaminants of concern, which represents only a fraction of the more than 100 available fish samples with analytical data that have been collected over the past two decades, and which is a significantly smaller sample size than used for other large sediment Superfund sites. Given the magnitude of the remedy Region 2 has proposed, all available data should be utilized to characterize the Site. Region 2 should incorporate all available LPRSA fish and crab tissue data in the HHRA and recalculate risk and hazard.

The number of samples utilized by the Region 2 is small in comparison to those from other Superfund sites involving large-scale remediation of sediment. USEPA documents pertaining to the Portland Harbor, Upper Columbia River, General Electric/Housatonic, and Lower Fox River and Green Bay sites indicate that >100 fish samples (**Table 1**) were

used to calculated exposure point concentrations (EPCs) (USEPA 2000a, 2000b, 2005, 2009, 2013; Wisconsin DNR 1999). For the Hudson River site, although fate and transport modeling was used to derive fish EPCs in the human health risk assessment (HHRA), the fish bioaccumulation model was calibrated using a database containing ~10,000 – 15,000 fish samples collected by multiple entities from the Hudson River. Comparatively, the sample size used in the HHRA appears insufficient and is at minimum two times smaller than other similar Superfund sites. Region 2 should use a larger sample size in order to be consistent with prior assessments for other similar sites and to better document the concentrations of chemicals in fish.

Table 1. Comparison of fish sample numbers used to develop remediation plans at various prominent, high dollar Superfund sites

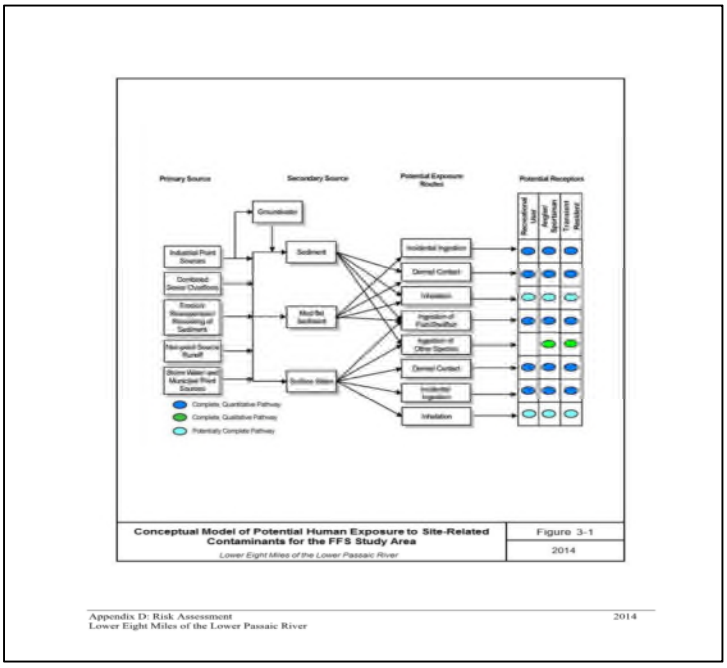
Superfund site	Number of fish samples used in human health risk assessments (HHRAs)
Lower Passaic River	39 (out of 126 available)
Portland Harbor	>100 (59 fillets; 61 whole-body)
Upper Columbia River	>150 (54 fillets; 155 whole-body)
GE/Housatonic River	>250
Lower Fox River and Green Bay	>400
Hudson River*	~10,000 - 15,000

*Exposure point concentrations (EPCs) derived from fate and transport (F&T) modeling calibrated using ~10,000 – 15,000 fish samples.

Importantly, in the 2007 draft FFS, Region 2 calculated fish and crab EPCs using analytical tissue data using between 66 – 83 unique samples from seven different LPR sampling events conducted between 1993 – 2001. Yet Region 2 in the current LPR FFS, derived EPCs using just 39 fish and 22 crab samples collected between 2010-2011 and disregarded all earlier sample data. It is unclear as to the scientific rationale behind basing fish and crab EPCs on such a limited fraction of the total available samples for the LPR site. Based on this observation, Region 2 should recalculate EPCs using all fish sample data that have been collected and validated for the lower eight miles of the Lower Passaic River (LPR). It is highly unlikely that the 39 fish samples and 22 crab samples used to calculate the EPCs for the FFS are representative of fish and crab contaminant body burden for the FFS Study Area. Moreover, using such a small number of fish and crabs is inconsistent with USEPA actions at other Superfund sites around the country.

Comment 2-4: Region 2 did not evaluate all complete exposure pathways at the site

Region 2 did not follow USEPA guidance in selecting appropriate receptors and exposure pathways to evaluate risk and hazard, despite acknowledging the existence of exposures beyond those experienced by anglers consuming fish and crab existed. Region 2 should revise the assessment to include all complete pathways that can be evaluated quantitatively, and in doing so, examine all COPCs associated with each pathway and receptor.



Region 2 selected a single exposure pathway and a single receptor for evaluating the LPR despite acknowledgements that many pathways are complete for various receptors and thus could be characterized quantitatively. These were clearly identified in the conceptual site model in the draft FFS (see blue circles in inset; Figure 3-1 in the draft the HHRA). When discussing recreational users, Region 2 states, "Potential exposure pathways include direct contact (ingestion and dermal contact) with sediment and surface water and inhalation exposures if activities occur in mudflat areas or near sediment where VOCs are present." Clearly, Region 2 acknowledges such exposures could occur, although it chose not to evaluate such quantitatively in the FFS, instead awaiting the RI/FS for the 17-mile LPRSA to do so and merely addressing (insufficiently) this topic as an uncertainty. Furthermore, in citing additional routes of exposure as sources of uncertainty in the HHRA, the Agency did not provide a quantitative evaluation of the contribution of risk and hazard from other exposure routes to the uncertainty inherent in its analysis.

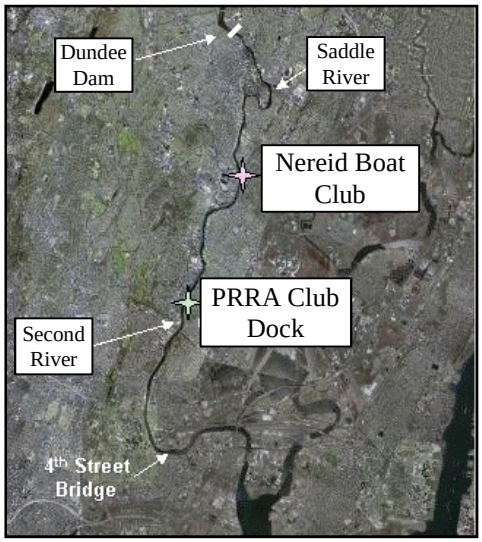
This significant oversight is particularly perplexing given that Region 2 cites a number of master plans from municipalities along the FFS Study Area that clearly identify uses associated with potential exposure beyond angler ingestion of fish and crab. For example, the FFS cites a 2012 City of Newark document for the downtown area of the LPR that describes plans to support building on existing designations for future park construction alongside medium-density development accompanied by public riverfront access. Moreover, plans for Ironbound, are to promote the riverfront as primarily a recreational area and to make provisions for better connections between upland and riverfront. Another document cited by Region 2, City of Newark (2010), "The Riverfront that

Newark Wants, Progress Report: 2009-2010," includes a map that designates a high school boating program site within Riverfront Park, as well as a public floating dock. This presentation also references a continuous riverfront walkway in the downtown region.

Also cited by Region 2 is a 2002 report by Heyer, Gruel and Associates 2002 titled, "Town of Kearny Master Plan Reexamination Report" that envisions new open spaces created via redevelopment along the Passaic River, as well as development of a publicly accessible Passaic River open space network running from North Arlington through Kearny to East Newark and Harrison. This resource also shows plans to connect the Passaic redevelopment area to residential area, and notably, to make improvements to walkway along river.

In addition, Region 2 cites a 2007 report by the New Jersey Department of Transportation (NJDOT) titled "New Jersey's Position on the Future Navigational Use on the Lower Passaic River, River Miles 0-8" that addresses upgrades to "a boat ramp at RM 7 (Bergen and Passaic Aves) and dock at RM 8 (Kearny Board of Education Crew Program) as focal points for public access." It notes that the Passaic River Boat Club (among other non-profit organizations) are working to improve waterfront access (e.g., locations, adequate depths, overcoming bridge limitations for boating), provide facilities (e.g., marinas, docks, anchorages, restaurants to attract and support boating), and spearhead recreational regional events (*e.g*., Spring Fishing Tournament, Fall Boat and Maritime Festival, Eco-tours). The NJDOT document discusses proposed plans from The Lower Passaic and Saddle River Alliance for a Water Kayak and Canoe Trail from Pompton River (RM 32) to the confluence with Newark Bay and up the Hackensack River. This report also includes a summary of desired future uses in Newark, such as recreational and entertainment uses: pleasure and dinner boating, marinas, floating restaurants, crew racing/ kayak centers, river festivals and water taxi services (downtown Newark to Manhattan and Jersey City).

As demonstrated by the following discussion and series of photos, exposures to COPCs are occurring via routes and receptors other than fish and crab ingestion in anglers along the LPR. Results of a shoreline survey conducted between the Second River and Newark Bay demonstrated that a variety of primary contact scenarios occur along the Lower Passaic (Proctor 2002). In several instances, the survey investigators observed individuals ingesting water from drainage pipes and wading, bathing, or washing clothes in the river. Such activities have been observed frequently and are commonly accepted to occur, as acknowledged by Region 2 in the draft FFS.



Kearny boat ramp looking east toward Riverbank Park (~RM 7)

In addition to documentation of boating activity along the Passaic in the shoreline survey, at least seven high school and two private rowing clubs use the River on a regular basis (see inset). The Passaic River Rowing Association (PRRA) activities span six miles up and down the River from their base location, which would take the crews almost to the mouth of Newark Bay As seen in the aggregate images below, these clubs are very active along the River. Also within these images, other boats and watercraft can be seen. Rowing events along the Passaic include summer camps for children and adults, competitive events, and community rowing programs. For example, teams from Kearny, Belleville, and Passaic high schools participated in the Passaic River Sprints on April 8, 2006. Rowers from the PRRA were also seen in the HBO series "The Sopranos," filmed near their docks at the Belleville Turnpike/7 Bridge. People were also observed jet skiing on the River during the shoreline survey.

HS CREW

Rolling on the river

ANDREW MILLER JOURNAL PHOTO

WET WEATHER AND ROUGH WATERS didn't stop the Kearny High School crew team on Saturday. Both the Kardinals boys and girls teams competed at the first annual Passaic River Sprints. Above, members of the Kearny boys team participate in a four-man race.

Rowing activities along the Lower Passaic River (Observer Online). These images were taken from PRRA.org and hopr.org. Note: rowing picture on the title page also an image of recreational activity on the Lower Passaic during wet weather conditions (http://www.theobserver.com/archives/2006/04-12-06/img/bellevilleboat.jpg).

Members of the local community have also been seen wading in the water in conjunction with a river cleanup project.

Various shoreline activities along the Lower Passaic. Images drawn from: http://thecanessacorner.blogspot.com/, http://www.passaicriver.com/, and http://www.flickr.com/photos/62515506@N00/

Clearly the exposures beyond fish and crab consumption by anglers exist on the LPR. Thus, it was not only incorrect, but also inconsistent with USEPA guidance in conducting risk assessment (see inset from USEPA 1989a) to" cherry pick" a single exposure pathway and receptor. The implications of this subjective decision are severe (see Section 2) as Region 2 is likely not quantifying significant cancer risks posed by polycyclic aromatic hydrocarbons (PAHs). Given the magnitude of the proposed remedy, the LPR risk assessment should include all relevant receptors and exposure pathways. Furthermore, Region 2 should examine all COPCs associated with each pathway and receptor (e.g., PAHs).

> **6.3.5 SUMMARIZE INFORMATION ON ALL COMPLETE EXPOSURE PATHWAYS**
>
> Summarize pertinent information on all complete exposure pathways at the site by identifying potentially exposed populations, exposure media, exposure points, and exposure routes. Also note if the pathway has been selected for quantitative evaluation; summarize the justification if a pathway has been excluded. Summarize pathways for current land use and any alternate future land use separately. This summary information is useful for defining the scope of the next step (quantification of exposure) and also is useful as documentation of the exposure pathway analysis. Exhibit 6-8 provides a sample format for presenting this information.

Comment 2-5: By focusing on fish and crab ingestion and ignoring direct sediment contact, Region 2 failed to identify PAHs as a significant risk driver.

The Region 2 LPR FFS did not account for direct sediment exposure, which represents a significant contribution to overall cancer risk when critical exposure and toxicity parameters (e.g., age-specific sediment adhesion factor, chemical-specific dermal absorption factors, high PAH concentrations in LPR sediment, and age-dependent adjustment factors accounting for PAH mutagenicity) are included in the assessment. Region 2 should revise the HHRA to include direct sediment exposure (dermal exposure and incidental oral ingestion) so that all relevant chemical exposures are accounted for in this risk assessment.

While the LPR FFS HHRA developed by Region 2 is based solely on angler exposures via fish and crab ingestion, it is clear from the LPR conceptual site model that other relevant exposure pathways and other COCs could represent additional risks and hazards. For example, PAHs are not expected to confer significant risk via fish and crab ingestion since these compounds do not bioaccumulate as a result of efficient biological metabolic processes. However, PAHs have been measured in LPR sediments at elevated concentrations, and as such, this group of compounds represents a direct contact exposure risk (a complete exposure pathway identified by Region 2). PAHs are comprised of several chemicals, the most toxicologically potent of which is thought to be benzo[a]pyrene (BaP). Unlike the traditionally defined dioxin-like compounds (PCDD/Fs and DL-PCBs), BaP and several other PAHs are known to be mutagenic to various degrees. Similar to DLCs, USEPA and other regulatory agencies have traditionally applied BaP-based relative potency factors (RPFs) to seven PAHs known to be mutagenic. As a result, PAH risk is typically comprised of the summed products of each respective PAH tissue concentration and RPF (in addition to methylnaphthalene).

The significance of Region 2's exclusion of risk and hazards associated with exposure to PAHs via contact to sediments is demonstrated in **Figure 1**. Using Region 2's calculations for fish and crab consumption, ToxStrategies added the sediment pathway

and included PAHs as a COC. Using the most recent PAH toxicity factors for both incidental sediment ingestion and dermal contact exposure pathways (USEPA 2013), excess cancer risk associated with sediment PAHs is demonstrated to be a significant driver of overall risk for the LPR FFS Study Area (**Figure 1**). Region 2 should revise their HHRA to include direct sediment exposure (dermal exposure and incidental oral ingestion) so that all relevant chemical exposures are accounted for, and so cancer excess risk is appropriately characterized for LPR receptors.

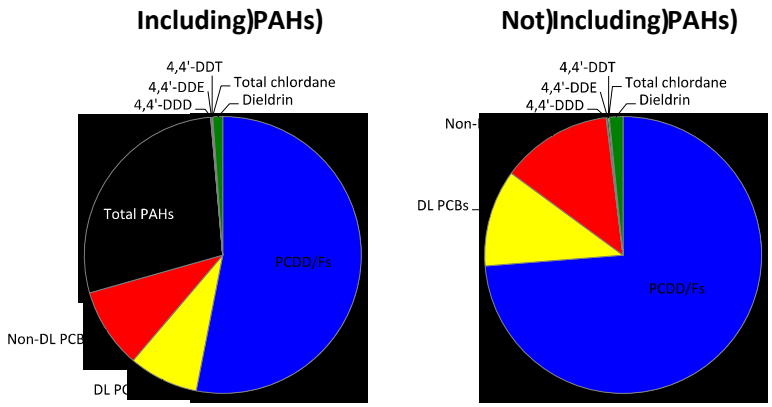


Figure 1. The relative impact of PAH exposure via sediment contact on excess cancer risk for the LPR using Region 2 assumptions (RME scenario for child receptor exposed via fish and crab ingestion, and ingestion of, and dermal contact with, sediment)

Comment 2-6: Region 2 should have evaluated the health risks from pathogens arising from the ongoing and government-sanctioned discharge of raw sewage into the Passaic River

Region 2 focused the FFS HHRA exclusively on chemical risk and hazard to LPR anglers. The presence of several pathogens arising from raw sewage routinely discharged into the LPR has already been well documented and currently presents a potentially serious public health threat to LPR anglers and other receptors. Therefore, pathogen risks should be integrated with results of the CERCLA baseline risk assessment to provide a more comprehensive understanding of overall risks at LPR.

The focus of the FFS HHRA is on the risk and hazard to anglers posed by chemicals levels in LPR fish and crab. While this is in keeping with CERCLA protocol, there is no mention of the acute health risks associated with the LPR pathogen loads that have been documented in both LPR water and sediments (Donovan et al. 2008a,b). There are 73 combined sewer overflows (CSOs) along the LPR that discharge raw untreated sewage to the river at various times. CSOs are designed to intentionally bypass wastewater treatment plants during a precipitation event and discharge directly to surface water bodies to avoid overloading the wastewater treatment plant. Pathogens have the opportunity to reach LPR surface waters when overflow events occur, leading to the discharge of storm water and sewage directly into the LPR, which over a 24- to 48-h

period can potentially include more than 100 million gallons of combined storm water and sewage. Some unintentional discharges may also occur during dry weather due to failures of the CSO conduits.

Water samples collected in and around the Lower Passaic River reveal that pathogens are present at levels that far exceed health-based water quality standards (Donovan et al. 2008a). Likewise, a subsequent study demonstrated that pathogens are also present in LPR sediments near CSOs at high levels, and that significant health risks are associated with contact with these sediments (Donovan et al. 2008b). Samples were found to contain many bacterial species that are associated with human fecal matter (at levels several orders of magnitude greater than water quality standards), as well as *Giardia* and several viral pathogens. Additionally, pathogenic resistance to antibiotics was also observed in the sediment samples, the exposure to which could be particularly serious for sensitive subpopulations (e.g., immunocompromised people, children, and the elderly).

Exposure to river pathogens can occur via incidental ingestion of the river water, as well through dermal exposure to water and sediments. Additionally, as a survey in Baltimore Harbor, MD demonstrated, another route of exposure is the transfer of pathogens from fish and water to an angler's hand after handling a catch (Roberts et al. 2007). Furthermore, if an angler has wounds or cuts on the exposed skin (not an unreasonable scenario given the likely handling of hooks and knives), direct contact with these pathogens via water or sediment could put the receptor at risk of systemic pathogenic infection. Such exposures would be expected for LPR anglers under the RME scenario.

In a recent press release (USEPA 2011c) regarding the initiation of a remedial action on the Passaic River, NJDEP Commissioner Bob Martin was quoted:

> *"Today marks an important step toward our ultimate goal -- a fully restored and healthy Passaic River that can once again be a swimmable and fishable natural resource to benefit Newark and New Jersey's other overburdened urban communities."*

This goal of NJDEP is impossible to achieve as long the USEPA and NJDEP permit the ongoing discharge of raw untreated sewage into the Passaic River. The risks posed by raw untreated sewage in the water and sediment of the Passaic River greatly exceeds the Region 2 hypothetical and non-scientifically defensible risk and hazard estimates alleged for chemicals from ingestion of Passaic River fish and crabs.

Effective LPR restoration will require a significant reduction in human health risks, which will require that all sources of such impacts be addressed. The available data indicate that pathogen levels are elevated above health-based criteria during both dry and rainy conditions. Given the serious acute health threat presented by pathogens, Region 2 should include a component of the HHRA that addresses the acute health risks associated with exposure to such pathogens in addition to those posed by chemicals in the fish and sediment.

Comment 2-7: Region 2 ignored site-specific data and OSWER directive 9200.1-120

In developing risk and hazard estimates for the latest FFS, Region 2 ignores site-specific information pertaining to potential receptor exposures; the LPR HHRA does not comport with USEPA guidance on risk assessment (including the recent OSWER directive 9200.1-120) and should be revised to do so.

The FFS identified PCDD/Fs and PCBs as the primary contributors to both the excess cancer risk and elevated noncancer health hazard based on ingestion of fish and crab from the FFS Study Area. Region 2 used overly conservative default and/or non-site-specific values for key exposure parameters in its risk assessment, rather than using values informed by site-specific data as called for in USEPA's own Guidance Manual on Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish (cited in Risk Assessment Guidance for Superfund sites), which states:

> *"Extrapolation of [default] values to local populations and recreational fisheries should generally be avoided… Whenever possible, data on local consumption patterns should be collected." (USEPA 1989b)*

The USEPA also addresses the use of site-specific data for deriving risk assessment exposure factors in its 2011 Exposure Factors Handbook:

> *"Many… [exposure] factors are best quantified on a site- or situation-specific basis. The decision as to whether to use site-specific or national values for an assessment may depend on the quality of the competing data sets as well as on the purpose of the specific assessment." (USEPA 2011a)*

Most recently, on February 6, 2014, USEPA's Office of Solid Waste and Emergency Response (OSWER) issued OSWER Directive 9200.1-120 to all Regional Superfund National Policy Managers that updated guidance on standard default exposure factors. The stated objective of the 2014 OSWER guidance is "to reduce variability and uncertainty in the exposure assumptions used by Regional Superfund staff to characterize exposures to human populations for human health risk assessments" (USEPA 2014). Regarding fish ingestion, the 2014 OSWER Directive specifically recommends that Regional Superfund staff use site-specific values.

There is a wealth of high-quality, site-specific data for the FFS Study Area including fish ingestion rates, species fraction ingested, exposure duration data, angling population size and type, etc. (Kinnell et al. 2007, 2013; Ray et al. 2007a,b). Yet Region 2 did not incorporate these data into the 2014 FFS HHRA. Because the goal of the FFS HHRA should be to determine potential human health risks and hazards that are scientifically defensible and compliant with USEPA risk assessment guidance, Region 2 should use the comprehensive and robust LPRSA creel angler survey (CAS) datasets to develop exposure factor parameter values relevant to the FFS Study Area.

Additionally, if Region 2 continues to elect to not utilize site-specific data available for the LPR, then it should provide a detailed explanation in the FFS HHRA of why it is discarding such data and not complying with USEPA guidance.

Comment 2-8: Region 2 did not utilize the extensive site-specific information collected as part of a multi-year Creel Angler Survey (CAS)

The fish and crab ingestion rates used by Region 2 in the LPR HHRA are not specific to the FFS Study Area, assume accessibility and angler avidity reflective of other regional fishing areas, and therefore lead to an overestimation of angler ingestion and hazard/risk; as such, they should be replaced with fish and crab ingestion rates derived from a robust and comprehensive LPR creel angler survey analysis of LPR river miles 0-8 (Kinnell et al. 2013).

Region 2 used fish and crab ingestion rates in the HHRA that are based on angler survey studies not specific to the FFS Study Area, as such, this fails to account for the distinct characteristics of the LPR, it does not relate to the angler activities specific to the LPR angler population and is inconsistent with OSWER directive 9200.1-120. In addition to addressing a larger geographical region with multiple water bodies, as well as describing a much broader, regional angling population, the angler surveys on which the Region 2 fish and crab ingestion rates are based are decades old, do not reflect current LPR angling activities, and do not provide any predictive value for evaluating future exposure scenarios. These critical shortcomings make the incorporation of these fish and crab ingestion rates in the HHRA for the FFS Study Area inapposite and not scientifically defensible. The Region 2 fish/crab ingestion estimates rely on unfounded assumptions that in turn introduce unacceptable uncertainty into the risk and hazard estimates that are ultimately used by Region 2 to justify an extensive and expensive remediation.

In contrast, more recent creel angler surveys (CAS) – based on year-long intercept study designs superior to the older surveys relied upon by Region 2 – have been conducted that document angler fishing and consumption activities specific to the LPR Study Area (Kinnell et al. 2013). **Table 2** below compares the fish and crab ingestion rates based on the older, non-site-specific angler surveys used by Region 2 with those based on the more recent, more comprehensive intercept CAS data.

Table 2. Comparison of Region 2 and Kinnell et al. (2013) LPR CAS consumer-only and all anglers fish and crab ingestion rates†

Media (g/day)	Adult			Adolescent			Child		
	EPA Region 2	Kinnell et al. (2013)	Fold Difference	EPA Region 2	Kinnell et al. (2013)	Fold Difference	EPA Region 2	Kinnell et al. (2013)	Fold Difference
RME – Consumers Only									
Fish	34.6	8.77	4	23.1	5.85	4	11.5	2.92	4
Crab	20.9	0.14	149	13.8	0.09	153	6.97	0.05	139
CTE – Consumers Only									
Fish	3.85	2.53	2	2.57	1.69	2	1.28	0.84	2
Crab	3	0.11	27	2	0.07	29	1	0.04	25
RME – All LPR Anglers (Consumers and Non-consumers)††									
Fish	34.6	1.98	11	23.1	1.32	11	11.5	0.66	11
Crab	20.9	0.1	300	13.8	0.07	300	6.97	0.03	300
CTE – All LPR Anglers (Consumers and Non-consumers)††									
Fish	3.85	0.35	17	2.57	0.23	18	1.28	0.12	17
Crab	3	0.01	209	2	0.01	207	1	0.00	209

Region 2 fish and crab ingestion rates based on survey of anglers of Newark Bay Complex (Burger 2002) and New York State (Connelly et al. 1992), respectively.
Kinnell et al. (2013) reports fish and crab ingestion rate estimates based on CAS of LPR Study Area (RM 0-8).
†The fish and crab ingestion rates derived from the comprehensive 2010-2011 LPR CAS would be much lower if all recreational anglers were accounted for (i.e., non-consumers in addition to consumers).
††Region 2 ingestions rates only account for fish and crab consumers.

The RME fish ingestion rate used in the 2014 FFS HHRA (34.6 g/day) was derived in an unpublished technical memo prepared by Region 2 (Region 2 2012). This fish ingestion rate was based on the average of the 90th percentile ingestion rate estimates derived from angler survey data reported by Burger (2002) and Connelly et al. (1992). This is a departure from the earlier draft 2007 LPR FFS HHRA, in which Region 2 applied the national default RME fish ingestion rate of 26 g/day based on the 1997 Environmental Factors Handbook (USEPA 1997). This earlier approach had been criticized for 1) not adhering to USEPA guidance on using site-specific data when it was available, and 2) utilizing a value that was based on the angling activities in areas of the nation very dissimilar in urbanization, industrialization, accessibility, and water body type relative to the LPR FFS Study Area (Urban et al. 2009; 2010a,b). And while the Burger and Connelly angler surveys represent geographic areas of closer proximity to the LPR FFS Study Area than the studies from which the 1997 EFH default fish ingestion was derived, they too are critically deficient in key areas, and thus their use by Region 2 for deriving a fish ingestion rate specific to the FFS Study Area is incorrect and not scientifically defensible.

The Burger (2002) study was an intercept survey conducted within the Newark Bay Complex (NBC). While the LPR is located within the NBC as defined in the Burger (2002) angler survey (Fig. 1 in the paper), no angler intercepts were reported within the LPR FFS Study Area; rather all 267 intercepts occurred in the other major waterways of the NBC. This is an important observation, since the FFS Study Area has physical characteristics that distinguish it from much of the rest of the NBC, thus impacting the degree of angling activities one would expect in this area. In fact, Region 2 was compelled to remove four of the records as high-end outliers, which itself illustrates the impact that increased access and angler avidity can have on the angling activities that occur along a particular waterway. It should be noted that the 2012 technical memorandum provides no statistical method or justification for identifying and removing

these records as “outliers” from the Burger (2002) dataset, so it is unclear if the fish ingestion calculated by Region 2 for this dataset is even representative of fish consuming anglers of the NBC.

Connelly et al. (1992) reported fish consumption from a mail survey of over 1,000 New York State anglers who fished in 1991. Region 2 used a prior analysis of the survey (USEPA 2000b) to obtain fish ingestion rates it considered to be relevant to LPR. However, these consumption rates reflect angling activity for all freshwater bodies within the state and do not discriminate based on proximity to heavily urbanized or industrialized areas or limited accessibility areas. In addition, the study was performed more that two decades ago, and the study design (mail survey) is highly susceptible to recall bias. For these reasons, it is highly unlikely that fish ingestion rates derived from the Connelly survey data in any way reflect the reality of LPR anger activity and consumption of LPR fish.

In contrast to these studies, there are angler activity data generated from the comprehensive creel angler surveys (CAS) conducted along the LPRSA in 2000-2001 and 2010-2011 generated angler activity data highly relevant to deriving LPR fish and crab ingestion rates (Kinnell et al. 2013). The earlier survey was a year-long, land and boat intercept study conducted on LPR River Miles 1-7, with an independent expert panel commissioned to evaluate the need for such a study as well as the adequacy of the CAS design for characterizing fish consumption endpoints (Finley et al. 2003). This expert panel was established in accordance with USEPA’s guidance on peer review panels (USEPA 2000). The study was specifically designed to characterize the angler population, as well as to determine site-specific exposure factors such as fishing and consumption frequency and duration, the species caught and consumed, actual meal preparation methods used, and fish consumption rates across this population. The results and analysis of the 2000-2001 CAS were then published in the peer-reviewed literature (Kinnell et al. 2007; Ray et al. 2007a,b), and illustrated that the LPR angler population was relatively small (n = 385) and consisted of recreational anglers - no subsistence anglers were identified. In addition, fish consumption rates based on the LPR CAS were an order of magnitude lower than the default USEPA Exposure Factors Handbook used by Region 2 (Ray et al. 2007b; USEPA 1997), while the ingestion of blue crab within the LPR CAS area was negligible (Ray et al. 2007b). The 2000-2001 CAS Expert Panel concluded that default exposure parameters for fish and crab ingestion (later used by Region 2 in the draft 2007 HHRA) were inadequate for the purposes of conducting a comprehensive HHRA of the LPR given the site-specific conditions and characteristics of the local angler population (Finley et al. 2003). **Table 3** compares the fish consumption rates used by Region 2 in the 2007 Draft LPR FFS HHRA with those derived from the 2000-2001 LPR CAS.

Table 3. Comparison of fish and crab ingestion rates used by Region 2 in 2007 Draft LPR FFS HHRA and those derived from 2000-2001 LPR CAS†

	EPA Region 2 (No LPR data)*			2000-2001 LPR CAS (RM 1-7)
Media	**Adult**	**Adolescent**	**Child**	**Adult****
RME				
Fish (g/day)	26	17	8	1.8
Crab (g/day)	23	15	8	0
CTE				
Fish (g/day)	8	5	3	0.42
Crab (g/day)	16	11	5	0

†Both sets of fish ingestion rates include both non-consuming and consuming anglers.
*Region 2 fish ingestion rates were from 1997 Exposure Factors Handbook, and the crab ingestion rates were derived from a survey of the Newark Bay Complex (Burger 2002).
**Fish ingestion rates derived from the 2000-2001 LPR CAS were calculated for adults only since children were not observed angling during the survey, nor did interviewed anglers report bringing their catch home to feed children (Ray et al. 2007b).

Region 2 and NJDEP were initially involved in the design of the 2000-2001 CAS, but later removed their support for the survey effort. Both regulatory agencies have criticized the use of fish and crab ingestion assumptions based on the 2000-2001 survey in subsequent HHRA efforts (Urban et al. 2009; Mugdan 2010; Buchanan et al. 2010; Region 2 2012). The major criticisms posed were as follows: 1) the survey was not designed or conducted in accordance with USEPA guidance; 2) survey angler population was too small to derive an accurate ingestion rate; 3) ingestion rates that included all anglers (both non-consumers and consumers) were incorrect for risk assessment; and 4) the survey data underestimated the real angler exposure since institutional controls (i.e., fish advisories) were in place that inherently skewed the survey results.

The first criticism is not accurate, as is explained at length in responses to two letters to the editor that had been submitted by both agencies (Urban et al. 2010a,b). Second, that the 2000-2001 LPR CAS angler population was small was not unexpected, and is a reflection of the nature of the LPR region (i.e., tidal estuary that is highly industrialized and urbanized with limited access for anglers). It is quite dissimilar to other waterbodies in the region; thus it is not appropriate to assume that there is a robust LPR angler population. Third, the criticism that ingestion rates should only account for anglers who consume their catch is inconsistent with how the USEPA has historically calculated national default fish ingestion rates. For example, in the 1997 Exposure Factors Handbook, USEPA recommended fish ingestion rates based on studies that accounted for both consuming and non-consuming anglers (USEPA 1997). Notably, these fish ingestion rates were used by Region 2 in its 2007 draft LPR FFS HHRA. Finally, the issue that the 2000-2001 LPR CAS did not quantitatively account for the impact of fish advisories on fish ingestion rates was a criticism that Region 2 applied inconsistently in its evaluation of regional angling activities, as neither Burger (2002) nor Connelly et al. (1992) dealt with this issue quantitatively either.

The CPG conducted a comprehensive, year-long intercept CAS along the lower 17.4 miles of the LPR in 2010-2011 that again was overseen by an independent expert panel,

also commissioned in accordance with USEPA guidance on establishing peer-review panels (USEPA 2000). As with the earlier CAS, the 2010-2011 CAS incorporated recommendations from the expert panel to improve the scientific basis of the survey. The resulting angler data for the lower eight miles (i.e., the FFS Study Area) demonstrated a relatively small angler population for this part of the Passaic River for the year (n = 416), supporting the earlier CAS observations. In fact, commercial development along the lower LPR had occurred since the 2000-2001 CAS, which had the effect of removing the most frequently utilized angling locations in the LPR Study Area, thereby decreasing the frequency of angler visits to the Six-Mile Study Area (Kinnell et al. 2013).

Using data from the two highly relevant LPR CAS surveys, along with data from data from two additional surveys on the angling trip preferences and frequency of recreational anglers in northern New Jersey (2003 and 2013), Veritas was able to fully characterize the LPR angler population and their fishing and consumption behavior under current and baseline exposure scenarios, the latter of which accounts for fish advisories. Veritas utilized these datasets to build a state-of-the-art fish consumption simulation model. The fish consumption model used the observational data from the relevant surveys to develop consumption distributions, which were used to derive percentile estimates of fish consumption for the LPR angler population. Additionally, the CAS data included species-specific data, which allowed for consumption distributions to be calculated for each of the fish species caught and consumed in the LPR. **Table 4** below presents the results of the species-specific LPR fish consumption estimates for baseline consuming anglers only.

Table 4. Species-specific ingestion rates (g/day) for baseline adult LPR Anglers (Kinnell et al. 2013)

Species	Average (g/day)	95th Percentile (g/day)
Blue crab	0.11	0.14
American eel	0.23	0.69
Catfish	0.23	0.73
Carp	0.69	2.45
Striped bass	0.27	0.88
White perch	1.11	4.02
All species	2.64	8.91

The Veritas baseline LPR fish and crab ingestion rates are based on multiple robust and comprehensive LPR-specific datasets, and therefore represent the most scientifically-defensible approach to calculating human health risk and hazard estimates associated with fish and crab ingestion. The availability of species-specific ingestion rates reduces the uncertainty in risk and hazard calculation estimates, as the ingestion rates are combined with their respective species-specific EPCs to improve the accuracy of angler ingestion exposures. In contrast, the fish ingestion estimates utilized by Region 2 in the 2014 LPR FFS HHRS are species-generic, non-site specific ingestion rates derived from water bodies that have little resemblance to the LPRSA. Compared with the LPR angler consumption modeling analysis conducted by Veritas, the fish and crab ingestion analysis

conducted by Region 2 does not provide any information on the LPR angling population size, nor their fishing behaviors. As a result, the Region 2 ingestion rates are of little predictive value for evaluating future risk. Therefore, Region 2 should update its risk assessment using the species-specific LPR fish ingestion rates derived by Kinnell et al. (2013).

Comment 2-9: Region 2 should not use a Fraction Ingestion (FI) value of 1

Region 2 did not follow USEPA guidance when justifying the assumption that 100% of the fish and crab consumed by LPR anglers came from LPR (i.e., Fraction Ingestion = 1.0). As a general matter, this assumption is unfounded and logically can only be assumed in the HHRA if utilizing fish and crab ingestion rates derived from site-specific angler activity. Therefore, at a minimum Region 2 should adjust FI to some value less than 1.0. However, the correct solution is for Region 2 to update the LPR FFS risk/hazard estimates by applying the fish and crab ingestion rates specific to the LPRSA derived by Kinnell et al. (2013).

The FFS reiterates the Region 2 rationale provided in the February 2, 2012 Technical Memorandum on Fish and Crab Consumption Rates for the HHRA in support of using a value of 1 (or 100%) for the Fraction Ingested (FI) parameter in the fish and crab risk and hazard calculations. Region 2 defines FI as "Fraction ingested from contaminated source (unitless)," citing 1989a RAGS Part A. Though Region 2 claims that RAGS guidance does not specifically address the application of FI for fish consumption (USEPA 2012: Section 4, page 12), this is not correct: on page 6-45, the RAGS document specifically presents the risk calculation for the residential ingestion of contaminated fish and shellfish, in which FI is defined as a "pathway-specific value" that "should consider local usage patterns" (RAGS Part A, Exhibit 6-17).

This is important to highlight since Region 2 notes, "a fraction ingested term would apply only if other sources of fish were included in the assessment" (presumably this is referring to FI < 100%). Region 2 provides a list of reasons why FI < 100% is incorrect for the LPRSA (e.g., adequate stock of quality LPR fish, dense population in the LPRSA with accessible angling locations, future plans to increase river accessibility). Although the accuracy of these assertions is debatable, they do not define nor describe in any meaningful way the "local usage patterns" per the RAGS definition for FI.

If the goal of the FFS is to provide accurate estimates of risks and hazards that will inform the development of realistic remediation solutions for the FFS Study Area, then the assumption of FI = 100% can *only* be true *if* the fish and crab ingestion rates reflect the angling and consumption activities specific to the FFS Study Area. On the other hand, *if* the consumption rates reflect the activities of the broader regions (i.e., Newark Bay Complex and New York State) and do not include angler activity specific to the FFS Study Area, *then* the contaminant concentrations measured in LPRSA fish and crab samples and used in the HHRA *cannot be assumed* to be in 100% of the fish and crab ingested by the anglers. Therefore, the utilization of the Region 2 fish ingestion rates logically requires a FI term that is less than 100%. At a minimum, Region 2 should

replace the FI value of 1 with a more appropriate assumption regarding angler use of various water bodies in the area.

Estimating an approximate value for FI < 100% that is representative of the Region 2 fish and crab ingestion rate is problematic, since the studies on which the ingestion rates are based do not include data on what fractions of fish and crabs consumed by these broader populations represented LPR Study Area biota. Thus, Region 2 should revise its HHRA risk and hazard estimates utilizing the fish and crab ingestion rates derived by Kinnell et al. (2013) with data from multiple comprehensive LPRSA CAS surveys. This would logically justify assuming FI = 100% per the RAGS Part A definition of FI.

Comment 2-10: Region 2 made several errors associated with the cooking loss variable in the HHRA calculations

The FFS HHRA assumes no cooking loss for RME exposure scenarios, an assumption that better approximates the consumption of raw, unprepared fish or crab and therefore is an improper assumption for the reasonably maximum exposure individual. Additionally, Region 2 applied incorrect cooking loss values for TCDD and PCBs in its CTE exposure scenario. Therefore, Region 2 should update the HHRA using proper cooking loss values for the RME individuals (e.g., 10th percentile cooking loss), and correct the CTE exposure estimates by replacing the erroneous TCDD and PCB cooking loss values with the correct values derived from the USEPA's own 2000 Guidance for Assessing Chemical Contaminant Data for Use in Fish.

In the HHRA, Region 2 notes that cooking loss of fish and crab tissue contaminants is largely dependent on personal preferences for various preparation and cooking methods and other related habits and states that habits such as consuming the fish and crab cooking juices could lead to the consumption of tissue contaminants that initially had been released from the tissues upon cooking. Given the variability and uncertainty in cooking methods, Region 2 assumed a 0% cooking loss for the RME individual. However, 0% cooking loss actually represents the consumption of a raw, untrimmed LPR catch, since even consuming the cooking juices is unlikely to result in 100% recovery of all of the contaminants lost. Therefore, 0% cooking loss is an overly conservative assumption that is inconsistent with a reasonable maximum exposure scenario.

The identification of RME values for other exposure factors is based on an upper percentile (e.g., 90th percentile) or upper confidence limit on the mean. Given the nature of the parameter, the inverse should be considered for RME cooking loss: i.e., RME cooking loss should be derived using a lower percentile of available cooking loss values (e.g., 10th percentile). To derive RME-appropriate cooking loss values for the LPR contaminants of potential concern, the 10th percentile cooking loss values were calculated using the same cooking loss dataset Region 2 relied on to develop its CTE cooking loss values for TCDD and the pesticides (USEPA 2000a). This dataset was also used to calculate cooking loss RME and CTE values for PCBs. These values are presented along with CTE values in **Table 5**.

Table 5. Recommended RME and CTE cooking loss values†

COPC	Exposure Scenario	
	RME (%)*	CTE (%)**
DDD	9	31
DDE	10	30
DDT	8	26
Chlordane (Total)	6	35
Dieldrin	8	29
Dioxins	37	54
PCBs	13	32
PAHs	0	0
Mercury	0	0

†Data used to derive cooking loss values is presented in Appendix C of 2000 USEPA Guidance on Fish Advisories, Volume 2. Only values that represent actual cooking methods are included in this analysis (i.e., chemical loss values for non-cooking fish preparation methods – trimming, dressing, etc. – were not used).
* RME values represent 10th percentiles of the cooking loss dataset for each COPC based on custom distribution.
** CTE values are 50th percentiles of the cooking loss dataset for each COPC based on custom distribution.

Additionally, Region 2 applied incorrect cooking loss values for PCDD/Fs and PCBs in calculating exposure for CTE individual. Region 2 identified a median cooking loss value of 49% based on the TCDD cooking loss values in the 2000 USEPA Guidance on Fish Advisories. However, accounting for all seven of the TCDD cooking loss values in the 2000 USEPA dataset results in an actual median cooking loss value of 54% for TCDD, and thus PCDD/Fs. Moreover, Region 2 identified a CTE cooking loss value of 30% for PCBs, yet it applied a PCB cooking loss of 20% in its risk and hazard calculations.

Region 2 should update the FFS HHRA using appropriate cooking loss values for RME exposure calculations (e.g., 10th percentile cooking loss), and correct the CTE exposure estimates by replacing the erroneous TCDD and PCB cooking loss values with the correct values. It should be noted that Region 2 did not consider PAHs in the HHRA since it limited its focus to a single exposure route rather than consider all relevant routes as would be expected for a significant Superfund site risk assessment. If they had considered all relevant exposure routes, PAHs would have been demonstrated significant risk. We assumed PAH cooking loss would be 0% for both RME and CTE given the paucity of data presented in the 2000 USEPA Guidance on Fish Advisories. However, these data indicate that smoking fish – a reasonable cooking method for RME individual – is very likely to increase the levels of PAHs in fish by approximately 3- to 5-fold (Zabik et al. 1996), thus increasing cancer risk and noncancer hazard related to PAH exposure for the RME individual.

Comment 2-11: Region 2 applied default exposure assumptions that are not consistent with OSWER directive 9200.1-120

In addition to not being site-specific, several default exposure parameters applied by Region 2 in the HHRA are not consistent with the most recent 2014 USEPA OSWER Directive. Region 2 should refer to the Directive and update the HHRA with the relevant parameters.

As noted previously, USEPA OSWER issued a Directive to all USEPA Regions updating the guidance on standard default exposure factors for risk assessment. Some important exposure parameter values utilized by Region 2 in the HHRA are outdated according to the OSWER Directive. The first is Exposure Duration: Region 2 assumes 24-year exposure duration for adults, and total residential exposure duration of 30 years (24 years as an adult + 6 years as a child). The new OSWER directive instructs regional risk assessors to use an exposure duration default of 20 years for an adult, and total residential exposure duration of 26 years.

In an effort to calculate a site-specific exposure duration estimate in the HHRA, Region 2 analyzed 2000 U.S. Census mobility data for Essex and Hudson counties to estimate the number of years local individuals reside along the river. They reported that the 95th percentile for the number of years before an individual would move out of the two-county region was about 95 years, and for the individual counties, ranges of approximately 55 years for Hudson County and 60 years for Essex County. Using these results, Region 2 concluded that an exposure duration assumption of 30 years is likely an underestimate of the duration of angler exposure to LPR fish and crab. There are a number of weaknesses in applying this sort of analysis to the HHRA. First, the 95th percentile for the region (both Essex and Hudson counties combined) yields a timeframe before an individual is expected to move out of the region that is unrealistic. For example, the 2000 U.S. Census data also reports that less than 1.6% of the Newark metropolitan population was 85 years of age or older,[1] of which an even smaller percentage would be expected to survive to 95 years of age. Thus, using the same data source (i.e., 2000 U.S. Census), Region 2's contention that it would be expected to take individuals in the 95th percentile of regional mobility approximately 95 years to move out of the region cannot be reconciled with the reality that more than 98% of area residents did not even live to 85 years of age at the time the mobility data were collected. Second, the Region 2 evaluation is really a projection of population mobility based on data collected between 1995-2000, and therefore is outdated in terms of the FFS risk assessment (which deals with current and future risk). Utilization of the available 2010 U.S. Census data would have been more appropriate for the purposes of Region 2's overall assessment.

Finally, there is no indication that the LPR angling population is congruent with the regional populations of these counties. This can be confirmed using the comprehensive site-specific LPR CAS data, which demonstrates that the 2000 U.S. Census mobility

[1] http://www.censusscope.org/us/m5640/chart_age.html

analysis presented by Region 2 does not comport with the exposure duration estimate modeled using actual angler observation and interview data. The Veritas CAS model demonstrates that adult LPR anglers have an exposure duration slightly longer than the older USEPA default (24.2 vs. 24 years). Given that this estimate is derived from site- and receptor-specific data, the assertion that the 30-year residential exposure duration underestimates exposure is not in agreement with the empirical data. In addition, it also suggests that the Region 2 analysis of the 2000 U.S. Census dataset is either flawed, or there are factors inherent to the dataset that render it unsuitable for application to the small LPR angling population. Region 2 did not present a detailed description of its methods for evaluating the 2000 U.S. Census data, so it is difficult to evaluate in more detail the accuracy of its Census tract calculations.

Two other exposure parameters have been updated for the default values in the OSWER Directive: Adult body weight (now 80 kg) and skin surface area (slight decrease for child receptors, and a slight increase for adult receptors). However, given the magnitude of the cleanup remedy being proposed by Region 2, the HHRA should be revised to account for the other relevant routes of exposure (e.g., oral and dermal exposure to sediment and water), in which case the latest skin surface area assumptions will need to be utilized.

Finally, as indicated above, the 2014 OSWER Directive specifically recommends that Regional Superfund staff use site-specific values for fish ingestion. This is compatible with the guidance provided in the 2011 Exposure Factors Handbook. Relying on outdated survey data of the larger region – as Region 2 did in deriving fish and crab ingestion rates (USEPA 2012) – does not satisfy this 2014 OSWER criterion. Again, Region 2 should update its LPR FFA HHRA with the site- and species-specific ingestion rates to decrease uncertainty and improve estimates of risk and hazard.

Comment 2-12: Region 2 used an out-of-date cancer slope factor for TCDD

Region 2 utilized a cancer slope factor for TCDD that was developed almost thirty years ago, thereby ignoring updated pathology classifications from the National Toxicology Program; Region 2 should utilize the CSF of 9,700 (mg/kg-day)-1 based on the updated pathology classification that is reported in the peer review literature.

Almost thirty years ago, USEPA derived a CSF of 156,000 $(mg/kg\text{-}day)^{-1}$ using a linear extrapolation approach based on the presence of hepatocellular carcinomas and adenomas identified on pathology slides from a chronic rat toxicity assay (USEPA 1985). The underlying study (Kociba et al. 1978) was conducted using male and female Sprague-Dawley rats (50 of each sex per dose group); these animals were given TCDD dissolved in acetone and mixed in their feed at doses of 0.1, 0.01, or 0.001 µg/kg-day, 5 days/week, for two years, with a control group comprised of an additional 86 animals of each sex. After two years, no evidence of toxicity was observed in the lowest dose group (0.001 mg/kg/day). In the 0.01 mg/kg-day group, liver lesions (including hepatocellular nodules) and lung lesions (including focal alveolar hyperplasia) were seen. In the high dose group (0.1 mg/kg-day), significant increases were observed in incidences of hepatocellular carcinomas, squamous cell carcinomas of lung, and squamous cell carcinomas of hard palate/nasal turbinates, or tongue. From these results, the USEPA

(1985) used the combined incidences of liver, lung, hard palate, and nasal turbinate lesions in female Sprague-Dawley rats – identified as the most sensitive animal in the study – as the quantitative basis for TCDD risk estimates. These data were then utilized in a linear dose response model to development the TCDD CSF.

Subsequent to the USEPA deriving the TCDD CSF using the data from the Kociba study, histopathological criteria for characterizing hepatic proliferative lesions were modified by the National Toxicology Program (NTP; Maronpot et al. 1986). An independent panel of pathologists reevaluated the pathology slides generated by the Kociba study and found significantly fewer tumors associated with exposure to 2,3,7,8-TCDD (Goodman and Sauer 1992). Specifically, some of the hyperplastic nodules originally seen in the Kociba et al. (1978) study were reclassified as non-neoplastic.

Thus, when the updated histopathological criteria were applied, the dose-response relationship between TCDD exposure and carcinogenic effects was significantly altered. Even though the updated pathology results were released more than twenty years ago, the USEPA has not issued a revised CSF based on the updated pathology classifications. However, Keenan et al. (1991) developed a CSF for TCDD that takes into account the revised pathology results. These authors incorporated the updated combined instances of hepatocellular carcinomas and adenomas into a linearized multistage model to derive an upper-bound CSF of 9,700 $(mg/kg\text{-}day)^{-1}$. The updated value is 16-fold lower than the 1985 USEPA CSF, thus demonstrating the significant impact of the re-classification of pathology data based on updated NTP criterion. As a result, human health risk assessments that investigate the carcinogenic health impact of dioxin-like compounds and employ the CSF utilized by Region 2 incorporate a considerable degree of conservatism based upon this factor alone. Thus, if Region 2 is going to rely on the data from Kociba et al. (1978), it is imperative that Region 2 uses the updated value for TCDD to account for the advances in science documented by the National Toxicology Program.

Comment 2-13: Region 2 incorrectly assumes that TCDD acts via a mutagenic mode of action

Because a CSF for TCDD was used in the FFS HHRA, Region 2 asserts that TCDD acts via mutagenic mode of action. This is incorrect; the consensus within the scientific community is that TCDD acts via a receptor-based mode of action. Because Region 2 used the CSF, the cancer risks determined in the HHRA are grossly inflated and not scientifically defensible. Region 2 should revise the FFS HHRA to incorporate a threshold-based mode of action for TCDD (e.g., RfD protective of both cancer and noncancer effects) – doing so will greatly impact the risk estimates for TCDD.

The TCDD CSF of 156,000 (USEPA 1995) utilized by Region 2 has been the subject of significant controversy for many years. In the almost 30 years since it was issued, a wealth of data has been generated for TCDD – and simultaneously, a number of advances in science and risk assessment have resulted in a greater understanding of how to better extrapolate effects in animal studies to human risk. Collectively, these concepts have led scientists to conclude that the dose response models utilized by USEPA to assess TCDD in 1985 assume a mode of action that is not applicable to this particular chemical (Keenan et al. 1991; Simon et al. 2009). This results in a level of conservatism in the CSF that is not reflective of the weight of the evidence for TCDD, nor is it reflective of the state-of-the-science in risk assessment practice.

In developing the CSF, the USEPA applied a linear dose response model. In this approach, a straight line is used to extrapolate a dose response relationship between a point of departure (in this case, the lowest dose associated with liver tumors in Kociba et al. 1978) to zero. In taking this approach, it is assumed that TCDD is capable of producing a direct genotoxic event, and implies that exposure to even one molecule of TCDD will present some carcinogenic risk. However, there is no evidence to support the idea that TCDD is directly genotoxic or mutagenic. In fact the USEPA has readily acknowledged in both its 2003 Dioxin Reassessment and the 2010 Draft Report, that TCDD is a nongenotoxic and nonmutagenic compound (USEPA 2010; USEPA 2003).

Additionally, the mode of action (MOA) for TCDD is reasonably well known (USEPA 2011), and it is well documented that TCDD is not mutagenic. The toxicology of TCDD, especially with respect to its carcinogenicity and tumor promotion capabilities, involves some of the most studied endpoints in toxicology. Thus, under the USEPA's own cancer guidelines (USEPA 2005), the overall weight of the evidence is sufficient to support a non-mutagenic MOA for TCDD, and in turn, support the evaluation of TCDD using a nonlinear approach. Many leading scientists, as well as other regulatory agencies, such as the World Health Organization's Joint Exposure Committee on Food Additives (JECFA, 2001), have concluded that TCDD is a threshold carcinogen. The European branch of the International Life Sciences Institute (ILSI) also recognized the threshold nature of TCDD's MOA in a published review of the thresholds of toxicological concern (TTC) method for establishing *de minimus* acceptable intake values for substances that are present at low levels in food. The Institute commented that linearized dose-response

extrapolation for establishing risk estimates is incorrect for nongenotoxic compounds like TCDD (Kroes et al. 2004).

The use of a nonlinear approach to evaluate TCDD carcinogenicity has been repeatedly suggested to the USEPA by a number of expert scientific panels, yet Region 2 has yet to follow any of the suggestions. Most recently, a Science Advisory Board review of the USEPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments recommended that USEPA use a nonlinear approach to evaluate cancer risk (USEPA 2011b). In their review, the 2011 SAB Panel concluded that the mode of action underlying dioxin toxicity is "largely known" and that USEPA's failure to develop an oral cancer slope factor (OSF) based on a nonlinear dose-response modeling approach is a "major deficiency" and thus represented a failure to respond adequately to the NAS recommendation on this topic.

The 2011 SAB recommendation was the fourth scientific review panel to make this recommendation. The 1995 Dioxin SAB Panel identified the USEPA's reliance on a linear model as a major deficiency and suggested using available data to construct an alternate model that would better fit minimal responses to low levels of environmental exposure (SAB 1995). The 2001 SAB Panel stated that non-linearity better described the receptor-mediated response and that, "*…given the current questions about how much more regulatory action is appropriate for dioxin, there is a legitimate need to also include "best estimates" of the cancer risk, and even a "lower" risk estimate that is not solely reliant on a linear model*" (SAB 2001). The 2006 NAS stated that "*EPA's decision to rely solely on a default linear model lacked adequate scientific support,"* and that "*…the committee unanimously agrees that the current weight of evidence on TCDD, other dioxins, and DLCs carcinogenicity favors the use of nonlinear methods for extrapolation below the point of departure (POD) of mathematically modeled human or animal data"* (NAS 2006). In this particular case, Region 2 has not addressed a scientifically justified recommendation made by multiple expert panels, the real world implication of which is that Region 2 is now proposing a very costly remedy to address cancer risks that either do not really exist or are greatly diminished compared to what Region 2 asserts.

It is also notable that during the period of time that the NAS expert committee was reviewing the USEPA's Dioxin Reassessment draft report (NAS 2006), the National Toxicology Program (NTP) released the results of a two-year cancer bioassay for 2,3,7,8-TCDD in rats and reported results similar to those of the pathology reevaluation of the original Dow study (Walker et al. 2006). The chronic NTP gavage study was based on the earlier dosed feed studies conducted by Kociba et al. (1978), and as such the study design, species, and dose range of 0.001 to 0.1 µg/kg-day were selected to reflect the earlier investigation. The NTP reported that TCDD induced tumors at seven sites (three of which were in the liver), and that the dose response curves for these endpoints were indicative of a nonlinear response. This is in agreement with the recent recommendations made by the National Academy of Science expert panel (NAS 2006) and recent SAB review of TCDD toxicity (USEPA 2011b).

Clearly, the science supports a non-linear approach for evaluating TCDD. As such, use of a CSF that does not rely on this approach is overly conservative, and does not reflect use of a toxicity factor based on sound science. Region 2 should not utilize a CSF for TCDD but rather should utilize a toxicity criterion value for TCDD that is based on the known mode of action (threshold) for this chemical. This toxicity criterion value should be an RfD that is protective of both cancer and noncancer endpoints.

Comment 2-14: TCDD has not been shown to be a human carcinogen

The TCDD cancer slope factor used by Region 2 in the FFS HHRA is based on animal data and is not reflective of what has been observed in high exposure occupational human studies. The TCDD exposures reconstructed in the NIOSH occupational cohort do not demonstrate an increase in mortality due to specific cancer types, nor are they likely to be associated with mortality due to all cancer types combined given confounding exposures to other chemical carcinogens, and therefore do not implicate TCDD as a human carcinogen. Region 2 should re-examine the evidence supporting TCDD being a low-dose human carcinogen rather than utilizing an animal-based oral cancer slope factor for the FFS cancer risk estimates.

The TCDD cancer slope factor used to calculate LPR TEQ risk by Region 2 is based on the development of liver adenomas and carcinomas in high dose, chronic oral TCDD animal bioassay (Kociba et al. 1978; USEPA 1985), but these effects are not observed at high doses in humans (Boffetta et al. 2011). The human health effects of TCDD exposures have been studied in several epidemiology cohorts for over three decades. The primary TCDD exposure human cohorts are: 1) the NIOSH cohort, a multisite occupational cohort subject to chronic TCDD exposures at 12 U.S. chemical plants (Fingerhut et al. 1991; Steenland et al. 2001 Cheng et al. 2006); 2) the Hamburg cohort, an occupational cohort also subject to chronic TCDD exposures at the Boehringer chemical plant in Hamburg, Germany (Becher et al. 1998); 3) the BASF cohort, an occupational cohort subject to peak TCDD exposures through cleanup following an industrial accident at the BASF AG production facility in Ludwigshafen, Germany (Ott and Zober 1996); 4) the Air Force Health Study Ranch Hand Unit, a cohort of U.S. airmen exposed to TCDD through the aerial spraying of herbicides containing TCDD during their service in the Vietnam; 5) and the Seveso cohort, a residential cohort in Seveso, Italy that experienced an acute TCDD exposure via the accidental aerial release of chemicals that included TCDD from a Givaudan SA chemical production facility near the town.

Of these, the largest of the four industrial cohorts considered in USEPA and IARC dioxin health assessments is the NIOSH cohort, which initially was comprised of 5,172 workers at 12 plants across the U.S. that produced phenoxy herbicides – such as 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and its derivatives – containing TCDD. In many instances these workers were exposed to very high levels of TCDD, as confirmed by blood sample analysis from a subcohort of workers from the 80 Lister site that is adjacent to the LPR. Initial mortality analyses of the overall cohort were presented in Fingerhut et al. (1991) and Steenland (1999), with no evidence of TCDD exposure associated with cancer on a target organ-specific basis. Steenland et al. (1999) observed a slight increase

in risk of mortality only when all cancer types were combined (standard mortality ratio = 1.13, 95% confidence interval = 1.02-1.25), and subsequent modeling of the NIOSH mortality data have reported similar results (Steenland et al. 2001; Aylward et al. 2005; Cheng et al. 2006). The USEPA found these NIOSH cohort results compelling enough to make them the focus of its most recent attempt to developing an oral cancer slope factor (OSF) (USEPA 2010). It issued a draft OSF based on the "combined cancers" results of the NIOSH analyses, although the effort to issue a finalized oral cancer slope factor for TCDD has stalled and there is no timetable for getting this portion of the USEPA's Dioxin Reanalysis finalized. This is likely due to the fact that these statistical observations were based on broad, non-quantitative assumptions about TCDD exposure. These include a highly subjective, qualitative job exposure matrix (Piacitelli et al. 2000); whole-cohort extrapolations of internal exposure based on single blood TCDD measurements collected from workers from a single NIOSH site (representing <5% of the total NIOSH cohort); and the absence of confounding co-exposures to other carcinogens present at these chemical plants (Cheng et al. 2006).

Of particular interest due to its proximity within the LPR Study Area is that one of the NIOSH study sites was the Diamond Alkali facility at 80 Lister Avenue in Newark (designated by NIOSH as Site 1). Specific mortality analysis of the workers at this site yielded no significant excess cancer risk, even when all cancers were combined (Cheng et al. 2006). Importantly, it should be noted that significant increase in mortality related to combined cancers was only observed at one of the NIOSH sites (the Hooker Chemical facility at Niagara Falls, NY, designated Site 10), and this was largely driven by smoking-related lung cancer mortality (Cheng et al. 2006). Furthermore, workers at each of the NIOSH study chemical facilities were likely exposed to some combination of approximately 35 chemical carcinogens during their respective periods of employment, as indicated by chemical process records available in the Dioxin Registry Reports drafted by NIOSH for each of the study sites (Marlow et al. 1984, 1986, 1989, 1990, 1991a, 1991b, 1997; Piacitelli et al. 1990).

In conclusion, the mortality analyses of the high-dose exposure NIOSH cohort does not support a causal relationship between TCDD exposure and "combined cancers," an endpoint that would be unique to TCDD among regulated chemicals, and for which there is little supportive mechanistic data. Therefore, the NIOSH cohort data do not support the assertion that TCDD is a human carcinogen, but rather indicate that a combination of smoking and exposures to multiple chemical carcinogens is most likely responsible for the increase combined cancers reported among this cohort. Given the lack of human epidemiology data supporting an association between TCDD and cancer risk in humans (Boffetta et al. 2011), Region 2 should not treat TCDD as a human carcinogen.

Comment 2-15: The Reference Dose (RfD) for TCDD is flawed and should not be used in the FFS HHRA

The TCDD RfD used by Region 2 in the HHRA is based on two studies of a single high-exposure incident that evaluated health endpoints of questionable relevance and that contains several critical flaws; the use of this RfD resulted in unreasonable estimates of noncancer hazard due to LPR fish or crab ingestion. Noncancer hazard should be recalculated using JECFA ADI.

Region 2 stated that noncancer health hazards were "much higher" than acceptable levels based on fish and crab ingestion as estimated in its most current FFS HHRA. This conclusion is based in part on noncancer hazard estimates calculated using USEPA's new oral reference dose (RfD) noncancer toxicity factor for TCDD. However, the study design and human health data from which the TCDD RfD was derived is of questionable relevance and scientific validity.

The USEPA derived the new noncancer RfD of 0.7 pg TCDD/kg-body weight/day based on dose-response data presented in two studies that evaluated reproductive and developmental endpoints in subpopulations of the Seveso, Italy cohort (Mocarelli et al. 2008; Baccarelli et al. 2008). This value is almost 10-fold lower than typical US population daily exposure in the 1970's.

Mocarelli et al. (2008) reported an association between compromised sperm characteristics (i.e., reduced sperm concentration, reduced sperm motility) and serum TCDD levels in men who had been between the ages of 1-9 years at the time of the Seveso chemical accident, an event that resulted in widespread dioxin exposure among the Seveso population. Likewise, Baccarelli et al. (2008) studied the effects of TCDD on the Seveso population, in this case regarding the impact of maternal dioxin exposures at the time of the event on congenital hypothyroidism (CH) in neonatal offspring conceived later in life (as indicated by increased levels of blood thyroid stimulating hormone - TSH). The RfDs derived from both studies by the USEPA were similar, so they considered them to be co-principal studies, and therefore identified male reproductive effects and increased TSH levels in neonates to be "co-critical effects." There are several critical flaws in both studies, and in how the USEPA interpreted the data for their RfD calculation, including:

Mocarelli et al. (2008)

- The 1976 Seveso exposure incident involved an acute high-level exposure that is not similar to exposures experienced along the LPR and at other environmental sites. This difference likely makes the RfD not applicable for use in chronic, low dose exposure situations.
- The USEPA identified reduced sperm concentration in the Seveso men exposed as boys as the critical endpoint and identified a LOAEL (lowest observable adverse effects level). However, none of the subjectively selected exposure groups had measured sperm concentrations that fell below the WHO clinical level of concern. In the absence of an actual effect, as well as the absence of a statistically observable dose-response relationship, the LOAEL identified by

USEPA to derive the RfD for TCDD is incorrect as it does not actually represent a statistically significant adverse health effect. Additionally, because there is no response, the number should have been classified as a NOAEL; and thus the uncertainty factor applied in the derivation of the RfD for the LOAEL to NOAEL uncertainty was not warranted.

- The study authors did not present information on the geographic origins of the control group. Several studies to date have demonstrated that sperm counts can vary dramatically from city to city and among different geographic regions. For example, Fisch et al. (1996) conducted a literature review of geographical sperm concentration data and reported a high degree of variability within the United States. Mean values reported by the authors ranged from 48 million/ml in Iowa to 134 million/ml in New York, the former value being equivalent to that reported by Mocarelli et al (2008) for the exposed 1-9 year olds from the Seveso cohort.
- Because of the small population size (n=71 for exposed 1-9 year old males), the study lacked the power necessary to conclude that TCDD exposure in young males affects semen quality, and thus male fertility.
- The association of serum TCDD levels in exposed 1-9 year old boys and serum quality was investigated without accounting for the other PCDD/Fs or DL-PCBs.
- The study investigators focused on the clinically insignificant reduction in sperm concentration and motility in the exposed 1-9 year old boys, but did not address the counterintuitive increase in sperm count and motility observed in the older boys (10-17 years old) exposed to TCDD relative to controls.
- Evaluation of the dose-response data presented in the tables and figures demonstrated that the first quartile group could not be statistically significantly different from the control group for either sperm concentration or motility measurements; therefore the USEPA's use of the median TCDD of the first quartile exposed group (68 ppt) as the starting point for the point of departure (POD) derivation was fundamentally flawed.
- In fact, if the POD were set based on the median of a group for which there was a demonstrable statistically significant difference from the control group, USEPA should have set the POD to 210 ppt for sperm concentration (the median of the entire exposed group) and 142 ppt for sperm motility (the median of the second quartile) rather than 68 ppt (the median of the first quartile). That is, the USEPA's POD for reduced sperm measures should be 2- to 3-fold larger (i.e., less potent) than the POD Region 2 called statistically significant.

Baccarelli et al. (2008)

- The authors utilized a clinically irrelevant screening level for CH: infant b-TSH levels were compared with a neonate TSH screening level recommended by the WHO in the early 1990s (5 µU/ml). However, this benchmark was not developed for CH screening but for iodine deficiency disease (IDD). A more clinically relevant and commonly used b-TSH screening value specific to CH is 10 µU/ml (Corbetta et al. 2009). This level was not exceeded by any of the 51 Seveso neonates in the study's matched mother-infant pair analysis that USEPA relied on to identify a LOAEL for RfD derivation. Since there was no clinical evidence of

CH in this study group, the analysis failed to support CH as a "critical" endpoint, and thus it should not serve as the basis for a TCDD RfD.

- As with the Mocarelli et al. (2008) study, it is unclear how the effects reported by Baccarelli et al. (2008) in a population that experienced acute TCDD exposures translate to the general population. In fact, several other studies have shown that background dioxin exposures are not associated with neonatal hypothyroidism. Both Giacomini et al. (2006) and Goodman et al. (2010) reviewed prior studies that looked at this possible association and found there was no consistent evidence that supported a relationship between low-level exposure to dioxins and neonatal thyroid hormone dysfunction.
- Even though Baccarelli et al. (2008) presented total TEQ data, the USEPA did not account for serum total TEQ when deriving its RfD, which - like the RfD-based on Mocarelli et al. (2008) - resulted in an overly conservative RfD value.
- Per recommendations made to USEPA by the National Academy of Science, an uncertainty analysis on the POD used by USEPA to derive the RfD demonstrated a very broad confidence interval: for the TCDD POD serum concentration of 240 ppt (239.88), the lower and upper 95% confidence boundaries were determined to be 47.86 and 1,600,000 ppt respectively. Factors contributing to the breadth of the confidence interval include a small dataset overall, particularly sparse data in the higher TCDD ranges, and that the relationship applies to the variables expressed on a logarithmic scale. Thus the large uncertainty associated with the RfD derived using the Baccarelli et al. (2008) dataset should indicate low confidence in the RfD.

All of the above suggests that the RfD likely utilized by Region 2 for TCDD is not scientifically justified and only serves to overestimate the TCDD noncancer hazard associated with ingestion of fish and crabs from the Passaic River. Superior toxicity criteria are available that Region 2 could have utilized for the evaluation of noncancer hazard for TCDD. Comment 2-15 provides an overview of alternative noncancer toxicity factors and the scientific justification for why Region 2 should replace the TCDD RfD in the LPR FFS hazard assessment with the JECFA ADI for TCDD.

Comment 2-16: Region 2 should use the JECFA TDI to evaluate the TCDD noncancer hazard

Region 2 should use a noncancer toxicity value for TCDD that represents the best available science instead of using the highly flawed reference dose in the FFS. Noncancer hazard should be recalculated using JECFA ADI.

Unlike the highly controversial, significantly flawed RfD used by Region 2 (see 2010 and 2011 comments to USEPA Science Advisory Board on the 2010 Dioxin Reassessment), the international community has demonstrated consensus on an approach for evaluating noncancer effects associated with exposures to TCDD. This approach is different than that used by the USEPA in the development of the RfD. Three international expert committees identified developmental effects on the male rat reproductive system following *in utero* and lactation exposures as the most sensitive adverse endpoints

identified for dioxin exposures and, hence, as the appropriate basis for risk assessment (ECSCF 2001; JECFA 2001; UKCOT 2001). As a result, these three international committees have all derived similar values to characterize safe levels of exposure to TCDD (~2 pg/kg-day). These values represent the best available science, as they have incorporated robust datasets, provided appropriate considerations for kinetics, and utilized the best dose-metric for TCDD. Region 2 should use a noncancer toxicity value consistent with these international consensus values, rather than use the flawed and controversial USEPA RFD.

The Joint Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO) Expert Committee on Food Additives (JECFA) arrayed a series of data for consideration in development of a tolerable intake for TCDD. From these studies, the lowest LOEL (lowest observed effect level) and NOEL (no observed effect level) were selected and further evaluated for toxicokinetic extrapolations to characterize material body burdens associated with effects in male rat offspring, as well as to extrapolate the dose metric from animal to human body burdens (*i.e.*, equivalent human monthly intakes). Then, safety factors were applied as appropriate: a default factor of 3.2 was used for inter-individual differences, and an additional factor of 3 was applied to the value based on the LOEL. Safety factors were not applied for differences in toxicodynamics in humans as the committee observed that humans might be less sensitive than rats to some effects, though the evidence was such that they could not fully discount the possibility that humans might be as sensitive to the effects of TCDD in the studies selected as the basis of the assessment. From these calculations, a range of provisional tolerable monthly intake (PMTI) values was generated; the midpoint of the range, 70 pg/kg bw-month, was then selected. Thus, the tolerable daily intake (TDI) equivalent of the PMTI is 2.3 pg/kg-d (based on the provisional monthly tolerable intake, PMTI; JECFA 2001).

This value represents the most robust analysis of noncancer endpoints based on the best available data and best science regarding dose metric. JECFA (2001) recognized the importance of toxicokinetics and selection of an appropriate dose metric for TCDD in its development of the PMTI. As documented by the committee, "*the long half-lives of PCDDs, PCDFs, and coplanar PCBs have several implications for the period of intake of relevance to the assessment,*" and "*rodents require appreciably higher daily doses (100-200 fold) to reach a body burden at steady state equivalent to that recorded in humans exposed to background concentrations*." These concepts are recognized as being particularly important when characterizing relationships between human intake and doses used in animal studies, and because of such, measures of body burden (i.e., how much is in the body) are considered the superior dose metric relative to daily dose. The expert committee applied these concepts in its evaluation of the toxicity data by conducting least-squares linear fits of dose versus maternal and fetal body burdens (power equations were also fit to evaluate data in the lower dose ranges) to assess steady state body burden, as well as intake doses that would lead to such.

The JECFA value is similar to values from two other expert committees (2 pg/kg-day; ECSCF 2001; UKCOT 2001), which also utilized developmental effects on the male rat reproductive system following *in utero* and lactation exposures as the most sensitive

adverse endpoints for evaluating noncancer effects. Collectively, the three expert committees used similar approaches to derive a toxicity value. Maternal body concentrations during gestation and lactation associated with LOAEL or NOAEL exposures were identified in rodent studies and a number of adjustments and/or uncertainty factors were applied, resulting in a target "safe" maternal body burden in humans. Then chronic dioxin intake rates that would result in maternal body burdens at or below the target "safe" level were estimated (resulting in allowable intakes of 2 or 2.3 pg/kg-day). Region 2 should utilize the JECFA value of 2.3 pg/kg/day to assess noncancer hazard in the FFS HHRA.

Comment 2-17: Region 2 should use the best available science for TCDD toxicity criteria

Region 2 utilized noncancer and cancer-based toxicity values for TCDD that did not represent the best available science. Region 2 should evaluate risk based upon the best scientific judgment, and in doing so, use toxicity factors that are generally accepted as the current state-of-the-science.

In selecting toxicity factors for TCDD in the cancer and noncancer assessment, Region 2 relied on the hierarchy of existing chemical toxicity value sources – Tiers 1-3, set forth in OSWER Directive 9285.7-53 (December 5, 2003):

> Tier 1- USEPA's Integrated Risk Information System (IRIS)
>
> Tier 2- USEPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs)
>
> Tier 3- Other Toxicity Values – includes additional USEPA and non-USEPA sources of toxicity information.

Region 2 notes that when Tier 3 values are to be utilized, consultation with USEPA's Superfund Technical Support Center is recommended, particularly when the contaminant appears to be a risk driver for the site. Region 2 selected a value from Tier 3 for the cancer toxicity factor. Region 2 does not demonstrate or report that the selection of this toxicity factor was in fact supported by the Technical Support Center. The FFS HHRA should be modified to provide information on what the Technical Support Center advised regarding the TCDD cancer slope factor.

Further, the rationale for the selection of the Tier 3 value is not robust, nor does it reflect the best available science, "*the selection of this value is preferred because of the incidence of all significant tumors combined, rather than based on the incidence of liver tumors alone as is the case with the CalEPA CSF"* (Region 2, 2014). Region 2 does not provide adequate scientific justification for selecting a value based on all tumors combined. Use of all tumors combined is not common practice in risk assessment. For example, JECFA (2001) noted, "*There are few precedents of carcinogens that cause an increase the risk of cancer for all tumours combined, without an excess risk for any tumour predominating,*" in their assessment of TCDD.

In addition to these shortcomings in their selection of toxicity factors, Region 2 has also ignored a previous OSWER directive (USEPA 1993) that is specifically cited in the directive used by Region 2. The 1993 directive (USEPA 1993) states "*the Agency should evaluate risk based upon its best scientific judgment and consider all credible and relevant information available to it*." This directive also states, "*when a toxicological value is questioned in a comment on the proposed plan, a written explanation for the value ultimately selected (whether it is the IRIS value or another number) must be included in the administrative record*."

Given the significant shortcomings with both the cancer and noncancer toxicity values it utilized, Region 2 should consider additional sources of toxicity values not specifically recommended in the hierarchy, as provided in the OSWER directive it cited (USEPA 2005). Rather than use the flawed RfD for characterizing noncancer effects, Region 2 should utilize the JECFA tolerable daily intake (TDI) equivalent of 2.3 pg/kg-day. For cancer, it is recommended that either (1) the CSF of 9700 mg/kg-day^{-1} reported by Keenan et al. (1991) be used instead of the CSF currently used in the draft, which is based on outdated pathology data, or (2) that USEPA develop toxicity criteria for TCDD that is based on a non-mutagenic mode of action. Both the JECFA value of 2.3 pg/kg/day and the CSF of 9,700 (mg/kg/day)$^{-1}$ are addressed in detail in separate comments. Use of such values would significantly improve the assessment.

Additionally, Region 2 should acknowledge that its approach for evaluating cancer is not consistent with the best available science. As detailed in a separate comment, the CSF of 156,000 mg/kg-day^{-1} was derived using a linear approach that does not consider the weight of the evidence for cancer effects, which suggests a threshold-based response. The JECFA TDI equivalent (JECFA, 2001) is protective of both cancer and noncancer risks:

> *"The Committee concluded that a tolerable intake could be established for 2,3,7,8-TCDD on the basis of the assumption that there is a threshold for all effects, including cancer. Carcinogenicity due to 2,3,7,8-TCDD was not linked to mutagenicity or DNA binding, and it occurred at higher body burdens in animals than other toxic effects. The Committee concluded that the establishment of a tolerable intake based on noncancer effects would also address any carcinogenic risk."*

Alternatively, Region 2 could consider an analysis conducted by Simon et al. (2009). These authors developed a cancer potency estimate that incorporated considerations of key events in the mode of action and identification of a tissue concentration-based point of departure. Using a nonlinear approach, the Simon et al (2009) calculated a cancer-based reference dose of 100 pg/kg-d. To provide perspective, the risk specific dose at 10^{-4} for the CSF used by Region 2 is 0.64 pg/kg-day. Thus, use of either of these values, 2.3 or 100 pg/kg-day to represent cancer risk would provide significantly different results should Region 2 select toxicological benchmarks that represent the best available science.

Comment 2-18: The dose of TCDD alleged to be received by anglers in the FFS HHRA is less than what an infant receives from breastfeeding

The estimated intake (dose) of DLCs from ingestion of fish or crab from the LPR is less than that received by nursing infants, yet breastfeeding is recommended by state and federal agencies. It is unreasonable to propose/require massive sediment remediation to address a dose of DLCs from the ingestion of fish or crab from the LPR that is similar to or less than what an infant receives on a daily basis in the first months of life from breast milk. How can ingestion of LPR fish and crab pose an unacceptable hazard when infants receive similar or larger doses from breastfeeding? Based on this issue, Region 2 should withdraw the draft FFS HHRA.

As part of calculating risks and hazards associated with consumption of fish and crab from the LPR, Region 2 generated intake estimates (dose) for each COPC, each age group, each exposure scenario (RME and CTE) for cancer and noncancer endpoints. Because of the exposure assumptions utilized, intake estimates were generally highest for children aged 1-6 years in the RME scenario for noncancer endpoints. The finding that intakes were highest for a child is important because many studies have demonstrated that lipophilic compounds, such as PCDD/Fs, are typically present in breast milk, and exposures from breastfeeding are relatively high early in life. In fact, USEPA scientists (Lorber and Phillips, 2002) estimated that breastfed infants are exposed to approximately 240 pg TEQ/kg-day at birth and about 170 pg TEQ/kg-day by one month. These estimates of DLC intake in a nursing infant are significantly higher than the intake estimates generated by Region 2 for children consuming fish or crab from the LPR (**Table 6**). Similar findings are observed when hazard indices are compared – the noncancer hazard associated with exposures to DLCs in breast milk far exceeds those estimated from consumption of fish or crab from the LPR (**Table 6**).

These comparisons demonstrate that the intake and hazard estimates associated with consumption of fish or crab from the LPR (the primary drivers for the remediation proposed in the FFS) are actually lower than those of nursing infants. This is an important comparison given that, despite levels of DLCs measured in breast milk, medical professionals continue to recommend breastfeeding. For example, the New

Table 6. Comparison of DLC intake derived by Region 2 and intake associated with breast milk consumption

Route	Intake Estimates (pg TEQ/kg-day)	Hazard	Reference
Fish ingestion	89*	128	FFS, Child (1-6 years) RME, Appendix D - Attachment 4; Table 4-18
Crab ingestion	40.1*	57	
Breast milk	242	403	Lorber et al. (2002); Infants at birth
	170	283	Lorber et al. (2002); Infants at one month
	80	133	Lorber et al. (2002); Infants at four months

*Based on exposure assumptions developed by Region 2 that are not scientifically defensible; use of site specific exposure information (e.g., LPR creel angler surveys) would dramatically lower these intake estimates making the comparison with the dose of DLCs from breastfeeding even more compelling.

Jersey Department of Health encourages all mothers to breastfeed (see inset; State of New Jersey 2014a). The State's website for Supplemental Nutrition Program for Women, Infant, and Children (WIC; State of New Jersey 2014b) states, "New Jersey WIC Services encourages all women to exclusively breastfeed unless there is a medical reason for the woman or baby not to breastfeed." These recommendations are consistent with those of the other health organizations such as the World Health Organization (WHO 2013) and American Academy of Pediatrics (AAP 2012). The benefits of breastfeeding were also recently recognized on a federal level in the US, highlighted by a Call to Action from the Surgeon General (US DHHS 2011), and federal laws supporting breastfeeding under the Patient Protection and Affordable Care Act of 2010 (US OPM 2013). This US law covers provisions allowing women to have reasonable break time to express milk, as well as health insurance benefits to defray costs associated with providing breast milk to infants, including coverage of breastfeeding education and supplies in non-grandfathered health insurance plans. Thus, US federal

laws have been enacted to support breastfeeding and consumption of breast milk to infants – a food source known to contain DLCs (as well as other lipophilic chemicals, including PCBs). Clearly the US government and medical professionals worldwide would not recommend breastfeeding if exposure to DLCs at such levels were believed to pose an imminent or substantial health threat.

Notably, this issue was also raised by the Texas Commission on Environmental Quality (TCEQ) during the USEPA's comment period related to the characterization of cancer and noncancer toxicity of TCDD (TCEQ 2010). The comments described this issue as a "paradox." In reference to the toxicity value for noncancer as it related to soil cleanup, the TCEQ commented,

> "If the draft RfD is a scientifically-defensible value for hazard assessment, it would be nonsensical at a remediation site with a limited number of adults and/or children for USEPA to allow a maximum dioxin HQ of 1 (corresponding to the draft interim PRGs) when estimated HQs for US infants being breastfed, a recommended practice, can be orders of magnitude higher and would be clearly unacceptable in the context of dioxin intake from contaminated soil at a federal Superfund site. *The bottom line is that the draft interim PRGs would drive cleanups at assumed dioxin TEQ intake levels orders of magnitude less than estimated dioxin TEQ intake for breastmilk-fed infants when breastfeeding is a recommended practice for the health of infants."*

Such comments demonstrate the need for justification of the "paradox" in which the fish and crab intakes (as well as hazards and risks) from the LPR are unacceptable, yet breastfeeding is encouraged.

It is unreasonable and lacks scientific validity to propose/require sediment remediation for the LPR to address a dose of DLCs from the ingestion of fish or crab that is similar to or less than what an infant receives on a daily basis in the first months of life from breast milk. In fact the US government encourages breastfeeding and apparently sees no significant health risk posed by this dose of DLC's. This issue alone is justification for Region 2 to withdraw the FFS HHRA.

Comment 2-19: Region 2 should calculate the excess cancer population risk for the anglers using the Passaic River

The cancer risk estimates calculated by Region 2 for the HHRA actually apply to a very small population. When the cancer risk estimates are put into the context of the LPR angling population, the population excess risk is 2.1 (i.e., approximately two excess cancers are expected among LPR anglers due to consumption of LPR fish and crab). The population risk reflects the overly conservative assumptions integrated into the HHRA as described in the comments above, and the population risk falls below 1 when site-specific exposure assumptions and more scientifically defensible toxicity factors are used to calculate excess cancer risk. Region 2 should update its risk calculations and include population risk estimates to provide appropriate context for the cancer risk estimates for the small LPR angler population and justify the proposed remediation expenditure of over $850 million per excess cancer prevented.

The highest excess cancer risk estimate calculated by the Region 2 in the HHRA was 5 x 10^{-3} (five excess cancers in one thousand people) for RME adult + child LPR fish consuming anglers. This risk estimate – as well as the others presented by Region 2 in the 2014 LPR FFS (e.g., other fish- and crab-consuming anglers) only applies to a relatively small population. For example, the earlier site-specific CAS of the lower six miles of the LPR estimated the annual angling population to consist of no more than 385 individuals (Ray et al. 2007), and the most recent survey of LPR RM 0-8 estimated the LPR angling population to be comprised of 416 individuals (Kinnell et al. 2013). In each case, these data were collected over a 1-year period of observation, and represent the most robust and comprehensive site-specific angler survey dataset available. The two LPR CAS surveys were conducted 10 years apart, and the observations indicate that the size of the angling population for the LPR Study Area has not changed substantially over this time. It is not surprising that the LPR angling population is small given the characteristics of the LPR region (tidal estuary that is highly industrialized and urbanized with limited access for anglers).

When the cancer risk estimates derived by Region 2 are put into the context of the small LPR angler population (n=416), the estimated risk for fish ingestion exposure among this population is 2.1. Put another way, approximately two excess cancer cases would be expected in this population due to LPR fish ingestion. However, the population risk estimate based on the risk calculations for the LPR Study Area is an unrealistically conservative estimate, primarily driven by unjustifiably high fish and crab ingestion rates (approximately 4- and 100-fold greater, respectively, than rates based on robust LPR CAS observations), incorrect 0% cooking loss assumption, and an outdated oral cancer slope factor for dioxin-like compounds.

Alternatively, the highest risk estimates calculated using appropriate site-specific exposure parameters, justifiable RME cooking loss estimates, scientifically defensible cancer slope factors, AND all relevant routes of exposure combined (i.e., fish ingestion, crab ingestion, and sediment exposures) results in an overall cancer risk estimate of 1 x 10^{-3} (for adolescent anglers). This results in a LPR angler population risk of 0.416, or less than one excess cancer within the LPR Study Area angler population. This is an excess

cancer risk impossible to discern from background lifetime cancer rates in the U.S. for the general population (30-40%) (Urban et al. 2009), and calls into question the human health benefit of the proposed very costly remedy. Clearly, the excess cancer risk posed by ingestion of fish from this site is not significant given that not even one excess cancer would be expected from all relevant LPR Study Area exposure routes under baseline usage conditions.

Comment 2-20: Region 2 did not follow USEPA guidance regarding the conduct of a TEF Sensitivity Analysis

Region 2 cited, but did not follow, USEPA guidance regarding the conduct of a sensitivity analysis to illustrate the impact of TEFs (USEPA, 2010). This is a critical oversight by Region 2 because the LPR sediment contains large concentrations of dioxin-like PCBs and failure to understand the uncertainty associated with the TEFs (and thus the risk and hazard) can leave risk managers with incomplete information. A TEF sensitivity analysis should be conducted.

Region 2 utilized toxic equivalency factors (TEFs) in developing exposure point concentrations (EPCs) for dioxin-like compounds (DLCs). Region 2 appropriately cited USEPA guidance in support of using these values. Region 2 did not, however, properly follow the guidance on TEFs. As stated by the USEPA in its 2010 document, "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds":

> "The EPA recommends that, for major risk assessments, as determined by U.S. EPA Program Offices or Regions, the conduct of a sensitivity analysis be considered to illustrate the impact the TEFs have on the TEQ value, which is consistent with good risk assessment practices (U.S. EPA, 2000)."
>
> "A TEF sensitivity analysis has at least two purposes: (1) to identify plausible upper and lower estimates of the TEQ to assess the potential range the TEQ may have, and (2) to identify the influence of TEF values for specific compounds on the TEQ."

The USEPA provides two possible approaches for identifying upper and lower TEQ estimates in the conduct of a sensitivity analysis. One utilizes a constant value of half a log (3.16) based on discussion provided by van den Berg et al. (2006), in which the TEF values are multiplied and divided by 3.16 and then applied to the media concentrations to generate upper and lower TEQ estimates, respectively. The other approach utilizes upper and lower values from the underlying distributions of relative potency (ReP) data that form the basis of each TEF value. Specifically, the USEPA suggests that the upper and lower TEQ estimates could be generated using the minimum and maximum data, the 10th and 90th percentiles, or the interquartile ranges from the ReP distributions.

The USEPA further suggests:

> "To identify the influence of specific compounds on the TEQ, EPA recommends that the list of compounds that are most influential to the TEQ, as defined in Eq. 1, be further explored. For each of these, the sensitivity of the TEQ to changes in the TEF values for the individual compounds may be conducted (i.e., varying the TEF value for one compound at a time). The same statistical ranges described above can be used to identify alternative TEF values."

Because Region 2 did not follow the USEPA guidance, ToxStrategies conducted a TEF sensitivity analysis using the data reported by Region 2. **Figures 2** and **3** below demonstrate the significant impact of the use of TEFs. Most notably, the portion of risk and hazard attributable to DL-PCBs changes dramatically when values from the upper end of the ReP distributions are utilized (90th percentile). Clearly, the use of static TEF values by Region 2 resulted in significant variability in the apportionment of risk and hazard, and subsequently, Region 2 should address the impact of this variability.

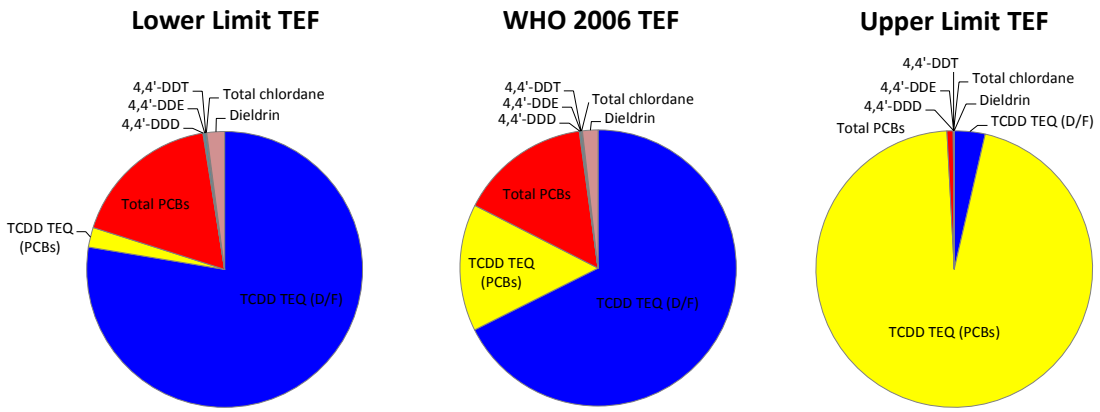


Figure 2. Impact of TEF distributions on the contribution to total cancer risk associated with fish consumption for RME scenario and the summed risk of the adult and child receptors.

It is of note that this topic as it relates to evaluation of risk and hazard associated with fish and crab consumption in the Lower Passaic River area has been investigated previously, and the information is available in peer-reviewed literature (Urban et al. 2009). This analysis also demonstrated that the TEFs significantly impact the apportionment of risk and hazard attributable to congeners other than TCDD. Additionally, several of the USEPA authors responsible for drafting the TEF guidance were also authors on a recent peer review publication titled, "*A sensitivity analysis using alternative toxic equivalency factors to estimate U.S. dietary exposures to dioxin-like compounds*," (Parvez et al. 2013). In this exercise the authors demonstrated that the daily intake from DLCs increased from 23 pg/day to 106 pg/day when the 90th percentile of the TEF distributions was utilized. Similarly, when the half-log (3.16) approach was utilized to generate estimates, the intake increased to 68 pg/day. These authors describe the various approaches and estimates as "a general characterization of the uncertainty in the TEQ estimates across alternative TEF values." These results highlight the importance of developing probability distributions for the TEFs. This application of a sensitivity analysis consistent with the USEPA TEF guidance, conducted by USEPA authors, demonstrates the significant impact TEFs have on TEQ.

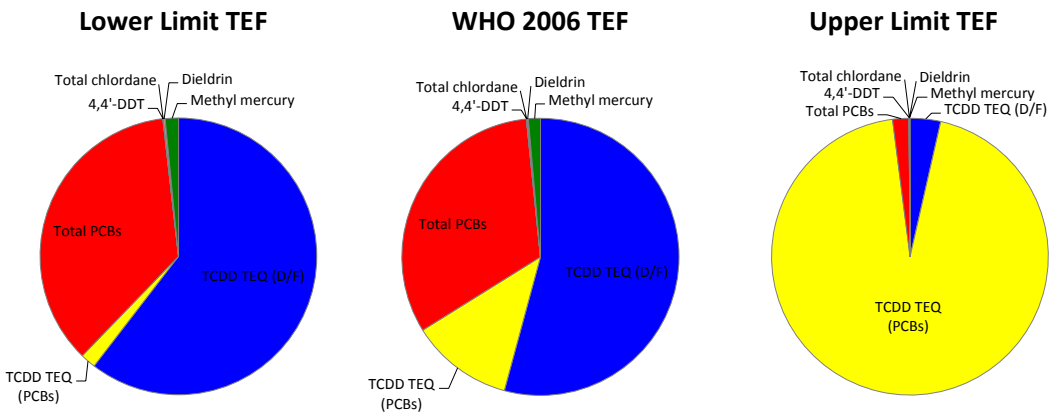


Figure 3. Impact of TEF distributions on the contribution to total noncancer hazard associated with fish consumption for RME scenario and child receptor.

In summary, the USEPA guidance on TEFs not only provides that a sensitivity analysis should be conducted for major risk assessments, but also provides information as to how such analyses could be conducted. Further, USEPA authors have published a demonstration of the impact of such sensitivity analyses for DLCs. As such, Region 2 should perform a sensitivity analysis to demonstrate the impact of TEFs on the TEQ, and subsequently, how use of TEFs impacts the risk and hazard estimates.

Comment 2-21: Region 2 does not sufficiently address uncertainty associated with TEFs

The discussion related to TEF uncertainty in the draft FFS is wholly insufficient; Region 2 should review and address the many uncertainties related to TEFs as discussed in USEPA guidance (USEPA, 2010).

Region 2 utilized toxic equivalency factors (TEFs) in developing exposure point concentrations (EPCs) for dioxin-like compounds (DLCs). Region 2 appropriately cited USEPA guidance in support of using these values but did not sufficiently characterize the uncertainties related to the use of TEFs in major risk assessments. Region 2 acknowledged that the USEPA guidance "*Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds* (USEPA 2010b)", provides uncertainties associated with the evaluation of TEFs for dioxins and dioxin-like PCBs, but does not go beyond the acknowledgement that such uncertainties exist. The USEPA 2010 guidance document specifically lists the following uncertainties, none of which Region 2 addressed:

UNCERTAINTY IN TEF METHOD ASSUMPTIONS

1. Dose additivity under the TEF method assumes a common mode of toxic action mediated through AhR binding and downstream biochemical and toxic responses. There is some evidence suggesting that some toxicities associated with some DLCs may be mediated through other ligands and processes (i.e., not mediated through the AhR). Effects mediated by other mechanisms (AhR independent) are not accounted for by the TEF method.

2. Dose additivity under the TEF method assumes parallel dose-response curves. This is supported by some empirical data, but, in practice, parallelism is difficult to show for all DLCs and exposure scenarios, particularly in the low response region of most interest in environmental risk assessment.

3. Dose additivity under the TEF method assumes that toxicological interactions are not occurring at environmental levels of the DLCs. Some data suggest that combined exposures of some DLCs may have antagonistic, rather than additive, effects; these could be species-specific. It may also be noted that joint toxic action of dioxins with non dioxin-like compounds could result in additive or nonadditive responses.

4. Under the TEF method, the TEF of a DLC is assumed to be equivalent for all exposure scenarios, for all end points of concern, and all are full agonists. The ranges of RePs shown in the Haws et al. (2006) database demonstrate the uncertainty in this assumption as the ranges represent RePs from various study types and endpoints.

5. Under the TEF method, it is assumed that RePs from animal studies are predictive of RePs in humans. However, the human AhR demonstrates some differences when compared to the AhR from experimental animal species.

UNCERTAINTY IN THE PROCESSES AND DATA USED TO DERIVE TEFs

1. Expert scientific judgment, which depends on the knowledge and evaluations of the expert scientists involved, was used to select the DLCs included in the WHO TEF approach by evaluating experimental data against specific criteria (van den Berg et al. 2006). It may be noted that not all of the DLCs identified in releases from anthropogenic sources are included.

2. Expert judgment and a consensus process were used to derive the WHO 2005 TEFs (van den Berg et al. 2006), including evaluation of information from the Haws et al. (2006) database.

3. The kinds of information available for comparing the responses to individual DLCs to those of the index compound are highly variable across chemicals, including many types and numbers of in vivo (including different test species) and in vitro studies. In addition, a number of different methods are employed to calculate ReP values (Haws et al. 2006). (See additional discussions of this below, under the section on Sensitivity Analysis Limitations.)

Given the extensive nature of the uncertainties related to TEFs, as well as the impact of the use of such in this FFS risk assessment, the current discussion of the TEF uncertainties is wholly insufficient. As drafted, the half-page discussion provided in Section 3.7.3.2 of Appendix D does not specifically address the uncertainties in use of the TEFs as described by the USEPA, and does not discuss the significance of these uncertainties. A robust discussion should be generated in order to fulfill the requirements associated with conducting a USEPA human health risk assessment (USEPA 1989a):

> "The second part of the uncertainty discussion is to summarize the major assumptions of the exposure assessment, to discuss the uncertainty associated with each, and to describe how this uncertainty is expected to affect the estimate of exposure."

> "Sometimes, a qualitative approach is the most practical approach to describing uncertainty in Superfund site risk assessments given the use of the information (e.g., identifying areas where the results may be misleading). Often the most practical approach to characterizing parameter uncertainty will be to develop a quantitative or qualitative description of uncertainty for each parameter and to simply indicate the possible influence of these uncertainties on the final risk estimates…"

Comment 2-22: Region 2 should use proper nomenclature to describe dioxin-like compounds.

Region 2 utilized a non-standard nomenclature for dioxin-like compounds; the nomenclature should be revised to be consistent with USEPA TEF guidance (USEPA, 2010).

Region 2 evaluated six classes of chemicals, three of which were described as PCDDs, PCDFs, and PCBs; it was also noted by Region 2 that "TEQ calculations were performed for D/F and coplanar (dioxin-like) PCB congeners." The TEQ calculations were then identified throughout the FFS Risk Assessment as "TCDD TEQ (D/F)" and "TCDD TEQ (PCBs)." In support of this approach, Region 2 cites the USEPA 2010 guidance on TEFs. The USEPA guidance document refers to dioxin-like chemical concentrations utilizing the TEF approach as "TEQ;" the document does not call such "TCDD TEQ" as Region 2 has done in the FFS. Thus, the use of nonstandard nomenclature by Region 2 suggests that Region 2 is attempting to highlight TCDD and downplay risk/hazard posed by PCBs. For example, the "TCDD TEQ (PCBs)" concentrations do not contain TCDD – such concentrations are based on specific PCB congeners. The use of "TCDD" prior to "TEQ" should be omitted.

Comment 2-23: Region 2 compounded conservatism in the FFS HHRA

The LPR FFS risk and hazard estimates used by Region 2 to inform remediation decisions are the deterministic products of compounded conservatism as each is based on exposure parameter values on the high end of their respective distributions, as well as toxicity values calculated using conservative assumptions. Region 2 should include a probabilistic risk assessment to characterize the impact of the compounded conservatism reflected in its risk and hazard estimates.

Region 2 calculated that RME cancer risk and noncancer hazard estimates for LPR anglers exceeded acceptable standards. The estimates reflect the compounding of conservative assumptions about angler exposures and COPC toxicity. As noted in several comments above, the assumptions made by Region 2 regarding fish and crab ingestion, cooking loss, and fraction of total fish and crab consumed coming from the LPR FFS Study Area are all overly conservative, with the former exposure parameter reflecting the 90th percentile of a non-representative angling population, and the latter two parameters reflecting the 100th percentiles in their respective exposure categories. When combined with conservative assumptions on fish tissue COPC levels (95% UCL on the mean of only two fish species) and the cancer and noncancer toxicity values applied for DLCs, it is not surprising that Region 2's risk and hazard estimates exceeded the acceptable standards. Region 2 did calculate risks and hazards based on central tendency values for

exposure parameters but did not account for these CTE estimates in its uncertainty analysis, nor did it incorporate them into any meaningful risk characterization or remedy assessment.

It has been well documented that the compounding of conservative assumptions in the individual parameter estimates can result in risk estimates larger than expected through the use of upper bound parameter values. For example, Cullen (1994) reviewed several deterministic risk assessments in which the 5th or 95th percentiles were assigned to inputs either negatively or positively correlated with risk or exposure, respectively. By comparing the resulting risk and intake estimates with the risk and intake distributions generated using probabilistic methods for each respective risk assessment study, it was reported that the deterministic risk and intake estimates consistently fell above the 95th percentile of the simulated output distributions, and exceeded the 99th percentile in the majority of studies reviewed. Similar analyses and results have been reported in the literature (Burmaster and Harris, 1993; Finley and Paustenbach, 1994; Viscusi et al. 1997). And because toxicity estimates are often derived using conservative assumptions, variation of toxicity estimates would very likely produce results that would be even more dramatic (e.g., Copeland et al. 1994).

Thus, compounding conservatism results in exposure and risk estimates that yield unrealistic results as opposed to reasonable maximum values. Given the extensive remedy recommended by Region 2, it is imperative that Region 2 update its HHRA with a probabilistic evaluation of risk and hazard estimates in order to properly characterize the associated uncertainty, and to demonstrate that its risk and hazard estimates in fact represent reasonable maximum exposures.

Comment 2-24: Remedy Proposed by Region 2 does not achieve acceptable risk and hazards even after the expenditure of billions of dollars

Based on the future risk estimates for LPR anglers modeled by Region 2, its proposed $1.7 billion dollar remediation alternative does not achieve acceptable cancer risk or hazard for LPR anglers. Also, there is no analysis of physical risks posed by the proposed remedy (e.g., likelihood of a truck or train accident). A single death or serious injury sustained while conducting the remediation will be far worse than choosing the no action alternative with regard to overall human health. In addition, the model used by Region 2 to predict future sediment COPC levels (and by extension, future fish and crab COPC concentrations) likely underestimated future COPC concentrations, and therefore risk, suggesting even higher unacceptable risks after the proposed remedy is complete. Region 2 should re-evaluate the remediation alternatives in the context of revised risk and hazard estimates based on scientifically defensible exposure factors and toxicity factors.

Region 2 proposed four potential remediation alternatives for the lower eight miles of the LPR. Using fish and crab tissue COPC estimates that were extrapolated from modeled sediment COPC concentration estimates based on LPR fate and transport assumptions for the four remedial alternatives, Region 2 selected a remedy that includes extensive

dredging and capping of the lower eight miles of the LPR (to accommodate flooding and commercial navigation of the river), with off-site disposal of the dredged material (Remedial Alternative 3 with Dredged Material Management Scenario B). Region 2 has estimated that this remedy would require the removal and disposal of over 4.3 million cubic yards of sediment, which will require huge numbers of dump truck/train trips to transport sediment. For this effort, Region 2 predicted that this remedial alternative would take approximately five years to complete, and presented a total present day cost estimate of $1.731 billion (Region 2, 2014; Appendix H).

Given that the dredged sediment will have to travel millions of miles over the course of implementation of the remedy, and given the tens of thousands of dump truck or train trips this effort will involve, it is highly likely that there will be at least one serious accident. A single truck or train accident involving a death or serious injury is significantly worse than simply selecting the no-action alternative for the FFS Study Area. These and other unforeseen events have not been factored into Region 2's cost/risk for the remedy they recommended. Region 2 should undertake an analysis of physical risks posed by the proposed remedy and compare such to the human health risks posed by the chemicals in the biota. Additionally, as long as sewage is allowed to bypass water treatment plants during precipitation events, pathogen hazards will continue to present a significant human health issue for LPR receptors since Remedial Alternative 3 does not include any prescriptions for addressing the inadequate LPR CSO systems. Finally, the Region 2 should propose remedies that are based on scientifically defensible exposure assumptions and toxicity criteria.

It should also be noted that the uncertainty in the LPR-NB model used to estimate future sediment COPC levels for the HHRA is such that predictions of future COPC levels are likely underestimated. As Region 2 notes in Appendix D, Section 5, two models were used to predict future COPC levels: LPR-NB and EMBM. Region 2 used the LPR-NB output for determining the impacts of the different remediation scenarios regarding the HHRA. However, comparing the results of the two models demonstrated that concentrations estimated with the LPR-NB Model are lower than those from the EMBM. Specifically, Total PCB estimates for Remedial Alternative 3 are nearly 10-fold lower using LPR-NB model compared to EMBM, and 4-fold lower for 2,3,7,8-TCDD. This means that it is likely that the future estimates upon which Region 2 relies for selecting Remedial Alternative 3 are overly optimistic, and that the future risks and hazards will be even less acceptable than predicted (using Region 2's exposure assumptions).

Therefore, Region 2 should re-evaluate the remedial alternatives in the context of revised risk and hazard estimates based on scientifically defensible exposure factors and toxicity factors.

Comment 2-25: Instead of citing Wikipedia, Region 2 should be citing peer-reviewed papers to provide scientific support for the LPR FFS methods and analysis

Region 2 cited a Wikipedia webpage in support of a statistical method applied in the LPR FFS. This is an unacceptable reference source. In addition to revising its HHRA with the peer-reviewed and scientifically valid approaches described in the comments above, Region 2 should review the LPR FFS to remove any improper references, including Wikipedia citations.

The biota analysis presented in Appendix A6 of Region 2's LPR FFS includes a description of the methodological approach Region 2 used to model biota tissue COPC levels from sediment concentrations. In a section describing the statistical extrapolation of limited PCB congener data from the 2003 REMAP dataset to estimates of Aroclor levels, the report cites a Wikipedia webpage on robust regression analysis in support of their approach (Region 2, 2014; see page 3-15 of Appendix A6 Data Evaluation Report No. 6: "Biota Analysis"). This citation is included in the reference section of the appendix as well (pg. 6-11).

Citing a popular website such as Wikipedia in support of a scientific study design is unacceptable in scientific writing for several reasons. First of all, these are not scientifically peer-reviewed references, as clearly stated in the website's General Disclaimer:

> *"Wikipedia is not uniformly peer reviewed; while readers may correct errors or engage in casual peer review, they have no legal duty to do so and thus all information read here is without any implied warranty of fitness for any purpose or use whatsoever."*

As a consequence, Region 2 cannot vouch for the validity of the source, as also clearly stated in the General Disclaimer on the Wikipedia website:

> ***"Wikipedia cannot guarantee the validity of the information found here.*** *The content of any given article may recently have been changed, vandalized or altered by someone whose opinion does not correspond with the state of knowledge in the relevant fields."*

Wikipedia cannot be considered an acceptable peer-reviewed reference for scientific analyses since anyone can anonymously create or alter topic entries, and therefore no one is ultimately responsible for these entries. While perhaps a practical resource in non-professional settings, relying on crowd-sourced sites like Wikipedia in scientifically professional situations suggests a lack of scientific rigor on the part of the author(s). It is unacceptable to include such sites as supporting references in a report that should be scientifically rigorous. Region 2 should take care to review the LPR FFS and remove this and any comparable references.

SECTION 3: State-of-the-Science HHRA

In this section, we present both a deterministic HHRA (DRA) as well as a probabilistic HHRA (PRA) that represent state-of-the science approaches and technical input for site-specific risk assessments. Most notably, both the DRA and the PRA demonstrate that PCBs (both dioxin-like and non-dioxin-like) and PAHs significantly contribute to hazard and risk in the LPR – and their contributions are greater than the hazards and risks associated with TCDD. These analyses demonstrate the impact of the shortcomings in Region 2's overly simplistic, biased HHRA, and by extension, demonstrate that the billion-dollar remedies proposed in the FFS lack robust scientific support.

Comment 3-1: State-of-the-Science Deterministic Risk Assessment (DRA)

To address the significant shortcomings of the HHRA conducted by Region 2, ToxStrategies performed a deterministic HHRA using site-specific data and toxicity criteria that better represent the state-of-the-science, as well as exposure pathways and COPCs relevant to the LPR. These results demonstrate the significance of Region 2's failure to conduct an HHRA consistent with USEPA guidance. Region 2 has significantly overestimated the risk and hazard posed by human ingestion of LPR fish and crab. This state-of-the-science DRA demonstrates that there is no excess cancer risk that exceeds the 1 x 10^{-4} benchmark and that hazard estimates are dramatically lower than Region 2 contends. Region 2 should revise the FFS HHRA by using site-specific exposure data and scientifically defensible toxicity criteria.

ToxStrategies used standard USEPA equations for estimating risks and hazards due to fish and crab consumption, and ingestion and dermal exposure to sediment. Risks and hazards were calculated for adult, adolescent and child anglers, as well as adult, adolescent and child recreators exposed to sediment. Species-specific ingestion rates were applied. Where site-specific data is unavailable, USEPA's new OSWER guidance was used as the initial source for obtaining default exposure factors.

Equations are based on those used in USEPA's RSLs (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/equations.htm). The addition of PAHs as COPCs added seven compounds considered mutagenic. USEPA's RSL equations for evaluating mutagens, along with USEPA's ADAFs for evaluating early-life exposures were used. As was done by Region 2 in its HHRA, ToxStrategies created tables consistent with the RAGS D approach, and calculated carcinogenic and noncarcinogenic intakes, to which the CSFs or RfDs were applied to calculate risks and hazards, respectively. Risks and hazards were determined for individual chemicals, including individual congeners for dioxins and dioxin-like compounds. Risks and hazards were also estimated for chemical groups and across all chemicals. Final values are presented for the combination of fish and crab (hepatopancreas + muscle [H+M]) consumption and sediment exposure (incidental ingestion and dermal contact), as well as for fish consumption, crab consumption (H+M) and sediment (ingestion and dermal contact) individually.

LPR Exposure Assessment: Exposure Parameter Values

As noted above, ToxStrategies applied the 2014 USEPA OSWER Guidance default exposure parameters for fish ingestion, sediment ingestion, and sediment dermal exposure scenarios unless values were available that had been derived using study data specific to the LPR. A full list of the exposure parameters used in the ToxStrategies LPR HHRA is presented in Appendix A. As **Figure 4** demonstrates, there are a few differences between some of the exposure parameter values applied by ToxStrategies and Region 2. Most notably, ToxStrategies applied fish and crab ingestion rates for the adult risk assessment that were derived from the LPR fish consumption model developed by Veritas using observational data from two LPR Study Area creel angler surveys (Kinnell et al. 2013).[2] In contrast, Region 2 elected to use ingestion rates derived from studies that surveyed anglers outside the LPR Study Area (USEPA 2012). The differences between these fish and crab ingestion rates are significant, with the Region 2 non-site specific fish (all species combined) and crab ingestion rates being approximately 4- and 150-fold greater, respectively, than the ingestion rates based on LPR Study Area-specific empirical data. Both ToxStrategies and Region 2 calculated ingestion rates for adolescent and child receptors by dividing the adult rates by 2/3 and 1/3, respectively, so the magnitude of the differences in ingestion rates applied to these receptors between the risk assessments are the same as the differences in adult receptor ingestion rates.

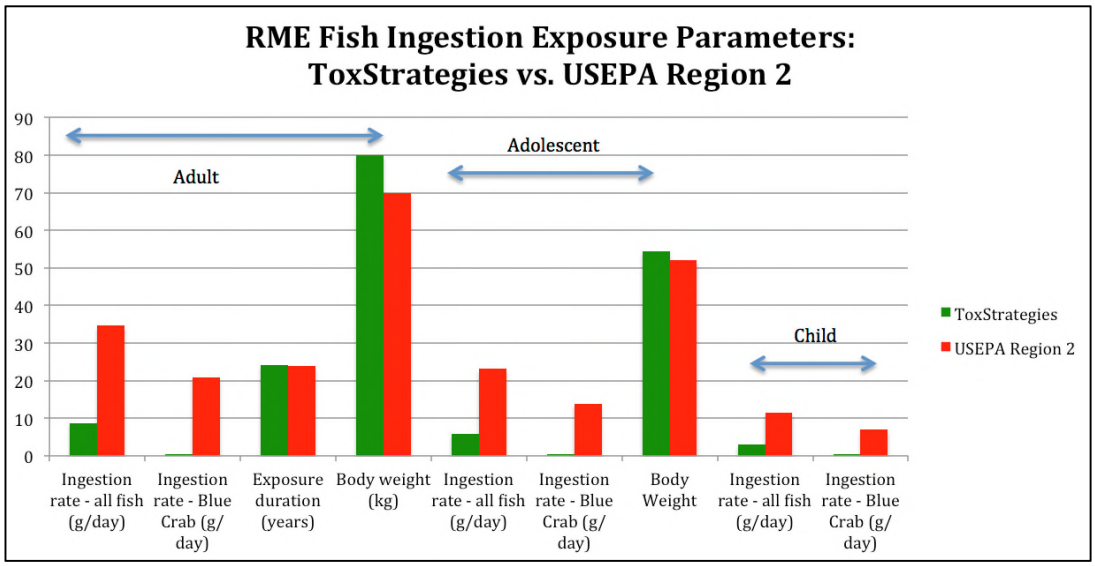


Figure 4. Comparison of key exposure parameters

[2] Shortly before the deadline to submit these comments to Region 2, Kinnell et al. updated the LPR CAS adult ingestion rate for fish/crab to 5.09 g/day from 8.9 g/day. While the risk and hazard estimates presented in these comments are based on the higher ingestion rate, this 43% decrease in the ingestion rate would only serve to further decrease risk and hazard estimates presented herein.

Figure 4 also illustrates some less significant differences between exposure duration and body weight. The exposure duration value of 24.2 years is again a value based on LPR observational survey data (Kinnell et al. 2013) and is very similar to the default value used by Region 2 (24 years). The Region 2 default is outdated, as the new 2014 USEPA OSWER Directive states that Superfund regional managers should assume an exposure duration value of 20 years in the absence of site-specific data. While the Region 2 HHRA evaluated mobility data from 2000 U.S. Census to suggest that a 24-year exposure duration could be a significant underestimate, it should be emphasized that these data are not specific to LPR anglers, and the Region 2 analysis of the U.S. Census dataset resulted in implausible conclusions (e.g., 95th percentile for the probability that an individual will move out of the Study Area is **95 years**). In addition to exposure duration, the USEPA OSWER Directive updated the default body weight for adults (from 70 kgs to 80 kgs). ToxStrategies applied this new adult body weight default in its HHRA, whereas the Region 2 HHRA results are based on the outdated default value. The body weights for adolescent receptor – thought different – were similar: the ToxStrategies value of 54.5 kg was based on an earlier LPR Restoration Project Pathways Analysis Report (Battelle 2005), and Region 2 used a mean value from 2008 USEPA Child Exposure Factors Handbook.

The other exposure parameter value for which there exists a significant difference between the ToxStrategies and Region 2 two risk assessments is cooking loss. For the RME individual, Region 2 assumes no loss of COPCs in fish tissue after cooking. This is akin to assuming the RME angler is eating the catch raw, which represents a "maximum" exposure scenario, but does not represent a "reasonable maximum exposure" value as it is defined in RAGS. ToxStrategies developed RME cooking loss values for the LPR HHRA (**Table 7**). These represent the 10th percentile of the cooking loss distributions based on the fish cooking loss datasets for TCDD, PCBs, chlordane, dieldrin, DDT, DDD, and DDE presented in USEPA's 2000 Fish Advisory Guidance document (USEPA 2000).

Table 7. ToxStrategies LPR HHRA RME and CTE Cooking Loss Values†

Chemical Class	Distribution Type	10th Percentile	50th Percentile
DDD	Custom	9	31
DDE	Custom	10	30
DDT	Custom	8	26
Dieldrin	Custom	8	29
Dioxin	Custom	37	54
PCB	Custom	13	32
Total Chlordane	Custom	6	35

†Based on the fish cooking loss datasets presented in 2000 USEPA Fish Advisory Guidance

Finally, ToxStrategies also applied the 2014 USEPA OSWER Directive default values to several of the exposure parameters that define incidental sediment ingestion and sediment dermal contact, exposure scenarios that Region 2 ignored in its HHRA. There are some notable exceptions, however.

Exposure Frequency was defined using the values applied in the USEPA's Hudson River Risk Assessment (USEPA 2000c), which found adolescents more likely to come into contact with river sediments than adults or children (USEPA 2000c). For such, Region 2 assumed that recreational exposures are most likely to occur during the summer months, and that for the RME recreator scenario, children and adults were assumed to be exposed to river sediments for one day/week during the 13 weeks of summer (13 days/year). The adolescent, who is less likely to be accompanied by an adult, was assumed to frequent the area three times as often (39 days/year).

Sediment ingestion rates for adults, adolescents and children, as well as the sediment adherence factor for adults, were based on the 2005 LPR exposure pathway analysis report (Battelle 2005). The adherence factors for adolescent and child receptors were based on the skin adherence data presented in Shoaf et al. (2005), and weighted by body parts assumed to be exposed per the 2004 USEPA Dermal RAGs guidance (USEPA 2004). While default adherence factors pertain to soil exposures, the values based on Shoaf et al. (2005) were used in the ToxStrategies HHRA because they provide a more realistic approximation of sediment adherence for children and young adolescents. Finally, the body weight and skin surface area parameters for the adolescent receptor were not defined in the 2014 USEPA OSWER guidance, so these values were pulled from the earlier 2005 LPR Restoration Project Pathways Analysis Report and 2011 USEPA Exposure Factors Handbook, respectively (Battelle 2005; USEPA 2011a).

LPR Toxicity Assessment: Selection of Cancer and Noncancer Toxicity Values
ToxStrategies identified the most scientifically defensible cancer and noncancer toxicity factors for all chemicals of potential concern included in the LPR exposure assessment. The full list of these values is presented in Appendix A of these comments. There are a few critical differences in the toxicity values used in the ToxStrategies risk assessment compared to the Region 2 HHRA. As shown in **Table 8**, the Region 2 oral cancer slope factor (CSF) of 150,000 $(mg/kg\text{-}day)^{-1}$ for dioxin-like compounds (DLCs) is based on an outdated assessment of the Kociba et al. (1978) rat bioassay study (USEPA 1985). In contrast, ToxStrategies used an oral CSF of 9,700 $(mg/kg\text{-}day)^{-1}$ for DLCs based on an updated tumor pathology analysis of the same study (Keenan et al. 1991). The oral CSFs for all other common COPCs were the same in the ToxStrategies and Region 2 risk assessments. For the noncancer assessment, Region 2 used the 2012 USEPA RfD of 0.7×10^{-9} mg/kg-day for TCDD to assess risk for DLCs (**Table 9**). However, this value is based on two highly flawed epidemiology studies and therefore does not represent the best available science regarding DLC noncancer toxicity. As such, ToxStrategies utilized the FAO/WHO JECFA Tolerable Daily Intake (TDI) value of 2.3×10^{-9} mg/kg/day for DLCs. This toxicity value is based on rodent maternal body concentrations associated with LOAEL or NOAEL exposures, and includes a number of adjustments and/or uncertainty factor adjustments, resulting in a target "safe" maternal body burden in humans (JECFA 2001). As with the cancer toxicity factors, all other noncancer values were the same for COPCs common to both the ToxStrategies and Region 2 HHRAs.

Table 8 - Cancer Toxicity Data: ToxStrategies vs. USEPA Region 2
Lower Passaic River

Chemical of Potential Concern	ToxStrategies			USEPA Region 2		
	Oral CSF $(mg/kg\text{-}day)^{-1}$	Source(s)	Date(s) (MM/DD/YYYY)	Oral CSF $(mg/kg\text{-}day)^{-1}$	Source(s)	Date(s) (MM/DD/YYYY)
PCDD/F/DL-PCBs	9.7E+03	Keenan et al. 1991	11/30/1991	1.5E+05	USEPA	9/1/1985
DL PCBs	9.7E+03	Keenan et al. 1991	11/30/1991	1.5E+05	USEPA	9/1/1985
Total Non-DL PCBs	2.0E+00	IRIS	6/1/1997	2.0E+00	IRIS	6/1/1997
PAHs	**[See PAH Tox Table]**			**Not Addressed in USEPA LPR FFS HHRA.**		
4,4'-DDD	2.4E-01	IRIS	8/22/1988	2.4E-01	IRIS	8/22/1988
4,4'-DDE	3.4E-01	IRIS	8/22/1988	3.4E-01	IRIS	8/22/1988
4,4'-DDT	3.4E-01	IRIS	5/1/1991	3.4E-01	IRIS	5/1/1991
Chlordane	3.5E-01	IRIS	2/7/1998	3.5E-01	IRIS	2/7/1998
Dieldrin	1.6E+01	IRIS	7/1/1993	1.6E+01	IRIS	7/1/1993
Methyl mercury	--	IRIS	5/1/1995	--	IRIS	5/1/1995

Definitions
(mg/kg-day)-1 per milligram per kilogram per day, CSF - cancer slope factor

Table 9 - Noncancer Toxicity Data: ToxStrategies vs. USEPA Region 2
Lower Passaic River

Chemical of Potential Concern	ToxStrategies			USEPA Region 2		
	Oral RfD (mg/kg-day)	Source(s)	Date(s) (MM/DD/YYYY)	Oral RfD (mg/kg-day)	Source(s)	Date(s) (MM/DD/YYYY)
PCDD/F/DL-PCBs	2.3E-09	JECFA 2001	6/30/2001	7.0E-10	IRIS	2/17/2012
DL PCBs	2.3E-09	JECFA 2001	6/30/2001	7.0E-10	IRIS	2/17/2012
Total Non-DL PCBs	2.0E-05	IRIS	11/1/1996	2.0E-05	IRIS	11/1/1996
PAHs	**[See PAH Tox Table]**			**Not Addressed in USEPA LPR FFS HHRA.**		
4,4'-DDD	--	--	--	--	--	--
4,4'-DDE	--	--	--	--	--	--
4,4'-DDT	5.0E-04	IRIS	2/1/1996	5.0E-04	IRIS	2/1/1996
Chlordane	5.0E-04	IRIS	2/7/1998	5.0E-04	IRIS	2/7/1998
Dieldrin	5.0E-05	IRIS	9/1/1990	5.0E-05	IRIS	9/1/1990
Methyl mercury	1.0E-04	IRIS	7/27/2001	1.0E-04	IRIS	7/27/2001

Definitions
mg/kg-day - milligram per kilogram per day, RfD - reference dose

Polycyclic aromatic hydrocarbons (PAHs) represents a group of compounds highly relevant to human health risk that Region 2 ignored in the FFS HHRA. **Table 10** lists the cancer and noncancer toxicity factors used in the ToxStrategies LPR HHRA. This is a critical group of COPCs that is particularly important to include in human health risk assessments that include sediment and/or soil exposure scenarios. ToxStrategies utilized the oral and dermal CSFs derived in USEPA's 2013 draft risk assessment for Benzo[a]pyrene (B[a]P). These B[a]P slope factors were then adjusted for the other 7 known PAH carcinogens analyzed in this assessment by using the PAH relative potency factors (RFPs) established by USEPA (1993). For the noncancer assessment, ToxStrategies also utilized the recent USEPA RfD value for B[a]P, as well as RfDs derived by USEPA for nine other PAH compounds.

Table 10 - Polycyclic Aromatic Hydrocarbon Toxicity Data (Chronic Values)
Lower Passaic River

Chemical of Potential Concern	Cancer Toxicity Factors					Non-Cancer Toxicity Factors		
	Oral CSF $(mg/kg\text{-}day)^{-1}$	Dermal CSF $(mg/day)^{-1}$	RPF (1)	Source(s)	Date(s) (MM/DD/YYYY)	Oral RfD mg/kg-day	Source(s)	Date(s) (MM/DD/YYYY)
Acenaphthene	--	--	--	--	--	6.0E-02	IRIS	4/1/1994
Anthracene	--	--	--	--	--	3.0E-01	IRIS	7/1/1993
Benz(a)anthracene	1.0E-01	0.5	0.1	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Benzo(a)pyrene	1.0E+00	5	1.0	USEPA 2013	8/31/2013	3.0E-04	USEPA 2013	8/31/2013
Benzo(b)fluoranthene	1.0E-01	0.5	0.1	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Benzo(k)fluoranthene	1.0E-02	0.05	0.01	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Chloronaphthalene, Beta-	--	--	--	--	--	8.0E-02	IRIS	11/1/1990
Chrysene	1.0E-03	0.005	0.001	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Dibenz(a,h)anthracene	1.0E+00	5	1.0	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Fluoranthene	--	--	--	--	--	4.0E-02	IRIS	7/1/1993
Fluorene	--	--	--	--	--	4.0E-02	IRIS	11/1/1990
Indeno(1,2,3-cd)pyrene	1.0E-01	0.5	0.1	USEPA 2013; 1993 RPFs	8/31/2013	--	--	--
Methylnaphthalene, 1-	2.9E-02	--	--	PPRTV	1/10/2008	7.0E-02	ATSDR	9/30/2005
Methylnaphthalene, 2-	--	--	--	--	--	4.0E-03	IRIS	12/22/2003
Naphthalene	--	--	--	--	--	2.0E-02	IRIS	9/17/1998
Pyrene	--	--	--	--	--	3.0E-02	IRIS	7/1/1993

Definitions

CSF - cancer slope factor, M - mutagenic, mg/day^{-1} - per milligram per day, $mg/kg\text{-}day^{-1}$ - per milligram per kilogram per day, mg/kg-day, milligram per kilogram per day, PAH - polycyclic aromatic hydrocarbon, RPF - relative potency factor

Notes

(1) RPFs from USEPA 1993.
(2) Dermal CSF from USEPA 2013.

The results of the alternative deterministic HHRA, which was conducted using site-specific exposure data and toxicity criteria that better reflect the state of the science, as well incorporation of COPCs and exposure pathways relevant to the LPR, resulted in the following key findings:

1. Utilizing more scientifically defensible/appropriate exposure assumptions and toxicity criteria than what Region 2 selected for its FFS HHRA, estimates of excess cancer risk associated with ingestion of fish or crabs from the LPR were determined to be below 1 x 10^{-4} for all chemicals evaluated for each receptor (child, adolescent and adult) (**Tables 11** and **12**; **Figure 5**). The adult + child combined group exceed 1 x 10^{-4} due to elevated total PCB cancer risk. Finally, these estimated excess cancer risks are less than those estimated by Region 2 after implementing the very expensive costly preferred remedy.

Table 11. Overall summary of current baseline risks and hazards (RME)

Fish, Crab (H+M) & Sediment Consumption		Fish Consumption	
Cancer Risk	**Hazard Index**	**Cancer Risk**	**Hazard Index**
Adult	**Adult**	**Adult**	**Adult**
3E-04	19	2E-04	18
Adolescent	**Adolescent**	**Adolescent**	**Adolescent**
5E-03	21	1E-04	18
Child	**Child**	**Child**	**Child**
9E-04	35	1E-04	33
Adult + Child	**Adult + Child**	**Adult + Child**	**Adult + Child**
1E-03	54	3E-04	51
Crab Consumption (H+M)		**Sediment (Ingestion + Dermal Contact)**	
Cancer Risk	**Hazard Index**	**Cancer Risk**	**Hazard Index**
Adult	**Adult**	**Adult**	**Adult**
1E-06	0.1	1E-04	0.09
Adolescent	**Adolescent**	**Adolescent**	**Adolescent**
5E-07	0.1	5E-03	3
Child	**Child**	**Child**	**Child**
5E-07	0.2	8E-04	2
Adult + Child	**Adult + Child**	**Adult + Child**	**Adult + Child**
2E-06	0.3	9E-04	2

Definitions: H+M - hepatopancreas + muscle, RME - reasonable maximum exposure.
Shaded boxes represent the receptor with the highest risk and hazard estimates for each exposure route/scenario.

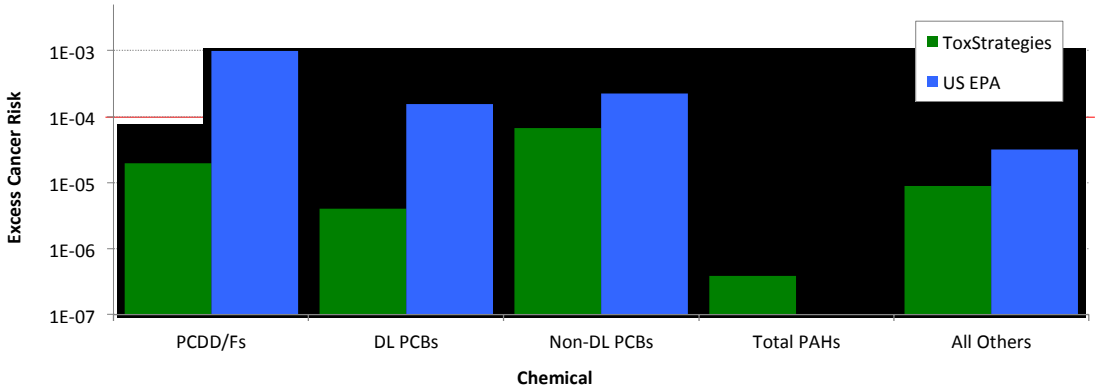


Figure 5. Cancer risk estimates associated with fish consumption for RME scenario and child receptor

Definitions: PCDD/Fs - polychlorinated dioxins and furans, PCBs, - polychlorinated biphenyls, DL – dioxin-like, Non-DL - non-dioxin-like, PAHs - polycyclic aromatic hydrocarbons

2. Utilizing more scientifically defensible exposure assumptions and toxicity criteria than what Region 2 selected for the FFS HHRA, noncancer hazard in the alternative risk assessment was 33, 18 and 18 for child, adolescent and adult respectively for fish ingestion (**Tables 11** and **12**; **Figure 6**). These hazard estimates are 6-7 fold lower than that estimated in the FFS HHRA. Moreover, these hazard estimates are similar to what Region 2 calculated the hazard would be after spending billions of dollars to implement the preferred remedy.

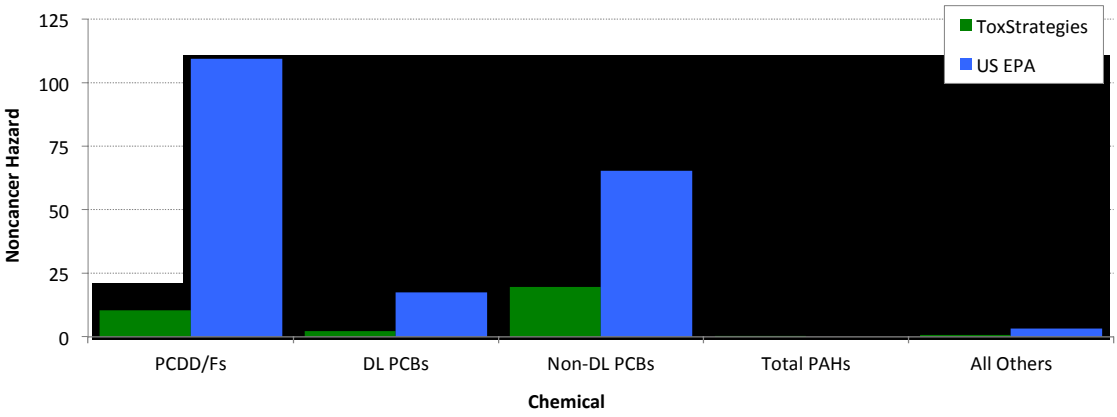


Figure 6. Noncancer hazard estimates associated with fish consumption for RME scenario and child receptor

Definitions: PCDD/Fs - polychlorinated dioxins and furans, PCBs, - polychlorinated biphenyls, DL – dioxin-like, Non-DL - non-dioxin-like, PAHs - polycyclic aromatic hydrocarbons

3. In the state-of-the-science HHRA for fish ingestion, PCDD/Fs account for 32% of noncancer hazard whereas PCBs (DL and NDL PCBs) account for 66% of the noncancer hazard (**Table 12, Figure 7**). PCBs are the most important chemical class to be addressed in remediation of the LPR. A similar result was observed for excess cancer risk where PCBs (DL and NDL PCBs) contributed 71% of the excess cancer risk whereas PCDD/Fs contributed 20% (**Table 12**, **Figure 8**).

Key Result:
PCDD/Fs account for 32% of hazard whereas PCBs (DL and NDL PCBs) account for 66% of hazard

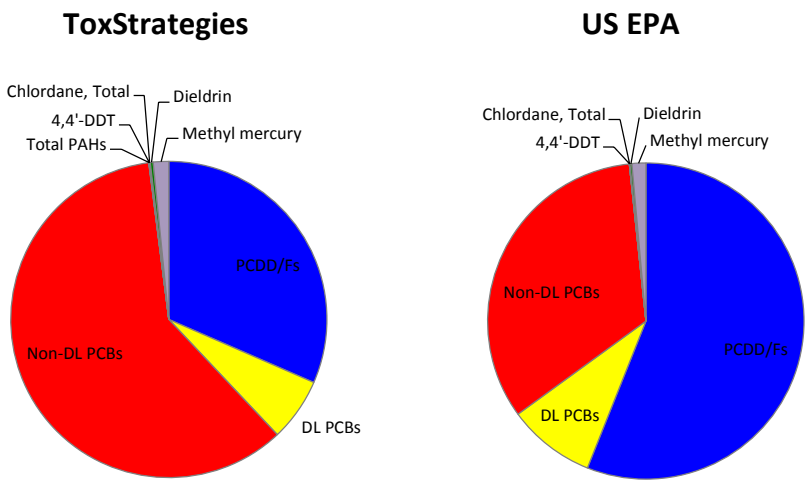


Figure 7. Percent contribution to total non-cancer hazard associated with fish consumption for RME scenario and child receptor

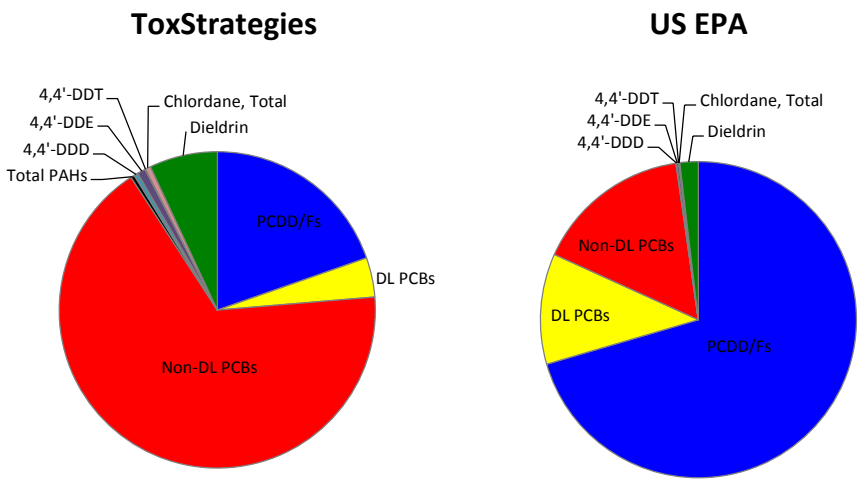


Figure 8. Percent contribution to total cancer risk associated with fish consumption for RME scenario and child receptor

4. Utilizing more scientifically defensible/appropriate exposure assumptions and toxicity criteria than what Region 2 selected for its FFS HHRA, ingestion of crab (muscle and hepatopancreas) from the LPR was found not to pose an unacceptable excess cancer risk and all hazard estimates were less than 1.0 for all receptors (child, adolescent and adult) (**Table 13**).

5. Region 2 failed to evaluate other complete exposure pathways. This is a serious error as it likely misses many other significant contributors to risk and hazard. For example, we examined direct contact with sediment and included PAHs in the analysis (**Table 14**). While PCDD/Fs and PCBS were not found to pose a significant excess cancer risk or noncancer hazard, the same cannot be said for PAHs. Utilizing the new toxicity criteria for PAHs developed by USEPA (oral and dermal slope factors) and available sediment data for PAHs in the LPR, PAHs were found to have an excess cancer risk of 5×10^{-3} for the adolescent receptor 8×10^{-4} for the child receptor. These values are clearly above the acceptable excess cancer benchmark of 1×10^{-4}; when overall risk is calculated for all exposure pathways, the risk contributed by PAHs exceeds risk of any other chemical or chemical class (**Figure 9**). For noncancer hazard, non-dioxin like PCBs were found to provide the largest contribution to hazard (**Figure 9**). It is unclear how these unacceptable cancer risks posed by PAHs will impact the proposed remedy; Region 2 should revise the FFS to consider this important class of compounds and likely should evaluate all chemicals in the sediment for direct contact risk and hazard. It is important to remember, that unlike TCDD, PAHs have a mutagenic mode of action and thus pose a special risk to users of the Passaic River.

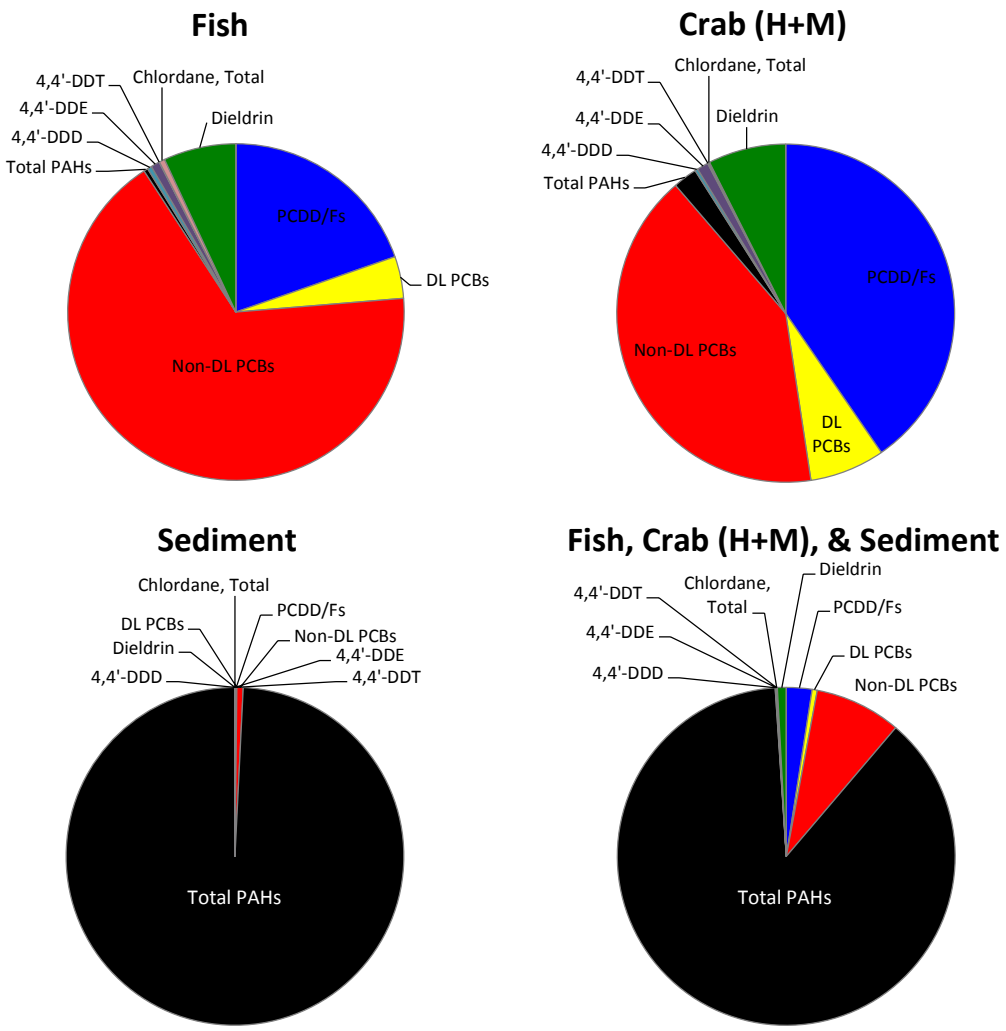


Figure 9. Percent contributions to total cancer risks associated with all relevant exposure routes for RME scenario and child receptor

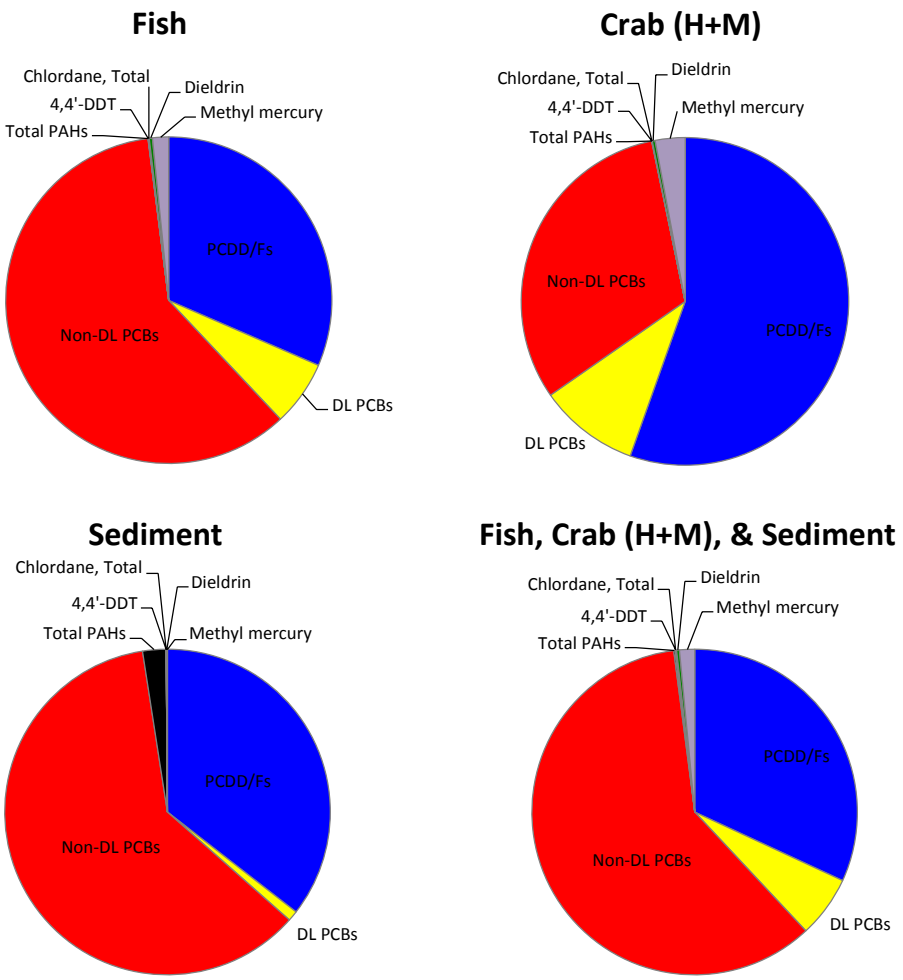


Figure 10. Percent contributions to total non-cancer hazards associated with all relevant exposure routes for RME scenario and child receptor

6. In the Region 2 FFS HHRA, TCDD TEQ (D/F) and PCBs (DL and NDL) accounted for 70% and 27% respectively of the excess cancer risk from fish ingestion (**Table 15**). In the revised HHRA, which uses superior exposure assumptions and toxicity criteria and the correct EPC for DL-PCBs, TCDD TEQ (D/F) and PCBs (DL and NDL) contribute 20% and 71% respectively of excess cancer risk for fish ingestion. This is a dramatic reversal from what was calculated by Region 2 in its HHRA. Region 2 should incorporate these factors into a revised FFS HHRA.

7. The revised HHRA demonstrates the importance of considering all exposure pathways at a site. When direct contact of sediment is considered along with fish and crab ingestion and PAHs are included in the evaluation (**Table 16, Figure 9**), PAHs provide the bulk of the excess cancer risk at the site; this conclusion is fundamentally different than that reached by Region 2, the result of Region 2 not having conducted a proper HHRA. Region 2 should revise its HHRA for the FFS to improve the exposure assumptions, consider all relevant exposure pathways and employ the proper toxicity criteria for TCDD.

Table 12 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Fish Consumption

COPC	Fish Cancer Risk - RME					Fish Noncancer Hazard - RME				
	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)
PCDD/Fs	4E-05	2E-05	2E-05	6E-05	20%	6	6	10	16	32%
DL PCBs	9E-06	4E-06	4E-06	1E-05	4%	1	1	2	3	6%
Non-DL PCBs	2E-04	7E-05	7E-05	2E-04	67%	11	11	20	31	60%
Total PAHs	2E-07	3E-07	4E-07	6E-07	0.4%	0.002	0.002	0.003	0.01	0.01%
4,4'-DDD	9E-07	5E-07	4E-07	1E-06	0.4%	--	--	--	--	--
4,4'-DDE	2E-06	9E-07	9E-07	3E-06	0.9%	--	--	--	--	--
4,4'-DDT	6E-08	3E-08	3E-08	8E-08	0.03%	0.001	0.001	0.002	0.003	0.005%
Total chlordane	1E-06	6E-07	6E-07	2E-06	0.6%	0.02	0.02	0.04	0.06	0.1%
Dieldrin	2E-05	8E-06	7E-06	2E-05	7%	0.06	0.06	0.1	0.2	0.3%
Methyl mercury	--	--	--	--	--	0.3	0.3	0.5	0.8	2%
Total Risk Across All Chemicals - Fish	**2E-04**	**1E-04**	**1E-04**	**3E-04**	**100%**	**18**	**18**	**33**	**51**	**100%**

Definitions

PCDD/Fs - dioxins and furans, DL - dioxin-like, Non-DL - non dioxin-like, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RME - reasonable maximum exposure

Table 13 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Crab (Hepatopancreas + Muscle) Consumption

COPC	Crab (H+M) Cancer Risk - RME					Crab (H+M) Noncancer Hazard - RME				
	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)
PCDD/Fs	4E-07	2E-07	2E-07	6E-07	40%	0.06	0.06	0.1	0.2	55%
DL PCBs	8E-08	4E-08	3E-08	1E-07	7%	0.01	0.01	0.02	0.03	10%
Non-DL PCBs	5E-07	2E-07	2E-07	6E-07	41%	0.03	0.03	0.06	0.09	31%
Total PAHs	6E-09	7E-09	1E-08	2E-08	2%	0.00003	0.00003	0.00005	0.0001	0.03%
4,4'-DDD	3E-09	2E-09	1E-09	5E-09	0.30%	--	--	--	--	--
4,4'-DDE	1E-08	6E-09	5E-09	2E-08	1.08%	--	--	--	--	--
4,4'-DDT	8E-10	4E-10	4E-10	1E-09	0.07%	0.00001	0.00001	0.00002	0.00004	0.01%
Total chlordane	1E-09	6E-10	5E-10	2E-09	0.11%	0.00002	0.00002	0.00004	0.00006	0.02%
Dieldrin	8E-08	4E-08	4E-08	1E-07	7.4%	0.00030	0.00029	0.00052	0.00082	0.3%
Methyl mercury	--	--	--	--	--	0.003	0.003	0.005	0.008	3%
Total Risk Across All Chemicals - Crab (H+M)	**1E-06**	**5E-07**	**5E-07**	**2E-06**	**100%**	**0.1**	**0.1**	**0.2**	**0.3**	**100%**

Definitions

PCDD/Fs - dioxins and furans, DL - dioxin-like, Non-DL - non dioxin-like, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RME - reasonable maximum exposure

Table 14 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Sediment Ingestion

COPC	Sediment Cancer Risk - RME					Sediment Noncancer Hazard - RME				
	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)
PCDD/Fs	3E-07	4E-06	2E-06	2E-06	0.2%	0.04	1	0.9	1.0	39%
DL PCBs	9E-09	1E-07	5E-08	6E-08	0.01%	0.001	0.03	0.03	0.03	1%
Non-DL PCBs	6E-07	1E-05	5E-06	5E-06	1%	0.04	2	1	1	58%
Total PAHs	1E-04	5E-03	8E-04	9E-04	99%	0.002	0.1	0.05	0.05	2%
4,4'-DDD	6E-10	1E-08	5E-09	5E-09	0.001%	--	--	--	--	--
4,4'-DDE	3E-09	6E-08	2E-08	2E-08	0.003%	--	--	--	--	--
4,4'-DDT	1E-10	2E-09	8E-10	9E-10	0.0001%	0.000002	0.0001	0.00005	0.00006	0.002%
Total chlordane	3E-10	5E-09	2E-09	2E-09	0.0003%	0.000005	0.0002	0.0001	0.0001	0.005%
Dieldrin	2E-08	5E-07	2E-07	2E-07	0.025%	0.00009	0.004	0.003	0.003	0.1%
Methyl mercury	--	--	--	--	--	0.000002	0.00003	0.00003	0.00004	0.001%
Total Risk Across All Chemicals - Sediment	**1E-04**	**5E-03**	**8E-04**	**9E-04**	**100%**	**0.1**	**3**	**2**	**2**	**100%**

Definitions

PCDD/Fs - dioxins and furans, DL - dioxin-like, Non-DL - non dioxin-like, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RME - reasonable maximum exposure

Table 15 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Fish, Crab (H+M) Consumption & Sediment Ingestion

COPC	Fish, Crab (H+M) & Sediment Consumption Cancer Risk - RME					Fish, Crab (H+M) & Sediment Consumption Noncancer Hazard - RME				
	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk (Child)	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Hazard (Child)
PCDD/Fs	5E-05	3E-05	2E-05	7E-05	2%	6	7	11	17	32%
DL PCBs	9E-06	5E-06	4E-06	1E-05	0.5%	1	1	2	3	6%
Non-DL PCBs	2E-04	9E-05	7E-05	2E-04	8%	11	13	21	32	60%
Total PAHs	1E-04	5E-03	8E-04	9E-04	88%	0.004	0.1	0.06	0.06	0.2%
4,4'-DDD	9E-07	5E-07	4E-07	1E-06	0.05%	--	--	--	--	--
4,4'-DDE	2E-06	1E-06	9E-07	3E-06	0.1%	--	--	--	--	--
4,4'-DDT	6E-08	3E-08	3E-08	8E-08	0.003%	0.001	0.001	0.002	0.003	0.005%
Total chlordane	1E-06	6E-07	6E-07	2E-06	0.1%	0.02	0.02	0.04	0.06	0.1%
Dieldrin	2E-05	8E-06	7E-06	2E-05	1%	0.06	0.06	0.1	0.2	0.3%
Methyl mercury	--	--	--	--	--	0.3	0.3	0.5	0.8	1%
Total Risk Across All Chemicals - Fish, Crab (H+M) & Sediment	**3E-04**	**5E-03**	**9E-04**	**1E-03**	**100%**	**19**	**21**	**35**	**54**	**100%**

Definitions

PCDD/Fs - dioxins and furans, DL - dioxin-like, Non-DL - non dioxin-like, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RME - reasonable maximum exposure

Table 16 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Fish Consumption - ToxStrategies vs EPA

COPC	Fish Cancer Risk - RME							
	ToxStrategies Adult	EPA Adult	ToxStrategies Child	EPA Child	ToxStrategies Adult + Child	EPA Adult + Child	ToxStrategies Percent Contribution to Total Risk (Child)	EPA Percent Contribution to Total Risk (Child)
PCDD/Fs	4E-05	3E-03	2E-05	1E-03	6E-05	4E-03	20%	70%
DL PCBs	9E-06	4E-04	4E-06	2E-04	1E-05	6E-04	4%	11%
Non-DL PCBs	2E-04	6E-04	7E-05	2E-04	2E-04	8E-04	67%	16%
Total PAHs	2E-07	NA	4E-07	NA	6E-07	NA	0.4%	NA
4,4'-DDD	9E-07	3E-06	4E-07	1E-06	1E-06	4E-06	0.4%	0.08%
4,4'-DDE	2E-06	7E-06	9E-07	3E-06	3E-06	1E-05	0.9%	0.21%
4,4'-DDT	6E-08	3E-07	3E-08	1E-07	8E-08	4E-07	0.03%	0.01%
Total chlordane	1E-06	4E-06	6E-07	1E-06	2E-06	5E-06	0.6%	0.10%
Dieldrin	2E-05	7E-05	7E-06	3E-05	2E-05	9E-05	7%	2%
Methyl mercury	--	ND	--	ND	--	ND	--	ND
Total Risk Across All Chemicals - Fish	**2E-04**	**4E-03**	**1E-04**	**1E-03**	**3E-04**	**5E-03**	**100%**	**100%**

COPC	Fish Noncancer Hazard - RME							
	ToxStrategies Adult	EPA Adult	ToxStrategies Child	EPA Child	ToxStrategies Adult + Child	EPA Adult + Child	ToxStrategies Percent Contribution to Total Risk (Child)	EPA Percent Contribution to Total Risk (Child)
PCDD/Fs	6	71	10	110	16	NA	32%	56%
DL PCBs	1	11	2	18	3	NA	6%	9%
Non-DL PCBs	11	42	20	65	31	NA	60%	33%
Total PAHs	0.002	NA	0.003	NA	0.01	NA	0.01%	NA
4,4'-DDD	--	ND	--	ND	--	NA	--	ND
4,4'-DDE	--	ND	--	ND	--	NA	--	ND
4,4'-DDT	0.001	0.004	0.002	0.007	0.003	NA	0.005%	0.004%
Total chlordane	0.02	0.06	0.04	0.1	0.06	NA	0.1%	0.05%
Dieldrin	0.06	0.2	0.1	0.4	0.2	NA	0.3%	0.2%
Methyl mercury	0.3	2	0.5	3	0.8	NA	2%	1%
Total Risk Across All Chemicals - Fish	**18**	**126**	**33**	**195**	**51**	**NA**	**100%**	**100%**

Definitions

PCDD/Fs - dioxins and furans, DL - dioxin-like, Non-DL - non dioxin-like, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RME - reasonable maximum exposure

Comment 3-2: TEF Uncertainty Analysis

The failure of Region 2 to conduct a TEF Uncertainty Analysis as provided in USEPA guidance (2010) was a critical oversight given that the LPR sediment contains large concentrations of dioxin-like PCBs and failure to understand the uncertainty associated with the TEFs (and thus the risk and hazard) will leave risk managers with incomplete information. Conduct of a TEF Uncertainty Analysis for the state-of-the-science DRA performed by ToxStrategies demonstrated that DL-PCBs are likely large contributors to the hazard and risk from ingesting LPR fish, a finding similar to that observed with a TEF sensitivity analysis conducted using Region 2 data.

As previously described in Comment 2-20, Region 2 did not follow the guidance on TEFs (USEPA 2010) with respect to the conduct of a sensitivity analysis. When the guidance was applied, the data demonstrated the significant impact of the use of TEFs, as the portion of risk and hazard attributable to DL-PCBs changed dramatically when values from the upper end of the ReP distributions were utilized (90th percentile). Using this same approach in the state-of-the science DRA (i.e., use of 10th and 90th percentiles of the underlying ReP distributions as recommended by Agency guidance), a similar pattern was observed (**Figures 11, 12**). When the upper ends of the distributions were utilized, the apportionment of cancer risk and noncancer hazard changed significantly – both were dominated by non-DL PCBs. This information is critical for risk managers, particularly when considering the magnitude of the proposed remedy.

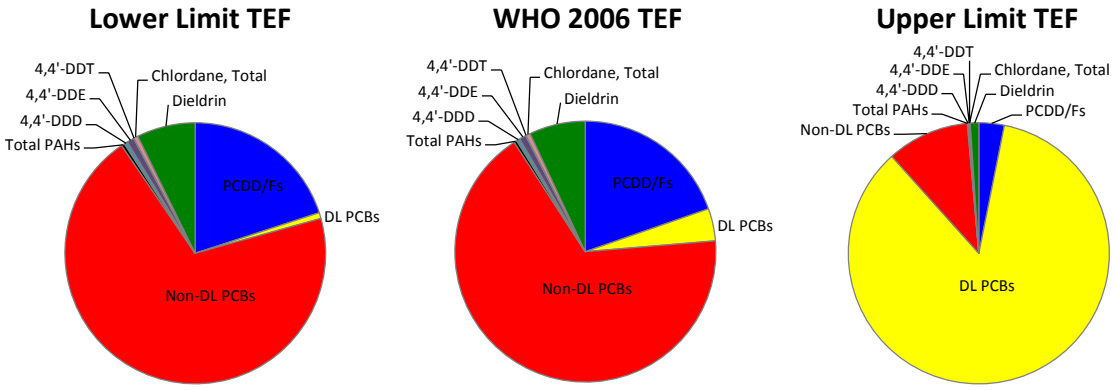


Figure 11. Contribution to total cancer risk by TEF associated with fish consumption for RME scenario and child receptor

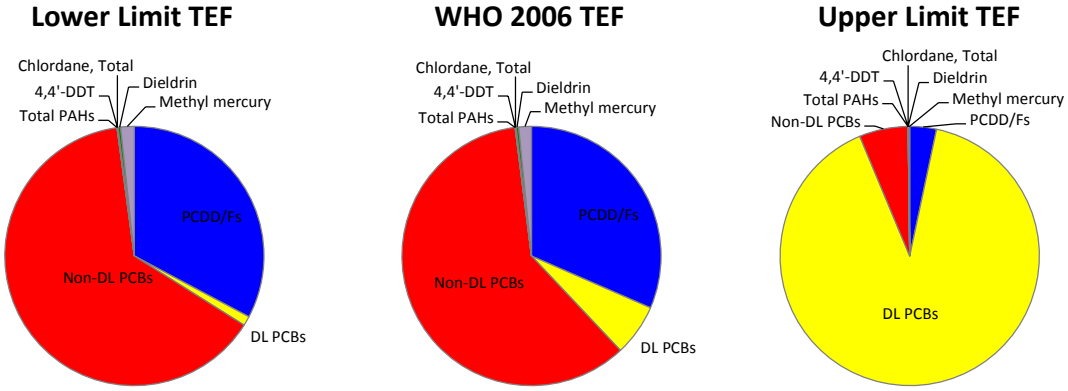


Figure 12. Contribution to total non-cancer hazard by TEF associated with fish consumption for RME scenario and child receptor

Table 17 - Chemical Contributions to Baseline Current Cancer Risks and Noncancer Hazards - Fish Consumption - ToxStrategies vs EPA

COPC	Fish Cancer Risk - RME															
	ToxStrategies Adult, TEF-LL	ToxStrategies Adult, WHO 2006 TEF	ToxStrategies Adult, TEF-UL	EPA Adult, WHO 2006 TEF	ToxStrategies Child, TEF-LL	ToxStrategies Child, WHO 2006 TEF	ToxStrategies Child, TEF-UL	EPA Child, WHO 2006 TEF	ToxStrategies Adult + Child, TEF-LL	ToxStrategies Adult + Child, WHO 2006 TEF	ToxStrategies Adult + Child, TEF-UL	EPA Adult + Child, WHO 2006 TEF	ToxStrategies Percent Contribution to Total Risk (Child); TEF - LL	ToxStrategies Percent Contribution to Total Risk (Child); WHO 2006 TEF	ToxStrategies Percent Contribution to Total Risk (Child); TEF - UL	EPA Percent Contribution to Total Risk (Child), WHO 2006 TEF
TCDD TEQ (D/F)	4E-05	4E-05	5E-05	3E-03	2E-05	2E-05	2E-05	1E-03	6E-05	6E-05	7E-05	4E-03	20%	20%	3%	70%
TCDD TEQ (PCBs)	2E-06	9E-06	1E-03	4E-04	7E-07	4E-06	6E-04	2E-04	2E-06	1E-05	2E-03	6E-04	1%	4%	85%	11%
Total PCBs (NDL)	2E-04	2E-04	2E-04	6E-04	7E-05	7E-05	7E-05	2E-04	2E-04	2E-04	2E-04	8E-04	70%	67%	10%	16%
Total PAHs	2E-07	2E-07	2E-07	NA	4E-07	4E-07	4E-07	NA	6E-07	6E-07	6E-07	NA	0.4%	0.4%	0.1%	NA
4,4'-DDD	9E-07	9E-07	9E-07	3E-06	4E-07	4E-07	4E-07	1E-06	1E-06	1E-06	1E-06	4E-06	0.4%	0.4%	0.1%	0.08%
4,4'-DDE	2E-06	2E-06	2E-06	7E-06	9E-07	9E-07	9E-07	3E-06	3E-06	3E-06	3E-06	1E-05	0.9%	0.9%	0.1%	0.21%
4,4'-DDT	6E-08	6E-08	6E-08	3E-07	3E-08	3E-08	3E-08	1E-07	8E-08	8E-08	8E-08	4E-07	0.03%	0.03%	0.00%	0.01%
Chlordane, Total	1E-06	1E-06	1E-06	4E-06	6E-07	6E-07	6E-07	1E-06	2E-06	2E-06	2E-06	5E-06	0.6%	0.6%	0.1%	0.10%
Dieldrin	2E-05	2E-05	2E-05	7E-05	7E-06	7E-06	7E-06	3E-05	2E-05	2E-05	2E-05	9E-05	7%	7%	1%	2%
Methyl mercury	--	--	--	ND	--	--	--	ND	--	--	--	ND	--	--	--	ND
Total Risk Across All Chemicals - Fish	**2E-04**	**2E-04**	**1E-03**	**4E-03**	**1E-04**	**1E-04**	**7E-04**	**1E-03**	**3E-04**	**3E-04**	**2E-03**	**5E-03**	**100%**	**100%**	**100%**	**100%**

COPC	Fish Noncancer Hazard - RME															
	ToxStrategies Adult, TEF-LL	ToxStrategies Adult, WHO 2006 TEF	ToxStrategies Adult, TEF-UL	EPA Adult, WHO 2006 TEF	ToxStrategies Child, TEF-LL	ToxStrategies Child, WHO 2006 TEF	ToxStrategies Child, TEF-UL	EPA Child, WHO 2006 TEF	ToxStrategies Adult + Child, TEF-LL	ToxStrategies Adult + Child, WHO 2006 TEF	ToxStrategies Adult + Child, TEF-UL	EPA Adult + Child, WHO 2006 TEF	ToxStrategies Percent Contribution to Total Hazard (Child); TEF - LL	ToxStrategies Percent Contribution to Total Hazard (Child); WHO 2006 TEF	ToxStrategies Percent Contribution to Total Hazard (Child); TEF - UL	EPA Percent Contribution to Total Hazard (Child), WHO 2006 TEF
TCDD TEQ (D/F)	6	6	6	71	10	10	11	110	16	16	17	NA	33%	32%	3%	56%
TCDD TEQ (PCBs)	0	1	165	11	0	2	293	18	1	3	457	NA	1%	6%	90%	9%
Total PCBs (NDL)	11	11	11	42	20	20	20	65	31	31	31	NA	64%	60%	6%	33%
Total PAHs	0.002	0.002	0.002	NA	0.003	0.003	0.003	NA	0.01	0.01	0.01	NA	0.01%	0.0%	0.00%	NA
4,4'-DDD	--	--	--	ND	--	--	--	ND	--	--	--	NA	--	--	--	ND
4,4'-DDE	--	--	--	ND	--	--	--	ND	--	--	--	NA	--	--	--	ND
4,4'-DDT	0.001	0.001	0.001	0.004	0.002	0.002	0.002	0.007	0.003	0.003	0.003	NA	0.006%	0.01%	0.001%	0.00%
Chlordane, Total	0.02	0.02	0.02	0.06	0.04	0.04	0.04	0.1	0.06	0.06	0.06	NA	0.1%	0.1%	0.0%	0.05%
Dieldrin	0.06	0.06	0.06	0.2	0.1	0.1	0.1	0.4	0.2	0.2	0.2	NA	0.3%	0%	0.0%	0%
Methyl mercury	0.3	0.3	0.3	2	0.5	0.5	0.5	3	0.8	0.8	0.8	NA	2%	2%	0%	1%
Total Risk Across All Chemicals - Fish	**17**	**18**	**182**	**126**	**31**	**33**	**324**	**195**	**48**	**51**	**506**	**NA**	**100%**	**100%**	**100%**	**100%**

Comment 3-3: State-of-the-Science Probabilistic Risk Assessment (PRA)

Due to the failure of Region 2 to conduct a probabilistic risk assessment (PRA) as specified in USEPA guidance (USEPA 2001), ToxStrategies performed a PRA using site-specific data and toxicity criteria that represent the state-of-the-science approach. In addition, ToxStrategies' PRA evaluated all exposure pathways and COPCs relevant to the LPR. The findings uniformly demonstrate that PCBs and PAHs present significant risk and hazard, thus highlighting the impact of the errors, bias, and omissions in the Region 2 HHRA, and supporting the request that Region 2 should withdraw the HHRA and instead conduct a proper HHRA in accordance with USEPA guidance.

Consistent with USEPA guidance, ToxStrategies conducted a probabilistic risk assessment for the FFS study area. The USEPA has recognized the utility of probabilistic assessments for over two decades (USEPA 1989a), highlighted by the release of an additional volume of RAGS to address the conduct of PRA, "Risk Assessment Guidance for Superfund: Volume III – Part A, Process for Conducting Probabilistic Risk Assessment," (USEPA 2001). In its guidance, USEPA supports the use of PRA to

"…make statements about the likelihood of exceeding a risk level of concern, given the estimated variability in elements of the risk equation. Since the results of point estimate methods generally do not lend themselves to this level of risk characterization (e.g., quantitative uncertainty assessment), PRA can provide unique and important supplemental information that can be used in making Superfund risk management decisions at Superfund sites."

These considerations are particularly important given the size of the proposed remedy (see inset) in combination with the flawed and biased DRA (i.e., point estimate). Region 2 did not attempt to conduct PRA in accordance with Agency guidance, despite the fact that the assumptions and parameters utilized by Region 2 were fraught with uncertainty and variability (as discussed throughout this comment document). Moreover, Region 2 compounded conservative assumption after conservative assumption to generate risk and hazard estimates that ignore Agency guidance. As a result, Region 2 has not correctly characterized risk and hazard for the FFS Study Area.

Given these issues, ToxStrategies performed a probabilistic HHRA using Agency prescribed approaches (USEPA 2001). To do so, ToxStrategies relied on the same risk assessment equations and toxicity criteria as described in detail in Comment 3-1 for the state-of-the-science deterministic HHRA framework. This PRA further explored risks and hazards for adult, adolescent and child anglers, as well as adult, adolescent and child recreators exposed to sediment by incorporating distributions for various chemical-specific and exposure parameters (Appendix B). Notably, distributions were used for two chemical-specific parameters: cooking loss and toxic equivalency factors (TEFs) for dioxin-like compounds.

A Monte Carlo analysis was conducted using Oracle®Crystal Ball v11.1.2.3.500. Distributions of cancer risk and noncancer hazards were determined by exposure pathway (fish ingestion, crab ingestion and sediment exposure) and by chemical group. Risks and hazards were also estimated for combinations of fish and crab (hepatopancreas + muscle [H+M]) consumption and sediment exposure (incidental ingestion and dermal contact) and by chemical group (PCCD/F, DL-PCBs, non-DL PCBs, PAHs and organics).

Results of the PRA demonstrate that the primary risk drivers in the LPR are PCBs and PAHs.

The results of the PRA are highlighted by the risk and hazard estimates for the child receptor (adolescent and adult evaluated but not shown here), as presented in **Figures 13** and **14** and **Tables 18** and **19**. Using the same approach as Region 2 and simply focusing on fish and crab ingestion, these data show that the primary COC in the FFS Study Area are PCBs, as the contribution of PCBs greatly exceeds all other groups at both the 50th and 95th percentile of risk. For fish consumption, dioxin-like and non-dioxin-like PCBs (i.e., total PCBs) contribute >80% of the overall risk and hazard at the 95th percentile of risk estimates (**Figure 13, Table 18**). At the 50th percentile, the contribution of risk is even more remarkable – Total PCBs contribute 96% of the risk and 95% of the hazard.

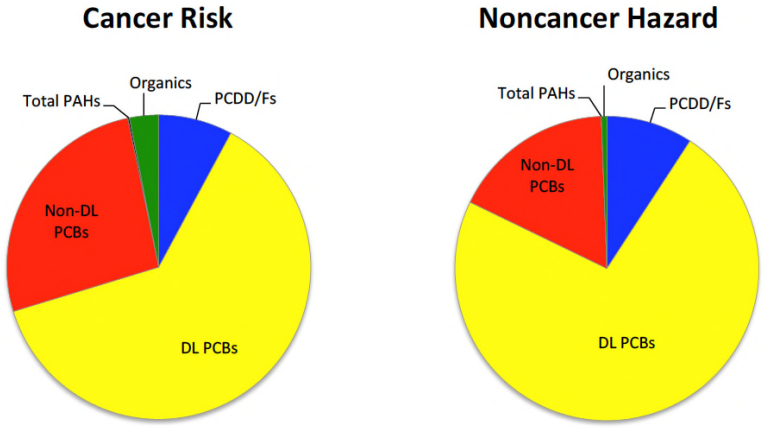


Figure 13. Results of PRA: Contributions of risks and hazards associated with fish consumption for the child receptor (95%ile)

For crab consumption, PCBs contribute 69% and 86% of the risk for the 50th and 95th percentile estimates, respectively; and for hazard, 67% and 87%, respectively. Similar to the DRA, the results of the state-of-the-science PRA also demonstrate that when other complete pathways are considered (i.e., contact with sediments), PAHs are the primary risk driver (**Figure 14**). At the 50th percentile of risk, PAHs contribute 97% of the estimated risk, whereas at the 95th percentile, PAHs contribute 96% of the risk.

Noncancer hazard estimates at the 50th percentile are dominated by Total PCBs (87%), and similarly, at the 95th percentile of hazard, PCBs contribute 82% of the hazard.

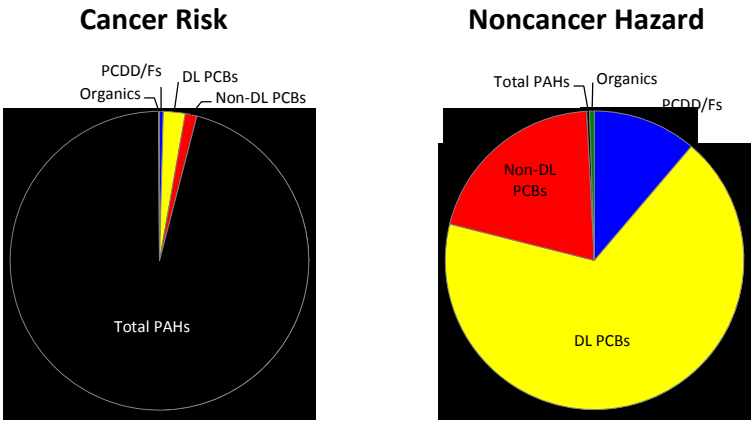


Figure 14. Results of PRA: Contributions of risks and hazards associated with all pathways for the child receptor (95%ile)

ToxStrategies also evaluated risks and hazards in the PRA using the TCDD toxicity factors utilized by USPEA Region 2. Even when these flawed and out-of-date values (See Section 2) were considered, the risk drivers remained the same (data not shown). For fish consumption, PCBs were the risk drivers; PCBs were also the risk driver for noncancer when all pathways were considered. For cancer risk, PAHs were the risk driver when all pathways were considered.

Collectively, these findings further highlight the significance of the errors, bias and omissions in Region 2's HHRA – the risks and hazards associated with PCBs and PAHs cannot be overlooked. These results show that Region 2 should withdraw the HHRA in the FFS and conduct a proper HHRA that conforms to USEPA guidance that considers all site specific data, all complete exposure pathways, all COCs present at the site, and that utilizes scientifically defensible toxicity criteria for the COCs.

Table 18. Probabilistic cancer risk estimates for the child scenario. Shaded cells indicate a risk level that exceeds 10^{-4}

Risk								
Chemical	**Fish**		**Crab (H+M)**		**Sediment**		**Total (Fish + $Crab_{H+M}$ + Sediment)**	
	50%	**95%**	**50%**	**95%**	**50%**	**95%**	**50%**	**95%**
PCDD/F	2.4E-06	1.2E-05	1.3E-07	2.2E-07	2.2E-06	7.9E-06	5.4E-06	1.7E-05
DL PCB	4.3E-06	9.5E-05	1.7E-07	2.0E-06	6.0E-07	9.9E-06	5.6E-06	1.0E-04
Non-DL PCB	9.6E-06	4.0E-05	1.3E-07	2.2E-07	6.1E-06	2.4E-05	1.8E-05	5.6E-05
Total PCB	1.7E-05	1.2E-04	3.2E-07	2.1E-06	7.4E-06	3.1E-05	2.8E-05	1.5E-04
PAH	7.6E-08	2.7E-07	7.1E-09	1.2E-08	1.1E-03	4.2E-03	1.1E-03	4.2E-03
Organics	1.3E-06	4.7E-06	2.8E-08	4.8E-08	2.8E-07	1.1E-06	1.8E-06	5.3E-06
All COCs (Sum PRA)	1.8E-05	1.5E-04	4.6E-07	2.5E-06	1.1E-03	4.3E-03	1.2E-03	4.4E-03
Percent Contribution								
Chemical	**Fish**		**Crab (H+M)**		**Sediment**		**Total (Fish + $Crab_{H+M}$ + Sediment)**	
	50%	**95%**	**50%**	**95%**	**50%**	**95%**	**50%**	**95%**
PCDD/F	14%	8%	28%	9%	0%	0%	0%	0%
DL PCB	24%	62%	37%	79%	0%	0%	0%	2%
Non-DL PCB	54%	26%	27%	9%	1%	1%	2%	1%
Total PCB	96%	82%	69%	86%	1%	1%	2%	3%
PAH	0%	0%	2%	1%	99%	99%	97%	96%
Organics	7%	3%	6%	2%	0%	0%	0%	0%
Total Risk	1.8E-05	1.5E-04	4.6E-07	2.5E-06	1.1E-03	4.3E-03	1.2E-03	4.4E-03

Table 19. Probabilistic noncancer hazard estimates for the child scenario. Shaded cells indicate a hazard index >1

Hazard								
Chemical	Fish		Crab (H+M)		Sediment		Total (Fish + $Crab_{H+M}$ + Sediment)	
	50%	95%	50%	95%	50%	95%	50%	95%
PCDD/F	1.25	6.28	0.07	0.12	1.15	4.13	2.82	9.00
DL PCB	2.23	49.80	0.09	1.02	0.31	5.16	2.90	54.35
Non-DL PCB	2.80	11.76	0.04	0.06	1.78	7.05	5.24	16.26
Total PCB	6.10	58.00	0.13	1.07	2.40	10.91	9.78	66.23
PAH	0.00	0.00	0.00	0.00	0.07	0.27	0.07	0.27
Organics	0.14	0.40	0.00	0.01	0.00	0.02	0.15	0.42
All COCs (Sum PRA)	6.43	68.25	0.20	1.21	3.31	16.62	11.19	80.29
Percent Contribution								
Chemical	**Fish**		**Crab (H+M)**		**Sediment**		**Total (Fish + $Crab_{H+M}$ + Sediment)**	
	50%	**95%**	**50%**	**95%**	**50%**	**95%**	**50%**	**95%**
PCDD/F	19%	9%	34%	10%	35%	25%	25%	11%
DL PCB	35%	73%	46%	84%	9%	31%	26%	68%
Non-DL PCB	44%	17%	19%	5%	54%	42%	47%	20%
Total PCB	95%	85%	67%	88%	72%	66%	87%	82%
PAH	0%	0%	0%	0%	2%	2%	1%	0%
Organics	2%	1%	2%	1%	0%	0%	1%	1%
Total Hazard	6.43	68.25	0.20	1.21	3.31	16.62	11.19	80.29

SECTION 4: Comments on PRGs (Appendix E) Prepared by Region 2

The preliminary remediation goals (PRGs) for LPR RM0-8 sediments presented by Region 2 were developed using similar deterministic methods and exposure assumptions employed in its HHRA, a derivation inconsistent with federal guidance. Like the HHRA, the LPR FFS PRGs do not represent the state-of-the-science in either derivation methodology or parameter input. In addition to ignoring site-specific data on fish and crab consumption, Region 2 applied inaccurate measures of PCBs that underestimated Total PCB exposures, resulting in PCB PRGs that may not lead to acceptable risk and hazard. Similarly, the Region 2 prepared a background risk assessment that used inaccurate measures of COPCs, thereby underestimating background risk and hazard estimates. Furthermore, there are significant errors in some of the sediment PRG calculations. As a result, the PRGs and background risk assessment presented by Region 2 are inadequate to support scientifically defensible remedial decisions. The PRGs should be corrected and revised to reflect the state-of-the-science as described in the comments in this section.

Comment 4-1: Region 2 derived PRGs for Total PCBs using inaccurate measures of PCBs, resulting in PRGs that underestimate Total PCB exposures, Total PCB cancer risk, and Total PCB noncancer hazard

Region 2 calculated Preliminary Remediation Goals (PRGs) for PCBs using modeled fish and crab tissue COPC concentration estimates based on Aroclor sediment data. This approach has two shortcomings: a) it likely underestimates the actual Total PCB sediment and (by extension) fish and crab tissue concentrations, and b) it precludes an accurate analysis of Total PCBs risk consistent with USEPA guidance, whereby the risk and hazard of both dioxin-like and non-dioxin-like PCBs is calculated. Ultimately, the effect of these shortcomings is the derivation of PCB PRGs that are not protective of exposures to Total PCBs (i.e., non-dioxin-like and dioxin-like PCBs). Region 2 should update its PCB PRG calculations to accurately and completely account for risk and hazard from Total PCBs.

Region 2 derived sediment Preliminary Remediation Goals (PRGs) for Total PCBs based on estimates of Aroclor concentrations and Aroclor-based toxicity factors. This approach is described in Appendix A6 of Region 2's 2014 LPR FFS. In Section 3 of Appendix A6, Region 2 justified its reliance on Aroclor data by noting that these PCB mixtures were reported for most of the sediment and tissue samples in the sampling datasets, and, it contended, therefore represented a continuity among datasets for establishing sediment-tissue relationships. The lone exception was the 2003 REMAP sediment dataset, which included limited PCB congener data but no Aroclor data, and which was considered an important addition to the analysis as it provided low level COPC data. Region 2 conducted regression analyses to estimate Aroclor concentrations for the 2003 REMAP dataset and used similar methods to determine a biota-sediment accumulation factor (BSAF) for PCBs for all datasets based on summing all Aroclor data for each sample in each dataset.

Importantly, non-detect results for individual Aroclors were not included in the sum, representing a potential underestimation of Total PCBs in Region 2's analysis. More importantly, Region 2 used a conversion factor of 1.25 it derived in the "Contaminant Inventory Analysis" (2014 LPR FFS Appendix A5) to the Aroclor data to approximate what the 209 congener-based Total PCB levels would be, a relationship applied to the tissue and sediment PCB Aroclor concentrations to derive the final Total PCB values used in the risk assessment. By employing this approach for establishing Total PCB concentration estimates and inter-media relationships, Region 2 likely underestimated Total PCB concentrations and ignored the cancer risk and hazard associated with dioxin-like PCBs (calculated using TCDD-based TEFs per 2010 USEPA TEF recommendations). Finley et al. (1997) used Passaic sediment and fish sampling to demonstrate the differences that a risk analysis based on Aroclors vs. PCB congeners can have on exposure and risk estimates. The investigators reported total risks were nearly 10-fold lower for sum Aroclor concentrations using an Aroclor slope factor compared to PCB congener-based risk calculations. Furthermore, evaluating DL-PCB congeners alone resulted in risk estimates over 100-fold greater than the Aroclor-risk analysis yielded. When risk was calculated for the proper Total PCBs (non-DL-PCB and DL-PCB congeners), it exceeded the Aroclor-based "Total PCBs" risk estimate by 25-fold. This observation is driven by the fact that the current USEPA cancer slope factor (CSF) and noncancer reference dose (RfD) for PCB mixtures likely underestimate the potency of the DL-PCBs since (1) the USEPA's CSF and RfD values for PCBs are based on the dose of PCB technical mixtures (Aroclor) and not the dose of the DL-PCBs within the Aroclor mixtures, and (2) the DL-PCBs represent only a fraction of the total dose of each Aroclor mixture. The Finley et al. (1997) study highlights the importance of accounting for PCB congener data in risk assessment, as Aroclor-based PCB data do not represent true "Total PCBs."

Therefore, it is very likely the case that the Total PCB-based PRG derived by Region 2 in its 2014 LPR FFS only accounts for a fraction of the actual PCBs present in the LPR. Moreover, the Region 2 Total PCB PRG does not comply with 2010 USEPA TEF guidance as it cannot account for the risk associated with DL-PCBs (given it is based on the sum of Aroclor mixtures), and thus greatly underestimates the risk of Total PCBs. Since the LPR FFS Study Area remedies considered by Region 2 do not account for DL-PCBs, the remedies are not appropriate for cleaning up the river to acceptable chemical risk levels. Region 2 should re-evaluate its PCB PRG using Total PCBs based on congener-specific data that accounts for dioxin-like PCBs.

Comment 4-2: Region 2 underestimated background cancer risk and hazards based on sediment COPC levels measured above the Dundee Dam

Region 2 calculated background risk and hazard estimates based solely on concentrations of TCDD and non-dioxin-like PCBs in sediments collected at River Mile 17.4 in the Upper Passaic River. These data represent only a fraction of all dioxins and furans (PCDD/Fs) and Total PCBs (non-dioxin-like and dioxin-like). Furthermore, the impact of background sediment PAHs on risk was not addressed.

Since the background risk and hazard is estimated to help risk managers put the LPR FFS Study Area risk and hazard estimates into context, ignoring these critical COPCs results in considerable underestimates of the background risks. Region 2 should revise its background site analysis to include PAHs, all dioxins, furans, and DL-PCBs so that the risks and hazards reported in the LPR FFS Study Area provide sufficient understanding to inform risk managers.

In addition to PRG calculations, Region 2 conducted a background risk assessment on sediment data collected above Dundee Dam (RM17.4). Risk assessments of these background sediments are important for contextualizing the risk estimates of the FFS Study Area. Background risk characterization helps contextualize the Study Area risks for USEPA risk managers, enabling them to make informed decisions on remedial actions. However, the background risk assessment conducted by Region 2 for the LPR FFS Study Area underestimates risk by leaving several critical COPCs unaccounted for, and thus is far from adequate. First, Region 2 did not incorporate DL-PCBs in the background risk assessment, only accounting for non-DL-PCBs. While Region 2 found the background non-DL-PCB concentrations alone yielded fish concentrations that resulted in unacceptable risk for combined adult and child anglers (excess cancer risk = 2×10^{-4}), and unacceptable hazard for adults (HI = 10) and children (HI = 16), they only reflect a portion of Total PCB risk and hazard since DL-PCBs would have increased both.

Second, Region 2 used only 2,3,7,8-TCDD sediment concentrations to represent all PCDD/Fs when deriving background risk and hazard estimates. They note that background sediment TCDD levels (2 ppt) are much lower than in the LPR FFS Study Area sediments, and that background TCDD risks and hazards are not elevated above unacceptable standards, evidence that the Upper Passaic River is not a source for TCDD at the Study Area. Again, however, by ignoring the other 16 PCDD/F congeners that are likely present in the Upper Passaic River sediments, Region 2 underestimates PCDD/F TEQ risks and hazards. Had the Agency included all relevant PCDD/F congeners in the background risk assessment (as required in any risk assessment per 2010 USEPA TEF guidance), the actual D/F TEQ risks and hazards may have actually exceeded unacceptable standards (assuming Region 2 applied the same exposure parameters and toxicity factors it used in the baseline LPR FFS Study Area risk assessment).

Additionally, the LPR FFS background assessment did not include PAHs for the HHRA. As demonstrated in the sediment direct contact risk evaluation presented above in Section 2, sediment PAHs are a major contributor to risk for the LPR FFS Study Area. Moreover, a major source of the PAHs in the LPR sediments is the Upper Passaic River, as sediment Total PAH concentrations just above Dundee Dam are nearly twice as high as those of the LPR RM0-8 (see Section 4.2.1 of the 2014 Region 2 Remedial Investigation Report). The fact that the Upper Passaic River is a significant and continuous contributor to human health risk to receptors of the LPR via Total PAHs calls into question the efficacy of any of the remediation alternatives considered by Region 2, since PAHs will continue to contaminate the LPR after any remedial activity has been completed.

Region 2 states, "Background contaminant contributions to the FFS Study Area were considered, to adequately understand contaminant sources and establish realistic risk reduction goals" (Region 2, 2014 – Appendix E). Yet Region 2 has recommended an extensive remediation alternative of LPR RM0-8 that in no way accounts for the unacceptable levels of Total PAHs and non-DL-PCBs in the background sediments that will continue to deposit in the LPR FFS Study Area during and after remedy completion. In its background risk assessment conclusions, Region 2 argues that even though the background sediments result in unacceptable risks (due to non-DL-PCB concentrations) above Dundee Dam, the mechanisms associated with mobilization and redeposition in the LPR FFS Study Area would have a diluting effect, with lower concentrations settling in the Study Area. In this, Region 2 implies that the contaminated background sediments will not impact the Study Area after it has been remediated. No fate and transport modeling on the background sediments was conducted to support this contention, however, which is a notable oversight given the effort expended by Region 2 on numerical modeling of the LPR FFS Study Area for the baseline and future risk assessments. Furthermore, an updated background risk assessment that accounts for the other critical COPCs described above is likely to yield even higher risks and hazards, making the idea that these background sediments would not impact risks and hazards at a remediated LPR FFS Study Area even less credible in the absence of a supporting fate and transport modeling assessment.

Region 2 should re-evaluate its background risk assessment by accounting for sediment PAHs (direct sediment contact) and all dioxins, furans, and DL-PCBs, so that LPR risk managers are provided with a complete and accurate characterization of the unacceptable risks associated with sediments that are feeding into the LPR FFS Study Area.

Comment 4-3: Region 2 PRGs are unnecessarily conservative

Contrary to USEPA guidance, Region 2 did not utilize the most relevant site-specific exposure parameter data (based on empirical data from comprehensive LPR creel angler surveys), or when site-specific data were not available, the most current USEPA OSWER default assumptions, in the development of the sediment PRGs for the LPR RM0-8. Furthermore, Region 2 did not apply the most scientifically defensible cancer risk or noncancer hazard toxicity factors in deriving PRGs for dioxin-like compounds. As a result, the Region 2 PRGs do not accurately reflect the LPR FFS Study Area conditions or the best science, and thus should not be used to make risk management decisions. Region 2 should revise its PRG values using the site-specific exposure data and most current USEPA OSWER default exposure parameters.

As with the baseline and future risk assessments performed for the LPR FFS Study Area, Region 2 should apply the relevant site-specific exposure parameter data, or when site-specific data were not available, the most current USEPA OSWER default assumptions in deriving PRGs for the LPR FFS Study Area. Regarding PCDD/Fs specifically, Region 2 also did not utilize the most scientifically defensible cancer risk or noncancer hazard toxicity factors in deriving these PRGs. Combined, these shortcomings resulted in Region 2 calculating unnecessarily conservative PRGs that do not reflect the Study Area population or characteristics. This is highlighted by the fact that these PRGs cannot be

achieved even after the extensive remediation alternative selected by Region 2 is completed, as their own calculations show that cancer risks and noncancer hazards post-remediation will continue to be unacceptable. Realistic PRGs can be derived if empirically-based, site-specific exposure characteristics and the most scientifically defensible toxicity factors are incorporated into the PRG calculations. Therefore, Region 2 should revise their fish, crab, and sediment PRGs using the exposure parameter values and toxicity factors described and applied above in Sections 2 and 3, respectively.

Comment 4-4: PRG Calculation Errors and Ambiguity

Region 2 developed sediment PRGs based on incorrect assumptions and erroneous calculations and did not present a clear methodology. Importantly, it appears that the sediment PRG calculated for TCDD TEQ by Region 2 is incorrect by a factor of 2 (7.1 pg/g vs. 14 pg/g for fish consumption, using the methods described in Region 2's LPR FFS PRG document). Region 2 should revise its PRG using the correct calculations.

Region 2 made several errors in conducting and reporting the preliminary remediation goals for both tissue and sediment in Appendix E – Development of Preliminary Remediation Goals that should be corrected. These include:

1. The sediment PRGs derived by Region 2 are based on averaging the estimated tissue concentrations of two fish species (American eel and white perch) without accounting for species-specific fish ingestion rates (Appendix E, Section 1.3, Tables 1-10 and 1-11). Region 2 justifies this approach by asserting that no species-specific consumption patterns exist for the LPR FFS Study Area (stated in 2014 USEPA FFS Appendix E pg. 1-11 and in footnotes (b) and (c) in Table 1-10). This is incorrect, as there have been multiple creel angler surveys conducted within the LPR FFS Study Area, the data from which have been used to develop scientifically-defensible species-specific ingestion rates described above in Comment Sections 2 and 3. In fact, species-specific data on fish ingestion are available for one of the surveys used by Region 2 to derive its fish ingestion rates (Connelly et al., 1992, as presented in TAMS, 2000), so it is unclear why Region 2 failed to derive species-specific fish ingestion rates for the LPR FFS, even if the data are not specific to the LPR. Furthermore, the focus on just these two fish species ignores the fact that three other fish species (catfish, carp and striped bass) are sometimes caught and consumed by LPR anglers. Thus, two of the underlying assumptions in the sediment PRGs derived by Region 2 – that eel and perch are consumed in equal proportions, and that only eel and perch are consumed – are incorrect. Thus, taking the average of sediment PRGs calculated for the two species results in inaccurate PRGs. PRGs should be developed that properly weight the species-specific consumption of each separate species.

2. Region 2 presents several erroneously calculated sediment PRGs for TCDD TEQ based on fish consumption in Table 1-10. Region 2 states that these sediment PRGs for fish are based on an average of the specific PRGs derived for American eel and white perch. Example calculations for these PRGs are presented in Table 1-9. While it is clear that the PRG for non-dioxin-like PCBs in fish

presented in Table 1-10 is the average of the species-specific non-dioxin-like PCB PRGs presented in Table 1-9, this is not the case for most of the TCDD TEQ PRGs. For example, the average of the American eel and white perch sediment PRGs for risk level 1 x 10^{-5} presented in Table 1-9 (3.1 and 1.2 pg/g, respectively) is 2.2 pg/g. However, the TCDD TEQ PRG presented in Table 1-10 for this risk level is 1.6 pg/g. Larger errors are observed for fish consumption-based sediment PRGs for TCDD TEQ at risk level 1 x 10^{-4} (average PRG = 66 pg/g vs. 22 pg/g) and noncancer hazard quotient of 1 (average PRGs = 14 pg/g vs. 7.1 pg/g). ***The erroneous TCDD TEQ hazard-based sediment PRG (7.1 pg/g) is particularly significant, since Region 2 has proposed this as the overall PRG for TCDD, when following its averaging method would actually double the sediment PRG for TCDD.***

3. The purpose of Table 1-11 in the PRG document is far from clear. Region 2 describes it as an "Example Calculation of the Sediment PRGs for TCDD TEQ Calculated for 56 Fish Meals," but the steps of this calculation presented in the table appear to be out of order (solving for tissue PRG rather than sediment PRG).

4. Region 2 PCB PRGs cannot be directly compared with the NJDEP "do not eat" fish advisory levels for PCBs. As shown in Table 1-8, the Region 2-calculated PRGs for "TCDD TEQ", which as defined by Region 2, only accounts for PCDD/Fs (i.e., "TCDD TEQ (D/F)"). Similarly, the PRGs for PCBs are only based on non-dioxin-like PCBs and do not account for dioxin-like PCBs (what the Agency has inaccurately termed "TCDD TEQ (PCBs)" or "TCDD (PCBs)"). However, the NJDEP "do not eat" fish advisories are based on set levels for 1) dioxins and furans (D/F TEQ), and 2) Total PCBs (accounting for both dioxin-like and non-dioxin-like PCBs). Therefore, the PCB PRGs derived by Region 2 underestimate risk and hazard relative to the NJDEP fish advisory levels for PCBs, since the former does not account for Total PCBs.

5. In its development of interim biota tissue PRGs (Appendix E, Section 1.2), Region 2 compares risk- and hazard-based tissue estimates associated with fish and crab meal frequency. Footnote (a) in Table 1-8 incorrectly states that 34 crab meals per year yields ~1.5 crab meals every week (52 weeks in a year, 34 crab meals per year is equal to 0.65 crab meals per week or 1 crab meal every 1.5 weeks). The same error is made later in Table 1-10. These errors should be corrected.

Given these shortcomings, Region 2 should utilize the available LPR species-specific fish consumption rates to calculate properly weighted sediment PRGs rather than PRGs based on average values. Furthermore, it is imperative that Region 2 recalculate their fish consumption-based PRG for TCDD TEQ since its current value is incorrect and underestimated (using its own methodology) by two-fold (7.1 pg/g vs. 14 pg/g).

Comment 4-5: Lack of rationale and information regarding interim PRGs.

Region 2 does not adequately explain the derivation, utility, or plan associated with the interim biota tissue PRGs. Such discussion must be significantly more robust, including specific information as to why this is useful in the context of the FFS.

In the development of LPR RM0-8 Study Area PRGs, Region 2 presents a discussion of interim biota tissue PRGs. These PRGs were calculated based on the monthly consumption of one eight-ounce fish or crab meal. The stated purpose of these interim PRGs is two-fold: (1) for comparison with current statewide fish and crab consumption advisories established by the NJDEP and the New Jersey Department of Health and Senior Services (NJDHSS), and (2) as a benchmark during post-remediation monitoring to evaluate if contaminant concentrations are decreasing toward PRGs as expected. However, it is unclear how these data would be used during post-remediation monitoring. These calculations do not provide additional insight beyond the information that would be provided through traditional sampling and comparison to target PRGs. Moreover, Region 2 does not provide any anticipated schedule for when it expects to switch from the interim PRGs to the permanent PRGs it developed for this Site. However, Region 2 derived their PRGs using a model that purports to predict sediment and tissue COPC levels during and 30-years after remediation alternatives are to be implemented. The PRG shortcomings described above notwithstanding, Region 2 should apply its modeled predictions to a schedule in which the point in time is clearly stated as to when it anticipates switching from the interim to permanent PRGs so that risk managers can make informed decisions.

Thus, Region 2 should clarify how and when interim PRGs will be used, and explicitly describe the decision-making process by which it expects the permanent PRGs to replace the interim PRGs.

SECTION 5: State-of-the-Science Evaluation of PRGs

Region 2 derived its sediment preliminary remediation goals (PRGs) for the LPR FFS Study Area that were derived in a deterministic manner using default fish/crab ingestion rates that are not reflective of the Passaic River angling community. ToxStrategies employed a state-of-the-science approach to determine health-protective PRGs for TCDD and PCBs. Specifically, a model was used to assess sediment concentrations that were protective of hazard and risks associated with exposure to TCDD and PCBs via fish and crab consumption. These data were then evaluated spatially to determine the location and volume of sediment that would be subject to remedial action in order to achieve the health-protective sediment concentrations (PRGs). The results demonstrated that a TCDD sediment PRG of 1 ppb was protective of both cancer risk and noncancer hazard. This sediment PRG resulted in only 9% of sediment area from RM0-8 requiring remedial action. In contrast, acceptable PCB risk and hazard were not achieved even if the TCDD PRG was decreased to 0.5 ppb, resulting in remedial action for 12% of the LPR sediment. For the current sediment condition, PCBs account for 74% of the noncancer hazard associated with fish ingestion using TEF distributions in the calculations. Conducting a similar analysis but focusing on PCB-containing sediments, the PRG analysis for consuming anglers shows a Total PCBs PRG of 0.7 ppm is health protective, which corresponds to remedial action for 71% of the LPR RM0-8 area. These calculations demonstrate that Region 2 can obtain acceptable risk and hazard for TCDD with much less remedial work than that proposed in the FFS. Region 2 should withdraw its proposed remedial options, conduct its PRG determination using the approach described herein, and thereafter revise its proposed remedial options consistent with the new information. These analyses further demonstrate that PCBs are widely distributed in the LPR sediment at elevated concentrations and pose much more of a risk/hazard to human health than does TCDD – a fact that was overlooked repeatedly by Region 2.

Comment 5-1: Removing surface sediment containing TCDD at 1 ppb and greater from the LPR will achieve acceptable risk and hazard values for ingestion of fish and crab

In an effort to improve on the overly simplistic approach utilized by Region 2 to derive PRGs, ToxStrategies derived health-protective PRGs using a state-of-the-science approach. The series of iterative analyses indicated that a PRG of 1ppb TCDD is protective for cancer risks and noncancer hazards associated with fish and crab consumption. Additonally, for consuming anglers, a PCB sediment PRG of 0.7ppm was found to be protective for cancer risks and noncancer hazards associated with PCB and all DLC (which includes TCDD as well as PCB congeners PCB-118 and PCB-126).

Region 2 has proposed sediment preliminary remediation goals (PRGs) for the LPR FFS Study Area that were derived in a deterministic manner using default fish/crab ingestion rates that are not reflective of the Passaic River angling community. Moreover, Region 2

used other conservative assumptions which, when combined, lead to non-scientifically defensible sediment PRGs.

To address the many shortcomings in the scientific approach utilized by Region 2 to derive PRGs, ToxStrategies used a state-of-the-science approach to develop health-protective PRGs that reflect site-specific data. To do so, an empirical bioaccumulation model was used to estimate current and future fish tissue concentrations of TCDD or PCBs based on various TCDD or PCB concentrations in sediment (Figure 15 and 16). The concentrations in sediment represent candidate PRG values. Using an iterative approach, various candidate PRG values were evaluated in an attempt to identify fish tissue concentrations that resulted in acceptable risk and hazard levels. Specifically, this method involved iteratively calculating risk and hazard with progressively decreasing exposure point concentrations until acceptable risk and hazard are achieved at the percentile of interest (i.e., the 95th percentile on the distributions of risk and hazard). The acceptable risk levels in fish were based on fish ingestion that resulted in cancer risk equal to or less than 1 x 10^{-4} ($\leq$ 1 x 10^{-4}) and noncancer hazard estimates less than 1.0 ($\leq$ 1.0). The probabilistic PRG assessment included distributions for the following parameters as defined in the probabilistic risk assessment (Appendix B): updated LPR creel angler survey (CAS) fish and crab ingestion rates, TEF, cooking loss, body weight and exposure duration. Predicted mean fish tissue concentrations from the empirical bioaccumulation model were used in the risk assessment. Additionally, the most scientifically robust, peer-reviewed toxicity factors available for TCDD were used in the PRG determination (see Appendix C for more detailed methods on the PRG calculations).

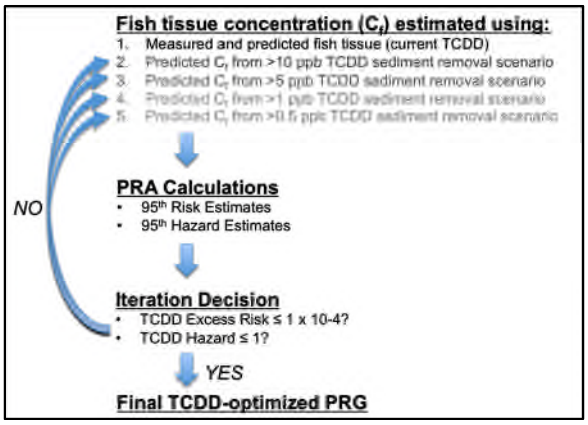


Figure 15. Process for identifying acceptable TCDD sediment PRGs

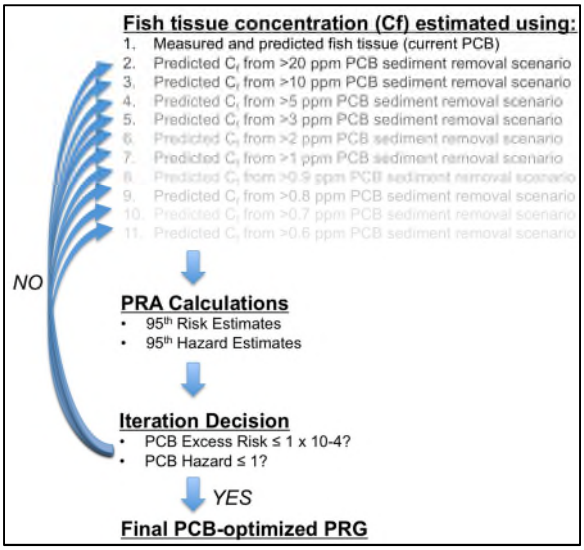


Figure 16. Process for identifying acceptable PCB sediment PRGs

These iterative exercises then resulted in health-protective sediment PRGs that are associated with acceptable cancer risk and noncancer hazard estimates for TCDD or PCBs (i.e., PCB-126, PCB-118 and Total PCBs (209 congeners)) in an adult angler

consuming fish and crab as well as all adult anglers (consumers and non-consumers). Because of the sophistication of the model, these exercises were carried out in two phases: 1) TCDD optimization and 2) PCB optimization. For the TCDD optimization phase, potential TCDD PRGs that were evaluated included the current sediment condition and 10ppb, 5ppb, 1ppb and 0.5ppb with the assumption that any sediment remediated would be replaced with material containing detection limit concentrations of TCDD and PCBs.

Key Finding:
A sediment PRG of 1 ppb for TCDD is health-protective.

The results of the TCDD-optimized modeling show that when all LPR RM0-8 anglers were considered (consumers and non-consumers of fish and crab), current sediment concentrations of TCDD were found to yield fish and crab tissue concentrations of TCDD that did not pose an unacceptable risk or hazard (Table 20). Further, for consuming anglers, a TCDD sediment PRG of 1ppb was found to be protective of both TCDD cancer risk and TCDD noncancer hazard associated with fish and crab consumption from the LPR.

Table 20. Results of the state-of-the-science evaluation of PRGs: TCDD-optimized model. Check marks indicate that acceptable risks were achieved at the given PRG.

Sediment Cleanup Scenario	All Anglers						Consuming Anglers					
	TCDD		DLC		Total PCB		TCDD		DLC		Total PCB	
	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard
Current	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗	✓	✗
10ppb - TCDD	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗
5ppb - TCDD	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗
1ppb - TCDD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
0.5ppb - TCDD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗

Scenario notes: RM0-8, Mean fish tissue EPCs, Distributed TEFs, TCDD Cancer Risk evaluation is based on a cancer slope factor (CSF) of 9700 $(mg/kg\text{-}day)^{-1}$ and Hazard based on JECFA value.

As shown in Table 20, when accounting for PCBs, a TCDD sediment PRG of 10ppb yielded acceptable cancer and noncancer hazards for all anglers (requiring a sediment cleanup of 2% of the RM0-8 area; see Comment 5-2). For consuming anglers, however, even if the TCDD PRG was decreased to 0.5ppb, both cancer risks and noncancer hazards associated with PCBs would remain unacceptable. For the current sediment condition, PCBs account for 63% to 74% of the noncancer hazard associated with fish ingestion, depending on the exposure scenario (all anglers and consuming anglers) using TEF distributions in the calculations. These results suggest that PCBs are widely distributed in the LPR sediment at concentrations that will require remedial action in the future.

Key Finding:
All candidate PRGs for PCBs were associated with unacceptable risk (i.e., no acceptable PCB sediment concentration was identified).

Results of the PCB-optimized model are shown in Table 21. In this series of iterative runs, the following candidate PCB PRGs were evaluated: current, 20ppm-, 10ppm-, 5ppm-, 3ppm-, 2ppm-, 1ppm-, 0.9ppm-, 0.8ppm-, 0.7ppm-, and 0.6ppm-Total PCBs. The PCB-optimized modeling show

that when all LPR RM0-8 anglers were considered (consumers and non-consumers of fish and crab), a PCB PRG of 10ppm is necessary to be protective of cancer risks and noncancer hazards (Table 21). Further, for consuming anglers, a PCB sediment PRG of 0.7ppm was found to be protective for cancer risks and noncancer hazards associated with PCB and all DLC (which includes TCDD as well as PCB congeners PCB-118 and PCB-126).

Table 21. Results of the state-of-the-science evaluation of PRGs: PCB-optimized model. Check marks indicate that acceptable risks were achieved at the given PRG.

Sediment Cleanup Scenario	All Anglers						Consuming Anglers					
	TCDD		DLC		Total PCB		TCDD		DLC		Total PCB	
	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard	Cancer Risk	Non-Cancer Hazard
Current	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗	✓	✗
20ppm - PCB	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗	✓	✗
10ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗
5ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✗
3ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
2ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
1ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
0.9ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
0.8ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
0.7ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
0.6ppm - PCB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Scenario notes: RM0-8, Mean fish tissue EPCs, Distributed TEFs, TCDD Cancer Risk evaluation is based on a cancer slope factor (CSF) of 9700 $(mg/kg\text{-}day)^{-1}$ and Hazard based on JECFA value.

Collectively, these calculations greatly improve upon the Region 2 assessment by incorporating exposure parameters specific to LPR RM 0-8 and scientifically defensible toxicity criteria for TCDD into a probabilistic risk assessment framework. Moreover, these calculations show that Region 2 can obtain acceptable risk and hazard for TCDD with much less remedial work than that proposed in the FFS. Thus, Region 2 should withdraw its proposed remedial options, conduct its PRG determination using the approach described herein, and revise its proposed remedial options. Finally, it is clear from this analysis that PCBs are widely distributed in the sediment of the LPR at elevated concentrations and pose much more of a risk/hazard to human health than does TCDD.

Comment 5-2: Spatial analyses conducted using a state-of-the-science approach indicate that only 9% of the Study Area should be remediated based on TCDD.

An independent spatial analysis reveals that a sediment remediation scenario based on a PRG of 1 ppb TCDD would require remediation of only 9% of the sediment area from RM0-8, which is only a small portion of the area Region 2 has proposed be subject to remedial action in the FFS as a result of its flawed and biased HHRA and PRG evaluation. This analysis demonstrates that the impact of Region 2's compounded conservatism and series of actions that are not supported by scientific data are associated with overly burdensome remedial actions (and thus cause undue waste of financial resources and unnecessary societal impacts to area residents).

1. TCDD in LPR sediments can be addressed in manner that is substantially smaller in scale than that proposed by Region 2. This analysis demonstrates that less than 10% of LPR sediment can be remediated and result in acceptable TCDD concentrations in fish and crab tissue.

2. PCBs are widely distributed in the LPR sediment at elevated concentrations. Approximately 70% of LPR sediment may require remediation to result in acceptable PCB concentrations in fish and crab tissue.

Based on the findings from the state-of-the-science evaluation of PRGs (Comment 5-1), the area and location of sediment that would need to be remediated was evaluated. This spatial assessment was conducted using weighted Thiessen polygons; specifically, remediation was simulated by identifying all polygons with sediment concentrations that exceed the specified target cleanup levels, and replacing these concentrations with post-remediation levels (i.e., chemical-specific detection limits).

The results of this spatial assessment show that a sediment cleanup scenario based on a PRG of 1 ppb TCDD would require remediation of only 9% of the sediment area from RM0-8 (**Table 22 and Figure 17**). As highlighted in Figure 17, the red polygons which represent areas of remedial action based on TCDD are only a small portion of the area Region 2 has proposed be subject to remedial action in the FFS as a result of their flawed and biased HHRA and PRG evaluation.

Figure 17. Potential remediation areas along LPR RM0-8 for 1 ppb TCDD PRG *(polygons highlighted in red indicate areas along RM0-8 with mean sediment concentrations that exceed 1 ppb-TCDD)*

Table 22. Summary of sediment concentrations and polygon areas associated with the TCDD-optimized PRG model.

TCDD Sediment Cleanup Scenario (ppt)	Mean Sediment Concentration (ng/kg)				Number of acres removed	% of Area for RM 0-8 TCDD cleanup
	TCDD	PCB-126	PCB-118	Total PCB Congeners (209)		
Current	857.96	163.16	41033.8	1591481.36	0	
>10,000	450.15	137.94	32364.76	1239578.34	12.3	
>5,000	313.44	121.53	27086.8	1028048.4	26.3	
>1,000	199.38	107.6	23543.57	879540.92	60.7	9%
>500	176.97	101.43	21854.94	813019.53	81	

Notes:

Total removal area for RM0-8 calculated as approximately 655 acres.

In contrast to the TCDD-optimized PRGs, PCB-optimized PRGs require a much more widespread remediation effort to achieve acceptable risk and hazards from exposure to PCBs (see Table 23 and Figure 18).

As illustrated in **Table 23**, a PCB sediment PRG of 3 ppm corresponds with remedial action for 7% of the LPR RM0-8 area and achieves acceptable risk and hazard for TCDD – however, it does not achieve acceptable risk and hazard for PCBs (see risk/hazard results in Table 21 above). The PCB sediment PRG of 0.7ppm results in 71% of LPR sediment being remediated (Table 23) in order to achieve acceptable risk and hazard for DLC and PCBs (see risk/hazard results in Table 21).

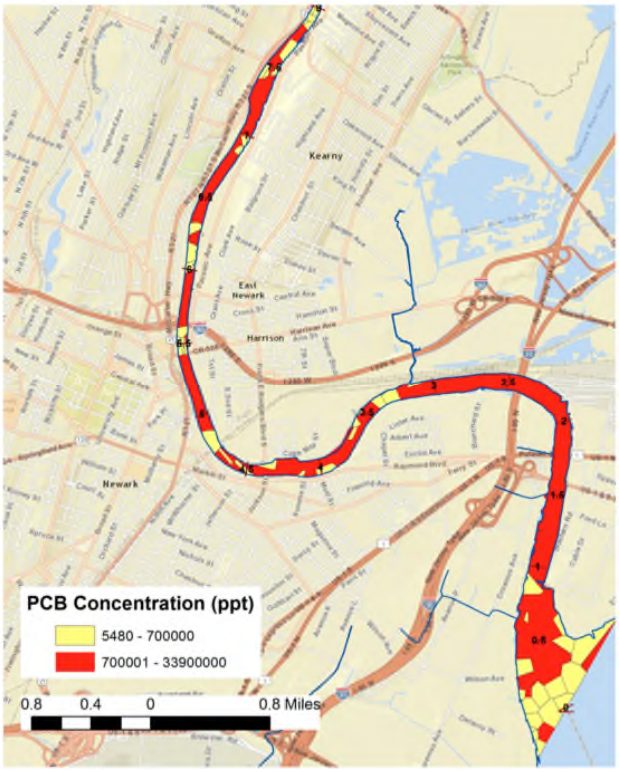


Figure 18. Potential remediation areas along LPR RM0-8 for 0.7 ppm PCB PRG *(polygons highlighted in red indicate areas along RM0-8 with mean sediment concentrations that exceed 0.7 ppm-Total PCB)*

Table 23. Summary of sediment concentrations and polygon areas associated with the PCB-optimized PRG model.

Total PCB Sediment Cleanup Scenario (ppt)	Mean Sediment Concentration (ng/kg)				Sum of acres 0-8	% of Area for RM 0-8 PCB cleanup
	TCDD	PCB-126	PCB-118	Total PCB Congeners (209)		
Current	857.96	163.16	41033.8	1591481.36	0	
>20,000,000	732.18	146.86	35728.97	1357213.5	6.3	
>10,000,000	613.14	133.2	30846.29	1161616.71	13.8	
>5,000,000	299.1	117.04	25850.54	974433.02	30.1	
> 3,000,000	258.02	108.89	23606.28	872384.09	47.0	7%
> 2,000,000	239.7	99.98	21226.87	759764.38	80.8	
> 1,000,000	102.8	56.64	10432	365449.44	281.6	
> 900,000	77.73	44.96	7366.74	267907.72	350.0	
> 800,000	57.83	35.02	5311.77	191105.19	408.7	
> 700,000	31.9	23.35	3521.45	127492.08	464.9	71%
> 600,000	20.84	15.41	2133.51	83199.85	508.5	

Notes:

Total removal area for RM0-8 calculated as approximately 655 acres.

These results have several important implications:

1. TCDD in LPR sediments can be addressed in a manner that is substantially smaller in scale than that proposed by Region 2. This analysis suggests that less than 10% of LPR sediment can be remediated to result in acceptable TCDD concentrations in fish and crab tissue.

2. PCBs are widely distributed in the LPR sediment at elevated concentrations. Approximately 70% of LPR sediment may require remediation to result in acceptable PCB concentrations in fish and crab tissue.

SECTION 6. References

American Academy of Pediatrics. 2012. Breastfeeding and the use of human milk: section on breastfeeding. Pediatrics. 129(3):e827-e841. Online: http://pediatrics.aappublications.org/content/129/3/e827.full.pdf+html. Accessed May 28, 2014.

Aylward LL, Brunet RC, Starr TB, Carrier G, Delzell E, Cheng H, Beall C. 2005. Exposure reconstruction for the TCDD-exposed NIOSH cohort using a concentration- and age-dependent model of elimination. Risk Anal. 25(4):945–956.

Baccarelli A, Giacomini SM, Corbetta C, Landi MT, Bonzini M, Consonni D, Grillo P, Patterson DG Jr., Pesatori AC, Bertazzi PA. 2008. Neonatal Thyroid Function in Seveso 25 Years after Maternal Exposure to Dioxin. PLoS Med. 5(7):e161.

Battelle. 2005. Lower Passaic River Restoration Project: Pathways Analysis Report. Prepared for USEPA Region 2 and US Army Corpus of Engineers, Kansas City District by Battelle Under Contract to Malcolm Pimie, Inc. July 2005.

Becher H, Steindorf K, Flesch-Janys D. 1998. Quantitative cancer risk assessment for dioxins using an occupational cohort. Environ Health Perspect. 106(Suppl. 2):663-70

Burger J. 2002. Consumption Patterns and Why People Fish. Environ Res. 90(2):125-35.

Burmaster DE, Harris RH. 1993. The Magnitude of Compounding Conservatisms in Superfund Risk Assessments. Risk Anal. 13(2):131-34.

Cheng H, Aylward L, Beall C, Starr TB, Brunet RC, Carrier G, Delzell E. 2006. TCDD Exposure-Response Analysis and Risk Assessment. Risk Anal. 26(4):1059-71.

City of Newark. 2010. The Riverfront that Newark Wants, Progress Report: 2009-2010. Presentation. Newark, NJ. June 2010.

City of Newark. 2012. Newark's River: A Public Access & Redevelopment Plan. Draft submitted to Newark Central Planning Board and Newark Municipal Council for approval. February 2012.

Connelly NA, Knuth BA, Bisogni CA. 2002. Effects of the health advisory and advisory changes on fishing habits and fish consumption in New York fisheries. Human Dimension Research Unit, Department of Natural Resources, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, NY.

Copeland TL, Holbrow AM, Otani JM, Connor KT, Paustenbach DJ. 1994. Use of probabilistic methods to understand the conservatism in California's approach to assessing health risks posed by air contaminants. J Air Waste Manage Assoc. 44:1399-1413.

Cullen, AC. 1994. Measures of compounding conservatism in probabilistic risk assessment. Risk Anal. 14(4):389-93

Donovan EP, Staskal DF, Unice KM, Roberts JD, Haws LC, Finley BL, Harris MA. 2008. Risk of gastrointestinal disease associated with exposure to pathogens in the sediments of the Lower Passaic River. Appl Environ Microbiol. 74:1004-1018.

Donovan E, Unice K, Roberts JD, Harris M, Finley B. 2008. Risk of gastrointestinal disease associated with exposure to pathogens in the sediments of the Lower Passaic River. Appl Environ Microbiol. 74:994-1003.

EC (European Commission). 2001. Opinion of the Scientific Committee on Food on the risk assessment of dioxins and dioxin-like PCBs in food. CS/CNTM/DIOXIN/20 final. Health and Consumer Protection Directorate-General, Brussels, Belgium.

Fingerhut MA, Halperin WE, Marlow DA, Piacitelli LA, Honchar PA, Sweeney MH, Greife AL, Dill PA, Steenland K, Suruda AJ. 1991. Cancer mortality in workers exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin. New Engl J Med. 324(4):212-18.

Finley BL, Iannuzzi TJ, Wilson ND, Kinnell JC, Craven VA, Lemeshow S, Teaf CM, Calabrese EJ, Kostecki PT. 2003. The Passaic River creel angler survey: expert panel review, findings, and recommendations. Hum Ecol Risk Assess. 9(3):829–855.

Finley B, Paustenbach D. 1994. The benefits of probabilistic exposure assessment: Three case studies involving contaminated air, water, and soil. Risk Anal. 14(1):53-73.

Finley BL, Trowbridge KR, Burton S, Proctor DM, Panko JM, Paustenbach DJ. 1997. Preliminary assessment of PCB risks to human and ecological health in the Lower Passaic River. J Toxicol Environ Health. 52(2):95-118.

Goodman DG, Sauer RM. 1992. Hepatotoxicity and carcinogenicity in female Sprague-Dawley rats treated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD): a pathology working group reevaluation. Regul Toxicol Pharmacol. 15(3):245-52.

Haws LC, Su SH, Harris M, Devito MJ, Walker NJ, Farland WH, Finley B, Birnbaum LS. 2006. Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. Toxicol Sci. 89(1):4-30.

Heyer, Gruel and Associates. 2002. “Town of Kearny Master Plan Reexamination Report.” Heyer, Gruel & Associates, Red Bank, NJ.

JECFA (Joint FAO/WHO Expert Committee on Food Additives). 2001. Fifty-seventh meeting. Rome, 5-14 June 2001.

Keenan RE, Paustenbach DJ, Wenning RJ, Parsons AH. 1991. Pathology reevaluation of the Kociba et al. (1978) bioassay of 2,3,7,8-TCDD: implications for risk assessment. J Toxicol Environ Health. 34(3):279-96.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013. "Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only". October 29, 2013.

Kinnell JC, Bingham MF, Hastings EA, Ray R, Craven V, Freeman M. 2007. A survey methodology for collecting fish consumption data in urban and industrial water bodies (part 1). J Toxicol Environ Health A. 70:477–495.

Kociba RJ, Keyes DG, Beyer JE, Carreon RM, Wade CE, Dittenber DA, Kalnins RP, Frauson LE, Park CN, Barnard SD, Hummel RA, Humiston CG. 1978. Results of a two-year chronic toxicity and oncogenicity study of 2.3.7.8-tetrachlorodibenzo-p-dioxin in rats. Toxicol Appl Pharmacol. 46:279-303

Kroes R, Renwick AG, Cheeseman M, Kleiner J, Mangelsdorf I, Piersma A, Schilter B, Schlatter J, van Schothorst F, Vos JG, et al. 2004. Structure-based thresholds of toxicological concern (TTC): Guidance for application to substances present at low levels in the diet. Food Chem Toxicol. 42:65-83.

Lorber M, Phillips L. 2002. Infant exposure to dioxin-like compounds in breast milk. Environ Health Perspect. 110(6):A325-332.

Marlow DA, Fingerhut MA. 1984. Dioxin registry site visit report of Occidental Chemical Corporation, Hooker Chemical Center, Niagara Falls, New York. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report Number 117.18. Reproduced by the U.S. Department of Commerce, National Technical Information Service, Report No. PB 85-221786.

Marlow DA, Fingerhut MA. .1986. Dioxin registry report prepared by review of documents from Diamond Shamrock Corporation, Diamond Alkali Company, Newark, New Jersey. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.16. Reproduced by the U.S. Department of Commerce, National Technical Information Service, Report No. PB 87-222808.

Marlow DA, Fingerhut MA, Piacitelli LA. 1989. Dioxin registry site visit report of Monsanto Company, Nitro, West Virginia. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.20. Reproduced by the U.S. Department of Commerce, National Technical Information Service Report, No. PB 91-107961.

Marlow DA, Fingerhut MA, Blade LM, Heam S. 1990. Dioxin registry report prepared by review of documents received from: Thompson-Hayward Chemical Company, Kansas City, Kansas. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.12.

Marlow DA, Fingerhut MA, Blade LM, Heam S, Jones J. 1991a. Dioxin registry report for Hercules, Inc., and Vertac Chemical Corporation, Jacksonville, Arkansas. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.10.

Marlow DA, Fingerhut MA, Blade LM, Piacitelli LA, Roberts D. 1991b. Dioxin registry report of The Dow Chemical Company, Midland, Michigan. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report Number 117.15. Reproduced by the U.S. Department of Commerce, National Technical Information Service Report: No. PB 92-121557.

Marlow DA, Fingerhut MA, Piacitelli LA. 1997. Dioxin registry site visit report of Monsanto Company, Sauget, Illinois. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.23.

Maronpot RR, Montgomery CA Jr., Boorman GA, McConnell EE. 1986. National Toxicology Program nomenclature for hepatoproliferative lesions of rats. Tox Path. 14(2):263-273.

Mocarelli P, Gerthoux PM, Patterson DG Jr., Milani S, Limonta G, Bertona M, Signorini S, Tramacere P, Colombo L, Crespi C, Brambilla P, Sarto C, Carreri V, Sampson EJ, Turner WE, Needham LL. 2008. Dioxin exposure, from infancy through puberty, produces endocrine disruption and affects human semen quality. Environ Health Perspect. 116(1):70-77

NAS. 2006. “Health Risks from Dioxin and Related Compounds: Evaluation of the EPA Reassessment by the Committee on EPA’s Exposure and Human Health.” The National Academies Press, Washington, DC.

Ott MG, Zober A. 1996. Cause specific mortality and cancer incidence among employees exposed to 2,3,7,8-TCDD after a 1953 reactor accident. J Occup Env Med. 53(9):606-12.

Parvez S, Evans AM, Lorber M, Hawkins BS, Swartout JC, Teuschler LK, Rice GE. 2013. A sensitivity analysis using alternative toxic equivalency factors to estimate U.S. dietary exposures to dioxin-like compounds. Regul Toxicol Pharmacol. 2013 Nov;67(2):278-84.

Piacitelli LA, Marlow DA, Fingerhut MA. 1990. Dioxin registry site visit report of Givaudan Corporation, Clifton, New Jersey. National Institute for Occupational Safety and Health, Industry Wide Studies Branch Report No. 117.22. Reproduced by the U.S. Department of Commerce, National Technical Information Service, Report No. PB 91-185199.

Piacitelli L, Marlow D, Fingerhut M, Steenland K, Sweeney MH. 2000. A retrospective job exposure matrix for estimating exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. Am J Ind Med. 38(1):28–39.

The New Jersey Department of Transportation (NJDOT). 2007. New Jersey's Position on the Future Navigational Use on the Lower Passaic River, River Miles 0-8. March 29, 2007.

Ray R, Craven V, Bingham M, Kinnell J, Hastings E, Finley B. 2007a. A statistical method for analyzing data collected by a creel/angler survey (part 2). J Toxicol Environ Health A. 70:496–511.

Ray R, Craven V, Bingham M, Kinnell J, Hastings E, Finley B. 2007b. Human health exposure factor estimates based upon a creel/angler survey of the lower Passaic River (part 3). J Toxicol Environ Health A. 70:512–528.

Roberts, J. D., E. E. Silbergeld, and T. K. Graczyk. 2007. A probabilistic risk assessment of Cryptosporidium exposure among Baltimore urban anglers. J. Toxicol. Environ. Health A 70**:**1568–1576.

Scientific Advisory Board (SAB). 1995. A Second Look at Dioxin: Science Advisory Board's Review of the Draft Dioxin Exposure and Health Effects Reassessment Documents. EPA-SAB-EC-95-021, September 29, 1995.

Scientific Advisory Board (SAB). 2001. Dioxin Reassessment – An SAB Review of the Revised Sections (Dose Response Modeling, Integrated Summary and Risk Characterization, and Toxicity Equivalency Factors) of the EPA's Reassessment of Dioxin by the Dioxin Reassessment Review Subcommittee of the EPA Science Advisory Board (SAB). EPA-SAB-EC-01-006, May 2001.

Shoaf MB, Shira JH, Kedan G. 2005. Child dermal sediment loads following playing in a tide flat. J Expo Anal Env Epid. 15:407-412.

Simon T, Aylward LL, Kirman CR, Rowlands JC, Budinsky RA. 2009. Estimates of cancer potency of 2,3,7,8-tetrachlorodibenzo-p-dioxin using linear and nonlinear dose-response modeling and toxicokinetics. Toxicol Sci. 112(2):490-506.

State of New Jersey Department of Health. 2014a. Breastfeeding. Online: http://www.nj.gov/health/fhs/newborn/feed.shtml. Accessed May 28, 2014.

State of New Jersey Department of Health. 2014b. WIC Breastfeeding Promotion and Support. Online: http://www.nj.gov/health/fhs/wic/breastfeedingpromsupp.shtml. Accessed May 28, 2014.

Steenland K, Deddens J, Piacitelli L. 2001. Risk assessment for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) based on an epidemiologic study. Am J Epidemiol. 154(5):451–8.

Steenland K, Piacitelli L, Deddens J, Fingerhut M, Chang LI. 1999. Cancer, heart, heart disease, and diabetes in workers exposed to 2,3,7,8-tetrochlorodibenzo-p-dioxin. J Natl Cancer Inst. 91(9):779-86.

Texas Commission on Environmental Quality (TCEQ). 2010. Regulatory implications of USEPA's draft oral slope factor and reference dose for dioxin and the Paradox of USEPA's surface soil draft interim preliminary remediation goal target risk/hazard levels for dioxin versus dioxin risk/hazard from typical dietary exposure and breast milk intake. Comments to the Science Advisory Board (SAB) Dioxin Review Panel for the October 27-29, 2010 Public Meeting, Washington, DC.

UK Food Standards Agency Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (UK FSA/COT). 2001. Statement on the Tolerable Daily Intake for Dioxins and Dioxin-Like polychlorinated biphenyls. July 2001.

US Census Bureau. 2000. 2000 Census of Population and Housing. Washington, DC. April 2004. Available at: http://www.census.gov/

U.S. Department of Health and Human Services. 2011. The Surgeon General's Call to Action to Support Breastfeeding. Washington, DC: U.S. Department of Health and Human Services, Office of the Surgeon General. Online: http://www.surgeongeneral.gov/library/calls/breastfeeding/calltoactiontosupportbreastfeeding.pdf. Accessed 28May14.

USEPA. 1985. Health Assessment Document for Polychlorinated Dibenzo-p-Dioxins. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-84/014F.

USEPA. 1989a. Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December 1989.

USEPA. 1989b. Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual. Office of Marine and Estuarine Protection/Office of Water Regulations and Standards, Washington DC. EPA-503/8-89-002.

USEPA. 1993. Use of IRIS Values in Superfund Risk Assessment. OSWER Directive 9285.7-16. Office of Solid Waste and Emergency Response, Washington, DC. December 21, 1993.

USEPA. 1997. Exposure Factors Handbook: volumes I-III. Washington, DC. Office of Research and Development, USEPA, Washington, DC. EPA/600/P-95/002F. August 1997.

USEPA. 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories - Volume 2: Risk Assessment and Fish Consumption Limits, Third Edition. Office of Water, EPA 823-B-00-008. November 2000.

USEPA. 2000b. Hudson River PCBs Reassessment RI/FS Phase 3 Report: Feasibility Study. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc. December 2000.

USEPA. 2000c. Phase 2 Report, Further Site Characterization and Analysis, Vol. 2F – Revised Human Health Risk Assessment, Hudson River PCBs Reassessment RI/FS. Upper Hudson River, Mid-Hudson River. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc., Gradient Corporation. November 2000.

USEPA. 2001.Risk Assessment Guidance for Superfund: Volume III – Part A, Process for Conducting Probabilistic Risk Assessment. Office of Emergency and Remedial Response, Washington, DC. EPA-540-R-02-002. December 2001

USEPA. 2003. Human Health Toxicity Values in Superfund Risk Assessments. OSWER Directive 9285.7-53. Office of Solid Waste and Emergency Response, Washington, DC. December 5, 2003.

USEPA. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. OSWER 9285.7-02EP. Office of Superfund Remediation and Technology Innovation, Washington, DC. July 2004.

USEPA. 2005a. Human Health Risk Assessment: GE/Housatonic River Site. Volume IIIA; Appendix B. Prepared for US Army Corps of Engineers and USEPA by Weston Solutions, Inc. West Chester, PA. February 2005.

USEPA. 2005b. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. U.S. Environmental Protection Agency, Washington, DC. EPA/630/R-03/003F. March 2005.

USEPA. 2009. Chemical-Specific Information: Handbook for implementing the supplemental cancer guidance at waste and cleanup sites. OSWER. Available at: http://www.epa.gov/oswer/riskassessment/sghandbook/chemicals.htm

USEPA. 2009. Human Health Risk Assessment Work Plan for the Upper Columbia River Site: Remedial Investigation and Feasibility Study. Prepared for USEPA Region 10 by Syracuse Research Corporation. March 2009.

USEPA. 2010a. EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments (External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/038A. May 2010.

USEPA. 2010b. Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds. Risk Assessment Forum, USEPA, Washington, DC. EPA/100/R-10/005. December 2010.

USEPA. 2011a. Exposure Factors Handbook: 2011 Edition (Final). Office of Research and Development, USEPA, Washington, DC. EPA/600/R-09/052F. September 2011.

USEPA. 2011b. SAB Review of EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments. Scientific Advisory Board, USEPA, Washington, DC. EPA-SAB-011-014. August 26, 2011.

USEPA. 2011c. EPA Begins Work to Remove Dioxin-laden Sediment from the Lower Passaic River. October 31, 2011. Available at: http://yosemite.epa.gov/opa/admpress.nsf/6427a6b7538955c585257359003f0230/c89899174234a79d8525793a00509e42!OpenDocument

USEPA. 2012. Technical Memorandum, Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment. February 2, 2012.

USEPA. 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120. Office of Solid Waste and Emergency Response, USEPA, Washington, DC. February 6, 2012.

USEPA. 2014. ProUCL Software. Available at: http://www.epa.gov/osp/hstl/tsc/software.htm#Documentation

U.S. Office of Personnel Management. 2013. Guide for Establishing a Federal Nursing Mother's Program. Online: https://www.opm.gov/policy-data-oversight/worklife/reference-materials/nursing-mother-guide.pdf. Accessed May 28, 2014.

Urban JD, Tachovsky JA, Staskal DF, Haws LC, and Harris MA. 2009. Assessment of human health risks posed by consumption of fish from the Lower Passaic River, New Jersey. Sci Total Environ. 408(2): 209-24.

Urban J, Tachovsky JA, Haws L, Staskal DF, Harris M. 2010a. Response to Bucanan et al.'s comment on Urban et al. "Assessment of Human Health Risks Posed by Consumption of Fish from the Lower Passaic River, New Jersey." Sci Total Environ. 408(8)2004-7

Urban J, Tachovsky JA, Haws L, Wikoff Staskal D, Harris M. 2010b. Response to Mugdan et al.'s comment on Urban et al. "Assessment of Human Health Risks Posed by Consumption of Fish from the Lower Passaic River, New Jersey." Sci Total Environ. 408(6):1468-1470.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci. 93(2):223-41.

Viscusi WK, Hamilton JT, Dockins PC. 1997. Conservative versus mean risk assessments: Implications for Superfund Policies. J Environ Eco Manage. 34:187-206.

Wisconsin Department of Natural Resources (DNR). 1999. Baseline Human Health and Ecological Risk Assessment: Lower Fox River Wisconsin. Prepared for Wisconsin Department of Natural Resources by ThermoRetec Consulting Corporation. February 24, 1999.

World Health Organization. 2013. Long Term Effects of Breastfeeding: A Systematic review. Online: http://apps.who.int/iris/bitstream/10665/79198/1/9789241505307_eng.pdf?ua=1. Accessed May 28, 2014.

Zabik ME, Booren A, Zabik MJ, Welch R, Humphrey H. 1996. Pesticide residues, PCBs and PAHs in baked, charbroiled, salt boiled and smoked Great Lakes lake trout. Food Chem. 55(3):231-239.

APPENDIX A: State-of-the-Science DRA Exposure Parameters and Toxicity Factors

Table A1 - RME Exposure Parameters - Adult
ToxStrategies vs EPA
Lower Passaic River

Receptor Population: Angler/Recreator (Adult)
Receptor Age: >18 Years

Exposure Route	Parameter Code	Parameter Definition	Units	ToxStrategies RME Value		ToxStrategies RME Rationale/Reference	EPA RME Value	EPA RME Rationale/Reference
Fish/Crab Ingestion	IReel	Ingestion rate of American Eel	g/day	0.69	a	Kinnell et al. 2013a	34.6 (IRfish)	USEPA Region 2 2012
	IRcat	Ingestion rate of Catfish	g/day	0.73	a	Kinnell et al. 2013a	NA	NA
	IRcarp	Ingestion rate of Carp	g/day	2.45	a	Kinnell et al. 2013a	NA	NA
	IRbass	Ingestion rate of Striped bass	g/day	0.88	a	Kinnell et al. 2013a	NA	NA
	IRperch	Ingestion rate of White perch	g/day	4.02	a	Kinnell et al. 2013a	NA	NA
	IRb	Ingestion rate of Blue Crab	g/day	0.14		Kinnell et al. 2013a	20.9	USEPA Region 2 2012
	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River
	EF	Exposure Frequency	days/year	365		USEPA 1989	365	USEPA 1989
	ED	Exposure Duration	years	24.2		Kinnell et al. 2013b	24	USEPA 1989
	Loss	Cooking Loss	g/g	Chemical-specific		USEPA 2000a (fish), Zabik et al. 1992 (crab)	0%	RME default
	BW	Body Weight	kg	80		USEPA 2014a	70	Mean adult body weight, males and females (USEPA 1989)
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	1		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	25,550	70-year lifetime exposure x 365 days/year (USEPA 1989)
	AT-NC	Averaging Time (Noncancer)	days	8,833		ED (years) x 365 days/year	8,760	ED (years) x 365 days/year
Sediment	IRsed	Ingestion rate of Sediment	mg/day	50		Battelle 2005	NA	NA
Incidental Ingestion	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
	EF	Exposure Frequency	days/year	13		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	24.2		Kinnell et al. 2013b	NA	NA
	BW	Body Weight	kg	80		USEPA 2014a	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	1		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	8,833		ED (years) x 365 days/year	NA	NA
Sediment	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
Dermal Contact	EF	Exposure Frequency	days/year	13		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	24.2		Kinnell et al. 2013b	NA	NA
	BW	Body Weight	kg	80		USEPA 2014a	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	1		USEPA 2014b	NA	NA
	SA	Skin surface area	cm^2/day	6,032		USEPA 2014a	NA	NA
	AF	Adherence factor	mg/cm^2	0.3		Battelle 2005	NA	NA
	ABS	Fraction of contaminant absorbed dermally from sediment	unitless	Chemical-specific		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	8,833		ED (years) x 365 days/year	NA	NA

Definitions
cm^2/day - square centimeter per day, g/day - gram per day, g/g - gram per gram, kg - kilogram, mg/cm^2 - milligram per square centimeter, NA - not applicable

Notes
Shaded cells differ between ToxStrategies' and EPA's approaches.
[a] Total adult fish ingestion rate, based on Kinnell et al. 2013a, is 8.91 g/day.

References

Battelle 2005. Lower Passaic River Restoration Project. Pathways Analysis Report. Prepared for USEPA Region 2 and US Army Corpus of Engineers, Kansas City District by Battelle Under Contract to Malcolm Pirnie, Inc. July.
Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013a. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 29.
Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013b. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 16.
USEPA 2014a. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120. February.
USEPA 2014b. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm
USEPA 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits, Third Edition. Office of Water, EPA 823-B-00-008. November.
USEPA 2000b. Phase 2 Report, Further Site Characterization and Analysis, Vol. 2F - Revised Human Health Risk Assessment, Hudson River PCBs Reassessment RI/FS. Upper Hudson River, Mid-Hudson River. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc., Gradient Corporation. November.
USEPA 1989. Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December.
Zabik M, Harte JB, Zabik MJ, Dickman G. 1992. Effect of Preparation and Cooking on Contaminant Distributions in Crustaceans: PCBs in Blue Crab, J. Agric. Food Chem. 40: 1197-1203.

Table A2 - RME Exposure Parameters - Adolescent
ToxStrategies vs EPA
Lower Passaic River

Receptor Population: Angler/Recreator (Adolescent)
Receptor Age: 7-18 Years

Exposure Route	Parameter Code	Parameter Definition	Units	ToxStrategies RME Value		ToxStrategies RME Rationale/Reference	EPA RME Value	EPA RME Rationale/Reference
Fish/Crab Ingestion	IReel	Ingestion rate of American Eel	g/day	0.46	a	2/3 the adult ingestion rate (USEPA default)	23.1 (Rfish)	2/3 the adult ingestion rate (USEPA 1997)
	IRcat	Ingestion rate of Catfish	g/day	0.49	a	2/3 the adult ingestion rate (USEPA default)	NA	NA
	IRcarp	Ingestion rate of Carp	g/day	1.63	a	2/3 the adult ingestion rate (USEPA default)	NA	NA
	IRbass	Ingestion rate of Striped bass	g/day	0.59	a	2/3 the adult ingestion rate (USEPA default)	NA	NA
	IRperch	Ingestion rate of White perch	g/day	2.68	a	2/3 the adult ingestion rate (USEPA default)	NA	NA
	IRb	Ingestion rate of Blue Crab	g/day	0.09		2/3 the adult ingestion rate (USEPA default)	13.9	2/3 the adult ingestion rate (USEPA 1997)
	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River
	EF	Exposure Frequency	days/year	365		USEPA 1989	365	USEPA 1989
	ED	Exposure Duration	years	12		USEPA 2000b	12	USEPA 1989
	Loss	Cooking Loss	g/g	Chemical-specific		USEPA 2000a (fish), Zabik et al. 1992 (crab)	0%	RME default
	BW	Body Weight	kg	54.5		Battelle 2005	52	Mean weight, males and females age 7-18 (USEPA 2008)
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	2.5		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	25550	70-year lifetime exposure x 365 days/year (USEPA 1989)
	AT-NC	Averaging Time (Noncancer)	days	4,380		ED (years) x 365 days/year	4,380	ED (years) x 365 days/year
Sediment	IRsed	Ingestion rate of Sediment	mg/day	50		Battelle 2005	NA	NA
Incidental Ingestion	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
	EF	Exposure Frequency	days/year	39		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	12		USEPA 2000b	NA	NA
	BW	Body Weight	kg	54.5		Battelle 2005	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	2.5		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	4,380		ED (years) x 365 days/year	NA	NA
Sediment	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
Dermal Contact	EF	Exposure Frequency	days/year	39		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	12		USEPA 2000b	NA	NA
	BW	Body Weight	kg	54.5		Battelle 2005	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	2.5		USEPA 2014b	NA	NA
	SA	Skin surface area	cm^2/day	4,591		USEPA 2011	NA	NA
	AF	Adherence factor	mg/cm^2	4.8		Shoaf et al. 2005	NA	NA
	ABS	Fraction of contaminant absorbed dermally from sediment	unitless	Chemical-specific		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	4,380		ED (years) x 365 days/year	NA	NA

Definitions

cm^2/day - square centimeter per day, g/day - gram per day, g/g - gram per gram, kg - kilogram, mg/cm^2 - milligram per square centimeter, NA - not applicable

Notes

Shaded cells differ between ToxStrategies' and EPA's approaches.

[a] Total adolescent fish ingestion rate, based on Kinnell et al. 2013a, is 5.94 g/day (2/3 of the adult ingestion rate).

References

Battelle 2005. Lower Passaic River Restoration Project. Pathways Analysis Report. Prepared for USEPA Region 2 and US Army Corpus of Engineers, Kansas City District by Battelle Under Contract to Malcolm Pirnie, Inc. July.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013a. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 29.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013b. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 16.

Shoaf MB, Shira JH, Kedan G. 2005. Child Dermal Sediment Loads Following Play in a Tide Flat. J. Expo. Anal. Env. Epid. 15:407-412.

USEPA 2014a. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120. February.

USEPA 2014b. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

USEPA 2011. Exposure Factors Handbook: 2011 Edition. EPA/600/R-090/052F. Office of Research and Development, Washington, DC, National Center for Environmental Assessment. September.

USEPA 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits, Third Edition. Office of Water, EPA 823-B-00-008. November.

USEPA 2000b. Phase 2 Report, Further Site Characterization and Analysis, Vol. 2F - Revised Human Health Risk Assessment, Hudson River PCBs Reassessment RI/FS. Upper Hudson River, Mid-Hudson River. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc., Gradient Corporation. November.

USEPA 1989. Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December.

Zabik M, Harte JB, Zabik MJ, Dickman G. 1992. Effect of Preparation and Cooking on Contaminant Distributions in Crustaceans: PCBs in Blue Crab, J. Agric. Food Chem. 40:1197-1203.

Table A3 - RME Exposure Parameters - Child
ToxStrategies vs EPA
Lower Passaic River

Receptor Population: Angler/Recreator (Child)
Receptor Age: 0 - 6 Years

Exposure Route	Parameter Code	Parameter Definition	Units	ToxStrategies RME Value		ToxStrategies RME Rationale/Reference	EPA RME Value	EPA RME Rationale/Reference
Fish/Crab Ingestion	IReel	Ingestion rate of American Eel	g/day	0.23	a	1/3 the adult ingestion rate (USEPA default)	11.5 (IRfish)	1/3 of the adult ingestion rate (USEPA 1997)
	IRcat	Ingestion rate of Catfish	g/day	0.24	a	1/3 the adult ingestion rate (USEPA default)	NA	NA
	IRcarp	Ingestion rate of Carp	g/day	0.82	a	1/3 the adult ingestion rate (USEPA default)	NA	NA
	IRbass	Ingestion rate of Striped bass	g/day	0.29	a	1/3 the adult ingestion rate (USEPA default)	NA	NA
	IRperch	Ingestion rate of White perch	g/day	1.34	a	1/3 the adult ingestion rate (USEPA default)	NA	NA
	IRb	Ingestion rate of Blue Crab	g/day	0.05		1/3 the adult ingestion rate (USEPA default)	6.97	1/3 of the adult ingestion rate (USEPA 1997)
	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River
	EF	Exposure Frequency	days/year	365		USEPA 1989	365	USEPA 1989
	ED	Exposure Duration	years	6		Battelle 2005	6	EPA default (USEPA, 1991)
	Loss	Cooking Loss	g/g	Chemical-specific		USEPA 2000a (fish), Zabik et al. 1992 (crab)	0	Assumes 100% chemical remains in fish/crab
	BW	Body Weight	kg	15		USEPA 2014a	15	Mean child weight (USEPA 1989); standard EPA default (USEPA 1991)
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	4.2		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	25550	70-year lifetime exposure x 365 days/year (USEPA 1989)
	AT-NC	Averaging Time (Noncancer)	days	2,190		ED (years) x 365 days/year	2190	ED (years) x 365 days/year
Sediment	IRsed	Ingestion rate of Sediment	mg/day	100		Battelle 2005	NA	NA
Incidental Ingestion	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
	EF	Exposure Frequency	days/year	13		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	6		Battelle 2005	NA	NA
	BW	Body Weight	kg	15		USEPA 2014a	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	4.2		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	2,190		ED (years) x 365 days/year	NA	NA
Sediment	FI	Fraction from Source	unitless	1		Assumes 100% exposure is from Passaic River	NA	NA
Dermal Contact	EF	Exposure Frequency	days/year	13		USEPA 2000b	NA	NA
	ED	Exposure Duration	years	6		Battelle 2005	NA	NA
	BW	Body Weight	kg	15		USEPA 2014a	NA	NA
	ADAF	Mutagenic Age-Dependent Adjustment Factor	unitless	4.2		USEPA 2014b	NA	NA
	SA	Skin surface area	cm^2/day	2,690		USEPA 2014a	NA	NA
	AF	Adherence factor	mg/cm²	4.7		Shoaf et al, 2005	NA	NA
	ABS	Fraction of contaminant absorbed dermally from sediment	unitless	Chemical-specific		USEPA 2014b	NA	NA
	AT-C	Averaging Time (Cancer)	days	25,550		70-year lifetime exposure x 365 days/year (USEPA 2014a)	NA	NA
	AT-NC	Averaging Time (Noncancer)	days	2,190		ED (years) x 365 days/year	NA	NA

Definitions

cm^2/day - square centimeter per day, g/day - gram per day, g/g - gram per gram, kg - kilogram, mg/cm^2 - milligram per square centimeter, NA - not applicable

Notes

Shaded cells differ between ToxStrategies' and EPA's approaches.

[a] Total child fish ingestion rate, based on Kinnell et al. 2013a, is 2.97 g/day (1/3 of the adult ingestion rate).

References

Battelle 2005. Lower Passaic River Restoration Project. Pathways Analysis Report. Prepared for USEPA Region 2 and US Army Corpus of Engineers, Kansas City District by Battelle Under Contract to Malcolm Pirnie, Inc. July.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013a. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 29.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013b. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 16.

Shoaf MB, Shira JH, Kedan G. 2005. Child Dermal Sediment Loads Following Play in a Tide Flat. J. Expo. Anal. Env. Epid. 15:407-412.

USEPA 2014a. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120. February.

USEPA 2014b. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

USEPA 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits, Third Edition. Office of Water, EPA 823-B-00-008. November.

USEPA 2000b. Phase 2 Report, Further Site Characterization and Analysis, Vol. 2F - Revised Human Health Risk Assessment, Hudson River PCBs Reassessment RI/FS. Upper Hudson River, Mid-Hudson River. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc., Gradient Corporation. November.

USEPA 1989. Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December.

Zabik M, Harte JB, Zabik MJ, Dickman G. 1992. Effect of Preparation and Cooking on Contaminant Distributions in Crustaceans: PCBs in Blue Crab, J. Agric. Food Chem. 40:1197-1203.

Table A4 - Cancer Toxicity Data (Chronic Values)
Lower Passaic River

Chemical of Potential Concern	Oral Cancer Slope Factor		TEF	RPF	Dermal CSF		Oral Absorption Efficiency for Dermal	Absorbed Cancer Slope Factor for Dermal		Dermal Absorption Efficiency	Mutagen	Oral CSF	
	Value	Units	(1)	(2)	(3)		(4)	Value	Units	(5)	(6)	Source(s)	Date(s) (MM/DD/YYYY)
Dioxin-like Compounds (7)													
2,3,7,8-TCDD	9.7E+03	(mg/kg-day)$^{-1}$	1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,7,8-PeCDD	9.7E+03	(mg/kg-day)$^{-1}$	1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,4,7,8-HxCDD	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,6,7,8-HxCDD	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,7,8,9-HxCDD	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,4,6,7,8-HpCDD	9.7E+03	(mg/kg-day)$^{-1}$	0.01	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
OCDD	9.7E+03	(mg/kg-day)$^{-1}$	0.0003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
2,3,7,8-TCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,7,8-PeCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.03	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
2,3,4,7,8-PeCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.3	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,4,7,8-HxCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,6,7,8-HxCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,7,8,9-HxCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
2,3,4,6,7,8-HxCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,4,6,7,8-HpCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.01	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
1,2,3,4,7,8,9-HpCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.01	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
OCDF	9.7E+03	(mg/kg-day)$^{-1}$	0.0003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-77	9.7E+03	(mg/kg-day)$^{-1}$	0.0001	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-81	9.7E+03	(mg/kg-day)$^{-1}$	0.0003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-126	9.7E+03	(mg/kg-day)$^{-1}$	0.1	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-169	9.7E+03	(mg/kg-day)$^{-1}$	0.03	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-105	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-114	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-118	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-123	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-156/157	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-167	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCB-189	9.7E+03	(mg/kg-day)$^{-1}$	0.00003	--	--	--	100%	9.7E+03	(mg/kg-day)$^{-1}$	0.019	--	Keenan et al. 1991	11/30/1991
PCBs													
Total Non-DL PCBs	2.0E+00	(mg/kg-day)$^{-1}$	--	--	--	--	100%	2.0E+00	(mg/kg-day)$^{-1}$	0.14	--	IRIS	6/1/1997
Total Non-DL PCBs (8)	1.0E+00	(mg/kg-day)$^{-1}$	--	--	--	--	100%	1.0E+00	(mg/kg-day)$^{-1}$	0.14	--	IRIS	6/1/1997
PAHs					--	--							
Acenaphthene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Anthracene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Benz(a)anthracene	1.0E-01	(mg/kg-day)$^{-1}$	--	0.1	0.5	(mg/day)$^{-1}$	100%	5.0E-01	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Benzo(a)pyrene	1.0E+00	(mg/kg-day)$^{-1}$	--	1.0	5	(mg/day)$^{-1}$	100%	5.0E+00	(mg/day)$^{-1}$	0.13	M	USEPA 2013	8/31/2013
Benzo(b)fluoranthene	1.0E-01	(mg/kg-day)$^{-1}$	--	0.1	0.5	(mg/day)$^{-1}$	100%	5.0E-01	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Benzo(k)fluoranthene	1.0E-02	(mg/kg-day)$^{-1}$	--	0.01	0.05	(mg/day)$^{-1}$	100%	5.0E-02	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Chloronaphthalene, Beta-	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Chrysene	1.0E-03	(mg/kg-day)$^{-1}$	--	0.001	0.005	(mg/day)$^{-1}$	100%	5.0E-03	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Dibenz(a,h)anthracene	1.0E+00	(mg/kg-day)$^{-1}$	--	1.0	5	(mg/day)$^{-1}$	100%	5.0E+00	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Fluoranthene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Fluorene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Indeno(1,2,3-cd)pyrene	1.0E-01	(mg/kg-day)$^{-1}$	--	0.1	0.5	(mg/day)$^{-1}$	100%	5.0E-01	(mg/day)$^{-1}$	0.13	M	USEPA 2013; 1993 RPFs	8/31/2013
Methylnaphthalene, 1-	2.9E-02	(mg/kg-day)$^{-1}$	--	--	--	--	100%	2.9E-02	(mg/kg-day)$^{-1}$	0.13	--	PPRTV	1/10/2008
Methylnaphthalene, 2-	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Naphthalene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Pyrene	--	--	--	--	--	--	100%	--	--	0.13	--	--	--
Pesticides & Organics					--	--							
4,4'-DDD	2.4E-01	(mg/kg-day)$^{-1}$	--	--	--	--	100%	2.4E-01	(mg/kg-day)$^{-1}$	0.1	--	IRIS	8/22/1988
4,4'-DDE	3.4E-01	(mg/kg-day)$^{-1}$	--	--	--	--	100%	3.4E-01	(mg/kg-day)$^{-1}$	0.1	--	IRIS	8/22/1988
4,4'-DDT	3.4E-01	(mg/kg-day)$^{-1}$	--	--	--	--	100%	3.4E-01	(mg/kg-day)$^{-1}$	0.03	--	IRIS	5/1/1991
Chlordane	3.5E-01	(mg/kg-day)$^{-1}$	--	--	--	--	100%	3.5E-01	(mg/kg-day)$^{-1}$	0.04	--	IRIS	2/7/1998
Dieldrin	1.6E+01	(mg/kg-day)$^{-1}$	--	--	--	--	100%	1.6E+01	(mg/kg-day)$^{-1}$	0.1	--	IRIS	7/1/1993
Methyl mercury	--	--	--	--	--	--	100%	--	--	0.01	--	IRIS	5/1/1995

Definitions

CSF - cancer slope factor, M - mutagenic, mg/day^{-1} - per milligram per day, mg/kg-day^{-1} - per milligram per kilogram per day, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RPF - relative potency factor, TEF - toxicity equivalence factor

Notes

(1) WHO TEFs from Van den Berg et al. 2006.
(2) RPFs from USEPA 1993.
(3) Dermal CSF from USEPA 2013.
(4) USEPA 2007.
(5) Roy et al. 2008 for dioxin-like compounds; TCEQ 2012 for methyl mercury; RAGS Part E, USEPA 2007 for other chemicals.
(6) Listed as mutagenic in USEPA 2013.
(7) The only differences between ToxStrategies' and EPA's carcinogenic toxicity factors are values for dioxin-like compounds (TCDD TEQ [D/F] and TCDD TEQ [PCBs] and PAHs. EPA used an oral cancer slope factor of 150,000 (mg/kg-day)$^{-1}$, for TCDD TEQ based on USEPA's 1997 HEAST. As EPA did not evaluate PAHs, no toxicity factors for PAHs were provided in EPA's risk assessment.
(8) Central estimate slope factor for exposures to PCBs.

References

Keenan RE, Paustenbach DJ, Wenning RJ, Parsons AH. 1991. Pathology Reevaluation of the Kociba et al. (1978) Bioassay of 2,3,7,8-TCDD:Iimplications for Risk Assessment. J. Toxicol. Environ. Health 34(3):279-96.
Roy TA, Hammerstrom K, Schaum J. 2008. Percutaneous Absorption of 2,3,7,8-Tetrachlorodibenzop- dioxin (TCOO) from Soil. J. Toxicol. Environ. Health, Part A. 71:1509-1515.
Texas Commission on Environmental Quality (TCEQ) Texas Risk Reduction Program (TRRP) Protective Concentration Level (PCL) Tables. June. Available at http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html
US Environmental Protection Agency (USEPA) 2014. Integrated Risk Information System (IRIS). Available at http://www.epa.gov/iris/
USEPA 2013. Toxicological Review of Benzo[a]pyrene (CASRN 50-32-8) In Support of Summary Information on the Integrated Risk Information System (IRIS.) Draft. EPA/635/R-10/006C. June.
USEPA 2008. Provisional Peer Reviewed Toxicity Values (PPRTV) for 1-Methylnaphthalene (CASRN 90-12-0). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment. Office of Research and Development. January.
USEPA 2007. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final (Update). Office of Superfund Remediation and Technology Innovation, Washington, DC. EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312.
USEPA 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. Office of Research and Development, Washington, DC. EPA/600/R-93/089.
Van den Berg M, Birnbaum LS, Denison M et al. 2006. The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. Toxicol. Sci. 93(2):223–241.

Table A5 - Noncancer Toxicity Data (Chronic Values)
Lower Passaic River

Chemical of Potential Concern	Oral RfD		TEF	Oral Absorption Efficiency for Dermal	Absorbed RfD for Dermal		Dermal Absorption Efficiency	Primary Target Organ(s)	RfD:Target Organ(s)	
	Value	Units	(1)	(2)	Value	Units	(3)		Source(s)	Date(s) (MM/DD/YYYY)
Dioxin-like Compounds (4)										
2,3,7,8-TCDD	2.3E-09	mg/kg-day	1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,7,8-PeCDD	2.3E-09	mg/kg-day	1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,4,7,8-HxCDD	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,6,7,8-HxCDD	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,7,8,9-HxCDD	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,4,6,7,8-HpCDD	2.3E-09	mg/kg-day	0.01	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
OCDD	2.3E-09	mg/kg-day	0.0003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
2,3,7,8-TCDF	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,7,8-PeCDF	2.3E-09	mg/kg-day	0.03	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
2,3,4,7,8-PeCDF	2.3E-09	mg/kg-day	0.3	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,4,7,8-HxCDF	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,6,7,8-HxCDF	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,7,8,9-HxCDF	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
2,3,4,6,7,8-HxCDF	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,4,6,7,8-HpCDF	2.3E-09	mg/kg-day	0.01	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
1,2,3,4,7,8,9-HpCDF	2.3E-09	mg/kg-day	0.01	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
OCDF	2.3E-09	mg/kg-day	0.0003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-77	2.3E-09	mg/kg-day	0.0001	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-81	2.3E-09	mg/kg-day	0.0003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-126	2.3E-09	mg/kg-day	0.1	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-169	2.3E-09	mg/kg-day	0.03	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-105	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-114	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-118	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-123	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-156/157	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-167	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCB-189	2.3E-09	mg/kg-day	0.00003	100%	2.3E-09	mg/kg-day	0.019	Developmental, Reproductive	JECFA 2001	6/30/2001
PCBs										
Total Non-DL PCBs (5)	2.0E-05	mg/kg-day	--	100%	2.0E-05	mg/kg-day	0.14	Immune System, Eye	IRIS	11/1/1996
PAHs				100%	--					
Acenaphthene	6.0E-02	mg/kg-day	--	100%	6.0E-02	mg/kg-day	0.13	Liver	IRIS	4/1/1994
Anthracene	3.0E-01	mg/kg-day	--	100%	3.0E-01	mg/kg-day	0.13	No Observed Effects	IRIS	7/1/1993
Benz(a)anthracene	--	--	--	100%	--	--	0.13	--	--	--
Benzo(a)pyrene	3.0E-04	mg/kg-day	--	100%	3.0E-04	mg/kg-day	0.13	Developmental, Neurological	USEPA 2013	8/31/2013
Benzo(b)fluoranthene	--	--	--	100%	--	--	0.13	--	--	--
Benzo(k)fluoranthene	--	--	--	100%	--	--	0.13	--	--	--
Chloronaphthalene, Beta-	8.0E-02	mg/kg-day	--	100%	8.0E-02	mg/kg-day	0.13	Respiratory, Liver	IRIS	11/1/1990
Chrysene	--	--	--	100%	--	--	0.13	--	--	--
Dibenz(a,h)anthracene	--	--	--	100%	--	--	0.13	--	--	--
Fluoranthene	4.0E-02	mg/kg-day	--	100%	4.0E-02	mg/kg-day	0.13	Kidney, Liver, Blood	IRIS	7/1/1993
Fluorene	4.0E-02	mg/kg-day	--	100%	4.0E-02	mg/kg-day	0.13	Blood	IRIS	11/1/1990
Indeno(1,2,3-cd)pyrene	--	--	--	100%	--	--	0.13	--	--	--
Methylnaphthalene, 1-	7.0E-02	mg/kg-day	--	100%	7.0E-02	mg/kg-day	0.13	Respiratory	ATSDR	9/30/2005
Methylnaphthalene, 2-	4.0E-03	mg/kg-day	--	100%	4.0E-03	mg/kg-day	0.13	Respiratory	IRIS	12/22/2003
Naphthalene	2.0E-02	mg/kg-day	--	100%	2.0E-02	mg/kg-day	0.13	Body Weight	IRIS	9/17/1998
Pyrene	3.0E-02	mg/kg-day	--	100%	3.0E-02	mg/kg-day	0.13	Kidney	IRIS	7/1/1993
Pesticides & Organics										
4,4'-DDD	--	--	--	100%	--	--	0.1	--	--	--
4,4'-DDE	--	--	--	100%	--	--	0.1	--	--	--
4,4'-DDT	5.0E-04	mg/kg-day	--	100%	5.0E-04	mg/kg-day	0.03	Liver	IRIS	2/1/1996
Chlordane	5.0E-04	mg/kg-day	--	100%	5.0E-04	mg/kg-day	0.04	Liver	IRIS	2/7/1998
Dieldrin	5.0E-05	mg/kg-day	--	100%	5.0E-05	mg/kg-day	0.1	Liver	IRIS	9/1/1990
Methyl mercury	1.0E-04	mg/kg-day	--	100%	1.0E-04	mg/kg-day	0.01	CNS, Developmental	IRIS	7/27/2001

Definitions

CNS - central nervous system, mg/kg-day - milligram per kilogram per day, PAH - polycyclic aromatic hydrocarbon, PCB - polychlorinated biphenyl, RfD - reference dose, TEF - toxicity equivalence factor

Notes

(1) WHO TEFs from Van den Berg et al. 2006.
(2) USEPA 2007.
(3) Roy et al. 2008 for dioxin-like compounds; TCEQ 2012 for methyl mercury; RAGS Part E, USEPA 2007 for other chemicals.
(4) The only differences between ToxStrategies' and EPA's noncarcinogenic toxicity factors are values for dioxin-like compounds (TCDD TEQ [D/F] and TCDD TEQ [PCBs] and PAHs. EPA used an oral reference dose of $7x10^{-10}$ (mg/kg-day) for TCDD TEQ based on USEPA's IRIS. As EPA did not evaluate PAHs, no toxicity factors for PAHs were provided in EPA's risk assessment.
(5) Based on noncancer toxicity values for Aroclor 1254.

References

Agency for Toxic Substances and Disease Registry (ATSDR) 2013. Minimal Risk Levels (MRLs) List. Available at http://www.atsdr.cdc.gov/mrls/mrllist.asp

Joint FAO/WHO Expert Committee on Food Additives (JECFA) 2001. Fifty-seventh meeting Rome, 5-14 June.

Roy TA, Hammerstrom K, Schaum J. 2008. Percutaneous Absorption of 2,3,7,8-Tetrachlorodibenzop- dioxin (TCOO) from Soil. J. Toxicol. Environ. Health, Part A. 71:1509-1515.

Texas Commission on Environmental Quality (TCEQ) Texas Risk Reduction Program (TRRP) Protective Concentration Level (PCL) Tables. June. Available at http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html

US Environmental Protection Agency (USEPA) 2014. Integrated Risk Information System (IRIS). Available at http://www.epa.gov/iris/

USEPA 2013. Toxicological Review of Benzo[a]pyrene (CASRN 50-32-8) In Support of Summary Information on the Integrated Risk Information System (IRIS.) Draft. EPA/635/R13/138a. August.

USEPA 2007. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final (Update). Office of Superfund Remediation and Technology Innovation, Washington, DC. EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312.

Van den Berg M, Birnbaum LS, Denison M et al. 2006. The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. Toxicol. Sci. 93(2):223–241.

APPENDIX B: State-of-the-Science PRA Distributions

Table B1
Chemical-Specific and Exposure Parameter Distributions for PRA

Parameter	Distribution Type	Additional Detail	Source
Chemical-Specific			
Cooking loss	Fish cooking loss - Custom distribution Crab cooking loss – assumed static at 0% for all COCs	Fish cooking loss custom distribution sampling from experimentally derived cooking loss values	USEPA 2000a
Fish, crab and sediment concentrations	Static	Static values; 95UCL mean concentrations	Tissue EPCs: 2009 Fish and Crab Tissue Sampling Sediment EPCs: 2008 CPG Low Resolution Coring Program, 2010 Benthic Sediment Study
Toxic equivalency factors (TEFs) for dioxin-like compounds	Lognormal (loc = 0, 25th percentile, 90th percentile) Custom distributions – continuous ranges (for PCB 156, -77, and 169) Uniform (min, max) Triangular (min, likeliest, max)	Lognormal distributions were truncated at the maximum observed relative potency (REP) value for a given congener.	USEPA 2010b

Parameter	Distribution Type	Additional Detail	Source
Exposure Parameters			
Adherence factor	Adolescent, child - lognormal (loc = 0, geometric mean, GSD) Adult – static	Body part-specific distributions for adolescent, child Adult – static (0.3 mg/m^3)	Shoaf et al. 2005 (adolescent, child) Battelle 2005 (adult)
Body weight	Custom distribution	Defined by percentiles from NHANES 2011-2012 body weight data	NHANES 2013
Exposure duration	Adult - lognormal (loc, 50th,percentile, 95th percentile) Adolescent and child – static	Adult – lognormal (loc = 0, 50th percentile = 6 years, 95th percentile = 24.2 years) Adolescent – static value (12 years) Child – static value (6 years)	Kinnell et al. 2013b
Exposure frequency	Fish/crab exposure frequency – static Sediment exposure frequency - Triangular (min, likeliest, max)	365 day/yr {min | likeliest | max} day/yr for : Adult {0|13|52} Adolescent {0|39|104} Child {0|13|52}	USEPA 2000c

Parameter	Distribution Type	Additional Detail	Source
Fish and crab ingestion rates	Lognormal (loc = 0, median, 95th percentile); species-specific values	Adult distributions obtained from Kinnell et la. 2013a. Assumed 2/3 of adult ingestion rate for adolescent, 1/3 of adult ingestion rate for child	Kinnell et al. 2013a
Sediment ingestion rate	Triangular (min, likeliest, max)	{min | likeliest | max} mg/day for : Adult {0 |25|50} Adolescent {0 |25|50} Child {0| 50|100}	Battelle 2005
Surface area	Lognormal (loc = 0, mean, 95th percentile)	Body part-specific distributions	USEPA 2011

Battelle. 2005. Lower Passaic River Restoration Project: Pathways Analysis Report. Prepared for USEPA Region 2 and US Army Corpus of Engineers, Kansas City District by Battelle Under Contract to Malcolm Pimie, Inc. July 2005.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013a. Preliminary Draft Baseline Risk Fish Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 29, 2013.

Kinnell JC, Bingham MF, Hickman SG, Woodard DM. 2013b. Preliminary Draft Baseline Risk Fisk Consumption Estimates for the Lower Passaic River Study Area, Preliminary Draft Estimates for Review and Discussion Purposes Only. October 16, 2013.

NHANES (National Health and Nutrition Examination Survey). 2013. 2011 - 2012 Data Documentation, Codebook, and Frequencies.

Shoaf MB, Shira JH, Kedan G. 2005. Child Dermal Sediment Loads Following Play in a Tide Flat. J. Expo. Anal. Env. Epid. 15:407-412.

USEPA 2011. Exposure Factors Handbook: 2011 Edition. EPA/600/R-090/052F. Office of Research and Development, Washington, DC, National Center for Environmental Assessment. September.

USEPA 2010b. Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds. Risk Assessment Forum, Washington, DC. EPA/100/R-10/005. December.

USEPA. 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits, Third Edition. Office of Water, EPA 823-B-00-008. November 2000.

USEPA. 2000c. Phase 2 Report, Further Site Characterization and Analysis, Vol. 2F – Revised Human Health Risk Assessment, Hudson River PCBs Reassessment RI/FS. Upper Hudson River, Mid-Hudson River. Prepared for USEPA Region 2 and US Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc., Gradient Corporation. November 2000.

APPENDIX C: State-of-the-Science PRG Methods and Supporting Information

Approach

Carcinogenic risk and non-carcinogenic hazards were calculated in a probabilistic framework for adult anglers consuming fish and crab that contain the following chemicals of concern: 2,3,7,8-TCDD and PCBs (i.e. PCB-126, PCB-118 and Total PCBs (209 congeners)). The specific fish and crab species evaluated in this assessment include: white perch, American eel, catfish, common carp, striped bass and blue crab. The equations, assumptions and values used in the calculation of risk and hazard for LPR RM0-8 are described below. Sediment PRGs were selected that met the acceptable cancer risk and noncancer hazard criteria of less than or equal to 1 in 10,000 ($\leq 1 \times 10^{-4}$) and 1 (≤ 1), respectively.

Health-protective sediment PRGs were determined using the equations in Appendix C in an iterative forward probabilistic manner as recommended by the USEPA *Risk Assessment Guidance for Superfund (RAGS) Volume 3, Part A* (2001). This method involves iteratively calculating risk and hazard with progressively decreasing exposure point concentrations until acceptable risk and hazard are achieved at the percentile of interest (i.e. the 95th percentile on the distributions of risk and hazard). **Figures 15** & **16** illustrate the iterative process used to identify sediment TCDD and PCB PRGs, respectively.

Equations and parameters

The equations below describe the risk and hazard equations used in this analysis for the fish ingestion pathway, and Table C1 provides definitions for each of the equation parameters. For the probabilistic analysis, distributions were used for parameters that are bolded in Table C1 The equations for cancer risk and non- cancer hazard (Equations 1-3) all contain an intake term and a toxicity value. Intake is based on exposure parameters such as species-specific ingestion rates, fish tissue concentrations, cooking loss, fraction ingested, exposure frequency and duration, averaging time and body weight. The specific toxicity values that were evaluated include the oral cancer slope factor (CSF) for risk calculations, and the oral reference dose (RfD) or the tolerable daily intake (TDI) for hazard calculations. Equation 4 is used to convert fish and crab tissue concentrations for dioxin-like compounds (i.e. PCB-126 and PCB-118) to a 2,3,7,8-TCDD toxic equivalency quantity (TEQ). Risks and hazards were calculated at the species level and then summed across multiple species to arrive at the total risk and total hazard posed by the fish ingestion pathway for a given chemical of interest.

Equation 1.

$$Risk_i = \sum_f \frac{C_{f,i} \cdot (1 - Loss_i) \cdot CF_1 \cdot IR_f \cdot CF_2 \cdot FI \cdot EF \cdot ED}{BW \cdot AT_c} \cdot CSF_i$$

Equation 2.

$$Hazard_{RfD,i} = \sum_f \frac{C_{f,i} \cdot (1 - Loss_i) \cdot CF_1 \cdot IR_f \cdot CF_2 \cdot FI \cdot EF \cdot ED}{BW \cdot AT_{nc}} \cdot \frac{1}{RfD_i}$$

Equation 3.

$$Hazard_{JECFA,i} = \sum_f \frac{C_{f,i} \cdot (1 - Loss_i) \cdot CF_1 \cdot IR_f \cdot CF_2 \cdot FI \cdot EF \cdot ED}{BW \cdot AT_{nc}} \cdot \frac{1}{TDI_i}$$

Equation 4.

$$C_{f,i}\left[\frac{ng - TEQ}{kg}\right] = C_{f,i}\left[\frac{ng}{kg}\right] \cdot TEF_i$$

Table C1 – Description of Parameters found in risk and hazard equations

Parameter	**Definition**
f	*The subscript "f" stands for fish/shellfish species. The species evaluated in this assessment include: white perch, American eel, catfish, common carp, striped bass, blue crab.*
i	*The subscript "i" stands for chemical species: 2,3,7,8-TCDD, PCB 126, PCB 118 and Total PCB Congeners (209).*
$C_{f,i}$	*Concentration of chemical, i, in fish species, f, (ng/kg for Total PCB Congeners (209) and ng-TEQ/kg for Dioxin-like compounds). Mean and 75th percentile concentrations were evaluated.*
CF_1	*Conversion factor from ng to mg, 0.000001 mg/ng.*
TEF_i	***Toxic equivalency factor for dioxin like compounds.***
Loss	***Chemical-specific loss due to cooking, (unit-less).***
IR_f	***Ingestion rate for fish species, f, (g/day).***
CF_2	*Conversion factor from g to kg, 0.001 kg/g.*
FI	*Fraction of intake, 1.*
EF	*Exposure frequency, 365 d/yr.*
ED	***Exposure duration, (yr).***
BW	***Body weight (kg).***
AT_c	*Lifetime averaging time for cancer evaluation (=70yr*365day/yr).*
AT_{nc}	***Noncancer hazard averaging time (=ED*365day/yr).***
CSF_i	*Chemical-specific oral cancer slope factor, $(mg/kg\text{-}day)^{-1}$.*
RfD_i	*Chemical-specific oral reference dose, (mg/kg-day).*
TDI_i	*Chemical-specific tolerable daily intake, (mg/kg-day).*

In this analysis, exposure point concentrations (fish tissue concentrations) originated from both observed fish tissue statistics (current, observed scenario) and the empirical bioaccumulation model (predicted scenarios). Briefly, the empirical bioaccumulation model uses total OC-normalized sediment concentrations to predict a range of expected lipid-normalized tissue concentrations for benthic and demersal (near bottom) invertebrates and fish (i.e., forage fish and carp) using biota-sediment accumulation factors (BSAFs); and forage fish-based accumulation factors (AFs) are used for piscivorous fish and blue crab that feed on small fish.

Representing RM0-8 with spatially weighted Thiessen polygons, remediation was simulated by identifying all polygons with sediment concentrations that exceed the specified target cleanup level and replacing these concentrations with post-remediation levels (i.e. chemical-specific detection limits). Sediment statistics for the RM0-8 post cleanup condition were then computed and used in the bioaccumulation model to predict fish tissue concentrations. The following scenarios were evaluated for TCDD:

- Current, observed sediment scenario (relies on area-weighted means for the actual sediment data (i.e. sediment samples collected from 2005-2012)),
- Current, predicted sediment scenario (from resampling of actual sediment data (mean of the 5000, 30-sample-means)),
- 10 ppb (resampling of a modified sediment dataset where sediment samples with 2,3,7,8-TCDD concentrations exceeding 10 ppb were selected to be replaced with detection limits for 2,3,7,8-TCDD and PCBs),
- 5 ppb (resampling of a modified sediment dataset where sediment samples with 2,3,7,8-TCDD concentrations exceeding 5 ppb were selected to be replaced with detection limits for 2,3,7,8-TCDD and PCBs),
- 1 ppb (resampling of a modified sediment dataset where sediment samples with 2,3,7,8-TCDD concentrations exceeding 1 ppb were selected to be replaced with detection limits for 2,3,7,8-TCDD and PCBs), and
- 0.5 ppb (resampling of a modified sediment dataset where sediment samples with 2,3,7,8-TCDD concentrations exceeding 0.5 ppb were selected to be replaced with detection limits for 2,3,7,8-TCDD and PCBs).

The Monte Carlo probabilistic caner risk and noncancer hazard calculations were conducted in Oracle Crystal Ball. 50,000 iterations were used to achieve sufficient numeric stability at the 95th percentile. Cancer risk and noncancer hazard calculations were conducted using the observed fish tissue concentrations (current – observed) and, from the empirical bioaccumulation model, predicted current fish tissue concentrations (current – predicted).

Parameter Definitions

Distributions and static parameters used in the PRG analysis are the same as those applied in the probabilistic HHRA (PRA) described in Comment 3-3.

Mark Harris, Ph.D., MBA

Principal Scientist
ToxStrategies, Inc.
23123 Cinco Ranch Blvd, Suite 220, Katy, TX 77494
Phone: 281-712-2062 x2001; Fax: 832-218-2756
mharris@toxstrategies.com

PROFESSIONAL PROFILE

Dr. Mark Harris is a Principal Health Scientist with ToxStrategies, Inc. He is a toxicologist with 21 years of experience in the environmental industry, and specializes in human health risk assessment, regulatory negotiations, risk based site investigations, and PRP investigations. Dr. Harris has studied and evaluated potential health effects of halogenated aromatic hydrocarbons such as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) and metals such as chromium. Dr. Harris has extensive experience in dealing with regulatory agencies ranging from implementation of administrative orders to negotiating site cleanup standards. Additionally, he has extensive experience in developing risk based site investigations for both industrial and residential sites and in conducting source identification studies using both chemical fingerprinting techniques and historical records searches.

Dr. Harris has co-authored over 35 scientific journal articles in his career and has participated in numerous technical seminars. He is a peer reviewer for several scientific journals including the *Journal of Soil and Sediment Contamination*, *Integrated Environmental Assessment and Management* (IEAM), *Journal of Air and Waste Management* and *Environmental Science and Technology* (ES&T).

EDUCATION AND DEGREES EARNED

Texas A&M University	Toxicology	Ph.D.	1990
Southern Methodist University	Business	M.B.A.	2000
Texas A&M University	Biochemistry	B.S.	1986

SELECTED PUBLICATIONS

- Urban, J. D., Wikoff, D. S., Bunch, A. T. G., **Harris, M. A.**, Haws, L. C. (2014). A review of background dioxin concentrations in urban/suburban and rural soils across the United States: Implications for site assessments and the establishment of soil cleanup levels. *Science of the Total Environment*, 466-467:586-597.
- Kopec, A. K., Kim, S., Forgacs, A. L., Zacharewski, T. R., Proctor, D. M., **Harris, M. A.**, Haws, L. C, Thompson, C. M. (2012). Genome-wide gene expression effects in B6C3F1 mouse intestinal epithelia following 7 and 90 days of exposure to hexavalent chromium in drinking water. *Toxicology and Applied Pharmacology*, 259(1):13-26.
- Scott, L. L. F., Staskal, D. F., Williams E. S., Luksemburg, W. J., Urban, J. D., Nguyen, L. M., Haws, L. C., Birnbaum, L. S., Paustenbach, D. J., **Harris, M. A.** (2009). Levels of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in southern Mississippi catfish and estimation of potential health risks. *Chemosphere*, 74(7): 1002-10.
- Urban, J. D., J. A. Tachovsky, D. F. Staskal, L. C. Haws, and **M. A. Harris** (2009). Assessment of Human Health Risks Posed by Consumption of Fish from the Lower Passaic River, New Jersey. *Sci Total Environ*., 408(2): 209-24.
- Donovan, E., K. Unice, J. D. Roberts, **M. Harris**, and B. Finley (2008). Risk of Gastrointestinal Disease Associated with Exposure to Pathogens in the Water of the Lower Passaic River. *Appl. Environ. Microbiol.*, 74:994-1003.
- Donovan, E. P., D. F. Staskal, K. M. Unice, J. D. Roberts, L. C. Haws, B. L. Finley, and **M. A. Harris** (2008). Risk of Gastrointestinal Disease Associated with Exposure to Pathogens in the Sediments of the Lower Passaic River. *Appl Environ Microbiol.*, 74:1004-1018.
- Henry, K. S., J. C. Petura, S. Brooks, S. Dentico, S. A. Kessel, and **M. Harris** (2007). Preventing Surface Deposition of Chromium with Asphalt caps at Chromite Ore Processing Residue Sites: A Case Study. *Canadian Geotechnical Journal*, 44:814-839.

- Ferriby, L. L., J. S. Knutsen, **M. Harris**, K. M. Unice, P. Scott, P. Nony, L. C. Haws, and D. Paustenbach (2007). Evaluation of PCDD/F and dioxin-like PCB serum concentration data from the 2001-2002 National Health and Nutrition Examination Survey of the United States Population. *J. Exp. Anal. Env. Epidemiol.*, 17: 358-371.
- Paustenbach, D. J., K. Fehling, P. Scott, **M. Harris**, and B. Kerger (2006). Identifying a soil clean-up criteria for dioxin in urban residential soils: How have 20 years of research and risk assessment experience affected the analysis? *J. Toxicol. Environ. Health*, Part B. 9:87-145.
- Haws, L., S. Su, **M. Harris**, M. DeVito, N. Walker, W. Farland, B. Finley, and L. Birnbaum (2006). Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. *Toxicol. Sci.*, 89(1):4-30.
- **Harris, M.**, T. Zacharewski, and S. Safe (1993). Comparative potencies of Aroclors 1232, 1248, 1254, and 1260 in male wistar rats—Assessment of the toxic equivalency factor (TEF) approach for polychlorinated biphenyls (PCBs). *Fund. Appl. Toxicol.*, 20:456-463.

Daniele (Staskal) Wikoff, Ph.D.

Toxicology Practice Leader
ToxStrategies, Inc.
9390 Research Blvd, Suite 250, Austin, TX 78759
Phone: 512-351-7178; Fax: 512-382-6945
dwikoff@toxstrategies.com

PROFESSIONAL PROFILE

Dr. Daniele Wikoff is the Toxicology Practice Leader for ToxStrategies based in Austin, Texas. With seven years of experience in the fields of toxicology and risk assessment, she specializes in evaluating potential human health risks associated with exposure to contaminants in environmental media (air, water, and soil), the food chain, consumer products and pharmaceuticals. Dr. Wikoff has evaluated the health effects and conducted risk assessments for a wide variety of compounds including polychlorinated dibenzodioxins and dibenzofurans, PCBs, PAHs, VOCs, and metals. She also has extensive experience assessing the toxicology, pharmacokinetics, mechanism of action, human exposure, and risks of brominated flame retardants. Dr. Wikoff has been involved with a number of product safety and environmental assessments related to the oil and natural gas industries, and she is currently developing a rapid-screening model to evaluate the toxicity and potential risk of products used in natural gas operations. Dr. Wikoff has conducted quantitative microbial risk assessments based on human exposure to a variety of pathogenic organisms, has significant experience with study design, implementation and analysis of biomonitoring investigations, and she has participated in many food safety evaluations (including GRAS assessment). When evaluating the human health risk associated with exposure to these compounds, her roles typically involve assessment and incorporation of toxicokinetic data, hazard identification, biologically-based mechanisms of action, evaluation of dose/response relationships, and weight of the evidence analyses. She has assisted in the preparation of reports for submission to public entities as well as state, regional and federal regulatory agencies.

Dr. Wikoff is active in the scientific community; she regularly participates in the peer review process for a number of scientific journals and has participated on an EPA expert review panel. Also, Dr. Wikoff served as a Co-Chair for the 30th International Symposium on Halogenated Persistent Organic Pollutants held in San Antonio in 2010.

EDUCATION AND DEGREES EARNED

University of North Carolina at Chapel Hill	Toxicology	Ph.D.	2005
Buena Vista University	Chemistry and Biology	B.S.	2000

RELEVANT WIKOFF PUBLICATIONS

- Urban, J. D., **Wikoff, D. S.**, Bunch, A. T. G., Harris, M. A., Haws, L. C. (2014). A review of background dioxin concentrations in urban/suburban and rural soils across the United States: Implications for site assessments and the establishment of soil cleanup levels. *Science of the Total Environment*, 466-467:586-597.
- Birnbaum, L. S. and **D. Staskal-Wikoff** (2010). 5th International PCB Workshop--summary and implications. *Environ Int.*, 36(8): 814-8.
- Rowlands, C. J., **D. F. Staskal**, B. Gollapudi, and R. Budinsky (2010). The Human AHR: identification of single nucleotide polymorphisms from six ethnic populations. *Pharmacogenet Genomics*, 20(5): 283-90.
- Tachovsky, J. A., J. D. Urban, **D. S. Wikoff**, L. C. Haws, and M. A. Harris (2010). Reduction of a large fish tissue analyte database: identifying and assessing data specific to a remediation site for risk assessment application. *Chemosphere*, 80(5): 481-8.
- Urban, J. D., J. A. Tachovsky, L. C. Haws, **D. Wikoff Staskal**, and M. A. Harris (2009). Assessment of human health risks posed by consumption of fish from the Lower Passaic River, New Jersey. *Sci. Total Environ.*, 408(2): 209-24.

- Scott, L. L. F., **Staskal, D. F.**, L. C. Haws, W. J. Luksemburg, L. S. Birnbaum, E. S. Williams, J. U. Urban, L. M. Nguyen, D. J. Paustenbach, and M. A. Harris (2009). Levels of Polychlorinated dibenzo-p-dioxins, Dibenzofurans, and Biphenyls in Southern Mississippi Catfish and Estimation of Potential Health Risks. *Chemosphere*, 74(7): 1002-10.
- Donovan, E. P., **D. F. Staskal**, K. M. Unice, J. D. Roberts, L. C. Haws, B. L. Finley, and M. A. Harris (2008). Risk of Gastrointestinal Disease Associated with Exposure to Pathogens in the Sediments of the Lower Passaic River. *Appl. Environ. Microbiol.*, 74:1004-1018.
- **Staskal, D. F.**, L. L. F. Scott, L. C. Haws, W. J. Luksemburg, L. S. Birnbaum, L. M. Nguyen, J. D. Urban, E. S. Williams, D. J. Paustenbach, and M. A. Harris (2008). Assessment of Polybrominated diphenyl ether Exposures and Health Risks Associated with Consumption of Southern Mississippi Catfish. *Environ. Sci. Technol.*, 42(17): 6755-61.
- **Staskal, D. F.**, J. J. Diliberto, M. J. DeVito, and L. S. Birnbaum (2005). Inhibition of Human and Rat CYP1A2 by TCDD and Dioxin-like Chemicals. *Toxicol. Sci.*, 84: 225-31.
- **Staskal, D. F.**, J. J. Diliberto, M. J. DeVito, and L. S. Birnbaum (2005). Toxicokinetics of BDE 47 in Female Mice: Effects of Dose, Route of Exposure, and Time. *Toxicol. Sci.*, 83: 215-23.

Jonathan D. Urban, Ph.D., DABT

Senior Scientist
ToxStrategies, Inc.
9390 Research Blvd, Suite 250, Austin, TX 78759
Phone: 512-351-7358; Fax: 512-382-6945
jurban@toxstrategies.com

PROFESSIONAL PROFILE

Dr. Jonathan Urban is a Senior Scientist with ToxStrategies, Inc. in Austin, TX. Dr. Urban has eight years of experience studying and evaluating the potential health effects of a range of chemicals of concern, including halogenated aromatic hydrocarbons (PCDD/Fs, PCBs, and PCNs), metals (Cr, Ni, Pb), hazardous air pollutants (BTEX), industrial compounds (various solvents and pesticides), food-related compounds (steviol glycosides, parabens, acrylamide), and consumer product contaminants (nonylphenol ethoxylate, 1,3-butadiene). Dr. Urban has utilized this expertise in the development of critiques and recommendations regarding risk-based toxicity criteria for regulatory agencies, industry and private sector businesses. In addition to chemical toxicology evaluations, Dr. Urban specializes in conducting human health risk assessment, federal and state site remediation investigations, and biomonitoring studies. Dr. Urban also develops and provides oversight for GLP and non-GLP studies in support of the FDA's pre-IND application process for biological pharmaceuticals, including CRO site study monitoring of non-clinical studies.

Dr. Urban earned a Ph.D. in toxicology at the University of North Carolina at Chapel Hill, where his studies focused on receptor-based signaling mechanisms of xenobiotics in neurological systems. Dr. Urban is a Diplomate of the American Board of Toxicology, has published both academic and professional studies in the peer-reviewed literature, and is a reviewer for various scientific journals.

EDUCATION AND DEGREES EARNED

University of North Carolina at Chapel Hill	Toxicology	Ph.D.	2006
University of Maryland at College Park	Biological Sciences	B.S.	1999

SELECTED PUBLICATIONS

- **Urban, J. D.**, D. S. Wikoff, A. T. Bunch, M. A. Harris, L. C. Haws (2014). A review of background dioxin concentrations in urban/suburban and rural soils across the United States: Implications for site assessments and the establishment of soil cleanup levels. *Sci. Total Environ.*, 446-467: 586-597.
- Rowlands, J. C., R. Budinsky, B. Gollapudi, M. Black, R. Wolfinger, D. Cukovic, A. Dombkowski, C. Thompson, **J. D. Urban**, R. Thomas (2013). A genomics-based analysis of relative potencies of dioxin-like compounds in primary rat hepatocytes. *Tox. Sci.*, 136(2):595-604.
- **Urban, J. D.**, J. C. Rowlands, R. A. Budinsky (2012). An evaluation of single nucleotide polymorphisms in the human heat shock protein 90kDa alpha and beta isoforms. *Drug Metabolism and Pharmacokinetics*, 27(2): 268-278.
- Rowlands J. C., **J. D. Urban**, D. S. Wikoff, R. A. Budinsky (2011). An evaluation of single nucleotide polymorphisms in the human aryl hydrocarbon receptor-interacting protein (AIP) gene. *Drug Metab Pharmacokinet.*, 26(4): 431-439.
- **Urban, J. D.**, J. C. Rowlands, R. A. Budinsky (2011). Single nucleotide polymorphisms in the human aryl hydrocarbon receptor nuclear translocator (ARNT) gene. *Drug Metab Pharmacokinet.*, 26(6):637-645.
- Tachovsky, J. A., **J. D. Urban**, D. S. Wikoff, L. C. Haws and M. A. Harris (2010). Reduction of a large fish tissue analyte database: identifying and assessing data specific to a remediation site for risk assessment application. *Chemosphere*, 80(5): 481-488.
- **Urban, J. D.**, J. A. Tachovsky, D. F. Staskal, L. C. Haws, and M. A. Harris (2009). Assessment of Human Health Risks Posed by Consumption of Fish from the Lower Passaic River, New Jersey. *Sci. Total Environ.*, 408(2): 209-224.

- Scott L. L. F., D. F. Staskal, L. C. Haws, W. J. Luksemburg, L. S. Birnbaum, **J. D. Urban**, E. S. Williams, L. M. Nguyen, D. J. Paustenbach, and M. A. Harris (2009). Levels of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in southern Mississippi catfish and estimation of potential health risks. *Chemosphere*, 74(7): 1002-1010.
- Staskal, D. F., L. L. F. Scott, L. S. Birnbaum, E. S. Williams, L. C. Haws, W. J. Luksemburg, **J. D. Urban**, L. M. Nguyen, D. J. Paustenbach, and M. A. Harris (2008). Polybrominated diphenyl ethers in farm-raised and wild-caught catfish from southern Mississippi. *Environmental Science and Technology*, 42(17): 6755-6761.

Camarie Skarovsky Perry, M.S.

Senior Scientist
ToxStrategies, Inc.
9390 Research Blvd, Suite 250,Austin, TX 78759
Phone: 512-366-3209; Fax: 512-382-6945
cperry@toxstrategies.com

PROFESSIONAL PROFILE

Camarie Perry was trained in toxicology and human health risk assessment and has approximately 16 years of experience. Her specific areas of expertise include human health toxicology; complex human health risk assessment; assembly, analysis, and summary of toxicological information; development of toxicity factors; remediation, including cleanup level calculation and development; and homeland security issues related to toxicology and health effects. She has extensive experience with state and federal remediation sites and analysis of sampling data. Ms. Perry has summarized complex human and animal toxicity information, written write papers, and contributed to development of rapid risk assessment tools for various chemical and biological agents.

Ms. Perry has experience in site evaluation and cleanup under EPA and various state criteria; Phase I environmental site assessments; evaluation and remediation of leaking petroleum storage tank sites; and ecological risk assessment. She has also worked on wastewater treatment plant design and projects involving public water supply regulations. In addition to her technical expertise, Ms. Perry also served as a project manager.

EDUCATION AND DEGREES EARNED

College of Pharmacy, University of Texas at Austin	Toxicology and Pharmacology	M.S.	1995
Texas A&M University, College Station	Genetics (*Cum Laude*)	B.S.	1992

PUBLICATIONS

- A. G. Bunch, **C. S. Perry**, L. Abraham, D. S. Wikoff, J. A. Tachovsky, J. G. Hixon, J. D. Urban, M. A. Harris, L. C. Haws (2014). Evaluation of impact of shale gas operations in the Barnett Shale region on volatile organic compounds in air and potential human health risks. *Science of the Total Environment*, 468-469(2014):832-842.
- Thompson, C. M., D. W. Gaylor, J. A. Tachovsky, **C. Perry**, M. C. Carakostas, L. C. Haws (2013). Development of a Choronic Noncancer Oral Reference Dose and Drinking Water Screening Level for Suloflane Using Benchmark Dose Modeling. *Journal of Applied Toxicology*, 33(12): 1395-1406.
- MacDonell, M., L. Haroun, L. Teuschler, G. Rice, R. Hertzberg, J. Butler, Y. Chang, S. Clark, A. Johns, **C. Perry**, S. Garcia, J. Jacobi, M. Scofield (2013). Cumulative Risk Assessment Toolbox: Methods and Approaches for the Practitioner. *Journal of Toxicology*, 2013:310904.
- Ramu, K., **Perry, C. S.**, Ahmed, T., Pakenham, G., and Kehrer, J. P. (1996). Studies on the basis for the toxicity of acrolein mercapturates. *Toxicology and Applied Pharmacology*, 140:487-498.
- Sauers, L. and **Perry, C.** (1996). Regulatory affairs - a growing opportunity for toxicologists. *SOT Communiqué*, May/June 1996.
- **Perry, C. S.**, Liu, X. L., Lund, L. G., and Kehrer, J. P. (1995). Differential toxicities of cyclophosphamide and its glutathione metabolites to A549 cells. *Toxicol. in Vitro*, 9:21-26.

Liz Abraham, M.S.

Engineer III
ToxStrategies, Inc.
23123 Cinco Ranch Blvd, Suite 220, Katy, TX 77494
Phone: 281-712-2062 x2004
labraham@toxstrategies.com

PROFESSIONAL PROFILE

Liz Abraham is an Engineer III at ToxStrategies. She holds a master's degree from the University of Texas at Austin in Environmental and Water Resources Engineering. She specializes in computational analysis/modeling and process engineering. Liz has performed dose-response modeling for dioxin and dioxin-like compounds to arrive at relative effect potencies (REPs). She has also developed indoor air quality models to assess risks from household consumer products. Her graduate research focused on innovative approaches to characterizing and monitoring contaminant exposure in contaminated sediments remediation. She has conducted field studies using a novel passive sampling technique to evaluate the effectiveness of remedy caps at Superfund sites. She has also conducted laboratory investigations detailing the sorption of contaminants onto various remedy capping amendments. Prior to her work in the field of environmental engineering, Liz was a practicing chemical engineer in the semiconductor industry, designing and optimizing key manufacturing processes.

EDUCATION AND DEGREES EARNED

University of Texas at Austin	Env. and Water Resources Engineering	M.S.	2010
Texas A&M University	Chemical Engineering	B.S.	2003

PUBLICATIONS

- Johnson, G. E., Soeteman-Hernandez, L. G., Gollapudi, B. B., Bodger, O. G., Dearfield, K. L., Heflich, R. H., Hixon, J. G, Lovell, D. P., MacGregor, J. T., Pottenger, L. H., Thompson, C. M., **Abraham, L.**, Thybaud, V., Tanir, J. Y., van Benthem, J., White, P. A. (2014). *Environmental and Molecular Mutagenesis*. doi: 10.1002/em.21870. [*Epub* ahead of print].
- Suh, M., Thompson, C., Kirman, C., Carakostas, M., Haws, L. C., Harris, M., Proctor, D., **Abraham, L.**, Hixon, J. G. (2014). High concentrations of hexavalent chromium in drinking water alter iron homeostasis in F344 rats and B6C3F1 mice. *Food and Chemical Toxicology*. (2014): doi: 10.1016/j.fct.2014.01.009.
- Suh, M., **Abraham, L.**, Hixon, J. G., Proctor, D. (2014). The effects of perchlorate, nitrate, and thiocyanate on free thyroxine for potentially sensitive subpopulations of the 2001-2002 and 2007-2008 National Health and Nutrition Examination Surveys. *Journal of Exposure Science and Epidemiology*. (2013):1-9.
- Bunch, A. G., C. S. Perry, **L. Abraham**, D. S. Wikoff, J. A. Tachovsky, J. G. Hixon, J. D. Urban, M. A. Harris, L. C. Haws (2014). Evaluation of impact of shale gas operations in the Barnett Shale region on volatile organic compounds in air and potential human health risks. *Science of the Total Environment*. 468-469(2014):832-842.
- Thompson, C. M., Y. Fedorov, D. D. Brown, M. Suh, D. M. Proctor, **L. Kuriakose**, L. C. Haws, M. A. Harris (2012). Assessment of Cr(VI)-Induced Cytotoxicity and Genotoxicity Using High Content Analysis. *PLoS ONE*. 7(8): e42720.
- Qian, Y. C., Y. Zheng, **L. Abraham**, K. Ramos, E. Castiglioni (2005). Differential profiles of copper-induced ROS generation in human neuroblastoma and astrocytoma cells. *Molecular Brain Research* 134(2): 323-332.

Exponent®
Failure Analysis Associates®

Comments on Organic Carbon and Chemical Fate & Transport Models in EPA's Focused Feasibility Study Report for the Lower Eight Miles of the Passaic River

August 2014

Prepared for:

Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared by:

Parmeshwar L. Shrestha, Ph.D., P.E., D.WRE, D.CE
Steave H. Su, M.P.H.
Exponent
Irvine, California
New York, New York

Comments on Organic Carbon and Chemical Fate & Transport Models in EPA's Focused Feasibility Study Report for the Lower Eight Miles of the Passaic River

I. The Organic Carbon and Chemical Fate and Transport (OC and CF&T) Models in the Focused Feasibility Study Report (the FFS Report; Louis Berger Group, Inc. 2014) are incomplete or inadequate in many respects, such that the proposition that specific Remedial Alternatives can or cannot reach the remediation goal lack technical credibility.

A. Summary

- The OC and CF&T models were not adequately calibrated for past conditions (i.e., history matching), and hence are not expected to accurately predict future conditions for Remedial Alternatives 2 and 3, or any other proposed alternative in the FFS Study Area.
- The OC and CF&T modeling work was incomplete because a mass balance diagnostic analysis, as recommended by the U.S. Environmental Protection Agency's (EPA's) peer reviewers, was not conducted to ensure sediment and contaminant mass are conserved across the models.
- The models excluded physical processes (e.g., resuspension due to ship traffic and wind-induced waves) that are necessary to accurately model contaminant concentrations.
- The models' assumed sediment and contaminant loadings from freshwater sources are incomplete and unrealistic.
- The CF&T model excluded potentially important COPCs such as PAHs.
- The models' uncertainty was not rigorously investigated and remains unquantified.

B. General Comments

1. The OC and CF&T models were not adequately calibrated to past conditions, and hence are not expected to accurately predict future conditions for Remedial Alternatives 2 and 3, or any other proposed alternative in the FFS Study Area.

The OC and CF&T models were not adequately calibrated to reproduce the 1995–2012 baseline condition. For example, model predictions of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) concentrations in sediment were within the five– and one-fifth–fold difference lines of the actual data for 67.5% of the data points as shown in Table 4-2 in the FFS Report Appendix BIII (The Louis Berger Group, Inc. 2014). This shows that nearly one-third of the actual sediment

concentrations were over-predicted by the model by more than five times or under-predicted by the model by more than a factor of one-fifth of the corresponding actual data. For water column concentrations of 2,3,7,8-TCDD, the percentage is 49.1%, which indicates that 50.9% (more than half) of the actual water column concentrations were over-predicted by more than five times or under-predicted by more than a factor of one-fifth of the actual data.. The models' ability to predict within a factor of five and a factor of one-fifth of the actual data is also inconsistent amongst the contaminants. For polychlorinated dibenzo-*p*-dioxin (PCDD) and dibenzofuran (PCDF) congeners, 67.5 to 83.6% of actual sediment concentrations were within factors of five and one-fifth of the actual concentrations, polychlorinated biphenyl (PCB) homologs 61.5 to 72%, and dioxin-like PCB congeners 50.4 to 73.9%. Similarly, modeled water column concentrations for PCDDs, PCDFs and PCBs were within factors of five and one-fifth for 49.1 to 92%, 31.5 to 74.7%, and 15.6 to 61.2%, respectively, of the actual data. The models' ability to reproduce the baseline conditions for the upstream (RM 8.3-17) and downstream (Newark Bay) areas is also inconsistent with the FFS area (RM 0-8.3) as shown in Figures 4-50 through 4-55 in Appendix BIII (The Louis Berger Group, Inc. 2014).

The contention that a remedial alternative can achieve the remediation goal, or vice versa, lacks technical credibility given the inadequate calibration of the OC and CF&T models. These models should be calibrated adequately for past conditions, so that there is confidence that the model can accurately predict future conditions for the proposed alternative.

2. ***The description of how well the models reproduce the baseline condition is not informative and is misleading.***

The FFS described the ability of the models to reproduce the baseline condition in unconventional terms such as the percentage of data within factors of five and one-fifth of the actual data, instead of using more conventional terms such as whether the predictions are within ±X% of actual value, or within the 95% confidence interval about the mean of the actual values. In the response to the comment by a peer reviewer of the model (HDR-HydroQual Inc. 2013, Comment #111), the FFS Report authors acknowledged that "the fraction of data falling within a factor of five, noted in the report [Appendix BIII (The Louis Berger Group, Inc. 2014)], is not an acceptance level, but is instead a value chosen to give the reader an idea of how the model is performing in a quantitative fashion."

The readers are not informed as to whether the model underpredicted or overpredicted actual data based on the percentage of model predictions within five– and one-fifth– fold difference lines. In fact, such a presentation of the model prediction is misleading, as demonstrated with a simple (for illustrative purposes only) hypothetical example. Assume that the actual data are 10 numbers from 1 to 10: 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. The 10 corresponding model predictions are: 2, 2, 2, 2, 2, 2, 2, 2, 2, and 2. In this example, 100% of actual data points are reproduced by the model within the five– and one-fifth–fold difference and may give the impression that the model performed well (within the five– and one-fifth–fold

difference) but, in fact, the model under-predicts the data 80% of the time. Thus, there is no quantification of bias in the predicted results.

3. ***The models excluded physical processes that are important for accurately estimating contaminant concentrations.***

   The FFS OC and CF&T model report (Appendix BIII) states, "There are also processes occurring in Newark Bay that are not represented in the contaminant model, particularly capital and maintenance dredging and resuspension from shipping traffic." Exclusion of capital and maintenance dredging indicates that potential bathymetric changes resulting from such activities are not represented in the model. The model does not attempt to evaluate and quantify sediment resuspension due to shipping traffic (propwash) and, therefore, the potential redistribution of these sediments, both spatially and temporally, is not represented in the model. Wind-induced wave resuspension in Newark Bay is another process that is not included in the model. As a result, resuspension of bed sediments is not captured accurately by the model, since the shear stresses induced on the sediment bed are due to currents alone, which are lower than that due to waves and currents. Also, recent resuspension potential (erodibility) data from the 2013 SEDFlume experiments (SEI 2013) were not utilized for setting up the initial bed conditions for Newark Bay. Consequently, the sediment resuspension currently predicted by the model in the Bay does not reflect recent erodibility data. It is also evident that the coarse-grid resolution adopted for the OC and CF&T models lacks the ability to realistically predict contaminant concentrations in the sediment bed and the water column. Spatial aggregation and the influence of grid size are important considerations for model development, but they are not fully considered or analyzed.

4. ***The FFS did not evaluate model performance with the same rigor as employed by previous Superfund models.***

   The FFS evaluated model performance based on non-statistical comparisons of averages or uninformative metrics (i.e., on the percentage of data within factors of five and one-fifth. For example, the comparison of predicted particulate-bound organic carbon (POC) from the OC model to the data was described as "the average of the model results compares well with the average of the POC data without a bias toward being high or low" (page 4-5 of Appendix BIII [The Louis Berger Group, Inc. 2014]) without any objective statistical comparison. In stark contrast, previous Superfund models for other sites in EPA Regions 1 and 2 evaluated the ability of the hydrodynamic, sediment transport, and contaminant fate and transport models to reproduce data using formalized and rigorous frameworks. For example, calibration of the model for PCBs in the water column at the Housatonic River, done in early 2000s, had specified as a calibration target that model predictions be within ±30% from the data in the quality assurance project plan (QAPP), and the model's actual performance was clearly documented and summarized (Weston Solutions Inc. 2004). For the Hudson River, model calibration documentation showed whether model predictions fall within the 95% confidence interval about the mean of data (TAM Consultant Inc. 2000).

5. ***The sensitivity analysis to support model calibration was inadequate.***

While the high computational demand of analyzing the impacts on each model prediction due to variations around each input parameter's optimum (calibrated) value is appreciated, the sensitivity analyses described in the FFS Report fall short of the expectations and professional due diligence for a project of this magnitude and importance. Specifically, each adjustable (calibration) parameter (e.g., initial conditions, upstream and downstream boundary conditions, partition coefficients, erosion rates, depth, and rate of mixing) should be evaluated as to its role in changing the simulated chemical of potential concern (COPC) concentrations, both in the sediment bed and the water column. This sensitivity analysis should be conducted on model input parameters that have been optimized (through the calibration effort and uncertainty quantification) to values that yield the closest match between measured and simulated site data, and then slight variations around these values should be considered to ensure a proper local sensitivity analysis. Most modern automated uncertainty quantification (UQ) software also conducts sensitivity analyses during uncertainty quantification so many of the requested results will also be yielded from the UQ effort (Doherty 2009).

In addition to individual parameter sensitivity, scenario sensitivity should be explored more fully. It is important to understand how the various COPC concentrations change when fundamental forces on the model change (e.g., initial bed conditions, initial and boundary flows, and 100-year flows).

Finally, while sensitivity analyses were performed for sensitivity due to upstream boundary loading over Dundee Dam, partition coefficients, depth of particle mixing, rate of particle mixing, and a one-in-one-hundred-year storm, no analyses were conducted to understand how predictions from one model affect the next model. The OC and CF&T model documentation explained that sensitivity (and uncertainty) analysis was not propagated from one model to the next due to high computational demand. This is an acknowledged practical consideration, but one that could be resolved with the help of state-of-the-art methods such as surrogate modeling. Even without surrogate models, it should be possible to vary the output from one model around its calibrated value to see how changing this input parameter to the next model influences subsequent predictions.

Absent a thorough sensitivity analysis, the reliability and usefulness of the model to predict future concentrations is severely limited. It is not evident where the authors addressed the peer reviewer's concern over unknown sensitivity in the CF&T model to the downstream boundary conditions (see HDR-HydroQual Inc. 2013, Comment #109).

6. ***The models' predictions are not credible without a mass balance diagnostic analysis, which ensures that sediment and contaminant masses are conserved across the models.***

   A diagnostic analysis for sediment and contaminant mass balance was not carried out by the modelers, and the exclusion of this analysis undermines the credibility of the models. This diagnostic analysis is essential; it evaluates whether sediment and contaminant masses are conserved in the model simulations in accordance with the equation, Input – Output = Storage. One of the peer reviewers stated that a mass balance diagnostic analysis should be conducted to assess the "model's credibility for projecting the system's response to remedial alternatives" (HDR-HydroQual Inc. 2013, Comment #13). The modelers responded that "Additional mass balance summary information … will be included in the final modeling report." However, this was not carried out. The lack of this mass balance diagnostic analysis undermines the credibility of the models.

7. ***The sediment concentrations simulated over the calibration period are not realistic and hence do not provide sufficient insight into the models' ability to reproduce future concentrations.***

   The transect plots from ~RM 17 to RM 5.0 (Figures 4-11 through 4-28) show a comparison of the sediment concentrations of 2,3,7,8-TCDD in the top 15 cm between model and data for various years from 1995 (initial conditions) to 2012 in Appendix BIII (The Louis Berger Group, Inc. 2014). Figure 4-11 shows that the initial conditions used in the model are not as variable and generally are greater than reflected by the data in both the channel and shoal areas. The report indicates that this is due to the spatial distribution of the data, the coarser model grid, and the use of geomorphic zones. It is obvious that the spatial aggregation based on geomorphic regions and grid size is not represented realistically in the model. Absent a more realistic approach to setting up the initial conditions, the sediment concentrations simulated over the calibration period are not realistic and hence do not provide credible insight into the models' ability to predict future concentrations. Many of these transect plots show a discrepancy between model results and data with variations greater than an order of magnitude, and, in some cases, more than two orders of magnitude.

   Comparisons of the sediment concentrations in the top 15 cm between model and data for various years from 1995 (initial conditions) to 2015 are shown in in Figures 4-29 through 4-35 for 2,3,7,8-TCDD, Figures 4-36 through 4-42 for total PCBs, and Figures 4-43 through 4-49 for mercury in Appendix BIII (The Louis Berger Group, Inc. 2014). The contaminant concentrations are averaged over the top 15 cm of the sediment bed. The plots show that some of the model results are outside the 95% confidence limits of the data mean. This is also true for the other 45 modeled contaminants, plots for which are shown in Attachments C-1 through C-4 of Appendix BIII (The Louis Berger Group, Inc. 2014). For example, the model generally overpredicts water-column concentrations in the LPR and underpredicts those in Newark Bay (Figures 4-34 and 4-35 for 2,3,7,8-TCDD, Figures 4-41 and 4-

42 for total PCBs, and Figures 4-48 and 4-49 for mercury in Appendix BIII [The Louis Berger Group, Inc. 2014]). This appears to be a result of the higher sediment resuspension in the LPR and lower resuspension in Newark Bay.

8. ***The models' assumption of sediment and contaminant loadings does not replicate actual conditions, because sediment and contaminant loadings from some of the freshwater sources were excluded.***

   Sediment and contaminant loadings from some of the freshwater sources were excluded from the respective models; hence, the model loading assumptions do not represent actual inputs to the model domain. In Appendix BII (The Louis Berger Group, Inc. 2014), the modelers accounted for sediment and contaminant loadings from freshwater sources such as the Passaic River, Saddle River, Second and Third Rivers and MacDonald Brook. However, the modelers excluded other freshwater inflows and corresponding loadings. For example, Peripheral Ditch and Piersons Creek empty directly into Newark Bay; Rahway and Elizabeth Rivers, Piles Creek, Morses Creek, and Fresh Kills Creek enter by way of the Arthur Kill tidal strait (Shrestha et al. 2014). It does appear that the modelers included contaminant loads from the Rahway and Elizabeth Rivers in RCATOX (contaminant transport model) using an alternative approach that was not described clearly in the report. The implication is that exclusion of sediment and contaminant loads from all freshwater sources does not realistically represent the nature of sediments and contaminant loading in the model domain.

9. ***The models' uncertainty was evaluated in a limited fashion using out-of-date methods that render the uncertainty analysis uninformative.***

   The method from Connolly and Tonelli (1985) was used to estimate the degree of uncertainty in the final model results. This nearly 30-year-old approach is outdated. Much more rigorous analyses of uncertainty and sensitivity are available, such as Null Space Monte Carlo analyses and surrogate modeling, and these approaches should have been used (Doherty 2009; Doherty 2010; Doherty and Hunt 2009; Gallagher and Doherty 2007; Herckenrath et al. 2011; Hunt et al. 2007; James et al. 2009; Moore et al. 2010).

   While the complexity of this model and its computational expense (30–50 days for each simulation) are fully appreciated, the uncertainty quantification (UQ) and sensitivity analyses (SA) fall short of the expectations and requirements for a project of this magnitude and importance. Whenever a model takes longer than one day of wall-clock time to run, UQ and SA are challenging for all but the most powerful computing centers (Ye et al. 2010). Fortunately, an enormous amount of research has been dedicated to interrogating computationally expensive models, and several much more efficient approaches are now available. Perhaps the most broadly used technique for reducing the computational expense inherent in UQ and SA is surrogate modeling. Razavi et al. (2012, and references therein) provide the definitive review of the two broad families of surrogate modeling, namely: *response surface surrogates*, which are statistical or empirical data-driven models emulating

high-fidelity model responses, and *lower-fidelity physically based surrogates*, which are simplified models of the original system. Either approach could be implemented for the models built for this project (hydrodynamics, sediment dynamics, contaminant fate and transport, mass balance, etc.). There are, of course, many examples of successful surrogate modeling for UQ and SA (Conrad et al. 2014; Cui et al. 2014; Doherty and Christensen 2011; Frangos et al. 2014; Keating et al. 2010; Li and Marzouk 2013). It is recommended that some sort of surrogate modeling be used to quantify the uncertainty in OC and CF&T model estimates while also assessing the relative importance of model input parameters on predictions of interest.

Although such a model can never be precisely built, it is assumed that the complex OC and CF&T models constitute a "faithful replica" of the environmental processes that they attempt to simulate. While these models "look like the real thing," they are clearly unwieldy; they may not be numerically stable across all parameter space; they have limited ability to receive information from the available dataset; and they are virtually incapable of quantifying the uncertainty of predictive outcomes upon which important management decisions will be made (e.g., remedial actions).

For the OC and CF&T models, it seems most likely that a lower-fidelity surrogate model (simple model) should be paired with the existing complex model for the UQ/SA exercise. This simple model may comprise fewer grid cells and layers and may fix insensitive model parameters, but it should still act as a repository for the historical measurements of system state (calibration data). In conjunction with the complex model, this simple/complex model pair can be used to make bias-corrected predictions of future system behavior while quantifying the uncertainty of such predictions and reducing the uncertainty of these predictions to its theoretical minimum, which is governed by the calibration dataset and the constraints of expert knowledge (e.g., available parameter space). An outline of one method that could be used for simple/complex model pairing uncertainty analysis follows (Doherty and Christensen 2011):

1. Generate many realizations of the complex model, and of the parameters that it employs. Categorical realizations of the structural features (e.g., boundary conditions, events, loadings, and initial conditions), as well as realizations of continuous parameter fields (e.g., partition coefficients, erosion rates, settling rates, and contaminant gradients) can be included in these runs.

2. Using each of these complex model realizations, compute model outputs that correspond to measurements that constitute the calibration dataset (e.g., sediment concentrations, and contaminant concentrations).

3. For each complex model realization, calibrate the simple model against these model outputs (with pertinent model outputs enhanced with a realization of measurement noise to be most accurate).

4. For each realization, make a single prediction of management interest with the complex model (e.g., 2,3,7,8-TCDD).

5. For each complex model realization, re-calibrate the simple model against the complex-model-generated counterpart to the calibration dataset (e.g., modeled sediment concentrations) enhanced with the prediction of management interest (e.g., COPC concentration) generated by the complex model. Use Tikhonov constraints (Doherty 2010; Yoon and McKenna 2012) to ensure that the new (prediction-included) parameter field emerging from this process (denoted as $\mathbf{k}_s$) differs from the corresponding prediction-excluded parameter field (denoted as $\underline{\mathbf{k}}_s$) to the smallest extent possible.

6. After repeating this procedure for many different realizations of the complex model, determine an empirical covariance matrix, $C(\mathbf{k}_s - \underline{\mathbf{k}}_s)$, as it pertains to the prediction of interest (Lu et al. 2013). A covariance matrix is a matrix whose element in the *i*, *j* position is the covariance between the ith and j^{th} elements of a vector of model parameters. Intuitively, the covariance matrix generalizes the notion of variance to multiple dimensions. As an example, the variation in a collection of random points in two-dimensional space cannot be characterized fully by a single number, nor would the variances in the *x* and *y* directions contain all of the necessary information; a 2×2 matrix would be necessary to fully characterize the two-dimensional variation.

7. Calibrate the simple model against the real-world calibration dataset (Doherty and Christensen 2011).

8. Using the Pareto model of Model-independent Parameter Estimation (PEST) (Doherty et al. 2011), or using PEST's null space Monte Carlo approach (Malama et al. 2013; Moore 2006; Tonkin and Doherty 2009), while employing the $C(\boldsymbol{\varepsilon})$ covariance matrix of measurement noise and the $C(\mathbf{k}_s - \underline{\mathbf{k}}_s)$ covariance matrix of post-calibration parameter variability determined in item 6 above, explore the uncertainty of the prediction of interest (e.g., COPC concentration).

Resting on an assumption of model linearity, a subspace approach such as that outlined above (i.e., individually calibrating the simple model to many realizations of both the complex model's simulated equivalent to the calibration dataset and the prediction of interest), the ramifications of model simplification can be explored. While most models are actually nonlinear, a subspace approach to simplification analysis allows exploration of concepts that have not been exposed through previous simplification studies. In particular, this approach allows consideration of the mechanisms through which bias can be introduced to model predictions through the simplification process.

10. The CF&T model excluded important COPCs such as PAHs.

The CF&T model was developed for 48 selected COPC/COPECs (PCDD/F congeners, PCB homologues, dioxin-like PCB congeners, DDTs, cadmium, mercury, and methyl mercury). The list excluded important COPCs such as PAHs and other contaminants, and the basis for the selected contaminants was not given in in Appendix BIII (The Louis Berger Group, Inc. 2014).

11. The sensitivity analysis was limited to a few selected contaminants and ignored other important contaminants.

The model sensitivity analysis was conducted for 2,3,7,8-TCDD and five other dioxin congeners. The report contended that "the other COPCs and COPECs, although not simulated, would be expected to behave similarly to 2,3,7,8-TCDD due to their persistent and particle reactive nature" (page 5-1 in Appendix BIII [The Louis Berger Group, Inc. 2014]). The expectation that other COPCs and COPECs will behave similarly to 2,3,7,8-TCDD due to their environmental properties is not valid, given that the model's ability to accurately model those environmental properties was not demonstrated, as seen from inconsistent model performance across the 48 COPCs and COPECs. The sensitivity analysis on COPCs and COPECs is rendered inadequate by excluding chemicals from other chemical classes. The sensitivity analysis should, at a minimum, include representative chemicals from each chemical class (dioxins, furans, PCBs, pesticides, and metals).

12. The models' performance is inconsistent across the model domain.

The FFS OC and CF&T Report found that the models over-predict total water column concentrations, particularly within the FFS area, and attributes this to the models' response to the high-flow events in 2007, 2010, and 2011 (page 4-13 of Appendix BIII [The Louis Berger Group, Inc. 2014]). The same effect of the high-flow events is not evident, however, upstream and downstream of the FFS Study Area. This inconsistency is unexpected and shows that the models' ability to accurately model total water column concentrations is inconsistent across the model domain.

II. Uncontrolled contaminant sources outside of the FFS Study Area significantly affect the predicted outcome of the FFS remediation.

A. Summary

- The FFS CF&T modeling results show that the remediation goal can be achieved sooner, or via better designed alternatives, by controlling sources of contaminated sediment upstream of the FFS Study Area.

- The FFS CF&T modeling results show significant amounts of tetra PCB and mercury loads from above Dundee Dam affecting the Lower Passaic River.

- The FFS CF&T modeling results show that significant amounts of COPC loads enter the FFS Study Area following construction.

- The FFS OC and CF&T modeling report concluded that Alternatives 2 and 3 will produce minor reduction of COPC loads into Newark Bay.

B. General Comments

13. The FFS CF&T modeling results show that the remediation goal can be achieved sooner, or via better-designed alternatives, by controlling sources of contaminated sediment upstream from the FFS Study Area.

The FFS OC and CF&T models showed that only the deep dredging (Alternative 2) and full capping (Alternative 3) of the FFS area (RM 0 – 8.3) can achieve the remediation goal 30 years after construction, by 2059 or 2052, respectively. The reason that 30 years post-construction, is required to reach the remediation goal is because large storm events will deliver upstream contaminated sediments into the post-construction (i.e., clean) FFS Study Area and significantly re-contaminate it. This is evident, for example, in Figure 1, where sediment concentration of TCDD increased in 2012 because of the effect of Hurricane Irene, which was a once-in-75-year event. The sediment concentration was predicted to increase again in 2024, 2039, and 2054 because the model recycled the 2007 and 2010 storms (both once-in-25-year events) every 15 years. For the deep dredging scenario (Alternative 2) the effect of these assumed storm events is quite large because sediment concentration was predicted to increase by nearly an order of magnitude. Based on these modeling results, we can anticipate that the FFS Study Area will not be as re-contaminated by large storms and will reach the remediation goal sooner if upstream sources of contaminated sediments are controlled.

14. The FFS CF&T modeling results show significant amounts of tetra PCB and mercury loads from above Dundee Dam reaching the Lower Passaic River.

The FFS CF&T modeling results showed significant amounts of tetra PCBs and mercury suspended in the water column, i.e., loads, from above the Dundee Dam reaching the Lower Passaic River after construction. The model estimates that over 50 kg of tetra PCBs and 100 kg of mercury are transported downstream at River Mile 16.7 during the period 2029 to 2060 (Figure 2).

15. The FFS CF&T modeling results show that significant amounts of COPC loads enter the FFS area following construction.

The FFS CF&T modeling results showed that significant amounts of 2,3,7,8-TCDD, tetra PCBs, and mercury loads enter the FFS area from upstream areas. Figure 3 shows that the model estimates that roughly 250 g of 2,3,7,8-TCDD, 150 kg of tetra PCB, and 500 kg of mercury are transported towards the downstream direction at River Mile 9.8 from 2029 to 2060. This figure also demonstrates the effect of the

modeled large storms occurring in 2039 and 2054, when large increases in the COPC loads are predicted.

16. The FFS OC and CF&T modeling report concluded that Alternatives 2 and 3 will produce minor reductions of COPC loads into Newark Bay.

The FFS OC and CF&T modeling report (The Louis Berger Group, Inc. 2014) concluded that Alternatives 2 and 3 will produce only minor reductions in the amounts of 2,3,7,8-TCDD, tetra PCBs, and mercury entering Newark Bay: "The mass transport comparisons show that the Deep Dredging and Full Capping alternatives reduce the transport of 2,3,7,8-TCDD, tetra-PCBs and mercury to Newark Bay by one third or less."

Given this finding that the majority (two-thirds or more) of COPC loads will enter Newark Bay following construction of the proposed alternatives, the proposed remediation plan to address the FFS area prior to controlling sources in the upstream areas is counter-intuitive.

III. Key modeling assumptions about future conditions are unrealistic; therefore, the proposed remedial alternatives and the costs to implement them lack technical support.

A. Summary

- The modeled future conditions for the four remedial alternatives are unrealistic, in that they have predicted, without support, high contaminant concentrations in sediments and a long timeframe for the contaminant concentration to reach the remediation target.

- The CF&T model's predicted future sediment concentrations are inflated, so that the 30-year average concentrations used in the bioaccumulation model and the selection of the preferred remedial alternative, are not credible.

B. General Comments

17. The modeled future conditions for the four remedial alternatives are unrealistic, in that they predict, without support, high contaminant concentrations in sediments and a long timeframe for the contaminant concentration to reach the remediation target.

Future conditions from 2013 to 2059 under the four remedial alternatives were simulated by the FFS OC and CF&T models. For these future simulations, the freshwater flows were specified by repeating 15 years of flow data three times. The flow data are measurements at Little Falls from October 1995 to October 2010. This 15-year hydrograph dataset included two high-flow (i.e., storm) events measured at Little Falls with daily-averaged flows of 15,500 cubic feet per second (cfs) on April 18, 2007, and 15,600 cfs on March 16, 2010. Based on the summary of return period of flows in the Passaic River presented in Table 5-1 of Appendix BI (The Louis

Berger Group, Inc. 2014), both of those high-flow events exceed the 25-year return period (i.e., less than once-in-25-year frequency). As a result of repeating this 15-year flow data three times, the models effectively assumed that there will be six once-in-25-year high-flow events over a 47-year span between 2013 and 2059.

The effect of these high flow events on the remedial alternatives is evident; for example, in Figure 1, model results show spikes of sediment concentrations (which are more substantial for Alternatives 2 and 3) when the high-flow events occur (i.e., 2024, 2039, and 2054, which are based on the April 2007 high-flow event; and 2027, 2042, and 2057, which are based on the March 2010 high-flow event). It is unrealistic to include flows that exceed a return period of 25 years six times to simulate future conditions in a 47-year model (2013-2059). The design and evaluation of the remedial alternatives should be refined based on future conditions modeled with a more realistic frequency of high-flow events.

A more reasonable approach to model future conditions in the next 47 years (2013–2059) would be to use a hydrograph for the previous 47-years (1966-2012), which represents the most recent past conditions without resorting to recycling the same 15-year hydrograph three times, nor making potentially biased assumptions about the frequency and intensity of high-flow events. The effects of a potential increase (or decrease) in the frequency and intensity of high-flow events in the future on the CF&T model-estimated sediment and water column concentrations are important for the FFS to evaluate and provide upper- and lower-bound estimates. However, evaluation of such effects from potential or hypothetical changes to the hydrograph should be presented as a part of the uncertainty analysis. This was not done.

18. The CF&T model's predicted future sediment concentrations are inflated so that the 30-year average concentrations used in the bioaccumulation model and the selection of the preferred remedial alternative are not credible.

The assumption of six once-in-25-year high-flow events within the period 2013 – 2059 resulted in overly frequent spiking of sediment concentrations over a 47-year span. The skewing of the predicted future sediment concentrations as a result of recycling the 15-year hydrographs inflates the 30-year average concentration calculations used in estimated bioaccumulation and in selection of the remedial alternatives. And because the modeled spikes of sediment concentrations are repeated multiple times, the time required for the sediment concentration to reach the remediation target is also exaggerated.

IV. The transparency of the FFS model is limited, with a number of key modeling assumptions and methods not clearly documented or communicated to the reader.

A. Summary

- Unlike key assumptions, such as the assumed number of fish meals per year, with which the other commenters take issue, for deriving the preliminary remediation goal (PRG) value that was clearly presented, the key assumption of multiple future high-

flow events (i.e., six once-in-25-year events in the next 47 years) that significantly elevates modeled future sediment concentrations was not communicated clearly to the reader.

- The impact of future storms and predicted future sediment concentrations, and hence, the risk assessment, was under-stated.
- Important data sources, derivation of key model parameters, and significant analyses were undocumented.
- Concentrations and loadings of contaminants were not presented in graphic form, so it is difficult to gauge the relative contribution of sediment and contaminant loadings to the model domain.
- Details on grid aggregation, where up to three sediment transport model grid cells were combined into a single contaminant fate and transport model grid cell along the length of the river, were not provided.
- The important role of relatively cleaner sediments from above Dundee Dam to support the remedial alternatives to reach the remediation goal was not clearly stated.

B. General Comments

19. Unlike key assumptions, such as the assumed number of fish meals per year, with which other commenters take issue, for deriving the PRG value that was clearly presented, the key assumption of multiple future high-flow events (i.e., six once-in-25-year events in the next 47 years) that significantly elevates modeled future sediment concentrations was not communicated clearly to the reader.

The key assumption of multiple future high-flow events (i.e., six once-in-25-year events in the next 47 years) that significantly elevates modeled future sediment concentrations, was not clearly communicated. The impact of this key assumption was presented only in Appendix BIII; in contrast, the number of fish meals per year, with which other commenters take issue, that was assumed for the preliminary remediation goal (PRG) was identified in four separate documents: the main FFS document, the FFS compiled document, Appendix D – Risk Assessment, and Appendix E – Development of PRGs ((The Louis Berger Group, Inc. 2014).

The basis for assuming an unrealistic number of large storms in the next 47 years was also not given.

20. The impact of future storms and predicted future sediment concentrations, and hence, the results of the risk assessment, were under-stated.

The impact of temporal variability of future storm events and predicted future sediment concentrations on future risk estimates was under-stated in Attachment 7 in Appendix D – Risk Assessment (The Louis Berger Group, Inc. 2014). Attachment 7 presented estimated relative percent differences (RPDs) calculated from the

predicted minimum and maximum annual average sediment concentrations for each COPEC for years 2041 through 2059 based on Alternative 1 (page 12 of Attachment 7). Attachment 7 concluded that the largest change in predicted future sediment concentrations (and impact to the risk assessment) due to storm events was estimated to be 21% for 2,3,7,8-TCDD, 14% for total mercury, 11% for total DDT, and 15% for total PCBs. The estimated impact from storm events for other Alternatives was not presented in Attachment 7, although Alternative 3 was identified as the preferred remedy. The estimated impact of future storms on the predicted future sediment concentrations for Alternative 3 can be observed from Figures 6-3 (for 2,3,7,8-TCDD), 6-15 (for tetra PCBs), and 6-27 (for mercury) in Appendix BIII (The Louis Berger Group, Inc. 2014). For years 2041 through 2059, the predicted sediment concentrations for 2,3,7,8-TCDD can increase by >700%, tetra PCBs by >300%, and mercury by >100%.

21. ***The derivation of partition coefficients for dioxin-like PCB congeners was not documented.***

    The OC and CF&T modeling parameters were, with few exceptions, based entirely on the CARP model's parameters. These modeling parameters include partition coefficients that describe the affinity of contaminants for sediment particles. Partition coefficients for dioxin-like PCB congeners were newly derived for the FFS CF&T model, because they were unavailable from the CARP model. The OC and CF&T model report (Appendix BIII [The Louis Berger Group, Inc. 2014]) failed to present any documentation on the derivation of these dioxin-like PCB congener partition coefficients. Also, the analysis of model prediction sensitivity to these parameters was inadequate.

22. ***Concentrations and loadings of contaminants were not presented in graphic form, so it is difficult to gauge the relative contribution of sediment and contaminant loadings to the model domain.***

    The OC and CF&T model report (Appendix BIII [The Louis Berger Group, Inc. 2014]) and supporting documentation from the sediment transport model did not present in graphic form the concentrations and loadings from all the freshwater sources that are included in the models. For example, Figures 3-2 through 3-6 in Appendix BII (The Louis Berger Group, Inc. 2014) show sediment concentrations and loadings for the Passaic, Saddle, Third, Second, and Hackensack rivers, but exclude information for MacDonald Brook. Similarly, Figures 3-1 through 3-4 and Figures 3-7 through 3-9 in Appendix BIII (The Louis Berger Group, Inc. 2014) exclude information on organic carbon and contaminant loadings from some of the freshwater sources. Absent this information, it is difficult to gauge the relative contribution of sediment and contaminant loadings to the model domain. Furthermore, the modelers neglected to include data for TSS and contaminant concentrations and derived loadings in the graphics, as suggested by one of the peer reviewers (see HDR-HydroQual Inc. 2013, Comment #8).

23. Inadequate details on grid aggregation, wherein up to three sediment transport model grid cells were combined into a single contaminant fate and transport model grid cell along the length of the river, were provided.

The model grid used in the hydrodynamic and sediment transport models was aggregated into coarser grid cells to model OC and CF&T for purposes of computation tractability. Up to three sediment transport model grid cells were combined into a single contaminant fate and transport model grid cell along the length of the river (i.e., longitudinal direction). There is a lack of specificity as to the exact methods used for transferring information from the hydrodynamic and sediment transport models to the OC and CF&T models during grid aggregation. There is no information, whatsoever, on how the hydrodynamic parameters were aggregated. It is unclear how translation of variables from the fine grid to the coarse grid (grid aggregation) influences the model results, uncertainty analysis, and sensitivity analysis. Is there a loss of information when doing any spatial or temporal averaging of results across models? The rationale for grid aggregation is set forth (computation tractability), but the impacts are not fully explored. In fact, grid aggregation might be considered one form of surrogate modeling. Overall, it should be demonstrated that mass has been conserved when transitioning from the fine to coarse model grids during aggregation. The parameters discussed in Table 2-4 in Appendix BIII (The Louis Berger Group, Inc. 2014) should be explored specifically as to how grid aggregation influenced them, for example, through a detailed mass balance. Also, at least one grid resolution study should be conducted to demonstrate that the coarse grid is sufficiently refined to yield converged OC and CF&T simulations.

24. Inadequate details are presented on how dispersion coefficients were collapsed from the sediment transport to the OC and CF&T models.

The modelers did not provide “further discussion of the dispersion properties and how they were collapsed from the sediment transport to the organic carbon/contaminant grid” in the OC and CF&F model report, as requested by one of the peer reviewers (see HDR-HydroQual Inc. 2013, Comment #5). The adjustment of the dispersion coefficient is important because of an increase in mixing lengths in the coarser grid.

25. The sensitivity analysis for fraction of organic carbon (FOC) was not adequately documented or investigated.

The modelers noted that there is heterogeneity in the fraction of organic carbon (FOC) in the LPR sediments, and a sensitivity analysis of this parameter in the OC model was conducted. The modelers described their conclusion but did not present results of the sensitivity analysis. Also, while the report stated that the changes in FOC values (e.g., double) will not significantly influence predicted contaminant concentrations, FOC varies by more than two orders of magnitude.

26. The FFS OC and CF&T model report stated that the data from 2012 CPG LRC and 1996–2006 Honeywell sampling programs are suspicious and they should be evaluated further. The results from such an evaluation were not included in the final report.

In the comparison of model prediction to actual sample data (model calibration), the FFS OC and CF&T model report concluded that the model predictions were more consistent with the higher sample concentration values than the lower values reported for the same model grids from the 2012 CPG LRC and the 1996-2006 Honeywell sampling programs (page 4-16 of Appendix BIII [The Louis Berger Group, Inc. 2014]). While this finding suggests that the model predictions may be biased high, EPA characterized the lower-value data as suspicious and recommended further evaluation. The results from the evaluation were not included in the final report, so that it is unclear whether the lack of good model fit reflects the model's biased estimate or deficient sample data quality. The suspicion over the 2012 CPG LRC data seems unfounded, since the FFS Data Evaluation Report (Appendix A, Section 2.12) reported the 2012 CPG LRC data were consistent with earlier data: "…2012 surface sediment concentrations for the parameters examined in the data evaluation reports are comparable to the concentrations from other data collected previously." For the 1996-2006 Honeywell sampling program dataset, the suspicion over its data quality is confusing to the readers, since Table 3-6 of Appendix BIII (The Louis Berger Group, Inc. 2014) shows this dataset had not been used for model development, but on the other hand, page 4-16 described the dataset was compared to the model prediction and was found to be suspicious.

27. The important role of relatively cleaner sediments from above the Dundee Dam to support the remedial alternatives to reach the remediation goal was under-stated.

The FFS Report highlighted only the engineering aspects of the proposed alternatives and their anticipated results in the form of model-predicted reduction of sediment contaminant concentrations in Section 6 of Appendix BIII (The Louis Berger Group, Inc. 2014). The FFS Report did not describe that, for Alternatives 2 and 3, the reduction of sediment contaminant concentrations over time is aided by cleaner sediment loads from above the Dundee Dam, which are responsible for one-third of the total sediment loads into the lower 17 miles. This aspect was only described in the EPA's FFS "compiled" document (EPA 2014): "Sediment particles coming from above Dundee Dam make up about one third of particles in the FFS Study Area water column. When those particles flow down to the FFS Study Area, they mix with the other particles in the system (including cleaner particles in the water column that would result from a remediated FFS Study Area); after they are deposited, they also mix with the clean material placed on the river bed as part of remediation." The EPA document noted the important role of cleaner sediments from above the Dundee Dam which the FFS Report neglected to describe.

References

Connolly, J.P., Tonelli, R., 1985. Modelling Kepone in the striped bass food chain of the James River estuary. Estuarine, Coastal and Shelf Science, 20(3): 349-366.

Conrad, P.R., Marzouk, Y.M., Pillai, N.S., Smith, A., 2014. Asymptotically exact MCMC algorithms via local approximations of computationally intensive models. arXiv, 1402: 1694.

Cui, T., Marzouk, Y.M., Willcox, K.E., 2014. Data-driven reduction for the Bayesian solution of inverse problems. arXiv, 1403: 4920.

Doherty, J.E., 2009. Manual for PEST: Model Independent Parameter Estimation, Watermark Numerical Computing, Brisbane, Australia.

Doherty, J.E., 2010. Addendum to the PEST Manual, Watermark Numerical Computing, Brisbane, Australia.

Doherty, J., Christensen, S., 2011. Use of paired simple and complex models to reduce predictive bias and quantify uncertainty. Water Resources Research, 47(12): W12534.

Doherty, J.E., Hunt, R.J., 2009. Two statistics for evaluating parameter identifiability and error reduction. Journal of Hydrology, 366(1-4): 119-127.

Doherty, J.E., James, S.C., Reimus, P.W., 2011. Model-based decision making: A new perspective, 13th International High-Level Radioactive Waste Management Conference. American Nuclear Society, Albuquerque, NM, pp. 1-10.

Frangos, M., Marzouk, Y.M., Willcox, K., van Bloemen Waanders, B., 2014. Surrogate and reduced-order modeling: A Comparison of approaches for large-scale statistical inverse problems. In: Earth, P.o. (Ed.), Computational Methods for Large-Scale Inverse Problems and Quantification of Uncertainty, pp. 27.

Gallagher, M.R., Doherty, J.E., 2007. Parameter interdependence and uncertainty induced by lumping in a hydrologic model. Water Resources Research, 43(5): W05421.

HDR-HydroQual Inc., 2013. Report of the Peer Review of Sediment Transport, Organic Carbon and Contaminant Fate and Transport Model.

Herckenrath, D., Langevin, C.D., Doherty, J., 2011. Predictive uncertainty analysis of a saltwater intrusion model using null-space Monte Carlo. Water Resources Research, 47(5): n/a-n/a.

Hunt, R.J., Doherty, J.E., Tonkin, M.J., 2007. Are models too simple? Arguments for increased parameterization. Ground water, 45(3): 254-262.

James, S.C., Doherty, J.E., Eddebbarh, A.-A., 2009. Practical postcalibration uncertainty analysis: Yucca Mountain, Nevada. Ground water, 47(6): 851-869.

Keating, E.H., Doherty, J., Vrugt, J.A., Kang, Q., 2010. Optimization and uncertainty assessment of strongly nonlinear groundwater models with high parameter dimensionality. Water Resources Research, 46(10): W10517.

Li, J., Marzouk, Y.M., 2013. Adaptive construction of surrogates for the Bayesian solution of inverse problems. arXiv, 1309: 5524.

Lu, D., Ye, M., Meyer, P.D., Curtis, G.P., Shi, X., Niu, X.-F., Yabusaki, S.B., 2013. Effects of error covariance structure on estimation of model averaging weights and predictive performance. Water Resources Research, 49(9): 6029-6047.

Malama, B., Kuhlman, K.L., James, S.C., 2013. Core-scale solute transport model selection using Monte Carlo analysis. Water Resources Research, 49: 1-15.

Moore, C., 2006. The use of regularized inversion in groundwater model calibration and prediction uncertainty analysis, University of Queensland, Brisbane, 300 pp.

Moore, C., Wöhling, T., Doherty, J., 2010. Efficient regularization and uncertainty analysis using a global optimization methodology. Water Resour. Res., 46(8): W08527.

Razavi, S., Tolson, B.A., Burn, D.H., 2012. Review of surrogate modeling in wate resources. Water Resources Research, 48: W07401.

SEI, 2013. SEDflume Analysis Data Report Newark Bay, New Jersey, Sea Engineering, Inc., Santa Cruz, CA.

Shrestha, P.L., Su, S.H., James, S.C., Shaller, P.J., Doroudian, M., Firstenberg, C.E., Thompson, C.T., 2014. Conceptual site model for Newark Bay—Hydrodynamics and sediment transport. Journal of Marine Science and Engineering 2(1): 123-139.

TAM Consultant Inc., 2000. Phase 2 Report – Review Copy, Further Site Characterization and Analysis, Volume 2d - Revised Baseline Modeling Report, Hudson River PCBs Reassessment RI/FS. January 2000. Prepared for U.S. Environmental Protection Agency, Region 2, and U.S. Army Corps of Engineers, Kansas City District. Volume 2D - Book 1 of 4, Fate and Transport Models. TAMS Consultants, Inc., Limno-Tech, Inc., Menzie-Cura & Associates, Inc., Tetra Tech, Inc.

The Louis Berger Group, Inc., 2014. Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River. Prepared for the U.S. Environmental Protection Agency Region 2 and the U.S. Army Corps of Engineers Kansas City District.

Tonkin, M.J., Doherty, J.E., 2009. Calibration-constrained Monte Carlo analysis of highly parameterized models using subspace techniques. Water Resources Research, 45(12): W00B10.

U.S. Environmental Protection Agency (EPA), 2014. U.S. Environmental Protection Agency, Region II. Lower Eight Miles of the Lower Passaic River, Part of the Diamond Alkali Superfund Site, Essex and Hudson Counties, New Jersey. April 2014.

Weston Solutions Inc., 2004. Model Calibration: Modeling Study of PCB Contamination in the Housatonic River, Environmental Remediation Contract, General Electric (GE)/Housatonic River Project, Pittsfield, Massachusetts, Contract No. DACW33-00-D-0006, Task Order No. 0003, DCN: GE-122304-ACMG. Prepared for U.S. Army Corps of Engineers, New England District, Concord, Massachusetts, and U.S. Environmental Protection Agency, New England Region, Boston, Massachusetts. Prepared by Weston Solutions, Inc., West Chester, Pennsylvania.

Ye, M., Meyer, P., Lin, Y.-F., Neuman, S., 2010. Quantification of model uncertainty in environmental modeling. Stochastic Environmental Research and Risk Assessment, 24(6): 807-808.

Yoon, H., McKenna, S.A., 2012. Highly parameterized inverse estimation of hydraulic conductivity and porosity in a three-dimensional, heterogeneous transport experiment. Water Resources Research, 48(10): W10536.

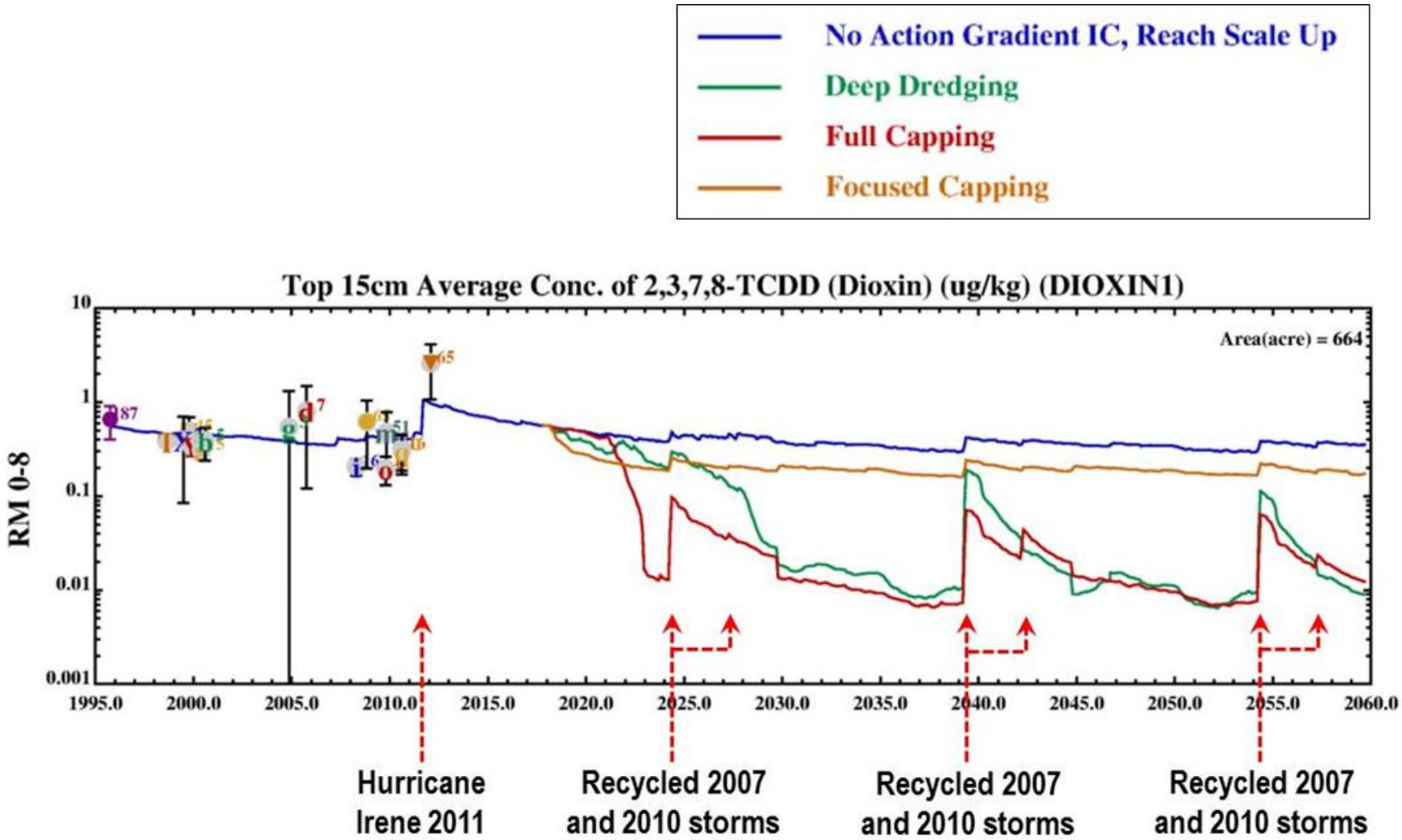


Figure 1. Temporal plot of 2,3,7,8-TCDD sediment concentrations for no action and three remedial alternatives (RM 0-8.3). (Source: Figure 6-3 in Appendix BIII [The Louis Berger Group, Inc. 2014]).

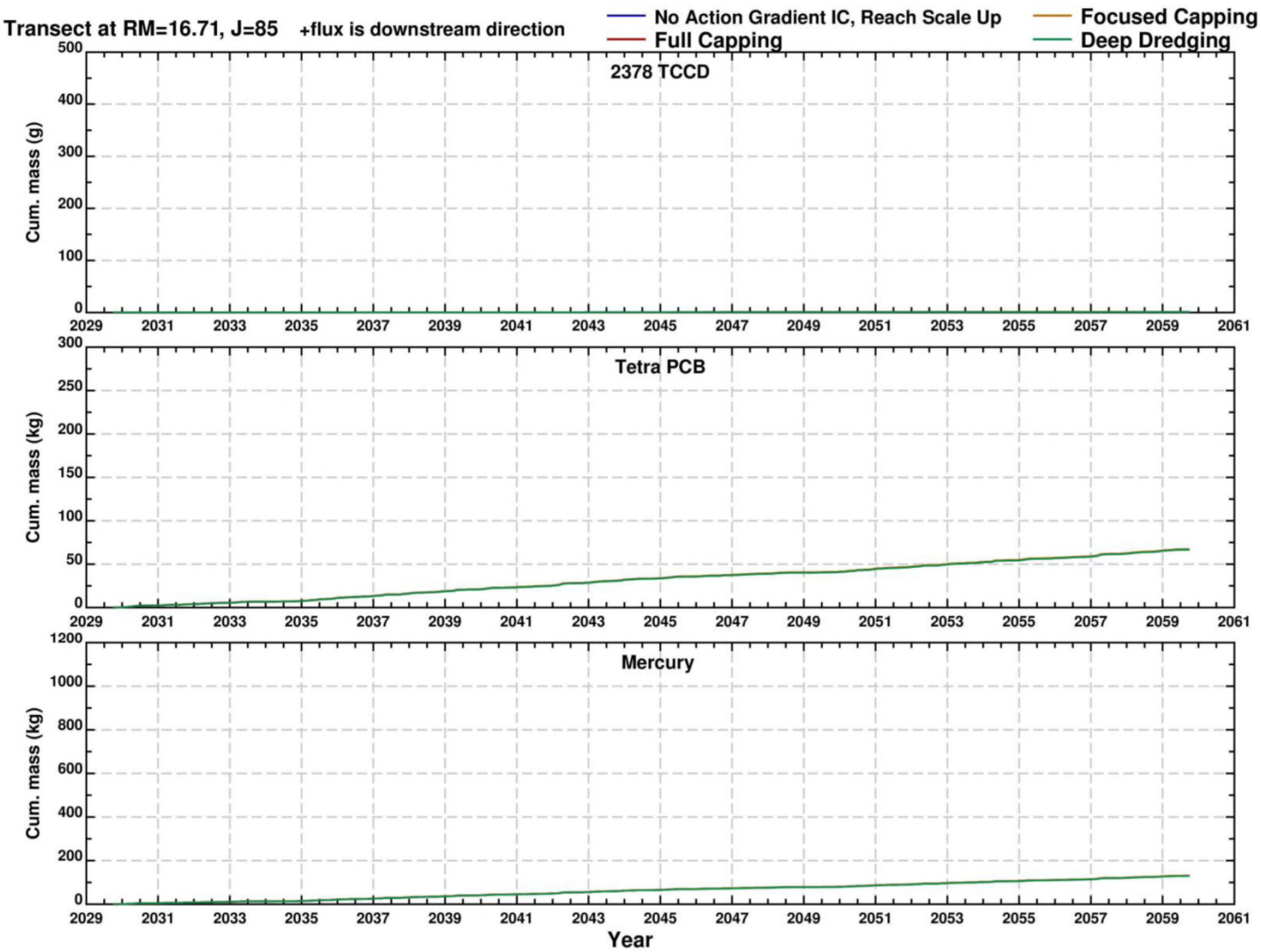


Figure 2. Cumulative (from 2024) water column contaminant mass transport at RM 16.7. (Source: Figure 6-39 in Appendix BIII [The Louis Berger Group, Inc. 2014]).

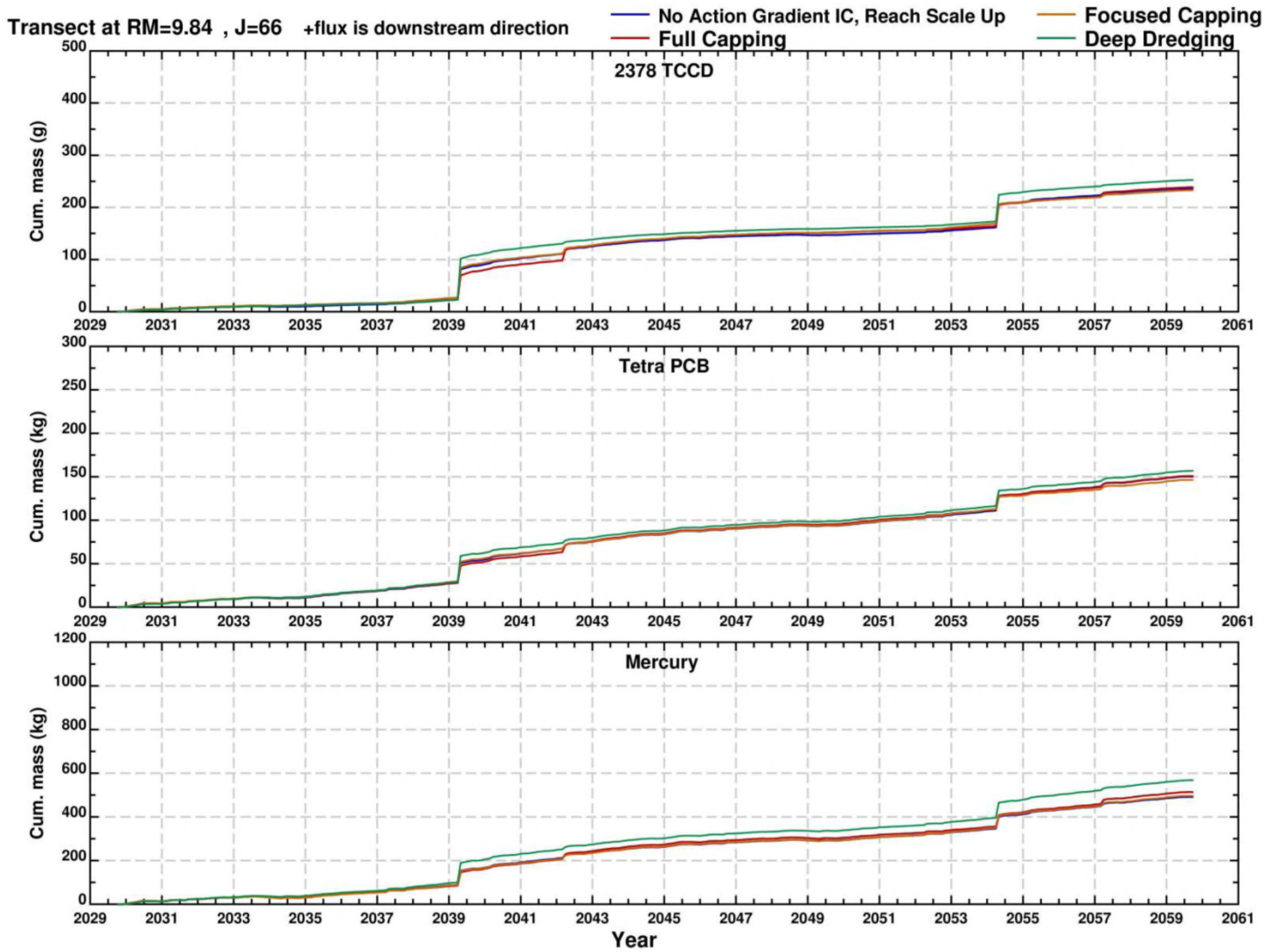


Figure 3. Cumulative (from 2024) water column contaminant mass transport at RM 9.8. (Source: Figure 6-42 in Appendix BIII [The Louis Berger Group, Inc. 2014]).

Parmeshwar L. Shrestha, Ph.D., P.E., D.WRE, D.CE

Senior Managing Engineer
Exponent
320 Goddard, Suite 200, Irvine, CA 92618
Phone: 949-242-6000; Fax: 949-242-6099
www.exponent.com

PROFESSIONAL PROFILE

Dr. Parmeshwar L. Shrestha (Pravi) is a Senior Managing Engineer in Exponent's Civil Engineering practice with over 25 years of experience in the field of water resources and environmental engineering. His experience in the area of hydrodynamic and sediment transport include the development and application of finite element and finite difference models for hydrodynamic and sediment transport modeling (both cohesive and noncohesive) and inherent physico-chemical processes in surface water systems. Specific experience includes development and application of numerical models for Sam Rayburn Lake (Texas), San Francisco Bay, San Diego Bay, Clear Lake (California), New York and New Jersey Harbors, Housatonic River (Massachusetts), Lavaca Bay (Texas), Green Bay (Wisconsin), Tannery Bay (Michigan), Lake Waban (Massachusetts), and the Arafura Sea (Indonesia) for purposes of water quality assessment and mitigation of potential adverse effects. He co-authored the hydrodynamic and sediment transport aspects for the conceptual site model for the Newark Bay Study Area. Dr. Shrestha's experience also include review of various reports on hydrodynamic, sediment transport and contaminant fate and transport, including the focused feasibility study report for the lower eight miles of the Lower Passaic River. Dr. Shrestha has also conducted workshops and hands-on training on the use of hydrodynamic and sediment transport models for Sandia National Laboratory (New Mexico), The Research Center on Flood and Drought Disaster Reduction (People's Republic of China), and Stevens Institute of Technology (New Jersey). His teaching experience includes courses in hydraulics and open channel flow at Virginia Tech and courses on sediment and pollutant transport at the Hong Kong University of Science and Technology.

Dr. Shrestha is currently serving as an Associate Editor for the *ASCE Journal of Hydrologic Engineering* and serves on the Editorial Board of the *Journal of Coastal Research of the Coastal Research* and Education Foundation. He was involved in the Water Environment Federation Watershed and Wet Weather Technical Bulletin Advisory Board. He served on the ASCE Task Committee on Contaminated Sediments and on the ASCE Task Committee on Fluid Mud. He is currently serving on the ASCE Standards Committee KSTAT (Fitting of Hydraulic Conductivity with Statistical Spatial Estimation), the ASCE Surface Water Hydrology Technical Committee, and the COPRI Navigation Engineering Task Committee. Dr. Shrestha served as a member of the organizing committee for InterCoh 2003. He was also a member of the advisory committee for the biennial conference on Estuarine and Coastal Modeling.

ACADEMIC CREDENTIALS

University of California, Davis	Water Resources Engineering	Ph.D.	1991
University of California, Davis	Water Resources Engineering	M.S.	1985
Jadavpur University	Civil Engineering (*First class honors*)	B.S.	1979

PROFESSIONAL HONORS

- Faculty of the Year Award, Department of Civil Engineering, Virginia Tech, 1994
- Dean's List for Outstanding Instructor, Virginia Tech, 1993, 1994
- Nominated for Engineering Sporn Award in Teaching Excellence, Virginia Tech, 1994
- Fulbright-Hays Scholar, M.S. Program, University of California, Davis, 1983-1986
- Colombo Plan Scholar, Bachelor program, Jadavpur University, 1974-1979

LICENSES AND CERTIFICATIONS

- Registered Professional Engineer (Civil), California, #67971
- Registered Professional Engineer (Civil), Arizona, #51083
- Registered Professional Engineer (Civil), Virginia, #026710

- Hong Kong Institution of Engineers, #MO0267236
- Diplomate, Water Resources Engineer, #00278
- Diplomate, Coastal Engineer, #65

SELECTED PUBLICATIONS

- **Shrestha, P. L.**, Su, S. H., James, S. C., Shaller, P. J., Doroudian, M., Firstenberg, C. E., Thompson, C. T. (2014). Conceptual site model for Newark Bay—Hydrodynamics and sediment transport. *Journal of Marine Science and Engineering*, 2(1):123-139.
- McAnally, W. H., Friedrichs, C., Hamilton, D., Hayter, E., **Shrestha, P.**, Rodriguez, H., Sheremet, A., Teeter, A. (2007). Management of fluid mud in estuaries, bays, and lakes. I: Present state of understanding on character and behavior. *ASCE Journal of Hydraulic Engineering*, 133(1):9−22.
- McAnally, W. H., Teeter, A., Schoellhamer, D., Friedrichs, C., Hamilton, D., Hayter, E., **Shrestha, P.**, Rodriguez, H., Sheremet, A., Kirby, R. (2007). Management of fluid mud in estuaries, bays, and lakes. II: Measurement, Modeling, and Management. *ASCE Journal of Hydraulic Engineering*, 133(1):23−38.
- James, S., **Shrestha, P.**, Roberts, J. (2006). Modeling noncohesive sediment transport using multiple sediment size classes. *Journal of Coastal Research*, 22(5):1125−1132.
- **Shrestha, P.**, Blumberg, A. (2005). Cohesive sediment transport. pp. 327−330. *Encyclopedia of Coastal Science*. Schwartz M (ed), Springer, The Netherlands.
- Roig, L. C., **Shrestha, P.**, Ramireddygari, S. R. (2000). Mixing and transport. *Water Environment Research*, 72(5):1-50.
- Govindaraju, R. S., Ramireddygari, S. R., **Shrestha, P.**, Roig, L. C. (1999). Continuum bed model for estuarial sediments based on nonlinear consolidation theory. *ASCE Journal of Hydraulic Engineering*, 125(3):300−304.
- **Shrestha, P.**, Orlob, G. T. (1996). Multiphase distribution of cohesive sediments and heavy metals in estuarine systems. *ASCE Journal of Environmental Engineering*, 122(8):730-740.

Steave H. Su, M.P.H.

Managing Scientist
Exponent
420 Lexington Avenue, Suite 1740, New York, NY 10170
Phone: 212-895-8100; Fax: 212-895-8199
www.exponent.com

PROFESSIONAL PROFILE

Mr. Steave Su is a Managing Scientist in Exponent's Health Sciences Center for Exposure Assessment and Dose Reconstruction. Mr. Su has over 20 years of experience studying a broad range of issues concerning the effects of chemical, physical, and biological agents on human health and the environment. Areas of his work include probabilistic risk analysis, chemical fingerprinting, sediment quality evaluation, sediment transport of pollutants, food-chain/food-web modeling, angler fish consumption, pathogens in recreational waters, epidemiology, and general toxicology. He provides state-of-the-art scientific support for site assessments, pollutant source identification and allocation, and evaluation of potential health and environmental impacts from new and existing products.

Mr. Su has considerable experience studying the effects of bioaccumulating chemicals, such as dioxins and PCBs, at several contaminated sediments sites, including the Lower Passaic River and Newark Bay (New Jersey), Lower Fox River (Wisconsin), and Housatonic River (Connecticut and Massachusetts). He provided inputs on the development of the conceptual site model for the Newark Bay Study Area. His experience also include review of contaminant fate and transport modeling report supporting the focused feasibility study report for the lower eight miles of the Lower Passaic River. His work has resulted in more realistic characterization of potential risk from exposure to environmental pollutants to support technically sound and cost-effective risk management actions. He also has served as a peer reviewer for several academic journals.

ACADEMIC CREDENTIALS

Yale University	Env. Health Sciences (*with Distinction*)	M.P.H.	1992
New York University	Chemistry	B.A.	1986

SELECTED PUBLICATIONS

- Shrestha, P. L., **Su, S. H.**, James, S. C., Shaller, P. J., Doroudian, M., Firstenberg, C. E., Thompson, C. T. (2014). Conceptual site model for Newark Bay—Hydrodynamics and sediment transport. *Journal of Marine Science and Engineering*, 2(1):123-139.
- Saba, T., **Su, S.** (2013). Tracking polychlorinated biphenyls (PCBs) congener patterns in Newark Bay surface sediment using principal component analysis (PCA) and positive matrix factorization (PMF). *Journal of Hazardous Materials*, 260(15):634-643.
- Connor, K. T., Eversen, M., **Su, S. H.**, Finley, B. L. (2005). Quantitation of polychlorinated biphenyls in fish for human cancer risk assessment: A comparative case study. *Environmental Toxicology & Chemistry*, 24(1):17−24.
- **Su, S. H.**, Pearlman, L. C., Rothrock, J. A., Iannuzzi, T. J., Finley, B. L. (2002). Potential long-term ecological impacts caused by disturbance of contaminated sediments: A case study. *Environmental Management*, 29(2):234−249.
- **Su, S.**, Rothrock, J., Pearlman, L., Finley, B. (2001). Health-based criteria for sediment disposal options: A case study of the Port of New York/New Jersey. *Human and Ecological Risk Assessment*, 7(6):1737−1756.
- Iannuzzi, T. J., Harrington, N. W., Shear, N. M., Curry, C. L., Carlson-Lynch, H., Henning, M. H,, **Su, S. H.** (1996). Distributions of key exposure factors controlling the uptake of xenobiotic chemicals in an estuarine food web. *Environmental Toxicology & Chemistry*, 15(11):1979-1992.
- Gillis, C. A., Bonnevie, N. L., **Su, S. H.**, Ducey, J. G., Huntley, S. L., Wenning, R. J. (1995). DDT, DDD, and DDE contamination of sediments in the Newark Bay Estuary. *Archives of Environmental Contamination and Toxicology*, 28:85-92.

- Huntley, S. L, Wenning, R. J., **Su, S. H.**, Bonnevie, N. L., Paustenbach, D. J. (1995). Geochronology and sedimentology of the Lower Passaic River, New Jersey. *Estuaries*, 18(2):351-361.
- Ehrlich, R., Wenning, R. J., Johnson, G. W., **Su, S. H.**, Paustenbach, D. J. (1994). A mixing model for polychlorinated dibenzo-p-dioxin and dibenzofurans in surface sediments from Newark Bay, New Jersey. *Archives of Environmental Contamination and Toxicology*, 27:486-500.

COMMENTS

Remedy, Engineering and Cost Related Comments

Lower Passaic River Focused Feasibility Study and Proposed Plan, April 2014

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
Paul J. Bluestein, P.E.
Tierra Solutions, Inc.

Robert Romagnoli, P.E.
The Intelligence Group, LLC.

Table of Contents

1 The FFS dismissed in-situ treatment; a technically implementable technology type that should be considered in the FFS. 1

2 The mechanical dredging and mechanical dewatering unit rates are underestimated; realistic rates should be identified and the FFS cost estimates revised accordingly. 3

3 The assumption of beneficial reuse of the sand fraction is ill-founded. Region 2 should evaluate data from the Phase I NTCRA regarding the sand fraction waste stream and amend the FFS accordingly. 3

4 There are no DUOs for the pre-design investigation. The Alternative 3 pre-design investigation task of sediment coring for chemical analyses serves no data use objective and should be eliminated from the FFS. 3

5 Region 2 used outdated unit costs. The unit rates used to develop the processing and disposal cost component are outdated, and as such, the FFS should be revised to incorporate current unit rates. 4

6 The cost sensitivity analysis of changes in dredging productivity is flawed and should be revised. 4

7 Region 2's upland processing facility (UPF) siting study is insufficient. Reliance on seven year old studies to conclude that an UPF is feasible is inadequate given its vital necessity to implementation of Region 2's proposed plan; a thorough study should be undertaken and included in a revised FFS. 4

8 The evaluation of the cost impact of increasing by an additional six inches the extent of the engineered cap to be armored fails to account for a large portion of the actual cost of this additional armoring. Region 2 should revise the FFS to include these costs. 5

9 The assumption for hazardous waste storage is incorrect. Temporary storage of hazardous waste for six months at the processing facility would violate RCRA; the FFS should be revised to evaluate proper management of hazardous waste. 6

10 A complete evaluation of hydraulic dredging should be prepared. Hydraulic dredging and mechanical dredging are too dissimilar to assume mechanical dredging as the representative process option; the FFS should be revised to adequately evaluate hydraulic dredging. 6

11 Dredging productivity and dredging season are not achievable. The assumed dredging productivity of 2,000 cubic yards per 24-hour day per dredge and a dredging season of 40 weeks [24-hour days, 6 work days per week, 240 days per year] are not realistic; these assumptions should be revised; this, in turn, calls into question the implementability of FFS Alternative 3 and greatly impacts costs. 7

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

12 Shoreline protection during dredging/capping operations is not adequately addressed; the FFS should be revised accordingly. 10

13 CAD/CDF-based approaches are more Implementable than and equally protective of and cost-effective as off-site disposal. This determination needs to be re-evaluated.....11

14 CADs and CDFs are proven, effective options 15

15 CAD Represents the “Green” Option.....16

16 CAD facilities are similar to Region 2’s proposed remedial alternative of capping contaminated sediment; therefore, there is no valid basis to screen out this alternative. 16

17 The assumptions made regarding the estimated volume of dredged material characterized as hazardous and requiring thermal treatment prior to disposal are incorrect and as such, the FFS should be revised accordingly. 17

18 The FFS fails to address logistics and implementability concerns as they relate to transitioning between different waste categories during dredging/processing. 19

19 References 20

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

1 The FFS dismissed in-situ treatment; a technically implementable technology type that should be considered in the FFS.

As discussed in Table 3-1 of the FFS Report, four process options were identified under the in-situ treatment technology type; (1) immobilization, (2) sequestration, (3) biological treatment, and (4) chemical treatment. Immobilization was eliminated as the two case studies discussed did not provide sufficient data to evaluate the effectiveness of this process option. Sequestration was considered to be technically implementable but was ultimately eliminated (Table 3-2 of the FFS) due to its unknown effectiveness and implementability in *"large areas and sites with higher contamination"* as compared to the demonstration projects discussed in the FFS. Biological treatment was deemed to not be technically implementable *"Since many of the Lower Passaic River contaminants are either not biodegradable (particularly heavy metals) or are very persistent in the environment (e.g., PCDD/F, PCB, pesticides)…"*. And chemical treatment was eliminated as there are no known applications of this process option to demonstrate effectiveness and implementability. The discussion that follows supports the need to retain in-situ treatment as a technology type, specifically the biological treatment and sequestration process options.

Over the past decade, significant scientific and technological advances have occurred that have altered our understanding of the biodegradation of hydrophobic chlorinated organics such as polychlorinated biphenyls (PCBs) and polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDD/PCDFs). Advances in genome-based identification have confirmed that *Chloroflex*i bacteria groups (e.g., *Dehalococcoides* sp) are present in contaminated environments similar to the LPRSA (Tas 2009, Tas 2011). These bacteria are capable of degradation of PCBs (Zhen 2014) and PCDD/PCDFs (Bunge 2003, Liu 2008), resulting in substantial reductions in the toxicities of these complex mixtures. This group of organisms is widely distributed at groundwater sites contaminated with chlorinated solvents and their activity forms the basis for many remedial actions selected in records of decision (RODs) at these sites. Substantial fundamental and practical experience has been gained at these sites in stimulating these organisms by providing carbon sources that ferment to H_2, the preferred electron donor for these populations, or by adding H_2 directly. Once these populations become active, they use chlorinated organic compounds in their metabolism as an electron acceptor, resulting in the sequential removal of chlorines, thus reducing their toxicity. In sites where these organisms are absent, bioaugmentation with commercially available cultures is widely practiced. A consequence of these activities is the formation of sulfides, which can completely sequester mercury (Hg) and other heavy metals present in the sediments. Because of this practical experience in creating conditions for growth and activation of these populations, permanent reduction in the toxicity of these sediments can be achieved; thus, in-situ bioremediation should be retained as a viable technology. Further, cases of successful PCB dechlorination date back to the 1990s when anaerobic microbial processes were used in the Hudson River with PCB contaminant reduction up to 55 percent (Harkness 1993).

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

The *o*-17/DF-1-type *Chloroflexi* has been correlated with the dechlorination of PCBs in sediment laboratory studies and were cultured from anaerobic sediments obtained from PCB impacted areas such as Baltimore Harbor, Palos Verdes (California), and the Hudson River (Bedard 2008). Further, *Chloroflexi* bacteria phylotypes have been shown to play a significant role in the dechlorination process of PCBs in the natural environment, and it would be suggested that these bacteria are relevant to the bioremedial strategies for PCB-impacted areas (Fagervold 2007). In addition to anaerobic dechlorination, the concurrent use of aerobic degrading bacteria (*Burkholderia xenovorans* LB400) was shown to reduce the mass of PCBs by 80 percent (Payne 2013). Through the dechlorination of PCBs, the potential risks (i.e., dioxin-like toxicity and carcinogenicity) and exposure (i.e., bioaccumulation) are reduced (Abramowicz 1995). Additionally, the degradation of PCDD/PCDFs has also been demonstrated through the natural chlorine cycle, and aerobic bacteria as the *Sphingomonas*, *Pseudomonas*, and *Burkholderia* species have been shown to degrade lower chlorinated dioxins, while higher chlorinated dioxins are dechlorinated reductively in anaerobic sediments (Field 2008). PCBs and PCDD/PCDFs are not the only compounds treated in novel ways for remediation, but biostimulation and more relevantly, bioaugmentation have been used as solutions for treating bio-refractory organic compounds (i.e., molecules and compounds that are resolute in treated water as they are resistant to conventional treatment methods), and these compound types have included petroleum products; polycyclic aromatic hydrocarbons (PAHs); chlorinated pollutants, such as trichloroethene, tetrachloroethane, and 2,4-D; pharmaceutical pollutants; industrial pollutants; and dyes and colored pollutants (Semrany et al., 2012). From both applicable environmental studies and laboratory microcosm studies, the reduction in PCBs and PCDD/PCDFs through bacterial dechlorination has been demonstrated to be a viable and feasible solution to reduce PCBs and PCDD/PCDFs in contaminated sediments (Payne 2013, Field 2008).

Table 3-2 of the FFS references two successful in-situ treatment (sequestration) demonstration projects conducted in 2006. Contrary to the results of the studies, Region 2's determination was that the effectiveness and implementability of this technology type/process option were *"unknown in larger areas and sites with higher contamination"*. Region 2 offers no substantive discussion for its decision and, at a minimum, proven technologies that need only to be proven in scale-up should be retained. The mention of only two demonstration projects, both of which were conducted nearly eight years ago, illustrates Region 2's bias towards dredging remedies and an unwillingness to fairly consider and evaluate innovative remedial technologies, specifically in-situ treatment. The Strategic Environmental Research and Development Program (SERDP) and The Environmental Security Technology Certification Program (ESTCP) are conducting an in-situ field pilot study in Puget Sound scheduled to be completed in 2015 (http://serdp-estcp.org/content/download/4895/70429/file/ER-0510-FR.pdf). In contrast to its dismissal of this technology, Region 2 approved and is conducting oversight of the effectiveness and implementability of in-situ sequestration under the LPRSA RM 10.9 Time-Critical Removal Action (TCRA). Further, in situ processes eliminate the introduction of risks borne by implementation of large dredging construction projects. In-situ treatment should be retained as an effective and implementable technology and considered in the remedial alternatives analysis of a revised FFS.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

2 The mechanical dredging and mechanical dewatering unit rates are underestimated; realistic rates should be identified and the FFS cost estimates revised accordingly.

Appendix H of the FFS assumes a mechanical dredging and mechanical dewatering unit rate of $25/CY and $50/CY, respectively. These unit rates are underestimated and should be confirmed with recent dredging removal actions on the Passaic River, i.e., the Phase I Non-Time-Critical Removal Action (NTCRA)[1], as well as the dredging remedy on the Hudson River. Then, Region 2 should revise the FFS cost estimates accordingly.

3 The assumption of beneficial reuse of the sand fraction is ill-founded. Region 2 should evaluate data from the Phase I NTCRA regarding the sand fraction waste stream and amend the FFS accordingly.

During design of Phase I NTCRA, the sand fraction generated from treatability studies exhibited similar chemistry to the finer sediments (Tierra 2011). Further evidence of this was evident during full scale operations due to the nature of the sand fraction (presence of organic matter). The expectation that the sand fraction will be beneficially reused is not supported by existing evidence. Prior work in the Passaic River reveals it is more likely that only 7% of the sand (42,000 tons) would be sent for thermal treatment and disposal and 93% of the sand (558,000 tons) would be sent for Subtitle C landfill disposal. This change in waste classification for the sand fraction will result in an increased cost for transportation, treatment and/or disposal and Region 2 should adjust the FFS cost estimates accordingly.

4 There are no DUOs for the pre-design investigation. The Alternative 3 pre-design investigation task of sediment coring for chemical analyses serves no data use objective and should be eliminated from the FFS.

As described in Appendix H: Cost Estimates of the FFS, an extensive sediment coring program (>2,700 cores) is proposed as a pre-design investigation task during pre-construction activities. As described in Appendix G: Dredged Material Management Assessments, the depth of dredging for Alternative 3 is driven solely by navigational depths and the thickness of the cap. In essence, Alternative 3 is a mass removal exercise not driven by the nature and extent of sediment contamination or risk. A sediment investigation should be eliminated as a pre-design task in the FFS, the size of which (>2,700 cores), is more than double the number of cores collected to date for the entire Lower Passaic River RI/FS.

[1] Administrative Settlement Agreement and Order on Consent for Removal Action, USEPA Region 2 CERCLA Docket No. 02-2008-2020

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

5 Region 2 used outdated unit costs. The unit rates used to develop the processing and disposal cost component are outdated, and as such, the FFS should be revised to incorporate current unit rates.

Appendix H of the FFS states that the cost estimates are based on January 2014 costs. However, a number of the cost items used to develop the cost estimates were obtained in 2011 and are therefore outdated and not representative of 2014 costs. In lieu of obtaining updated unit rates, the FFS, at a minimum, should have adjusted the 2011 unit rates for inflation. Outdated unit rates should not be used to develop the cost estimates; cost items in the FFS should be reevaluated to ensure the use of 2014 dollars in cost estimates.

6 The cost sensitivity analysis of changes in dredging productivity is flawed and should be revised.

As stated in Section 5.3.2.2 of the FFS, decreasing the dredging productivity by 25 percent decreased the present value (PV) by as much as 5 percent. The major reason for this reduction in PV is because a majority of the cost items are based upon unit quantity pricing and not unit time pricing. While this reasoning is fair, the analysis should be amended to consider the impact of time. A dredging contractor will be willing to work under a unit quantity pay item arrangement with an understanding of what time-related constraints will be placed on the contract, e.g., dredging productivity. If the dredging productivity is constrained by forces outside of the contractor's control, it will still require compensation for its time. All other cost items that are based upon unit quantity pricing will have a similar increase in cost due to the decreased dredging productivity. Thus, the cost impact of a decrease in dredging productivity is understated in the FFS, and the cost sensitivity analysis should be revised accordingly. (See Comment #11, below, for further discussion on the impact of dredging productivity on Alternative 3's implementability.)

7 Region 2's upland processing facility (UPF) siting study is insufficient. Reliance on seven year old studies to conclude that a UPF is feasible is inadequate given its vital necessity to implementation of Region 2's proposed plan; a thorough study should be undertaken and included in a revised FFS.

Section 3.3 of Appendix G of the FFS begins with identifying some 20+ desirable site characteristics that would contribute to the feasibility of a UPF in the vicinity of the FFS study area. These desirable site characteristics are simply provided as a bulletized list. The section then goes on to summarize the findings of two siting studies conducted in 2007 and ultimately concludes that developing a UPF is technically feasible; however, *"Future screening would be conducted during the design phase of a remedial alternative in the FFS Study Area."* This concluding statement in Section 3.3.3 alone raises doubts about the FFS' conclusion of a feasible UPF. Region 2's proposed plan is not implementable without a UPF, and to defer final resolution on this issue to the design phase is a fatal flaw in Region 2's plan. Before this

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

alternative can be considered, the list of desirable site characteristics should be fully evaluated for all potential UPF locations and an updated siting study produced that includes visual surveys, site reconnaissance tasks, and preliminary contact with property owners and city planners. Region 2 estimates the need for 26 acres to accommodate the construction of a UPF to support the processing of dredged material under Alternative 3: Dredged Material Management (DMM) Scenario B (Off-Site Disposal). Any UPF must allocate space to barge unloading, mechanical dewatering, wastewater treatment, processed material storage, reclaimed sand storage, debris processing, water storage, roadways, loading of rail cars, rail spur(s), and ancillary support areas. The size of these work areas would be consistent with GE's Hudson River processing facility which operates at a daily throughput of processed material consistent with Region 2's assumed daily throughput in the FFS (4,000 CY per day). To achieve this throughput, GE's Hudson River processing facility is constructed on more than 100 acres of land (http://www.hudsondredging.com/hudson-pcb-cleanup-how-dredging-is-performed). The size of GE's processing facility stands in stark contrast to Region 2's estimate of 26 acres. The acreage assumed by Region 2 to support a viable UPF is grossly underestimated; considering the siting studies Region 2 references in the FFS, it is highly improbable that siting is a UPF is technically feasible in the region.

In addition, rail loadout and transportation logistics is an important aspect of dredged material management and should be evaluated fully in considering of recent dredging remedies, i.e., Hudson River. Issues of concern include; (1) availability of services (train engines, rail cars, etc.), (2) adequate rail spur length to support the necessary fleets of rail cars, (3) and thorough transportation logistics planning between the (a) origin (UPF loadout area), (b) transportation supplier (railroad company(s)), and (c) destination (treatment and/or disposal facilities). Unless the 5-10 highest ranking site locations are viable to support the required UPF, no alternative requiring a UPF can be chosen for the proposed plan. This updated siting study should then be incorporated into a revised FFS to ensure the implementability of Region 2's proposed plan. It should be noted that the first desirable site characteristic listed in Section 3.3 of Appendix G is *"Proximity to the FFS Study Area"*. However, of the 12 *"high"* ranked sites listed in Table 3-1 of Appendix G, only one is located within the FFS Study Area (Kearny Point) and only two others are located in the vicinity of Newark Bay (Bergen Point and Port Newark). Availability of a UPF is essential to the implementability of Region 2's preferred alternative; if a suitable site for a UPF does not exist within a suitable distance, Alternative 3 cannot be implemented. This gap should be addressed prior to remedy selection, not during remedial design.

8 The evaluation of the cost impact of increasing *by an additional six inches* the extent of the engineered cap to be armored fails to account for a large portion of the actual cost of this additional *armoring*. Region 2 should revise the FFS to include these costs.

As stated in Section 5.3.2.3 the impact of increasing the extent of the engineered cap that is armored under Alternatives 3 and 4 was considered for review, and Region 2 was determined that the cost of purchasing and installing the armor has a negligible impact on the PV.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

However, these are only two of many cost items that are impacted by increasing the armor area. Including an armor layer into the engineered cap increases the total thickness of the cap by six inches. As a result, an additional six inches of dredging would be required, and all cost items impacted by the volume of dredged material, including, but not limited to, dredging, barge transport, hydraulic off-loading, mechanical dewatering, transport and disposal, would increase. As a result, the FFS should be revised to properly consider all impacts of increasing the extent of armoring the engineered cap.

9 The assumption for hazardous waste storage is *incorrect*. Temporary storage of hazardous waste for six months at the processing facility would violate RCRA; the FFS should be revised to evaluate proper management of hazardous waste.

Section 3.4.3 of Appendix G assumes that a temporary storage area with a six-month storage capacity for hazardous waste would be constructed and operated. Given the estimated tonnage of hazardous waste to be generated from the dewatering operations, two options are administratively feasible (in accordance with RCRA): (1) remove accumulated hazardous waste within 90 days of generation, or (2) obtain a RCRA permit to operate a hazardous waste storage facility. The capacity of existing incinerators (357,000 tons per year as stated in the FFS) appears to be sufficient to manage the immediate handling of hazardous waste generated, assuming proper rail loadout and transportation logistics (See Comment 7). This operational change would alleviate the need to store hazardous waste, eliminating the hazards (worker health and safety, quality of life concerns, etc.) inherent in such an operation. As such, the FFS should be revised to evaluate proper management of hazardous waste and its related cost implications.

10 A complete evaluation of hydraulic dredging should be prepared. Hydraulic dredging and mechanical dredging are too dissimilar to assume mechanical dredging as the representative process option; the FFS should be revised to adequately evaluate hydraulic dredging.

The FFS Report assumes mechanical dredging as the representative sediment removal process option for cost estimation purposes and states *"Should an alternative be selected that requires construction, the best process option would be determined during the remedial design phase."* While the FFS does provide total costs for each alternative when employing hydraulic dredging, it does not provide backup for these costs, and further does not adequately consider the implementability benefits of hydraulic dredging versus mechanical dredging. By way of example, quality of life impacts are greatly reduced, if not eliminated, by employing hydraulic dredging, as use of a pipeline in lieu of barge loading/transport alleviates odors and impacts to air quality and traffic; produces less noise and requires less artificial light.

In addition, the claim made in Section 3.5.3 of the FFS that hydraulic dredging generates more water and therefore would require a larger wastewater treatment plant than a mechanical

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

dredging wastewater treatment plant is not necessarily true. The process of hydraulic dredging creates a sediment-water slurry on the order of 5-10% solids (Palermo 2004, USEPA 2005), much lower than the percentage of solids of the material generated from a mechanical dredging operation. However, as stated in the FFS, mechanically dredged sediment will be transported to the UPF for dewatering by way of introduction of water to create a sediment-water slurry. This operation was also employed during the Phase I NTCRA whereby a sediment-water slurry on the order of 10% solids was fed to the upland processing facility to ensure effective operation of the screens, thickeners, and filter presses. It is not a valid statement that hydraulic dredging would necessarily require handling and treatment of more water than mechanical dredging.

Due to the lack of backup for the hydraulic dredging costs, and the implementability benefits of hydraulic dredging versus mechanical dredging, as described above, a more detailed evaluation of hydraulic dredging as the sediment removal process option should be conducted in a revised FFS and not postponed until the remedial design phase.

11 Dredging productivity and dredging season are not achievable. The assumed dredging productivity of 2,000 cubic yards per 24-hour day per dredge and a dredging season of 40 weeks [24-hour days, 6 work days per week, 240 days per year] are not realistic; these assumptions should be revised; this, in turn, calls into question the implementability of FFS Alternative 3 and greatly impacts costs.

As stated in Section 2.4 of Appendix F of the FFS, the dredging production rate was assumed to be 2,000 cubic yards per 24-hour day per mechanical dredge. This production rate was based upon site specific data from the Environmental Dredging Pilot Study in the Passaic River as well as data from the Hudson River and Fox River environmental dredging projects. With regard to the Pilot Study, 4,150 cubic yards was dredged over a 5 day period (830 cubic yards per day) with no associated performance standards on resuspension or residuals. Assuming 2,000 cubic yards per day on the basis of the Pilot Study is simply unfounded. With respect to the Fox River, hydraulic and not mechanical dredging is being employed. Again, using the Fox River as a basis for the assumed production rate is ill-founded, given that it used a different type of dredge. Further, as a result of a peer review process conducted after the first dredging season on the Hudson River (http://www.epa.gov/hudson/pdf/hudsonriverphase1dredgingreport_final.pdf) a productivity performance standard of 350,000 cubic yards per 180-day year (approximately 2000 cubic yards per 24-hour day for 4 mechanical dredges; or 500 cubic yards per 24-hour day per dredge) was proposed by the peer review panel and ultimately enforced by Region 2 for subsequent dredging seasons. Certain other performance standards, specifically resuspension and residuals, were considered of primary import; as such, the reduced dredging productivity performance standard was employed to ensure minimizing resuspension and residuals to the greatest extent practicable.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

There is a reasonable expectation that Region 2 and other stakeholders will place similar importance on resuspension and residuals for any dredging remedy conducted on the Passaic River. As such, a more realistic dredging production rate of 500 cubic yards per 24-hour day per mechanical dredge (consistent with the Hudson River project) should be assumed in the FFS.

As stated in Section 2.4 of Appendix F of the FFS, the dredging season was assumed to be 40 weeks [24-hour days, 6 work days per week, 240 days per year] *"…to account for equipment maintenance, weather, and some degree of fish window restrictions."* A dredging season of 180 days is a more realistic assumption for the following reasons: (1) the months of January and February are not conducive to safe working conditions on the Passaic River, and (2) the fish window restriction occurs during the months of March, April, May and June. The FFS provides no basis for concluding that dredging in the Passaic River can achieve a longer dredging year than Region 2 imposed for the Hudson River.

The more realistic production rate and dredging season impact implementability (technical feasibility and availability of services and materials). In light of this, two operational changes on either extreme exist, (1) maintain the dredging duration of five calendar years by operating 10 mechanical dredges, or (2) maintain the calendar year productivity of 360,000 cubic yards and increase the dredging duration to 12 years. The following discussion expands upon the feasibility of maintaining a five-year dredging duration.

Based upon the assumptions in the FFS, 960,000 cubic yards of material would be dredged each calendar year (4,000 CY/day; 240 days/year) resulting in a total dredging duration of five years to remove the estimated volume of 4,300,000 CY. Employing the more realistic assumptions derived from the Hudson River dredging project, the volume of material dredged during a five-year dredging duration would be limited to 900,000 cubic yards (1,000 CY/Day X 180 days/year X 5 years); only 1/5th of the estimated total volume. As a result, five-times as many mechanical dredges (10) would be required to maintain a five-year dredging duration, not two dredges as assumed in the FFS.

The following set of comments discusses only some of the impacts to implementability by considering the more accurate assumptions described above. A full analysis and evaluation of the remaining eight (8) CERCLA criteria needs to be performed.

a) Implementability

i) Technical Feasibility

Dredging in ten work areas simultaneously will prove to be a significant technical challenge logistically. Assuming the dredging sequence remains RM8.3 to RM0, as described in the FFS, vessel and equipment traffic/congestion in the work areas will be of concern when considering dredges, barges, tugboats, support boats, monitoring buoys, silt curtains, etc. In all likelihood the work areas will need to be spaced sufficiently distant from each other throughout the FFS study area to avoid this congestion and the inherent work hazards. While not the focus of this comment, a

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

change of this nature will require re-running the models to understand sediment resuspension and chemical fate and transport from the dredging activities.

Since ten mechanical dredges would operate simultaneously, ten barges (one per dredge; 500 CY capacity) will be required at the work area. The FFS assumes the upland processing facility will be designed to operate continuously and maintain productivity consistent with the dredging. Therefore, at least 20 barges, and more likely 30, will be required for the loading of dredged material, transportation to the UPF, off-loading at the UPF, and return to the dredging work areas. In order for dredging production not to be interrupted, dredged material will need to be hydraulically off-loaded at a rate of 500 CY per 2.2 hours with the remaining two hours required to return the off-loaded barges to the dredging work areas. The following table illustrates barge movement logistics when employing two fleets of 10 barges (20):

Day 1	Day 2	Day 3	Day 4
Dredging	Dredging	Dredging	Dredging
Barge Fleet #1 Loading	Barge Fleet #2 Loading	Barge Fleet #1 Loading	Barge Fleet #2 Loading
	Barge Fleet #1 (Full) Transport to UPF	Barge Fleet #2 (Full) Transport to UPF	Barge Fleet #1 (Full) Transport to UPF
	Barge Fleet #1 Hydraulic Off-loading	Barge Fleet #2 Hydraulic Off-loading	Barge Fleet #1 Hydraulic Off-loading
	Barge Fleet #1 Sediment Processing	Barge Fleet #2 Sediment Processing	Barge Fleet #1 Sediment Processing
	Barge Fleet #1 (Empty) Transport to Dredges	Barge Fleet #2 (Empty) Transport to Dredges	Barge Fleet #1 (Empty) Transport to Dredges

Based upon the Phase I NTCRA (Tierra 2011), 500 CY of sediment equates to approximately 3,100 CY of sediment slurry. Therefore, 31,000 CY of sediment slurry (3,100 CY X 10 barges) will require hydraulic off-loading every 24 hour day. While further evaluation to determine the implementability of such a massive off-loading effort is necessary, based upon the Phase I NTCRA, this efforts appears to be infeasible. Therefore, an additional fleet of barges (10) will need to be put into service to allow for adequate time to perform hydraulic off-loading and not delay dredging production. Clearly, employing ten mechanical dredges introduces significant logistical and implementability challenges.

ii) Availability of Services and Materials

While a survey of available equipment was not conducted, it would be surprising to find sufficient dredging, barging, off-loading, and ancillary equipment necessary to support implementation of this operational change, which calls into question the implementability of this remedial alternative.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

b) Quality of Life Impacts

As discussed above, a five-year dredging duration would require a substantial increase in work activities in the FFS Study Area with a major impact on the communities' quality of life (QoL). Regardless of best management practices, adverse impacts will include odors, air quality, noise, lighting and traffic 24 hours a day, 180 days a year, for five years. In all likelihood, performance standards will be set for each of these QoL impacts, the result of which will undoubtedly hinder the ability to maintain dredging productivity and therefore extend the dredging duration. Further, aesthetics will be greatly impacted throughout the FFS study area and recreation in the FFS Study Area, as well as up- and down-river for boaters wishing to transit to/from Newark Bay, essentially will be precluded throughout the duration of dredging.

12 Shoreline protection during dredging/capping operations is not adequately addressed; the FFS should be revised accordingly.

Appendix G of the FFS assumes that dredging for Alternatives 2 and 3 *"would extend to within approximately two feet of the wall and the resulting side slopes would be essentially vertical."* For Alternative 2 only, the FFS incorporates shoreline protection via sheet piling for approximately 20% of existing linear pier/bulkheads (Appendix H of the FFS). The following discussion addresses (a) the lack of shoreline protection for Alternative 3, (b) the underestimated linear feet of necessary shoreline protection, and (c) the administrative feasibility of shoreline protection.

a) Shoreline Protection for Alternative 3

Although the depth of dredging for Alternative 3 is only 2.5 feet, insufficient data exist to suggest that existing bulkheads, most of which date back to the early/mid 1900s, would not be impacted during the dredging activities. At a minimum, the bulkheads could shift as a result of the nearby dredging, requiring repair and restoration, and at worst could fail, potentially causing serious damage to the upland property. Shoreline protection should be evaluated consistent with Alternative 2.

b) Linear Feet of Shoreline Protection

The FFS assumes that 20% of the existing bulkheads would require shoreline protection; no justification accompanies this assumption, nor does the FFS consider other shoreline features, i.e., riprap, that may require protection. Surveys conducted in 1999/2000 of the lower six miles of the Passaic River revealed that greater than 80% of the shoreline consists of bulkheads and riprap (Ludwig 2005). Assuming a similar percentage across the entire FFS Study Area would equate to approximately 68,000 linear feet of bulkheads/riprap (80% of 8+8 miles). And given the age and likely suspect integrity of the existing bulkheads and riprap, it is not unreasonable to assume that 80% would require shoreline protection. The FFS should be revised to assume that 34,000 linear feet of existing bulkheads would require shoreline protection during the dredging/capping operations of Alternatives 2 and 3.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

c) Administrative Feasibility of Shoreline Protection

The shoreline protection will be constructed in the tidelands of the Passaic River. These tidelands, in many instances, are controlled by the adjacent upland property's owners through either a Tidelands Lease or Grant[2]. As such, any new construction within these lease or grant areas will require permission from the property owners. And, regardless of any controlling interest in the adjoining tideland, a property owner retains right of first refusal for any action taken within such tideland. There may be situations where a property owner has a waterfront development permit or a property owner may, in the first instance, simply deny access to the tidelands. The resulting negotiations will result in monetary compensation and/or compensation through development of the property owner's waterfront post-completion of the shoreline construction. A discussion of this administrative feasibility issue is not addressed in the FFS.

Based upon the above, the FFS requires revision to address the scope, cost, and administrative feasibility of necessary shoreline protection during dredging/capping activities.

13 CAD/CDF-based approaches are more Implementable than and equally protective of and cost-effective as off-site disposal. This determination needs to be re-evaluated.

The FFS stated that the use of Confined Aquatic Disposal (CAD) for dredged material management has been demonstrated to be technically feasible, however, was likely administratively infeasible. As stated in the FFS:

"DMM Scenario A is likely to face significant administrative and legal impediments because the State of New Jersey is the owner of the bay bottom and strongly opposes construction of a CAD site in Newark Bay. The State's position is clearly articulated in a letter dated November 28, 2012 from Governor Chris Christie to former USEPA Administrator Lisa Jackson. This opposition is likely to make DMM Scenario A administratively infeasible. USFWS and NOAA also oppose construction of a CAD site in Newark Bay."

Despite administrative opposition, the National Remedy Review Board and the Contaminated Sediments Technical Advisory Group (collectively, the Boards) recommended that Region 2 reconsider the less costly CAD scenario. In a memo dated April 11, 2014, the Boards stated the following:

"The Region's preferred alternative (alternative 3) includes DMM scenario B (offsite disposal), which is approximately $840 million higher (total net present value) than alternative 3 with DMM scenario A [confined aquatic disposal (CAD)]. The Boards also note that CADs have been used at other Superfund sites and by the Army Corps of Engineers as part of other dredging projects. The Boards further note that a CAD would be somewhat similar, on a conceptual basis, to the capping of the remaining contaminated sediments within the LPR, which would occur post-

[2] Tidelands Act; N.J.S.A. 12:3

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

dredging under the Region's preferred approach. Therefore, the Boards recommend that the Region reconsider the less costly CAD scenario and clearly explain in its decision documents the basis for the Region's preferred off-site disposal scenario." (Legare and Ells 2014)

As described herein, CAD is a proven alternative for disposal of contaminated sediment. Therefore, as suggested by the Boards, CAD should remain as a feasible option for DMM and should not be screened out based solely on administrative opposition. As pointed out in the Boards' statement above, CADs have been successfully used at other dredging Superfund sites throughout the country, establishing a strong overall track record.

CADs are but one type of CDF and offer an efficient solution to manage dredged contaminated sediment. Generally speaking, all CDFs use engineered dikes, berms, or sheet piles to isolate the contaminated sediment from the environment. Once filled, the CDF is covered with an impermeable cap, and the new land surface thereafter is available to use for other purposes. CADs are a type of CDF, except that the capping takes place below the surface of the water, typically to match the local bathymetry. CADs can be placed in existing natural depressions or can be constructed by excavating a depression into which the sediment is deposited. Currently, as many as 29 sediment CDFs/CADs are used for DMM (Palermo and Bosworth 2008).

There are significant advantages to using CAD compared to Region 2's preferred DMM Scenario B, off-site disposal. CADs/CDFs are more implementable than off-site disposal because they eliminate the need for siting of an upland facility on the banks of the LPR or Newark Bay. In addition, CADs/CDFs reduce risks to human health and the environment as compared to off-site disposal, and typically result in less than 50% of the cost. These advantages are further discussed below.

a) Implementability

There are multiple advantages of using CAD from an implementation standpoint. CAD is a proven and reliable technology that is relatively simple and faster to design, build and operate, and there are usually sites available within the general vicinity of where the dredging is being performed. In addition, impacts to the local community can be significantly minimized as the work can generally be confined to the waterway of interest.

The in-water disposal scenario described in the FFS contemplates that dredged sediments would be barged directly to a planned CAD in Newark Bay (or elsewhere in the immediate area), thus eliminating the need for siting an upland sediment processing facility on the banks of the LPR or Newark Bay. This latter point is particularly important, especially in a crowded urban region such as Newark, New Jersey. Finding a suitable upland processing site with adequate river access; viable off-site transportation routes; and space for sediment processing, water treatment, material storage and transfer, and associated equipment that does not adversely impact the surrounding community is a significant challenge (see Comment #7. Under DMM Scenario B, dredging of the river with off-site disposal would require siting of a 26 to 28 acre upland sediment processing facility on the banks of the LPR or Newark Bay. Operation of the facility would result in more odors, noise, light pollution, potential air quality impacts, greater risk

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

of accidents from equipment operation, and increased traffic on local roads. Operating a sediment processing and water treatment plant virtually year-round would also require a significant investment in site infrastructure such as buildings and other temperature-regulating equipment. Therefore, off-site disposal would result in more on-land impacts to the local community and workers than if CAD were the chosen DMM scenario.

b) Risk to Human Health and Environment

The principal risk to human health and the environment identified in the FFS is the resuspension of contaminated legacy sediment. The FFS focuses on contaminants that are strongly hydrophobic and adsorb strongly to sediment. Once this sediment is isolated from the environment, it will pose little further risk; as a result, use of a CDF or CAD is appropriate.

In the context of sediment remediation, it is critical to consider the net risks presented by various methods of dredged material handling in order to explicitly identify the risk tradeoffs resulting from various remedial decisions. For example, removal of contaminated sediment from the environment may reduce the environmental risks posed by that sediment to aquatic biota, but if the price of this risk reduction is increased risks to other media (such as those resulting from air emissions from dewatering and materials handling), there may be no net risk benefit and another action should be chosen. USEPA guidance acknowledges this concept, explaining that *"Contaminated Sediments may be handled and rehandled a number of times during the implementation of a remedial alternative. The costs and contaminant losses of each of these handling operations may be significant"* (USEPA 1994). Further, *"… no remedial alternative for contaminated sediments is without some environmental consequence …"* and the *"… balancing of environmental benefit vs. cost is a critical part of the evaluation of sediment remedial alternatives"* (USEPA 1994). In the case of the off-site disposal alternative, such contaminant losses would include air emissions from dewatering and materials handling, wastewater, and other mechanisms. CAD is associated with less rehandling of material and fewer contaminant transfer pathways. Upland disposal can result in greater dermal contact, volatile emissions, and groundwater pathways. Upland disposal also increases risks of highway accidents, which can lead to injury and death (Fredette 2006). Environmental and human health risk assessment of the CAD cell alternative has shown that it can provide one of the lowest-risk options compared with other alternatives (Kane-Driscoll et al. 2002). Given these considerations, a CAD may be the lowest-risk option for DMM.

Region 2 appears to have considered only the risk reduction associated with the removal of sediment from the aquatic environment, without also considering the risks that will be created by execution of the remedial action. In addition to the resuspension of contaminated sediment inherent to any dredging activity, the management of dredged materials will itself create some risks, including the potential discharge of contaminants to air or water associated with materials handling and dewatering; worker safety issues associated with these large-scale industrial processes; and the risk of highway or other accidents associated with the movement of such large volumes of material. For example, under the preferred alternative, it will be necessary for contaminated sediment to be shipped across country via railway for 1,000 miles or more. Off-

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

site disposal requires a greater amount of handling of material and can result in greater dermal contact, volatile emissions, and groundwater pathways. Upland disposal also increases risks of rail and highway accidents, which can lead to injury or death.

As such, Region 2 should not make any remedial decisions until these and comparable risks have been properly evaluated in detail, a position consistent with relevant USEPA guidance. When such risks are considered, use of a CAD will be the lowest-risk alternative for managing dredged materials.

c) Cost-Effectiveness

CERCLA mandates that the NCP require consideration of cost-effectiveness as one of the balancing criteria for selecting among remedial alternatives that are sufficiently protective (42 U.S.C. §9605[a][7]). In this case, use of a CAD (or CDF) would be a more cost-effective method to achieve whatever environmental benefits would result from the massive dredging remedial alternative proposed by Region 2. Cost-effectiveness has been a major factor in selecting a CDF or CAD (versus off-site disposal) at a number of sediment remediation sites. For example, in determining that the CAD alternative was appropriate at the Puget Sound Naval Shipyard Superfund site, Region 10 determined it most *"… protective of human health and the environment and provide[d] the best overall effectiveness proportional to its cost"* (USEPA 2000). In considering the same general alternatives at another site, the Minnesota Pollution Control Agency (MPCA) reached the same conclusion in assessing alternatives under the Minnesota Environmental Response and Liability Act (Minn. Stat. §§ 115B.01-115B.24). In selecting between a CAD hybrid approach and one involving dredging and off-site disposal, MPCA found that the CAD alternative *"… achieves a comparable or superior degree of long-term effectiveness than other alternatives, and does so at a total cost that is approximately half the cost of the one other alternative that provides comparable long-term effectiveness"* (MPCA 2004).

In its joint guidance, Great Lakes Confined Disposal Facilities, the USACE, and USEPA stated that *"… confined disposal has been, and remains, the most commonly used management alternative for contaminated sediment …"* because *"… it is the most dependable, cost-effective means available"* (USACE and USEPA 2003). Here, Region 2's own analyses demonstrate the more cost-effective nature of the CAD-based approach. For either of the two active remedial options considered in the FFS, use of a CAD results in less than 50 percent of the cost of off-site disposal. Where Region 2 is proposing a dredging remedy of such a large magnitude, cost-effectiveness considerations are even more salient than usual.

As evidenced above, CAD, is at least as protective as off-site disposal, and is considerably more implementable and cost-effective. Therefore, CAD should be the preferred DMM option in the FFS.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

14 CADs and CDFs are proven, effective options

Both CADs and CDFs are proven methods for long-term sequestration of contaminated sediments in many ports and waterways. For example, CAD was used at sites in both New Bedford, MA and Providence, RI (USEPA 2012). In the case of the New Bedford Site, Region 1 chose to use a CAD because it allowed for quicker and cheaper completion of the lower harbor cleanup (USEPA 2012). A CAD was also successfully used in a CERCLA remedy involving dredging and confined disposal of PCB- and mercury-contaminated sediment at the Puget Sound Naval Shipyard Complex in Bremerton, Washington. At that site, Region 10 concluded that use of a CAD *"… would provide the same reduction in human health and environmental risk …"* as another alternative remedy involving off-site disposal of the same sediment (USEPA 2000). In October 2002, the United States Navy conducted the required 5-year review of this remedy, which concluded that the CAD was *"… protective of human health and the environment in the short-term …"* and determined that the CAD-based remedy would also be protective in the long term based on the anticipated completion of a comprehensive management plan for the site (USEPA 2002). The second 5-year review in 2007 confirmed that the CAD *"… remain[ed] protective of human health and the environment"* (Naval Facilities Engineering Command 2007).

Similar to CADs, CDFs have successfully been used as a method for dealing with contaminated sediments. For example, USEPA has successfully used CDFs at a number of Superfund sites, including the Commencement Bay Superfund Site, and is considering use of a CDF at the Portland Harbor Superfund Site. At the Milwaukee Waterway CDF in Tacoma, Washington, construction was completed in 1995, and follow-up studies have confirmed that contaminants are not leaching from the CDF (Fabian and Spadaro 2006). Similarly, the Blair Slip 1 nearshore CDF contains almost 640,000 CY of sediment contaminated with persistent pollutants, such as PCBs and PAHs, pursuant to a USEPA-selected CERCLA remedy. The Blair Slip 1 CDF accepted contaminated dredged material from the Hylebos and Middle Waterways, among other Operable Units in the Commencement Bay area (USEPA 2010a).

Interestingly, a subaqueous CAD already exists in Newark Bay (located between the Port Newark Channel and the Elizabeth Channel) and was used from 1997-2012 for the disposal of 1.5 million CY of contaminated navigational dredge material from the New York/New Jersey Harbor (Porebski and Vogt 2010). In this case, the subaqueous CDF is below the water surface and is essentially a CAD, with the difference being the terminology used by Porebski and Vogt 2010 to refer to the cell.

Finally, Region 2 has already endorsed the use of confined disposal as a remedy for heavily contaminated sediment from the LPR, including sediment that Region 2 has itself described as containing *"… extremely high concentrations of 2,3,7,8-tetrachloro-dibenzo-p-diozin"* (Basso 2008). In a 2008 Administrative Order on Consent between Occidental Chemical Corporation and Region 2, Region 2 authorized the development of a Non-Time-Critical Removal Action involving heavily contaminated sediment in the LPR, with Phase II of the Removal Action to involve *"… the transport and disposal of [dredged] materials to a Confined Disposal Facility ("CDF") located on-site"* (CERCLA Docket No. 02-2008-2020, ¶ 9). Given that Region 2 has already agreed to a CDF for such highly contaminated sediment, no justification exists for

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

rejecting the use of a CDF for materials having lower concentrations of TCDD. Accordingly, use of a CAD or CDF is an acceptable approach to managing dredged Passaic River sediment generated by any remedial option selected through the FFS process.

Based on recommendations from the Boards and the precedent of successful use of CADs in ports and waterways across the U.S., it is not appropriate for CAD to be screened out as a DMM option based strictly on administrative opposition. Therefore, CAD should be the preferred DMM option in the FFS.

15 CAD Represents the "Green" Option

CAD is not only a proven and effective method for managing contaminated sediment; it is also a more *"sustainable"* option than any of the other alternatives proposed in the FFS. Overall, a CAD will generate a much smaller carbon footprint than the selected DMM option.

Active dewatering and treatment operations are known to produce air emissions, noise and odors, all of which will be commonplace for extended periods of time. More importantly, the significant truck traffic through urban roads and neighborhoods will be not only physically dangerous to local residents, but will also produce a tremendous amount of exhaust fumes.

The advantage of a CAD is that the dredged material primarily stays within the waterway footprint throughout the process, from the point of dredging through final disposal. Barges also have significantly greater carrying capacity per unit. Depending on its size, one barge can carry the equivalent of one to two hundred trucks' worth of material. The CAD also would be in relatively close proximity to the dredging site, as opposed to hundreds or in some cases thousands of miles away, considerably reducing the air emissions and greenhouse gases associated with transportation. The energy inputs needed for the handling, dewatering, and treatment of the material should also be considered, as these are not necessary for CAD disposal. These considerations are consistent with Region 2's Clean and Green Policy (USEPA 2009), which has the stated goal of *"… enhancing the environmental benefit of federal cleanup programs by promoting technologies and practices that are sustainable"* (USEPA 2009).

With its *"green advantages,"* CAD is more favorable than off-site disposal, is consistent with Region 2 policy, and therefore should be the preferred DMM option in the FFS.

16 CAD facilities are similar to Region 2's proposed remedial alternative of capping contaminated sediment; therefore, there is no valid basis to screen out this alternative.

The National Remedy Review Board and the Contaminated Sediments Technical Advisory Group (collectively, the Boards) noted *"…that a CAD would be somewhat similar, on a conceptual basis, to the capping of the remaining contaminated sediments within the LPR, which would occur post-dredging under the Region's preferred approach"* (Legare and Ells 2014). The evaluation below supports the Boards' assertion that the use of a CAD is very

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

similar to the preferred option of engineered capping; therefore, CAD should remain as a feasible scenario for DMM.

Technically, both a CAD facility and an engineered cap rely upon containment to secure and isolate contaminated sediments. Much like in-situ capping, once a CAD cell is filled, an engineered cover is constructed to close the cell and the original bathymetry is restored. This in-situ containment technology serves to reduce risk by minimizing exposure to, and release of, the isolated materials.

Both the covered CAD cell and engineered cap require long-term monitoring and maintenance to ensure that containment measures are performing as designed. In addition to long-term monitoring, institutional controls (e.g., vessel speed restrictions, prohibitions on anchoring vessels) would be necessary in perpetuity to protect the integrity of the cap.

Based on the above evaluation, a CAD is very similar in nature to the selected option of engineered capping, and therefore should be retained as a technically and administratively feasible scenario for DMM.

17 The assumptions made regarding the estimated volume of dredged material characterized as hazardous and requiring thermal treatment prior to disposal are incorrect and as such, the FFS should be revised accordingly.

The FFS indicates that at least three main waste categories of dredged material will result, including:

a) non-hazardous waste that can be washed and beneficially reused,
b) non-hazardous waste that must be disposed in a landfill and,
c) hazardous waste that requires thermal treatment prior to disposal in a landfill.

Off-site disposal of dredged sediments will require characterization prior to selection of the disposal facility as well as any treatment required to meet Land Disposal Restrictions (LDRs). The FFS correctly specifies that removed sediment that does not exceed the Toxicity Characteristic (TC) can be directly landfilled, while sediment that exceeds the TC will require further profiling to determine if it exceeds ten times (10x) the Universal Treatment Standards (UTS) for all Underlying Hazardous Constituents (UHCs). Material that exceeds 10x the UTS for UHCs requires treatment prior to placement in a landfill. Approved treatment technologies are outlined in RCRA (40 CFR 268.48) for the various UHCs.

For cost estimating purposes, the FFS used the following process to identify the volume of removed sediment that may require treatment prior to disposal:

a) Analytical chemistry results and associated Toxicity Characteristic Leaching Procedure (TCLP) values obtained from the Phase I NTCRA area were plotted on a graph to develop a correlation.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

b) Such correlations were then applied to analytical data within the various FFS removal areas to identify where there could be TCLP exceedances.
c) In cases where TCLP exceedances did 'occur', it was assumed that UHCs were present above 10x the UTS and that thermal treatment via incineration was necessary.

There are two main concerns with this approach:

a) The correlations developed between analytical data and TCLP values were extracted from a small section of the River that would represent unique, localized relationships.
b) The assumption that every TCLP exceedance results in the need for thermal treatment (specifically incineration) is unfounded.

The conservative steps taken to identify a correlation between chemistry and TCLP may or may not be appropriate for the rest of the FFS Study Area due to differences in source material, grain size, TOC, etc. The leachability of the TCLP compounds are directly related to the surface area of the sediment (as represented by grain size) (van der Sloot 1997). Another key factor that influences actual TCLP test results is the homogeneity of particle sizes. The less homogeneous the sediment, the more difficult it becomes to compare among different sample locations. This may result in a test sample with a surface area that is significantly larger or smaller than the surface area in material with a positive correlation, which results in a consequential distortion in leaching performance.

Region 2 incorrectly, and conservatively, assumed, based on its correlation to the TCLP data, that 59 samples exceeded the threshold for thermal treatment. In fact, only 14 samples exceeded both the RCRA TC criteria as well as the UTS threshold by the requisite factor of 10. Using these 14 values and interpolating between data points to develop the volume of material that requires thermal treatment results in approximately 28,000 CY, or about 1% or the proposed removal volume. This is in stark contrast to Region 2's value of 301,000 CY, or 7% of the proposed removal volume. See table below for calculations.

RCRA and 10x UTS Exceedances

River Mile Classification	Channel/Shoal	Proposed Dredge Depth	Total Number of Cores	Total Number of Samples	Total Number of Exceedances		
					RCRA Criteria	10xUTS	Both RCRA Criteria and 10xUTS
RM 0-1.2	Channel	33	12	64	3	0	0
RM 0-1.2	Shoal	2.5	52	103	2	0	0
RM 1.2-1.7	Channel	30.5	7	32	0	3	1
RM 1.2-1.7	Shoal	2.5	21	49	1	0	0
RM 1.7-2.2	Channel	35.5	7	26	6	0	0

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

River Mile Classification	Channel/Shoal	Proposed Dredge Depth	Total Number of Cores	Total Number of Samples	Total Number of Exceedances		
					RCRA Criteria	10xUTS	Both RCRA Criteria and 10xUTS
RM 1.7-2.2	Shoal	2.5	19	48	2	0	0
RM 2.2-8.3	Channel	2.5	128	407	21	29	9
RM 2.2-8.3	Shoal	2.5	237	395	24	20	4
		Total =	483	1124	59	52	14

Given these incorrect assumptions regarding waste characterization and thermal treatment, the FFS should be revised accordingly.

18 The FFS fails to address logistics and implementability concerns as they relate to transitioning between different waste categories during dredging/processing.

Although the FFS specifies that dredging will progress one sediment management unit (SMU) at a time, it is not evident that the transition between the three main waste categories, as described in Comment #17, has been considered in the cost and schedule. Lessons learned from the Phase I NTCRA, which had only two primary waste categories, included the need for precision in delineating the different in-situ waste categories for purposes of clearly transitioning during both dredging and upland processing activity. The steps required to prevent the comingling of one category of waste with another will reduce dredging production as the dredging contractor nears the transition. For the Phase I NTCRA, the transition in the processing plant consisted of approximately one additional day in the schedule to allow one category of material to be completely processed before dredging of the other category commenced. More specifically, if improper processing and decontamination is performed during a transition from a hazardous waste to a non-hazardous waste, cross contamination would ensue, resulting in re-categorizing non-hazardous waste as hazardous waste, thereby increasing treatment and disposal costs. As a result, this logistical and implementation issue should be properly evaluated and factored into a revised FFS.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

19 References

Abramowicz, D.A. 1995. Aerobic and Anaerobic PCB Biodegradation in the Environment. Environmental Health Perspectives, 103:97-99.

Basso, Ray. 2008. EPA Region 2 Memorandum to Alan Steinberg (Regional Administrator, EPA Region 2) re: Documentation of Concurrence with the preparation of an Engineering Evaluation/Cost Assessment in support of a Non-Time-Critical Removal Action at the Diamond Alkali Superfund Site in New Jersey. June 12.

Bedard, D.L. 2008. A Case Study for Microbial Biodegradation: Anaerobic Bacterial Reductive Dechlorination of Polychlorinated Biphenyls – From Sediment to Defined Medium. Annual Review of Microbiology, 62:253-270.

Bunge, M., Adrian, L., Kraus, A., Opel, M., Lorenz, W.G., Andreesen, J.R., Görisch, H., and Lechner, U. 2003. Reductive dehalogenation of chlorinated dioxins by an anaerobic bacterium. Nature, 421:357-360.

Fabian, K and P.A. Spadaro. 2006. The Role of Confined Disposal Facilities in Contaminated Sediment Remediation, presented at the Third European Conference on Contaminated Sediments, Budapest, Hungary. March.

Fagervold, S.J., May, H.D, and Sowers. K.R. 2007. Microbial Reductive Dechlorination of Aroclor 1260 in Baltimore Harbor Sediment Microcosms is Catalyzed by Three Phylotypes within the Phylum *Chloroflexi*. Applied and Environmental Microbiology, 73:3009-3018.

Field, J.A., and Sierra-Alvarez, R. 2008. Microbial degradation of chlorinated dioxins. Chemosphere, 71:1005-1018.

Fredette, T.J. 2006. Why Confined Aquatic Disposal Cells Often Make Sense. Integrated Environmental Assessment and Management. Volume 2, Number 1-pp. 35-38.

Harkness, M.R., McDermoot, J.B., Abramowicz, D.A., Salvo, J.J., Flanagan, W.P., Stephens, M.L., Mondello, F.J., May, R.J., Lobos, J.H., and Carroll, K.M. 1993. In situ Stimulation of aerobic PCB biodegradation in Hudson River sediments. Science, 259:503-507.

Kane-Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.

Legare, A.R., Chair and Ells, S.E., Chair. (2014). Memorandum. Subject: National Remedy Review Board and Contaminated Sediments Technical Advisory Group Recommendations for the Diamond Alkali Superfund Site, Lower Eight Miles of the Lower Passaic River (Focused Feasibility Study Area). April 11.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

Liu, F., and Fennell, D.E. 2008. Dechlorination and Detoxification of 1,2,3,4,7,8-Hexachlorodibenzofuran by a Mixed Culture Containing *Dehalococcoides ethenogenes* Strain 195. Environmental Science and Technology, 42(2):602-607.

Ludwig, D.F., and Iannuzzi, T.J., 2005. Integrated Environmental Assessment and Management. Volume 1, Number 4-pp. 1-17.

Luthy, Richard G., Cho, Yeo-Myoung, Ghosh, Upal, Bridges, Todd S., and Kennedy, Alan J. 2009. Final Report - Field Testing of Activated Carbon Mixing and In situ Stabilization of PCBs in Sediment at Hunters Point Shipyard Parcel F, San Francisco Bay, California. ESTCP Project ER-0510

Minnesota Pollution Control Agency (MPCA). 2004. Record of Decision for the Sediment Operable Unit St. Louis River/Interlake/Duluth Tar Site, Duluth, Minnesota, Under the Minnesota Environmental Response and Liability Act. § 6.2.5.

Naval Facilities Engineering Command. 2007. Second Five-Year Review, Bremerton Naval Complex, Bremerton, Washington. § 9.

Palermo, M.R., N.R. Francingues, and D.E. Averett. 2004. Operational Characteristics and Equipment Selection Factors for Environmental Dredging. Journal of Dredging Engineering, Western Dredging Association, Vol. 5, No. 4.

Palermo, M. and W. Bosworth. 2008. Use of Confined Disposal Facilities for Sediment Remediation. Proceedings of the 39th Texas A&M Dredging Seminar and Western Dredging Association XVIII Technical Conference, June 8-11, 2008, St. Louis MO.

Payne, R.B, Fagervold, S.K., May, H.D., and Sowers, K.R. 2013. Remediation of Polychlorinated Biphenyl Impacted Sediment by Concurrent Bioaugmentation with Anaerobic Halorespiring and Aerobic Degrading Bacteria. Environmental Science and Technology, 47:3807-3815.

Porebski, L. and Vogt, C. 2010. International Assessment of the Use of Confined Aquatic Disposal Facilities for Contaminated Dredged Material. Proceedings of the Western Dredging Association Thirtieth Technical Conference & Forty-First Texas A&M Dredging Seminar. June 6.

Semrany, S, Favier, L., Djelal, H., Taha, S., and Amrane, A. 2012. Bioaugmentation: Possible solution in the treatment of Bio-Refractory Organic Compounds (Bio-ROCs). Biochemical Engineering Journal, 69:75-86.

Tas, N., van Eekert, M.H, Schraa, G., Zhou, J., de Vos, W.M., and Smidt, H. 2009. Tracking functional guilds: “Dehalococcoides” spp. in European river basins contaminated with hexachlorobenzene. Applied and Environmental Microbiology, 75:4696–4704.

Tas, N., van Eekert, M.H., Wagner, A., Schraa, G., de Vos, W.M., and Smidt, H. 2011. Role of "Dehalococcoides" spp. In the Anaerobic Transformation of Hexachlorobenzene in European Rivers. Applied and Environmental Microbiology, 77(13):4437-4445.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

Tierra Solutions. 2011. Design Analysis Report. Phase I Removal Action, CERCLA Non-Time-Critical Removal Action – Lower Passaic River Study Area. Revision 2. Tierra Solutions, Inc., East Brunswick, New Jersey. July.

United States Army Corps of Engineers (USACE) and United States Environmental Protection Agency (USEPA). 2003. Great Lakes Confined Disposal Facilities.

United States Environmental Protection Agency (USEPA). 1994. ARCS Remediation Guidance Document. EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office, Chapter 8.

USEPA. 2000. EPA Superfund Record of Decision: Puget Sound Naval Shipyard Complex. WA-2170023418. §11.1.

USEPA. 2002. Final Five-Year Review of Record of Decision, Bremerton Naval Complex, Bremerton, Washington. Environmental Restoration Project. § 8.

USEPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. Office of Solid Waste and Emergency Response; EPA-540-R-05-012 OSWER 9355.0-85. December.

USEPA. 2009. EPA Region 2 Clean and Green Policy. March 17.

USEPA. 2010. Commencement Bay, Nearshore/Tideflats. See also U.S. Environmental Protection Agency. 2003. Explanation of Significant Differences Commencement Bay Nearshore/Tideflats Superfund Site: Mouth of Hylebos Waterway Problem Area.

USEPA. 2012. Superfund Site Update - New Bedford Harbor Superfund Site. February.

Van der Sloot, H.A., L. Heasman, and Ph. Quevauviller. 1997. Harmonization of Leaching/Extraction Tests. Studies in Environmental Science 70. Elsevier.

Zhen, H., Du, A., Rodenburg, L.A., Mainelis, G., and Fennel, D.E. 2014. Reductive dechlorination of 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin and Aroclor 1260, 1254 and 1242 by a mixed culture containing *Dehalococcoides mccartyi* strain 195. Water Research, 52:51-62.

Two Tower Center Blvd. 10th Floor
East Brunswick, NJ 08816

Paul J. Bluestein, P.E.

Project Manager
Tierra Solutions, Inc.

PROFILE SUMMARY

Paul Bluestein is a professional engineer with over 13 years' experience in the environmental field. Proficient in the management of multi-site portfolios, his responsibilities have ranged from design and implementation of groundwater/soil treatment systems to oversight of a major sediment remediation engineering/construction project. In addition to working under the environmental regulations of numerous states within the eastern U.S., Paul is experienced with federal regulatory compliance (e.g., CERCLA, RCRA).

EDUCATION

Virginia Polytechnic Institute and State University, Blacksburg, VA	Mining and Minerals Engineering	B.S.	1997

PROFESSIONAL EXPERIENCE

Management:

Design, construction and implementation of dredging removal (approx. 40,000 cubic yards) in the Passaic River, New Jersey, USA.

Design work was supported by pre-design investigations/data collection including sediment chemistry, geotechnical properties, physical oceanographic data and sediment dynamics, as well as groundwater and hydrodynamic modeling.

The project included the design of a combination wall steel enclosure, dredging analysis, debris and sand removal, dewatering via membrane filter presses, water treatment, and off-site waste transport, treatment and disposal. All work was conducted under USEPA oversight with concurrence from NJDEP, USACE, NOAA and USFWS.

Administrative requirements included procurement of permits for items such as waterfront development, land use, surface water discharge, water allocation and air emissions. Also required were assessments/evaluations of items such as essential fish habitat, floodplain, historic preservation and wetlands. Health and safety plans were developed and utilized for both workers and the community.

Management:

Operation, maintenance and monitoring (OMM) of a groundwater withdrawal system, groundwater treatment plant and engineered cap for an interim remedial measure conducted under USEPA/NJDEP oversight.

Work conducted requires monthly compliance sampling in accordance with state air and water discharge permits and monthly inspections/reporting on the performance of the interim remedy components.

Management:

Development/implementation of regulatory agency approved investigation work plans and corrective/remedial action work plans at numerous petroleum service stations impacted by leaking underground storage tanks.

Investigations included the installation of groundwater monitoring wells and soil borings to assess the nature and extent of petroleum-related contaminants of concern, as well as to support the remedial decision-making process. Corrective/remedial actions ranged from monitoring natural attenuation to design/construction and operation and maintenance of various soil and/or groundwater treatment systems including pump and treat, soil vapor extraction and high vacuum dual-phase extraction.

SPECIALIZATIONS

- Project Management
- Contaminated Sediment/Soil Remediation
- Remedial Investigations
- Water treatment
- Hazardous Waste Management
- CERCLA
- RCRA
- Multi-State Regulations

REGISTRATIONS/CERTIFICATIONS

- Professional Engineer (License #23175), Commonwealth of Kentucky, 2003.

PROFESSIONAL AFFILIATIONS/MEMBERSHIPS

- Sediment Management Work Group

PUBLICATIONS AND PRESENTATIONS

- Reed R., Orchard B., **Bluestein P.** Challenges/Successes Associated with the Phase I Removal Action in the Lower Passaic River Study Area. Poster presented at: Remediation of Contaminated Sediments. Proceedings of the Seventh International Conference on Remediation of Contaminated Sediments; 2013 Feb; Dallas, Texas.
- Kellems B., Parmelee R., **Bluestein P.**, Brzozowski P. Comparison of Sediment Processing and Filtrate Water Treatment Design Criteria to Full-Scale Performance Results. Paper presented at: Remediation of Contaminated Sediments. Proceedings of the Seventh International Conference on Remediation of Contaminated Sediments; 2013 Feb; Dallas, Texas.
- Roster G., Bonkoski B., **Bluestein P.**, Brzozowski P. In Situ Waste Characterization and Disposal: Phase I Non-Time-Critical Removal Action in the Lower Passaic River. Paper presented at: Remediation of Contaminated Sediments. Proceedings of the Seventh International Conference on Remediation of Contaminated Sediments; 2013 Feb; Dallas, Texas.
- Chwalibog A., **Bluestein P.**, Brzozowski P. Lower Passaic River: Phase I Removal Action Sediment Excavation Enclosure Design, Construction, and Monitoring. Paper presented at: Remediation of Contaminated Sediments. Proceedings of the Seventh International Conference on Remediation of Contaminated Sediments; 2013 Feb; Dallas, Texas.
- Dunn S., Shatt R., Parmelee R., Stephenson G., **Bluestein P.** Volatilization from Dredged Material: Approach to Air Monitoring. Poster presented at: Remediation of Contaminated Sediments. Proceedings of the Seventh International Conference on Remediation of Contaminated Sediments; 2013 Feb; Dallas, Texas.
- Beaver J., Hunt A., Becker C., Chwalibog A., **Bluestein P.**, Brzozowski P. Sediment Excavation Enclosure: Achieving Practical Design in Response to Technical Challenges. Poster presented at: Remediation of Contaminated Sediments. Proceedings of the Sixth International Conference on Remediation of Contaminated Sediments; 2011 Feb; New Orleans, Louisiana.
- Kellems B., Orchard B., Dunn S., Spadaro P., Dielhof R., Van Dam H., **Bluestein P.**, Brzozowski P. Sediment Processing for the Passaic River Phase I Removal Project. Poster presented at: Remediation of Contaminated Sediments. Proceedings of the Sixth International Conference on Remediation of Contaminated Sediments; 2011 Feb; New Orleans, Louisiana.

Robert Romagnoli, PE

Managing Director
The Intelligence Group
Professional Engineer, NY – NY license #50902
Professional Engineer, NJ – NJ license #24GE04659400

SUMMARY

Mr. Romagnoli has more than 25 years of experience in the environmental consulting industry, 23 of those dedicated to the management of contaminated sediments. During his career, he has developed expertise in the following general areas: technical and strategic support related to aquatic system investigation, remediation and restoration; multi-phase environmental process management evaluations; and wastewater/ground-water treatment system design. Mr. Romagnoli also has provided oversight and project management services for several major construction projects.

ACADEMIC QUALIFICATIONS

Cornell University	General Management	MBA	1990
Bucknell University	Civil Engineering	BS	1986

PROFESSIONAL EXPERIENCE

The Intelligence Group, Syracuse, New York, October 2012 to Present Managing Director

Managing Director in the firm's Environmental Services Practice. Provides a variety of professional services and strategic input on numerous environmental matters. Area of expertise includes managing large-scale and high-profile sediment remediation projects, regulatory negotiations, development of sediment-related strategies and investigations, design, remedy construction oversight, agency interaction, community outreach and litigation support from start to finish.

Arcadis/BBL, Syracuse, New York, July 1990 to October 2012, Sr. Vice President

Served as manager of ARCADIS' in-house Waterfront and Sediment Group, and provided high-level strategic services to clients that faced sediment liabilities. This included such tasks as designing large-scale sediment dredging projects, interacting and negotiating with various federal and state agencies, and directing large project teams that focused on the implementation of remedial investigation studies, risk assessments, hydrodynamic modeling, and feasibility studies. Served as Engineer of Record and Program Manager for the Passaic River Phase I Dredging Project.

Roy F. Weston, West Chester, Pennsylvania, September 1987 to August 1988, Project Engineer

Assisted in developing various work plans, feasibility studies and related health and safety plans. Managed and supported investigative field operations such as well installations and associated Ground Water sample collection programs.

Gray Associates, Flemington, New Jersey, July 1986 to July 1987, Project Engineer

Assisted in the design of bridge overpasses and provided construction oversight services. Coordinated all material supply needs for related field efforts.

TRAINING AND CERTIFICATIONS

- OSHA 40-Hour Training and Supervisory Course
- CPR/First Aid

SELECT REPRESENTATIVE PROJECTS

- Served as Program Manager and Engineer of Record for 40,000 cubic yard (cy) dredging project in lower Passaic River. Sediments had been shown to contain elevated levels of metals, dioxins, PCBs and other organics. This high profile project required constant communication/interface with USEPA and State personnel, along with other stakeholders including the local community advisory group.

- Served as Program Manager for the Remedial Investigation/Feasibility Study (RI/FS) of a 6-mile stretch of the Passaic River. Significant responsibilities included interacting with USEPA and other federal and state agencies; developing strategy for the client; assessing bed stability and sediment resuspension dynamics; overseeing a significant CSO investigation to understand mass loadings into the river system; and developing potential remedial options for the site.
- Acted as Program Manager for large-scale RI/FS in Newark Bay, one of the largest ports in the country. As part of this, Mr. Romagnoli oversaw numerous technical services associated with sampling design, risk assessment, modeling, and remedial option development.
- Served as Program Manager for a sediment site located within the Hackensack River. Provided overall strategic support and sampling design services. Also included management of IDW characterization and disposal program.
- Served as RI/FS Project Manager for a large-scale PCB sediment site. Managed the following aspects of the project: development and in-field testing of a cutting-edge remedial technology (particle broadcasting); development of a performance specification used to implement dredging, dewatering, and disposal of approximately 3,500 cy of PCB-containing river sediment; and implementation of a sediment transport model to understand the deposition/scour areas within the river.
- Managed the RI/FS process associated with a tributary to the Ottawa River. Tributary sediments had been shown to contain high levels of PCBs. Developed plans and specifications to remediate the site via mechanical dredging. Efforts also addressed remediation and restoration of the low-lying wetlands that bordered the site. The resulting sediment remediation project was labeled by the USEPA Region 5 Administrator as one of the “best” completed in the region.
- Provided engineering expertise for sediment dredging/dewatering project within the Lower Duwamish River. Primarily responsible for overseeing design of sheet pile cofferdam required for removal operations.
- Provided engineering services for development of the FS for the Lower Fox River. Managed the development of multiple alternatives for this 40-mile stretch of river, focusing primarily on sediments. In addition, managed the review/critique of Wisconsin Department of Natural Resource’s voluminous and highly technical RI/FS report.

PRESENTATIONS

- **Romagnoli, R.**, P. Spadaro, P. Bluestein (2012). Lower Passaic River Study Area Phase I Removal Action – 2012. Presented at *Sediment Management Work Group Meeting*, Newark, NJ.
- **Romagnoli, R.**, E. Peck, P. Spadaro, P. Bluestein (2009). Removal Action through Potentially Responsible Party Initiative in the Lower Passaic River, New Jersey. Presented at *Battelle’s Fifth International Conference on Remediation of Contaminated Sediments*, Jacksonville, FL.
- **Romagnoli, R.**, E. Peck, P. Spadaro, P. Bluestein (2008). Removal Action through Potentially Responsible Party Initiative in the Lower Passaic River, New Jersey. Presented at *EKOS Conference*, Brazil.
- **Romagnoli, R., P.E.**, J. Bryz-Gornia, J. Schiller (2007). Interpreting the Process and Results of the Lower Passaic River Dredging Pilot Study. Presented at *Western Dredging Association’s Eighteenth World Dredging Congress*, Lake Buena Vista, FL.
- **Romagnoli, R., P.E.**, C. Barnes, M. Henderson, and K. Powell (2007). Newark Bay Remedial Investigation: Complexity of a Multi-Chemical, Multi-Source Site. Presented at *Battelle’s Fourth International Conference on Remediation of Contaminated Sediments*, Savannah, GA.
- **Romagnoli, R., P.E.** (2006). Remedial Investigation of the Newark Bay Estuary – Conceptual Model of Multichemical Investigations. Presented at the *International Society of Environmental Forensics workshop “Environmental Forensics: Urban Ports and Harbors – Sediment Assessments in Complex Systems”*, Baltimore, MD.

TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

COMMENTS

Source-Related and Sediment Chemistry Trends

August 15, 2014

Prepared For:
Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared By:
Dennis P. Farley
Robert Romagnoli, P.E.

2014 RI Report for the FFS
Source-Related Comments

Summary

1. The theory that legacy sediments are the primary source of contaminated material to the system is flawed and should not be used as the basis for any remedial action. Many of Region 2's analyses that support this theory misrepresent, or are inconsistent with, actual river conditions, and therefore should be reassessed prior to selection of any remedial alternative.

2. Region 2's approach to quantifying external sources is flawed and should be replaced with relevant and quantitative analyses. The discussion of boundary conditions underestimates the impact of contributions from outside sources, and Region 2 fails to consider any upland sources within the Focused Feasible Study (FFS) Study Area. Evaluation of such sources demonstrates that ongoing contaminant discharges will continue to impact the FFS Study Area during and post-remediation. This portends a high likelihood that the remedy will be rendered ineffective and therefore, should not be implemented.

3. The diagnostic ratio of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (-TCDD) to Total TCDD, used by Region 2 to link estuary-wide dioxins to the LPRSA, is unfounded and should not be used as a fingerprinting tool. The 2,3,7,8-TCDD/Total TCDD ratio could result from a combination of any of several different sources and causes, and those possibilities were not considered in the FFS. As such, purported this line of evidence should not be used in a manner that supports Region 2's legacy sediment theory, which in turn attempts to justify the massive remedy proposed in the FFS.

General Comments

1. The theory that legacy sediments are the primary source of contaminated material to the system is flawed and should not be used as the basis for any remedial action.

As indicated throughout the Remedial Investigation (RI) Report and associated FFS, a bank-to-bank remedy has been selected based upon the premise that contaminated legacy sediments continue to feed the water column via scour/resuspension, and that the suspended particles mix throughout the FFS Study Area in a relatively uniform fashion so that surface concentrations generally remain consistent both spatially and temporally. A key assumption supporting this theory is that loadings from external sources are minor in comparison to the resuspension element. While resuspension may, in fact, have some impact on contamination of Lower Passaic River sediments, other sources play a much larger role than Region 2 acknowledges (see General Comment 2). This aspect alone would call into question any and all conclusions developed through this theory. However, there are other reasons for doubting this underlying foundation for the FFS. Each reason is discussed further below.

a. Region 2 is incorrect that surface concentrations of hazardous substances have remained constant from 1995 to 2012. In fact, surface concentrations have been decreasing over time, which undermines Region 2's justification for such extensive remedial action and demonstrates that its legacy sediment source theory is incorrect.

As highlighted in ARCADIS' General Comment 2, it is clear from the data that, contrary to Region 2's analysis, mean surface sediment concentrations (beginning in 1995) are subject to a *decreasing* trend over time. In fact, for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD), concentrations decreased by approximately 28%. Region 2's analysis to the contrary is incorrect because it erroneously included the 2012 Cooperating Parties Group (CPG) surface dataset, which was at least partially biased towards anticipated hot spots. Because of this bias, the mean concentrations from this sampling program would naturally be elevated above those that would have been found during random sampling, thereby skewing the resulting trend. This finding demonstrates that Region 2's legacy sediment theory is incorrect, in that surficial sediment concentrations are not in fact remaining constant over time. More importantly, it suggests that the river (and sediment) is naturally attenuating. Because Region 2's proposed remedy is based on an erroneous conclusion that natural attenuation is not occurring, it should not be implemented. Rather, natural attenuation should be evaluated in the RI/FS—including the collection of more data, if necessary—so that this important issue can be correctly analyzed.

b. Region 2 claims that the salt wedge or Estuarine Turbidity Maximum [ETM]) extends as far upstream as RM 12, and under typical flow conditions, is located between RM 2 and RM 10. The description of the salt wedge and ETM neglects to describe that they rarely reach as far upstream as RM 12, and thus, re-suspension of downstream legacy sediments does not explain the concentrations observed throughout the Lower Passaic River Study Area (LPRSA).

Region 2 utilizes the ETM as a "line of evidence" to explain the temporal and spatial surficial concentration equilibrium supposedly detected in the FFS Study Area, which in turn ultimately supports their justification for such a massive remedy. As discussed below, Tierra believes that the Region's ETM analysis is faulty, and should therefore be re-assessed.

The ETM is defined as a relative maximum in suspended solids concentrations compared to concentrations located landward or seaward (Dyer, 1988). Limited observations suggest that the ETM in the LPRSA is typically several kilometers (km), long, and may be as long as 5 km. Further, the ETM is often located near the upstream edge of the salt wedge. At other times, ECOMSED results and observations suggest that its centroid is located well back, or even landward, of the salt front. Sometimes, model results show multiple ETM. Thus, the location of the ETM is not well known, nor are the reasons for its variable position relative to the salt front. Nonetheless, the position of the salt front is the best available surrogate for ETM centroid position.

Movement of the salt wedge and ETM in a tidal estuary is bi-directional, and favors the downstream direction and mixing of surface sediment in the FFS Study Area with sediment from RM 8 and above. Region 2 claims that the ETM extends as far upstream as RM12, and, under typical flow conditions, is located between RM 2 and RM 10 (RI Report, page 6-1). The assertion that "during low flow conditions, the salt wedge and ETM reach as far upstream as approximately RM 12," does not appear to be based on observations, but rather on modeling analysis. Given the inadequate nature of the model calibration effort, the lack of uncertainty analysis, the lack of mass balance diagnostic analysis, and exclusion of some sediment loading sources, the assertion of ETM movement to approximately RM 12 based on modeling is not substantiated. Furthermore, the RI Report does not provide any information on the frequency of occurrence of the ETM with respect to RM. In fact, the report's Conceptual Site Model

(CSM), which serves as the guiding knowledge base for any system, fails to even mention the ETM.

The location and locational frequency of occurrence of the salt wedge and ETM in the LPR are understood through empirical data and curve-fitting mathematical analysis. Under typical flow conditions, the salt wedge and ETM are usually located below RM 6 (Tierra, 2012), based on the 2 psu isohaline (defined herein as the average surface and bottom salinities), and are increasingly infrequent further upstream or downstream. Statistical analysis of CPG's hydrodynamic simulations show that the ETM is typically (more than 50% of time) below RM 6 and reaches RM 10.2 less than 1% of the time (Fig. 1 below).

The location and locational frequency of occurrence of the salt wedge and ETM are not the only processes affecting sediment chemical concentrations. More sediment from upstream areas and tributaries moves in the downstream direction to mix with the sediment in the FFS Study Area than there is FFS Study Area sediment moving upstream (Tierra, 2013). The ETM moves upstream and downstream in a tidally driven cycle. This means that the ETM moves in the upstream direction for a period of time (i.e., during flood) and then reverses direction towards the downstream direction for a period of time (i.e., during ebb). The amount of time associated with the downstream direction is greater than that associated with the upstream direction (i.e., tidal asymmetry), which is consistent with the observations that the LPR feeds into Newark Bay in a positive direction for both freshwater and associated sediment.

Given Region 2's seemingly inadequate assessment of the LPRSA ETM and its relative importance in justifying the supposed need for a bank-to-bank remedy, it only seems prudent to require that this important phenomenon be better understood before undertaking such a significant remedial action. In fact, the findings produced from Tierra's own ETM analysis runs counter to Region 2's, which further supports the need for more careful study.

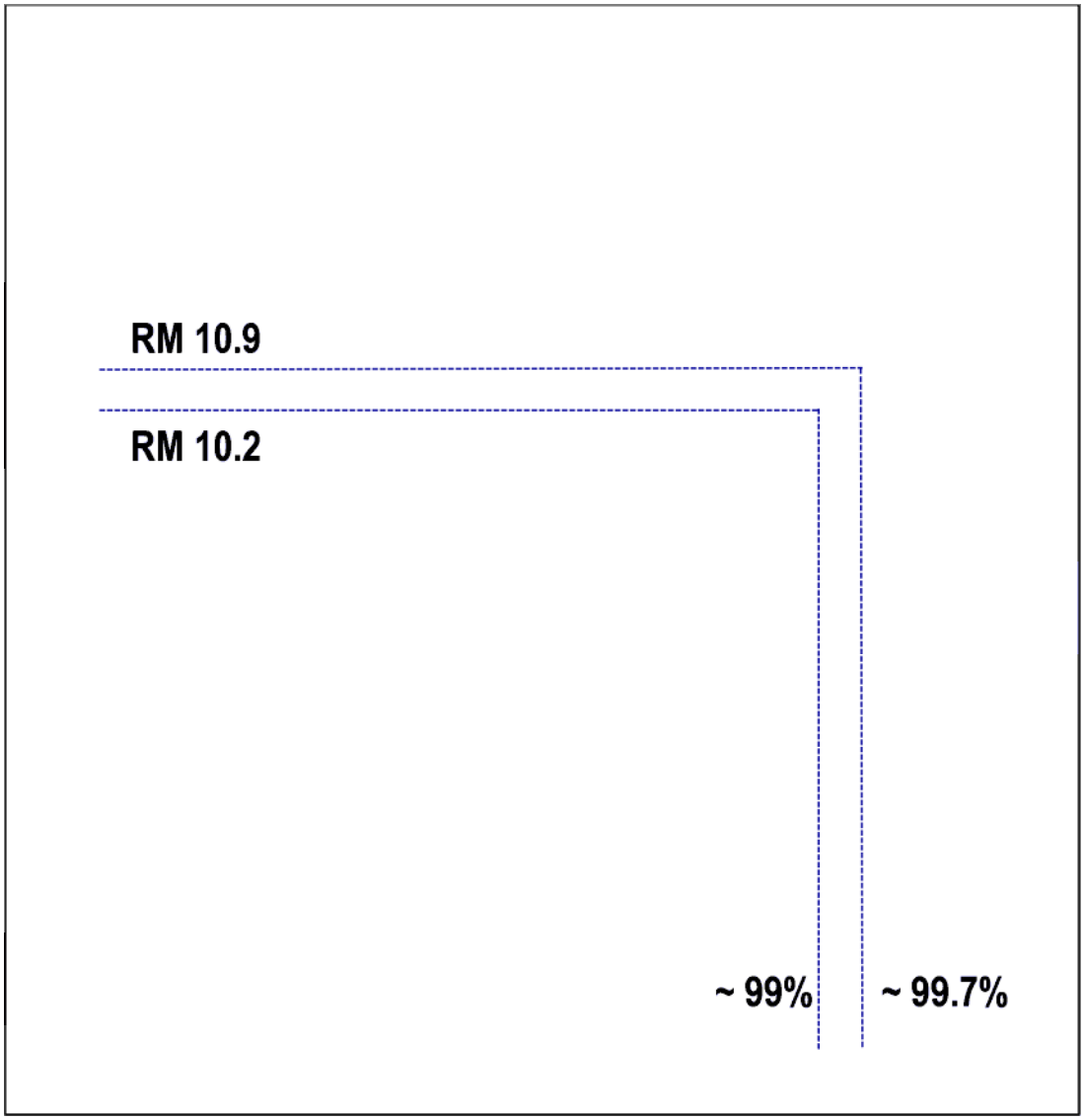


Figure 1. Probability of ETM occurrence with respect to river mile (RM 0 represents the mouth of the LPR). The plot is based on the 2 psu isohaline derived from CPG's hydrodynamic simulations for water years 1995-2004 and 110 years (1900-2010) of daily Dundee Dam discharge data. The vertical dashed lines indicate the mean ± one standard deviation.

c. **Even if legacy sediments were found to be the most significant ongoing source of contaminants to the FFS Study Area, an alternate approach focusing on "hot spot" remediation would be at least as effective as the proposed remedy, with far less impact on the river and surrounding communities.**

In light of the ongoing natural reduction of surface contamination levels, mitigating the more highly contaminated sediment pockets (i.e., "hot spots") would better serve the purpose of an interim remedy than Region 2's proposed bank-to-bank remedy, allowing for completion of the RI/FS process while the prospects for natural recovery are more thoroughly considered. This is precisely what is intended by the concept of Adaptive Management as supported by USEPA (USEPA, 2002). This is particularly important given the acknowledged negative aspects of dredging remedies, particularly one of this magnitude. In fact, a hot spot removal process is already underway, including both the Tierra Phase I Removal Action, which removed 40,000 cy of the most contaminated material known to be present in the LPRSA, and the RM10.9 dredge/cap operations that followed, which removed an additional 20,000 cy of contaminated sediments along the Lyndhurst shoreline. Such measures, while admittedly less extensive than Region 2's proposed remedy, have undoubtedly eliminated any potential future threat associated with these legacy sediment areas, and accomplished targeted, near-term mitigation that better fits the goals of interim or early actions under CERCLA. Especially for a system as complex as the Passaic, such an interim, step-wise strategy would be a more logical next step, allowing the RI/FS to be completed using knowledge gained from the various interim actions.. The massive remedy called for in the FFS is unjustifiable at this this juncture, given the uncertainties regarding natural recovery and the opportunity for hot spot dredging and/or capping to achieve near-term benefits.

2. **Region 2's approach to quantifying external sources is flawed and should be replaced with relevant and quantitative analyses. The discussion of boundary conditions in the RI Report's Data Evaluation Report 2 (DER 2) underestimates the impact of contribution from outside sources, and Region 2 fails to consider any upland sources within the FFS Study Area. Because proper evaluation of such sources shows that ongoing contaminant discharges will continue to impact the FFS Study Area, remediation of the FFS Study Area is premature before these ongoing sources are controlled.**

Region 2's evaluation of remedial alternatives presented in the FFS is based on its LPRSA conceptual site model (CSM). The CSM was developed based on various analyses conducted and presented in the RI report and its various Data Evaluation Reports. DER 2 provides an analysis of the boundary conditions considered in developing the CSM; the purpose of this evaluation is to identify contaminant inputs to the LPRSA and evaluate their respective contribution to the observed conditions within the Study Area. These boundary conditions include an upstream boundary (Dundee Dam), a downstream boundary (Newark Bay), and other inputs to the system: tributaries (Region 2 evaluated the Saddle, Third, and Second Rivers), combined sewer overflows (CSOs), storm water outfalls (SWOs), groundwater inputs, and atmospheric deposition. This discussion of boundary conditions did not, however, consider upland sources bordering the LPRSA.

Region 2's conclusion that the contaminants being contributed from the assessed boundary conditions are not significant is based on a flawed analysis. Region 2 compared these inputs to the mean concentrations in LPRSA surface sediments on a mass basis. DER 2 suggests

that, where the mass-normalized mean concentrations of contaminants delivered from outside sources is less than the mass-normalized mean concentrations of surface sediments, sources within the LPRSA must be the more significant source compared to the boundary condition. (As upland sources adjacent to the LPRSA have not been considered in Region 2's analysis, the "LPRSA sources" at issue result from resuspensions of legacy sediments.) But comparing these contaminant flows based on their mass-normalized mean concentrations ignores important issues.

Contaminants of concern (COCs) delivered to the LPRSA from these sources, , tend to accumulate adjacent to their point of delivery to the LPRSA or in other areas of preferential deposition. This process will form "hot spots," of elevated concentration, which are important considerations in correctly developing and understanding the CSM for the LPRSA. Further, the presence of such hot spots is not hypothetical; it is well evidenced in the LPRSA sediment data as discussed below.

More important, however, is the application of these boundary conditions in evaluating proposed remedies: DER 2 clearly states that some of the COCs delivered from various boundary conditions are "important," and in some cases, "major" and "dominant" contributors to the contaminant burden in the LPRSA (DER 2, Table 3-2). Indeed, even sources that are not important, major, or dominant in the context of the current conditions would promptly become important sources of COCs to newly-remediated areas. As these sources are ongoing, remedy selection must consider this continued input of contaminants to the LPRSA. Region 2's neglect of these sources means that its proposed plan will merely result in the replacement of the existing contaminated sediment bed with a re-contaminated cap.

Many of these concepts are further discussed throughout these source-related comments. Below are identified important issues in Region 2's evaluation of each of the boundary conditions as presented in DER 2, followed by a discussion of upland sources.

a. Upstream Boundary

DER 2 clearly identifies a number of COCs that are significant, ongoing inputs of contaminants to the LPRSA. Table 3-2 of DER 2 provides a qualitative assessment of the relative importance of Upper Passaic River loads from above Dundee Dam to the LPRSA:

- Polycyclic aromatic hydrocarbons (PAHs) from above Dundee Dam are identified as the "Dominant contributor" to the contamination identified in the LPRSA: *Upper Passaic River load represents the single largest contribution of the contaminant. Other sources of solids to the Lower Passaic River serve to dilute the solids burden delivered by the Upper Passaic River.* "Dominant contributor" is defined as contributing greater than 125% of the observed contaminant load in the LPRSA.

- Certain pesticides from above Dundee Dam, including Dieldrin and Aldrin, are identified as a "Major contributor" to the contamination identified in the LPRSA. "Major contributor" is defined as contributing between 75% and 125% of the observed contaminant load in the LPRSA.

- A number of various contaminants from above Dundee Dam, including polychlorinated biphenyls (PCBs), dichlorodiphenyl-trichloro-ethene (DDT), mercury, lead, chromium, and copper are identified as an "Important contributor" to the contamination identified in the LPRSA. "Important contributor" is defined as contributing between 25% and 75% of the observed contaminant load in the LPRSA.

Each of these identified contaminants is deemed by Region 2 to be significant in compared with the existing surface sediment conditions in the LPRSA. Post remedy, the ongoing source of these contaminants – the Upper Passaic River – obviously poses a significant recontamination threat to any remediated area in the LPRSA. This is a compelling reason to, as USEPA's guidance provides (USEPA, 2002), control these sources before selecting a remedial action for the lower eight miles of the LPRSA.

LPRSA RM 8-17, which abuts the FFS Study Area, represents the true upstream boundary condition for the FFS Study Area, and its potential contribution was not evaluated by Region 2. While the inputs from the Upper Passaic River as calculated by Region 2 can be readily understood, the additional contribution of legacy sediments and ongoing sources in LPRSA RM 8-17 must also be considered. Region 2 has indicated their own understanding of such, as evidenced by their requirement for a Time Critical Removal Action at RM 10.9. Several lines of evidence indicate that LPRSA RM 8-17 contributes contaminants to the LPRSA:

- Figures 2-A through 2-L of these comments assess spatial differences in the data through Theisson polygon plots of COCs detected at surface sample locations.

- As shown in Figure 3, concentrations of various COCs representing the upper 10% of concentrations observed in LPRSA surface sediments are found at locations within LPRSA RM 8-17. Thus, elevated hot spots exist in surface sediments within RM 8-17 for contaminants, including 2,3,7,8-TCDD, Total TCDD, Total DDT, dieldrin, Total congener PCBs, Total Aroclor PCBs, mercury, lead, copper, Total PAHs and Total Chlordanes.

- The majority of these hot spots is located at, or in proximity to, the RM 10.9 area. This area has been the focus of extensive work by Region 2 and others as a risk to downstream sediments requiring remediation due to the potential mobility of this mass of COCs. Surficial concentrations of several of these contaminants within the LPRSA actually peak within this area. As shown in Figure 3, not all of these hot spots are located within the area recently remediated at RM 10.9; thus, they pose a risk for ongoing release to the FFS Study Area.

- Region 2's RI itself demonstrates the risk of these hot spot areas recontaminating the FFS Study Area at RM 0-8. For example, Figure 4-10 of DER 2, provided here as Figure 4, is used by Region 2 to depict the concentration gradient of 2,3,7,8-TCDD surface concentrations from the LPRSA into Newark Bay at the downstream boundary of the LPRSA. Based on this, Region 2 concludes that the LPRSA is a

source to Newark Bay sediments as the gradient profile decreases across the LPRSA and further into Newark Bay. A similar gradient of 2,3,7,8-TCDD surface concentrations trends from the area of RM 10.9 into the FFS Study Area, demonstrating that the RM 10.9 area is an ongoing source of 2,3,7,8-TCDD to the FFS Study Area.

Both recent and ongoing sources of the contaminants observed at these LPRSA RM 8-17 "hot spots" are known to exist and similarly pose a risk of recontaminating the FFS Study Area.

- The co-location of elevated concentrations of such a wide range of contaminants in one of these hot spot areas is due to a common source that historically discharged to this area: the Third River Yantacaw Bypass operated by the Passaic Valley Sewerage Commissioners (PVSC). This source has been discussed in great detail in various documents submitted to Region 2, and its history is reflected in numerous public records and documents (Killam, 1976; PVSC, 1951-2007; Lubetkin, 1994). The Bypass discharged large volumes of sewage containing various contaminants and hazardous substances from numerous communities located north of RM 10.9 (and also north of the LPRSA) directly into the LPRSA. The bypassed sewage was not diluted by storm water, as the sewerage systems served by this bypass are, with the exception of the city of Paterson, separately sewered (non-CSO) municipalities. Legacy sediment contamination from this source forms a significant portion of the inventory of contaminated sediments in this local area, only some of which will be addressed by the recent Time Critical Removal Action at RM 10.9. Further, while routine discharges from the Third River Yantacaw Bypass are now prohibited by law, the bypass is maintained in a ready state for emergency bypass needs, and thus, may further discharge contaminants in a future bypass scenario. A review of publically-available records also shows that discharge volumes from other large CSOs (Market St., Paterson – PVSC 1951-2007) operated by PVSC have increased since the time at which bypassing at Yantacaw was prohibited. The Market St., Paterson CSO is located above Dundee Dam, influencing the contamination contributed by the Upper Passaic River Boundary Condition.

- The former Givaudan Site, located in Clifton near the RM 10.9 area, generated 2,3,7,8-TCDD and other COCs, and its role as a source of these contaminants to this area of the LPRSA is presently under investigation (USEPA et al., 2013). While remediation of areas impacted by 2,3,7,8-TCDD at the Givaudan Site has been completed, further evaluation and remediation of potential discharge routes from the site has not, and thus ongoing sources of contaminant discharge to the LPRSA may still exist. Evidence of such consists of surficial sediment contamination with 2,3,7,8-TCDD and related contaminants in this area of the LPRSA, and the identification of a near-term (circa 2000) external dioxin discharge by Region 2's consultant (Garvey et al., 2011). Regarding the presence of a circa 2000 TCDD peak at RM 7.8, 11, and 12.6, the consultant's report states that: "Event circa 2000 is documented across three cores and can be identified as an external dioxin load, with a unique dioxin

pattern. Lack of response in other contaminants rules out sediment resuspension." As remediation and redevelopment of the Givaudan site preceded and/or was contemporaneous with this circa 2000 discharge, the evaluation of potential sources in this area of the LPRSA must consider the possibility that former discharge routes from the Givaudan site are reservoir sources of contaminants, with the potential for continuing discharge.

To summarize the upstream boundary condition, a number of sources of ongoing sediment contaminant contribution have been shown. These include ongoing sources from above Dundee Dam, as well as legacy contaminated sediments and ongoing or recent sources within LPRSA RM 8-17 immediately adjacent to the FFS Study Area. As indicated previously, there is more sediment from upstream areas and tributaries moving downstream to mix with sediment in the FFS Study Area than FFS Study Area sediment moving upstream (Tierra, 2013). The risk for recontamination of remediated areas in the FFS Study Area is significant. Accordingly, a bank-to-bank remedial action should not be taken in the lower eight miles until these ongoing sources are controlled.

b. Newark Bay

The RI Report (including DER 2) analyzed the LPRSA's Lower Boundary Condition at Newark Bay, but failed to consider much of the RI/FS work available for the Newark Bay Study Area (NBSA), particularly the CSM for the NBSA (NBSA CSM) (Tierra, 2013

Region 2 concludes in DER 2 that bi-directional transfer of sediments between the LPRSA and Newark Bay takes place, serving to confound a straightforward analysis of contaminant inputs to the LPRSA from the NBSA. Region 2 itself recognized that there is a clear transport scenario for contaminants, such as mercury and PCBs, from the LPRSA into the NBSA, "due to likely NBSA sources of these contaminants," but did not analyze what level of contaminant input the NBSA contributes to the LPR nor how that would affect the remedy.

Region 2's identification of northern Newark Bay sources of mercury and PCBs is in agreement with the findings of the NBSA CSM, which identified likely ongoing sources of these and other contaminants from upland sites and industrial operations adjacent to the northern NBSA. In particular, significant mercury sources have been identified for both the northern and central NBSA, with concentrations of mercury in sediments within these areas an order-of-magnitude higher than those in the LPRSA FFS Study Area, and in particular, the lower 2 miles of the LPRSA adjacent to the NBSA. Figure 5 provides a scatter plot showing surface concentrations of mercury in the LPRSA and NBSA based on distance from LPRSA RM 0 (the plot was prepared in accordance with Region 2's analysis of the LPRSA data, with the mercury levels normalized to lead). As shown, concentration gradients from the northern NBSA into the LPRSA exist, demonstrating the NBSA is a likely ongoing source of mercury contamination to LPRSA sediments. Post remediation, the potential for significant recontamination exists.

The NBSA CSM identifies other contaminants at elevated levels in surficial sediments that are likely associated with local, upland sources. In addition to mercury and PCBs, these include several pesticides as well as compounds identified by Region 2 as associated with the formation of dioxins, including 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T), 2,4,5-TP (Silvex), and 2,4-Dichlorophenoxyacetic acid (2,4-D). These surficial sediment contaminants are located adjacent to a contaminated upland site that has not undergone site remediation. This property, the Central Steel Drum Site in Newark, is similarly contaminated with these same compounds, as well as 2,3,7,8-TCDD and other polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Given the potential for ongoing discharges from this site, the NBSA CSM recommended that a comprehensive characterization of the site be completed. Similar to mercury, the for the contribution of contaminants from the area of this site to the LPRSA post remediation is significant.

c. Tributaries

As described in DER 2, Region 2's RI work attempted to characterize contaminant contribution to the LPRSA from three tributaries: the Saddle River, the Third River, and the Second River. Unfortunately, Region 2's approach fails to adequately represent contaminant contribution from each of these tributaries and likely also overlooked several other tributaries that may be locally important contributors of contamination to the FFS Study Area.

The methodology employed by Region 2 consisted of collecting water column samples to represent suspended sediment prior to deposition, sediment trap samples with detectable Be-7 concentrations (reportedly to confirm deposition occurring within the prior several weeks), and surface sediment samples (reportedly to confirm deposition occurring within the prior several months). All samples were collected above the head-of-tide (HOT) within each tributary, reportedly to ensure that tidal exchange of contaminants from the LPRSA did not influence estimates of each tributary's contribution. Several shortcomings in Region 2's approach suffice to illustrate why these ongoing sources of contamination to the LPRSA are under-represented by Region 2's analysis:

- By collecting samples only above the HOT, the analysis eliminates the lower 3.2 miles of the Saddle River, the lower 2 miles of the Third River, and the lower 1.4 miles of the Second River. These omitted river sections are, or historically were, the most industrialized sections of each of these tributaries with the greatest likelihood for the discharge of contaminants within each. While Region 2 estimates a correction factor for the additional solids loads omitted, no such correction factor or alternative approach can be considered to account for and evaluate contaminant contribution from these most industrialized sections of each tributary. Historical industrial sites, and other sources located adjacent to each of these tributary areas below the HOT, have not undergone remediation. The potential for ongoing

contaminant contribution to the LPRSA for each of these tributaries below the HOT has not been adequately characterized.

- Peak measured concentrations of several contaminants, PCBs, and PAHs were observed in water column suspended matter collected during a storm event. Peak concentrations ranged up to 1,400 µg/kg for PCBs and 790 mg/kg for PAHs. DER 2 acknowledges that the elevated concentrations detected are likely due to increased runoff during the storm event, but then attempts to discount these data, as they "may not be reflective of the longer-term average concentrations captured by the other two sampling techniques." The rationalization to ignore these results completely discounts the primary source of potential contaminant input from the tributaries: runoff from contaminated sites and related discharges during wet-weather, high-flow events. In such a scenario–common enough that USEPA routinely implements runoff-prevention strategies in upland site remediation–peak contaminant discharge would actually occur at such times, rather than during dry, static conditions. The sampling strategy employed by Region 2 did collect such data, which it then elected to discount from consideration. As indicated above, the detected concentrations of PCBs and PAHs are not insignificant in comparison to existing FFS Study Area surface sediments and certainly are quite important from a source perspective relative to any contemplated remediation.

- Continuing with the wet-weather discharge scenario, the sampling strategy employed by Region 2 failed to even consider this most significant potential source. Region 2's collection of recent surface sediments and sediment trap samples does not adequately measure contaminant input during storm events, as such scoured solids will tend not to accumulate within the tributary. During wet weather events capable of scour and the removal of solids from upland contaminated sites, small tributaries such as these serve primarily as a transport mechanism to their receiving water bodies, in this case the LPRSA. Additionally, any legacy sediments remaining within the tributary are available for scour and transport to the LPRSA. The implemented sampling techniques focused only on recently-deposited sediments within the tributaries, and thus, failed to identify and characterize any reservoir inventory of legacy contaminants.

- Further, DER 2 incorrectly concludes that contaminant loads from the tributaries can only be important if the mean contaminant concentration is at least one order-of-magnitude greater than the observed concentration on recently deposited sediments of the LPRSA. Region 2 reaches this conclusion by estimating that the total solids load from the three tributaries contributes less than 10% of the solids load to the LPRSA; thus, they are an order-of-magnitude smaller than the load delivered by the Upper Passaic River. (That logic dictated that any contaminant inputs greater than 25% of the surface sediment concentrations in the LPRSA was important based on its estimate that the Upper Passaic load is approximately equivalent to the average mass of sediment that accumulates annually in the LPRSA.) The flaw in this logic is

the calculation of means and making comparisons on a mass-balance basis, as this approach does not consider the importance of local hot spots as they relate to the proposed remedy.

Local inputs of elevated concentrations of contaminants do affect surface concentrations in the LPRSA, contributing to the observed contaminant hot spots at various source discharge locations. A review of Figure 3 reveals the presence of surface sediment hot spots for various COCs adjacent to the discharge point of each tributary to the LPRSA. Their presence is simply dismissed by Region 2 as heterogeneity in the CSM's resuspension and re-deposition of legacy sediments theory, rather than identifying the hot spot as an anomaly to be characterized and investigated. In addition to the tributaries considered by Region 2, others exist in the LPRSA that are important in terms of contaminant input to the FFS Study Area: Frank's Creek, discharging to the LPRSA from the north at RM 3.1; Lawyers Creek, discharging to the LPRSA from the west at RM 1.7; Harrison Ditch, discharging to the LPRSA from the west at RM 1.5; and Plum Creek, discharging to the LPRSA from the west at RM 0.6. All four of these tributaries drain areas that were (historically) virtually 100% industrial in nature and given their location relative to the proposed remedy, particularly those that discharge to the lower 2 miles of the Passaic, their omission is unjustifiable. While field data were not collected from any of the four during Region 2's RI/FFS, a review of Figure 3 confirms the presence of surface sediment "hot spots" for various COCs adjacent to the discharge point of each to the FFS Study Area.

To summarize the tributary boundary condition, Region 2 failed to adequately characterize contaminant input from the tributaries studied by ignoring the portions of each tributary below the HOT and by failing to assess data during their peak times of contaminant discharge, namely storm events. Furthermore, the data collected were improperly evaluated utilizing a mass balance approach, and an additional four tributaries serving historically industrial areas were not included in the analysis. Thus, the contaminant input from tributaries is significantly under-reported by Region 2, resulting in an incorrect conclusion that tributaries do not serve an important role in on-going contaminant transport to the LPRSA.

d. CSOs/SWOs: Contaminant input from CSOs and SWOs has not been adequately characterized and poses a threat for recontamination of remediated areas. Region 2 should fully characterize ongoing discharges and further evaluate legacy sediment contaminant hot spots associated with these discharges prior to considering remedial alternatives for sediments in the FFS Study Area.

Overflows and discharges from CSOs have historically been an important source of contaminants to the LPRSA. CSOs and their related sewerage system infrastructure have discharged billions of gallons annually to the LPRSA, consisting of a mixture of storm water industrial, commercial, and domestic waste (Killam, 1976; CFM, Inc. 1986; Lubetkin, 1994; PVSC, 1951-2007). Significant quantities of hazardous substances

have been discharged with these system overflows and bypasses over time, and such discharges continue today.

The PVSC operates this regional system, which consists of municipally owned sewage-collection systems that discharge into a series of interceptors that it owns and operates. Of the 48 municipalities comprising this network, waste from most of them can be, and has been, discharged into waters of the LPRSA by the PVSC. Currently, 32 CSOs are located within the FFS Study Area, in addition to two Emergency Relief Points (ERPs; formerly "bypasses") that have historically been used by the PVSC to bypass large volumes of waste from other parts of the system into the LPRSA (NJDEP, 2005).

Review of publicly available information and records reveals that the volume of discharges from the PVSC system to the LPRSA has decreased over time, although significant volumes are still discharged routinely from CSOs (PVSC, 1951-2007). While discharges from the two ERPs located within the FFS Study Area are now prohibited, these are maintained in a ready state for emergency bypass needs, and thus, may further discharge contaminants in an emergency bypass scenario.

SWOs within the LPRSA have similarly been a historically important source of contaminants to the LPRSA. While the majority of the FFS Study Area is drained by combined sewers, specific areas within upland areas draining to the FFS Study Area are today served by separated municipal storm sewers. Additionally, many of the industrial facilities that are presently or were formerly located adjacent to the LPRSA had privately constructed storm drainage networks on their properties that drain to the LPRSA. As a result, the vast majority of SWOs in the FFS Study Area serve present and/or former industrial areas and properties, with a potential to discharge hazardous substances into the LPRSA as a result of both direct spills and contaminated runoff.

Region 2's assessment of the continuing threat posed by CSOs and SWOs in the LPRSA consisted of the collection of samples from five CSO locations in the LPRSA (all located within the FFS Study Area) and eight SWOs (two of which were located in the FFS Study Area). Based on the results of this work, Region 2 concluded that CSO and SWO discharges are not a significant source of contamination to the LPRSA. Region 2 acknowledges that the discharges are not free of contamination, but contends that the volume and concentration of contaminated solids represent a minimal contribution of contaminants compared with other sources.

Region 2's conclusion is insupportable; the work conducted to date is insufficient to adequately assess the continued threat posed for a number of reasons:

- **A full characterization of CSO and SWO discharges is not complete, and efforts currently underway must be completed.**

  Occidental is the Respondent to the Region 2 Administrative Order on Consent (AOC) and Settlement Agreement dated September 27, 2011, by which it agreed to perform a qualitative assessment of CSO discharges to the LPRSA. The purpose of

this work, as stated in the AOC, is to "determine the nature and extent of contamination and any threat to the public health, welfare, or the environment caused by the release or threatened release of Waste Material or other hazardous substances, pollutants or contaminants emanating from the Combined Sewer Overflows ("CSOs") and Storm Water Outfalls ("SWOs") discharging into the LPRSA…." The proposed work consists of two phases:

- Phase I: Pilot study of three sampling methods for the collection and analysis of CSO samples. In this phase, three sampling methods (High Solids Method, Low Solids Method, and whole water sampling) will be utilized to sample effluent from two selected CSO locations during one overflow event.

- Phase II: Collection and analysis of samples from 19 locations using a technique selected from the Phase I results. Locations will include eight CSOs, ten SWOs, and influent at the PVSC treatment plant.

This work will include the Phase I pilot study, which is designed to determine the most representative sampling technique of the three to be compared. The pilot study is essential to obtaining representative samples to accurately estimate contaminant inputs to the LPRSA from each of the sampling locations. Conversely, Region 2's work (conducted by Malcolm Pirnie, Inc. in 2007 & 2008) performed no such analysis to determine the appropriate sampling technique, and as such, may not be representative of actual conditions. Further, the Region 2 work was not as extensive as the work being conducted under the AOC. Field work for Phase I of this present effort was initiated in June of 2013, and is continuing. To accurately determine the extent of contaminant contribution to the LPRSA from CSOs and SWOs, the work under this AOC needs to continue to completion, and the results should be considered in remedy selection.

- **The conclusions of Region 2's CSO and SWO sampling work are not in agreement with either prior studies or with readily visible impacts from CSOs and SWOs in the LPRSA.** Prior studies, as well as surficial sediment contamination patterns in the LPRSA, demonstrate that CSOs and SWOs impact the LPRSA through the ongoing discharge of contaminants to LPRSA sediments and by the historical creation of contaminated sediment hot spots where surficial sediment contamination is elevated compared with LPRSA surface sediments.

  - **Evidence of the importance of ongoing CSO and SWO discharges has been plainly identified in various prior studies:**

    - CARP (Great Lakes Environmental Center [GLEC] 2008) sampled and analyzed discharges from a variety of Publicly Owned Treatment Works (POTWs), CSOs, and SWOs in the NY-NJ Harbor Estuary, including the FFS Study Area within the LPRSA. The findings showed that significant

loads of hazardous substances were discharged annually to the estuary from POTWs. While these loads were not calculated for the CSO and SWO data, the concentrations of contaminants in CSO and SWO discharges analyzed were consistently higher than those collected from the POTWs. Among the SWOs sampled, the Blanchard St. SWO in Newark (located within the FFS Study Area) was highest for a number of contaminants, including PCBs and PAHs. The Blanchard St. SWO services an entirely industrial drainage area.

Region 2's own sampling conducted in 2007-2008 showed similar concentrations of PCBs and PAHs, as well as other contaminants, in in the Blanchard Street SWO samples that were elevated above, or within the same concentration range as, LPRSA surface sediments in the vicinity of the outfall. The continued discharge of contaminants at these levels from the Blanchard St. SWO will re-contaminate remediated sediments in this area.

- Tierra (1995; work published under Iannuzzi et al., 1997) conducted a study in which shallow surface samples were collected in an array adjacent to four CSOs in the FFS Study Area of the LPRSA. The purpose of this work was to: (1) characterize chemical contamination in sediments impacted by these CSOs, (2) evaluate the spatial distribution of contaminants, and (3) evaluate the possible sources of contaminants within the respective CSO districts. A key finding of this study was the presence of certain, unique COCs adjacent to certain CSO outfalls that were statistically significant in comparison to the data set. These unique COCs were, in each case, related to a Significant Industrial User (SIU) discharger in that CSO district, providing source-pathway-receptor proof. Examples exhibiting this relationship include the Worthington Ave. CSO, at which cyanide was detected in 70% of the samples, ranging from 1.55 mg/kg to 269 mg/kg vs. zero in samples from the other three CSOs. Of note, an SIU was permitted for cyanide discharges to the Worthington CSO district and had received multiple notices of violation for exceeding its permit levels for cyanide (Iannuzzi et al., 1997). Further examples are provided in the following section that illustrate the ongoing risk to remediated sediments posed by these CSO outfalls.

- **Evidence of CSO and SWO impacts within the FFS Study Area are readily visible in the surface sediment data, including both ongoing discharges from active CSOs/SWOs and legacy sediments at CSO and ERP locations:**

  - Elevated concentrations of several COCs, including PCBs (Aroclors and congeners) and PAHs, are evident in surface sediments in the vicinity of the Roanoke Ave. CSO in Newark (Figs. 2-A, 2-B, and 2-I). This CSO,

which is not operated by PVSC, services a highly industrialized section of Newark, and discharges into the FFS area at LPRSA RM 1.1. The Roanoke Avenue CSO has a long history of ongoing hazardous substance discharges, as evidenced by public records, including a long history of PAH discharges associated with a former industrial discharger illegally tied into the CSO (Clinton Bogert Associates, 1979). Portions of this drainage area now consist of abandoned industrial sites.

- Elevated concentrations of several COCs, including PAHs and lead, are evident in surface sediments in the vicinity of the Worthington Avenue CSO in Kearny (Figs. 2-I and 2-L). This CSO services a highly industrialized section of Kearny and discharges into the FFS Study Area of the LPRSA at RM 3.5. In addition to lead and PAHs, surface sediments were contaminated with elevated concentrations of cyanide associated with a discharger to the Worthington CSO district in the 1995 Tierra work referenced above (Iannuzzi et al., 1997).

- Elevated concentrations of several COCs, including Total DDT and PAHs, are evident in surface sediments in the vicinity of the Herbert Place CSO in Newark (Figs. 2-F and 2-I). This CSO services an industrialized and residential section of Newark and discharges into the FFS area of the LPRSA at RM 6.8. In the 1995 Tierra work, surface sediments in the vicinity of this CSO were also identified as contaminated with silver and toluene at elevated concentrations. A precious metals refiner with a history of silver discharge to the combined sewer system was known to exist in this district, providing an explanation for the somewhat rare finding of high silver concentrations in sediments local to the CSO. Also, a prior Region 2 investigation reported the presence of 29 µg/L toluene in effluent discharging from the Herbert Place CSO; several SIUs in the Herbert Place CSO district were permitted for toluene (Iannuzzi et al., 1997).

- Significantly elevated concentrations of a wide range of COCs are present in RM 7-8 surface sediments, including PCBs (Aroclors and congeners), 2,3,7,8-TCDD, Total TCDD, Total DDT, PAHs, mercury, copper, and lead (Figs. 2-A through 2-D, 2-F, and 2-I through 2-L). This elevated hot spot represents a large reservoir of legacy sediments contaminated both at depth and at the surface. The co-location of elevated concentrations of such a wide range of contaminants is due to a common source that historically discharged to this area: the Second River Joint Meeting Bypass operated by the PVSC. Similar to the Third River Yantacaw Bypass, this source has been discussed in great detail in various documents submitted to Region 2 (Killam, 1976; PVSC, 1951-2007; Lubetkin, 1994), and its history is reflected in numerous public

records and documents. The bypass historically discharged large volumes of sewage containing various contaminants and hazardous substances from numerous communities located west of the Passaic River directly into the LPRSA at this location. The bypassed sewage was not diluted by storm water, as the sewerage systems served by this bypass are non-CSO municipalities. While routine discharges from the Second River Joint Meeting Bypass are now prohibited, the Bypass is maintained as an ERP in a ready state for emergency bypass needs, and thus, could discharge contaminants in a future bypass scenario.

- Significantly elevated concentrations of a wide range of COCs are present in surface sediments at RM 0.3, including PCBs (Aroclors and congeners), Total DDT, PAHs, mercury, and copper (Figs. 2-A, 2-B, 2-F, and 2-I through 2-K). The co-location of elevated concentrations of such a wide range of contaminants is due to a common source that historically discharged to this area: the Newark Bay Bypass operated by the PVSC. This bypass point for the PVSC POTW treatment plant in Newark has been discussed in great detail in various documents submitted to Region 2 (NJDEP, 1980; USDOJ, 1980; Lubetkin, 1994), and its history is reflected in numerous public records and documents. The bypass has, historically, discharged large volumes of untreated sewage containing various contaminants and hazardous substances from the entire PVSC system directly into the LPRSA at this location. While routine discharges from the Newark Bay Bypass are now prohibited by law, the bypass is maintained as an ERP in a ready state for emergency bypass needs, and thus, could further discharge contaminants in a bypass scenario.

As shown in these examples and discussion, contaminant input from CSOs and SWOs has not been adequately characterized and poses a threat for recontamination of remediated areas. A full characterization of ongoing discharges and further evaluation of legacy sediment contaminant hot spots associated with these discharges should be completed prior to consideration of remedial alternatives for sediments in the FFS Study Area.

e. Upland Sources: Upland sources of contaminants within the LPRSA discharge on an ongoing basis to the FFS Study Area. Full characterization and remediation of these discharges is should be completed prior to remediating sediments in the FFS Study Area.

The majority of land use adjacent to both shorelines of the FFS Study Area is industrial and formerly industrial in nature. Numerous industrial sites and facilities operated along the banks of the LPRSA over the prior 2 centuries, many of which contributed to legacy contaminated sediments within the FFS Study Area. The present inventory of these former operating sites ranges from abandoned sites, to operating industrial facilities, to remediated, demolished, and re-developed properties. A concise inventory of these

properties is beyond the scope of these comments; however, over the past decade, information regarding the operating histories and contaminant discharges from a significant number of these facilities has been developed and submitted to Region 2 in the form of PRP Evidence Packages. What follows is a brief description of several examples, that exemplify the need to complete the characterization of these sites and remediate ongoing discharges.

- **The Municipal Sanitary Landfill Authority (MSLA)-1D Landfill Site** – This site, located on the northern shoreline of the FFS Study Area between RM 2.4 and 3, is a 94-acre landfill that contains municipal and industrial waste. The site was in operation from approximately 1968 to 1982, during which time it received hazardous substances from industry throughout northern New Jersey. The site was closed pursuant to an NJDEP Administrative Order in 1982, in part because MSLA failed to maintain a leachate collection system. The site was never properly closed and the final cover was insufficient, leading to the ongoing generation and discharge of leachate. Engineering information published in 1985 estimated that 250,000 gallons/ day of leachate containing motor oil, heavy metals, and other hazardous substances discharged to the Passaic River (Topousis, 1995).

  Leachate, surface runoff, and site drainage discharge from the landfill into on-site ditches that flow to the Passaic River via the Cedar Creek Pumping Station located within the FFS Study Area at RM 2.5. On-site drainage ditches located at the west end of the site discharge into Frank's Creek, and ultimately, into the Passaic River within the FFS Study Area at RM 3.1. Site contaminants detected in soil, leachate, and site sediments include PCBs, 2,3,7,8-TCDD, PAHs, and mercury. As shown in Figures 2-A through 2-C, 2-I, and 2-J, these same contaminants (along with other PCDDs/PCDFs) also are present at elevated concentrations in LPRSA surface sediments adjacent to these discharge points.

  Closure of the site was undertaken by the NJDEP Site Remediation Program in 2003, and in 2007, a Final Surface Water and Sediment Investigation Report was completed. Levels of 2,3,7,8-TCDD ranging up to 8.84 ppb were detected on site during this work, and a tidal study demonstrated that the dioxin-contaminated area of the site was not tidally influenced, indicating that the landfill was the source of the observed dioxin contamination. Throughout 2010-2011, plans were discussed to design and install a leachate-collection system to prevent the ongoing discharge of leachate to surrounding areas and the Passaic River. To date no contracts have been approved to install this system and the site remains an on-going source of contamination to the FFS Study Area.

- **The Riverside Industrial Park Site**–This site, located on the western shore of the FFS Study Area at RM 6.8-7.1, was owned and operated by PPG from 1902 to 1972 and then by multiple industries operating as the Industrial Development Association from 1973 to 1993, when the city of Newark foreclosed on the property. PPG manufactured paints, varnishes, and other products at the site, and various operators

during more recent years utilized the site for the repackaging of dyes and pigments, precious metals refining, and chemical manufacturing, among other operations.

Prior to 2010, characterization of onsite contamination was limited to select parcels associated with various occupants during the Industrial Development Association operation of the site. In 2009, Region 2 responded to a reported discharge of hazardous substances from the site into the Passaic River. At that time, Region 2 initiated an emergency removal action, and in 2010, a site-wide characterization of site media. Work included the collection of soil and groundwater samples, sediments, and materials in site buildings and basements, and material found leaching from the site riverbank into the Passaic River. Results obtained to date show the presence of PAHs, volatile organic compounds (VOCs), metals including lead, mercury, and chromium, and PCDDs/PCDFs. Discharges documented by Region 2 include site runoff of soil contaminants and direct discharges from sumps and various historical drains at the site. Site characterization work is ongoing.

Surface and subsurface sediments in the vicinity of this site are contaminated with many of the same COCs found at elevated concentrations on site. Sediment sampling performed by Tierra and submitted to Region 2 as long ago as 1993 confirmed elevated concentrations of VOCs, metals, and other hazardous substances associated with the site. As identified by Region 2, this site poses a threat for continued discharge to the Passaic River pending its final remediation; it therefore poses a significant threat to recontamination of FFS Study Area remediated sediments.

As these examples illustrate, the ongoing discharge of COCs has only recently been assessed for these sites, which were identified as sources of discharge to the Passaic River many years ago. Numerous other sites exist along the waterfront areas of the FFS Study Area that have not been fully characterized and remediated. Evidence suggests that these other upland sites may likewise be ongoing sources of contamination to the LPRSA and pose a risk of recontaminating FFS Study Area remediated sediments. Some examples include:

- The former Clark Thread Co. Sites, Newark and Kearny, occupy properties on the east and west shoreline of the FFS Study Area at RM 5.8-6.1, having operated from the late 1800s to the mid 1900s, and FFS Study Area sediments in the vicinity of these sites are contaminated with PCBs, PAHs, and lead (Figs. 2-A, 2-I, and 2-L).

- The former W.A.S. Terminals / MacArthur Petroleum & Solvent Co. Site, Newark, located on the west shoreline of the FFS Study Area at RM 6.3, historically operated as a bulk petroleum and solvent storage, repackaging, and distribution facility. Companies operating here have a long history of compliance issues and violations, including the distribution of waste oil containing PCBs. Sediments in the vicinity of the site are contaminated with PCBs, PAHs, solvents, and various metals (Figs. 2-A, and 2-I).

- The former Commercial Solvents Site, Newark, located on the west shoreline of the FFS Study Area at RM 2.6, historically operated as a manufacturer of industrial organic chemicals, including solvents, pesticides, and plasticizers. In 1987, Region 2 conducted a removal action and site assessment following the abandonment of the site, identifying site contamination with various metals and other hazardous substances in very limited soil sampling. More follow-up was required at the time and the extent to which full characterization and remediation of the site was considered is not known. The site appears presently abandoned and uncontrolled. Based on substances identified during the Region 2 removal action and the potential for widespread site contamination, this site poses a significant risk for ongoing discharges to the FFS Study Area of the LPRSA that would recontaminate any remediated sediments.

As shown by these examples, the potential for ongoing discharges of COCs and hazardous substances to the LPRSA and FFS Study Area is high. These and other upland sources of contaminants within the LPRSA discharge on an ongoing basis to the FFS Study Area. Full characterization and remediation of these discharges should be conducted prior to remediating sediments in the FFS Study Area.

3. Given the high likelihood that the very costly remedy will be completely negated by the on-going contaminant sources such as those described above, the proposed remedial action should not be implemented.

As indicated in General Comment 2, there is strong evidence that numerous (and significant) external sources continue to affect the LPRSA, and in particular, the FFS Study Area. These continued sources serve to not only question the legacy sediment theory as presented in the RI Report, but more importantly, would contaminate the relatively clean surface of any newly constructed engineered caps/backfill. While concentrations of the recontaminated surface are difficult to predict (even with a model), it is evident that the resident biota will again be exposed to surface-based contaminants.

Region 2 itself considers numerous COCs that emanate from above Dundee Dam as being significant in comparison to the *existing* surface sediment conditions in the LPRSA. This ongoing source of COCs – the Upper Passaic River – will alone re-contaminate the remediated area.

This concept reinforces Principle #1 of USEPA's 11 Guiding Principles, which recommend early control of sources before any active remediation is undertaken (USEPA, 2002). Without this first step, significant time and money will be wasted. Therefore, the current RI/FS should be completed, during which a more thorough evaluation of sources should be conducted. All of this in combination with currently on-going hot-spot remediation will lead to a much better final outcome than the one contemplated in the FFS.

Specific Comments

1. **The overall RI Scope should have included an element to identify and quantify all external source loadings to the FFS Study Area (Section 1.1, RI Report).** According to Section 1.1, the scope of the RI for the lower 8.3-mile FFS includes the collection of data needed to:

    - Characterize the nature and extent of contamination.
    - Characterize the mechanisms governing long-term fate and transport of site contaminants.
    - Assess the human health and ecological risks posed by contamination.
    - Support the development and evaluation of remedial alternatives in the FFS.

    As seen throughout the RI Report, identifying sources is a fundamental concept to the overall conclusion that "legacy" sediments are recontaminating the surface and therefore should be the focal point of any active remediation. The absence of a statement recognizing this impact calls into question the effort put forth in assessing external sources as a whole, which potentially undermines the entire legacy sediment theory, and the efficiency of the proposed remedial action.

2. **Region 2 fails to identify known contaminated sites in the LPR and should have included such sites in its source analysis (Section 1.2.1, pages 1-3 of RI Report).** On page 1-3, Region 2 states that:
    "The Upper Passaic River watershed is 805 square miles (defined at the dam for the purpose of the RI and FFS) and includes approximately 1,200 Known Contaminated Sites, 3 Chromate Waste Sites, 15 NPL Sites and 200 Toxic Release Inventory Facilities as defined by Region 2 and NJDEP." As part of this, Region 2 claims asserts that very few discharge directly to the Passaic River, and suggests that these remaining sites would not play a significant role in re-contaminating the system.
    This assumption is flawed, as is discussed in detail in General Comment 2. Whether or not connected directly to the river, all of these sites could potentially impact the system as a whole. Either way, Region 2's acknowledgement of the multitude of problematic sites should at least call for a thorough understanding of their potential relevance.

    Second, it is unclear why similar information was not provided for the LPR. The same holds true for the entire watershed of the NY/NJ Harbor Estuary, considering that the associated water bodies are so closely linked (as indicated by Region 2). In either case, the record should be corrected, at a minimum. More to the point, however, these "other" sources not identified by Region 2 should be included in the overall source analysis; otherwise, the remedy selection, and the overall process to get there, is flawed.

3. **The ratio of 2,3,7,8–TCDD to Total TCDD is unfounded, and should not be used as a fingerprinting tool (Section 3.2.1.2, DER 3). -** The FFS calls upon a study by Chaky (2003) showing the purported usefulness of the 2,3,7,8-TCDD/Total TCDD ratio in tracing the impact of Passaic River dioxins throughout metropolitan New York Harbor. For the reasons discussed below, Region 2's reliance upon Chaky's work introduces fatal

uncertainty into the hypotheses and findings based thereon. More specifically, this line of reasoning should not be used in a manner that supports Region 2's legacy sediment theory, which in turn attempts to justify the massive remedy proposed in the FFS.

Flaws in Chaky's work:

Chaky's theory is that the LPR is the primary source of 2,3,7,8-TCDD in sediments as far away as Hastings, New York (more than 30 miles from Newark Bay). That argument was based on use of the 2,3,7,8-TCDD/Total TCDD ratio, which in turn is based on a deeply flawed assumption. Chaky argued that a high ratio of 2,3,7,8-TCDD to Total TCDD ("TCDD ratio") in the sediments of upper Newark Bay and the Passaic River is diagnostic of 2,4,5-T production. Chaky argued that this ratio was also particularly useful due to similar physical properties of both 2,3,7,8-TCDD and Total TCDD. That is, the chemical properties of both analytes used in a ratio are similar; thus, the ratio should be minimally affected by alteration processes. In further support of this argument, Chaky pointed to a 2,3,7,8-TCDD-Total TCDD ratio of 0.71 in sediments of upper Newark Bay, as compared to much lower ratios for three other background or presumed source areas identified as: (1) Central Park (Manhattan, NY) Sediments (0.06, primarily used as background location representative of urban atmospheric sources), (2) Newtown Creek (Queens, NY) Sediments (0.04,– primarily a sewage source), and (3) upstream Hudson River sediments (<0.05).

Considering the high ratios in Newark Bay and low ratios in Central Park, Newtown Creek, and upstream Hudson River, Chaky then made a leap in logic, concluding that any sample in Newark Bay, New York Harbor, or the Hudson River with a TCDD ratio >0.06 constitutes evidence of an LPR dioxin source. His rationale for this argument was based upon two unstated assumptions:

a. Within his data set (67 samples), four areas represent pure source "end-members": (1) upstream Hudson River (industrial source not identified), (2) Newtown Creek (primary source: sewage), (3) Central Park (primary source: atmospheric), and (4) the "Western Harbor" or Passaic River source (primary source: 2,4,5-T production).

b. Chaky assumes that there are no other PCDD/ PCDF sources in the region, or at least that there are no other sources with a TCDD ratio >0.06.

The data presented by Chaky are insufficient to support these assumptions. One need look no further than Chaky's thesis to find two examples that refute his key assumptions. Chaky's study included Core JB13 from Jamaica Bay, NY. Jamaica Bay, a tidal marsh near JFK Airport, connects to the Atlantic Ocean through an inlet. There is no direct link to New York Harbor or Newark Bay, except via the open ocean. Dioxin data were collected from only two samples in Core JB13. The deeper sample (32 cm to 36 cm) from this core yielded a TCDD ratio of 0.28, which is much higher than 0.06. In Jamaica Bay, Chaky discounted the possibility of an LPR source because of geographic constraints, and instead, considered the possibility that Silvex (2,4,5-TP) might have been used there as an herbicide. He did not offer an hypothesis on what circumstances might preclude the use of such a product elsewhere in the region.

Another exception to Chaky's assumption is seen in one sample collected far upstream of Hastings on the Hudson River. In his inter-laboratory data comparison, Chaky included PCDD/PCDF analyses from two different labs: Axys and Severn-Trent. Chaky evaluated potential inter-laboratory bias by looking at PCDD/PCDF data in blind duplicates run by both labs. One of the blind duplicates was from the upper Hudson River, just downstream of

Federal Dam. The Axys duplicate yielded a TCDD ratio of 0.14. The Severn-Trent blind duplicate yielded a TCDD ratio of 0.28. Chaky reported that this sample had the poorest agreement among the seven blind duplicates analyzed, but he omitted the fact that both analyses yielded ratios greater than twice that of the Central Park and Newtown Creek values. Unlike the Jamaica Bay data, Chaky declined to speculate on the source of TCDD in this sample.

In summary, the data presented by Chaky are not only insufficient to support his key assumptions, but even go so far as to contradict his assumptions. Certainly, the TCDD ratio has not yet undergone sufficient scrutiny to be used as a diagnostic fingerprinting tool, and therefore should have no place in attempting to justify the massive remedy proposed in the FFS.

References

CFM Incorporated (1986). Investigation of Organic Priority Pollutants in the Influent to the Passaic Valley Sewerage Commissioners Treatment Plant. May.

Chaky (2003). Polychlorinated Biphenyls, Polychlorinated Dibenzo-p-Dioxins and Furans in the New York Metropolitan Area; Interpreting Atmospheric Deposition and Sediment Chronologies." Ph.D. Thesis, Rensselaer Polytechnic Institute, Troy, NY. August.

Clinton Bogert Associates (1979). City of Newark, NJ Feasibility Study – Pollution Abatement Program. January.

Dyer , K. R. (1988). Fine sediment particle transport in estuaries. In: Physical Processes in Estuaries, Donkers, J. and W. van Leussen (eds.), Springer-Verlag, New York, 295-310.

Garvey et al. (2011) Dioxin in the Passaic River (NJ): The Case for Two Dioxin Sources. Battelle Sixth International Conference on the Remediation of Contaminated Sediments. February.

Great Lakes Environmental Center (2008) New York - New Jersey Harbor Estuary Program, New Jersey Toxic Reduction Work Plan (NJTRWP) Study 1-G Project Report.

Iannuzzi et al. (1997) Combined Sewer Overflows (CSOs) as Sources of Sediment Contamination in the Lower Passaic River, New Jersey. 1. Priority Pollutants and Inorganic Chemicals. Chemosphere, Vo. 34, No. 2.

Killam Associates, Inc. (1976) Report upon Overflow Analysis to Passaic Valley Sewerage Commissioners – Passaic River Overflows.

Lubetkin (1994). Affidavit of Seymour A. Lubetkin, former Chief Engineer of the Passaic Valley Sewerage Commissioners. January 6.

New Jersey Department of Environmental Protection (NJDEP) (1980) Administrative Order entered by New Jersey Department of Environmental Protection concerning In The Matter of the Passaic Valley Sewerage Commissioners.

NJDEP (2005). NJPDES Permits for Combined Sewer Overflows Issued to: Passaic Valley Sewerage Commissioners, City of Newark, Town of Harrison, Town of Kearny, Borough of East Newark.

Passaic Valley Sewerage Commissioners (1951-2007). Various public records of the Passaic Valley Sewerage Commissioners regarding bypassing and throw-out from CSOs.

Tierra Solutions (2012). Comments on FFS Summary provided by USEPA Region 2 (October 11, 2012). November 19.

Tierra Solutions (2013). Newark Bay Study Area Remedial Investigation, Conceptual Site Model. July.

Topousis, T. (1995). "Reversing a Trend; HMDC Seeking to Reopen Landfill." Bergen Record. July 20.

USDOJ (1980) Consent Judgment entered in U.S. District Court for District of New Jersey in matter entitled United States of America and State of New Jersey v. Passaic Valley Sewerage Commissioners.

USEPA (2002). Memorandum from Marianne Lamont Horinko; Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites. February 12.

USEPA / Lockheed Martin (2013). Quality Assurance Project Plan, Givaudan: Transport Pathway to Passaic River, Clifton, NJ. November.

USEPA (2014). Remedial Investigation Report for the Focused Feasibility Study of the Lower Eight Miles of the Lower Passaic River. [Note: also includes DER 2 and DER 3]

Dennis P. Farley President & CEO

President & CEO
The Intelligence Group
State of New Jersey Licensed Private Detective #6423
State of New York Licensed Investigator #11000116681

SUMMARY

Mr. Farley has more than 30 years of experience in the environmental field. His areas of expertise include conducting and directing environmental investigations, providing litigation support, and providing consulting services to corporate and government clients on a domestic and international basis. He has extensive experience in the areas of liability investigation, source identification and the investigation of PRPs.

ACADEMIC QUALIFICATIONS

New Jersey Institute of Technology, Newark, New Jersey	Dept. of Civil and Environmental Engineering	M.S.	1988
Moravian College, Bethlehem, PA (in (conjunction with Lehigh University)	Geology/Physics	B.S.	1982

PROFESSIONAL EXPERIENCE

The Intelligence Group, Bedminster, New Jersey, October 1999 to Present, PRESIDENT & CEO

Provides a variety of professional services and strategic guidance to corporate clients including environmental liability investigation, source identification and the investigation of Potentially Responsible Parties (PRPs). Areas of expertise include conducting and directing environmental investigations, and providing litigation support and related consulting services to corporate clients on a domestic and international basis. Manage major projects undertaken by the firm regarding historic environmental liability investigation, analysis and litigation support. Manage projects in the areas of environmental liability investigation and analysis, including historic investigation of former operating facilities, regional sediment sites, landfills and regional groundwater issues. Conduct historic investigations in support of toxic tort litigation, including asbestos, silica and mold-related claims. Direct all business and marketing operations of the firm.

Kroll Associates, New York, New York; Parsippany and Newark, New Jersey, November 1991 to October 1999, MANAGING DIRECTOR

Managing Director of Environmental Services Division of multi-national security and investigations consulting firm. Managed numerous projects in the areas of environmental liability investigation and analysis, including historic investigation of former operating facilities, regional sediment sites, landfills and regional groundwater issues. Conducted numerous historic investigations in support of toxic tort litigation, including asbestos, silica and mold-related claims. Conducted technical investigations for purposes such as allocation assessment, litigation support in cost recovery actions, PRP identification, and other internal corporate matters including compliance and fraud analysis. Conducted environmental due diligence assignments for real estate transactions, and monitoring and assessing waste disposal vendors for corporate clients. Conducted internal investigations regarding fraud, product tampering and related security issues.

Hart / McLaren-Hart Environmental Management Corporation, New York, New York and Liberty Corner, New Jersey, September 1984 to November 1991, SENIOR PROJECT MANAGER and DIRECTOR, FIELD SERVICES DIVISION

Conducted and managed numerous environmental site investigations for purposes of site characterization and remediation at numerous NPL and private party sites. Expertise with remedial investigation of soil, sediment and groundwater contamination at a wide variety of operating facilities, waste disposal and regional sites. Founded and developed internal Field Services Division to provide

onsite mobile laboratory, drilling, sampling and monitoring well installation services. Acquired and maintained State of NJ Drilling and Well Installation license.

NUS Corporation, Edison, New Jersey, October 1982 to September 1984, STAFF GEOLOGIST

Responsible for conducting site assessments and remedial investigations at NPL and Cerclis sites in USEPA Region II. Designed and implemented sampling and site characterization plans, and managed field teams in major NPL site investigations within the region.

PROFESSIONAL AFFILIATIONS

- American Society of Industrial Security

SELECT REPRESENTATIVE PROJECTS

- Project Manager and lead investigator for the Source Identification Program component of a full-scale RI/FS Program Implementation at a bay and tributary complex NPL site in the northeast U.S. Responsibilities include the inventory of historic and present-day sources of organic and inorganic sediment contamination, the identification of evidence regarding discharges from identified sources, and compilation of source sampling plans and strategies. Scope of effort is focused on point sources ranging from industrial operating facilities to large scale storm sewer, sanitary and combined sewer networks and regional treatment facilities.
- Project Manager and lead investigator for PRP Committee charged with the identification and evaluation of PRP liability cases for an urban river complex NPL site in the northeast U.S. Responsibilities include the development of investigation plans and implementation of liability investigations regarding historic and present-day industrial operations. Present evidentiary packages to USEPA regarding PRP liability.
- Project Manager and lead investigator for the initial PRP named at an urban river complex NPL site in the northeast U.S. Responsibilities included the historic reconstruction of 150 years of regional industrial operations, shipping and commerce, the development of local and regional sewerage infrastructure and waste treatment capabilities, and identification of historic and present-day discharge pathways. Developed investigation plans and implemented liability investigations of PRPs; compiled evidentiary packages and presented to USEPA. Resulted in General Notice Letter distributions by USEPA to more than forty PRPs, allowing for formation of PRP steering committee and take-over of remedial and enforcement-related work at the site.
- Project Manager for historic liability analysis and PRP identification regarding third-party manufacturing facility in northeastern U.S. Responsibilities included analysis of regional groundwater contamination sources, and investigation of historic operations conducted at select off-site facilities regarding contribution of observed contamination at site. Identified historic tenant operations, conducted financial viability analysis of select entities, and developed evidence of hazardous substance releases. Developed nexus of U.S. government-contracted operations during WW II timeframe, and investigated and documented operations conducted at the site.
- Project Manager for PRP committee charged with the identification and evaluation of PRP liability cases for a regional groundwater contamination NPL site in the western U.S. Developed inventory of potential sources and investigated specific historic industrial operations for evidence of hazardous substance use and discharge. Developed evidence for use in PRP negotiation and allocation mediation.
- Project Manager for several PRPs identified as waste generators at a local municipal landfill in the northeast U.S. Investigated the local hauling and waste disposal operations that took place at the time of filling, and identified waste generators and haulers that had historically utilized the site.
- Project Manager for PRP charged with the identification and evaluation of PRP liability cases for an urban river complex NPL site in the Midwestern U.S. Responsibilities included analysis of regional sediment contamination sources, and investigation of historic operations conducted at select facilities regarding the discharge of hazardous substances.

Robert Romagnoli, PE

Managing Director
The Intelligence Group
Professional Engineer, NY – NY license #50902
Professional Engineer, NJ – NJ license #24GE04659400

SUMMARY

Mr. Romagnoli has more than 25 years of experience in the environmental consulting industry, 23 of those dedicated to the management of contaminated sediments. During his career, he has developed expertise in the following general areas: technical and strategic support related to aquatic system investigation, remediation and restoration; multi-phase environmental process management evaluations; and wastewater/ground-water treatment system design. Mr. Romagnoli also has provided oversight and project management services for several major construction projects.

ACADEMIC QUALIFICATIONS

Cornell University	General Management	MBA	1990
Bucknell University	Civil Engineering	BS	1986

PROFESSIONAL EXPERIENCE

The Intelligence Group, Syracuse, New York, October 2012 to Present Managing Director

Managing Director in the firm's Environmental Services Practice. Provides a variety of professional services and strategic input on numerous environmental matters. Area of expertise includes managing large-scale and high-profile sediment remediation projects, regulatory negotiations, development of sediment-related strategies and investigations, design, remedy construction oversight, agency interaction, community outreach and litigation support from start to finish.

Arcadis/BBL, Syracuse, New York, July 1990 to October 2012, Sr. Vice President

Served as manager of ARCADIS' in-house Waterfront and Sediment Group, and provided high-level strategic services to clients that faced sediment liabilities. This included such tasks as designing large-scale sediment dredging projects, interacting and negotiating with various federal and state agencies, and directing large project teams that focused on the implementation of remedial investigation studies, risk assessments, hydrodynamic modeling, and feasibility studies. Served as Engineer of Record and Program Manager for the Passaic River Phase I Dredging Project.

Roy F. Weston, West Chester, Pennsylvania, September 1987 to August 1988, Project Engineer

Assisted in developing various work plans, feasibility studies and related health and safety plans. Managed and supported investigative field operations such as well installations and associated Ground Water sample collection programs.

Gray Associates, Flemington, New Jersey, July 1986 to July 1987, Project Engineer

Assisted in the design of bridge overpasses and provided construction oversight services. Coordinated all material supply needs for related field efforts.

TRAINING AND CERTIFICATIONS

- OSHA 40-Hour Training and Supervisory Course
- CPR/First Aid

SELECT REPRESENTATIVE PROJECTS

- Served as Program Manager and Engineer of Record for 40,000 cubic yard (cy) dredging project in lower Passaic River. Sediments had been shown to contain elevated levels of metals, dioxins, PCBs and other organics. This high profile project required constant communication/interface with USEPA and State personnel, along with other stakeholders including the local community advisory group.

- Served as Program Manager for the Remedial Investigation/Feasibility Study (RI/FS) of a 6-mile stretch of the Passaic River. Significant responsibilities included interacting with USEPA and other federal and state agencies; developing strategy for the client; assessing bed stability and sediment resuspension dynamics; overseeing a significant CSO investigation to understand mass loadings into the river system; and developing potential remedial options for the site.
- Acted as Program Manager for large-scale RI/FS in Newark Bay, one of the largest ports in the country. As part of this, Mr. Romagnoli oversaw numerous technical services associated with sampling design, risk assessment, modeling, and remedial option development.
- Served as Program Manager for a sediment site located within the Hackensack River. Provided overall strategic support and sampling design services. Also included management of IDW characterization and disposal program.
- Served as RI/FS Project Manager for a large-scale PCB sediment site. Managed the following aspects of the project: development and in-field testing of a cutting-edge remedial technology (particle broadcasting); development of a performance specification used to implement dredging, dewatering, and disposal of approximately 3,500 cy of PCB-containing river sediment; and implementation of a sediment transport model to understand the deposition/scour areas within the river.
- Managed the RI/FS process associated with a tributary to the Ottawa River. Tributary sediments had been shown to contain high levels of PCBs. Developed plans and specifications to remediate the site via mechanical dredging. Efforts also addressed remediation and restoration of the low-lying wetlands that bordered the site. The resulting sediment remediation project was labeled by the USEPA Region 5 Administrator as one of the “best” completed in the region.
- Provided engineering expertise for sediment dredging/dewatering project within the Lower Duwamish River. Primarily responsible for overseeing design of sheet pile cofferdam required for removal operations.
- Provided engineering services for development of the FS for the Lower Fox River. Managed the development of multiple alternatives for this 40-mile stretch of river, focusing primarily on sediments. In addition, managed the review/critique of Wisconsin Department of Natural Resource’s voluminous and highly technical RI/FS report.

PRESENTATIONS

- **Romagnoli, R.**, P. Spadaro, P. Bluestein (2012). Lower Passaic River Study Area Phase I Removal Action – 2012. Presented at *Sediment Management Work Group Meeting*, Newark, NJ.
- **Romagnoli, R.**, E. Peck, P. Spadaro, P. Bluestein (2009). Removal Action through Potentially Responsible Party Initiative in the Lower Passaic River, New Jersey. Presented at *Battelle’s Fifth International Conference on Remediation of Contaminated Sediments*, Jacksonville, FL.
- **Romagnoli, R.**, E. Peck, P. Spadaro, P. Bluestein (2008). Removal Action through Potentially Responsible Party Initiative in the Lower Passaic River, New Jersey. Presented at *EKOS Conference*, Brazil.
- **Romagnoli, R., P.E.**, J. Bryz-Gornia, J. Schiller (2007). Interpreting the Process and Results of the Lower Passaic River Dredging Pilot Study. Presented at *Western Dredging Association’s Eighteenth World Dredging Congress*, Lake Buena Vista, FL.
- **Romagnoli, R., P.E.**, C. Barnes, M. Henderson, and K. Powell (2007). Newark Bay Remedial Investigation: Complexity of a Multi-Chemical, Multi-Source Site. Presented at *Battelle’s Fourth International Conference on Remediation of Contaminated Sediments*, Savannah, GA.
- **Romagnoli, R., P.E.** (2006). Remedial Investigation of the Newark Bay Estuary – Conceptual Model of Multichemical Investigations. Presented at the *International Society of Environmental Forensics workshop “Environmental Forensics: Urban Ports and Harbors – Sediment Assessments in Complex Systems”*, Baltimore, MD.

Confined Aquatic Disposal

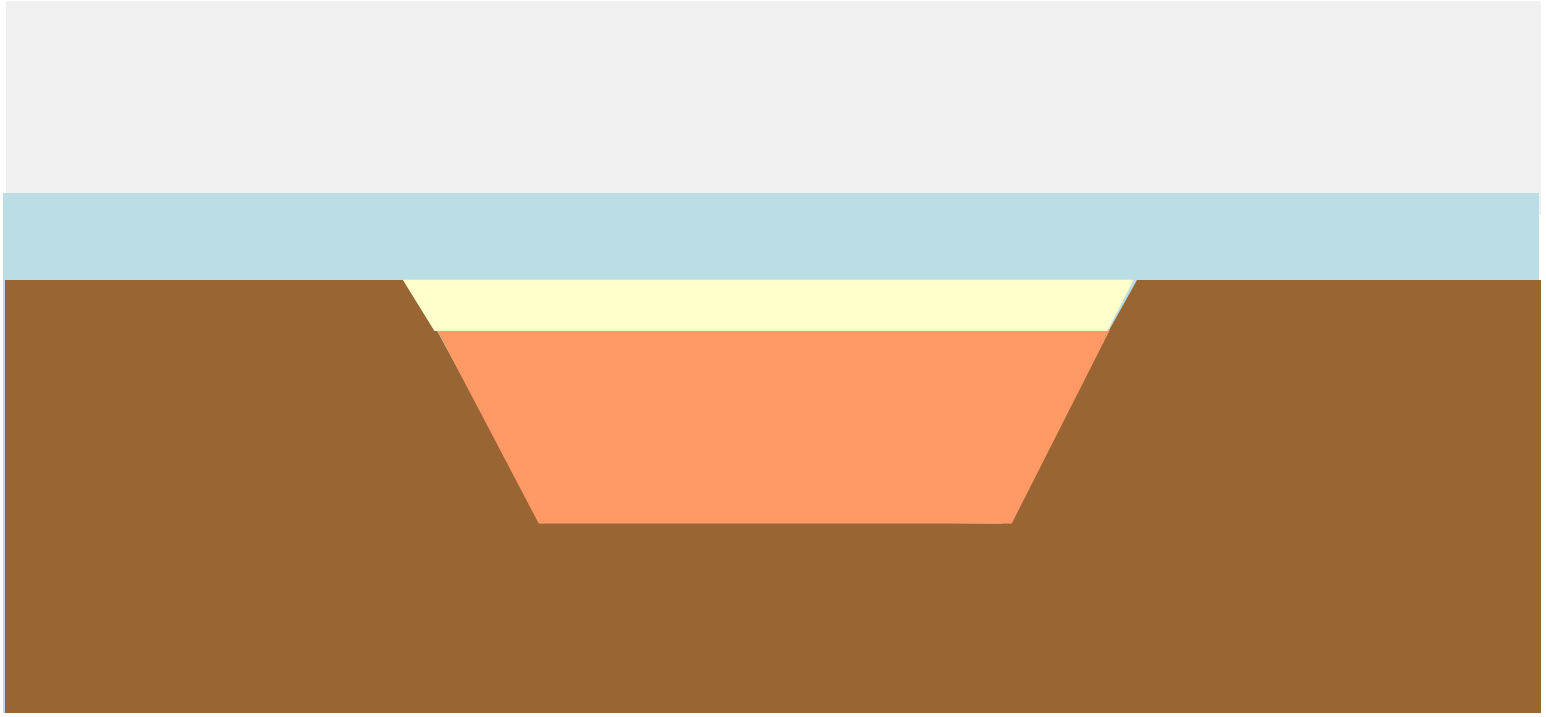
- What is the CAD technology?
- Have CAD sites been used before?
- Why do CAD sites work?
- Why is CAD a more effective technology?
- Are CAD sites successful?

TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

July 2014

What is the technology?

Confined aquatic placement of dredged material inside a confining depression or excavation in a body of water followed by engineered capping

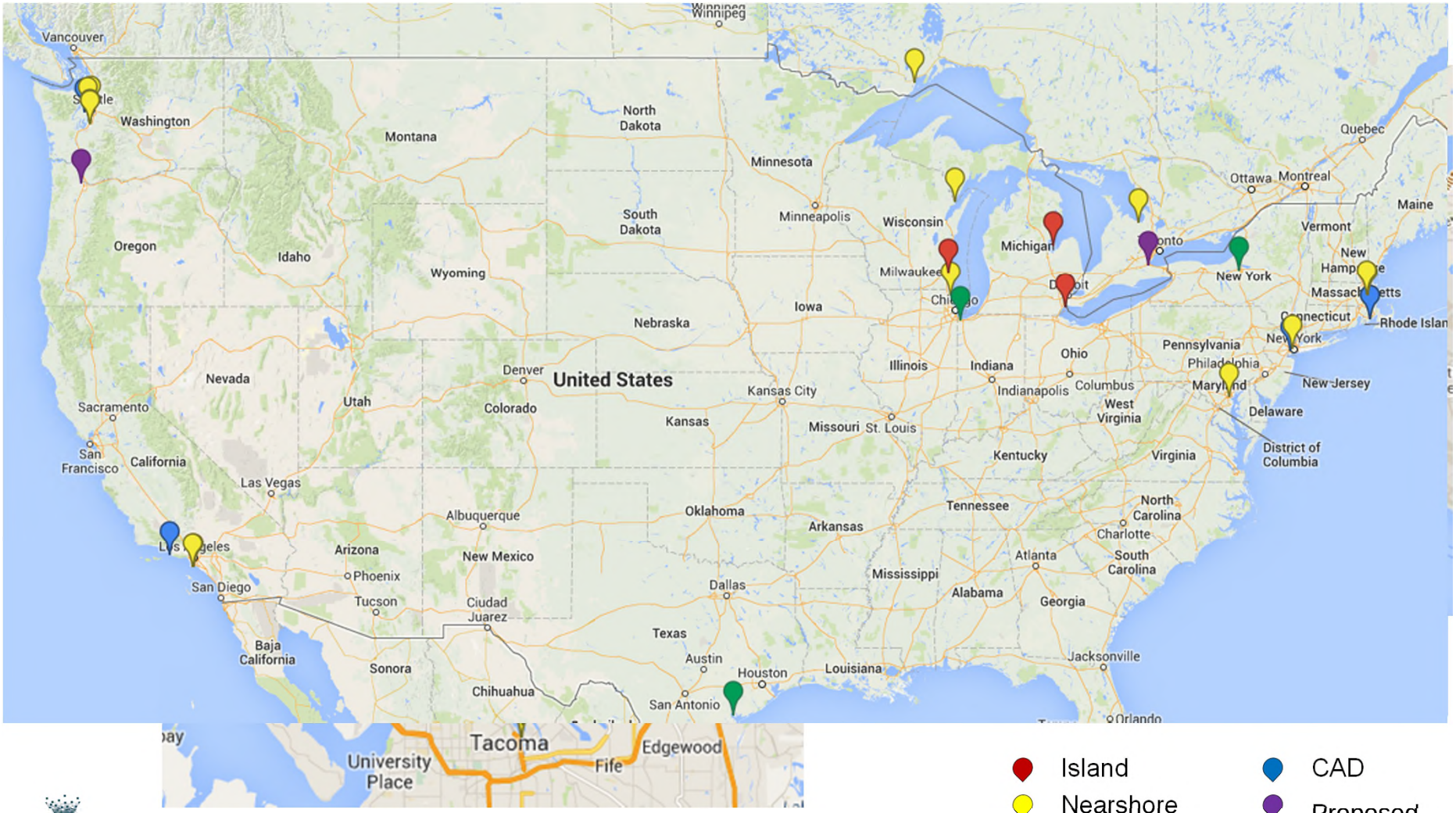


TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Have CAD Sites Been Used Before?

- The CAD technology, and the related nearshore CDF technology, have been used extensively and successfully worldwide for over 30 years
- Many successful Superfund examples
- Published compilations (Palermo and Bosworth, 2008) list 29 CAD/CDF sites
- Several sites have been created since that publication
- Total volume successfully contained is likely in the millions of cubic yards
- Successfully used in Newark Bay

Locations of Existing and Proposed Confined Disposal Facilities



Island
Nearshore
Upland
CAD
Proposed

TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Key Applications of the Technology

Site	Location	Importance
Commencement Bay	Washington	Several nearshore CDFs successfully containing millions of cubic yards of Superfund sediments. Many years of monitoring clearly show there are no problems.
New Bedford Harbor	Massachusetts	Multiple CAD sites for Superfund sediments. Many design features for CAD sites in a Superfund setting defined
Port Hueneme	California	CAD site is possible even in relatively permeable sediments
Boston Harbor	Massachusetts	Multiple CAD sites in navigational area. Many design and construction issues figured out. Consolidation and capping behavior well studied
Malmøykalven	Norway	CAD site in deep (over 200 feet) water. Complex placement issues addressed
Puget Sound Naval Shipyard	Washington	Demonstrated the importance of careful placement.
Newark Bay	New Jersey	Successful on-site CAD site.

TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Why do CAD Sites Work?

- Contaminants remain bound to mineral and organic particulates in conditions that are wet and depleted of dissolved oxygen
- Under such conditions, contaminants are controlled/isolated when the particulates are controlled/isolated
- Passaic River conditions prove the above

Potential Losses During and After Placement

- Potential losses during placement are reduced through good site design, control of disposal events, and possible use of barriers
- Potential losses after placement are reduced through good site selection, site design, and engineered cap design
- These potential losses are less consequential than losses occurring with dewatering and off-site disposal
- Performance standards such as suspended solids and dissolved oxygen have been maintained

Why is CAD a Better Technology?

- A proven reliable technology
- Greater control for EPA and others…both during and after implementation
- Excellent sites available
- Relatively simple and faster to design, build, and operate
- On-land transport of contaminated sediments is avoided and overall material handling is reduced
- Lower exposure to workers and the community
- Fewer quality of life (noise, light, odor) impacts
- Smaller carbon footprint – more favorable scoring when considering overall net environmental benefit analysis.
- Significantly safer for the community and site workers than dewatering and off-site disposal

TheIntelligenceGroup
RESEARCH ▾ INVESTIGATIONS ▾ FORENSICS

Are CAD Sites Successful?

- Of all the CAD and CDF sites in use today, none have failed
- Robust and stable physical isolation
  - Local geology and hydrogeology favorable for CAD site – local sediment and bedrock easily excavated yet relatively impermeable
  - Reliable and secure chemical isolation
  - CAD Technology not sensitive to contaminant concentration in sediment
  - Short-term and long-term potential water quality impacts can be controlled

Summary

- Extensively and successfully used
- Easy to build and operate
- Safer and more reliable
- On-site solution
- Net Environmental impact to community is much less than other alternatives

Philip A. Spadaro, LG

Managing Director / Principal Scientist
The Intelligence Group
Licensed Geologist, WA; Licensed Geologist, OR

SUMMARY

Mr. Spadaro is a leading international expert in sediment cleanup, environmental effects of dredging, and waterfront redevelopment. Technically based in environmental chemistry with strong proficiency in hydrogeology, geology, regulatory affairs, and remediation technology, Mr. Spadaro has 30 years of experience applying his expertise and management skills to projects where sediment quality is a prominent issue. As a senior technical advisor, Mr. Spadaro has extensive expertise in the siting, design, permitting, and construction of confined disposal facilities and in the fate and transport of contaminants in estuarine, riverine, and marine aquatic environments. He is an expert advisor to clients for international sediment management and remediation projects in Europe, the Mid-East and Asia. In addition, Mr. Spadaro provides technical support for litigation, allocation, construction claims, cost-recovery actions and other matters related to sediment remediation.

Through years of work focused entirely on the remediation of contaminated sediment and land on the urban and industrial waterfront, Mr. Spadaro has developed expertise in application of the available technologies including dredging, capping, monitored natural attenuation, and source control. The successful execution of these highly complex sediment remediation projects demands meticulous planning, strong scientifically sound technical approaches, and credibility with regulatory authorities. Mr. Spadaro's international reputation for designing and implementing inventive, appropriate, and cost effective waterfront solutions is anchored in these qualities and in his commitment to seek out and respect the unique needs of every project, client, and cultural setting.

EDUCATION

University of Chicago	Geochemistry	M.Sc.	1983
Cook College at Rutgers University	Chemistry	B.Sc.	1981

EXPERTISE

- Contaminated Sediment Investigation and Remediation
- Environmental Effects of Dredging
- Confined Disposal Facility Siting and Design
- Source Identification and Control
- Technical Support for Litigation, Allocation, Construction Claims
- Design Coordination and Management

PROFESSIONAL EXPERIENCE

- **Technical Consultation and Allocation/Litigation Support, Portland Harbor Superfund Site.** Oregon Department of Justice, Portland Harbor Superfund Site, Portland, Oregon—2009-Ongoing.
- **Technical Consultation and Litigation Support, Yosemite Slough Time-Critical Removal Action.** Yosemite Slough PRP Group, San Francisco, California—2008-Ongoing.
- **Technical Consultation and Allocation/Litigation Support, Lower Duwamish Waterway Superfund Site.** Washington State Attorney General and Department of Transportation, Seattle, Washington—2011-Ongoing.
- **Removal Action Studies, Design, and Construction Management, Passaic River Superfund Site.** Confidential Client, Passaic River, Newark, New Jersey—2008-2012.
- **Xiawangang Canal Remedial Action Conceptual Design.** OTEK Pty. Ltd. Of Australia and the Zhuzhou Municipal Economic Authority. Zhuzhou City, Hunan Province, China—2011-2012.
- **Department of Sediment Investigation and Remediation Guidance Documents.** Energy Institute, United Kingdom—2011.
- **Design of Engineered Containment Facility for Contaminated Sediments.** Hamilton Port Authority, Hamilton, Ontario—2004-2011.

- **Development of Conceptual Dredged Material Management Plan.** Louisiana Office of Coastal Protection and Research, Baton Rouge, Louisiana—2011.
- **Peer Review of Confined Disposal Facility Design and Management.** US Army Corps of Engineers, New Orleans, Louisiana—2009.
- **Evaluation of CDF Feasibility**. Retia (Arkema), Portland, Oregon—2009-2010.
- **Sediment Investigation and Remediation Strategic Consulting, Rada di Augusta, Priolo Site.** ExxonMobil Corporation, Priolo, Sicily, Italy 2005-2009.
- **EE/CA for Non-Time-Critical Removal Action and Nearshore CDF.** Port of Portland, Portland, Oregon—2003-2005.
- **North Channel Confined Disposal Facility.** Port Authority of Venice, Venice, Italy—2001-2002.
- **Design of Hylebos Waterway, Phase I Dredging, Slip 1 CDF Disposal.** Port of Tacoma, Tacoma, Washington—1999-2002.
- **Hylebos Waterway, Area 5106 Dredging and Disposal Project.** Port of Tacoma, Tacoma, Washington—1999-2002.
- **Ross Island CAD Cells Assessment.** Port of Portland, Portland, Oregon—1998-2000.
- **Thea Foss and Wheeler-Osgood Waterways Pre-Remedial Design.** City of Tacoma, Tacoma, Washington—1994-2003.
- **Brooklyn Navy Yard Confined Disposal Area Feasibility Study.** Brooklyn Navy Yard Development Corporation, Brooklyn, New York—1998-2000.
- **Claremont Channel Deepening.** Hugo Neu Schnitzer East (HNSE), Jersey City, New Jersey—1997-2002.
- **Nearshore Confined Disposal Facility.** River Terminal Development Corporation, New Jersey—1996-1999.
- **Remedial Investigation/Feasibility Study (RI/FS) of Shipyard Sediment Operable Unit.** Lockheed Martin Corporation, Seattle, Washington—1994-2000.
- **Sediment Assessment of Blair Waterway, Slip 2 Nearshore Fill.** Port of Tacoma, Tacoma, Washington—1987-1990.

PROFESSIONAL AFFILIATIONS

- American Chemical Society
- Central Dredging Association
- Western Dredging Association
- Society of Environmental Toxicology and Chemistry

PUBLICATIONS AND PRESENTATIONS

Available on request.

Application of a Net Environmental Benefit Analysis Framework to USEPA Region 2's Focused Feasibility Study for the Lower Eight Miles of the Passaic River

August 2014

Prepared for:

Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

Prepared by:

Joseph Nicolette, M.S., C.F.S.
Rick Wenning, M.E.M.
Mark Rockel, Ph.D.
Justine Harrison, M.S., P.E.
Ryan Slakman, M.P.H.

ENVIRON International Corporation

ENVIRON

Table of Contents

1 Background - 1 -
1.1 Purpose - 2 -

2 USEPA Policy, Guidance, and Direction for the Remedial Decision Process - 4 -

3 Failings of the FFS in the Remedial Decision Process - 8 -
3.1 Absence of Preferences for Green Remediation - 12 -
3.2 Absence of Preferences for Sustainable Solutions - 13 -
3.3 Absence of an Evaluation of Environmental Footprints - 15 -
3.4 Inadequate Analysis of Environmental and Social Risks - 16 -
3.5 Absence of Net Environmental, Economic and Social Benefit and Cost Considerations - 18 -

4 NEBA and its Application to the FFS - 27 -
4.1 What is NEBA? - 27 -
4.2 NEBA Support in Decision-Making Mandated by USEPA - 29 -
4.3 Application of NEBA by USEPA and Federal Resource Agencies - 29 -
4.4 Using NEBA to Improve Remedial Evaluation in the FFS - 31 -

5 Preliminary Carbon Footprinting Analysis of Remedial Alternatives in the FFS - 32 -
5.1 USEPA Mandate to Minimize Greenhouse Gas Emissions - 32 -
5.2 Calculation of Carbon Footprints - 33 -
5.3 Calculation of Fine Particulate Matter ($PM_{2.5}$) - 40 -

6 Findings and Conclusions - 46 -

7 Bibliography - 48 -

Tables

Attachment A: Checklist for Regulatory Impact Analysis

Appendices
Appendix A: Policy, Guidance and Direction Documents
Appendix B: Case Studies and NEBA Framework Examples
Appendix C: Carol Browner Memorandum (USEPA, 1995)
Appendix D: Carbon Footprinting Calculation Tables

List of Tables

Table 1. Remediation Planning Activities that Region 2 Failed or Inadequately Considered to Understand the Environmental Footprint of the Various Remedy Alternatives
Table 2. Excerpts from the LPRSA Eight-Mile FFS that Address the Evaluation of Short-Term Effectiveness and Potential Impacts

Table 3. Estimated Volume of Clean Fill Material Needed for Restoration Activities (in Text)
Table 4. Examples of Potential Short-Term and Long-Term Environmental Risks and Service Benefits for the Various Remedial Options that Should Be Considered by Region 2 in the FFS
Table 5. NEBA Framework Table Considerations
Table 6. Greenhouse Gas Emission Sources
Table 7. Comparison of CO_2e Emissions by Remediation Alternative and DMM Scenario
Table 8. Comparison of Diesel Particulate Matter and $PM_{2.5}$ Emissions by Remediation Alternative and DMM Scenario

List of Figures

Figure 1. Remedial Alternative Considerations that Region 2 Failed to Quantify
Figure 2. Impacts Associated with DMM Scenario A that Region 2 Failed to Quantify
Figure 3. Impacts Associated with DMM Scenario B that Region 2 Failed to Quantify
Figure 4. Impacts Associated with DMM Scenario C that Region 2 Failed to Quantify
Figure 5. Core Elements of a Cleanup Project
Figure 6. Elements of Sustainable Sediment Remediation Strategies that Should be Considered in Remedial Alternative Development
Figure 7. Two Human Health Risk Categories of Remedial Actions
Figure 8. Human Health Risks Associated with Sediment Concentrations and Implementation of Remedial Actions
Figure 9. What if Remedial Implementation Risks Exceeded Risks Associated with Sediment Concentrations?
Figure 10. Region 2 Remedy Update Based upon NEBA Demonstration
Figure 11. Potential Sources of Scope 1, 2, and 3 GHG Emissions
Figure 12. Predicted Total CO_2e Emissions for Each of Region 2's Remedial Alternatives Described in the FFS
Figure 13. Predicted Average Annual Total CO_2e Emissions for Each of Region 2's Remedial Alternatives Described in the FFS
Figure 14. Predicted Total CO_2e Emissions for Each of Region 2's DMM Scenarios Described in the FFS
Figure 15. Predicted Average Annual CO_2e Emissions for Each of Region 2's DMM Scenarios Described in the FFS
Figure 16. Ranking of CO_2e Emissions for Each of Region 2's Remedial Alternatives and DMM Scenarios Described in the FFS
Figure 17. Predicted Total $PM_{2.5}$ Emissions for Each of Region 2's Remedial Alternatives Described in the FFS
Figure 18. Predicted Annual $PM_{2.5}$ Emissions for Each of Region 2's Remedial Alternatives Described in the FFS
Figure 19. Predicted Total $PM_{2.5}$ Emissions for Each of Region 2's DMM Scenarios
Figure 20. Predicted Annual $PM_{2.5}$ Emissions for Each of Region 2's DMM Scenarios
Figure 21. Ranking of $PM_{2.5}$ Emissions by Remedial Alternative and DMM Scenario

1 Background

In April 2014, Region 2 of the United States Environmental Protection Agency (Region 2) released for public comment the Focused Feasibility Study (FFS) and Proposed Plan for the Lower Eight-Miles (FFS Study Area) of the Lower Passaic River Study Area (LPRSA)[1]. The FFS included evaluation of four remedial alternatives and three dredged material management (DMM) options that could be implemented to address potential risks associated with sediment contamination in the FFS Study Area[2]. The four remedial alternatives evaluated in the FFS are as follows:

- *Alternative 1, No Action,* is a required alternative in the Superfund program and is typically considered as a baseline for comparison with other remedial alternatives.
- *Alternative 2, Deep Dredging with Backfill,* involves bank-to-bank dredging of approximately 9.7 million cubic yards of contaminated fine-grained sediment in the lower eight miles followed by placement of a two-foot thick layer of clean backfill material in the bottom of the river to replace the removed material.
- *Alternative 3, Capping with Dredging for Flooding and Navigation,* involves placement of a two foot thick bank-to-bank engineered cap (or backfill) on the bottom of the river along the lower eight miles. The cap would be placed after dredging approximately 4.3 million cubic yards of contaminated fine-grained sediment to avoid additional flooding and accommodate the future use of a portion of the navigation channel.
- *Alternative 4, Focused Capping with Dredging for Flooding,* focuses on areas that have the potential to release the most contaminants into the water in the FFS Study Area. A two-foot thick engineered cap would be placed over these areas after dredging approximately 1 million cubic yards of contaminated fine-grained sediment to avoid additional flooding.

The three DMM options refer to the method for disposing of contaminated sediment dredged from the river. The three DMM scenarios are as follows:

- *Scenario A, Confined Aquatic Disposal (CAD),* involves construction of a confined aquatic disposal site in the bottom of Newark Bay, and placement of the dredged sediment beneath an engineered cap to isolate the dredged sediment from the bay.
- *Scenario B, Offsite Disposal,* involves barging the dredged sediment to a facility located on the shores of the Passaic River or Newark Bay to be dewatered, loaded onto trains and sent to incinerators and landfills located in the U.S. or Canada.
- *Scenario C, Local Decontamination and Beneficial Use,* also involves barging of the dredged sediment to a facility on the shores of the Passaic River or Newark Bay. The material would be treated using technologies that separate sediment particles from the contaminants, and the smaller volume of contaminants disposed in landfills located in the U.S. or Canada and clean sediment used for environmental projects.

[1] http://www.epa.gov/region2/passaicriver/pdf/prap_overview_fact_sheet_english_june_2014.pdf
[2] http://www.epa.gov/region2/passaicriver/pdf/cleanup_options_overview_fact_sheet_english_may_2014.pdf

Region 2's preferred alternative is "Capping with Dredging for Flooding & Navigation" with "Off-Site Disposal of Dredged Materials", described in the FFS and Proposed Plan as "Alternative 3 with DMM Scenario B". This Plan is the culmination of more than seven years of study conducted by several contractors to Region 2. Region 2 concluded that despite fish and shellfish advisories warning against eating local fish and shellfish, such advisories for the LPRSA have been ignored and fishing may be occurring for cultural or subsistence reasons. Region 2's cleanup Proposed Plans would address this and other concerns by removing contaminants from the river, thereby reducing possible health hazards for people eating fish and shellfish, protecting wildlife, and reducing the possibility for migration of contaminated sediment from the FFS Study Area to upstream portions of the river or to Newark Bay[3].

Region 2 estimates that its preferred remedial alternative would cost $1.7B, but the actual costs are projected to be higher because of the numerous technical hurdles and uncertainties associated with scope, schedule, and day-to-day activities typical in very large, complex projects (see e.g., Fox and Miller 2006; Capka 2004). Large, complex projects involving remediation and restoration of urban rivers face similar engineering, environmental, project management and social challenges, which have been demonstrated repeatedly as the reasons for increasing cleanup costs well above initial estimates (see e.g., Tracy 2014; Bridges and Gustavson 2014; Lee et al. 2014; Claudio 2001).

1.1 Purpose

These comments were prepared by ENVIRON International Corporation (ENVIRON) on behalf of Tierra Solutions, Inc. to (1) provide a review of the approach used by USEPA to evaluate the remedial alternatives as presented in the FSS, (2) identify those technical deficiencies apparent in the approach, and (3) propose an approach to help Region 2 improve the evaluation and selection of a preferred sediment remedy for the FFS Study Area. Our comments are provided in the following sections:

Section 2, *USEPA Policy, Guidance, and Direction[4] for the Remedial Decision Process,* provides an overview of USEPA policy, guidance, and direction, which obliges that the environmental impacts associated with each remedial alternative be carefully considered as part of the decision-making process for selection of a preferred remedy. Region 2 falls well short of meeting its technical guidance and policy obligations for providing a detailed and transparent assessment of the environmental, social and economic impacts associated with each remedial alternative and dredged material management option specified in the FFS.

Section 3, *Failings of the FFS in the Remedial Decision Process,* describes the failings of the remedial decision-making process conveyed in the FFS. USEPA guidance, together with White House executive orders and other federal policies, dictate that the preferred remedy should be sustainable, minimize opportunities to generate short- and long- term environmental harm arising from the remediation work, demonstrate a net benefit to the environment and affected

[3] http://www.epa.gov/region2/passaicriver/pdf/cleanup_options_overview_fact_sheet_english_may_2014.pdf
[4] Policy, Guidance, and Direction includes formal policy statements, formal guidance documents, and informal but documented references as to the direction of the USEPA in promoting environmental sustainability, net benefits, and/or an understanding of the environmental footprint of remedial actions.

communities, and achieve an outcome that is protective of human health and the environment. The LPRSA FFS offers few assurances that these considerations were fully vetted.

Section 4, *NEBA Framework and Application to the FFS,* describes how the remedial decision-making process might be improved in the FFS by applying a net environmental benefits analysis (NEBA) approach. A NEBA approach provides a framework for identifying the environmental and social requirements important to stakeholders and systematically identifies the desirable technical aspects of a remedial strategy (e.g., dredging controls, air emissions, solids and water treatment and disposal) that must satisfy the essential environmental, economic and social requirements. Region 2's decision regarding the preferred remedy would benefit greatly from a NEBA framework that focuses on optimizing the net benefits of the individual actions comprising the preferred remedy and associated strategy.

Section 5, *Preliminary Carbon Footprint Analysis of Remedy Alternatives in the FFS,* presents a preliminary carbon footprint analysis conducted to illustrate the importance of considering this and other environmental and social performance metrics in the FFS within a NEBA framework. The carbon footprint analysis identified significant differences between the various remedial alternatives that are not captured in the FFS. Examination of additional environmental and social performance metrics is needed to further understand how the various remedial alternatives affect ecological, social, and economic attributes to therefore provide a transparent evaluation that supports selection of the appropriate remedy.

Lastly, **Section 6**, *Findings and Conclusions,* summarizes the comments and points to a path forward from which Region 2 can examine the remedial alternatives to make an informed decision regarding a preferred remedy for the FFS Study Area. By "informed," we mean an approach that is systematic, consistent, defensible and understandable to all stakeholders. Decisions with these traits achieve environmental objectives in a timely and cost-effective manner, while providing a transparent basis for decision making. The overarching goal is to balance the risks, benefits and trade-offs between competing remedial alternatives.

2 USEPA Policy, Guidance, and Direction for the Remedial Decision Process

Remedial decision-making policy and guidance obligates Region 2 to evaluate the environmental impacts associated with potential remedial actions and dictates that the remedies should be sustainable and demonstrate a net environmental benefit. USEPA has made greener cleanups part of its cleanup program mission, which the Agency has stated strives to reduce adverse impacts on the environment, use natural resources and energy efficiently, minimize or eliminate pollution at its source, use renewable energy and recycled materials whenever possible, and reduce waste to the greatest extent possible[5]. According to USEPA, the practice of "green remediation" involves strategies that consider all environmental effects associated with remedy implementation at contaminated sites, and the selection of options that maximize the net environmental benefit of cleanup actions (USEPA 2008a).

Fulfilling a commitment made in his 2012 State of the Union Address, President Obama signed Executive Order (EO) 13604 directing Federal agencies, including the USEPA, to institutionalize their efforts to modernize and transform how the Federal government fulfills its responsibilities to improve the efficiency of Federal permitting and the project review process[6]. The implementation of best practices with specific and measurable actions was mandated to create a more transparent, more predictable, and better performing process that maintains the confidence of stakeholders, improves engagement with project sponsors, and reduces project timelines while protecting the public's health and safety, security, and the environment. The USEPA and other Federal agencies were directed to achieve two goals:

- More efficient and effective review of proposed large-scale and complex infrastructure projects, resulting in better projects, improved outcomes for communities, and faster permit decision-making and review timelines; and,
- Transparency, predictability, accountability, and continuous improvement of routine infrastructure permitting and reviews.

The U.S. Army Corps of Engineers (USACE), which has an important role in the planning and implementation of Region 2's proposed Plan for the FFS Study Area, has adopted procedures responsive to the President's directive. The USACE performance improvement plan for permitting and review of large, complex projects includes actions and commitments such as convening independent peer-review panels in cases where the risk and magnitude of the proposed project warrant critical examination by an independent and qualified team of experts[7]. This commitment is intended to reinforce the Corps' competencies, improve the quality of work products and deliver projects more cost-effectively in a manner that would result in the realization of anticipated public benefits in the shortest amount of time.

USEPA has made similar, albeit somewhat less specific, commitments responsive to the President's executive order. Policy, guidance, and direction concerning contaminated sediment

[5] http://www.epa.gov/Region5/waste/cars/remediation/index.html
[6] http://www.permits.performance.gov/sites/all/themes/permits2/files/federal_plan.pdf
[7] http://www.usace.army.mil/Portals/2/docs/civilworks/news/2013exppermit_eo-corps_agncplan_sep2012.pdf

remediation focuses on the need to evaluate preferred or selected remediation strategies and demonstrate the degree to which remedies are expected to:

- Manage ecological and human health risks;
- Provide a “net benefit” to the public;
- Provide a sustainable solution;
- Support human and ecological use and reuse of remediated land;
- Minimize impacts to water quality and water resources;
- Reduce air emissions and greenhouse gas production;
- Minimize material use and waste production; and,
- Conserve natural resources and energy (USEPA 2002, 2005; NRC 2007).

The comparative net risk evaluation approach recommended by USEPA and the National Academy of Sciences Committee on Remediation of PCB-Contaminated Sediments precedes and comports with these considerations (NRC 2001; USEPA 2005). The use of comparative net risk evaluation ensures that on a site-specific basis decision-makers consider, at the remedy selection stage, not only the benefits of a remedial approach, but also the residual risks associated with the approach and the risks associated with implementing the remedial approach (USEPA 2005). This differs from the traditional approach of either considering implementation risks at the remedy implementation stage or assuming that remedial approaches will be 100% effective on implementation thereby bypassing any consideration of residual risk. Comparative net risk evaluation is consistent with the National Oil and Hazardous Substances Pollution Contingency Plan’s (NCP) 9 criteria (40 CFR §300.430(e)(9)(iii)), which require evaluation and balancing of short-term and long-term risks and benefits, including residual risk. Failure to account for implementation risks and residual risk during the remedial evaluation stage can skew remedy selection and result in a less effective and less protective remedy than anticipated, a result neither the Agency nor responsible parties should find acceptable.

Several USEPA guidance documents introduce decision-analysis tools such as comparative net risk evaluation and recommend their use for making decisions in the public interest pertaining to the protection of human health and welfare. Most of these tools are quantitative and assess the benefits and risks associated with proposed alternatives with the objective of selecting the best option (Stahl 2003). For example, multi-criteria integrated resource assessment (MIRA) has been proposed as an alternative framework to existing decision analysis approaches at USEPA (Stahl et al. 2002, 2003; USEPA 2000). MIRA is a process that directs stakeholders on methods for organizing and interpreting scientific data to perform trade-off analyses. These trade-off analyses are used to determine the relative importance of different decision criteria. Another example is USEPA’s “Framework for Responsible Environmental Decision-Making”, which was developed to assist the Office of Pollution Prevention and Toxics during the development of guidelines promoting the use of environmentally preferable products and services (USEPA 2000). The framework is a decision-making method that provides a foundation for linking life cycle indicators with technical and economic factors for decision makers when quantifying the environmental performance of competing products.

Similar comprehensive decision analysis methods and approaches have been proposed to consider the broad range of environmental and social benefits and costs during remedy selection at contaminated land sites and waterways in the Superfund Program (Kiker et al. 2005; Linkov et al. 2011; Gamper-Rabindran et al. 2011). Examples of relevant policy, guidance and direction documents are provided in **Appendix A**.

The following six citations from USEPA and NJDEP guidance illustrate the importance to USEPA for providing adequate, clear, and transparent information:

Example 1. Risk managers must assess and balance risks between site contaminants and proposed remedies (USEPA 1997).

EPA Superfund ERA Guidance (Step 8) specifically states that:
"The risk manager must balance (1) residual risks posed by site contaminants before and after implementation of the selected remedy with (2) the potential impacts of the selected remedy on the environment independent of contaminant effects."

"In instances where substantial ecological impact will result from the remedy (e.g., dredging a wetland), the risk manager will need to consider ways to mitigate the impact of the remedy and compare mitigated impacts to the threats posed by the site contamination."

Example 2. This balance should be incorporated into the decision-making process for contaminated sediment sites (USEPA 2005).

"Project managers are encouraged to use the concept of comparing net risk reduction between alternatives as part of their decision-making process for contaminated sediment sites, within the overall framework of the NCP remedy selection criteria. Consideration should be given not only to risk reduction associated with reduced human and ecological exposure to contaminants, but also to risks introduced by implementing the alternatives [...] Evaluation of both implementation risk and residual risk are existing important parts of the NCP remedy selection process. By evaluating these two concepts in tandem, additional information may be gained to help in the remedy selection process."

Example 3. Feasibility Studies should include a comparison of environmental footprints (USEPA 2008a)

"Green remediation focuses on maximizing the net environmental benefit of cleanup, while preserving remedy effectiveness as part of the Agency's primary mission to protect human health and the environment [...] Key opportunities for integrating core elements of green remediation can be found when designing and implementing cleanup measures. Regulatory criteria and standards serve as a foundation for building green practices." Key elements include reducing atmospheric release of toxic or priority pollutants, and reducing emissions of greenhouse gases that contribute to climate change.

"In accordance with green remediation strategies, feasibility studies could include comparison of the environmental footprint expected from each cleanup alternative, including GHG emissions, carbon sequestration capability, and water drawdown (lowering of the water table or surface water levels)."

Example 4. Green remediation technologies should be considered for USEPA Region 2 response actions (USEPA 2011)

"The EPA Region 2 Superfund program supports the adoption of 'green site assessment and remediation,' which is defined as the practice of considering all environmental impacts of studies, selection and implementation of a given remedy, and incorporating strategies to maximize the net environmental benefit of cleanup actions. EPA Region 2 has established a 'Clean & Green' policy to enhance the environmental benefits of Superfund cleanups by promoting technologies and practices that are sustainable. The policy applies to all Superfund cleanups. Under this policy, certain green remediation technologies will serve as touchstones for Region 2 response actions." (USEPA 2011a)

Example 5. Green remediation, as defined by USEPA, will be considered a mitigating condition for selection of remedial alternatives (NJDEP 2009)

"The use of Green Remediation concepts as part of remedial activities at sites will be considered a mitigating condition. Green Remediation is defined by the United States Environmental Protection Agency (USEPA) as 'the practice of considering all environmental effects of remedy implementation and incorporating options to maximize the net environmental benefit of cleanup actions'."

Example 6. USEPA has identified a framework to quantify various metrics to help understand and reduce a project's environmental footprint (USEPA 2012b)

"Green remediation strategies can include a detailed analysis in which components of a remedy are closely examined and large contributions to the footprint are identified. More effective steps can then be taken to reduce the footprint while meeting regulatory requirements driving the cleanup [...] The term "environmental footprint" as referenced in the methodology comprehensively includes metrics such as energy use and water use as well as air emissions to fully represent the effects a cleanup project may have on the environment."

"The methodology is a general framework to help site teams understand the remedy components with the greatest influence on the project's environmental footprint. Quantifying the metrics can serve as an initial step in reducing the remedy footprint. The overall process allows those involved in the remedial process to analyze a remedy from another perspective and potentially yields viable and effective improvements that may not have been identified otherwise."

3 Failings of the FFS in the Remedial Decision Process

It is evident from review of the FFS that Region 2 failed to fully evaluate the environmental and social consequences of the various sediment remedial alternatives and its preferred remedy. The FFS did not address four critical aspects of large, complex projects and remedial evaluation:

1. Sustainability and green remediation practices were not evaluated quantitatively;
2. Social and community impacts were not evaluated quantitatively;
3. Environmental footprints such as carbon and other greenhouse gas emissions were not evaluated quantitatively; and,
4. Net environmental, economic and social benefits and costs were not evaluated either qualitatively or quantitatively.

The primary work flow of the three main remedial alternatives and the three dredged material management scenarios described in the FFS is presented in **Figure 1** through **Figure 4**. At each stage of work, there is insufficient information in the FFS to demonstrate that potentially important factors with environmental, social and economic implications (listed next to each oval and rectangle in each figure) were addressed in Region 2's remedial evaluation process; this reflects the reason for criticism in these comments regarding the lack of transparency in Region 2's remedial evaluation process.

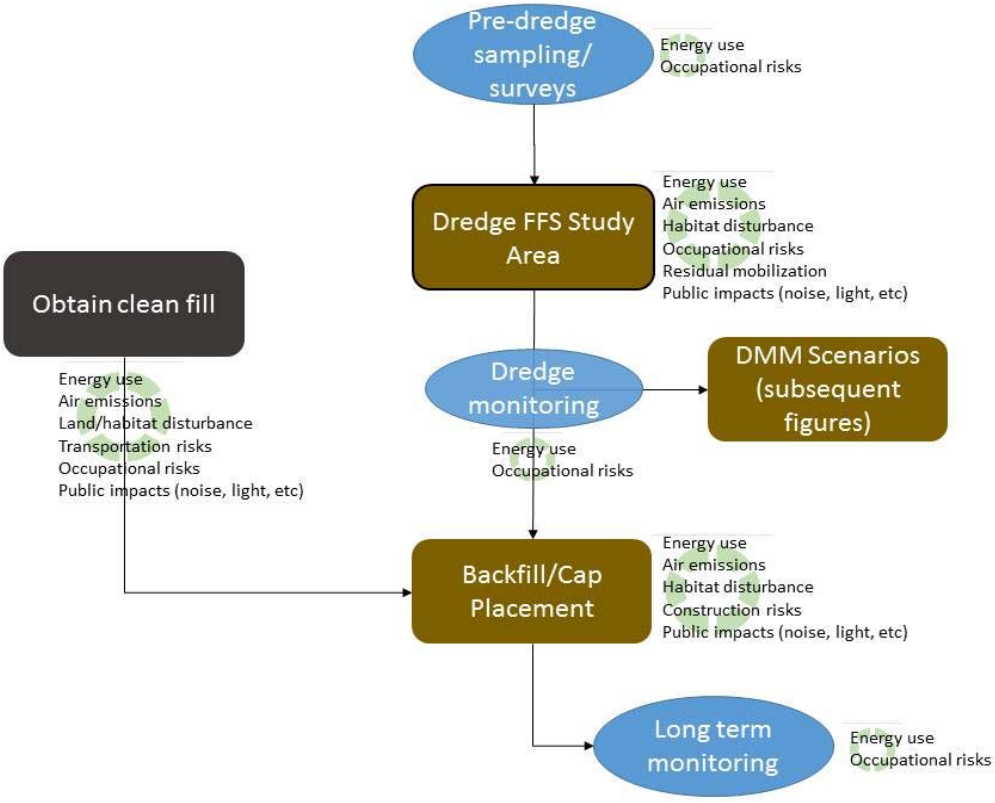


Figure 1. Remedial Alternative Considerations that Region 2 Failed to Quantify.

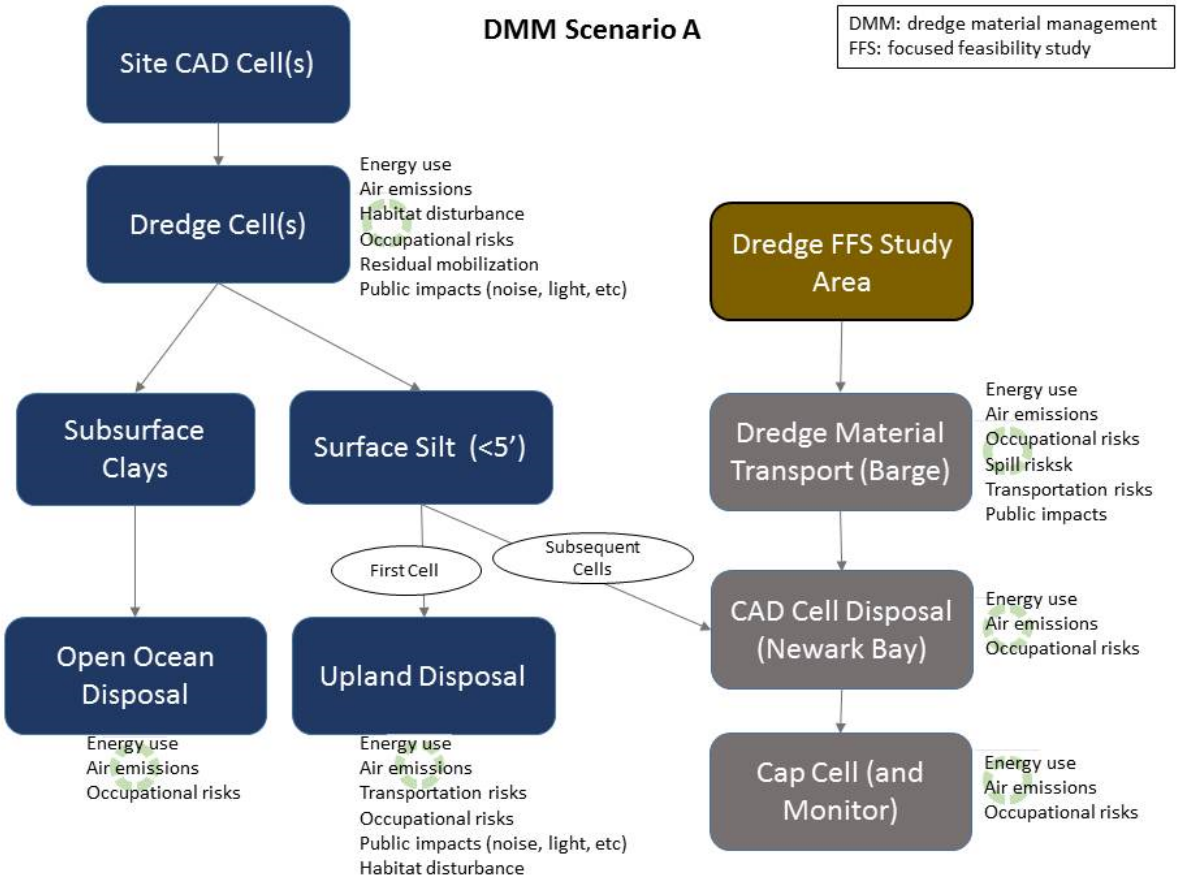


Figure 2. Impacts Associated with DMM Scenario A that Region 2 Failed to Quantify.

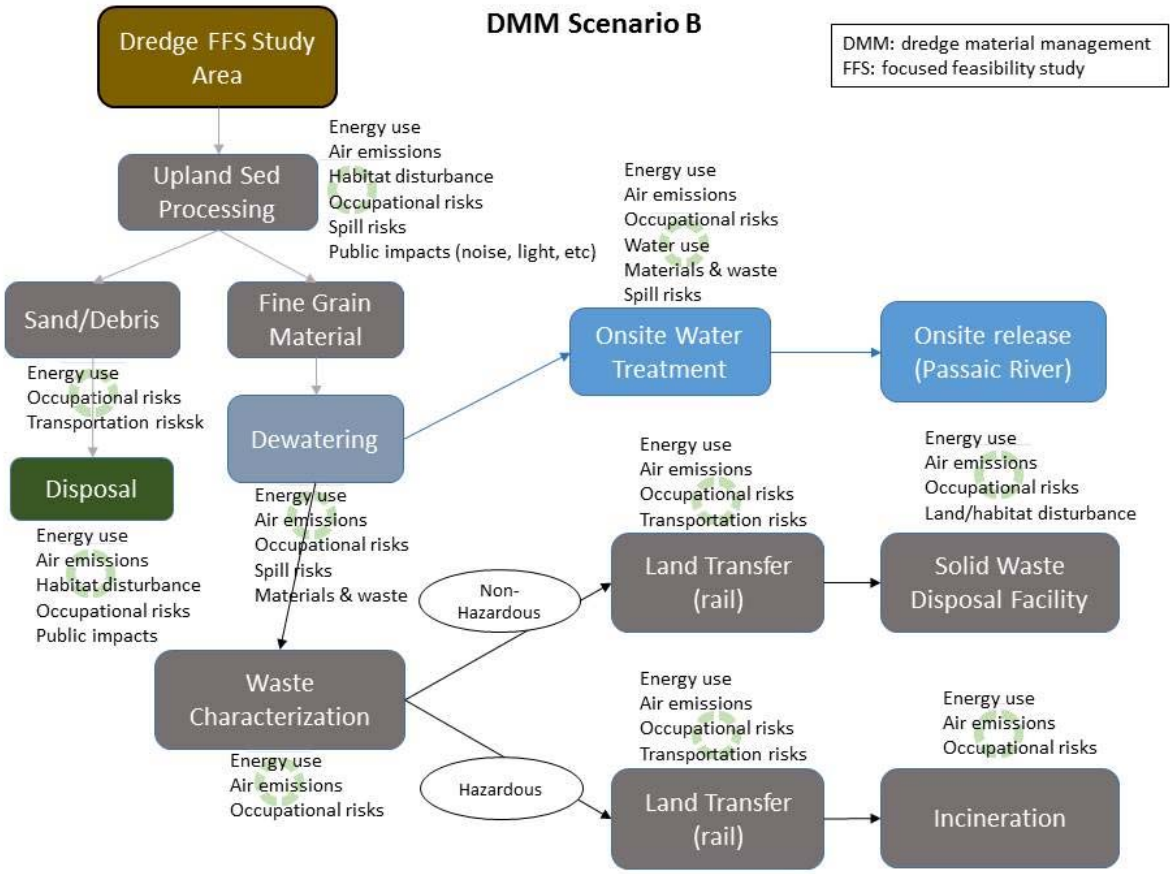
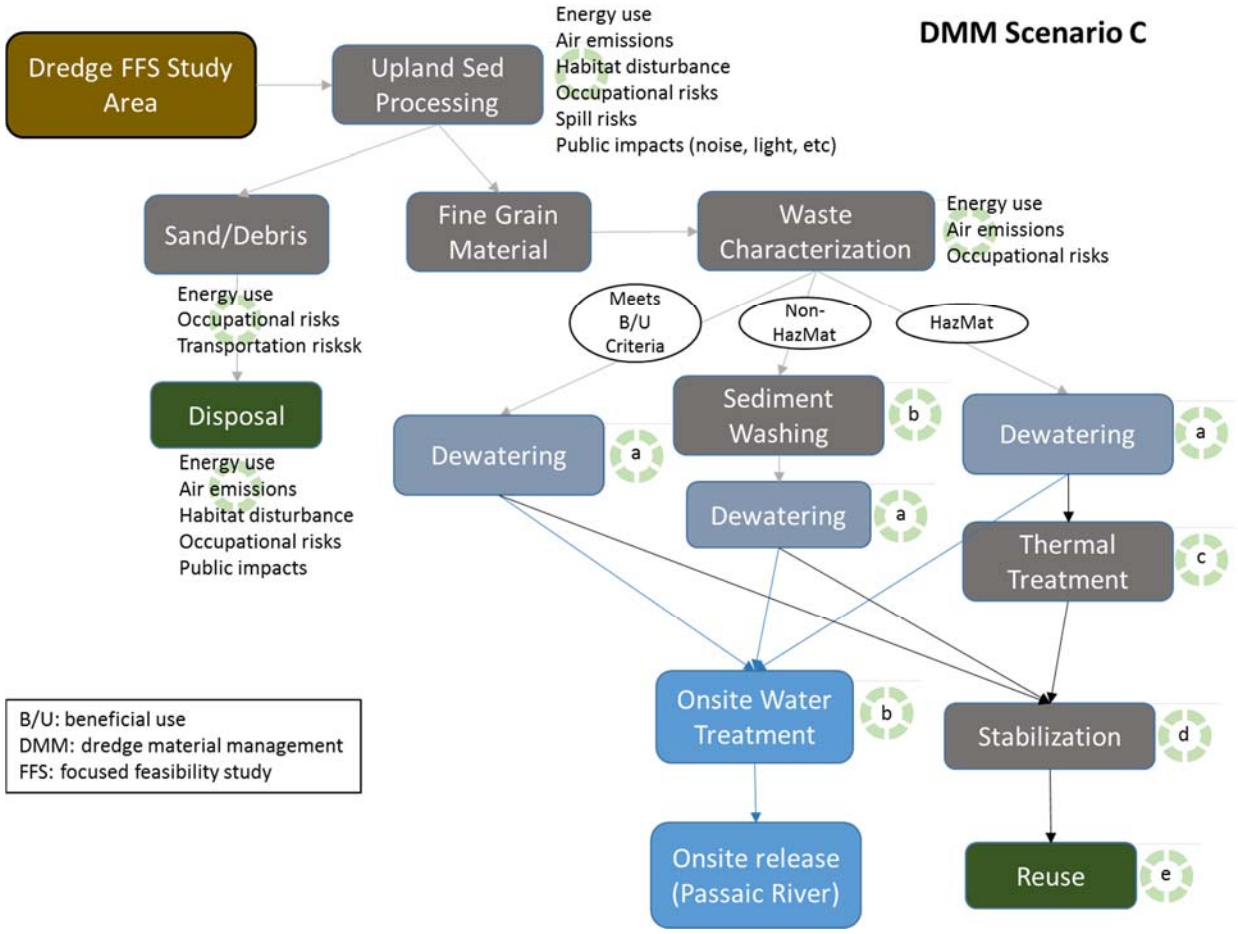


Figure 3. Impacts Associated with DMM Scenario B that Region 2 Failed to Quantify.



Notes:

a. Energy use, air emissions, occupational risks, spill risks, materials & waste

b. Energy use, air emissions, occupational risks, spill risks, water use, materials & waste

c. Energy use, air emissions, occupational risks, spill risks, materials & waste

d. Energy use, occupational risks, spill risks, materials & waste

e. Energy use, air emissions, occupational risks, transportation risks, public impacts (noise, light, etc.)

Figure 4. Impacts Associated with DMM Scenario C that Region 2 Failed to Quantify.

As such, given the policy, guidance and direction of the USEPA (including Region 2 specific policy), there is insufficient information in the FFS to demonstrate that Region 2 adequately and transparently considered important factors with environmental, social and economic implications as outlined in USEPA policy, guidance and direction. These factors and considerations are discussed, in turn, in the following sections.

3.1 Absence of Preferences for Green Remediation

The FFS does not appear to address the concepts of green remediation embodied in state and federal policy and guidance documents. The metrics useful for measuring how remedial alternatives affect sustainability and ecosystem services were either inadequately considered or not considered at all. Specifically, **Table 1** demonstrates that out of 31 metrics, none were adequately considered, seven were inadequately considered, and 24 were not considered at all. The lack of consideration of these metrics resulted in an inadequate understanding of the environmental footprint of the various remedial alternatives. As such, Region 2 did not present a transparent, technical, and defensible basis for demonstrating how its proposed actions will promote environmental sustainability and stewardship, and protect the health of the local community. Even when these metrics were identified in the FFS, Region 2 failed to provide any quantitative analysis among the various remedial alternatives and DMM scenarios. Additionally, metrics that may have significant social and economic impacts (e.g., GHG emissions, energy and resource consumption) or ecological impacts (e.g., terrestrial habitat disturbance required for upland disposal) were omitted from consideration in the FFS.

As defined by USEPA, green remediation "is the practice of considering all environmental effects of remedial implementation and incorporating options to minimize the environmental footprints of cleanup actions." NJDEP has indicated that "the use of Green Remediation concepts as part of remedial activities at sites will be considered a mitigating condition," (NJDEP 2009), and Region 2 has implemented its "Clean & Green" policy that is aimed at enhancing "the environmental benefits of federal cleanup programs by promoting technologies and practices that are sustainable" (USEPA 2012a).

The selection and analysis of sustainability metrics is necessary to define the environmental footprint for remedial alternatives in order to compare their relative benefits versus negative impacts. USEPA, in accordance with EO 13423, has identified six core elements of sustainability that should be developed into quantifiable and qualitative metrics to evaluate the environmental footprint of a remedial action (**Figure 5**; USEPA 2008a). The metrics within each of these elements can be classified as environmental, social, or economic components, referred to as the "three pillars" of sustainability (United Nations, 2005). These "three pillars" are interdependent, and effects to one can affect another. As such, sustainable alternatives require an understanding of the potential inter- and intra- tradeoffs among these environmental, social, and economic components so as to maximize human well-being (Nicolette et al, 2013).

Figure 5. Core Elements of a Cleanup Project

Methods for quantifying and identifying opportunities to reduce the environmental footprint of a federally-funded or federally-mandated project have been presented in several Agency publications including, but not limited to, the following:

- Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (USEPA 2008a),

- Green Remediation: Best Management Practices for Excavation and Surface Restoration (USEPA 2008b),
- Methodology for Understanding and Reducing a Project's Environmental Footprint (USEPA 2012b).

Furthermore, the FFS is almost entirely silent on the social consequences of the preferred remedial alternative, a concept that USEPA has long-recognized for its importance in decision-making under Superfund and other federal environmental programs. From the 1980s, federal risk assessment guidance has described frameworks for considering potential risks to local communities and to remediation workers during the implementation of the Agency's preferred or selected remedy. Two important CERCLA guidance documents, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final (USEPA 1988) and Risk Assessment Guidance for Superfund (RAGS) Part C (USEPA 1991), directly address the importance of designing and implementing remediation work that balances environmental protection with the health and safety of workers and the protection of the health of members of communities potentially affected directly or indirectly by the work. In the early 2000s, USEPA advocated a new tool, health impact assessment (HIA), "…by which a policy, program, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population"[8]. USEPA encourages the use of HIA to systematically identify how new projects or policies might affect public health, observing that HIAs contribute to a decision-maker's understanding of the health issues and if not conducted, or conducted poorly, may result in decision-makers pursuing actions that have unintended environmental or economic consequences. The goal of USEPA's sustainable and healthy community program, which relates directly to the focus of HIA, is to achieve the right mix of policies and investments that protect our environment, are socially just, improve public health, support economic vitality, make the most efficient use of public dollars, and enhance the quality of life for community residents)[9].

3.2 Absence of Preferences for Sustainable Solutions

Sustainable remediation practices are encouraged in USEPA and federal guidance, and consider economic and natural resources, ecology, human health and safety, and quality of life. Elements of sustainable sediment remediation strategies that should be considered in remedial alternative development are presented in **Figure 6**. Sustainable practices incorporate environmental factors <u>and</u> social responsibility (e.g., minimizing risk to surrounding communities). According to USEPA guidance (USEPA 2008a, 2009a, 2010, 2012a, 2012b), sustainable remediation expands upon current environmental practices and employs strategies for site cleanup that use natural resources and energy efficiently, reduce negative impacts on the environment, minimize or eliminate pollution at its source, protect and benefit the community at large, reduce air emissions and greenhouse gas production, and reduce waste to the greatest extent possible. These and other strategies are intended to minimize the environmental "footprint" and maximize the overall benefit of cleanup actions.

[8] (see http://www.epa.gov/sustainability/analytics/health-impact.htm)
[9] (see http://www2.epa.gov/sites/production/files/2013-12/documents/shc-fact-sheet.pdf)

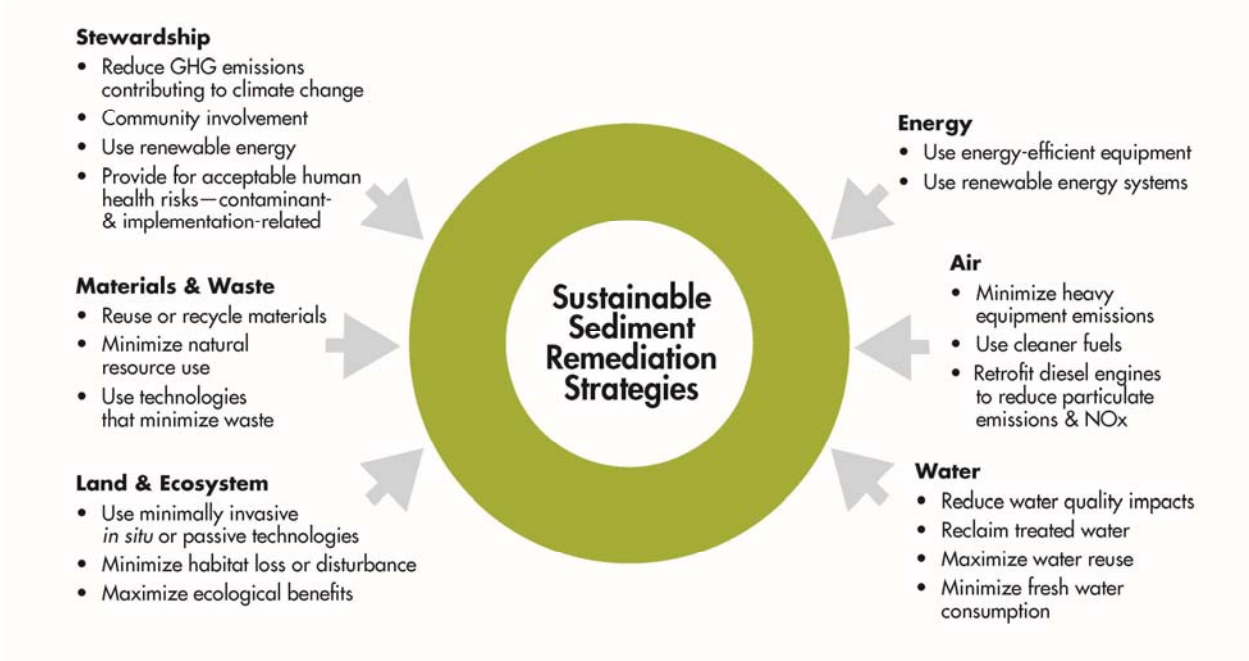


Figure 6. Elements of Sustainable Sediment Remediation Strategies that should be Considered in Remedial Alternative Development.

USEPA (2008a; 2009a; 2010) and various organizations in which the Agency is a participant (ITRC 2011), point to several concepts and principles associated with sustainable remediation that the Agency has stated should be considered in the planning and implementation of sustainable remediation practices. With regard to the FFS, however, the Agency has failed to demonstrate clear and transparent consideration of the following oft-stated Agency objectives:

Objective #1: Remedies protect human health and the environment. Remediation work should remove unacceptable risks to human health and to the environment, with due consideration to the costs, benefits and technical feasibility.

Objective #2: Remedies require safe working practices. Remediation work should be safe for workers on-site, local communities and the environment.

Objective #3: Remedial decision-making is consistent, clear and based on reproducible evidence. Sustainable remediation decisions should be made with regard to the current and future implications of environmental, social and economic factors. A sustainable remediation solution should deliver the maximum net benefit achievable.

Objective #4: Remedial decisions and the underlying foundations for decisions are transparent. Remediation decisions, including the assumptions and supporting data used to reach them; should be documented in a clear and easily understood format.

Objective #5: Remedial decisions require good governance and stakeholder involvement. Remediation decisions should be made with regard to the views of stakeholders

and following a clear process that they can participate in. In situations where non-optimum remediation decisions must be made because other factors are more influential for optimizing the net benefits, a clear and transparent record of indicating why such a decision was taken is a minimum requirement in any decision making process.

Objective #6: Remedial decisions are based on sound science. Decisions should be made on the basis of sound science, relevant and accurate data, and clearly explained assumptions. Decisions should be based on the best available information and should be justifiable and reproducible. In selecting and deciding between remedial solutions, the requirements that flow from the application of these principles that must be satisfied versus those requirements that are desirable but not mandatory should be identified. At a minimum, remedial solutions should be restricted to those solutions that are likely to satisfy the essential requirements.

Sustainable remediation practices imply directly that the environmental footprint of the preferred remedial option (i.e., the impacts on environmental media and society that are a direct or indirect consequence of performing the remedial action) is as small as possible. Despite USEPA guidance (USEPA 2010, 2012b), the FFS fails to communicate opportunities to increase sustainability and minimize the environmental footprint in all phases of remediation (i.e., site investigation, remedial selection, remedial design and construction, operation, monitoring, and site closeout) associated with the preferred remedy.

3.3 Absence of an Evaluation of Environmental Footprints

Aside from recognizing the traditional requirements associated with remediation under CERCLA (namely, protection of human health and the environment and compliance with applicable or relevant and appropriate requirements), Region 2 failed to present evidence in the FFS of an evaluation of the significant differences (if any) in the environmental footprint among the different remedial alternatives that meets the requirements prescribed by Agency guidance (USEPA 2012b). As an example, in accordance with EO 13514 (EOP 2009) that requires agencies to measure, manage, and reduce greenhouse gas emissions, USEPA[10] provides common methods for calculating a project's environmental footprint; however, the use of these methods was not evident in the FFS. According to USEPA[11], it has used environmental footprinting to support Agency decision-making.

For example, the FFS provides no indication that Region 2 considered the following:

a. Identification of sustainability metrics (e.g., materials and waste, water, energy, and air) relevant to the FFS Study Area;

b. Establishing and applying a methodology to quantify each remedial alternative's effect on each metric;

[10] http://www.epa.gov/sustainability/analytics/environmental-footprint.htm
[11] http://www.epa.gov/sustainability/analytics/environmental-footprint.htm.

c. Obtaining consensus regarding how metrics are weighed against each other and against traditional criteria in selecting the preferred remedial approach; and,

d. Identifying methods to reduce the environmental footprint of different remedial components.

Basically, Region 2 failed to show compliance with EO 13423 (EOP 2007), which mandates that all federal agencies "conduct their environmental, transportation, and energy activities under the law in support of their respective missions in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.", and that an environmental footprint be considered in support of project development. In addition, Region 2 failed to show compliance with the Federal plan for implementing EO 13604 (EOP 2012), which states that "Federal agency permitting and review responsibilities seek to ensure that a project's potential impacts on safety, security, and environmental and community resources such as air, water, land, and historical and cultural resources are considered and minimized, as required by law, throughout the planning process."

3.4 Inadequate Analysis of Environmental and Social Risks

Region 2's remedial evaluation approach provides only a partial evaluation of how alternatives influence human health and ecological risks. The scope of the FFS evaluation is narrow and clearly focuses on risks based solely upon chemical concentrations of the contaminants of concern (COC) in the sediments. In doing so, Region 2 neglected to consider factors other than chemical sediment concentrations during the implementation of the preferred remedial alternative that also have the potential to influence, either positively or negatively, human health and ecological risks.

For example, the remedial alternative evaluation contained in the FFS does not consider increased human health risks to nearby communities or the environment associated with the implementation of the remedies themselves, independent of the contaminant risks. Environmental risks can arise from several factors including increased emissions of particulate contaminants associated with remedial equipment and or transport vehicles (trucks, rail, etc.), physical human health risks associated with machinery operation, increased accidents and other risks associated with traffic and truck/rail transport, increased community stress (odor, noise, etc.), increased GHG emissions, physical impacts of remedial actions on habitats, losses in human use recreational uses, plus others.

Region 2's failure to adequately evaluate risks can be conceptually depicted in the following series of figures. In **Figure 7**, the pie chart depicts two potential human health risks: 1) those associated with the in situ concentrations of contaminants in the sediments, and 2) those associated with the implementation of the remedy. Since the human health effects of remedy implementation have not been formally evaluated by Region 2, and for depiction purposes, they have been set equal to each other.

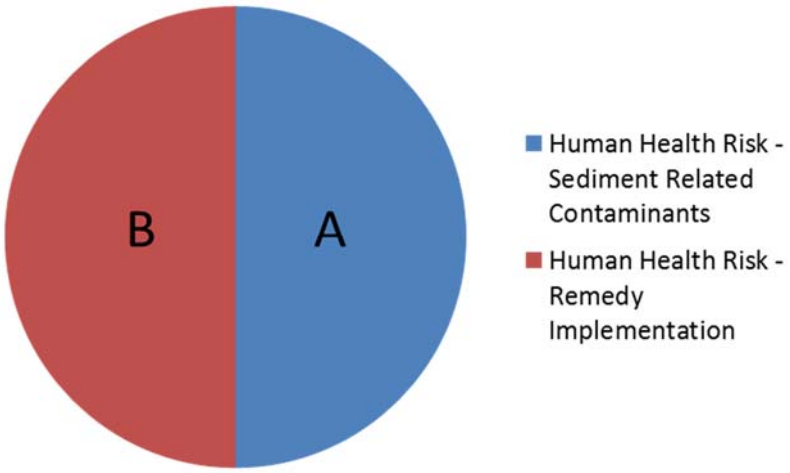


Figure 7. Two Human Health Risk Categories of Remedial Actions.

In examining the human health risks associated with the implementation of the remedy more closely (see **Figure 8**); it is well known that the potential human health risks associated with remedy implementation are typically derived from several activities and consequences of activities. The risks are additive; that is, the risk associated with remedy implementation (B) is the sum of the risks associated with each individual component of remedy implementation (B = B1 + B2 + B3 + B4 + B5).

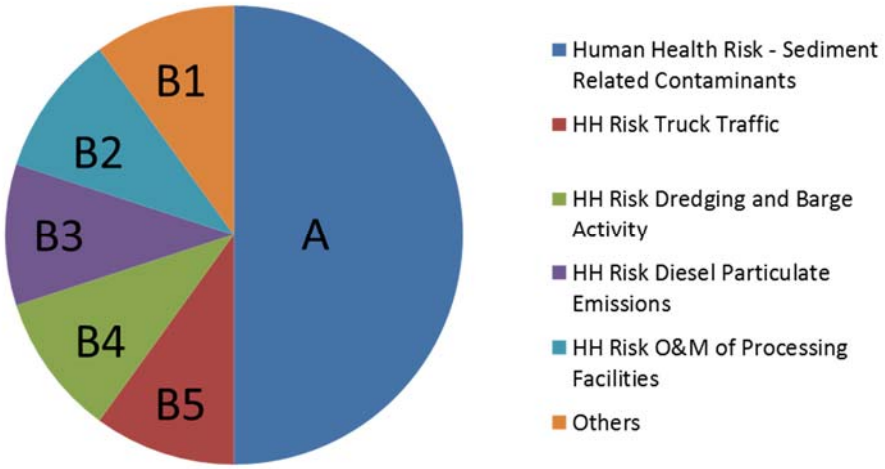


Figure 8. Human Health Risks Associated with Sediment Concentrations and Implementation of Remedial Actions.

Included among the technical questions that were not answered by Region 2 regarding the risk of remedy implementation are the following:

- What is the significance of the human health risks in categories A and B? Which poses a greater concern to the local community potentially affected by the preferred remedy described in the FFS? Which poses a greater concern to worker safety?

- Are risk categories A and B equal, or is it possible or probable that the activities associated with risk category B (i.e., B1 + B2 + B3 + B4 + B5) are greater than risk category A (see **Figure 9**)?

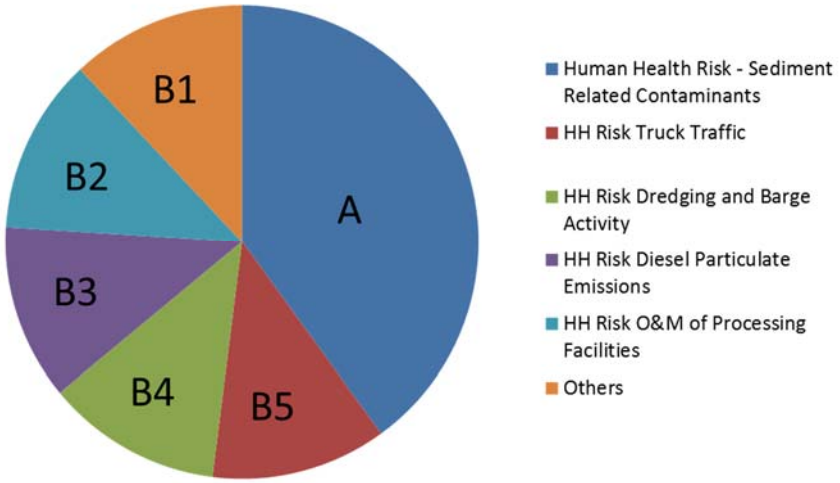


Figure 9. What if Remedial Implementation Risks (the sum of B1 through B5) Exceeded Risks Associated with Sediment Concentrations?

3.5 Absence of Net Environmental, Economic and Social Benefit and Cost Considerations

The FFS is not consistent with Agency and federal guidance and policy. As stated in EOP 2012, "Federal agency permitting and review responsibilities seek to ensure that a project's potential impacts on safety, security, and environmental and community resources such as air, water, land, and historical and cultural resources are considered and minimized, as required by law, throughout the planning process.". The FFS does not follow a prescribed remedial evaluation process that includes clear, transparent, and detailed environmental analyses. The FFS does not reflect a complete evaluation of the potential risks and the net benefits (or detriments) to local communities and the environment associated with the implementation of the different remedial alternatives, including Region 2's preferred remedy. The USEPA claims this is paramount for sound decision-making,[12] and the White House provides a checklist (**Attachment A**) to aid in meeting this important requirement that specifically asks "does the preferred option have the highest net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires a different approach?"[13]

A summary of excerpts from the FFS indicating potential short-term impacts and risks associated with the different remedial alternatives is presented in **Table 2**. Throughout the FFS,

[12] See for example, http://www.epa.gov/osa/ .
[13] See for example, http://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/RIA_Checklist.pdf .

statements were made regarding potential impacts and/or risks *without any quantitative comparative analysis.* In addition, Region 2 failed to consider or inadequately considered the following:

- "Risks posed by sediment processing at upland processing and transfer facilities (e.g., spills, accidents, or emissions)." – Section 5.2.2, page 5-23;
- "Risks posed by transportation of dewatered materials to off-site disposal or treatment facilities (e.g., spills, accidents)." – Section 5.2.2, page 5-23;
- "[R]isks posed by increased river traffic…" – Section 5.2.2, page 5-23;
- "[P]otential occupational risks to site workers from direct contact, ingestion, and inhalation of COPCs and COPECs…and routine physical hazards…" – Section 5.2.2, page 5-24;
- "[I]ncrease in-water vessel traffic and cause on-land impacts to the community (e.g., increased vehicle traffic and air quality impacts)…" – Section 5.2.3, page 5-38;
- "Sediment removal may result in short-term adverse impacts to the river exposure of the water column, fish, and biota to contaminated sediments due to resuspension of contaminated sediments during dredging." – Section 5.2.3, page 5-39;
- "[A]ctivities would result in some temporary disruption of commercial/recreational uses and boating access during remediation." – Section 5.2.3, page 5-43; and
- "[T]emporary noise, light, odors, blocked views, potential air quality impacts and disruptions to commercial and recreational river users…" – Section 5.2.4, page 5-52;

Throughout the FFS, Region 2 provides, at best, only a qualitative comparison of the impacts of the remedial alternatives. Among the clearest examples of such deficiencies is the following statement from Section 5.3:

> "DMM Scenario A would have the *least impact on the community and site workers* but the *most impact on the aquatic habitat* because the transport and disposal occurs on or in the water. DMM Scenario C would have a *greater impact on the local community and workers* than DMM Scenario B because the decontamination technologies require a slightly larger upload processing facility, incorporates local thermal treatment unit with potential air emissions, and may require more trucking to transport beneficial end use products to local destinations." [*Emphasis* added].

The use of quantitative metrics, such as those identified by USEPA (2012b), is essential for informed decision-making. These metrics would have been valuable to support and help demonstrate the sustainability, overall net environmental benefit, and environmental footprint of each alternative. In addition, it is readily apparent that Region 2 neglected to or failed to adequately conduct an analysis of the following potential environmental and social impacts:

- Social and environmental consequences of different river and treatment/disposal activities;
- Analysis of alternate energy sources and more efficient alternatives for remedies that would otherwise require high energy demand; and,

- Impacts from the transport, storage, and use of raw materials, supplies, vessels, vehicles, and equipment needed to support the different remedial actions.

Several tools are available for conducting quantitative assessments that could have provided Region 2 with a more informed and technically sound basis to make decisions regarding sustainable choices and the overall net environmental benefit of the preferred remedial alternative. Metrics that were neglected by Region 2 in the FFS include the following:

- **Energy Consumption**: Electric power production represents approximately one-third of the total carbon dioxide (CO_2) emissions in the US energy sector (USEPA 2008b). In addition to USEPA's work in analyzing "the extent of energy use and cost of various technologies used to treat contaminated media at NPL sites," the Federal Energy Independence and Security Act of 2007[14] sets goals to conserve the U.S. energy supply and reduce dependence on fossil fuel sources of energy. As such, energy consumption from non-renewable versus renewable sources is an important metric to consider when selecting remedial alternatives. Activities that can result in energy consumption include on-site electrical use, fuel consumed by on-site equipment and transportation vehicles/vessels, sediment pre-treatment and disposal, and energy used for the production of consumables associated with the remedy. Electricity use on-site can be determined through meter readings for existing systems and/or by performing engineering calculations for each piece of equipment.

  Energy consumption will differ significantly between remedial alternatives due to the varying time periods for construction, and between DMM scenarios due to the distinct energy requirements required for treatment. The length of the dredging ranges from 1.5 years (Alternative 4) to 11 years (Alternative 2); however, the FFS fails to assess the effects related to energy consumption in the evaluation of short-term effects assessments (Section 5.2 of the FFS, Section 4.2 of the Engineering Evaluation Appendix F). Further, Region 2 does not quantify the amount of energy required for any of the remedial alternatives.

- **GHG Emissions**: The FFS does not address greenhouse gas emissions (GHGs), which USEPA has declared to be major air pollutants with adverse human health and environmental effects (USEPA 2009b). Sources of GHG emissions have been defined by USEPA as consisting of the following:

  – Scope 1. Emissions from direct anthropogenic sources (e.g., equipment used onsite);

  – Scope 2. Emissions from the generation of electricity, heat, or steam by a separate, offsite entity purchased and/or used onsite; or,

  – Scope 3. Emissions from other indirect anthropogenic sources (e.g., employee trips, contracted waste disposal).

  The excavation and transport of millions of cubic yards of sediment will require extensive operation of heavy machinery in the river and at upland sediment processing and treatment facilities. In addition, management of the dredged material will require transport,

[14] http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

processing, and potential offsite disposal (to as close as New York or as far as California and Oregon) and onsite or offsite incineration. These activities can result in a potentially significant contribution of GHG emissions that has not been quantified by Region 2. Further, the level of GHG emissions is expected to vary significantly between remedial alternatives and DMM scenarios.

For demonstration purposes, a preliminary quantification of carbon footprints that compares the GHG impacts between remedial alternatives and DMM scenarios is presented in Section 5 of these technical comments. The technical scope follows USEPA's GHG Inventory Guidance that is used by industries that are required to document GHG emissions (USEPA 2014a).

- **Criteria Pollutant Emissions**: Air emission of criteria pollutants, regulated by the Clean Air Act of 1970, can cause smog and adverse health effects such as asthma, bronchitis, lung cancer, and eye irritation. Criteria air pollutants include: sulfur oxides (SOx), oxides of nitrogen (NOx), particulate matter (PM), carbon monoxide (CO), ozone, and lead due to various activities such as transportation, electrical usage, and heavy machinery and equipment use during remedial implementation. Several computer programs developed by USEPA are useful to determine emission estimates and inventories for various sources associated with remedial activities.

  Section 4.2.5 of the Engineering Evaluations (Appendix F to the FFS) addresses potential air quality effects associated with remedial alternatives. On pages 4-13 and 4-14, it acknowledges that air quality may be adversely affected in the short-term due to the following factors:

  – Volatilization of contaminants from dredged materials
  – Air emissions from equipment during dredging and capping operations
  – Emissions from transport vessels during transportation of sediment to a processing or disposal site
  – Workers commuting to the job site in personal vehicles

  However, rather than quantifying the potential emissions of pollutants such as particulate matter due to these factors, the FFS provides a qualitative assessment that minimizes any short-term effects on air quality because "dredging and capping operations would be spread over a large section of the river and the time spent in any one location would be relatively short,"[15] and mitigation measures can be implemented to reduce any impacts. Further, the assessment only qualitatively compares impact by remedial alternative or by DMM scenario, not by remedial alternative ***and*** DMM scenario. As such, the FFS fails to provide the transparency needed for stakeholders to fully understand how the effects on air quality contribute to the remedy selection. Without a quantitative assessment of potential emissions, there is no reliable way to determine whether Region 2's assessment is reasonable or whether mitigation measures can realistically be expected to reduce impacts.

[15] Section 4.2.5, page 4-14, of the Engineering Evaluations Appendix (F)

- **Water Impacts**: Water consumption can be evaluated both qualitatively and quantitatively. Water can be a lost resource if water from an aquifer is wasted or conversely as a gained resource if contaminated water is treated and re-injected into the aquifer for beneficial use. In addition, water is consumed to produce electricity and manufacture consumables that may be used during remedial activities. Given the substantial energy requirements associated with the proposed remedial alternatives and DMM scenarios, there are likely to be significant water requirements associated with the generation of electricity for the sediment and wastewater treatment facilities and the generation of treatment materials. The FFS fails to address any aspect of water consumption associated with any of the remedial alternatives even though USEPA guidance (USEPA 2012b) specifically includes water metrics in the quantification of a project's environmental footprint.
- **Ecological Impacts**: Ecological impacts include adverse effects such as: introduction of invasive species, changes in ecosystem structure or shifts in the geographic distribution and extent of major ecosystem types, disturbance to soil and surface water bodies, and destruction of habitats. These impacts should be evaluated along with the positive ecological effects of site remediation.

  The FFS addresses potential adverse environmental impacts associated with the various remedies in multiple sections (e.g., Sections 3.4.4, 3.5, 4.2.3, and 4.3.3 of the Engineering Evaluation [Appendix F] and throughout Section 5.2 of the main report). Although the FFS addresses potential effects to a variety of species, including fish (Section 3.4.4.2), benthic invertebrates (Section 3.4.4.3), and birds (Section 3.4.4.4), and critical habitat types, including wetlands (Section 3.4.5.2), mudflats (Section 3.4.5.3), and subtidal shallows (Section 3.4.5.4), it includes minimal quantification of the potential adverse effects and concludes that losses will be temporary and will scale based on project duration and volume dredged (Table 5-4 of FFS). There is no attempt to quantify the extent to which adverse effects scale based on sediment volume, level of impact, and time.

  In addition, the evaluation of different DMM scenarios in Section 4.3.3 of the Engineering Evaluations (Appendix F) is focused, primarily, on the area of Newark Bay directly affected by the placement of the confined aquatic disposal (CAD) cells. Quantification of impacts is limited to delineating the CAD cell areas for each of the different sediment removal alternatives. Potential adverse impacts to upland areas associated with DMM scenarios B and C are minimized because impacts are "likely to be limited to urban and industrial neighborhoods with much less likelihood for native habitat disturbance."[16] In order to mitigate for potential adverse effects related to dredging activities and the CAD cell, the FFS indicates that compensatory mitigation will be required to offset temporary impacts (i.e., dredging) at an offset ratio of 1:1 while an offset ratio of 3:1 will be required to offset permanent impacts related to the CAD cell (Section 3.5 of the Engineering Evaluations Appendix). No scientific basis (i.e., appropriate scaling of mitigation to level of injury) for the compensatory mitigation referenced in the FSS was provided by Region 2 and, as such, this evaluation does not provide a transparent basis for determining the appropriate level of compensatory mitigation.

[16] Section 4.3.3, page 4-20, of the Engineering Evaluations Appendix (F)

Another important concern for sediment remediation is the release of dredged materials from spills or accidents. Although the FFS acknowledges that sediment removal "may result in short-term adverse impacts to the river including exposure of the water column, fish, and biota to contaminated sediments due to resuspension"[17], Region 2 fails to quantify the potential extent of those adverse effects. In addition to the unavoidable resuspension and mobilization of previously buried COCs due to the physical disturbance of dredging, there are risks of large scale accidental rerelease of those materials during sediment processing. For example, dredge material management protocols adopted during the environmental dredging of the Duwamish Waterway in 2004 were inadequate and resulted in the release of sediments containing elevated concentrations of PCBs into the waterway. Following sediment removal, the residual sediment concentrations at the site exceeded the maximum allowed limits and were several times higher than what was predicted prior to dredging.[18] In the FFS, Region 2 fails to address, qualitatively or quantitatively, the potential risks of accidental releases of dredged material back into the river or adjacent upland areas. Consequently, the FFS does not provide a transparent view of the potential health risks following remediation.

Overall, the FFS provides minimal quantification of potential ecological impacts associated with each remedial alternative. The potential impacts associated with the various sediment removal alternatives are assumed to scale based on project duration and volume dredged but the nature of that relationship is not explored. Given the large differences in sediment volume and project duration, that range of ecological impacts among the different removal alternatives is likely to be large, but it is not quantified. In addition, the risks of ecological impacts associated with long-range transport of the dredge material and the extent of terrestrial habitat disturbance required for upland disposal of dredged material is not addressed.

- **Resource Consumption**: Consumption of resources that are not specifically identified in other metrics, such as landfill space, topsoil, and backfill/cap material also can be an important metric. The benefits of capping or backfilling to manage dredge residuals are discussed in Section 2.2 of the Engineering Evaluations (Appendix F). It describes, in general terms, the physical characteristics of the material but does not consider the potential impacts associated with obtaining and transporting the volume of clean material required for the engineered cap or backfill. Similarly, the evaluation of short-term effects in Section 5.2 of FFS does not address these impacts either. The Cost Estimates (Appendix H) provide the following preliminary total estimate of clean fill material for backfill, mudflat restoration, and shoreline restoration:

[17] FFS Section 5.2.4, p. 5-53
[18] http://community.seattletimes.nwsource.com/archive/?date=20040610&slug=duwamish10m

Table 3. Estimated Volume of Clean Fill Material Needed for Restoration Activities

	Alternative 2	Alternative 3	Alternative 4
Backfill material	1,800,000 cy	2,700,000 cy	N/A
Mudflat reconstruction and restoration	915,000 cy	203,000 cy	103,500 cy
Shoreline reconstruction or bank armoring	30,000 cy	192,000 cy	92,000 cy
Engineered cap	N/A	2,600,000 cy	930,000 cy
Total:	**2,745,000 cy**	**5,695,000 cy**	**1,125,500 cy**

The volumes specified for the various remedial alternatives readily demonstrate that the different alternatives have substantially different clean fill requirements; however, the FFS does not include any assessment of the impacts (ecological or social) associated with obtaining or transporting fill or dredged materials. Similarly, there is no quantitative or qualitative assessment of the impacts associated with obtaining and transporting the other chemical and earthen materials that appear to be required to treat and stabilize the sediments as described in DMM Scenarios B and C.

- **Worker Safety**: Worker safety/accident risk is the risk of fatality or injury of carrying out a specific task of a remedial activity. The guiding principle of any activity undertaken by USEPA is to "operate safely". Therefore, worker safety is paramount. During remedial action operations, higher risk activities include working around heavy equipment and machinery, and transportation. Several organizations (including Automobile Transport Statistics, Airplane Transport Statistics, Railroad Transport Statistics, and Labor Statistics) provide statistics of both fatalities and injuries that occur during various remediation activities. Section 4.2.4 of the Engineering Evaluations Appendix and the evaluation of short-term effects of each remedial alternative in Section 5.2 of the FFS discuss the potential for accidents and risks to workers at the sites. Both sections qualitatively describe some of the risks involved and indicate that those risks will be minimized by proper health and safety plans. However, the FFS fails to quantitatively evaluate potential worker safety risks associated with any of the remedial alternatives or DMM scenarios. If proper health and safety plans are considered in evaluating worker safety, likewise, it is appropriate to consider institutional controls in evaluating health and safety associated with contaminant concentrations, however, these controls and comparisons are not included as part of the human health risk assessment and, therefore, stakeholders are not provided with a clear and transparent view of the overall effects of the remedy.
- **Community Impacts**: Community impacts are local disturbances and health and safety issues caused by remedial activities, such as: noise; traffic issues, including accidents during transportation; odor; dust; and emissions of VOCs and other contaminants. Section 4.2.6 of the Engineering Evaluations Appendix provides a list of potential community impacts associated with the remedial alternatives including the following:
  - Adverse impacts on in-water recreational and commercial navigation
  - Impairments to views of the river for residents along the river
  - Disruption of waterfront festivals and parks

- Increased vehicular traffic near an upland sediment processing facility
- Increased in-water vessel traffic could affect ground transportation due to bridge openings
- Potential odors and air quality impacts could adversely impact recreational activities along the river
- Elevated noise levels from traffic and machinery, particularly during evening and night hours
- Artificial lighting effects along the river due to 24-hour operations.

Despite providing a list of potential community effects, no rigorous quantification of the types of activities and numbers of vehicle, train, and barge miles required for each of the remedial alternatives was conducted by Region 2. Instead, Section 4.2.6 in the Engineering Evaluations Appendix and the evaluation of short-term effects in Section 5.2 of the FFS indicate that mitigation measures can be deployed to reduce the magnitude of these community effects. However, the FFS does not specify the scale of the activities required and the extent to which mitigation measures will offset the potential effects. USEPA specifically identifies an HIA as an approach to evaluate these impacts; however, an HIA was not included as part of the FSS. As such, the FFS does not provide a transparent view of the potential impacts of the remedial alternatives to the community.

Natural remediation, ecological enhancements, and/or monitored natural recovery can provide greater benefits than the traditional remedial alternatives evaluated in the FFS (i.e., dredging and capping). Typically, remedial technologies provide environmental relief through source control or removal of residual contaminants to acceptable levels. The ability of the remediated resource, particularly surface soil, surface water and sediments, to return to a pre-release functional level is seldom addressed in the remedial process. However, the use of ecological enhancement techniques can provide additional benefits such as improvement of instream cover for fish and macroinvertebrates following sediment excavation. Such alternatives can be cost-effective for returning the resource to a productive capacity that might exceed that achieved following simple remediation of the impacted media. For example, habitat enhancement measures can mitigate for common stressors such as sediment erosion/deposition, mitigation of nonpoint source pollutants (e.g., nutrients), and regional habitat loss. As community acceptance is one of the nine criteria used in selecting a remedy (40 CFR 300.430), such measures would receive high marks at sites where local stakeholders are actively involved in the remedial process.

Examples of environmental, economic, and public benefits not quantified in the FFS include the following:

- Improving conditions for wildlife – Both natural remediation technologies and end use plantings can be attractive to wildlife, potentially providing significant new habitat or restoring lost or damaged habitat.
- Biodegradation of environmental contaminants – Natural remediation technologies enhance both aerobic and anaerobic biochemical degradation of various contaminants,

including volatile organic compounds, polynuclear aromatics, and various other hydrocarbons, as well as some pesticides.

- Enhancing natural attenuation/ biodegradation remedies – As a component of some more complex remedies, natural remediation technologies can serve to facilitate attainment of specified remediation goals via mitigation of effects from physical and/or nonpoint stressors.
- Controlling sediment and erosion – Both natural remediation technologies and end use plantings, once established, reduce sediment transport and soil erosion from storm events due to stabilization from plant roots. This provides both environmental and social benefits because it prevents degradation of aquatic communities and stabilizes stream and river banks.
- Sequestration of carbon – Both natural remediation technologies and end use plantings can result in net sequestration of atmospheric carbon dioxide, which reduces greenhouse gases to mitigate global warming.
- Minimizes environmental exposures – In situ natural remediation technologies reduce the need to excavate and haul impacted sediment. Excavation and hauling potentially creates additional exposure pathways during the movement of the sediment, thereby increasing environmental and human health risks.
- Improves environmental stability – In situ natural remediation technologies avoid disrupting the waterway, thereby improving the stability of the local ecosystem.

4 NEBA and its Application to the FFS

Net environmental benefit analysis (NEBA) has been identified by USEPA as an important decision-making tool in the Superfund program (USEPA Science Advisory Board [SAB] 2009). In addition, the Region 2 Superfund program supports the adoption of 'green site assessment and remediation,' which is defined as the practice of considering all environmental impacts of studies, selection and implementation of a given remedy, and incorporating strategies to maximize the net environmental benefit of cleanup actions. Other USEPA Regions (i.e., Region 4) have also committed to prioritizing and emphasizing green remediation approaches and maximizing the net environmental benefit of Superfund cleanups (USEPA 2013).

USEPA and other federal agencies are using NEBA to guide remedial decision-making, including recent remediation work on the Kalamazoo River[19]. The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Coast Guard identify the use of NEBA to evaluate opportunities for no net loss of resources and habitats during oil spill response planning (Aurand et al. 2000; NOAA 2011), and has used NEBA to evaluate environmental responses on the Mississippi River (Aurand et al. 2004) and the Gulf of Mexico (NOAA 2011). The U.S. Army Environmental Center (USAEC) also identifies NEBA as an important tool for assessing natural resource injury (USAEC 2005).

4.1 What is NEBA?

In a site remediation context, a NEBA is a framework for comparing site remedial alternatives that includes the incorporation of a broad array of human, social, economic and environmental metrics to demonstrate differences among the various remedial alternatives with regard to human and ecological chemical and physical risk profiles; community and socioeconomic benefits and costs; ecological habitat value; human recreational value effects; GHG emissions (i.e., carbon footprinting); and remedial costs. The formalized framework for NEBA, as recognized by the USEPA Science Advisory Board (USEPA SAB 2009), is provided in Efroymson et al, 2004.

A NEBA framework can be used to demonstrate the net positive or negative changes in ecosystem service (ecological, social, and economic) values between various remedial alternatives. A NEBA framework also is useful for assessing and comparing the sustainability of different remedial alternatives through the quantification of impacts over time associated with the implementation and long-term performance of each alternative (Efroymson et al, 2004; Nicolette et al, 2013).

NEBA has been shown to be an objective approach for evaluating the risks, benefits, and tradeoffs associated with different alternatives for remediation and environmental restoration work (Efroymson et al, 2003, 2004; USEPA SAB 2009; NOAA 2011). The NEBA approach is consistent with USEPA risk management objectives (USEPA SAB 2009) and provides a framework to help USEPA comply with its policy, guidance, and direction, particularly with large

[19] See http://www.epa.gov/enbridgespill/pdfs/20121003-cover-letter-re-proposed-order.pdf

scale remedial programs where the benefits and impacts of potential alternatives are significant and need to be evaluated closely.

A NEBA framework incorporates quantified analyses that consider changes in various metrics that influence ecosystem service (ecological, social, and economic) values which, in turn, help to highlight potential differences between remedial alternatives. NEBA is a systematic process for quantifying and comparing the benefits and costs among competing alternatives; it does not rely solely on monetization but rather also includes non-monetary environmental metrics. A NEBA framework can be useful for assessing and comparing the sustainability of remedial alternatives through the quantification of impacts over time from each remedial alternative (Nicolette et al, 2013). A NEBA framework for comparing each remedial alternative described in the FFS should include, among others, the incorporation of a broad array of metrics to demonstrate associated changes in human and ecological chemical and physical risk profiles; community and socioeconomic issues; ecological habitat value; human recreational value effects; GHG emissions (i.e., carbon footprinting); and remedial costs.

NEBA is similar to cost-benefit analysis (CBA), which USEPA and other federal agencies have used for decades to support decision-making. NEBA and CBA both consider time accumulated service flows (i.e., benefits and costs over time); since these benefits and costs occur over varying time frames, they can be normalized to their net present value using a discount rate. The NEBA approach, however, moves beyond the traditional CBA approach by demonstrating environmental stewardship and sustainability through the quantification of environmental metrics. A NEBA for a contaminated site typically involves comparison of several management alternatives that may include: (1) leaving the contamination in place; (2) physically, chemically or biologically treating COCs; (3) improving ecological value through restoration alternatives that do not directly focus on removal of chemical contamination; or (4) a combination of those alternatives (Efroymson et al, 2004). Understanding these benefits, and how they may change among remedial actions, maximizes benefits to the environment and the public while managing costs and site risks.

NEBA typically considers a broader range of environmental effects than the traditional remedial investigation/feasibility study (RI/FS) or Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) risk assessment process. Typically, RI/FS and RFI work consider only the remedial alternatives' ability to limit exposure and human risks from a contaminant release. The effects on other ecosystem services (e.g., human use value, ecological service value) associated with implementation of the work are typically not considered in the standard RI/FS or RFI remedial assessment process. A NEBA shows formally the positive and negative effects on ecosystem services[20] and/or surrogate metrics associated with a remedial action in relation to the incremental changes in risk. By considering the effects on all services provided by the site, the net effects of remedial and reuse alternatives on all service flows are considered, including any potential loss of services. In some cases, for example, a remedial action or reuse alternative may destroy or significantly degrade the ecological landscape and achieve little or no reduction in ecological or human health risk. In simpler terms, NEBA can be used to determine, for each remedial alternative, whether "the cure is worse than the disease."

[20] A NEBA can also be referred to as a net ecosystem service analysis (NESA) (Nicolette et al., 2013).

4.2 NEBA Support in Decision-Making Mandated by USEPA

NEBA has been conducted by several federal agencies, including USEPA because it provides an approach for balancing the risks, benefits and tradeoffs associated with competing remedial alternatives in a transparent manner by which all stakeholders can understand the Agency's decisions. The merits of using a NEBA framework (based on formally quantified metrics) for transparent decision-making associated with site remediation, compensatory restoration and ecosystem service tradeoffs have been discussed by various authors (Efroymson et al, 2003; 2004; Colombo et al, 2011; Nicolette, et al 2013). Additional case study references and NEBA framework papers are listed in **Appendix B**.

The need for transparency in decision-making by the USEPA is made apparent in the 1995 EPA Risk Characterization Program memorandum by Carol Browner[21], former USEPA Administrator (USEPA SAB 1995, **Appendix C**). In the Browner memorandum, the core values that the USEPA is striving to achieve are transparency, clarity, consistency and reasonableness. These same core values have been repeated often in Agency guidance from the 1990s to the present.

Excerpts from Memorandum Written by Former USEPA Administrator, Carol Browner (USEPA SAB, 1995)
*"First, we must adopt as values **transparency** in our decision-making process and **clarity** in communication with each other and the public regarding environmental risk and the uncertainties associated with our assessments of environmental risk."*
*"Second, because **transparency** in decision-making and **clarity** in communication will likely lead to more outside questioning of our assumptions and science policies, we must be more vigilant about ensuring that our core assumptions and science policies are **consistent** and comparable across programs, well grounded in science, and that they fall within a "zone of **reasonableness**." While I believe that the American public expects us to err on the side of protection in the face of scientific uncertainty, I do not want our assessments to be unrealistically conservative. We cannot lead the fight for environmental protection into the next century unless we use common sense in all we do."*

4.3 Application of NEBA by USEPA and Federal Resource Agencies

A NEBA approach has been used by USEPA and other federal natural resource agencies to demonstrate transparency and clarity in regulatory evaluations. Several examples are provided in **Appendix B**, and include the following:

- NEBA has been used by NOAA and USEPA to support remedial decision-making since 1989; NOAA (2011) describes several examples of qualitative and quantitative applications of NEBA.

[21] Memorandum from former USEPA Administrator Carol Browner to assistant administrators, associate administrators, regional administrators, general counsel, and the inspector general.

- NEBA has been used by USEPA Region 2 to evaluate remedial options at the Woodlands Superfund Site.
- NEBA was used by USEPA Region 6 to evaluate remedial alternatives at orphan sites located in Texas.
- USEPA funded pilot studies to evaluate the use of NEBA for analysis of ecological and economic metrics associated with site cleanup in the Superfund program.
- NEBA has been studied as a decision-making tool by the USEPA Science Advisory Board (USEPA SAB 2009) and by NOAA (2010).
- NEBA methods were incorporated in 1998 by the USEPA Regional Response Team (Region 9) for the San Francisco Bay Ecological Risk Assessment.
- NEBA has been used by USEPA Region 5 to address environmental restoration challenges on the Mississippi River and at Isle Royale National Park on Lake Superior.
- A NEBA approach was integrated into emergency response decision-making by USEPA and NOAA as part of the Deepwater Horizon incident in 2010.
- NEBA was used by USEPA Region 5 to evaluate remediation options addressing a petroleum release on the Kalamazoo River in 2010.
- NEBA was used to support environmental restoration decision-making by NOAA in the Gulf of the Farallones and Cordell Banks National Marine Sanctuaries in 2012.
- NEBA has been identified by the Interstate Technical and Regulatory Council (ITRC) as a valuable decision-making tool in ITRC technical guidance addressing site remediation (ITRC 2004, 2006, and 2011).

As referenced above, NEBA was used by Region 2 (see **Appendix B**: Reference 6) at the Woodlands Superfund site located in New Jersey. Region 2 applied NEBA to assess the ecological impacts of the preferred remedial action. The NEBA demonstrated that while the preferred remedy (pump and treat) would cause injury to the ecosystem, a lower cost alternative remedy (air sparge/vapor extraction) would not cause injury and would save $87 million in remedial costs. The Record of Decision (ROD) was subsequently changed by Region 2 to the new alternative supported by the NEBA. Region 2 deemed the application of NEBA as successful in an agency-published report describing the remedial decision at the Woodlands Superfund site (**Figure 10**):

Region 2 Woodlands, NJ Route 72 Route 532	5/16/90 7/1/99 (ROD-A)	12/93 7/1/99	PRP	Ground water	State supported the change. The site is located in a rural area and the local population supports the remedy change.	Fed = 150 hours Contr. = $0 Est'd Savings = $ 87.6 M
	Type of Change: From - ground water pump and treat; To - air sparging/soil vapor extraction and natural attenuation.					
	Factual Basis: BTAG memo indicated that the ground water pump and treat system would dewater the nearby wetlands. In addition, during remedial design, the PRP successfully identified alternatives that would meet ROD objectives at much lower cost.					

Figure 10. Region 2 Remedy Update Based upon NEBA.

4.4 Using NEBA to Improve Remedial Evaluation in the FFS

It is evident from the FFS that Region 2 did not fully consider the environmental impacts, health risks and socio-economic consequences of both the short-term and the long-term impacts of sediment removal, capping, and dredged material handling and disposal in the FFS Study Area. Each certain or possible impact should have been included in a formal analysis using a NEBA framework. The potential short-term and long-term environmental risks are listed in **Table 4**.

A tableau for organizing a NEBA is conceptually presented in **Table 5** and can include a variety of key metrics. The NEBA compares the different alternatives using various metrics to evaluate the effect of each remedial alternative over time with respect to each particular attribute (sensitive populations and demographic groups also should be evaluated with respect to those attributes). For each metric the remedial alternative would need to be evaluated using a consistent timeframe and duration. Discounting could be employed, although for sensitivity analysis, the discount rate could be varied.

As written, the FFS does not provide sufficient information to support and conduct a credible or detailed quantitative NEBA as important metrics are not considered, evaluated and/or quantified as demonstrated in this document. Significant additional work is needed by Region 2 to provide a scientifically-sound basis for remedial decision-making. Specifically, and per USEPA guidance, the FFS should provide complete transparency and consistency in the evaluation and decision-making process so that stakeholders and the public are aware of the full extent of potential social, health, and environmental impacts of the proposed remedy.

The FSS provides insufficient information to demonstrate that Region 2 adequately and transparently considered important factors with environmental, social and economic implications as outlined in USEPA policy, guidance and direction. Specifically, the FSS did not demonstrate (1) a preference for green remediation or a sustainable solution; (2) the environmental footprints of the various remedial alternatives; (3) the environmental and social risks associated with the various remedial alternatives; and (4) the consideration of net environmental, economic and social benefits. As it stands, the FFS is incomplete and should not be considered in its current state for decision-making purposes.

5 Preliminary Carbon Footprinting Analysis of Remedial Alternatives in the FFS

To illustrate how a NEBA framework, using quantified values, can inform remedial decision-making, ENVIRON conducted a preliminary carbon footprinting exercise comparing the remedial alternatives and DMM scenarios. There is no indication in the FFS that this work was performed by Region 2. The approach followed by ENVIRON to perform the greenhouse gas emissions and carbon footprinting analysis is provided in this section, followed by a presentation of the preliminary results.

5.1 USEPA Mandate to Minimize Greenhouse Gas Emissions

When emitted, GHGs are capable of trapping heat in the atmosphere. GHGs include CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. GHG emissions are the result of both anthropogenic (e.g., fossil fuel use, land use changes, agriculture) and biogenic sources (i.e., plants, animals, or microorganisms [USEPA 2011b]). The relative effectiveness of each GHG to trap heat in the atmosphere is expressed in terms of Global Warming Potential (GWP). That is, on a pound-for-pound basis, the GWP reflects how long each GHG remains in the atmosphere and how strongly it absorbs energy. GHG emissions are typically measured in terms of carbon dioxide equivalent (CO_2e), which is the product of the mass of a given GHG and its specific GWP.

There is international scientific consensus that anthropogenic emissions of GHGs have and will continue to contribute to changes in the global climate. Although there is uncertainty concerning the magnitude, rate, and ultimate effects of this change, it is generally accepted that climate change will result in significant adverse environmental impacts. For example, climate change may impact crops (yield reduction from flooding and drought), oceans (sea level rise, ocean acidification), oceanic changes due to Arctic ice melt, energy production and delivery (disruptions in service), forests (wild fires), water cycle and water demand, and human health (worsened air quality, heat waves, climate-sensitive diseases; USEPA 2014b). In fact, in December 2009, USEPA issued the Endangerment Finding under Section 202(a) of the Clean Air Act concluding that GHGs in the atmosphere threaten the public health and welfare of current and future generations (USEPA 2009b).

The current administration and USEPA have clearly stated the importance of addressing climate change. On February 18, 2012, the Council on Environmental Quality (CEQ) of the Executive Office of the President (EOP) issued a memorandum documenting draft guidance for evaluating the effects of climate change and GHG emissions on projects subject to the National Environmental Policy Act (NEPA; EOP 2010). In the draft guidance, the CEQ suggests that projects subject to the NEPA process take into consideration “(1) the GHG emission effects of a proposed action and alternative actions; and (2) the relationship of climate change effects to a proposed action or alternatives, including the relationship to proposal design, environmental impacts, mitigation and adaptation measures.” In June 2013, the Executive Office of the President issued The President’s Climate Action Plan (EOP 2013), in which President Obama identified several measures for achieving his 2009 pledge to reduce America’s GHG emissions by 2020 to approximately 17 percent below 2005 levels, including cutting carbon pollution in

America. Gina McCarthy, the Administrator of USEPA, recently stated that climate change is the biggest health issue facing the United States (Chumley 2014). In addition, USEPA has been implementing initiatives and standards in an effort to achieve GHG emission reductions, including vehicle GHG rules, New Source Performance Standards (NSPS) for power plants, and a reduction of USEPA's own carbon footprint by 25% by 2020 (USEPA 2011c). It should also be noted that New Jersey implemented the Global Warming Response Act in 2007 that requires stabilization of statewide GHG emissions to 1990 levels by 2020 and an 80% reduction of GHG levels below 2006 emissions by 2050. Consideration of a project's climate change impact, therefore, is essentially an analysis of a project's contribution to a cumulatively significant global impact through its emission of GHGs.

5.2 Calculation of Carbon Footprints

A carbon footprint is the quantification of the amount of CO_2 and other GHGs that are emitted as a result of a defined population, activity, or system. More specifically, for the FFS Study Area, a carbon footprint is an estimate of the direct and indirect CO_2 emissions associated with the remedial alternatives and DMM scenarios. A number of different guidance protocols can be used to develop a carbon footprint, including, but not limited to, the GHG Protocol developed by the World Resources Institute (WRI 2004) and the General Reporting Protocol developed by The Climate Registry (TCR 2013). These protocols identify the total GHG emissions as being a combination of the following:

- Scope 1. Emissions from direct anthropogenic sources (e.g., equipment used onsite);
- Scope 2. Emissions from the generation of electricity, heat, or steam by a separate, offsite entity purchased and/or used onsite; or,
- Scope 3. Emissions from other indirect anthropogenic sources (e.g., employee trips, contracted waste disposal).

A schematic depicting Scope 1, Scope 2, and Scope 3 sources of GHG emissions is presented in **Figure 11**.

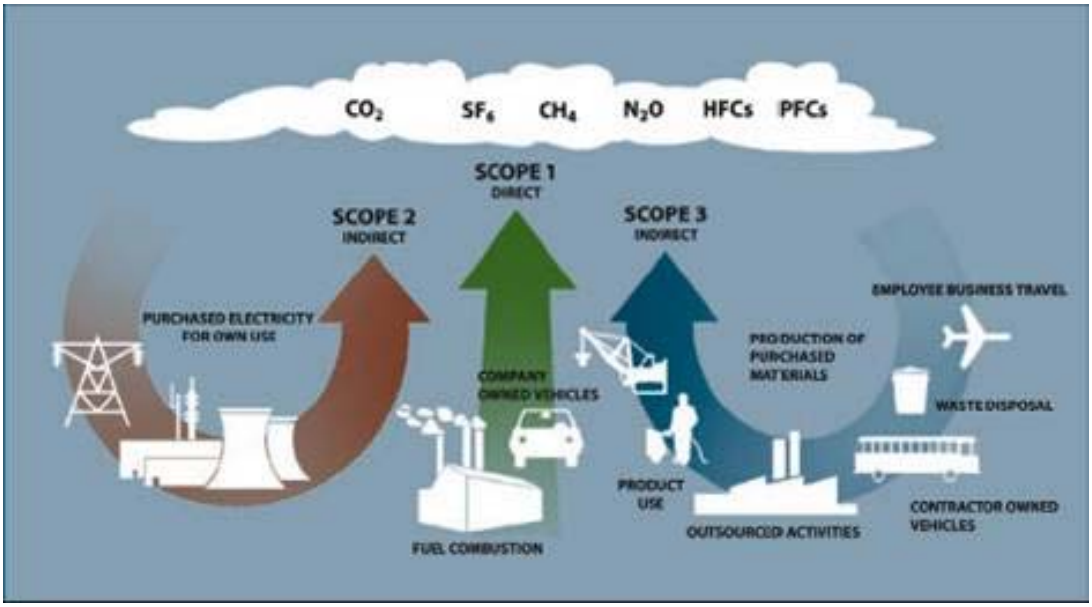


Figure 11. Potential Sources of Scope 1, 2, and 3 GHG Emissions (Source: USEPA)

The project-specific activities associated with the remedial alternatives and DMM scenarios were adopted from Appendix H (Cost Estimate) in the FFS and categorized by scope, in accordance with USEPA and TCR guidance (**Table 6**):

- Scope 1 (Direct). Mobile and stationary sources, including marine vessels, other off-road mobile sources, fuel-fired investigation and dredging equipment, and on-site thermal treatment.
- Scope 2 (Indirect). The generation of electricity purchased for use at the upland support/processing facility.
- Scope 3 (Indirect). Transport of waste to offsite locations, import of raw materials, and off-site thermal treatment.

The preliminary carbon footprint for each remedial alternative and DMM option, expressed in terms of CO_2e, was calculated based on project-specific Scope 1 and Scope 3 activities. Emissions from Scope 2 sources and from several indirect activities (e.g., transportation of employees to and from the work site and equipment mobilization and demobilzation) were not included in the preliminary calculations. All of the direct and indirect activities associated with Scope 1, 2 and 3 sources would need to be identified by Region 2 to fully evaluate the carbon footprint associated with the different remedial options and the Agency's preferred remedial alternative.

The parameters describing each activity and source (i.e., harbor craft, stationary sources, rail, trucks and thermal treatment) were obtained from the FFS, and secondarily from the Phase I work for the Lower Passaic River that was completed in 2012.[22] Emission factors that are

[22] Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area, prepared by Tierra Solutions, Inc. for USEPA Region 2, March 20, 2013.

widely accepted and publically available from scientific literature were used to calculate GHG emissions (**Appendix D**). In total, nine different scenarios were evaluated (3 remedial alternatives each with 3 DMM scenarios). Remedial Alternative 1, the no action alternative, was assumed to represent the baseline condition.

As illustrated in **Table 7** and **Figure 12 below**, total expected CO_2e emissions range from more than 1.5 million tons (Alternative 2, DMM Scenario B) to less than 50,000 tons (Alternative 4, DMM Scenario A). Preliminary calculations indicate that remedial Alternative 2 will have higher total expected CO_2e emissions than remedial Alternative 3, which in turn will have higher total expected CO_2e emissions than remedial Alternative 4. Preliminary calculations also indicate that DMM Scenario B will have higher total expected CO_2e emissions than DMM Scenario C, which in turn will have higher total expected CO_2e emissions than DMM Scenario A. The potential environmental impact will be greatest for remedial Alternatve 2 and DMM Scenario B due to the longer duration of the construction work, handling of larger volumes of contaminated material, and off-site thermal treatment.

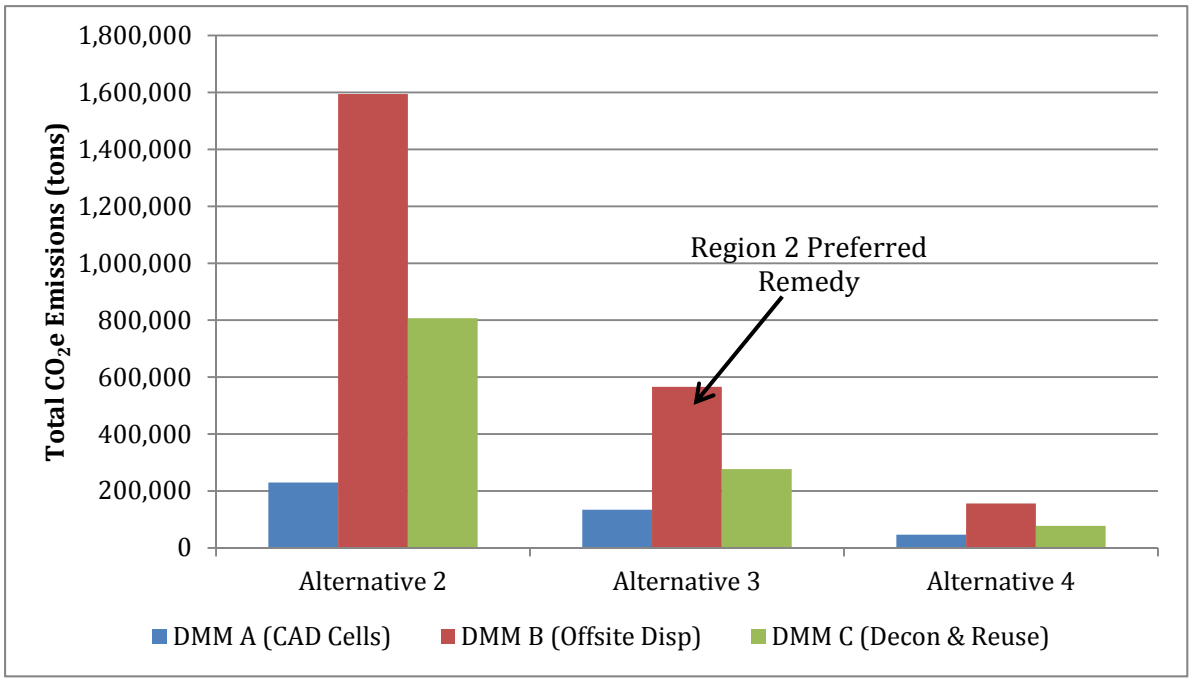


Figure 12. Predicted Total CO_2e Emissions for Each of Region 2's Remedial Alternatives Described in the FFS Study Area

Using 2012 data obtained from USEPA's FLIGHT system, the average annual CO_2e emissions predicted to be generated by Region 2's preferred remedy ranks in the top quartile of all industries in the State of New Jersey that are subject to GHG reporting.[23] Further, for perspective, with one exception (remedial Alternative 2 using DMM Scenario A), the average annual CO_2e emissions for all remedial options exceed the federal government's regulatory

[23] USEPA's Facility Level Information on Greenhouse Gases Tool (FLIGHT). http://ghgdata.epa.gov/ghgp/main.do.

reporting limit of 25,000 metric tonnes (27,600 short tons) of CO_2e per year under the GHG Reporting Rule[24] for covered sources (**Figure 13**).

For additional perspective, under the California Environmental Quality Act (CEQA), the California Air Pollution Control Officers Association (CAPCOA) recommends not only that projects subject to CEQA consider GHG impacts, but also provides guidance on how to set significance thresholds for GHG emissions above which mitigation measures should be considered.[25] As a result of CAPCOA's guidance, California Air Districts including the South Coast Air Quality Management District (SCAQMD) and the Santa Barbara County Air Pollution Control District (SBCAPCD) adopted a CEQA significance threshold of 10,000 metric tons of CO_2e per year.

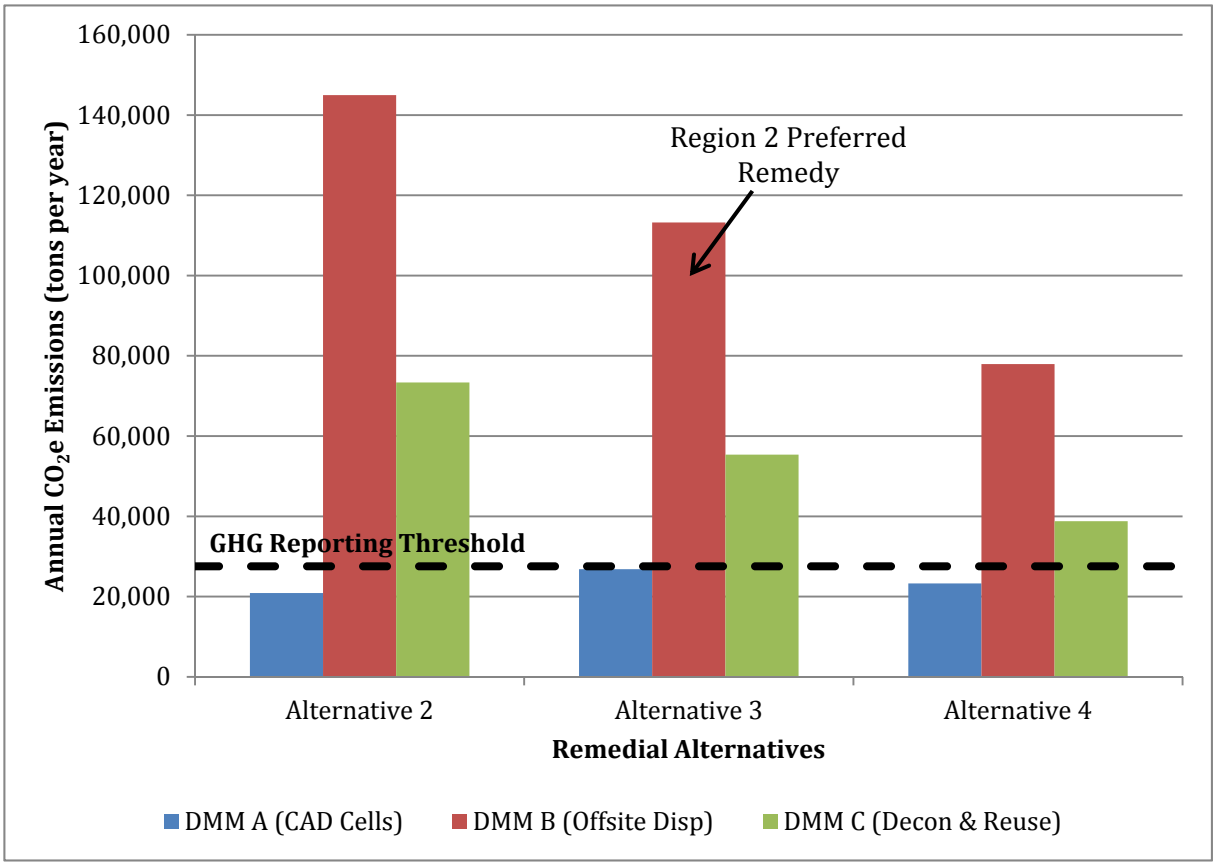


Figure 13. Predicted Average Annual Total CO_2e Emissions for Each of Region 2's Remedial Alternatives Described in the FFS Study Area

With respect to the handling of dredged material from the river, the use of thermal incineration described in DMM Scenario B and DMM Scenario C yields significantly greater CO_2e emissions than DMM Scenario A. The use of truck and rail transportation for offsite disposal described in DMM Scenario B contributes to the significantly higher level of CO_2e emissions than in DMM

[24] Greenhouse Gas Reporting Rule, 40 CFR Part 98.
[25] CEQA & Climate Change, Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act, issued by CAPCOA, January 2008.

Scenario A and DMM Scenario C. Specifically, the following trends in total CO_2e emissions were observed between Region 2's various DMM scenarios (**Figure 14**):

- DMM Scenario A (CAD Cells): Predicted total CO_2e emissions for remedial alternative 2 are nearly double total CO_2e emissions for remedial Alternative 3 and approximatley five times greater than remedial Alternative 4.
- DMM Scenario B (Offsite Disposal): Predicted total CO_2e emissions for remedial Alternative 2 are approximately three times greater than total CO_2e emissions for remedial Alternative 3 and more than one order of magnitude greater than for remedial Alternative 4.
- DMM Scenario C (Local Decontamination and Reuse): Similar to DMM Scenario B, predicted total CO_2e emissions for remedial Alternative 2 are approximately three times greater than total CO_2e emissions for remedial Alternative 3 and more than one order of magnitude greater than for remedial Alternative 4.

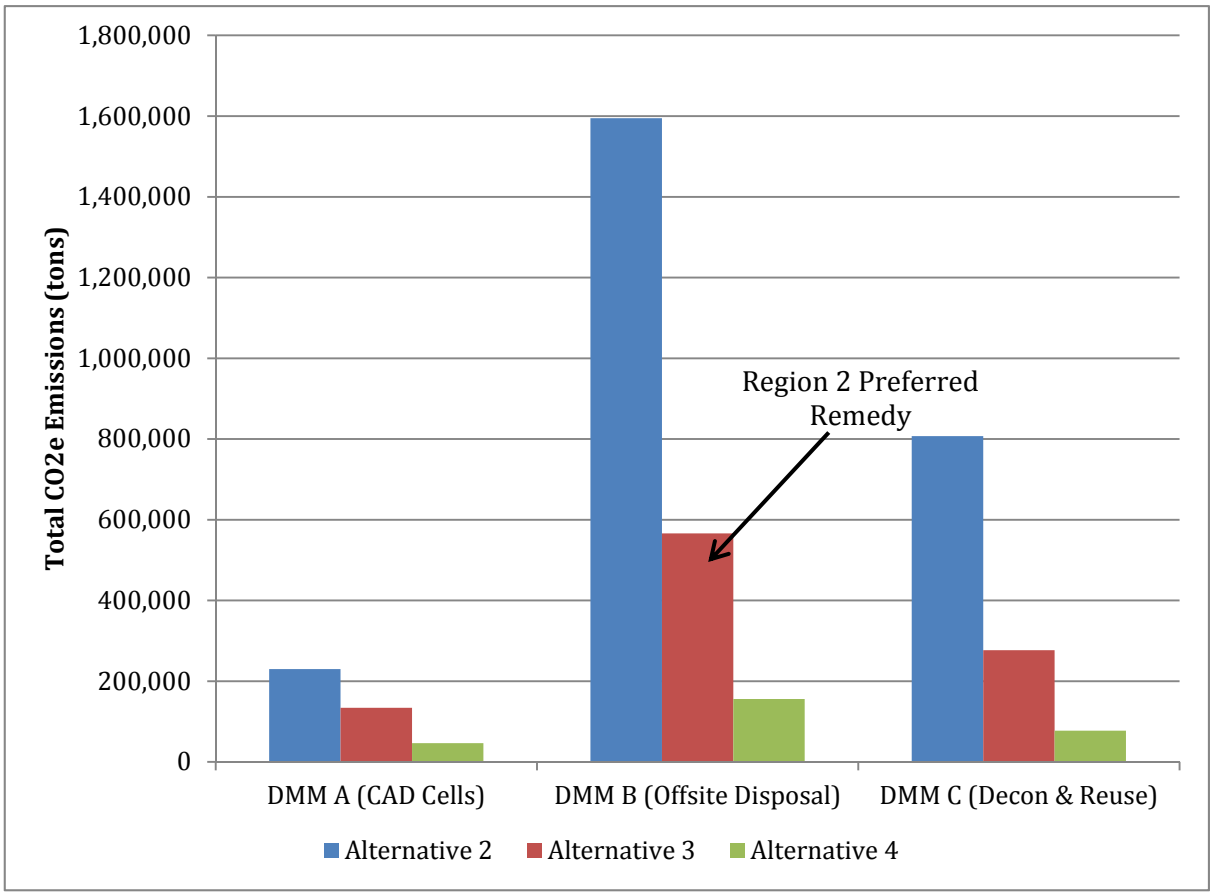


Figure 14. Predicted Total CO_2e Emissions for Each of Region 2's DMM Scenarios Described in the FFS Study Area

The predicted annual average CO_2e emissions follow a similar decreasing trend between the different remedial alternatives, although the estimated percent reduction between the different alternatives is significantly less than predicted total CO_2e emissions. Specifically, the following

trends in total annual CO_2e emissions were identified between Region 2's various DMM Scenarios (**Figure 15**).

- DMM Scenario A (CAD Cells): Predicted annual CO_2e emissions were generally consistent between each remedial alternative and significantly less than DMM Scenarios B and C.
- DMM Scenario B (Offsite Disposal): Predicted annual CO_2e emissions decreased from remedial alternative 2 to remedial alternatives 3 and 4 by approximately 25 percent and 50 percent, respectively, and were generally double the annual emissions predicted for DMM Scenario C.

DMM Scenario C (Local Decontamination and Reuse): Similar to DMM Scenario B, predicted annual CO2e emissions decreased from remedial Alternative 2 to remedial Alternatives 3 and 4 by approximately 25 percent and 50 percent, respectively.

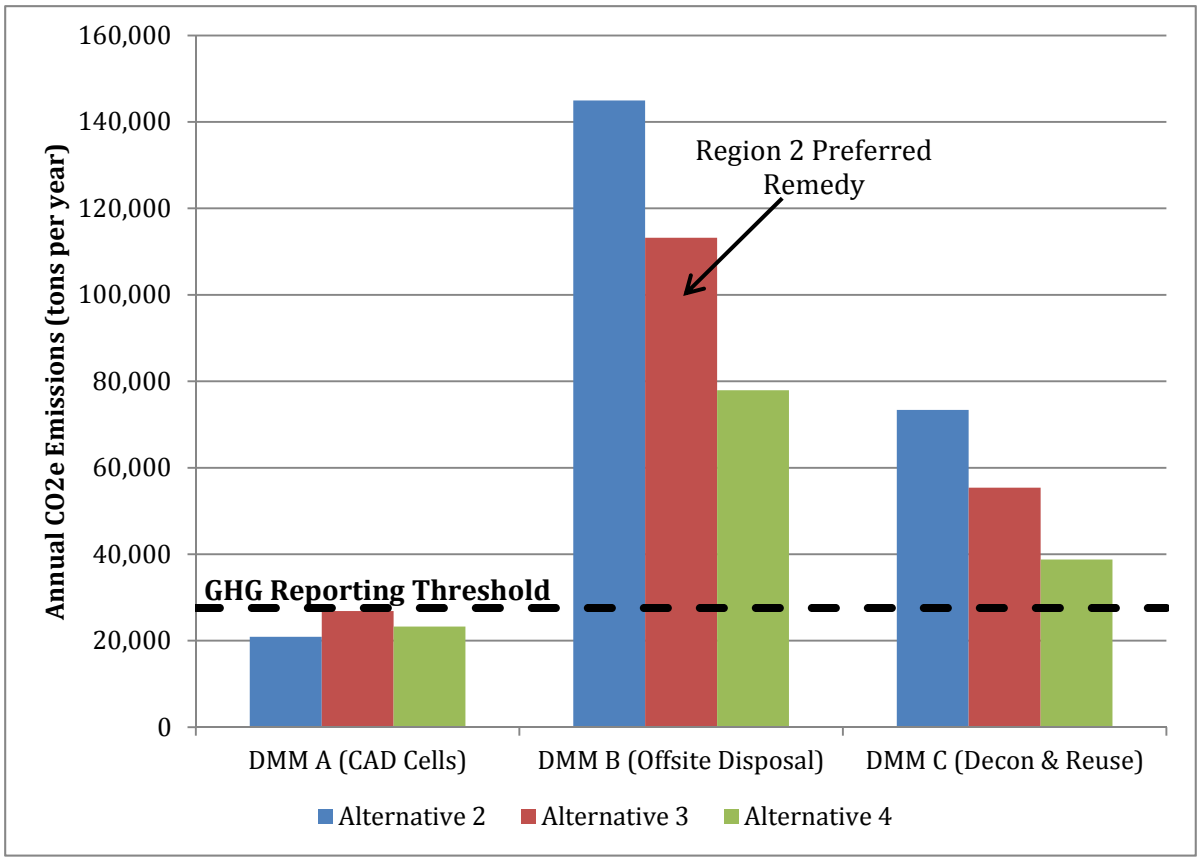


Figure 15. Predicted Average Annual CO_2e Emissions for Each of Region 2's DMM Scenarios Described in the FFS Study Area

ENVIRON's preliminary carbon footprint evaluation presents a conservative estimate of total CO_2e emissions for each of the remedial alternatives and dredged material disposal options presented by USEPA in the FFS. A full-scale carbon footprint analysis that includes additional

Scope 2 and Scope 3 activities not included in ENVIRON's preliminary analysis would result in greater total CO_2e emissions.

Total CO_2e emissions are ranked from lowest to highest in **Figure 16**. The results clearly indicate that each remedial alternative presented in the FFS will exceed the federal reporting threshold benchmark for GHG emissions and have potentially significant environmental impacts. Further, the preferred remedy ranks second highest in average annual CO_2e emissions, represents more than four times the level that would trigger federal GHG reporting requirements for an operational facility subject to the rule, and is in the top quartile of all industries in New Jersey that are required to report GHG emissions.

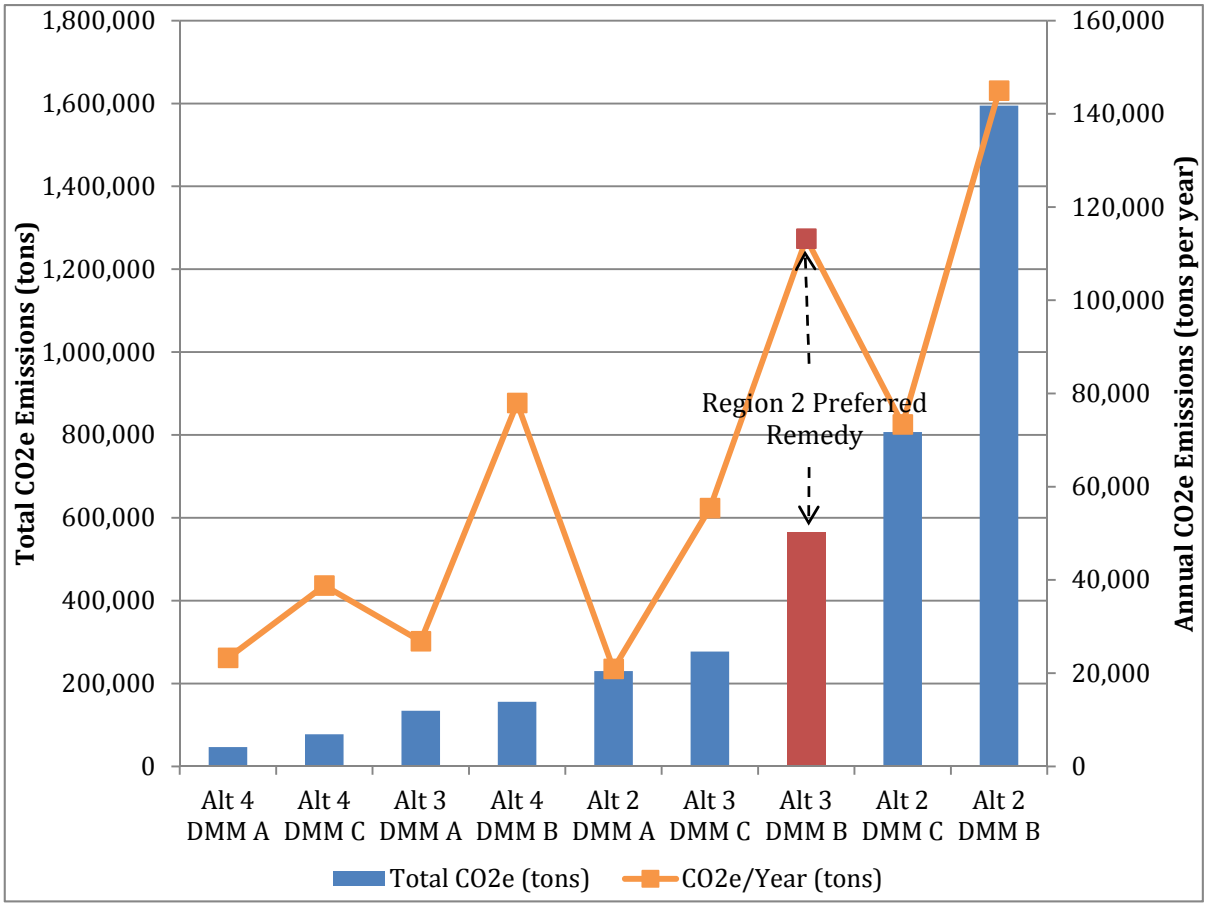


Figure 16. Ranking of CO_2e Emissions for Each of Region 2's Remedial Alternatives and DMM Scenarios Described in the FFS Study Area.

In summary, Region 2 has failed to consider the impact of GHG emissions in the FFS Study Area. It is evident from ENVIRON's preliminary calculations that the potential impacts to the local community and region are not insignificant. As such, and in the absence of a carbon footprint analysis (as well as other comparative environmental impact analyses, i.e., a NEBA) for each of the proposed alternatives, Region 2's selection of a preferred remedial for the FFS

Study Area is premature at this time. All stakeholders would not have a transparent basis for decision-making to evaluate each alternative. The preliminary carbon footprinting quantification exercise comparing the remedial alternatives and DMM scenarios presented here demonstrates that important information relevant to remedial decision-making is absent from the FFS. A NEBA that includes a carbon footprint and GHG emissions analysis is needed as part of a more comprehensive evaluation by Region 2 to identify the remediation strategy that best serves the interests of the public and the environment.

5.3 Calculation of Fine Particulate Matter ($PM_{2.5}$)

To further illustrate how NEBA can inform remedial decision-making, ENVIRON conducted a preliminary analysis of emissions of fine particulate matter associated with each of Region 2's proposed remedial alternatives. Particulate matter is one of USEPA's six criteria air pollutants. Fine particulate matter is comprised of "inhalable coarse particles" (PM_{10}) and fine particles ($PM_{2.5}$) that form when gases emitted from power plants, industries and automobiles react in the air.

According to USEPA, fine particulate matter affects both public health and public welfare[26]:

- Health Effects - Scientific studies have linked exposure to particle pollution to premature death in people with heart or lung disease, non-fatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms.
- Environmental Effects - $PM_{2.5}$ is the main contributor to reduced visibility (i.e., haze); can be carried over long distances before settling and causing increased acidity to lakes and streams, changes to the nutrient balance in coastal waters and large rivier basins, depletion of nutrients in the soil, damage to sensitive forests and croplands, and affects to ecosystem diversity; and, may stain and damage stone and other materials including culturally important objects.

ENVIRON's preliminary evaluation of $PM_{2.5}$ emissions was conducted for the same sources that were evaluated as part of the preliminary carbon footprinting analysis. The input parameters for each activity and source were obtained from the FFS and the Phase I work for the Lower Passaic River completed in 2012 (**Appendix D**). Nine different scenarios were evaluated (3 remedial alternatives, each involving the 3 DMM scenarios). Remedial Alternative 1, the no action alternative, was assumed to represent the baseline condition.

As illustrated in **Table 8** and **Figure 17**, predicted total $PM_{2.5}$ emissions range from more than 6,500 tons (Alternative 2, DMM Scenario B) to approximately 30 tons (Alternative 4, DMM Scenario A). Because $PM_{2.5}$ emissions from the sources that were evaluated as part of this analysis primarily result from mobile sources and the burning of fuels, the treatment and transportation of dredged and raw materials are the primary contributors to overall particulate levels. As such, DMM Scenario A is not expected to generate signficant levels of $PM_{2.5}$. However, the use of thermal incineration either offsite (DMM Scenario B) or at an upland processing facility (DMM Scenario C) is predicted to generate more than 90 percent of the total

[26] http://www.epa.gov/airquality/particlepollution/health.html

$PM_{2.5}$ emissions. Because remedial Alternative 2, DMM Scenario B will generate the largest volume of dredge material for incineration, remedial Alternative 2 will result in the highest emissions of $PM_{2.5}$ (more than 6,500 tons). Remedial Alternatives 3 and 4 are predicted to generate approximately 25 percent and 5 percent, respectively, of the mass of $PM_{2.5}$ generated by remedial Alternative 2.

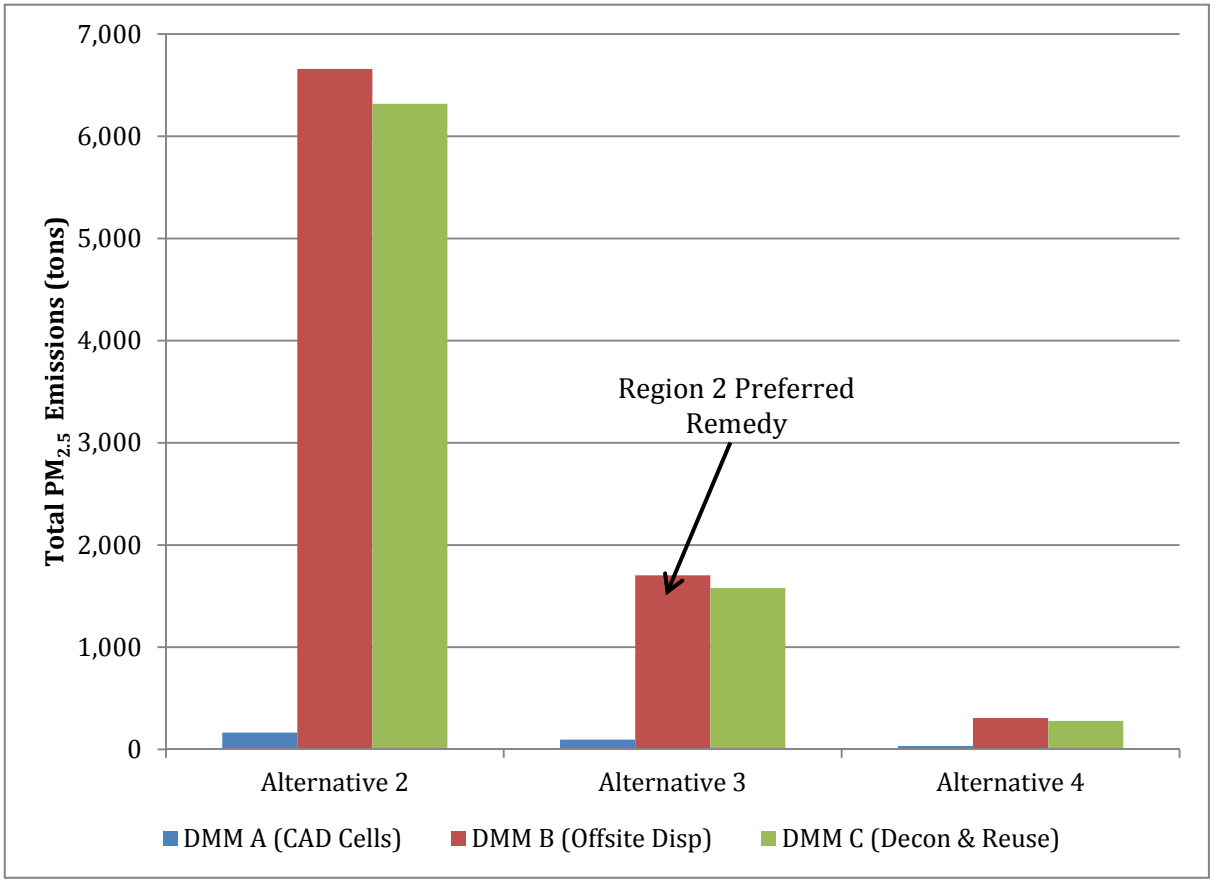


Figure 17. Predicted Total $PM_{2.5}$ Emissions for Each of Region 2's Remedial Alternatives Described in the FFS Study Area.

According to the New Jersey Administrative Code (NJAC, Title 7, Chapter 27, Subchapter 22), a major source is a facility that has the potential to emit more than 100 tons per year (tpy) of $PM_{2.5}$. As a major source of $PM_{2.5}$ emissions, a stationary source (i.e., operating facility) would be subject to Title V permitting requirements. This includes applying for and obtaining a federally-enforceable operating permit, subject to NJDEP and USEPA review and public notice and comment. Sources subject to Title V permitting requirements are often subject to increased monitoring, reporting, and recordkeeping requirements, including stack testing and emissions monitoring. Under NJAC, Title 7, Chapter 27, Subchapter 22, a stationary source with potential $PM_{2.5}$ emissions greater than 250 tpy are subject to Prevention of Significant Deterioration (PSD) requirements under 40 CFR Part 52. Sources subject to PSD are required to evaluate

best achievable control technologies (BACT) and perform air dispersion modeling to assess impacts with respect to the National Ambient Air Quality Standards (NAAQS) as part of the construction permtting process. On an annual basis, predicted average $PM_{2.5}$ emissions for offsite disposal and local decontamination and reuse of dredged material associated with each remedial alternative exceeds the NJDEP major source threshold and the predicted $PM_{2.5}$ emissions from these same waste management scenarios exceeds the PSD threshold for remedial Alternatives 2 and 3 (**Figure 18**).

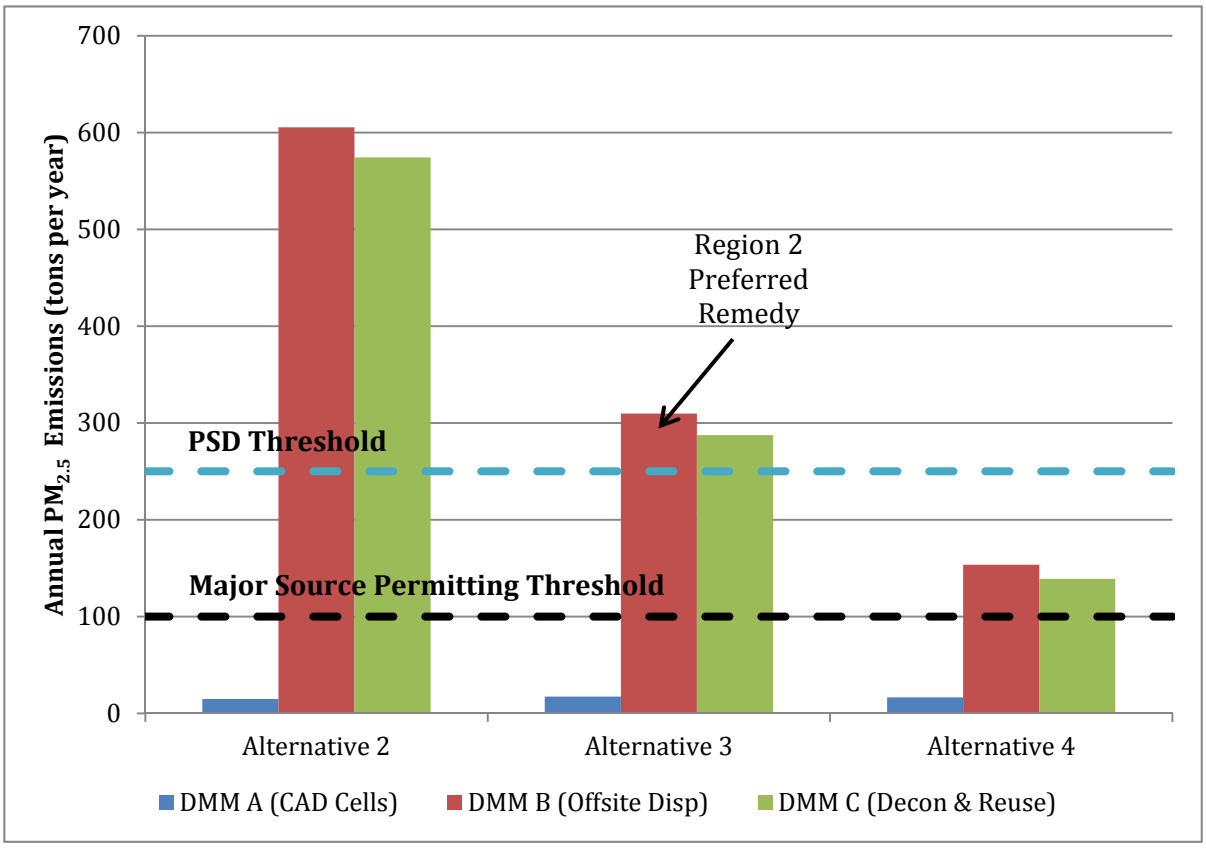


Figure 18. Predicted Annual $PM_{2.5}$ Emissions for Each of Region 2's Remedial Alternatives Described in the FFS Study Area.

The use of thermal incineration described by Region 2 for DMM Scenarios B and C contributes to more than 90 percent of predicted total $PM_{2.5}$ emissions. As such, the use of CAD cells will generate signficantly less $PM_{2.5}$ than the other waste management scenarios. The predicted total and average annual $PM_{2.5}$ emissions for DMM Scenario B are approximately 5 to 10 percent higher than those for DMM Scenario C, primarily due to the offsite shipping of waste material via rail (**Figures 19** and **Figure 20**).

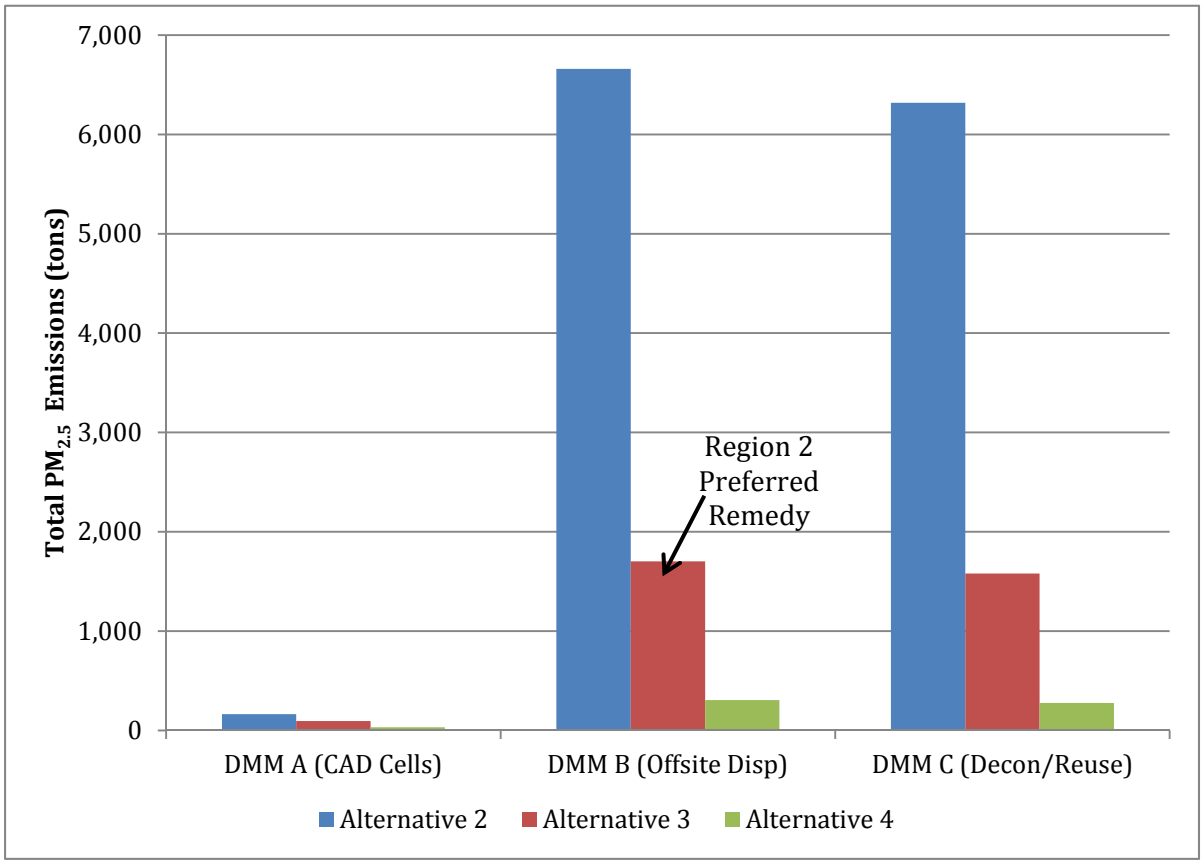


Figure 19. Predicted Total $PM_{2.5}$ Emissions for Each of Region 2's DMM Scenarios

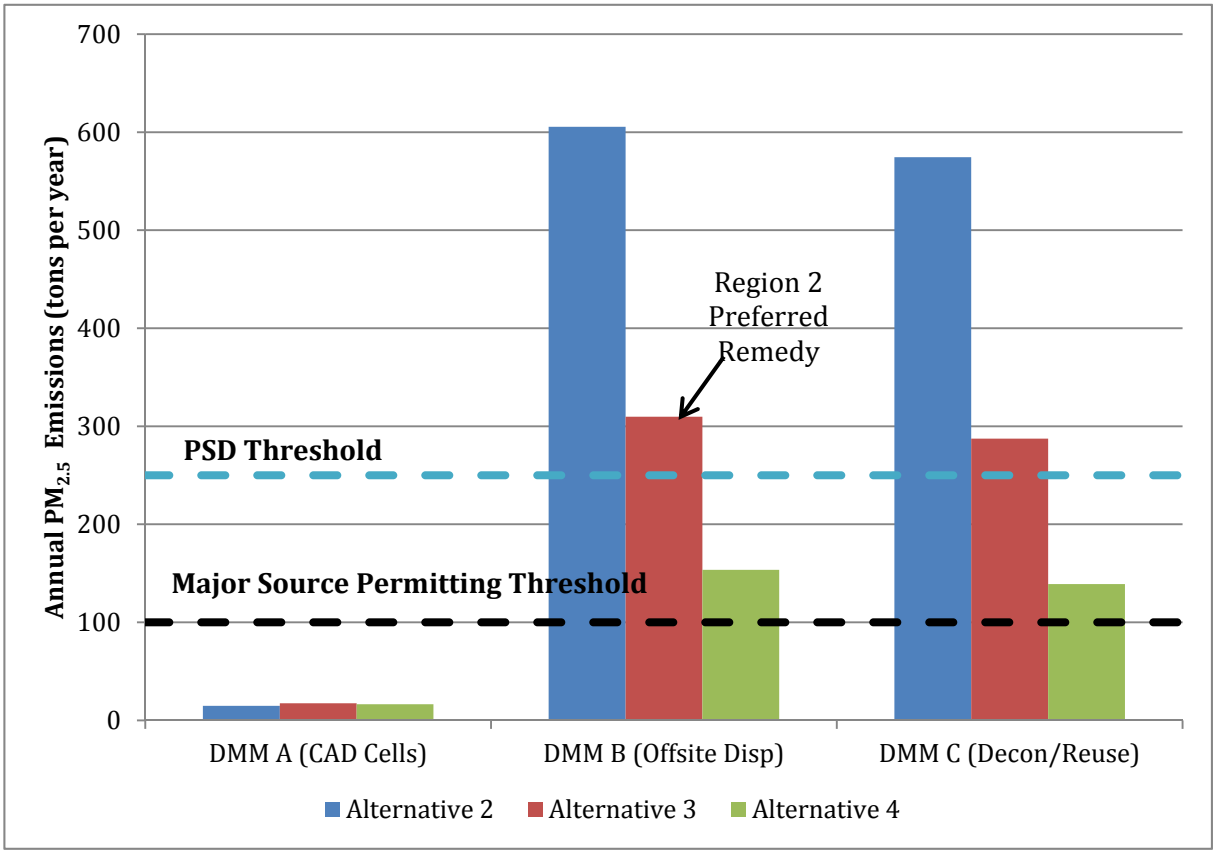


Figure 20. Predicted Annual $PM_{2.5}$ Emissions for Each of Region 2's DMM Scenarios

In summary, Region 2 failed to consider the impact of emissions of fine particulate matter in the FFS Study Area. It is evident from ENVIRON's preliminary calculations that the potential impacts to the local community and region are not insignificant. The results of ENVIRON's preliminary analysis indicate that, with the exception of the use of CAD cells, the proposed remedial alternatives and dredged material disposal options are predicted to generate total and annual levels of $PM_{2.5}$ emissions that will have a significant impact to local communities (**Figure 21**). Further, the predicted average annual emissions for offsite disposal and local decontamination and reuse options for each alternative exceed NJDEP's permitting threshold criteria for major facilities and that these same DMM scenarios for Alternatives 2 and 3 exceed the PSD construction permitting thresholds that would be subject to significant controls and permitting efforts.

As such, and in the absence of a complete comparative environmental impact analysis (i.e., NEBA) of each of the proposed remedial alternatives, Region 2's selection of a preferred remedial for the FFS Study Area is premature at this time. All stakeholders would not have a transparent basis for decision-making to evaluate each alternative. The preliminary analysis of fine particulate matter for each of the remedial alternatives and DMM scenarios described by Region 2 demonstrates that important information relevant to remedial decision-making is absent from the FFS.

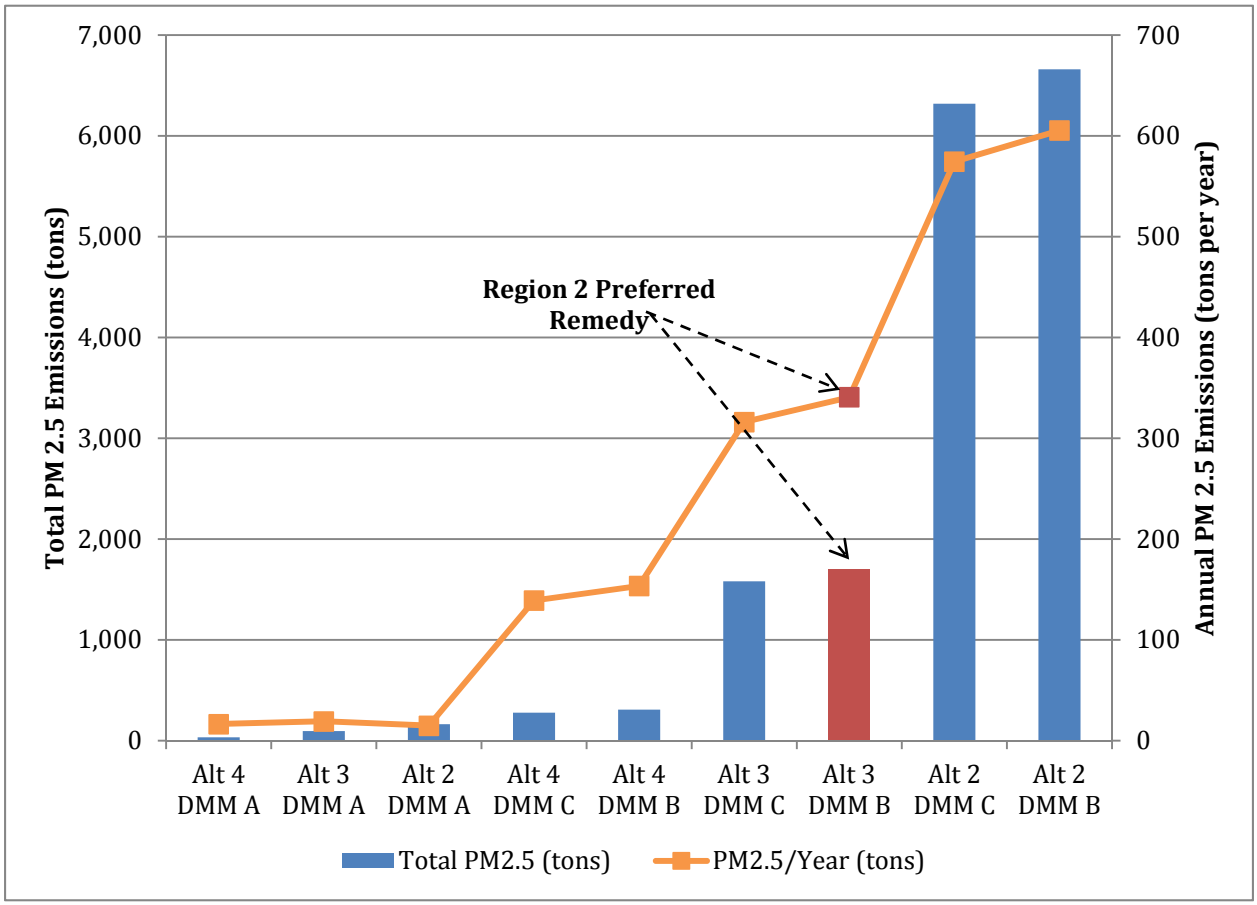


Figure 21. Ranking of $PM_{2.5}$ Emissions by Remedial Alternative and DMM Scenario

6 Findings and Conclusions

These comments were prepared by ENVIRON on behalf of Tierra Solutions Inc. and focused on Region 2's approach to evaluating the various remedial alternatives, as well as the basis for selecting the preferred remedy described in the *Focused Feasibility Study for the Lower Eight-Miles of the Lower Passaic River Study Area*. The Region's preferred cleanup method is a $1.7B plan for bank-to-bank dredging of approximately 4.3 million cubic yards of sediment from the lower 8.3 miles of the Passaic River, installation of cap material up to two feet thick on some portions of the river bottom, and off-site disposal.

ENVIRON's findings are summarized as follows:

- The FFS is inconsistent with federal policy, technical guidance, and direction for evaluating remedial alternatives. During remedial evaluation in the Superfund program, USEPA guidance, policy and direction obliges that the environmental impacts associated with each remedial alternative be carefully considered as part of the decision-making process for selection of a preferred remedy. In addition, USEPA guidance together with White House executive orders and other federal policies dictate that the preferred remedy should be sustainable, minimize opportunities to generate short- and long- term environmental harm arising from the remediation work, demonstrate a net benefit to the environment and affected communities, and achieve an outcome that is protective of human health and the environment.
- The FFS is not a detailed, complete, and transparent analysis of the remedial alternatives evaluated. The FFS does not demonstrate, in terms of environmental, economic and social indicators, that Region 2 has arrived at an acceptable balance between the risks, benefits and tradeoffs between the various remedial alternatives. The cumulative consequences of all dredging, capping, treatment and disposal activities associated with undertaking Region 2's preferred remedy and the associated net environmental benefits delivered by the preferred remedy have not been demonstrated.
- There is little indication in the FFS that Region 2 applied a decision-making process that 1) identified the environmental and social requirements important to stakeholders that must be satisfied versus those requirements that are desirable but not mandatory; and, 2) systematically identified and selected a remedial strategy (i.e., source treatment, pathway interception or receptor modification) that would satisfy the essential requirements, and optimize the net benefits of the individual actions that make up the strategy.
- At best, Region 2's approach to remedial alternative evaluation as presented in the FFS provides only a "partial" evaluation of how the various remedial alternatives potentially influence, positively and/or negatively, human health and ecological risks associated with the alternatives evaluated. Region 2 neglected to evaluate implementation risks to human health and ecological receptors including impacts to the local community. As such, the risks (ecological and human health) associated with implementation of the preferred remedy may outweigh the risks associated with contaminants in the sediments.
- Concerns that Region 2's preferred remedy may be harmful to local communities and environment are inadequately addressed in the FFS. The FFS is narrowly focused on the

remedial alternatives that address human health and ecological risks based solely upon chemical concentrations of certain contaminants of concern (COC) in sediments. The FFS does not contain an analysis of the environmental footprints associated with each of the different remedial alternatives. Region 2 neglected to evaluate factors, outside of chemical sediment concentrations, that have the potential to influence human health, ecological risks, and overall environmental quality associated with implementation of the potential remedial alternatives.

- By way of example, a preliminary analysis of alternative emission impacts (including GHG emissions and fine particulate emissions) was conducted to demonstrate the need for consideration of these and other environmental metrics that Region 2 failed to consider in the FFS. The preliminary calculations performed by ENVIRON identified significant differences between the remedial alternatives that were not captured in the FFS. Examination of additional metrics will further help to differentiate between alternatives and support a transparent decision.

As such, the FSS provides insufficient information to demonstrate that Region 2 adequately and transparently considered important factors with environmental, social and economic implications as outlined in USEPA policy, guidance and direction. Specifically, the FSS did not demonstrate (1) a preference for green remediation or a sustainable solution; (2) the environmental footprints of the various remedial alternatives; (3) the environmental and social risks associated with the various remedial alternatives; and (4) the consideration of net environmental, economic and social benefits. As it stands, the FFS is incomplete and should not be considered in its current state for decision-making purposes.

Additional work including, but not limited to, performing a comprehensive environmental footprint and sustainability analysis that supports a clear and transparent indication of the net environmental benefit of the remedial alternatives for the FFS Study Area is needed to understand the environmental and social impacts of those alternatives on the local community and to guide the decision-making process.

7 Bibliography

Aurand, D., L. Walko, and R. Pond. (2000). Developing Consensus Ecological Risk Assessments: Environmental Protection In Oil Spill Response Planning A Guidebook. United States Coast Guard. Washington, D.C. 148p.

Aurand, D., and G. Coelho. (2004). Net Environmental Benefit (ecological Risk) Assessment: Consensus Workshop. Environmental Tradeoffs Associated with Oil Spill Response Technologies. Upper Mississippi River Pools 7 and 19. A report to USCG District 8 and USEPA Region 5. Ecosystem Management & Associates, Inc., Lusby, MD. Technical Report 04-02, 48p.

Bridges, T. S., & Gustavson, K. (2014). Risk Management for Contaminated Sediments. In *Processes, Assessment and Remediation of Contaminated Sediments,* D.D. Reible, ed. (pp. 197-226). Springer: New York.

Capka, J.R. 2004. Megaprojects – They are a different breed. Public Roads. 68(1). Federal Highway Administration: Virginia. Accessed on the internet at https://www.fhwa.dot.gov/publications/publicroads/04jul/01.cfm. (24 July 2014).

Chumley, C. 2014. EPA's Gina McCarthy: Climate Change 'biggest public health challenge we face'. The Washington Times. http://www.washingtontimes.com/news/2014/apr/22/epas-gina-mccarthy-climate-change-biggest-public-h/

Claudio, E. (2001). How the EPA may be selling General Electric down the river: A law and economics analysis of the $460 million Hudson River cleanup plan. Fordham Envtl Law Journal: 409.

Colombo, F., Nicolette, J., Wenning, R., Travers, M. Incorporating Ecosystem Service Valuation in the Assessment of Risk and Remedy Implementation. Chem. Eng. Trans. 2012, 28, 55–60.

Efroymson, R., Nicolette, J., and Suter, G. A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Petroleum-Contaminated Sites; ORNL/TM-2003/17; Oak Ridge National Laboratory: Oak Ridge, TN, USA, 2003.

Efroymson, R., Nicolette, J., and Suter, G. A Framework for net environmental benefit analysis for remediation or restoration of contaminated sites. Environmental Management. 2004, 34, 315–331.

Executive Office of the President (EOP). 2007. Executive Order 13423 – Strengthening Federal Environmental, Energy, and Transportation Management. Washington DC: Federal Register 72, no. 17: 3,919-3,923.

Executive Office of the President (EOP), Council on Environmental Quality (CEQ). 2009. Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance. Washington DC: Federal Register 74, no. 194: 52,117-52,127.

Executive Office of the President (EOP), Council on Environmental Quality (CEQ). 2010. Memorandum for Heads of Federal Departments and Agencies: Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions. Washington DC: EOP, CEQ.

Executive Office of the President (EOP). 2012. Implementing Executive Order 13604 in Improving Performance of federal Permitting and review of Infrastructure Projects: A Federal Plan for Modernizing the Federal Permitting and review Process for Better Projects, Improved Environmental and Community Outcomes, and Quicker Decisions. Washington DC: EOP.

Executive Office of the President (EOP). 2013. The President's Climate Action Plan. Washington DC: EOP.

Fox, J.R., and Miller, D.B. (2006). Challenges in Managing Large Projects. Defense Acquisition University Press: Virginia. ISBN: 0-16-073987-X. Accessed on the internet at https://myclass.dau.mil/bbcswebdav/institution/Courses/Common_Resources/Reference__Material/Challenges_in_Managing_LCPs.pdf. (24 July 2014).

Gamper-Rabindran, S., Mastromonaco, R., and Timmins, C. (2011). Valuing the benefits of Superfund site remediation: Three approaches measuring localized externalities. National Bureau of Economic Research, Working Paper No. 16655. January. Accessed on the internet at http://www.nber.org/papers/w16655. (24 July 2014).

Interstate Technology and Regulatory Council (ITRC). 2004. Making the Case for Ecological Enhancements (ECO-1). Washington, DC: IRTC and the Wildlife Habitat Council.

Interstate Technology and Regulatory Council (ITRC). 2006. Planning and Promoting Ecological Land Reuse of Remediated Sites. Washington, DC: ITRC, Ecological Reuse Team.

Interstate Technology and Regulatory Council (ITRC). 2011. Green and Sustainable Remediation: A Practical Framework. Washington, DC: ITRC, Green and Sustainable Remediation Team.

Kiker, G. A., Bridges, T. S., Varghese, A., Seager, T. P. and Linkov, I. (2005), Application of multicriteria decision analysis in environmental decision making. Integr Environ Assess Manag, 1: 95–108. doi: 10.1897/IEAM_2004a-015.1

Lee, Y., Chang H., and Hong, Y. (2014). Is a costly river restoration project beneficial to the public? Empirical evidence from the Republic of Korea. *Desalin and Water Treat*. DOI:10.1080/19443994.2014.923209. Accessed on the internet at http://www.tandfonline.com/doi/abs/10.1080/19443994.2014.923209#.U9J6FIBdXzd. (24 July 2014).

Linkov, I., Welle, P., Loney, D., Tkachuk, A., Canis, L., Kim, J. B., and Bridges, T. (2011), Use of Multicriteria Decision Analysis to Support Weight of Evidence Evaluation. Risk Analysis, 31: 1211–1225. doi: 10.1111/j.1539-6924.2011.01585.x

New Jersey Department of Environmental Protection (NJDEP). 2009. Guidance on When The Department of Environmental Protection May Undertake Direct Oversight of a Remediation of a Contaminated Site (Version 1.0). Trenton, NJ: NJDEP, Site Remediation Program.

Nicolette, J., Burr, S., and Rockel, M. 2013. A Practical Approach for Demonstrating Environmental Sustainability and Stewardship through a Net Ecosystem Service Analysis. Sustainability 5: 2152-2177; doi: 10.3390/su5052152, Published May 10, 2013.

NOAA 2011. (Shigenaka, G.) Summary Report for Fate and Effects of Remnant Oil Remaining in the Environment. Annex M - Net Environmental Benefit Analysis. National Oceanic and Atmospheric Administration (NOAA).

National Research Council (NRC). 2001. A Risk-Management Strategy for PCB-Contaminated Sediments. National Research Council. National Academies Press, Washington, DC.

National Research Council (NRC). 2007. Sediment Dredging at Superfund Megasites: Assessing the Effectiveness. National Research Council. National Academies Press, Washington, DC.

Stahl CH. 2003. Multi-criteria integrated resource assessment (MIRA): A new decision analytic approach to inform environmental policy analysis [thesis]. Wilmington (DE), USA: University of Delaware.

Stahl CH, Cimorelli AJ, and Chow AH. 2002. A new approach to environmental decision analysis: Multi-criteria integrated resource assessment (MIRA). *Bulletin of Science, Technology and Society* **22**: 443–459.

The Climate Registry (TCR). 2013. General Reporting Protocol, Version 2.0. http://www.theclimateregistry.org/downloads/2013/03/TCR_GRP_Version_2.0.pdf (accessed June 2014).

Tracy, Nicole M., "Lessons learned from urban river restoration projects: application of restoration treatments on the Los Angeles River." (2014). *Master's Projects.* Paper 23. Accessed on the internet at http://repository.usfca.edu/capstone/23. (24 July 2014).

United Nations General Assembly. 2005 World Summit Outcome, Resolution A/60/1, adopted by the General Assembly on 15 September 2005. http://unpan1.un.org/intradoc/groups/public/documents/un/unpan021752.pdf

United States Army Environmental Center. (2005). United States Army Natural Resource Injury Guidance. September. http://aec.army.mil/portals/3/cleanup/nri-guide.pdf

United States Environmental Protection Agency (USEPA). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final (EPA/540/G-89/004). OSWER Directive 9355.3-01. October. Washington DC: USEPA, Office of Solid Waste and Environmental Response (OSWER).

United States Environmental Protection Agency (USEPA). 1991. Superfund: Volume 1 - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives; 9285.7-01C). Washington DC: USEPA, Office of Solid Waste and Environmental Response (OSWER).

United States Environmental Protection Agency (USEPA). 1991. Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives; 9285.7-01C). Washington DC: USEPA, Office of Solid Waste and Environmental Response (OSWER).

United States Environmental Protection Agency (USEPA). 1995. Memorandum, EPA Risk Characterization Program. Washington, DC: USEPA, Office of the Administrator, Carol Browner.

United States Environmental Protection Agency (USEPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (EPA 540-R-97-006). Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2000. *Framework for responsible environmental decision-making (FRED): Using life cycle assessment to evaluate preferability of products*. Washington, DC: USEPA. EPA/600/R-00/095.

United States Environmental Protection Agency (USEPA). 2001. Updating Remedy Decisions at Select Superfund Sites (EPA-540-R-01-00). Washington DC: USEPA, Office of Emergency and Remedial Response (OERR).

United States Environmental Protection Agency (USEPA). 2002. Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites. OSWER Directive 9285.6-08. February 2002

United States Environmental Protection Agency (USEPA). 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA-540-R-05-012, OSWER 9355.0-85). Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2008a. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (EPA 542-R-08-002). Washington DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2008b. Green Remediation: Best Management Practices for Excavation and Surface Restoration (EPA 542-F-08-012). Washington DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2009a. Principles for Greener Cleanups. Washington DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2009b. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act. Washington DC: Federal Register 74, no. 239: 66,496-66,546.

United States Environmental Protection Agency (USEPA). 2010. Superfund Green Remediation Strategy. Washington DC: USEPA, OSWER, Office of Superfund Remediation and Technology Innovation.

United States Environmental Protection Agency (USEPA). 2011a. Greener Cleanups: Contracting and Administrative Toolkit. Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2011b. Deferral for CO_2 emissions from bioenergy and other biogenic sources under the Prevention of Significant Deterioration (PSD) and Title V programs: Proposed rule (EPA-HQ-OAR-2011-0083). Washington DC: Federal Register 76, no. 54: 15,249-15,266.

United States Environmental Protection Agency (USEPA). 2011c. Strategic Sustainability Performance Plan, FY 2010-FY 2020. Washington DC: USEPA.

United States Environmental Protection Agency (USEPA). 2012a. Clean & Green Policy. New York: USEPA Region 2.

United States Environmental Protection Agency (USEPA). 2012b. Methodology for Understanding and Reducing a Project's Environmental Footprint (EPA 542-R-12-002). Washington DC: USEPA, OSWER, Office of Superfund Remediation and Technology Innovation.

United States Environmental Protection Agency (USEPA). 2013. Region 4 Superfund Annual Report 2013. USEPA. http://www.epa.gov/region4/superfund/images/allmedia/pdfs/annualreport2013.pdf.

United States Environmental Protection Agency (USEPA). 2014a. "Center for Corporate Climate Leadership." USEPA. http://www.epa.gov/climateleadership/ (accessed May 2014).

United States Environmental Protection Agency (USEPA). 2014b. "Climate Change Impacts and Adapting to Change." USEPA. http://www.epa.gov/climatechange/impacts-adaptation/ (accessed May 2014).

United States Environmental Protection Agency (USEPA) Science Advisory Board (SAB). 2009. Valuing the Protection of Ecological Systems and Services (EPA-SAB-09-012). Washington, DC: USEPA Science Advisory Board.

World Resources Institute (WRI) and World Business Council for Sustainable Development. 2004. The Greenhouse Gas Protocol. http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf (accessed June 2014).

Additional Literature Cited in Appendix A and Appendix B

Dellens, A.D. 2007. Green Remediation and the Use of Renewable Energy Sources for Remediation Projects. Washington, DC: United States Environmental Protection Agency (USEPA), Office of Solid Waste and Environmental Response (OSWER), Office of Superfund Remediation and Technology Innovation (OSRTI).

Fitzpatrick, F. 2012. Net Environmental Benefit Analysis (NEBA) Relative Risk Ranking Conceptual Design. US Geological Survey.

ITRC. 2006. Planning and Promoting Ecological Land Reuse of Remediated Sites. Washington, DC: ITRC, Ecological Reuse Team.

Magar, V.S., K. Merritt, M. Henning, M. Sorensen, and R.J. Wenning. 2008. Approaches Used for Remedy Selection at Contaminated Sediment Sites. In Real-Time and Deliberative Decision Making. I. Linkov et al. (eds). Springer.

Morford, JM, and Curtiss, SS. 2009. Steps Toward Net Environmental Benefit in Agency Decisions. Oregon Insider: 453 (p. 1 - 7).

National Institute of Environmental Health Sciences (NIEHS). Examples of SBRP-funded Activities at Hazardous Waste Sites. Research Triangle Park, NC: NIEHS, Superfund Research Program (SRP).

NJDEP. 2012. "Innovative Technology: Site Remediation." NJDEP, Sustainability and Green Energy http://www.nj.gov/dep/sage/siterem.html (29 May 2014).

NJDEP. 2012. N.J.A.C. 7:26E Technical Requirements for Site Remediation. http://www.nj.gov/dep/rules/nj_env_law.html (29 May 2014).

Nicholas, D., Nicolette, J., Weier, J., and Rockel, M. 2008. Demonstrating the Net Benefit of Site Cleanup: An Evaluation of Ecological and Economic Metrics at Two Superfund Sites. USEPA, OSWER.

Nicolette, J.P., D. Pelletier, and M. Rockel. 2011. Incorporating Ecosystem Service Valuation into Remedial Decision Making: Net Ecosystem Service Analysis. Superfund and Natural Resource Damages Litigation Committee Newsletter 7(1):9-13.

Operational Science Advisory Team (OSAT-2). 2011. Summary Report for Fate and Effects of Remnant Oil in the Beach Environment. US Coast Guard, New Orleans, LA.

Roberson, B. Net Environmental Benefit Analysis (NEBA) Decision-Making Tool: Developing Consensus for Environmental Decision-Making In Emergency Response. Washington DC: USEPA.

Shigenaka, G. 2011. Summary Report for Fate and Effects of Remnant Oil Remaining in the Environment. Annex M - Net Environmental Benefit Analysis. National Oceanic and Atmospheric Administration (NOAA).

Slack, S. 2010. The Incorporation of an Ecosystem Services Assessment into the Remediation of Contaminated Sites. Washington, DC: USEPA, OSWER, OSRTI.

Stanislaus, M. 2013. Memorandum: Encouraging Greener Cleanup Practices through Use of ASTM International's Standard Guide for Greener Cleanups. Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2006. Ecological Benefits Assessment Strategic Plan (EPA-240-R-06-001). Washington, DC: USEPA.

United States Environmental Protection Agency (USEPA). 2009. Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices (EPA 530-R-09-017). Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2010. "Green Remediation Measurements/Evaluation Subgroup - Metrics." USEPA Region 2. http://www.epa.gov/region02/superfund/green_remediation/metrics.html (29 May 2014).

United States Environmental Protection Agency (USEPA). 2010. "Principles for Greener Cleanups". USEPA, OSWER. http://www.epa.gov/oswer/greenercleanups/pdfs/oswer_greencleanup_principles.pdf (29 May 2014).

United States Environmental Protection Agency (USEPA). 2010. Green Remediation Best Management Practices: Clean Fuel & Emission Technologies for Site Cleanup (EPA 542-F-10-008). Washington, DC: USEPA, OSWER.

United States Environmental Protection Agency (USEPA). 2011. Hudson River PCBs Superfund Site: Quality of Life Performance Standards. General Overview Winter 2011 Update. New York, NY: USEPA Region 2.

United States Environmental Protection Agency (USEPA). 2014. "Greener Cleanup Consensus Standard Initiative." USEPA, OSWER. http://www.epa.gov/oswer/greenercleanups/standard.html (29 May 2014).

United States Environmental Protection Agency (USEPA). No Date. "EPA Office of Solid Waste and Emergency Response (OSWER) Study Information". http://www.gsa.gov/graphics/fas/WhatIsGreenRemediation-May.pdf (30 May 2014).

United States Environmental Protection Agency (USEPA) Science Advisory Board. 2011. “Review of EPA’s Draft Oil Spill Research Strategy.” http://yosemite.epa.gov/sab/sabproduct.nsf/065558902A0353FB8525791A0072613B/$File/EPA-SAB-11-016-unsigned.pdf (29 May 2014).

Tables

Table 1 - Remediation Planning Activities that USEPA Failed to or Inadequately Considered to Understand the Environmental Footprint of the Different Remedy Alternatives

Remediation Planning Activities	Adequately Considered	Inadequately Considered	Not Considered
Stewardship			
Efforts to minimize carbon footprint	.	.	✔
Consider opportunities to minimize short-term of human health risks	.	.	✔
Identifiy benchmarks for implementing adaptive management approaches to avoid or minimize short- or long- term environmental risks	.	✔	.
Community involvement to increase public awareness	.	✔	.
Use of renewable energy systems to power long-term cleanup and future activities on redeveloped land	.	.	✔
Materials & Waste			
Use of technologies designed to minimize waste generation	.	.	✔
Reuse or recycle of materials whenever possible	.	.	✔
Minimize non-renewable materials and disposal	.	.	✔
Land & Ecosystem			
Use of minimially invasive *in situ* technologies	.	.	✔
Use of passive energy treatment technologies as primary remedies or finishing steps where possible/effective.	.	.	✔
Identify and preserve esstential and valued ecosystem services	.	.	✔
Minimize river bottom habitat disturbances	.	✔	.
Minimize river shoreline disturbances	.	✔	.
Consider opportunities to minimize short-term elevation of ecological risks	.	.	✔
Minimize opportunities for bioavailability of contaminants through adequate source and plume controls	.	.	✔
Minimize of noise pollution	.	✔	.
Minimize lighting disturbance	.	✔	.

Table 1 - Remediation Planning Activities that USEPA Failed to or Inadequately Considered to Understand the Environmental Footprint of the Different Remedy Alternatives

Remediation Planning Activities	Adequately Considered	Inadequately Considered	Not Considered
Water			
Minimize water use and maximize opportunities for water reuse	.	.	✔
Prevent or reduce water quality impacts on downstream water bodies	.	✔	.
Minimization of water demand for revegetation of upland areas	.	.	✔
Use of reclaimed treated water for beneficial reuse	.	.	✔
Air			
Minimize greenhouse gas (GHG) emissions	.	.	✔
Minimize the use of heavy equipment requiring high fuel volumes	.	.	✔
Minimize emissions of toxic or priority pollutants	.	.	✔
Minimize release and dispersions of particulate and contaminants in particulate	.	.	✔
Use of cleaner fuels for equipment	.	.	✔
Minimize emissions from heavy equipment	.	.	✔
Energy Use			
Consider use of optimized passive-energy technologies that enable remediation objectives to be met	.	.	✔
Identify opportunities to use energy efficient equipment	.	.	✔
Optimize energy efficiency of light and heavy equipment	.	.	✔
Consider renewable energy sources to replace or offset energy requirements	.	.	✔

Notes:
Adapted from Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (USEPA, 2008)

Table 2 - Excerpts from the LPRSA Eight-Mile FFS that Address the Evaluation of Short-Term Effectiveness and Potential Impacts

Section	Description
Introductory Sections	
Executive Summary (Detailed Analysis)	p. ES-12, "The short-term effectiveness of alternatives was assessed considering such factors as: protection of the community and workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives would be achieved."
Selection of Representative Technologies and Process Options (**Section 3.7**)	p. 3-18, "CAD is more efficiently integrated with dredging (e.g., transporting and offloading dredged material to a CAD cell causes fewer short-term impacts to the community and would be more cost-effective than transporting and offloading to an off-site landfill). Therefore, a CAD site is selected as the representative process option for disposal of dredged sediments."
Section 4: Development and Screening of Remedial Alternatives	
Upland Sediment Processing Facility (**Section 4.2.7**)	p. 4-17, Considerations for siting the facility include: adequate water frontage, sufficient land area, access to rail facilities/highways, current land use of adjacent properties (e.g., sensitive receptors or restoration areas), and quality of life issues (e.g., noise, odor).
Additional Considerations (**Section 4.2.8**)	Generic list of components of a selected remedy, including pre-design investigation; design; upland facility site selection; work plans; equipment mobilization; project timeline; debris management; environmental monitoring; confirmatory sampling; long-term monitoring and maintenance; and five-year reviews.
Section 5: Detailed Analysis of Remedial Alternatives	
Threshold Criterion 1: Overall protection (**Section 5.1.1**)	Quantitative evaluation of human health exposure via fish consumption once remedy complete (**no metric for quantification of interim exposures**). Same true for protection of environment.
Long-term Effectiveness (**Section 5.1.3**)	Metrics: Magnitude of residual risks (mass and concentration of remaining material and same exposure modeling as criterion 1, above), reliability of controls (no quantitative metric identified), remedy replacement (identified metrics relate to monitoring period)
Reduction in Toxicity, Mobility, or Volume (**Section 5.1.4**)	Metrics: treatment process, mass of material treated/destroyed, degree of reduction in tox/mob/volume, permanence, type and quantity of residuals, and ability to satisfy statutory preference for treatment
Short-term Effectiveness (**Section 5.1.5**)	Metrics: time to implement the remedy, "adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy" (p. 5-8)
Implementability (**Section 5.1.6**)	Metrics: technical and administrative.
Cost (**Section 5.1.7**)	Metric: capital, O&M, and present value cost estimate (+50% to -30%)
Alternative 2 Evaluation (**Section 5.2.2**). Short-Term Effectiveness, Implementability	p. 5-21, "Implementation of Alternative 2 *would have the greatest impact on the community, workers and the environment* as compared to other alternatives because the construction period would be the longest (11 years) and Alternative 2 requires handling the largest volume of contaminated sediments (9.7 million cy)." p. 5-23, "Risks posed by sediment processing at upland processing and transfer facilities (e.g., spills, accidents, emissions)." p. 5-23, "Risks posed by transportation of dewatered materials to off-site disposal or treatment facilities (e.g., spills, accidents)." p. 5-23, "risks posed by increased river traffic" Mitigation measures described but the magnitude of traffic increase is not quantified. p. 5-24, "potential occupational risks to site workers from direct contact, ingestion, and inhalation of COPCs and COPECs...and routine physical hazards" Mitigation measures described but risks not quantified. p. 5-24, "sediment removal may result in short-term adverse impacts to the river including exposure of fish and biota to contaminated sediments..." and "temporary loss of benthos and habitat for the ecological community". Resuspension exposures not quantified and habitat effects considered temporary (<5 yrs); no mitigation required. p. 5-26, "DMM Scenarios B and C have greater on-land impacts" Quantification limited to footprint of sediment processing facility. No quantification of other impacts associated with sediment treatment. p. 5-28, "activities would result in some temporary disruption of commercial/recreational uses and boating access during remediation." Mitigation measures described but potential impacts not quantified.

Table 2 - Excerpts from the LPRSA Eight-Mile FFS that Address the Evaluation of Short-Term Effectiveness and Potential Impacts

Section	Description
Alternative 3 Evaluation (**Section 5.2.3**). Short-Term Effectiveness, Implementability	p. 5-37, "impacts [to community, workers, and the environment] important to address since remediation project would be five years and would require handling of 4.3 million cy of dredged materials." p. 5-37, "risk of some adverse short-term impacts to human health and the environment during the construction period due to the increased potential for exposure to the COPCs ... resuspended during dredging." p. 5-38, "Under DMM Scenario A,...increased barge traffic to and from CAD site may interfere with existing commercial port traffic and increase the potential for waterborne commerce accidenct." Mitigation measures described but risks not quantified. p. 5-38, DMM Scenarios B and C "would increase in-water vessel traffic and cause on-land impacts to the community (e.g., increased vehicle traffic and air quality impacts)". p. 5-38, "Alternative 3 would pose potential occupational risks to site workers from direct contact, ingestion, and inhalation of COPCs and COPECs from surface water and sediments," p. 5-39, "Sediment removal may result in short-term adverse impacts to the river including exposure of the water column, fish, and biota to contaminated sediments due to resuspension of contaminated sediments during dredging." "Impacts from construction include temporary loss of benthos and habitat for the ecological community in dredged and capped areas" Resuspension exposures not quantified, habitat effects temporary and no mitigation required. p. 5-43, "activities would result in some temporary disruption of commercial/recreational uses and boating access during remediation." Mitigation measured described but potential impacts not quantified.
Alternative 4 Evaluation (**Section 5.2.4**). Short-Term Effectiveness, Implementability	p. 5-52, "Alternative 4 would have less of an impact on the community, workers and the environment than Alternatives 2 and 3 due to the smaller volume of material handled and the shorter project duration." p. 5-52, "may be a risk of some adverse short-term impacts to human health and the environment during the construction period due to the increased potential for exposure to the COPCs..." p. 5-52, "temporary noise, light, odors, blocked views, potential air quality impacts and disruptions to commercial and recreational river users" p. 5-52, "increased barge traffic to and from the CAD site may interfere with existing commercial port traffic and increase the potential for waterborne commerce accidents" Mitigation measures described by risks that were not quantified. p. 5-53, DMM Scenarios B and C "would increase in-water vessel traffic and cause on-land impacts to the community (e.g., increased vehicle traffic and air quality impacts)". p. 5-53, "Alternative 4 would pose potential occupational risks to site workers from direct contact, ingestion, and inhalation of COPCs and COPECs from the surface water and sediments, and routine physical hazards associated with construction activities" Mitigation measures described by risks that were not quantified. p. 5-53, "Sediment removal may result in short-term adverse impacts to the river including exposure of the water column, fish and biota to contaminated sediments due to resuspension..." Resuspension exposures/risks not quantified p. 5-58, "Sediment removal and engineered capping activities woudl result in some temporary disruption of commercial/recreational uses and boating access during remediation." Mitigation measures desribed by potential impacts not quantified
Comparative Analysis (**Section 5.3**)	p. 5-62, "Alternative 2 is expected to have a *greater impact on the community and site workers* because of the long duration of the construction and the handling of larger volumes of more contaminated dredged material (9.7 million cy versus 4.3 million cy versus 1 million cy). *Alternative 4 would have the least impact on the community and site workers*." p. 5-63, "DMM Scenario A would have the *least impact on the community and site workers but the most impact on the aquatic habitat* because the transport and disposal occurs on or in the water. DMM Scenario C would have a *greater impact on the local community and* workers than DMM Scenario B because the decontamination technologies require a slightly larger upland processing facility, incorporates local thermal treatment unit with potential air emissions, and may require more trucking to transport beneficial end use products to local destinations."

Table 2 - Excerpts from the LPRSA Eight-Mile FFS that Address the Evaluation of Short-Term Effectiveness and Potential Impacts

Section	Description
Comparative Analysis Table (**Table 5-4**)	Short-term effectiveness: "There may be a risk of some adverse short-term impacts to human health and the environment during the construction period due to the increased potential for exposure…" *Protection of the Community* : "quality of life impacts (noise, odors, lighting, traffic, impacts to navigation, aesthetics, and recreation) related to dredging and processing activities. Potential impacts due to accidents..." *Protection of Workers during Remedial Actions* : "risk of accidents associated with dredging or processing activities. In-water accidents associated with dredging...On-land accidents associated with DMM Scenarios B and C...Impacts are the greatest under Alternative 2 due to project duration and volume dredged." *Potential Adverse Environmental Impacts resulting from Construction and Implementation:* "Water quality and ecological concerns resulting from resuspension, contaminant release, and residuals related to dredging...Temporary loss of benthos and habitat for the ecological community in mudflats, wetlands, and disturbed areas during dredging...Potential air quality impacts from thermal treatment process under DMM Scenario C."
Appendix F: Engineering Evaluations (Short-term Remediation Impacts Evaluation)	
Impacts to Biota and Habitat - Remedial Alternatives (**Section 4.2.3**)	p. 4-13, "Short-term impacts related to biota and habitat [e.g., mudflat areas, wetlands, biologically active zone, fish spawning periods, critical habitat, waterways] would be greatest under Alternative 2 primarily due to the greater duration of the project and would be the least for Alternative 4 due to the smaller extent of the dredging program." Quantification of potential impacts limited to project duration and dredged areas.
Accidents - Remedial Alternatives (**Section 4.2.4**)	May result in injury (people or property), and can cause a release of contaminants during transport and placement of capping materials; transportation, treatment, and disposal of dredged material; and, mobilization, operation, and demob of treamtent facilities.
Air Quality - Remedial Alternatives (**Section 4.2.5**)	Temporary impacts from volatization from dredged material, emissions from equipment, emissions from transport vessels and processing areas, and worker commutes.
Quality of Life - Remedial Alternatives (**Section 4.2.6**)	Noise, lighting (during nighttime activities), traffic (on land and in-water), navigation, aesthetics (residential and commercial views), and recreation (Waterfront festivals and parks) (p. 4-15). Remedial activities assumed to occur 24 hours per day, 6 days per week for 40 weeks per year. Short-term impacts can be managed by performance standards.
Impacts to Biota and Habitat - DMM Scenarios (**Section 4.3.3**)	DMM Scenario A has the greatest potential to disrupt habitat in Newark Bay and would require the mitigation of impacts of 19 to 171 acres. DMM Scenarios B and C involve the construction of upland sediment processing facilities (25 to 40 acres) that would disrupt land that would potentially serve as local habitat to upland birds and wildlife and/or would likely be located in urban and industrial neighborhoods. Quantification based solely on physical footprint of disposal/processing areas.
Accidents - DMM Scenarios (**Section 4.3.4**)	DMM Scenario C likely to have the greatest potential for short-term impact from accidents due to the number and complexity of the material handling operations. DMM Scenario B is second due to the use of rail transfer, and DMM Scenario A has the least potential for accidents due to the limited site operations and people involved in the process.
Air Quality - DMM Scenarios (**Section 4.3.5**)	DMM Scenario A likely to have the least impact, followed by DMM Scenario B and then DMM Scenario C. Scenarios B and C require construction of an upland processing facility, the construction phase of which is anticipated to have between 12 and 24 months of impacts on air quality. Continued impacts will occur through the duration of the project, with more emissions being the result of DMM Scenario C due to the additional treatment activities.
Quality of Life - DMM Scenarios (**Section 4.3.6**)	DMM Scenario A: Recreational and commercial navigation and recreation, aesthetics, vessel traffic. DMM Scenarios B & C: Increased road traffic and elevated noise. All Scenarios: Odor (equipment and vehicle exhaust, odors from dredged material, processing facility), noise and light.

Notes:
CAD: confined aquatic disposal
COC: chemical of concern
DMM: dredged material management
p: page

Table 4 - Examples of Potential Short-Term and Long-Term Environmental Risks and Service Benefits for the Different Remedy Options that Should be Considered by USEPA in the FFS

Ecological Services	Human Use Services	Environmental Risk	Human Health Risk
Short Term Impacts			
● Aquatic habitat disturbance during dredging ● Terrestrial habitat loss from staging area/roads ● Air quality decline from increased truck traffic ● Water quality decline through dewatering ● Habitat destruction to dig new channel	● Potential loss of access to river for recreational use during construction/dredging operations ● Beneficial use of non hazardous sediments in cement production ● Nuisance to nearby workers from noise, dust, and light at night	● Risk of hazardous material spills during truck and barge transportation ● Increased bioavailability of contaminants in deep sediments	● Risk of traffic accidents during sediment transport ● Worker exposure to hazardous sediments throughout remediation process ● Increased exposure risk from perceived water quality improvements (e.g. more people fishing and eating fish)
Long Term Impacts			
● Aquatic habitat improved through removal of contaminants ● Terrestrial habitat improvement through landscaping/ replanting ● Water quality improvement ● Terrestrial habitat improvement from use of dredge spoils, and creation/loss of habitat from new channel and filling riverbed	● Boating, walking, fishing, and other recreational opportunities ● Educational opportunities with improved habitat ● Improved navigation potential from dredging ● Reduced risk of flood damage from river widening	● Reduced risk of exposure to contaminants	● Reduced risk of exposure to contaminants

Table 5 - NEBA Framework Table Considerations

NEBA Considerations		Human Health Pathways				Ecological Services			Social					Costs
Passaic River NEBA Framework		Fish consumption	Traffic accidents to workers and exposed population from sediment transport	Pollution effects from remediation activities to workers and exposed population	Noise, dust from remediation activities to exposed population	Benthic communities	Fish communities	Avian communities	GHG emissions/ carbon foot-printing	Emissions from increased truck traffic	Emissions from dredging operations (Dredging vessel, dewatering, etc)	Total Energy Used	Recreational Use	Capital and O&M
		Environmental Justice Concerns												
Alternative	**Disposal Scenario**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**	**Metric(s)**
1) No Action	None	Cancer exposure/ deaths	Deaths/ morbidity	Deaths/morbidity in general and special populations such as asthmatic children	Quality of life years (QUALYs) to general and sensitive populations	HEA based DSAYs	HEA based DSAYs	REA based bird years	Tons of carbon emitted	Tons of NOx, SOx PMx emitted	Tons of NOx, SOx PMx emitted	MMBTUs	Trips (e.g., fishing, boating, walking, picnicing)	Net present value in real dollars
2) Deep Dredging with Backfill	with CAD													
	with Off-Site													
	with Decontamination													
3) Capping with Dredging for Flooding and Navigation	with CAD													
	with Off-Site													
	with Decontamination													
4) Focused Capping with Dredging for Flooding	with CAD													
	with Off-Site													
	with Decontamination													

Notes:
CAD: confined aquatic disposal
DSAY: discounted service acre year
GHG: greenhouse gas
NEBA: Net Environmental Benefit Analysis
O&M: operation and management

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Pre-Construction Activities																
Design	Y	Y	Y	--												
Regulatory Requirements, Legal, and Community Outreach	Y	Y	Y	--												
Contractor Work Plans and Submittal	Y	Y	Y	--												
Pre-Construction Support Facility	Y	Y	Y	--						X						
Pre-Construction Oversight	Y	Y	Y	--										X		
General Survey and Coring Vessels Mobilization	Y	Y	Y	--											X	
Pre-Design Investigation - Chemical, Waste Characterization, and Geological Sample Collection	Y	Y	Y	Y	X		X				DM			X		
Pre-Design Investigation - Geotechnical Sample Collection	Y	Y	Y	Y	X		X				DM			X		
Pre-Design Investigation - Chemical Analysis	Y	Y	Y	--												
Pre-Design Investigation - Waste Characterization Analysis	Y	Y	Y	--												
Pre-Design Investigation - Geological Analysis	Y	Y	Y	--												
Pre-Design Investigation - Geotechnical Analysis	Y	Y	Y	--												
Biological Monitoring Baseline Studies	Y	Y	Y	--	N/A									X		
Pore Water Evaluation	N	Y	Y	--												
Sub-bottom Geophysics and Bathymetric Survey	Y	Y	Y	Y	X									X		
Video Survey for Debris Identification	Y	Y	Y	Y	X									X		
Habitat Survey	Y	Y	Y	--	N/A											
Cultural Survey (in river)	Y	Y	Y	--	N/A									X	X	
Fish Spawning Study	Y	Y	Y	--												
Borrow Site Pre-Screening	Y	Y	Y	Y			X							X	X	
Borrow Material Characterization	Y	Y	Y	Y			X							X		
Cap Erosion Modeling for Armor Placement Design	N	Y	Y	--												
Mobilization and Demobilization																
Dredge Equipment Mobilization/Demobilization	Y	Y	Y	--											X	
Backfilling/Capping Equipment Mobilization/Demobilization	Y	Y	Y	--											X	
Monitoring Equipment Mobilization/Demobilization	Y	Y	Y	--											X	
Debris Removal Equipment Mobilization/Demobilization	Y	Y	Y	--											X	
Shoreline Protection Equipment Mobilization/Demobilization	Y	Y	Y	--											X	
New Season Restart	Y	Y	Y	--											X	
Testing and Monitoring During Dredging and Backfilling/Capping																
Bathymetric Survey	Y	Y	Y	Y	X									X		
Water Quality Monitoring	Y	Y	Y	Y	X									X		
Sediment Monitoring	Y	Y	Y	--										X		
Biological Monitoring	Y	Y	Y	--	N/A									X		
Air Monitoring	Y	Y	Y	--										X		
Monitoring Reports	Y	Y	Y	--												
Dredging																
Mechanical Dredging	Y	Y	Y	Y	X									X		
Large Debris Removal, Off-Loading, Transport, and Disposal	Y	Y	Y	Y							X			X		
Utility Protection	Y	N	N	Y			X							X		

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Bridge/Abutment/Bulkhead Protection	Y	N	N	--	N/A		N/A							X		
Barge Transport of Dredged Material	Y	Y	Y	Y			N/A				X			X		
Shallow Water Sediments - Double Handling	N	Y	Y	--			N/A							X		
Hydraulic Offloading of Dredged Material	Y	Y	Y	--			N/A							X		
Controls for Quality of Life Impacts	Y	Y	Y	--		N/A	N/A							X		
Backfill and/or Engineered Cap																
Backfill/Engineered Cap Material Purchase and Delivery	Y	Y	Y	Y								X				
Backfill/Engineered Cap Material Placement	Y	Y	Y	Y	X	X								X		
Armor Material Purchase and Delivery	N	Y	Y	Y								X				
Armor Layer Placement	N	Y	Y	Y	X									X		
Confirmation Coring	N	Y	Y	Y	X									X		
Seiment Recontamination Monitoring	N	Y	Y	--										X		
Mudflat Backfill/Engineered Cap	Y	Y	Y	Y	X							X		X		
Mudflat Reconstruction	Y	Y	Y	Y	X							X		X		
Natural Shoreline Reconstruction	Y	N	N	Y	X							X		X		
Natural Shoreline Biostabilization	Y	N	N	--		N/A								X		
Riprapped Shoreline Repairs and Replacement	Y	Y	Y	--		N/A								X		
Dredged Material Management - CAD (DMM Scenario A)																
Pre-Construction Activities for DMM				--												
Design	Y	Y	Y	--												
Regulatory Requirements, Legal, and Community Outreach	Y	Y	Y	--												
Land Acquisition	Y	Y	Y	--												
Contractor Work Plans and Submittal	Y	Y	Y	--												
Pre-Construction Oversight	Y	Y	Y	--										X		
Upland Support Facility Site Investigation - Geotechnical	Y	Y	Y	Y			X							X		
Upland Support Facility Site Investigation - Chemical	Y	Y	Y	--										X		
Topographic Survey - Upland Support Facility Site	Y	Y	Y	--										X		
Pre-Design Investigation of CAD Site - Chemical Sample Collection	Y	Y	Y	Y	X		X							X		
Pre-Design Investigation of CAD Site - Geotechnical Sample Collection	Y	Y	Y	Y	X		X							X		
Pre-Design Investigation of CAD Site - Chemical Analysis	Y	Y	Y	--												
Pre-Design Investigation of CAD Site - Geotechnical Analysis	Y	Y	Y	--												
Pre-Design Investigation of CAD Site - Historic Area Remediation Site (HARS)	Y	Y	Y	--	N/A	N/A								X		
Habitat Survey (upland support facility site)	Y	Y	Y	--										X		
Cultural Survey (upland support facility site)	Y	Y	Y	--										X		
Elutriate Evaluation	Y	Y	Y	--												
Sub-bottom Geophysics and Bathymetric Survey	Y	Y	Y	Y	X									X		
Miscellaneous Tests for DMM Design	Y	Y	Y	--												
CAD Excavation				--												
Dredge Mobilization/Demobilization	Y	Y	Y	--											X	
Monitoring Equipment and Debris Removal Mobilization/Demobilization	Y	Y	Y	--											X	

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Large Debris Removal	Y	Y	Y	Y	X						X			X		
Contaminated Sediment Dredging	Y	Y	Y	Y	X						X			X		
Contaminated Sediment Testing and Disposal (First Cell)	Y	Y	Y	--												
Contaminated Sediment Dredging and Disposal (Subsequent Cells)	Y	Y	N	Y	X						X			X		
Clay Dredging/Transport/Disposal at HARS	Y	Y	Y	Y	X						X			X		
Containment System Installation	Y	Y	Y	Y	X		X							X		
Silt Curtain at CAD Entrance Channel	Y	Y	Y	--	N/A		N/A							X		
Air Monitoring During Construction	Y	Y	Y	--										X		
Testing and Monitoring	Y	Y	Y	Y	X									X		
Upland Support Facility				--												
Mobilization and Demobilization	Y	Y	Y	--											X	
Layout and Documentation Survey	Y	Y	Y	--										X		
Fencing	Y	Y	Y	Y		X								X		
Exterior Lighting	Y	Y	Y	Y		X								X		
Security	Y	Y	Y	--										X		
Buildings	Y	Y	Y	Y		X								X		
Utilities	Y	Y	Y	--						X				X		
Earthwork	Y	Y	Y	Y		X								X		
Stormwater Management	Y	Y	Y	Y		X								X		
Paving	Y	Y	Y	Y		X								X		
Pier/Dock structure	Y	Y	Y	Y		X								X		
Wastewater Treatment System for Contact Water	Y	Y	Y	--						X				X	X	
CAD Closure				--												
Cap Material Purchase and Delivery	Y	Y	Y	Y	X							X		X	X	
Engineered Cap Material Placement	Y	Y	Y	Y	X									X		
Confirmation Coring	Y	Y	Y	Y	X									X		
Remove Containment System	Y	Y	Y	Y	X		X							X		
Bathymetric Survey	Y	Y	Y	Y	X									X		
Additional Habitat Mitigation	Y	Y	Y	--	N/A									X		
Site Decommissioning/Restoration	Y	Y	Y	Y		X					N/A			X		
Dredged Material Management - Off-Site Disposal (DMM Scenario B)																
Pre-Construction Activities				--												
Design	Y	Y	Y	--												
Regulatory Requirements, Legal, and Community Outreach	Y	Y	Y	--												
Land Acquisition	Y	Y	Y	--												
Contractor Work Plans and Submittal	Y	Y	Y	--												
Pre-Construction Oversight	Y	Y	Y	--										X		
Upland Sediment Processing Facility Site Investigation - Geotechnical	Y	Y	Y	Y			X							X		
Upland Sediment Processing Facility Site Investigation - Chemical	Y	Y	Y	--										X		
Topographic Survey - Upland Sediment Processing Facility Site	Y	Y	Y	--										X		

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Habitat Survey	Y	Y	Y	--	X									X		
Cultural Survey	Y	Y	Y	--										X		
Miscellaneous Tests for DMM Design	Y	Y	Y	--												
Upland Sediment Processing Facility				--												
Mobilization and Demobilization	Y	Y	Y	--											X	
Mechanical and Electrical	Y	Y	Y	--												
Layout and Documentation Survey	Y	Y	Y	Y		X								X		
Fencing	Y	Y	Y	Y		X								X		
Exterior Lighting	Y	Y	Y	Y		X								X		
Security	Y	Y	Y	--										X		
Buildings	Y	Y	Y	Y		X								X		
Utilities	Y	Y	Y	Y		X								X		
Earthwork	Y	Y	Y	Y		X								X		
Stormwater Management	Y	Y	Y	Y		X								X		
Paving	Y	Y	Y	Y		X								X		
Pier/Dock structure	Y	Y	Y	Y		X								X		
Pre-fabricated Building for Dewatered Sediment Storage	Y	Y	Y	Y		X				X				X		
Storage Area - Concrete Slab and Push Walls	Y	Y	Y	Y		X								X		
Storage Area - Subgrade Material	Y	Y	Y	Y		X								X		
Storage Area - Fabric Filter	Y	Y	Y	Y		X								X		
Storage Area - Vapor Emissions Control	Y	Y	Y	Y		X								X		
Piping	Y	Y	Y	Y		X								X		
Upfront Storage and Recycle Water Tanks	Y	Y	Y	Y		X								X		
Loadout Facility	Y	Y	Y	Y		X								X		
Rail Line Spur/Railcar Storage	Y	Y	Y	Y		X								X		
Temporary Bunkers for Loadout Facility	Y	Y	Y	Y		X								X		
Hazardous Material Storage Area	Y	Y	Y	Y		X								X		
Air Monitoring During Construction	Y	Y	Y	--										X		
Equipment				--												
Operating Equipment	Y	Y	Y	Y		X								X		
Wastewater Treatment Plant	Y	Y	Y	--										X		
Processing and Disposal				--												
Mechanical Dewatering Using Filter Presses	Y	Y	Y	--						X				X		
Dewatered Material Testing for Disposal	Y	Y	Y	--							DM					
Transport off-site to Thermal Treatment	Y	Y	Y	Y							X					
Thermal treatment and disposal	Y	Y	Y	Y							X		X			
Transport to Subtitle C Landfill	Y	Y	Y	Y							X					
Off-Site Disposal in Subtitle C Landfill	Y	Y	Y	--												X
Decontamination and Disposal of Medium-Sized Debris	Y	Y	Y	Y							X					
Debris Transport and Disposal (Small Organic Fraction) in Subtitle C Landfill	Y	Y	Y	Y							X					X
Reclaimed Sand Processing, Transport and Beneficial Use	Y	Y	Y	Y							X					
Site Decommissioning/Restoration	Y	Y	Y	Y		X					N/A			X		

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Dredged Material Management - Local Decontamination and Beneficial Use (DMM Scenario C)																
Pre-Construction Activities				--												
Design	Y	Y	Y	--												
Regulatory Requirements, Legal, and Community Outreach	Y	Y	Y	--												
Land Acquisition	Y	Y	Y	--												
Contractor Work Plans and Submittal	Y	Y	Y	--												
Pre-Construction Oversight	Y	Y	Y	--										X		
Upland Sediment Processing Facility Site Investigation - Geotechnical	Y	Y	Y	Y			X							X		
Upland Sediment Processing Facility Site Investigation - Chemical	Y	Y	Y	--										X		
Topographic Survey - Upland Sediment Processing Facility Site	Y	Y	Y	--										X		
Habitat Survey	Y	Y	Y	--										X		
Cultural Survey	Y	Y	Y	--										X		
Miscellaneous Tests for DMM Design	Y	Y	Y	--												
Upland Sediment Processing Facility				--												
Mobilization and Demobilization	Y	Y	Y	--											X	
Mechanical and Electrical	Y	Y	Y	--												
Layout and Documentation Survey	Y	Y	Y	Y		X								X		
Fencing	Y	Y	Y	Y		X								X		
Exterior Lighting	Y	Y	Y	Y		X								X		
Security	Y	Y	Y	--										X		
Buildings	Y	Y	Y	Y		X								X		
Utilities	Y	Y	Y	Y		X								X		
Earthwork	Y	Y	Y	Y		X								X		
Stormwater Management	Y	Y	Y	Y		X								X		
Paving	Y	Y	Y	Y		X								X		
Pier/Dock structure	Y	Y	Y	Y		X								X		
Pre-fabricated Building for Dewatered Sediment Storage	Y	Y	Y	Y		X				X				X		
Storage Area - Concrete Slab and Push Walls	Y	Y	Y	Y		X								X		
Storage Area - Subgrade Material	Y	Y	Y	Y		X								X		
Storage Area - Fabric Filter	Y	Y	Y	Y		X								X		
Storage Area - Vapor Emissions Control	Y	Y	Y	Y		X								X		
Piping	Y	Y	Y	Y		X								X		
Upfront Storage and Recycle Water Tanks	Y	Y	Y	Y		X								X		
Loadout Facility	Y	Y	Y	Y		X								X		
Transfer Vehicle Storage	Y	Y	Y	Y		X								X		
Temporary Bunkers for Loadout Facility	Y	Y	Y	Y		X								X		
Hazardous Material Storage Area	Y	Y	Y	Y		X								X		
Air Monitoring During Construction	Y	Y	Y	--										X		
Equipment Costs				--												
Operating Equipment	Y	Y	Y	Y		X								X		
Wastewater Treatment Plant	Y	Y	Y	--										X		

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Local Decontamination				--												
Mechanical Dewatering Using Filter Presses	Y	Y	Y	--						X				X		
Dewatered Material Testing for Disposal	Y	Y	Y	--							DM					
Thermal Treatment (On-Site/Local Facility)	Y	Y	Y	Y				X		X	X	N/A		X		
Sediment Washing	Y	Y	Y	Y			X			X	X	N/A		X		
Sediment Amendment	Y	Y	Y	Y						X	X	N/A		X		
Decontamination and Disposal of Medium-Sized Debris	Y	Y	Y	Y							X					
Debris Transport and Disposal (Small Organic Fraction) in Subtitle C Landfill	Y	Y	Y	Y							X					X
Reclaimed Sand Processing, Transport and Beneficial Use	Y	Y	Y	Y							X					
Site Decommissioning/Restoration	Y	Y	Y	Y		X					N/A			X		
Dredged Material Management Site O&M - CAD (DMM Scenario A)																
Operational Testing	Y	Y	Y	--	X									X		
Upland Support Facility O&M	Y	Y	Y	--						X				X		
Operations Management/Coordination	Y	Y	Y	--						X				X		
Air Monitoring	Y	Y	Y	--										X		
Dredged Material Management Site O&M - Off-Site Disposal (DMM Scenario B)				--												
Wastewater Treatment Plant O&M	Y	Y	Y	--						X				X		
Sediment Processing Site O&M	Y	Y	Y	--						X				X		
Operations Management/Coordination	Y	Y	Y	--						X				X		
Wastewater Testing	Y	Y	Y	--										X		
Air Monitoring	Y	Y	Y	--										X		
Dredged Material Management Site O&M - Local Decontamination and Beneficial Use (DMM Scenario C)																
Wastewater Treatment Plant O&M	Y	Y	Y	--						X				X		
Sediment Processing Site O&M	Y	Y	Y	--						X				X		
Operations Management/Coordination	Y	Y	Y	--						X				X		
Wastewater Testing	Y	Y	Y	--										X		
Air Monitoring	Y	Y	Y	--										X		
Annual O&M																
Annual Monitoring Activities				--												
Community Outreach	Y	Y	Y	--										X		
Mobilization and Demobilization of Monitoring Equipment	Y	Y	Y	--											X	
Bathymetric Survey	Y	Y	Y	Y	X									X		
Water Column Sampling and Analysis	Y	Y	Y	Y	X						DM			X		
Sediment Sampling and Analysis	Y	Y	Y	Y	X		X				DM			X		
Biological Monitoring	Y	Y	Y	--	N/A									X		
Habitat Recolonization using SPI	Y	Y	Y	Y	X									X		
Annual Monitoring Reports	Y	Y	Y	--												
Annual Maintenance Activities				--												
Mobilization and Demobilization of Cap Maintenance Activities	Y	Y	Y	--											X	
Ice Scour Evaluation for Cap along Shoreline	Y	Y	Y	Y	X									X		
Annual Cap Maintenance	Y	Y	Y	--	DM									X		

ENVIRON

Table 6 - Greenhouse Gas Emission Sources

Phase and Activity	Included in Alternative?			Include in Project Scope?	GHG Emission Sources[1]											
					Scope 1 - Direct Anthropogenic Sources					Scope 2 - Indirect Anthropogenic	Scope 3 - Other Indirect Anthropogenic Sources					
					Mobile		Stationary									
	2	3	4		Harbor Craft [2]	Other Off-Road Mobile Sources	Combustion Sources	Thermal Destruction	Other	Electricity [3]	Waste Shipping	Raw Material Transport	Thermal Treatment	Employee Trips [3]	Equipment Mob [3]	Subtitle C Landfill [3]
Periodic O&M																
Periodic Monitoring Activities				--												
Community Outreach	Y	N	N	--										X		
Supplemental Biological Monitoring	Y	Y	Y	--	N/A									X		
Supplemental Habitat Recolonization using SPI	Y	Y	Y	--	DM									X		
Performance Review Report	Y	Y	Y	--												
Periodic Maintenance Activities				--												
Periodic Cap Maintenance	Y	Y	Y	--	DM									X		
Natural Shoreline Maintenance	Y	Y	Y	--					X					X		

Notes:
(1) General Reporting Protocol, Version 2.0, The Climate Registry, March 2013, and USEPA's Greenhouse Gas Emission Reductions (http://www.epa.gov/greeningepa/ghg/)
(2) Includes auxillary emissions
(3) Not included in this preliminary assessment
CAD: confined aquatic disposal
DM: Assumed to be *de minimis* - not included in the calculations
GHG: greenhouse gas
O&M: operation and maintenance
N/A: Not enough information was available to include in the calculations
SPI: sediment profile imaging

Table 7 - Comparison of CO2e Emissions by Remediation Alternative and DMM Scenario

Project Phase	Alternative 2 (Total: 11 years)			Alternative 3 (Total: 5 years)			Alternative 4 (Total: 2 years)		
	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)
Pre-Construction Activities	2,499	2,499	2,499	1,212	1,212	1,212	339	339	339
Mobilization and Demobilization	--	--	--	--	--	--	--	--	--
Testing and Monitoring During Dredging and Backfilling/Capping	26,645	26,645	26,645	12,111	12,111	12,111	4,845	4,845	4,845
Dredging	61,324	67,918	67,918	27,625	30,441	30,441	10,534	11,203	11,203
Backfill and/or Engineered Cap	33,896	33,896	33,896	41,042	38,547	38,547	13,919	13,938	13,938
Pre-Construction Activities for DMM	116	2.7	3.7	57	2.7	3.7	17	2.7	3.7
CAD Excavation	88,761	--	--	42,169	--	--	11,050	--	--
Upland Support/ Processing Facility	752	25,931	12,414	752	25,931	12,414	752	25,931	12,414
Sediment Disposal	--	1,436,073	661,952	--	456,136	180,461	--	97,908	33,056
CAD Closure	11,809	--	--	5,371	--	--	1,193	--	--
Site Decommissioning/ Restoration	43	64	107	43	64	107	43	64	107
Annual O&M	4,099	1,668	1,668	3,856	1,668	1,668	3,856	1,668	1,668
Total CO_2e Emissions (tons):	**229,943**	**1,594,697**	**807,103**	**134,238**	**566,115**	**276,965**	**46,548**	**155,899**	**77,573**
Avg. Annual CO2e Emissions (tpy):	**20,904**	**144,972**	**73,373**	**26,848**	**113,223**	**55,393**	**23,274**	**77,950**	**38,787**

Notes:

CO_2e: carbon dioxide equivalents

tpy: tons per year

ENVIRON

Table 8 - Comparison of PM2.5 Emissions
by Remediation Alternative and DMM Scenario

Project Phase	Alternative 2 (Total: 11 years)			Alternative 3 (Total: 5 years)			Alternative 4 (Total: 2 years)		
	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)	DMM A (CAD Cells)	DMM B (Offsite Disp)	DMM C (Decon/Reuse)
Pre-Construction Activities	1.9	1.9	1.9	0.88	0.88	0.88	0.23	0.23	0.23
Mobilization and Demobilization	--	--	--	--	--	--	--	--	--
Testing and Monitoring During Dredging and Backfilling/Capping	20	20	20	9.2	9.2	9	3.7	3.7	3.7
Dredging	41	46	46	18	20	20	6.9	7.4	7.4
Backfill and/or Engineered Cap	24	24	24	29	28	28	10	10	10
Pre-Construction Activities for DMM	0.087	--	--	0.043	--	--	0.013	--	--
CAD Excavation	65	--	--	31	--	--	8.2	--	--
Upland Support/ Processing Facility	2.2E-02	0.11	0.17	2.2E-02	0.11	0.17	2.2E-02	0.11	0.17
Sediment Disposal	--	6,565	6,224	--	1,642	1,520	--	283	254
CAD Closure	8.3	--	--	3.8	--	--	0.82	--	--
Site Decommissioning/ Restoration	0.033	0.050	0.002	0.033	0.050	0.002	0.033	0.050	0.002
Annual O&M	3.1	2.4	2.4	3.0	2.4	2.4	3.0	2.4	2.4
Total Emissions (tons):	**164**	**6,659**	**6,318**	**96**	**1,703**	**1,580**	**33**	**307**	**278**
Avg. Annual Emissions (tpy)	**15**	**605**	**574**	**17**	**310**	**287**	**16**	**154**	**139**

Notes:
PM2.5 : Fine Particulate Matter (diameter of 2.5 micrometres or less)
(1) Total $PM_{2.5}$ emissions include $PM_{2.5}$ from fugitives and exhaust. When information about the breakdown of $PM_{2.5}$ in the DPM emissions was unknown, the $PM_{2.5}$ from exhaust sources was not included in the total PM2.5 emission estimates.

Attachment A:
Checklist for Regulatory Impact Analysis

Agency Checklist: Regulatory Impact Analysis

With this document, the Office of Information and Regulatory Affairs is providing a checklist to assist agencies in producing regulatory impact analyses (RIAs), as required for economically significant rules by Executive Order 12866 and OMB Circular A-4.

Nothing herein alters, adds to, or reformulates existing requirements in any way. Moreover, this checklist is limited to the requirements of Executive Order 12866 (available at: http://www.reginfo.gov/public/jsp/Utilities/EO_12866.pdf) and Circular A-4 (available at: http://www.whitehouse.gov/OMB/circulars/a004/a-4.pdf); it does not address requirements imposed by other authorities, such as the National Environmental Policy Act, the Regulatory Flexibility Act, the Unfunded Mandates Reform Act, the Paperwork Reduction Act, and various Executive Orders that require analysis. Executive Order 12866 and Circular A-4, as well as those other authorities, should be consulted for further information.

Checklist for Regulatory Impact Analysis:

- Does the RIA include a reasonably detailed description of the **need for the regulatory action**? [1],[2]
- Does the RIA include an explanation of how the regulatory action will **meet that need**?[3]
- Does the RIA use an appropriate **baseline** (i.e., best assessment of how the world would look in the absence of the proposed action)?[4]
- Is the information in the RIA based on **the best reasonably obtainable scientific, technical, and economic information** and is it presented in an **accurate, clear, complete, and unbiased manner**?[5]
- Are the data, sources, and methods used in the RIA provided to the public **on the Internet** so that a qualified person can reproduce the analysis?[6]
- To the extent feasible, does the RIA quantify and monetize the anticipated **benefits** from the regulatory action?[7],[8]
- To the extent feasible, does the RIA quantify and monetize the anticipated **costs**?[9]
- Does the RIA explain and support **a reasoned determination that the benefits of the intended regulation justify its costs** (recognizing that some benefits and costs are difficult to quantify)?[10]
- Does the RIA assess the **potentially effective and reasonably feasible alternatives**?[11]
    - Does the RIA assess the benefits and costs of different regulatory provisions separately if the rule includes a number of distinct provisions?[12]
    - Does the RIA assess at least one alternative that is less stringent and at least one alternative that is more stringent?[13]
    - Does the RIA consider setting different requirements for large and small firms?[14]

- Does the preferred option have the highest **net benefits** (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires a different approach? [15]

- Does the RIA include an explanation of why the planned regulatory action is **preferable** to the identified potential alternatives?[16]

- Does the RIA use appropriate **discount rates** for benefits and costs that are expected to occur in the future?[17]

- Does the RIA include, if and where relevant, an appropriate **uncertainty analysis**?[18]

- Does the RIA include, if and where relevant, a separate description of **distributive impacts** and **equity**?[19]

  - Does the RIA provide a description/accounting of transfer payments?[20]
  - Does the RIA analyze relevant effects on disadvantaged or vulnerable populations (e.g., disabled or poor)?[21]

- Does the analysis include a clear, plain-language **executive summary**, including an **accounting statement** that summarizes the benefit and cost estimates for the regulatory action under consideration, including the qualitative and non-monetized benefits and costs?[22]

- Does the analysis include a clear and transparent **table** presenting (to the extent feasible) anticipated benefits and costs (quantitative and qualitative)?[23]

---

[1] Required under Executive Order 12866, Section 6(a)(3)(B)(i): "The text of the draft regulatory action, together with a reasonably detailed description of the need for the regulatory action and an explanation of how the regulatory action will meet that need."

[2] Circular A-4 states: "If the regulation is designed to correct a significant market failure, you should describe the failure both qualitatively and (where feasible) quantitatively." (P. 4)

[3] See note 1 above.

[4] Circular A-4 states: "You need to measure the benefits and costs of a rule against a baseline. This baseline should be the best assessment of the way the world would look absent the proposed action… In some cases, substantial portions of a rule may simply restate statutory requirements that would be self-implementing, even in the absence of the regulatory action. In these cases, you should use a pre-statute baseline." (P. 15-16)

[5] Circular A-4 states: "Because of its influential nature and its special role in the rulemaking process, it is appropriate to set minimum quality standards for regulatory analysis. You should provide documentation that the analysis is based on the best reasonably obtainable scientific, technical, and economic information available… you should assure compliance with the Information Quality Guidelines for your agency and OMB's Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies..." (P. 17). The IQ Guidelines (paragraph V.3.a) define objectivity to include "whether disseminated information is being presented in an accurate, clear, complete, and unbiased manner." http://www.whitehouse.gov/omb/assets/omb/fedreg/reproducible2.pdf

[6] Circular A-4 states: "A good analysis should be transparent and your results must be reproducible. You should clearly set out the basic assumptions, methods, and data underlying the analysis and discuss the uncertainties

associated with the estimates. A qualified third party reading the analysis should be able to understand the basic elements of your analysis and the way in which you developed your estimates. To provide greater access to your analysis, you should generally post it, with all the supporting documents, on the internet so the public can review the findings." (P. 17). OMB IQ Guidelines (paragraph V.3.b.ii) further states: "If an agency is responsible for disseminating influential scientific, financial, or statistical information, agency guidelines shall include a high degree of transparency about data and methods to facilitate the reproducibility of such information by qualified third parties."

[7] Required under Executive Order 12866, Section 6(a)(3)(C)(i): "An assessment, including the underlying analysis, of benefits anticipated from the regulatory action (such as, but not limited to, the promotion of the efficient functioning of the economy and private markets, the enhancement of health and safety, the protection of the natural environment, and the elimination or reduction of discrimination or bias) together with, to the extent feasible, a quantification of those benefits."

[8] Circular A-4 states: "You should monetize quantitative estimates whenever possible. Use sound and defensible values or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible. If monetization is impossible, explain why and present all available quantitative information." (P. 19). Circular A-4 also offers a discussion of appropriate methods for monetizing benefits that might not easily be turned into monetary equivalents.

[9] Required under Executive Order 12866, Section 6(a)(3)(C)(ii): "An assessment, including the underlying analysis, of costs anticipated from the regulatory action (such as, but not limited to, the direct cost both to the government in administering the regulation and to businesses and others in complying with the regulation, and any adverse effects on the efficient functioning of the economy, private markets (including productivity, employment, and competitiveness), health, safety, and the natural environment), together with, to the extent feasible, a quantification of those costs;" See also note 6 above.

[10] Executive Order 12866, Section 1(b)(6) states that to the extent permitted by law, "[e]ach agency shall assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." As Executive Order 12866 recognizes, a statute may require an agency to proceed with a regulation even if the benefits do not justify the costs; in such a case, the agency's analysis may not show any such justification.

[11] Required under Executive Order 12866, Section 6(a)(3)(C)(iii): "An assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable nonregulatory actions)..."

[12] Circular A-4 states: "You should analyze the benefits and costs of different regulatory provisions separately when a rule includes a number of distinct provisions." (P. 17)

[13] Circular A-4 states: "you generally should analyze at least three options: the preferred option; a more stringent option that achieves additional benefits (and presumably costs more) beyond those realized by the preferred option; and a less stringent option that costs less (and presumably generates fewer benefits) than the preferred option." (P. 16)

[14] Circular A-4 states: "You should consider setting different requirements for large and small firms, basing the requirements on estimated differences in the expected costs of compliance or in the expected benefits. The balance of benefits and costs can shift depending on the size of the firms being regulated. Small firms may find it more costly to comply with regulation, especially if there are large fixed costs required for regulatory compliance. On the other hand, it is not efficient to place a heavier burden on one segment of a regulated industry solely because it can better afford the higher cost. This has the potential to load costs on the most productive firms, costs that are disproportionate to the damages they create. You should also remember that a rule with a significant impact on a substantial number of small entities will trigger the requirements set forth in the Regulatory Flexibility Act. (5 U.S.C. 603(c), 604)." (P. 8)

[15] Executive Order 12866, Section 1(a) states: "agencies should select those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity) unless a statute requires another regulatory approach."

[16] Required under Executive Order 12866, Section 6(a)(3)(C)(iii): "An assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable nonregulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives."

[17] Circular A-4 contains a detailed discussion, generally calling for discount rates of 7 percent and 3 percent for both benefits and costs. It states: "Benefits and costs do not always take place in the same time period. When they do not, it is incorrect simply to add all of the expected net benefits or costs without taking account of when they actually occur. If benefits or costs are delayed or otherwise separated in time from each other, the difference in timing should be reflected in your analysis.... For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent.... If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." (PP. 31, 34, 36)

[18] Circular A-4 provides a detailed discussion. Among other things, it states: "Examples of quantitative analysis, broadly defined, would include formal estimates of the probabilities of environmental damage to soil or water, the possible loss of habitat, or risks to endangered species as well as probabilities of harm to human health and safety. There are also uncertainties associated with estimates of economic benefits and costs, such as the cost savings associated with increased energy efficiency. Thus, your analysis should include two fundamental components: a quantitative analysis characterizing the probabilities of the relevant outcomes and an assignment of economic value to the projected outcomes." (P. 40). Circular A-4 also states: "You should clearly set out the basic assumptions, methods, and data underlying the analysis and discuss the uncertainties associated with the estimates." (P. 17)

[19] Executive Order 12866, Section 1(b)(5) states; "When an agency determines that a regulation is the best available method of achieving the regulatory objective, it shall design its regulations in the most cost-effective manner to achieve the regulatory objective. In doing so, each agency shall consider incentives for innovation, consistency, predictability, the costs of enforcement and compliance (to the government, regulated entities, and the public), flexibility, *distributive impacts*, and *equity*" (emphasis added).

Circular A-4 states: "The term 'distributional effect' refers to the impact of a regulatory action across the population and economy, divided up in various ways (e.g., income groups, race, sex, industrial sector, geography)… Your regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency… Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups." (P. 14)

[20] Circular A-4 states: "Distinguishing between real costs and transfer payments is an important, but sometimes difficult, problem in cost estimation. . . . Transfer payments are monetary payments from one group to another that do not affect total resources available to society. . . . You should not include transfers in the estimates of the benefits and costs of a regulation. Instead, address them in a separate discussion of the regulation's distributional effects." (P. 14)

[21] Circular A-4 states: "Your regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers

can properly consider them along with the effects on economic efficiency. Executive Order 12866 authorizes this approach. Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups." (P. 14)

[22] Circular A-4 states: "Your analysis should also have an executive summary, including a standardized accounting statement." (P. 3). OMB recommends that: "Regulatory analysis should be made as transparent as possible by a prominent and accessible executive summary—written in a "plain language" manner designed to be understandable to the public—that outlines the central judgments that support regulations, including the key findings of the analysis (such as central assumptions and uncertainties)…If an agency has analyzed the costs and benefits of regulatory alternatives to the planned action (as is required for economically significant regulatory actions), the summary should include such information." See *2010 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*, page 51. Available at: http://www.whitehouse.gov/sites/default/files/omb/legislative/reports/2010_Benefit_Cost_Report.pdf

[23] Circular A-4 states: "You need to provide an accounting statement with tables reporting benefit and cost estimates for each major final rule for your agency." (P. 44). Circular A-4 includes an example of a format for agency consideration. OMB recommends "that agencies should clearly and prominently present, in the preamble and in the executive summary of the regulatory impact analysis, one or more tables summarizing the assessment of costs and benefits required under Executive Order 12866 Section 6(a)(3)(C)(i)-(iii). The tables should provide a transparent statement of both quantitative and qualitative benefits and costs of the proposed or planned action as well as of reasonable alternatives. The tables should include all relevant information that can be quantified and monetized, along with relevant information that can be described only in qualitative terms. It will often be useful to accompany a simple, clear table of aggregated costs and benefits with a separate table offering disaggregated figures, showing the components of the aggregate figures. To the extent feasible in light of the nature of the issue and the relevant data, all benefits and costs should be quantified and monetized. To communicate any uncertainties, we recommend that the table should offer a range of values, in addition to best estimates, and it should clearly indicate impacts that cannot be quantified or monetized. If nonquantifiable variables are involved, they should be clearly identified. Agencies should attempt, to the extent feasible, not merely to identify such variables but also to signify their importance." See *2010 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*, page 51. Available at: http://www.whitehouse.gov/sites/default/files/omb/legislative/reports/2010_Benefit_Cost_Report.pdf

Appendices

Appendix A:
Policy, Guidance and Direction Documents

	Source	Citation	Quote / Summary
(1)	NJDEP	New Jersey Department of Environmental Protection (NJDEP). 2012. N.J.A.C. 7:26E Technical Requirements for Site Remediation. http://www.nj.gov/dep/rules/nj_env_law.html (accessed May 29, 2014).	**p19:** 7:26E-1.9 Green and sustainable practices: "The Department encourages the use of green and sustainable practices during the remediation of contaminated sites."
(2)	NJDEP	NJDEP. 2012. "Innovative Technology: Site Remediation." Sustainability and Green Energy. http://www.nj.gov/dep/sage/ siterem.html (accessed May 29, 2014).	The Sustainability and Green Energy (SAGE) program promotes programs that reduce greenhouse gas emissions to ensure compliance with teh NJ Global Warming Response Act, and is currently "working with the Site Remediation Program to identify technologies that have undergone independent third party verification of performance claims regarding the cleanup of specific contaminants at contaminated sites."
(3)	NJDEP	NJDEP. 2009. Guidance on When The Department of Environmental Protection May Undertake Direct Oversight of a Remediation of a Contaminated Site (Version 1.0). Trenton, NJ: NJDEP, Site Remediation Program.	**p4:** "The use of Green Remediation concepts as part of remedial activities at sites will be considered a mitigating condition. Green Remediation is defined by the USEPA as the practice of considering all environmental effects of remedy implementation and incorporating options to maximize the net environmental benefit of cleanup actions."
(4)	USEPA Region 2	United States Environmental Protection Agency (USEPA). 2013. "Region 2 Clean & Green Touchstone Practices." USEPA Region 2. http://www.epa.gov/region2/superfund/green_remediat ion/touchstones.html (accessed May 29, 2014).	The following practices "are the point of departure for Superfund cleanups, and will be standard unless a site-specific evaluation demonstrates impracticability or favors an alternative green approach." • Use of 100% of electricity from renewable sources; • Clean diesel fuels and technologies; • Methane capture at landfill sites; • Material Reuse, Reduction or Recycling (Industrial materials, concrete made with coal combustion products, construction and demolition materials; organic materials generated on site); and, • Capture geothermal energy with pump and treat remediation systems to heat/cool structures
(5)	USEPA Region 2	USEPA. 2012. "EPA Region 2 'Clean & Green' Policy." USEPA Region 2. http://www.epa.gov/region2/superfund/green_remediation/policy.html (accessed May 29, 2014).	"The goal of the Region 2 Clean & Green Policy is to enhance the environmental benefits of federal cleanup programs by promoting technologies and practices that are sustainable." The objectives of Green Remediation are to: • Protect human health and the environment by achieving remedial action goals • Support human and ecological use and reuse of remediated land • Minimize impacts to water quality and water resources • **Reduce air emissions and greenhouse gas production** • Minimize material use and waste production • Conserve natural resources and energy The policy establishes a preference for use of: • 100% use of renewable energy, and energy conservation and efficiency approaches including EnergyStar equipment • Cleaner fuels and clean diesel technologies and strategies • Water conservation and efficiency approaches including WaterSense products • Sustainable site design • **Industrial material reuse or recycling within regulatory requirements** • Recycling applications for materials generated at or removed from the site • Environmentally Preferable Purchasing - • **Greenhouse gas emission reduction technologies**
(6)	USEPA Region 2	USEPA. 2011. Hudson River PCBs Superfund Site: Quality of Life Performance Standards. General Overview Winter 2011 Update. New York, NY: USEPA Region 2.	Quality of life concerns identified in the RS were related to traffic, noise, construction lighting, air quality, odor, aesthetics, and recreation (Table 4-1). Performance standards were subsequently developed that included mitigation and other contingencies.

	Source	Citation	Quote / Summary
(7)	USEPA Region 2	USEPA. 2010. "Green Remediation Measurements/Evaluation Subgroup - Metrics." USEPA Region 2. http://www.epa.gov/ region02/superfund/green_remediation/metrics.html (accessed May 29, 2014).	Provides goals, data requirements, and methods for calculating environmental metrics for the five green remediation practices that are the touchstones of the USEPA Region 2 response action within the Region 2 Clean and Green Policy.
(8)	USEPA	USEPA. 2012. Methodology for Understanding and Reducing a Project's Environmental Footprint. Washington, DC: USEPA, OSWER, OSRTI.	**p1:** "Green remediation strategies can include a detailed analysis in which components of a remedy are closely examined and large contributions to the footprint are identified. More effective steps can then be taken to reduce the footprint while meeting regulatory requirements driving the cleanup [...] The term "environmental footprint" as referenced in the methodology comprehensively includes metrics such as energy use and water use as well as air emissions to fully represent the effects a cleanup project may have on the environment." **p2:** "The methodology is a general framework to help site teams understand the remedy components with the greatest influence on the project's environmental footprint. Quantifying the metrics can serve as an initial step in reducing the remedy footprint. The overall process allows those involved in the remedial process to analyze a remedy from another perspective and potentially yields viable and effective improvements that may not have been identified otherwise." **p35-36:** "Excavation remedies: The largest contributions to energy and air footprints for excavation remedies are the transport of the excavated material or backfill material from one location to another [...] as a result, minimizing this horizontal transport distance and choosing the optimal mode of transportation would be key areas of focus in reducing the footprints of excavation remedies [...] The use of renewable fuels (e.g., biodiesel) could increase the percentage of energy from renewable resources. It could also reduce the GHG footprint for the remedy. Although there may be a GHG footprint for onsite soil treatment, there is also a footprint associated with landfill activities that could partially or completely offset the footprint of the onsite treatment."
(9)	USEPA	USEPA. 2010. "Principles for Greener Cleanups." USEPA, OSWER. http://www.epa.gov/oswer/greenercleanups/pdfs/oswer_greencleanup_principles.pdf (accessed May 29, 2014).	**p4:** "OSWER cleanup programs should consider these recommended elements when carrying out greener cleanup environmental footprint assessments and evaluating best practices that may be useful during the cleanup process. 1. Minimize Total Energy Use and Maximizes Use of Renewable Energy • Minimize energy consumption (e.g. use energy efficient equipment) • Power cleanup equipment through onsite renewable energy sources • Purchase commercial energy from renewable resources **2. Minimize Air Pollutants and Greenhouse Gas Emissions** • Minimize the generation of greenhouse gases • Minimize generation and transport of airborne contaminants and dust • Use heavy equipment efficiently (e.g. diesel emission reduction plan) • Maximize use of machinery equipped with advanced emission controls • Use cleaner fuels to power machinery and auxiliary equipment • Sequester carbon onsite (e.g., soil amendments, revegetate)"

	Source	Citation	Quote / Summary
(10)	USEPA	USEPA. 2010. Superfund Green Remediation Strategy. Washington, DC: USEPA, OSWER.	**p5:** "Utilization of green remediation strategies within the scope of a Superfund response may help ensure a protective remedy." **p6**: "When developing options for remedial actions that are consistent with remedial action objectives, project managers should consider alternatives that include opportunities for reducing the environmental footprint of remedial design and construction activities." **p7:** "Policy and guidance development will focus on a single key action intended to integrate green remediation within the Program and provide an overall context for using green remediation strategies to the maximum extent practicable." **p8:** "Environmental footprint evaluation topics may include life cycle assessment of remedial actions, use of liquid fuels during site operations, energy and water consumption, and GHG emissions." **p9:** "OSWER encourages the use of renewable energy as one way to reduce GHG emissions in site operations [...] OSWER also encourages reduced energy consumption and GHG emissions in site operations at all Superfund sites..." **p12:** "The Agency plans to modify SOW language in remedial and removal contracts (and/or associated work assignments or task orders) to require contractors to annually and/or monthly report on concerns such as energy and fuel usage..."
(11)	USEPA	USEPA. 2008. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (EPA 542-R-08-002). Washington, DC: USEPA, OSWER.	**p6-7:** "Green remediation focuses on maximizing the net environmental benefit of cleanup, while preserving remedy effectiveness as part of the Agency's primary mission to protect human health and the environment [...] Key opportunities for integrating core elements of green remediation can be found when designing and implementing cleanup measures. Regulatory criteria and standards serve as a foundation for building green practices. Key elements include: <u>Air emissions</u> • Minimize use of heavy equipment requiring high volumes of fuel; • Use cleaner fuels and retrofit diesel engines to operateheavy equipment, when possible; • Reduce atmospheric release of toxic or priority pollutants; and, • Minimize dust export of contaminants. <u>Long-term stewardship actions</u> **• Reduce emission of CO2, N2O, CH4, and other greenhouse gases contributing to climate change,** **p19:** "OSWER is analyzing the extent of energy use, CO2 emissions, and energy cost of technologies used to treat contaminated media at NPL sites" in order to establish benchmarks, examin operational and management practices used to implement these technologies, and identify methods for reducing energy consumption." **p20:** " In accordance with green remediation strategies, feasibility studies could include comparison of the environmental footprint expected from each cleanup alternative, including GHG emissions, carbon sequestration capability, and water drawdown (lowering of the water table or surface water levels)."

	Source	Citation	Quote / Summary
(12)	USEPA	USEPA. 2014. "Greener Cleanup Consensus Standard Initiative." USEPA, OSWER. http://www.epa.gov/oswer/greenercleanups/ standard.html (accessed May 29, 2014).	"ASTM International issued the final Standard Guide for Greener Cleanups (E2893-13) in November 2013. The standard guide is intended to complement regulatory and voluntary cleanup programs and accommodate each phase of a cleanup. It includes: • A systematic protocol to identify, prioritize, select, implement and report on the use of best management practices (BMPs) to reduce the environmental footprint of cleanup activities • A list outlining more than 160 greener cleanup BMPs that are linked to the core elements of a greener cleanup and to relevant cleanup technologies • Guidelines to quantify the environmental footprint of cleanup activities, and • Establishing a framework to support new tools for evaluating impacts from cleanups, and • Building upon state and local government incentives for greener cleanups."
(13)	USEPA	Stanislaus, M. 2013. Memorandum: Encouraging Greener Cleanup Practices through Use of ASTM International's Standard Guide for Greener Cleanups. Washington, DC: USEPA, OSWER.	**p2:** "The Guide includes the following features: a systematic protocol to identify, prioritize, select, implement, and report on the use of best management practices to reduce the environmental footprint of cleanup activities; a list ofgreener cleanup best management practices; guidelines to quantify the environmental footprint of cleanup activities; and a reporting structure to promote public availability ofinformation relating to the decision-making process and communication of outcomes across the five core elements. In line with the Agency's pursuit ofa cleaner, safer environment, I recommend that regions and OSWER programs facilitate and encourage use of ASTM's Standard Guide for Greener Cleanups in your efforts to implement greener cleanup practices."
(14)	USEPA	USEPA. 2009. Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices (EPA 530-R-09-017). Washington, DC: USEPA, OSWER.	**p24:** "EPA and other organizations involved with cleaning up contaminated land may find opportunities to employ cleanup techniques that provide an equivalent level of environmental and human health protection while emitting lower amounts of GHGs through: 1) optimizing remedies and treatment systems both for new and existing remedies; 2) using alternative energy derived from cleaner and renewable energy sources; and 3) accounting for the technical needs of potential reuse options and incorporating them throughout the cleanup processes to facilitate sustainable reuse of the property and preservation of greenfields." **p25:** "Green remediation practices are being employed at contaminated sites, which can reduce GHG emissions. For example, some remediation projects use solar energy to operate ground water pump and treat systems; others are reducing construction engine idling time, and using alternative fuels to reduce GHG emissions."

	Source	Citation	Quote / Summary
(15)	USEPA	USEPA. No Date. "EPA Office of Solid Waste and Emergency Response (OSWER) Study Information." http://www.gsa.gov/graphics/ fas/WhatIsGreenRemediation-May.pdf (accessed May 30, 2014).	**p3-4:** "Green remediation strategies are derived from CERCLA and NCP frameworks but also involve concepts from executive orders and federal or state statutes and regulations that specifically address reductions in energy and water consumption, increased use of renewable energy, and conservation of other natural resources. • The Energy Independence and Security Act of 2007 builds on the Energy Policy Act of 2005 by setting additional goals for energy consumption and associated GHG emissions, including increased use of alternative fuels for vehicles and accelerated research on alternative energy resources. • Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, requires federal agencies to: Increase energy efficiency; Measure, report, and reduce GHG emissions from direct and indirect sources; Conserve and protect water resources through efficiency, reuse, and stormwater management; Eliminate waste, recycle, and prevent pollution; Leverage agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services; Design, construct, maintain, and operate high performance buildings in sustainable locations; and Strengthen vitality and livability of communities where federal facilities are located • In the context of EO 13514, EPA activities include government remediation of Superfund sites. Draft guidance on federal GHG accounting and reporting indicates that emissions associated with this activity are subject to "scope 3" voluntary reporting.
(16)	USEPA	USEPA. 2010. Green Remediation Best Management Practices: Clean Fuel & Emission Technologies for Site Cleanup (EPA 542-F-10-008). Washington, DC: USEPA, OSWER.	**p1:** "Minimizing emission of air pollutants such as greenhouse gases (GHGs) and particulate matter (PM) resulting from cleanup activities, including those needing fossil or alternative fuel, is a core element of green remediation strategies. Efforts to reduce these emissions during site investigation, remedial or corrective actions, and long-term operation and maintenance (O&M) must meet Clean Air Act (CAA) requirements and state air quality standards as well as requirements of federal and state cleanup programs."
(17)	USEPA	Dellens, A.D. 2007. Green Remediation and the Use of Renewable Energy Sources for Remediation Projects. Washington, DC: USEPA, OSWER, OSRTI.	**p20:** "It could be projected that an estimated 10% of all operational P&T systems in the Superfund program use a source of clean, renewable energy for an estimated 30 percent of the remediation system's energy requirements. Using a DOE Energy Information Administration estimate of 1.37 pounds of CO_2 per kW hour generated the hypothetical energy savings equate to approximately 8,794.35 tons of avoided CO_2 emissions per year. These emissions savings are equivalent to the electricity consumed by approximately 1,024 households over one year, or the CO_2 sequestered by 204,567 tree seedlings over ten years of growth."
(18)	USEPA	USEPA. 2006. Ecological Benefits Assessment Strategic Plan (EPA-240-R-06-001). Washington, DC: USEPA.	**p3:** "Benefit Cost Analysis (BCA) is an accepted economic approach for comparing the advantages and disadvantages of policies in a consistent format to help decisionmakers make more informed choices (Arrow et al., 1996). Support for BCA has increased over time, as reflected in Executive Order 12866, the Safe Drinking Water Act (SDWA), and in parts of the Clean Air Act (CAA). BCA estimates the net benefits to society as a whole by comparing the expected benefits accruing to those made better off by a policy to the expected costs imposed on those made worse off. BCA can be used prospectively to provide information to decisionmakers for choosing among proposed alternative policies. It also can be applied retrospectively to determine whether a policy has been successful, to learn from any unintended consequences, or to determine whether further action is needed. Furthermore, the results of BCAs can be useful for communicating to the public the value of EPA's regulatory programs and for providing guidance for its voluntary programs."

	Source	Citation	Quote / Summary
(19)	USEPA	USEPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA-540-R-05-012, OSWER 9355.0-85). Washington, DC: USEPA, OSWER.	**p2-14:** Implementing in-situ capping, dredging, or excavation "might result in increased risk of exposure to contaminants released during sediment removal, transport, or disposal; other community impacts (e.g., accidents, noise, residential or commercial disruption); worker exposure during sediment removal and handling; and disruption of the benthic community." **p6-6:** "It is important to determine whether the loss of a contaminated habitat is a greater impact than the benefit of providing a new, modified but less contaminated habitat. **p7-13:** "Project managers **are encouraged to use the concept of comparing net risk reduction between alternatives as part of their decision-making process for contaminated sediment sites** , within the overall framework of the NCP remedy selection criteria. Consideration should be given not only to risk reduction associated with reduced human and ecological exposure to contaminants, **but also to risks introduced by implementing the alternatives [...] Evaluation of both implementation risk and residual risk are existing important parts of the NCP remedy selection process. By evaluating these two concepts in tandem, additional information may be gained to help in the remedy selection process.**"
(20)	USEPA	USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (EPA 540-R-97-006). Washington, DC: USEPA, OSWER.	**p8-3:** "Consideration of the environmental effects of the remedy itself might result in a decision to allow contaminants to remain on site at levels higher than the threshold for effects on the assessment endpoint. Thus, selection of the most appropriate ecologically based remedy can result in residual contamination that presents some risk. " **p8-4:** "With an understanding of potential adverse effects posed by residual levels of site contaminants and posed by the remedial actions themselves, the risk manager can balance the ecological costs and benefits of the available remedial options." **p8-3:** "In instances where substantial ecological impacts will result from the remedy, the risk manager will need to consider ways to mitigate the impacts of the remedy and compare the mitigated impacts to the threats posed by the site contamination." **p8-3:** ""The risk manager must balance (1) residual risks posed by site contaminants before and after implementation of the selected remedy with (2) the potential impacts of the selected remedy on the environment independent of contaminant effects."
(21)	ITRC	Interstate Technology and Regulatory Council (ITRC). 2011. Green and Sustainable Remediation: A Practical Framework. Washington, DC: ITRC, Green and Sustainable Remediation Team.	**p43:** "Remedy optimization involves the evaluation of existing remediation systems to improve the performance, reduce the annual operating cost or environmental footprint, or other factors associated with the remediation system while ensuring that it is still protective of human health and the environment." **p44:** "Considering Green and Sustainable Remediation (GSR approaches early in the remediation process (e.g., site investigation, **remedy evaluation and selection**) is the best approach to reduce GSR impacts [...] During the remedy selection phase of a project, several remedies are often evaluated to identify the optimal remedy from the standpoint of protectiveness, cost, time, and stakeholder acceptance."

	Source	Citation	Quote / Summary
(22)		USEPA. 2011. Greener Cleanups: Contracting and Administrative Toolkit.Washington, DC: USEPA, OSWER.	**p29:** “The EPA Region 2 Superfund program supports the adoption of “green site assessment and remediation,” which is defined as the practice of considering all environmental impacts of studies, selection and implementation of a given remedy, and incorporating strategies to maximize the net environmental benefit [emphasis added] of cleanup actions. EPA Region 2 has established a "Clean & Green" policy to enhance the environmental benefits of Superfund cleanups by promoting technologies and practices that are sustainable. The policy applies to all Superfund cleanups. Under this policy, certain green remediation technologies will serve as touchstones for Region 2 response actions.“

Appendix B:
Case Studies and NEBA Framework Examples

	Source	Citation	Quote / Summary
(1)	Case Study	Colombo, F., J. Nicolette, R. Wenning, and M. Travers. 2012. Incorporating Ecosystem Service Valuation in the Assessment of Risk and Remedy Implementation. Chemical Engineering Transactions 28:55-60.	**p56:** " An ecosystem services assessment conducted concurrently with risk assessment and prior to the promulgation of protection goals could provide site remediation managers with the knowledge necessary to limit negative effects from the remediation work at the site [...] the potential exists for remedial actions based upon risk assessment and protection goal(s) to create more harm to the ecosystem than predicted by the risk assessment (which largely drove the remedial action in the first place) or provide only marginal benefit for the cost and effort expended."
(2)	Case Study	Fitzpatrick, F. 2012. Net Environmental Benefit Analysis (NEBA) Relative Risk Ranking Conceptual Design. US Geological Survey.	This document describes the (NEBA) process used to rank the potential impacts from specific submerged oil recovery actions (monitored natural attenuation, enhanced deposition, agitation toolbox, sweep/push collection, dredging/vacuum truck, dewater/excavate, scraping, and sheen collection) on ecological resources present within eight distinct habitats of the Kalamazoo River.
(3)	Case Study	Magar, V.S., K. Merritt, M. Henning, M. Sorensen, and R.J. Wenning. 2008. Approaches Used for Remedy Selection at Contaminated Sediment Sites. In Real-Time and Deliberative Decision Making. I. Linkov et al. (eds). Springer.	**p5:** "In the context of human health, failure to adequately evaluate implementation risks during the remedy selection process can result in unanticipated injuries (or even fatalities) to workers and nearby residents during cleanup. Consequences may also include costly delays associated with substantial remedy modifications or abandonment of an incomplete remedy." **p5:** "Risk-of-remedy analyses often are used in conjunction with the evaluation of costs to identify the appropriate and logical remedy for a given site. The goal is to meet risk-reduction goals at the most reasonable cost, while minimizing negative impacts to the natural environment, and minimizing short-term risks to human health associated with remedy implementation."
(4)	Case Study	Nicholas, D., Nicolette, J., Weier, J., and Rockel, M. 2008. Demonstrating the Net Benefit of Site Cleanup: An Evaluation of Ecological and Economic Metrics at Two Superfund Sites. USEPA, OSWER.	"There is a growing consensus to consider ecosystem services associated with actions. Further, there is a need to quantify and maximize these ecosystem service values (e.g., demonstrate values to the public). NEBA is a tool that can be used to assist EPA in demonstrating transparency, clarity, and consistency in decision-making."
(5)	Case Study	Operational Science Advisory Team (OSAT-2). 2011. Summary Report for Fate and Effects of Remnant Oil in the Beach Environment. US Coast Guard, New Orleans, LA.	**p33:** "The results of the analysis indicate that the environmental effects of the residual oil remaining after cleanup are relatively minor, especially when considered in the context of pre-spill background of shoreline oiling and longer-term monitoring to ensure that cleanup guidelines are not exceeded. Continued cleanup to a higher degree, on the other hand, would be expected to result in an increasingly greater extent of negative impact to habitats and associated resources as more and more effort is directed toward removing diminishing amounts of oil."
(6)	Case Study	USEPA, 2001. Undating Remedy Decisions at Select Superfund Sites. OERR 540-R-01-00 OSWER 9355.0-76 March 2001	Actions and decisions that affect habitats/land, etc., can substantially affect ecosystem service values, and changes to these values can be quantified and evaluated. In this case, a NEBA evaluation of remedies for the Woodlands site in New Jersey identified alternatives that would be objectives set forth in the Record of Decision for the site "at a much lower cost, and the resultant estimated savings exceeed $87.0 million."

	Source	Citation	Quote / Summary
(7)	Case Study	Shigenaka, G. 2011. Summary Report for Fate and Effects of Remnant Oil Remaining in the Environment. Annex M - Net Environmental Benefit Analysis. NOAA.	**p3:** In the case of the Exxon Valdez, NOAA determined that "there was no net environmental benefit to be gained by shoreline excavation and washing and that this technology has the potential of aggravating the injury to the environment caused by the spill." **p33:** During the 1967 Torrey Canyon spill on the English coast, the use of highly toxic petroleum -based shoreline cleaning agents caused widespread acute toxicity to intertidal invertebrates on the rocky shore and impeded recovery of algal communities. Seneca and Broome (1982) described long -term damage to marsh habitat impacted by both oil and cleanup during the Amoco Cadiz spill in France. Baker (1999) used the Amoco Cadiz example to illustrate both the quandary as well as the potential operational compromise presented by heavy oiling and cleanup in a highly sensitive habitat. **p43:** for the Deepwater Horizon, "the defined NFT guidelines are supported and that in most cases, **treatment beyond those guidelines is likely to cause more environmental harm than the continued presence of the three oil types on the sand beaches**."
(8)	Framework Paper	Efroymson, R.A., J.P. Nicolette, and G.W. Suter II. 2003. A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Petroleum-Contaminated Sites (ORNL/TM-2003/17). Oak Ridge, TN: ORNL, Environmental Sciences Division.	**p6: "** Remedial goals are defined based on health or ecological risks from the contaminants, but the remedial technologies are chosen based primarily on two engineering criteria: the ability to achieve those goals and cost-effectiveness. This focus on engineering criteria rather than environmental goals tends to restrict the range of options considered." **p13:** "The planning phase for a NEBA includes: setting the goals of assessment; selecting a limited and feasible suite of alternative actions; defining the temporal and spatial scope of assessment; identifying contaminant and remediation stressors; selecting environmental services and other ecological properties of interest; selecting metrics and methodologies for the comparison of alternatives; selecting a reference state; establishing a link between stressors and services (conceptual model); and developing an analysis plan. The planning phase is comparable to the planning and problem formulation phases in a risk assessment (EPA 1998). A comparative assessment such as a NEBA should have a plan that encompasses all relevant, alternative actions." **p14:** "It is possible that (1) vehicle movement, grading, tilling, or trampling could constitute stressors in the process of restoring an ecosystem, (2) the restoration may fail and result in physical damage, or (3) the restoration of habitat for one population could decrease habitat for another." **p18:** "The conceptual model for NEBA of remediation alternatives should include stressor-service pathways for remedial technologies..."
(9)	Framework Paper	Efroymson, R.A., J.P. Nicolette, and G.W. Suter. 2004. A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Contaminated Sites. Environmental Management 34(3):315-331.	Development of a framework for NEBA, demonstrating how benefits and residual adverse effects from natural attenuation, traditional remediation, and ecological restoration options can be compared systematically.

	Source	Citation	Quote / Summary
(10)	Framework Paper	ITRC. 2006. Planning and Promoting Ecological Land Reuse of Remediated Sites. Washington, DC: ITRC, Ecological Reuse Team.	**p64: "**During remedy selection, the EPA Directive asks that the risk managers examine the likelihood of the response alternatives to achieve success and the timeframe for a biological community to fully recover. The EPA suggests that an evaluation of ecological effects resulting from implementation of various alternatives be discussed in the feasibility study (FS) or the engineering evaluation/cost analysis (EE/CA) and should include input from the ecological risk assessor and the federal and/or state trustees responsible for the resources that may be impacted by the response." **p64:** "The best time to conduct a NEBA is in conjunction with an FS. This allows for full consideration of natural resources issues to be integrated with the development of remedial alternatives. A NEBA can also be used to help screen out FS alternatives so that alternatives with disproportionate cost/benefit issues can be eliminated."
(11)	Framework Paper	Morford, JM, and Curtiss, SS. 2009. Steps Toward Net Environmental Benefit in Agency Decisions. Oregon Insider: 453 (p. 1 - 7).	"The opportunity for regulated industry is huge cost savings by reducing the energy and resource consumption that flows from narrowly focused mandates in existing laws and the flexibility to control environmental impacts in innovative ways rather than through adherence to proscriptive requirements. The public stands to benefit from lesser environmental impacts, while at the same time enjoying the indirect benefits of the cost savings for regulated industries (e.g., less expensive products and services and job retention resulting from more competitive American industry)."
(12)	Framework Paper	Nicolette, J.P., D. Pelletier, and M. Rockel. 2011. Incorporating Ecosystem Service Valuation into Remedial Decision Making: Net Ecosystem Service Analysis. Superfund and Natural Resource Damages Litigation Committee Newsletter 7(1):9-13.	**p13:** "in many cases, with the completion of focused source removal, additional work to remove residual contamination through dredging or capping may not be beneficial. The alternative providing the maximum net environmental benefit is based upon the quantification as to how each remedy affects ecological services, human use services, and the risk scenario. In many cases, if potential risks are small and uncertain, the public may be better off with an alternative that couples MNR with restoration that creates “certain” benefits to the public in lieu of “uncertain” losses."
(13)	Framework Paper	Roberson, B. Net Environmental Benefit Analysis (NEBA) Decision-Making Tool: Developing Consensus for Environmental Decision-Making In Emergency Response	NEBAs look to identify the best ways to minimize impacts while enhancing recovery, taking into account the tradeoffs between the results of one action versus another. "The NEBA process provides the basis for comparing and prioritizing risk. If every alternative presents some level of risk, then such an approach can provide the basis for choosing between alternatives."
(14)	Framework Paper	Slack, S. 2010. The Incorporation of an Ecosystem Services Assessment into the Remediation of Contaminated Sites. Washington, DC: USEPA, OSWER, OSRTI.	**p11:** "Once the site’s ecosystem services are identified, decision makers can begin prioritizing the services. Since there may be a multitude of services provided by one site, it may not be possible to evaluate and mitigate negative remedial affects on each service due to circumstantial constraints such as lack of time or funding. This may especially be the situation at a larger site or a site that encompasses multiple ecosystem types. If this is the case, decisions will need to be made to determine which services are priorities to preserve or which require reduced impacts." **p15:** "Ecosystems are complex and intricate interacting systems. One single action may have an obvious direct impact on the ecosystem; however, it may also have one or more not-so obvious indirect effects. Again returning to the earlier discussion example, the direct impact of heavy site traffic is the compaction of soil. In contrast, the indirect effects are the soil erosion, runoff, and potential decreases in water quality." **p16:** "If multiple remedial options are available, project managers have the opportunity to consider the results of the ecosystem services assessment during the remedy selection process."
(15)	Framework Paper	USEPA Science Advisory Board. 2011. Review of EPA’s Draft Oil Spill Research Strategy	Following the DWH, EPA developed a research strategy on potential human and environmental risks from oil spills and the application of dispersants, surface washing agents, bioremediation agents, and other mitigation measures for FY12 through FY15.

	Source	Citation	Quote / Summary
(16)	Case Study	National Institute of Environmental Health Sciences (NIEHS). Examples of SBRP-funded Activities at Hazardous Waste Sites. Research Triangle Park, NC: NIEHS, Superfund Research Program (SRP).	"Dr. Kirby (KC) Donnelly, Texas A&M University SBRP, worked collaboratively with EPA Region 6 Remedial Project Manager (RPM) Robert Sullivan and Risk Assessor Ghassan Khoury to provide technical support to communities and city/state health departments impacted by these two wood preserving sites [...] His data were used in the Net Environmental Benefit Analysis (NEBA) that was utilized in the ecological risk assessment. In March, 2007, Dr. Khoury sent Dr. Donnelly a letter thanking him for helping the Superfund technical team by providing ecological analysis that reduced uncertainty in the decision making process for the two sites."

Appendix C:
Carol Browner Memorandum (USEPA 1995)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

THE ADMINISTRATOR

MAR 21 1995

MEMORANDUM

SUBJECT: EPA Risk Characterization Program

TO: Assistant Administrators
Associate Administrators
Regional Administrators
General Counsel
Inspector General

EPA has achieved significant pollution reduction over the past 20 years, but the challenges we face now are very different from those of the past. Many more people are aware of environmental issues today than in the past and their level of sophistication and interest in understanding these issues continues to increase. We now work with a populace which is not only interested in knowing what EPA thinks about a particular issue, but also how we come to our conclusions.

More and more key stakeholders in environmental issues want enough information to allow them to independently assess and make judgments about the significance of environmental risks and the reasonableness of our risk reduction actions. If we are to succeed and build our credibility and stature as a leader in environmental protection for the next century, EPA must be responsive and resolve to more openly and fully communicate to the public the complexities and challenges of environmental decisionmaking in the face of scientific uncertainty.

As the issues we face become more complex, people both inside and outside of EPA must better understand the basis for our decisions, as well as our confidence in the data, the science policy judgments we have made, and the uncertainty in the information base. In order to achieve this better understanding, we must improve the way in which we characterize and communicate environmental risk. We must embrace certain fundamental valuesso that we may begin the process of changing the way in which we interact with each other, the public, and key stakeholders on environmental risk issues. I need your help to ensure that these values are embraced and that we change the way we do business.

First, we must adopt as values **transparency** in our decisionmaking process and **clarity** in communication with each other and the public regarding environmental risk and the uncertainties associated with our assessments of environmental risk. This means that we must fully, openly, and clearly characterize risks. In doing so, we will disclose the scientific analyses, uncertainties, assumptions, and science policies which underlie our decisions as they are made throughout the risk assessment and risk management processes. I want to be sure that key science policy issues are identified as such during the risk assessment process, that policymakers are fully aware and engaged in the selection of science policy options, and that their choices and the rationale for those choices are clearly articulated and visible in our communications about environmental risk.

I understand that some may be concerned about additional challenges and disputes. I expect that we will see more challenges, particularly at first. However, I strongly believe that making this

change to a more open decisionmaking process will lead to more meaningful public participation, better information for decisionmaking, improved decisions, and more public support and respect for EPA positions and decisions. There is value in sharing with others the complexities and challenges we face in making decisions in the face of uncertainty. I view making this change as essential to the long term success of this Agency.

Clarity in communication also means that we will strive to help the public put environmental risk in the proper perspective when we take risk management actions. We must meet this challenge and find legitimate ways to help the public better comprehend the relative significance of environmental risks.

Second, because **transparency** in decisionmaking and **clarity** in communication will likely lead to more outside questioning of our assumptions and science policies, we must be more vigilant about ensuring that our core assumptions and science policies are **consistent** and comparable across programs, well grounded in science, and that they fall within a "zone of **reasonableness**." While I believe that the American public expects us to err on the side of protection in the face of scientific uncertainty, I do not want our assessments to be unrealistically conservative. We cannot lead the fight for environmental protection into the next century unless we use common sense in all we do.

These core values of transparency, clarity, consistency, and reasonableness need to guide each of us in our day-to-day work; from the toxicologist reviewing the individual cancer study, to the exposure and risk assessors, to the risk manager, and through to the ultimate decisionmaker. I recognize that issuing this memo will not by itself result in any change. You need to believe in the importance of this change and convey your beliefs to your managers and staff through your words and actions in order for the change to occur. You also need to play an integral role in developing the implementing policies and procedures for your programs.

I am issuing the attached EPA Risk Characterization Policy and Guidance today. I view these documents as building blocks for the development of your program-specific policies and procedures. The Science Policy Council (SPC) plans to adopt the same basic approach to implementation as was used for Peer Review. That is, the Council will form an Advisory Group that will work with a broad Implementation Team made up of representatives from every Program Office and Region. Each Program Office and each Region will be asked by the Advisory Group to develop program and region-specific policies and procedures for risk characterization consistent with the values of **transparency, clarity, consistency, and reasonableness** and consistent with the attached policy and guidance.

I recognize that as you develop your Program-specific policies and procedures you are likely to need additional tools to fully implement this policy. I want you to identify these needed tools and work cooperatively with the Science Policy Council in their development. I want your draft program and region-specific policies, procedures, and implementation plans to be developed and submitted to the Advisory Group for review by no later than May 30, 1995. You will be contacted shortly by the SPC Steering Committee to obtain the names of your nominees to the Implementation Team.

/s/

Carol M. Browner

Appendix D:
Carbon Footprinting Calculation Tables

Table D1 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	2,404	1.4E-02	1.8	1.4E-02	1.8
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	13,152	2,187	6.2E-02	2.8E-01	2,212		1.7		1.7	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing & Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	31,680	5,267	0.15	0.68	5,329	26,645	4.0	20	4.0	20
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	63,360	21,070	0.60	2.7	21,316		16		16	
Dredging	Channel Dredgers	2	--	--	896		51%	63,360	43,980	1.3	5.7	44,503	61,224	29	41	29	41
	Dredge Tenders	2	--	--	687		38%	19,008	7,537	0.22	1.0	7,627		4.9		4.9	
	Survey Boats	2	--	--	224		38%	12,672	1,638	4.7E-02	0.21	1,658		1.1		1.1	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	15	14	4.0E-04	1.8E-03	14		9.1E-03		9.1E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	15	0.37	3.0E-06	1.5E-05	0.37		1.9E-03		1.9E-03	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	7,534	7,147	0.21	0.93	7,232		4.7		4.7	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	7,534	189	1.5E-03	7.7E-03	190		1.0		1.0	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	13,247	12,567	0.36	1.6	12,716	33,896	8.2	24	8.2	24
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	13,247	333	2.7E-03	1.4E-02	334		1.8		1.8	
	Channel Dredgers - backfill	2	--	--	896		51%	10,794	7,492	0.22	1.0	7,582		4.9		4.9	
	Dredge Tenders - backfill	2	--	--	687		38%	3,238	1,284	3.7E-02	0.17	1,299		0.84		0.84	
	Survey Boats - backfill	2	--	--	224		38%	2,159	279	8.1E-03	3.6E-02	282		0.18		0.18	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	6,967	6,609	0.19	0.86	6,688		4.3		4.3	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	6,967	175	1.4E-03	7.1E-03	176		0.93		0.93	
	Channel Dredgers- mudflat, etc. backfill	2	--	--	896		51%	5,677	3,940	0.11	0.51	3,987		2.6		2.6	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	1,703	675	2.0E-02	8.8E-02	683		0.44		0.44	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	1,135	147	4.3E-03	1.9E-02	149		0.10		0.10	
Pre-Construction of CAD	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	12	2.0	5.7E-05	2.6E-04	2.0	111	1.5E-03	8.4E-02	1.5E-03	8.4E-02
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	564	94	2.7E-03	1.2E-02	95		7.2E-02		7.2E-02	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	84	14	4.0E-04	1.8E-03	14		1.1E-02		1.1E-02	

ENVIRON

Table D1 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
CAD Excavation	Channel Dredgers	4	--	--	896		51%	16,906	23,469	0.68	3.1	23,749	88,399	15	64	15	64
	Dredge Tenders	4	--	--	687		38%	5,072	4,022	0.12	0.52	4,070		2.6		2.6	
	Survey Boats	4	--	--	224		38%	3,381	874	2.5E-02	0.11	885		0.57		0.57	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	15	14	4.1E-04	1.9E-03	14		9.3E-03		9.3E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	15	0.38	3.1E-06	1.5E-05	0.38		2.0E-03		2.0E-03	
	Cont. Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	710	674	2.0E-02	8.8E-02	682		0.44		0.44	
	Cont. Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	710	18	1.4E-04	7.2E-04	18		9.5E-02		9.5E-02	
	Uncont Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	51,019	48,398	1.4	6.3	48,974		32		32	
	Uncont Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	51,019	1,283	1.0E-02	5.2E-02	1,287		6.8		6.8	
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	17,280	5,746	0.16	0.74	5,813		4.4		4.4	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	8,640	1,437	4.1E-02	0.18	1,453		1.1		1.1	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	8,640	1,437	4.1E-02	0.18	1,453		1.1		1.1	
CAD Closure	Cap Material Scow Tug Boat - main	1	--	--	1,836	--	68%	6,848	6,496	0.19	0.8	6,574	11,579	4.3	8.3	4.3	8.3
	Cap Material Scow Tug Boat - aux	1	--	--	--	210	43%	6,848	172	1.4E-03	7.0E-03	173		0.91		0.91	
	Channel Dredgers - backfill	2	--	--	896		51%	5,580	3,873	0.11	0.51	3,919		2.5		2.5	
	Dredge Tenders - backfill	2	--	--	687		38%	1,674	664	1.9E-02	8.7E-02	672		0.44		0.44	
	Survey Boats - backfill	2	--	--	224		38%	1,116	144	4.2E-03	1.9E-02	146		9.5E-02		9.5E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	498	83	2.4E-03	1.1E-02	84		6.4E-02		6.4E-02	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	72	12	3.4E-04	1.5E-03	12		9.2E-03		9.2E-03	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	1,440	479	1.4E-02	6.1E-02	484	4,091	0.37	3.1	0.37	3.1
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,600	599	1.7E-02	7.7E-02	606		0.46		0.46	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	7,758	1,290	3.7E-02	0.17	1,305		1.0		1.0	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	10,080	1,676	4.8E-02	0.21	1,696		1.3		1.3	
Total									**225,691**	**6.5**	**29**	**228,350**		163		163	

ENVIRON

Table D1 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario A

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[12]

Project Phase	Vessel Type					
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel
Pre-Construction	108	13,152	--	108	924	--
Testing and Monitoring During Dredging and Backfilling	31,680	--	63,360	--	--	--
Dredging	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	--	--	--	--	--
Pre-Construction of CAD	12	564	--	--	84	--
CAD Excavation[13]	8,640	8,640	17,280	--	--	--
CAD Closure	72	498	--	--	--	--
Annual O&M[14]	3,600	7,758	1,440	--	--	10,080

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[15]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,17]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[17]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Dredge rate of clay[1]:	5,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to CAD[6]:	5.3 river miles		
Hours of operation per roundtrip:	1.3 hours		
Amount of large debris removed[1]:	8,000 tons =	146,789 cubic feet =	5,437 cubic yards
Amount of sediment removed[1]:	9,681,000 cubic yards		
Amount of sediment barged[1]:	15,635,000 cubic yards		
Number of large debris trips (total)[8]:	11		
Number of sediment trips (total):	5,686		
Dredged Material from CAD			
Distance to Upland Disposal Area:	20 river miles		
Distance to HARS:	47 river miles		
Hours per roundtrip to UDA:	5 hours		
Hours per roundtrip to HARS:	11.75 hours		
Amount of large debris removed[1]:	1,000 tons =	18,349 cubic feet =	680 cubic yards
Amount of sediment removed (1st cell)[1]:	388,000 cubic yards		
Amount of sediment removed (other cells)[1]:	786,000 cubic yards		
Amount of sediment removed to HARS[1]:	11,153,000 cubic yards		
Time to dredge sediment (per vessel):	704 days =	16,906 hours	
Number of large debris trips (total)[8]:	3		
Number of sediment trips to UDA[10]:	142		
Number of sediment trips to HARS:	4,342		

Backfill Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 river miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill		
Amount of backfill[1]:	1,799,000 cubic yards	
Number of trips (total):	654 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	450 days =	10,794 hours
Mudflat/Mudflat Reconstruction/Natural Shoreline Backfill		
Amount of backfill[1]:	946,093 cubic yards	
Number of trips (total):	344 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	237 days =	5,677 hours

Table D1 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario A

CAD Cap Material		
Amount of Cap Material[1]:	930,000 cubic yards	
Number of trips (total):	338 per scow	
Cap Material placement rate/vessel[1]:	2,000 cy/day	
Time to place Cap Material (total):	233 days =	5,580 hours

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] From mid-point of 8-mile study area (Figure 1-1 of FFS) to mid-point of CADs in Newark Bay (Figure 4-1 of FFS)

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Only for sediment removed from first cell.

[11] Includes contaminated sediment (disposed of in CAD or Upland Disposal Area) and uncontaminated sediment (disposed of in HARS).

[12] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[13] Water survey vessel assumed to operate 24 hours/day.

[14] Assuming 30 years of annual O&M.

[15] Average PM_{10} emission factor for Tier 1 Engines

[16] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[17] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D2 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	13,152	13.63	1.1E-04	5.5E-04	13.67	13.67	7.2E-02	7.2E-02	7.2E-02	7.2E-02
Dredging	Sheet Pile Driver - Utility Protection	228	0.58	50%	1,600	38	3.1E-04	1.5E-03	38	38	0.20	0.20	0.20	0.20
Pre-Construction of CAD	Vibracoring Equipment	10	0.025	50%	564	0.58	4.7E-06	2.4E-05	0.59	0.59	3.1E-03	3.1E-03	3.1E-03	3.1E-03
CAD Excavation	Vibratory Pile Driver - Containment System	228	0.58	50%	5,840	138	1.1E-03	5.6E-03	138	138	0.73	0.73	0.73	0.73
CAD Closure	Sheet Pile Remover - vibratory equipment	10	0.025	50%	5,840	6.1	4.9E-05	2.5E-04	6.1	6.1	3.2E-02	3.2E-02	3.2E-02	3.2E-02
Annual O&M	Vibracoring Equipment	10	0.025	50%	7,758	8.0	6.5E-05	3.3E-04	8.1	8.1	4.3E-02	4.3E-02	4.3E-02	4.3E-02
Total						**204**	**0**	**0**	**205**		1.1		1.1	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	13,152
Dredging	Sheet Pile Driver[3]	1,600
Pre-Construction of CAD	Vibracoring Equipment	564
CAD Excavation	Sheet Pile Driver[3]	5,840
CAD Closure	Sheet Pile Removal[6]	5,840
Annual O&M	Vibracoring Equipment	7,758

Table D2 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book*, *26th Edition*, Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[6] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D3 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[8]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Fugitive Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	81	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	343	--	18	--	--	18		7.6E-03		--	
Dredging	Sheet Pile Driver Crane - Utility Protection	1	226	29%	1,600	--	61	--	--	61	61	1.2E-02	1.2E-02	--	--
Pre-Construction of CAD	Drill Rig - USF Geotechnical	1	206	43%	10	--	0.52	--	--	0.52	4.9	2.2E-04	2.1E-03	--	--
	Barge-Auger	1	206	43%	84	--	4.3	--	--	4.3		1.9E-03		--	
CAD Excavation	Sheet Pile Driver Crane - Containment System	1	226	29%	5,840	--	224	--	--	224	224	4.3E-02	4.3E-02	--	--
Upland Support Facility	Rubber-tired Dozers	4	255	40%	104	--	25	--	--	25	752	7.9E-03	0.71	2.2E-02	2.2E-02
	Tractors/Loaders/ Backhoes	10	97	37%	1,714	--	470	--	--	470		0.57		--	
	Excavators	1	162	38%	64	--	2.3	--	--	2.3		8.4E-04		--	
	Graders	1	174	41%	64	3.4	2.7	--	--	2.7		1.1E-03		1.5E-05	
	Cranes	1	226	29%	1,610	--	62	--	--	62		1.2E-02		--	
	Forklifts	3	89	20%	1,840	--	64	--	--	64		1.8E-02		--	
	Generator Sets	1	84	74%	1,840	--	74	--	--	74		5.6E-02		--	
	Welders	1	46	45%	1,840	--	29	--	--	29		3.1E-02		--	
	Pavers	2	125	42%	144	--	8.9	--	--	8.9		3.7E-03		--	
	Paving Equipment	2	130	36%	144	--	8.0	--	--	8.0		3.6E-03		--	
	Rollers	2	80	38%	144	--	5.7	--	--	5.7		3.3E-03		--	
CAD Closure	Sheet Pile Remover - Crane	1	226	29%	5,840	--	224	--	--	224	224	4.3E-02	4.3E-02	--	--
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	160	--	6.2	--	--	6.2	43	4.2E-03	1.7E-02	--	3.3E-02
	Excavators	3	162	38%	160	--	17	--	--	17		6.3E-03		--	
	Rubber-tired Dozers	2	255	40%	160	--	19	--	--	19		6.1E-03		3.3E-02	
Total							**1,389**	**0**	**0**	**1,389**		**0.86**		**5.5E-02**	

ENVIRON

Table D3 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[8] (lb/VMT)	$PM_{2.5}$[8] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	343
Dredging	Sheet Pile Driver[3]	1,600
Pre-Construction of CAD	Drill Rig - Upland Support Facility	10
	Barge-Auger	84
CAD Excavation	Sheet Pile Driver[3]	5,840
CAD Closure	Sheet Pile Removal[9]	5,840

USF Site Area[1]: 5 acres

ENVIRON

Table D3 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	5	Rubber Tired Dozers	3	8
		Tractors/ Loaders/ Backhoes	4	8
Grading	8	Excavators	1	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Tractors/ Loaders/ Backhoes	3	8
Building Construction	230	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/ Loaders/ Backhoes	3	7
		Welders	1	8
Paving	18	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	20	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D3 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book*, *26th Edition*, Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 25,150 sf of General Light Industrial on 5-acre site; Climate Zone 1; Urban

[8] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

[9] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D4 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario B

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	2,404	1.4E-02	1.8	1.4E-02	1.8
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	13,152	2,187	6.2E-02	0.28	2,212		1.7		1.7	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing & Monitoring During Dredging & Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	31,680	5,267	1.5E-01	0.68	5,329	26,645	4.0	20	4.0	20
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	63,360	21,070	0.60	2.7	21,316		16		16	
Dredging	Channel Dredgers	2	--	--	896		51%	63,360	43,980	1.3	5.7	44,503	67,819	29	46	29	46
	Dredge Tenders	2	--	--	687		38%	19,008	7,537	0.22	1.0	7,627		4.9		4.9	
	Survey Boats	2	--	--	224		38%	12,672	1,638	4.7E-02	0.21	1,658		1.1		1.1	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	28	26	7.6E-04	3.4E-03	26		1.7E-02		1.7E-02	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	28	0.69	5.6E-06	2.8E-05	0.69		3.7E-03		3.7E-03	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	14,215	13,485	0.39	1.8	13,645		8.8		8.8	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	14,215	357	2.9E-03	1.4E-02	359		1.9		1.9	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	13,247	12,567	0.36	1.6	12,716	33,896	8.2	24	8.2	24
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	13,247	333	2.7E-03	1.4E-02	334		1.8		1.8	
	Channel Dredgers - backfill	2	--	--	896		51%	10,794	7,492	0.22	1.0	7,582		4.9		4.9	
	Dredge Tenders - backfill	2	--	--	687		38%	3,238	1,284	3.7E-02	0.17	1,299		0.84		0.84	
	Survey Boats - backfill	2	--	--	224		38%	2,159	279	8.1E-03	3.6E-02	282		0.18		0.18	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	6,967	6,609	0.19	0.86	6,688		4.3		4.3	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	6,967	175	1.4E-03	7.1E-03	176		0.93		0.93	
	Channel Dredgers- mudflat, etc. backfill	2	--	--	896		51%	5,677	3,940	0.11	0.51	3,987		2.6		2.6	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	1,703	675	2.0E-02	8.8E-02	683		0.44		0.44	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	1,135	147	4.3E-03	1.9E-02	149		0.10		0.10	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maint.Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**130,881**	**3.8**	**17**	**132,426**		**94**		**94**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	13,152	--	108	924	--	--
Testing and Monitoring During Dredging and Backfilling	31,680	--	63,360	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	--	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	8,000 tons =	146,789 cubic feet =	5,437 cubic yards
Amount of sediment removed[1]:	9,681,000 cubic yards		
Amount of sediment barged[1]:	15,635,000 cubic yards		
Number of large debris trips (total)[8]:	11		
Number of sediment trips (total):	5,686		

Backfill Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill		
Amount of backfill[1]:	1,799,000 cubic yards	
Number of trips (total):	654 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	450 days =	10,794 hours
Mudflat/Mudflat Reconstruction/Natural Shoreline Backfill		
Amount of backfill[1]:	946,093 cubic yards	
Number of trips (total):	344 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	237 days =	5,677 hours

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D5 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	13,152	14	1.1E-04	5.5E-04	14	14	7.2E-02	7.2E-02	7.2E-02	7.2E-02
Dredging	Sheet Pile Driver - Utility Protection	228	0.58	50%	1,600	38	3.1E-04	1.5E-03	38	38	0.20	0.20	0.20	0.20
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**58**	**4.7E-04**	**2.4E-03**	**58**		0.31		0.31	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	13,152
Dredging	Sheet Pile Driver[3]	1,600
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D5 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D6 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	81	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	343	--	18	--	--	18		7.6E-03		--	
Dredging	Sheet Pile Driver Crane - Utility Protection	1	226	29%	1,600	--	61	--	--	61	61	1.2E-02	1.2E-02	--	--
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	52	--	2.7	--	--	2.7	2.7	1.2E-03	1.2E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	520	--	125	--	--	125	1,611	3.9E-02	1.4	0.11	0.11
	Tractors/Loaders/ Backhoes	9	97	37%	3,600	--	888	--	--	888		1.1		--	
	Excavators	2	162	38%	360	--	26	--	--	26		9.5E-03		--	
	Graders	1	174	41%	360	19	15	--	--	15		5.9E-03		8.3E-05	
	Scrapers	2	361	48%	360	--	74	--	--	74		2.1E-02		--	
	Cranes	1	226	29%	3,080	--	118	--	--	118		2.3E-02		--	
	Forklifts	3	89	20%	3,520	--	123	--	--	123		3.5E-02		--	
	Generator Sets	1	84	74%	3,520	--	142	--	--	142		0.11		--	
	Welders	1	46	45%	3,520	--	56	--	--	56		5.9E-02		--	
	Pavers	2	125	42%	280	--	17	--	--	17		7.1E-03		--	
	Paving Equipment	2	130	36%	280	--	15	--	--	15		7.0E-03		--	
	Rollers	2	80	38%	280	--	11	--	--	11		6.4E-03		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	36,000	--	2,959	--	--	2,959	24,321	3.6	9	--	--
	Skid Steer	1	65	37%	36,000	--	660	--	--	660		0.9		--	
	Excavator	1	162	38%	36,000	--	1,308	--	--	1,308		0.5		--	
	Dump Truck	4	400	38%	36,000	--	12,929	--	--	12,929		2.5		--	
	Water Truck	1	400	38%	36,000	--	3,232	--	--	3,232		0.6		--	
	Street Sweeper	1	400	38%	36,000	--	3,232	--	--	3,232		0.6		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	240	--	9.3	--	--	9.3	64	6.4E-03	2.5E-02	--	5.0E-02
	Excavators	3	162	38%	240	--	26	--	--	26		9.5E-03		--	
	Rubber-tired Dozers	2	255	40%	240	--	29	--	--	29		9.1E-03		5.0E-02	
Total							**26,141**	**0**	**0**	**26,141**		**10**		**0.16**	

Engine Characteristics and Emission Rates

ENVIRON

Table D6 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	13,152
	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	343
Dredging	Sheet Pile Driver[3]	1,600
Pre-Construction of UPF	Drill Rig - Upland Support Facility	52
UPF Operations[8,9]	All	36,000

USF Site Area[1]: 27.5 acres

Table D6 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	20	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	45	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	440	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	35	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	30	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D6 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D7 - Emission Estimates from Rail Transport
Remedial Alternative 2, DMM Scenario B

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[10]
Processing and Disposal	Rail Cars Hauling Sediment from UPF to Incinerator	740,000	4,556	99,441	0.34	7.8E-05	99,543	816,535	32	32
	Rail Cars Hauling Sediment from UPF to Landfill	6,630,000	3,086	603,476	1.4	2.0E-03	603,893		197	197
	Rail Cars Hauling Large Debris from UPF to Landfill	785,781	4,556	105,593	0.36	8.8E-05	105,701		34	34
	Rail Cars Hauling SOF from UPF to Landfill	55,000	4,556	7,391	2.5E-02	4.3E-07	7,398		2.4	2.4
Total				**815,901**	**2.1**	**2.1E-03**	**816,535**		**266**	**266**

Distance by Rail[3]

Trip	Roundtrip Distance (miles)
From UPF to Clive Transfer Facility[4]	4,556
From UPF to Avard Transfer Facility[5]	3,086

Assumptions

Amount of Sediment Incinerated[1]:	740,000	tons		
Amount of Sediment Landfilled[1]:	6,630,000	tons		
Amount of Large Debris Landfilled[1]:	534,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	55,000	tons		
Fuel Economy of Trains[8]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		
Amount of Sediment per Container[3]:	22.5	tons		
Amount of Large Debris per Container:	22.5	tons		
Amount of SOF Debris per Container:	22.5	tons		
Emission factor conversion[9]:	1 g/gal =	0.048	gal/bhp-hr	
Weight per cubic foot of large debris[6]:	109	lb/cf =	2,943	lb/cy

ENVIRON

Table D7 - Emission Estimates from Rail Transport
Remedial Alternative 2, DMM Scenario B

Emission Factors[7,8]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[4] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Clive Transfer Facility is 2,261 driving miles.

[5] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Avard Transfer Facility is 1,526 driving miles.

[6] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[7] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[8] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[9] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[10] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D8 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario B

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Sediment from Transfer Facility to Incinerator	32,889	20	1,248	3.5E-03	3.7E-03	1,250	53,685		3.1
	Trucks Hauling Ash from Thermal Incinerator Site to Landfill	8,223	105	1,645	4.6E-03	4.9E-03	1,647			4.1
	Trucks Hauling Sediment from Transfer Facility to Landfill	294,667	60	33,557	9.3E-02	9.9E-02	33,588			83.3
	Trucks Hauling Large Debris from Transfer Facility to Landfill	34,924	52	3,447	9.6E-03	1.0E-02	3,450			8.7
	Trucks Hauling Small Organic Fraction from Transfer Facility to Landfill	2,445	52	241	6.7E-04	7.1E-04	242			0.61
	Trucks Hauling Sand for Beneficial Use	71,112	100	13,497	3.8E-02	4.0E-02	13,510			3.9
Total				**53,636**	**0.15**	**0.16**	**53,685**			104

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from Transfer Facility to Incinerator Site[4,8]	20
Distance from Incinerator Site to Landfill[4,7]	105
Distance from Transfer Facility to Landfill[4,10]	60
Distance from Transfer Facility to Landfill - Large Debris[4,11]	52
Distance from Transfer Facility to Landfill - Small Organic Fraction Debris[11]	52
Distance from UPF to Beneficial Use Site[13]	100

Table D8 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario B

Assumptions

Ash Production Rate by weight[3]:	20%			
Amount of Sediment Incinerated[1]:	740,000	tons		
Amount of Ash Disposal:	148,000	tons		
Amount of Sediment Landfilled[1]:	6,630,000	tons		
Amount of Large Debris Landfilled[1]:	534,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	55,000	tons		
Amount of Sand transported for Beneficial Use[1]:	1,600,000	tons		
Amount of Sediment Transported per Truck[4,9]:	22.5	tons		
Amount of Ash Transported per Truck:	18	tons		
Amount of Large Debris Transported per Truck:	22.5	tons		
Amount of SOF Debris Transported per Truck:	22.5	tons		
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile		
Weight per cubic foot of large debris[12]:	109	lb/cf =	2,943	lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[14]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in UT	0.009558856
Truck transfer in OK	0.009422301
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D8 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Aragonite Incinerator, Utah to Grassy Mountain Subtitle C Landfill, Utah

[8] Clive Transfer Facility, Utah to Aragonite Incinerator, Utah

[9] 22.5 tons of sediment per container

[10] Avard Transfer Facility, OK to Lone Mountain Subtitle C Landfill Facility, OK

[11] Clive Transfer Facility, Utah to Grassy Mountain Subtitle C Landfill, Utah

[12] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[13] No activity data provided in FFS.

[14] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in OK and UT, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D9 - Emission Estimates from Thermal Incineration
Remedial Alternative 2, DMM Scenario A

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	740,000	7,000	518,000	161	--	565,853	6,194

Emission Factors

Pollutant	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D9 - Emission Estimates from Thermal Incineration
Remedial Alternative 2, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4*, Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

Table D10 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario C

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	2,404	1.4E-02	1.8	1.4E-02	1.8
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	13,152	2,187	6.2E-02	0.28	2,212		1.7		1.7	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing & Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	31,680	5,267	1.5E-01	0.68	5,329	26,645	4.0	20	4.0	20
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	63,360	21,070	0.60	2.7	21,316		16		16	
Dredging	Channel Dredgers	2	--	--	896		51%	63,360	43,980	1.3	5.7	44,503	67,819	29	46	29	46
	Dredge Tenders	2	--	--	687		38%	19,008	7,537	0.22	1.0	7,627		4.9		4.9	
	Survey Boats	2	--	--	224		38%	12,672	1,638	4.7E-02	0.21	1,658		1.1		1.1	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	28	26	7.6E-04	3.4E-03	26		1.7E-02		1.7E-02	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	28	0.69	5.6E-06	2.8E-05	0.69		3.7E-03		3.7E-03	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	14,215	13,485	0.39	1.8	13,645		8.8		8.8	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	14,215	357	2.9E-03	1.4E-02	359		1.9		1.9	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	13,247	12,567	0.36	1.6	12,716	33,896	8.2	24	8.2	24
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	13,247	333	2.7E-03	1.4E-02	334		1.8		1.8	
	Channel Dredgers - backfill	2	--	--	896		51%	10,794	7,492	0.22	1.0	7,582		4.9		4.9	
	Dredge Tenders - backfill	2	--	--	687		38%	3,238	1,284	3.7E-02	0.17	1,299		0.84		0.84	
	Survey Boats - backfill	2	--	--	224		38%	2,159	279	8.1E-03	3.6E-02	282		0.18		0.18	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	6,967	6,609	0.19	0.86	6,688		4.3		4.3	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	6,967	175	1.4E-03	7.1E-03	176		0.93		0.93	
	Channel Dredgers- mudflat, etc. backfill	2	--	--	896		51%	5,677	3,940	0.11	0.51	3,987		2.6		2.6	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	1,703	675	2.0E-02	8.8E-02	683		0.44		0.44	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	1,135	147	4.3E-03	1.9E-02	149		0.10		0.10	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maintenance Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**130,881**	**3.8**	**17**	**132,426**		**94**		**94**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	13,152	--	108	924	--	--
Testing and Monitoring During Dredging and Backfilling	31,680	--	63,360	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	--	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	8,000 tons =	146,789 cubic feet =	5,437 cubic yards
Amount of sediment removed[1]:	9,681,000 cubic yards		
Amount of sediment barged[1]:	15,635,000 cubic yards		
Number of large debris trips (total)[8]:	11		
Number of sediment trips (total):	5,686		

Backfill Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill		
Amount of backfill[1]:	1,799,000 cubic yards	
Number of trips (total):	654 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	450 days =	10,794 hours
Mudflat/Mudflat Reconstruction/Natural Shoreline Backfill		
Amount of backfill[1]:	946,093 cubic yards	
Number of trips (total):	344 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	237 days =	5,677 hours

Table D10 - Harbor Craft Emission Estimates
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D11 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	13,152	14	1.1E-04	5.5E-04	14	14	7.2E-02	7.2E-02	7.2E-02	7.2E-02
Dredging	Sheet Pile Driver - Utility Protection	228	0.58	50%	1,600	38	3.1E-04	1.5E-03	38	38	0.20	0.20	0.20	0.20
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**58**	**4.7E-04**	**2.4E-03**	**58**		0.31		0.31	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	13,152
Dredging	Sheet Pile Driver[3]	1,600
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D11 - Stationary Combustion Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D12 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	81	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	343	--	18	--	--	18		7.6E-03		--	
Dredging	Sheet Pile Driver Crane - Utility Protection	1	226	29%	1,600	--	61	--	--	61	61	1.2E-02	1.2E-02	--	--
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	72	--	3.7	--	--	3.7	3.7	1.6E-03	1.6E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	840	--	202	--	--	202	2,685	6.4E-02	2.3	0.17	0.17
	Tractors/Loaders/ Backhoes	9	97	37%	6,020	--	1484	--	--	1,484		1.8		--	
	Excavators	2	162	38%	600	--	44	--	--	44		1.6E-02		--	
	Graders	1	174	41%	600	27	25	--	--	25		9.8E-03		1.2E-04	
	Scrapers	2	361	48%	600	--	123	--	--	123		3.5E-02		--	
	Cranes	1	226	29%	5,180	--	198	--	--	198		3.8E-02		--	
	Forklifts	3	89	20%	5,920	--	207	--	--	207		5.9E-02		--	
	Generator Sets	1	84	74%	5,920	--	239	--	--	239		0.18		--	
	Welders	1	46	45%	5,920	--	93	--	--	93		9.9E-02		--	
	Pavers	2	125	42%	440	--	27	--	--	27		1.1E-02		--	
	Paving Equipment	2	130	36%	440	--	24	--	--	24		1.1E-02		--	
	Rollers	2	80	38%	440	--	18	--	--	18		1.0E-02		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	14,400	--	1,183	--	--	1,183	9,728	1.4	3	--	--
	Skid Steer	1	65	37%	14,400	--	264	--	--	264		0.3		--	
	Excavator	1	162	38%	14,400	--	523	--	--	523		0.2		--	
	Dump Truck	4	400	38%	14,400	--	5,172	--	--	5,172		1.0		--	
	Water Truck	1	400	38%	14,400	--	1,293	--	--	1,293		0.2		--	
	Street Sweeper	1	400	38%	14,400	--	1,293	--	--	1,293		0.2		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	400	--	15.5	--	--	15.5	107	1.1E-02	4.2E-02	--	1.8E-03
	Excavators	3	162	38%	400	--	44	--	--	44		1.6E-02		--	
	Rubber-tired Dozers	2	255	40%	400	--	48	--	--	48		1.5E-02		1.8E-03	
Total							**12,667**	**0**	**0**	**12,667**		**6**		**0.18**	

ENVIRON

Table D12 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	13,152
	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	343
Dredging	Sheet Pile Driver[3]	1,600
Pre-Construction of UPF	Drill Rig - Upland Support Facility	72
UPF Operations[8,9]	All	14,400

USF Site Area[1]: 39.5 acres

ENVIRON

Table D12 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	30	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	75	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	740	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	55	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	50	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D12 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to n

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D13 - Emission Estimates from Rail Transport
Remedial Alternative 2, DMM Scenario C

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance[3] (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[7]
Processing and Disposal	Rail Cars Hauling SOF from Brill Yard Transfer Station to Subtitle C Landfill	55,000	1,480	2,401	2.7E-03	1.5E-08	2,402	2,402	0.78	0.78
Total				**2,401**	**2.7E-03**	**1.5E-08**	**2,402**		**0.78**	**0.78**

Assumptions

Amount of SOF Debris Landfilled[1]:	55,000	tons		
Fuel Economy of Trains[5]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Emission factor conversion[9]:	1 g/gal =	0.048	gal/bhp-hr	
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		

Emission Factors[4,5,6]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D13 - Emission Estimates from Rail Transport
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] Distance from Brills Yard Transfer Facility to Roachdale, IN is 740 driving miles one way.

[4] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[5] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[6] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[7] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D14 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario C

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Thermally Treated Sediment for Beneficial Reuse	8,222	100	1,561	4.3E-03	4.6E-03	1,562	93,697		0.46
	Trucks Hauling Washed Sediment for Beneficial Reuse	369,600	100	70,152	0.20	0.21	70,215			20
	Trucks Hauling Amended Sediment for Beneficial Reuse	6,222	100	1,181	3.3E-03	3.5E-03	1,182			0.34
	Trucks Hauling Decontaminated Medium-Sized Debris	34,924	100	6,629	1.8E-02	2.0E-02	6,635			1.9
	Trucks Hauling SOF to Brills Yard Transfer Station	2,444	28	130	3.6E-04	3.8E-04	130			3.8E-02
	Trucks Hauling SOF from Transfer Station to Roachdale Subtitle C Landfill	2,444	100	464	1.3E-03	1.4E-03	464			1.1
	Trucks Hauling Sand for Beneficial Use	71,111	100	13,497	3.8E-02	4.0E-02	13,509			3.9
Total				**93,613**	**0.26**	**0.28**	**93,697**			**28**

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from UPF to Beneficial Use - Thermally Treated Sediment[8]	100
Distance from UPF to Beneficial Use - Washed Sediment[8]	100
Distance from UPF to Beneficial Use - Amended Sediment[8]	100
Distance from UPF to Medium-Size Debris Landfill[8]	100
Distance from UPF to Brills Yard Transfer Station[4]	28
Distance from Transfer Station to Roachdale Subtitle C Landfill[8]	100
Distance from UPF to Sand Beneficial Use Site[8]	100

Table D14 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario C

Assumptions

Ash Production Rate by weight[3]:	20%		
Amount of Sediment Incinerated[1]:	740,000	tons	
Amount of Ash Beneficially Reused:	148,000	tons	
Amount of Washed Sediment[1]:	6,160,000	cubic yards =	8,316,000 tons
Amount of Amended Sediment[1]:	140,000	tons	
Amount of Medium-Sized Debris[1]:	534,000	cubic yards =	785,781 tons
Amount of SOF Debris Landfilled[1]:	55,000	tons	
Amount of Sand transported for Beneficial Use[1]:	1,600,000	tons	
Amount of Sediment Transported per Truck[4]:	22.5	tons	
Amount of Ash Transported per Truck:	18	tons	
Amount of Large Debris Transported per Truck:	22.5	tons	
Amount of SOF Debris Transported per Truck:	22.5	tons	
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile	
Weight per cubic foot of sediment[7]:	100	lb/cf =	2,700 lb/cy
Weight per cubic foot of large debris[7]:	109	lb/cf =	2,943 lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[9]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in IN	0.009217468
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D14 - Emission Estimates from Truck Traffic
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] No activity data provided in FFS. Assume truck trip = 50 miles one way.

[9] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in IN, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D15 - Emission Estimates from Thermal Incineration
Remedial Alternative 2, DMM Scenario C

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	740,000	7,000	518,000	161	--	565,853	6,194

Emission Factors

GHG	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D15 - Emission Estimates from Thermal Incineration
Remedial Alternative 2, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed June 2014).

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4* , Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory and applied $PM_{2.5}$ to PM_{10} factor.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

Table D16 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	1,124	1.4E-02	0.85	1.4E-02	0.85
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	5,544	922	2.6E-02	0.12	933		0.71		0.71	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing and Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	14,400	2,394	6.8E-02	0.31	2,422	12,111	1.8	9.2	1.8	9.2
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	28,800	9,577	0.27	1.2	9,689		7.3		7.3	
Dredging	Channel Dredgers	2	--	--	896		51%	28,800	19,991	0.58	2.6	20,229	27,625	13	18	13	18
	Dredge Tenders	2	--	--	687		38%	8,640	3,426	0.10	0.45	3,467		2.2		2.2	
	Survey Boats	2	--	--	224		38%	5,760	745	2.2E-02	0.10	754		0.49		0.49	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	7	6.3	1.8E-04	8.2E-04	6		4.1E-03		4.1E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	7	0.17	1.4E-06	6.8E-06	0.17		8.8E-04		8.8E-04	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	3,217	3,052	8.8E-02	0.40	3,088		2.0		2.0	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	3,217	81	6.6E-04	3.3E-03	81		0.43		0.43	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	20,051	19,021	0.55	2.5	19,248	41,042	12	29	12	29
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	20,051	504	4.1E-03	2.0E-02	506		2.7		2.7	
	Channel Dredgers - backfill	2	--	--	896		51%	16,338	11,341	0.33	1.5	11,476		7.4		7.4	
	Dredge Tenders - backfill	2	--	--	687		38%	4,901	1,943	5.6E-02	0.25	1,967		1.3		1.3	
	Survey Boats - backfill	2	--	--	224		38%	3,268	422	1.2E-02	5.5E-02	428		0.28		0.28	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	22	6.3E-04	2.8E-03	22		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	1,414	1,341	3.9E-02	0.17	1,357		0.88		0.88	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	1,414	36	2.9E-04	1.4E-03	36		0.19		0.19	
	Channel Dredgers-armor	2	--	--	896		51%	1,152	800	2.3E-02	0.10	809		0.52		0.52	
	Dredge Tenders - armor	2	--	--	687		38%	346	137	4.0E-03	1.8E-02	139		9.0E-02		9.0E-02	
	Survey Boats - armor	2	--	--	224		38%	230	30	8.6E-04	3.9E-03	30		2.0E-02		2.0E-02	
	Mudflat Scow Tug Boat - main	1	--	--	1,836	--	68%	2,997	2,843	8.2E-02	0.37	2,877		1.9		1.9	
	Mudflat Scow Tug Boat - aux	1	--	--	--	210	43%	2,997	75	6.1E-04	3.1E-03	76		0.40		0.40	
	Channel Dredgers-mudflat	2	--	--	896		51%	2,442	1,695	4.9E-02	0.22	1,715		1.1		1.1	
	Dredge Tenders - mudflat	2	--	--	687		38%	733	290	8.4E-03	3.8E-02	294		0.19		0.19	
	Survey Boats - mudflat	2	--	--	224		38%	488	63	1.8E-03	8.2E-03	64		4.1E-02		4.1E-02	
Pre-Construction of CAD	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	12	2.0	5.7E-05	2.6E-04	2.0	55	1.5E-03	4.1E-02	1.5E-03	4.1E-02
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	276	46	1.3E-03	5.9E-03	46		3.5E-02		3.5E-02	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	36	6.0	1.7E-04	7.7E-04	6		4.6E-03		4.6E-03	

ENVIRON

Table D16 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
CAD Excavation	Channel Dredgers	4	--	--	896		51%	7,742	10,748	0.31	1.4	10,876	41,951	7.0	31	7.0	31
	Dredge Tenders	4	--	--	687		38%	2,323	1,842	5.3E-02	0.24	1,864		1.2		1.2	
	Survey Boats	4	--	--	224		38%	1,548	400	1.2E-02	5.2E-02	405		0.26		0.26	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	10	9.5	2.7E-04	1.2E-03	10		6.2E-03		6.2E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	10	0.25	2.0E-06	1.0E-05	0.25		1.3E-03		1.3E-03	
	Cont. Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	510	484	1.4E-02	6.3E-02	490		0.32		0.32	
	Cont. Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	510	13	1.0E-04	5.2E-04	13		6.8E-02		6.8E-02	
	Uncont Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	22,819	21,647	0.63	2.8	21,904		14		14	
	Uncont Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	22,819	574	4.7E-03	2.3E-02	576		3.0		3.0	
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	11,520	3,831	0.11	0.49	3,876		2.9		2.9	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	958	2.7E-02	0.12	969		0.73		0.73	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	958	2.7E-02	0.12	969		0.73		0.73	
CAD Closure	Cap Material Scow Tug Boat - main	1	--	--	1,836	--	68%	3,093	2,934	8.5E-02	0.38	2,969	5,233	1.9	3.8	1.9	3.8
	Cap Material Scow Tug Boat - aux	1	--	--	--	210	43%	3,093	78	6.3E-04	3.2E-03	78		0.41		0.41	
	Channel Dredgers - backfill	2	--	--	896		51%	2,520	1,749	5.1E-02	0.23	1,770		1.1		1.1	
	Dredge Tenders - backfill	2	--	--	687		38%	756	300	8.7E-03	3.9E-02	303		0.20		0.20	
	Survey Boats - backfill	2	--	--	224		38%	504	65	1.9E-03	8.5E-03	66		4.3E-02		4.3E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	228	38	1.1E-03	4.9E-03	38		2.9E-02		2.9E-02	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	48	8.0	2.3E-04	1.0E-03	8		6.1E-03		6.1E-03	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	1,440	479	1.4E-02	6.1E-02	484	3,848	0.37	2.9	0.37	2.9
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,600	599	1.7E-02	7.7E-02	606		0.46		0.46	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	7,758	1,290	3.7E-02	0.17	1,305		1.0		1.0	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	8,640	1,437	4.1E-02	0.18	1,453		1.1		1.1	
Total									**131,441**	**3.8**	**17**	**132,989**		95		95	

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

ENVIRON

Table D16 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario A

Harbor Craft Hours of Operation[12]

Project Phase	Vessel Type					
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel
Pre-Construction	108	5,544	--	108	924	--
Testing and Monitoring During Dredging and Backfilling	14,400	--	28,800	--	--	--
Dredging	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--
Pre-Construction of CAD	12	276	--	--	36	--
CAD Excavation[13]	5,760	5,760	11,520	--	--	--
CAD Closure	48	228	--	--	--	--
Annual O&M[14]	3,600	7,758	1,440	--	--	8,640

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[15]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,17]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[17]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D16 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario A

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Dredge rate of clay[1]:	5,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to CAD[6]:	5.3 river miles		
Hours of operation per roundtrip:	1.3 hours		
Amount of large debris removed[1]:	6,000 tons =	110,092 cubic feet =	4,077 cubic yards
Amount of sediment removed[1]:	4,304,000 cubic yards		
Amount of sediment barged[1]:	6,676,000 cubic yards		
Number of large debris trips (total)[8]:	5		
Number of sediment trips (total):	2,428		
Dredged Material from CAD			
Distance to Upland Disposal Area:	20 river miles		
Distance to HARS:	47 river miles		
Hours per roundtrip to UDA:	5 hours		
Hours per roundtrip to HARS:	12 hours		
Amount of large debris removed[1]:	500 tons =	9,174 cubic feet =	340 cubic yards
Amount of sediment removed (1st cell)[1]:	278,000 cubic yards		
Amount of sediment removed (other cells)[1]:	278,000 cubic yards		
Amount of sediment removed to HARS[1]:	5,062,000 cubic yards		
Time to dredge sediment (per vessel):	323 days =	7,742 hours	
Number of large debris trips (total)[8]:	2		
Number of sediment trips to UDA[10]:	102		
Number of sediment trips to HARS:	1,942		

Backfill/Engineered Cap Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 river miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	2,723,000 cubic yards	
Number of trips (total):	990 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	681 days =	16,338 hours
Armor Material		
Amount of armor material[1]:	192,000 cubic yards	
Number of trips (total):	70 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	48 days =	1,152 hours
Mudflat Cap/Mudflat Reconstruction		
Amount of backfill[1]:	407,000 cubic yards	
Number of trips (total):	148 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	102 days =	2,442 hours
CAD Cap Material		
Amount of Cap Material[1]:	420,000 cubic yards	
Number of trips (total):	153 per scow	
Cap Material placement rate/vessel[1]:	2,000 cy/day	
Time to place Cap Material (total):	105 days =	2,520 hours

Table D16 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] From mid-point of 8-mile study area (Figure 1-1 of FFS) to mid-point of CADs in Newark Bay (Figure 4-1 of FFS)

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Only for sediment removed from first cell.

[12] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[13] Water survey vessel assumed to operate 24 hours/day.

[14] Assuming 30 years of annual O&M.

[15] Average PM_{10} emission factor for Tier 1 Engines

[16] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[17] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D17 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	5,544	5.74	4.7E-05	2.3E-04	5.76	5.76	3.0E-02	3.0E-02	3.0E-02	3.0E-02
Pre-Construction of CAD	Vibracoring Equipment	10	0.025	50%	276	0.29	2.3E-06	1.2E-05	0.29	0.29	1.5E-03	1.5E-03	1.5E-03	1.5E-03
CAD Excavation	Vibratory Pile Driver - Containment System	228	0.58	50%	3,520	83	6.7E-04	3.4E-03	83	83	0.44	0.44	0.44	0.44
CAD Closure	Sheet Pile Remover - vibratory equipment	10	0.025	50%	3,520	3.6	3.0E-05	1.5E-04	3.7	3.7	1.9E-02	1.9E-02	1.9E-02	1.9E-02
Annual O&M	Vibracoring Equipment	10	0.025	50%	7,758	8.0	6.5E-05	3.3E-04	8.1	8.1	4.3E-02	4.3E-02	4.3E-02	4.3E-02
Total						**101**	**8.2E-04**	**4.1E-03**	**101**		0.54		0.54	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	5,544
Pre-Construction of CAD	Vibracoring Equipment	276
CAD Excavation	Sheet Pile Driver[3]	3,520
CAD Closure	Sheet Pile Removal[6]	3,520
Annual O&M	Vibracoring Equipment	7,758

Table D17 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[6] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D18 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[8]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Fugitive Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	82	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	354	--	18	--	--	18		7.9E-03		--	
Pre-Construction of CAD	Drill Rig - USF Geotechnical	1	206	43%	10	--	0.52	--	--	0.52	2.4	2.2E-04	1.0E-03	--	--
	Barge-Auger	1	206	43%	36	--	1.9	--	--	1.9		8.0E-04		--	
CAD Excavation	Sheet Pile Driver Crane - Containment System	1	226	29%	3,520	--	135	--	--	135	135	2.6E-02	2.6E-02	--	--
Upland Support Facility	Rubber-tired Dozers	4	255	40%	104	--	25	--	--	25	752	7.9E-03	0.71	2.2E-02	2.2E-02
	Tractors/Loaders/ Backhoes	10	97	37%	1,714	--	470	--	--	470		0.57		--	
	Excavators	1	162	38%	64	--	2.3	--	--	2.3		8.4E-04		--	
	Graders	1	174	41%	64	3.4	2.7	--	--	2.7		1.1E-03		1.5E-05	
	Cranes	1	226	29%	1,610	--	62	--	--	62		1.2E-02		--	
	Forklifts	3	89	20%	1,840	--	64	--	--	64		1.8E-02		--	
	Generator Sets	1	84	74%	1,840	--	74	--	--	74		5.6E-02		--	
	Welders	1	46	45%	1,840	--	29	--	--	29		3.1E-02		--	
	Pavers	2	125	42%	144	--	8.9	--	--	8.9		3.7E-03		--	
	Paving Equipment	2	130	36%	144	--	8.0	--	--	8.0		3.6E-03		--	
	Rollers	2	80	38%	144	--	5.7	--	--	5.7		3.3E-03		--	
CAD Closure	Sheet Pile Remover - Crane	1	226	29%	3,520	--	135	--	--	135	135	2.6E-02	2.6E-02	--	--
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	160	--	6.2	--	--	6.2	43	4.2E-03	1.7E-02	--	3.3E-02
	Excavators	3	162	38%	160	--	17	--	--	17		6.3E-03		--	
	Rubber-tired Dozers	2	255	40%	160	--	19	--	--	19		6.1E-03		3.3E-02	
Total							**1,148**	**0**	**0**	**1,148**		**0.81**		**5.5E-02**	

ENVIRON

Table D18 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[8] (lb/VMT)	$PM_{2.5}$[8] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	354
Pre-Construction of CAD	Drill Rig - Upland Support Facility	10
	Barge-Auger	36
CAD Excavation	Sheet Pile Driver[3]	3,520
CAD Closure	Sheet Pile Removal[9]	3,520

USF Site Area[1]: 5 acres

ENVIRON

Table D18 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	5	Rubber Tired Dozers	3	8
		Tractors/ Loaders/ Backhoes	4	8
Grading	8	Excavators	1	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Tractors/ Loaders/ Backhoes	3	8
Building Construction	230	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/ Loaders/ Backhoes	3	7
		Welders	1	8
Paving	18	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	20	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D18 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 25,150 sf of General Light Industrial on 5-acre site; Climate Zone 1; Urban

[8] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

[9] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D19 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario B

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	1,124	1.4E-02	0.85	1.4E-02	0.85
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	5,544	922	2.6E-02	0.12	933		0.71		0.71	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing and Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	14,400	2,394	6.8E-02	0.31	2,422	12,111	1.8	9.2	1.8	9.2
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	28,800	9,577	0.27	1.2	9,689		7.3		7.3	
Dredging	Channel Dredgers	2	--	--	896		51%	28,800	19,991	0.58	2.6	20,229	30,441	13	20	13	20
	Dredge Tenders	2	--	--	687		38%	8,640	3,426	0.10	0.45	3,467		2.2		2.2	
	Survey Boats	2	--	--	224		38%	5,760	745	2.2E-02	0.10	754		0.49		0.49	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	13	12	3.4E-04	1.5E-03	12		7.8E-03		7.8E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	13	0.31	2.5E-06	1.3E-05	0.32		1.7E-03		1.7E-03	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	6,070	5,758	0.17	0.75	5,827		3.8		3.8	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	6,070	153	1.2E-03	6.2E-03	153		0.81		0.81	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	20,051	19,021	0.55	2.5	19,248	38,547	12	28	12	28
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	20,051	504	4.1E-03	2.0E-02	506		2.7		2.7	
	Channel Dredgers - backfill	2	--	--	896		51%	16,338	11,341	0.33	1.5	11,476		7.4		7.4	
	Dredge Tenders - backfill	2	--	--	687		38%	4,901	1,943	5.6E-02	0.25	1,967		1.3		1.3	
	Survey Boats - backfill	2	--	--	224		38%	3,268	422	1.2E-02	5.5E-02	428		0.28		0.28	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	40	1.1E-03	5.1E-03	40		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	1,414	1,341	3.9E-02	0.17	1,357		0.88		0.88	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	1,414	36	2.9E-04	1.4E-03	36		0.19		0.19	
	Channel Dredgers-armor	2	--	--	896		51%	1,152	800	2.3E-02	0.10	809		0.52		0.52	
	Dredge Tenders - armor	2	--	--	687		38%	346	137	4.0E-03	1.8E-02	139		9.0E-02		9.0E-02	
	Survey Boats - armor	2	--	--	224		38%	230	30	8.6E-04	3.9E-03	30		2.0E-02		2.0E-02	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	1,499	1,422	4.1E-02	0.19	1,438		0.93		0.93	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	1,499	38	3.1E-04	1.5E-03	38		0.20		0.20	
	Channel Dredgers-mudflat, etc. backfill	2	--	--	896		51%	1,221	848	2.5E-02	0.11	858		0.56		0.56	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	366	145	4.2E-03	1.9E-02	147		0.10		0.10	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	244	32	9.2E-04	4.1E-03	32		2.1E-02		2.1E-02	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maintenance Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**82,908**	**2.4**	**11**	**83,885**		**60**		**60**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	5,544	--	108	924	--	--
Testing and Monitoring During Dredging and Backfilling	14,400	--	28,800	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	6,000 tons =	110,092 cubic feet =	4,077 cubic yards
Amount of sediment removed[1]:	4,304,000 cubic yards		
Amount of sediment barged[1]:	6,676,000 cubic yards		
Number of large debris trips (total)[8]:	5		
Number of sediment trips (total):	2,428		

Backfill/Engineered Cap Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	2,723,000 cubic yards	
Number of trips (total):	990 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	681 days =	16,338 hours
Armor Material		
Amount of armor material[1]:	192,000 cubic yards	
Number of trips (total):	70 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	48 days =	1,152 hours
Mudflat/Mudflat Reconstruction		
Amount of backfill[1]:	203,500 cubic yards	
Number of trips (total):	74 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	51 days =	1,221 hours

Table D19 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D20 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	5,544	5.7	4.7E-05	2.3E-04	5.8	5.8	3.0E-02	3.0E-02	3.0E-02	3.0E-02
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**13**	**1.0E-04**	**5.1E-04**	**13**		6.7E-02		6.7E-02	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	5,544
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D20 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D21 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	82	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	354	--	18	--	--	18		7.9E-03		--	
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	52	--	2.7	--	--	2.7	2.7	1.2E-03	1.2E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	520	--	125	--	--	125	1,611	3.9E-02	1.4	0.11	0.11
	Tractors/Loaders/ Backhoes	9	97	37%	3,600	--	888	--	--	888		1.1		--	
	Excavators	2	162	38%	360	--	26	--	--	26		9.5E-03		--	
	Graders	1	174	41%	360	18	15	--	--	15		5.9E-03		7.9E-05	
	Scrapers	2	361	48%	360	--	74	--	--	74		2.1E-02		--	
	Cranes	1	226	29%	3,080	--	118	--	--	118		2.3E-02		--	
	Forklifts	3	89	20%	3,520	--	123	--	--	123		3.5E-02		--	
	Generator Sets	1	84	74%	3,520	--	142	--	--	142		0.11		--	
	Welders	1	46	45%	3,520	--	56	--	--	56		5.9E-02		--	
	Pavers	2	125	42%	280	--	17	--	--	17		7.1E-03		--	
	Paving Equipment	2	130	36%	280	--	15	--	--	15		7.0E-03		--	
	Rollers	2	80	38%	280	--	11	--	--	11		6.4E-03		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	36,000	--	2,959	--	--	2,959	24,321	3.6	8.7	--	--
	Skid Steer	1	65	37%	36,000	--	660	--	--	660		0.86		--	
	Excavator	1	162	38%	36,000	--	1,308	--	--	1,308		0.47		--	
	Dump Truck	4	400	38%	36,000	--	12,929	--	--	12,929		2.5		--	
	Water Truck	1	400	38%	36,000	--	3,232	--	--	3,232		0.62		--	
	Street Sweeper	1	400	38%	36,000	--	3,232	--	--	3,232		0.62		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	240	--	9.3	--	--	9.3	64	6.4E-03	2.5E-02	--	5.0E-02
	Excavators	3	162	38%	240	--	26	--	--	26		9.5E-03		--	
	Rubber-tired Dozers	2	255	40%	240	--	29	--	--	29		9.1E-03		5.0E-02	
Total							**26,080**	**0**	**0**	**26,080**		**10**		**0.16**	

ENVIRON

Table D21 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	5,544
	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	354
Pre-Construction of UPF	Drill Rig - Upland Support Facility	52
UPF Operations[8,9]	All	36,000

USF Site Area[1]: 26 acres

ENVIRON

Table D21 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	20	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	45	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	440	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	35	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	30	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D21 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D22 - Emission Estimates from Rail Transport
Remedial Alternative 3, DMM Scenario B

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[10]
Processing and Disposal	Rail Cars Hauling Sediment from UPF to Incinerator	180,000	4,556	24,188	8.3E-02	4.6E-06	24,213	298,620	7.9	7.9
	Rail Cars Hauling Sediment from UPF to Landfill	2,460,000	3,086	223,914	0.52	2.7E-04	224,069		73	73
	Rail Cars Hauling Large Debris from UPF to Landfill	350,217	4,556	47,062	0.16	1.8E-05	47,110		15	15
	Rail Cars Hauling SOF from UPF to Landfill	24,000	4,556	3,225	1.1E-02	8.2E-08	3,228		1.1	1.1
Total				**298,390**	**0.77**	**2.9E-04**	**298,620**		**97**	**97**

Distance by Rail[3]

Trip	Roundtrip Distance (miles)
From UPF to Clive Transfer Facility[4]	4,556
From UPF to Avard Transfer Facility[5]	3,086

Assumptions

Amount of Sediment Incinerated[1]:	180,000	tons		
Amount of Sediment Landfilled[1]:	2,460,000	tons		
Amount of Large Debris Landfilled[1]:	238,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	24,000	tons		
Fuel Economy of Trains[8]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		
Amount of Sediment per Container[3]:	22.5	tons		
Amount of Large Debris per Container:	22.5	tons		
Amount of SOF Debris per Container:	22.5	tons		
Emission factor conversion[9]:	1 g/gal =	0.048	gal/bhp-hr	
Weight per cubic foot of large debris[6]:	109	lb/cf =	2,943	lb/cy

ENVIRON

Table D22 - Emission Estimates from Rail Transport
Remedial Alternative 3, DMM Scenario B

Emission Factors[7,8]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[4] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Clive Transfer Facility is 2,261 driving miles.

[5] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Avard Transfer Facility is 1,526 driving miles.

[6] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[7] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[8] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[9] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[10] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D23 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario B

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Sediment from Transfer Facility to Incinerator	8,000	20	304	8.5E-04	9.0E-04	304	19,876		0.76
	Trucks Hauling Ash from Thermal Incinerator Site to Landfill	2,000	105	400	1.1E-03	1.2E-03	400			1.0
	Trucks Hauling Sediment from Transfer Facility to Landfill	109,334	60	12,451	3.5E-02	3.7E-02	12,462			31
	Trucks Hauling Large Debris from Transfer Facility to Landfill	15,566	52	1,536	4.3E-03	4.5E-03	1,538			3.9
	Trucks Hauling Small Organic Fraction from Transfer Facility to Landfill	1,067	52	105	2.9E-04	3.1E-04	105			0.27
	Trucks Hauling Sand for Beneficial Use	26,667	100	5,062	1.4E-02	1.5E-02	5,066			1.5
Total				**19,858**	**5.5E-02**	**5.9E-02**	**19,876**			38

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from Transfer Facility to Incinerator Site[4,8]	20
Distance from Incinerator Site to Landfill[4,7]	105
Distance from Transfer Facility to Landfill[4,10]	60
Distance from Transfer Facility to Landfill - Large Debris[4,11]	52
Distance from Transfer Facility to Landfill - Small Organic Fraction Debris[11]	52
Distance from UPF to Beneficial Use Site[13]	100

ENVIRON

Table D23 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario B

Assumptions

Ash Production Rate by weight[3]:	20%			
Amount of Sediment Incinerated[1]:	180,000	tons		
Amount of Ash Disposal:	36,000	tons		
Amount of Sediment Landfilled[1]:	2,460,000	tons		
Amount of Large Debris Landfilled[1]:	238,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	24,000	tons		
Amount of Sand transported for Beneficial Use[1]:	600,000	tons		
Amount of Sediment Transported per Truck[4,9]:	22.5	tons		
Amount of Ash Transported per Truck:	18	tons		
Amount of Large Debris Transported per Truck:	22.5	tons		
Amount of SOF Debris Transported per Truck:	22.5	tons		
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile		
Weight per cubic foot of large debris[12]:	109	lb/cf =	2,943	lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[14]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in UT	0.009558856
Truck transfer in OK	0.009422301
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D23 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Aragonite Incinerator, Utah to Grassy Mountain Subtitle C Landfill, Utah

[8] Clive Transfer Facility, Utah to Aragonite Incinerator, Utah

[9] 22.5 tons of sediment per container

[10] Avard Transfer Facility, OK to Lone Mountain Subtitle C Landfill Facility, OK

[11] Clive Transfer Facility, Utah to Grassy Mountain Subtitle C Landfill, Utah

[12] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[13] No activity data provided in FFS.

[14] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in OK and UT, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D24 - Emission Estimates from Thermal Incineration
Remedial Alternative 3, DMM Scenario B

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	180,000	7,000	126,000	39	--	137,640	1,507

Emission Factors

Pollutant	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D24 - Emission Estimates from Thermal Incineration
Remedial Alternative 3, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed June 2014).

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4* , Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory and applied $PM_{2.5}$ to PM_{10} factor.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

ENVIRON

Table D25 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario C

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	1,124	1.4E-02	0.85	1.4E-02	0.85
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	5,544	922	2.6E-02	0.12	933		0.71		0.71	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	924	154	4.4E-03	2.0E-02	155		0.12		0.12	
Testing and Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	14,400	2,394	6.8E-02	0.31	2,422	12,111	1.8	9.2	1.8	9.2
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	28,800	9,577	0.27	1.2	9,689		7.3		7.3	
Dredging	Channel Dredgers	2	--	--	896		51%	28,800	19,991	0.58	2.6	20,229	30,441	13	20	13	20
	Dredge Tenders	2	--	--	687		38%	8,640	3,426	0.10	0.45	3,467		2.2		2.2	
	Survey Boats	2	--	--	224		38%	5,760	745	2.2E-02	0.10	754		0.49		0.49	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	13	12	3.4E-04	1.5E-03	12		7.8E-03		7.8E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	13	0.31	2.5E-06	1.3E-05	0.32		1.7E-03		1.7E-03	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	6,070	5,758	0.17	0.75	5,827		3.8		3.8	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	6,070	153	1.2E-03	6.2E-03	153		0.81		0.81	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	20,051	19,021	0.55	2.5	19,248	38,547	12	28	12	28
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	20,051	504	4.1E-03	2.0E-02	506		2.7		2.7	
	Channel Dredgers - backfill	2	--	--	896		51%	16,338	11,341	0.33	1.5	11,476		7.4		7.4	
	Dredge Tenders - backfill	2	--	--	687		38%	4,901	1,943	5.6E-02	0.25	1,967		1.3		1.3	
	Survey Boats - backfill	2	--	--	224		38%	3,268	422	1.2E-02	5.5E-02	428		0.28		0.28	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	40	1.1E-03	5.1E-03	40		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	1,414	1,341	3.9E-02	0.17	1,357		0.88		0.88	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	1,414	36	2.9E-04	1.4E-03	36		0.19		0.19	
	Channel Dredgers-armor	2	--	--	896		51%	1,152	800	2.3E-02	0.10	809		0.52		0.52	
	Dredge Tenders - armor	2	--	--	687		38%	346	137	4.0E-03	1.8E-02	139		9.0E-02		9.0E-02	
	Survey Boats - armor	2	--	--	224		38%	230	30	8.6E-04	3.9E-03	30		2.0E-02		2.0E-02	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	1,499	1,422	4.1E-02	0.19	1,438		0.93		0.93	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	1,499	38	3.1E-04	1.5E-03	38		0.20		0.20	
	Channel Dredgers-mudflat, etc. backfill	2	--	--	896		51%	1,221	848	2.5E-02	0.11	858		0.56		0.56	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	366	145	4.2E-03	1.9E-02	147		0.10		0.10	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	244	32	9.2E-04	4.1E-03	32		2.1E-02		2.1E-02	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maintenance Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**82,908**	**2.4**	**11**	**83,885**		**60**		**60**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	5,544	--	108	924	--	--
Testing and Monitoring During Dredging and Backfilling	14,400	--	28,800	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	6,000 tons =	110,092 cubic feet =	4,077 cubic yards
Amount of sediment removed[1]:	4,304,000 cubic yards		
Amount of sediment barged[1]:	6,676,000 cubic yards		
Number of large debris trips (total)[8]:	5		
Number of sediment trips (total):	2,428		

Backfill Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	2,723,000 cubic yards	
Number of trips (total):	990 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	681 days =	16,338 hours
Armor Material		
Amount of armor material[1]:	192,000 cubic yards	
Number of trips (total):	70 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	48 days =	1,152 hours
Mudflat/Mudflat Reconstruction		
Amount of backfill[1]:	203,500 cubic yards	
Number of trips (total):	74 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	51 days =	1,221 hours

Table D25 - Harbor Craft Emission Estimates
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 μm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D26 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	5,544	5.7	4.7E-05	2.3E-04	5.8	5.8	3.0E-02	3.0E-02	3.0E-02	3.0E-02
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**13**	**1.0E-04**	**5.1E-04**	**13**		6.7E-02		6.7E-02	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	5,544
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D26 - Stationary Combustion Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D27 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	924	--	48	--	--	48	82	2.0E-02	3.5E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	354	--	18	--	--	18		7.9E-03		--	
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	72	--	3.7	--	--	3.7	3.7	1.6E-03	1.6E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	840	--	202	--	--	202	2,685	6.4E-02	2.3	0.17	0.17
	Tractors/Loaders/ Backhoes	9	97	37%	6,020	--	1484	--	--	1,484		1.8		--	
	Excavators	2	162	38%	600	--	44	--	--	44		1.6E-02		--	
	Graders	1	174	41%	600	25	25	--	--	25		9.8E-03		1.1E-04	
	Scrapers	2	361	48%	600	--	123	--	--	123		3.5E-02		--	
	Cranes	1	226	29%	5,180	--	198	--	--	198		3.8E-02		--	
	Forklifts	3	89	20%	5,920	--	207	--	--	207		5.9E-02		--	
	Generator Sets	1	84	74%	5,920	--	239	--	--	239		0.18		--	
	Welders	1	46	45%	5,920	--	93	--	--	93		9.9E-02		--	
	Pavers	2	125	42%	440	--	27	--	--	27		1.1E-02		--	
	Paving Equipment	2	130	36%	440	--	24	--	--	24		1.1E-02		--	
	Rollers	2	80	38%	440	--	18	--	--	18		1.0E-02		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	14,400	--	1,183	--	--	1,183	9,728	1.4	3.5	--	--
	Skid Steer	1	65	37%	14,400	--	264	--	--	264		0.34		--	
	Excavator	1	162	38%	14,400	--	523	--	--	523		0.19		--	
	Dump Truck	4	400	38%	14,400	--	5,172	--	--	5,172		1.0		--	
	Water Truck	1	400	38%	14,400	--	1,293	--	--	1,293		0.25		--	
	Street Sweeper	1	400	38%	14,400	--	1,293	--	--	1,293		0.25		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	400	--	15.5	--	--	15.5	107	1.1E-02	4.2E-02	--	1.8E-03
	Excavators	3	162	38%	400	--	44	--	--	44		1.6E-02		--	
	Rubber-tired Dozers	2	255	40%	400	--	48	--	--	48		1.5E-02		1.8E-03	
Total							**12,606**	**0**	**0**	**12,606**		**5.9**		**0.18**	

ENVIRON

Table D27 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	5,544
	Barge-Auger	924
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	354
Pre-Construction of UPF	Drill Rig - Upland Support Facility	72
UPF Operations[8,9]	All	14,400

USF Site Area[1]: 36 acres

ENVIRON

Table D27 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	30	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	75	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	740	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	55	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	50	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D27 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D28 - Emission Estimates from Rail Transport
Remedial Alternative 3, DMM Scenario C

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance[3] (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[7]
Processing and Disposal	Rail Cars Hauling SOF from Brill Yard Transfer Station to Subtitle C Landfill	24,000	1,480	1,048	1.2E-03	2.8E-09	1,048	1,048	0.34	0.34
Total				**1,048**	**1.2E-03**	**2.8E-09**	**1,048**		**0.34**	**0.34**

Assumptions

Amount of SOF Debris Landfilled[1]:	24,000	tons		
Fuel Economy of Trains[5]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Emission factor conversion[9]:	1 g/gal =	0.048	gal/bhp-hr	
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		

Emission Factors[4,5,6]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D28 - Emission Estimates from Rail Transport
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] Distance from Brills Yard Transfer Facility to Roachdale, IN is 740 driving miles one way.

[4] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[5] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[6] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[7] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D29 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario C

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Thermally Treated Sediment for Beneficial Reuse	2,000	100	380	1.1E-03	1.1E-03	380	41,773		0.11
	Trucks Hauling Washed Sediment for Beneficial Reuse	173,400	100	32,912	9.2E-02	0.10	32,942			10
	Trucks Hauling Amended Sediment for Beneficial Reuse	889	100	169	4.7E-04	5.0E-04	169			4.9E-02
	Trucks Hauling Decontaminated Medium-Sized Debris	15,565	100	2,954	8.2E-03	8.7E-03	2,957			0.86
	Trucks Hauling SOF to Brills Yard Transfer Station	1,067	28	57	1.6E-04	1.7E-04	57			1.7E-02
	Trucks Hauling SOF from Transfer Station to Roachdale Subtitle C Landfill	1,067	100	202	5.6E-04	6.0E-04	203			0.49
	Trucks Hauling Sand for Beneficial Use	26,667	100	5,061	1.4E-02	1.5E-02	5,066			1.5
Total				**41,735**	**0.12**	**0.12**	**41,773**			**13**

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from UPF to Beneficial Use - Thermally Treated Sediment[8]	100
Distance from UPF to Beneficial Use - Washed Sediment[8]	100
Distance from UPF to Beneficial Use - Amended Sediment[8]	100
Distance from UPF to Medium-Size Debris Landfill[8]	100
Distance from UPF to Brills Yard Transfer Station[4]	28
Distance from Transfer Station to Roachdale Subtitle C Landfill[8]	100
Distance from UPF to Sand Beneficial Use Site[8]	100

ENVIRON

Table D29 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario C

Assumptions

Ash Production Rate by weight[3]:	20%			
Amount of Sediment Incinerated[1]:	180,000	tons		
Amount of Ash Beneficially Reused:	36,000	tons		
Amount of Washed Sediment[1]:	2,890,000	cubic yards =	3,901,500	tons
Amount of Amended Sediment[1]:	20,000	tons		
Amount of Medium-Sized Debris[1]:	238,000	cubic yards =	350,217	tons
Amount of SOF Debris Landfilled[1]:	24,000	tons		
Amount of Sand transported for Beneficial Use[1]:	600,000	tons		
Amount of Sediment Transported per Truck[4]:	22.5	tons		
Amount of Ash Transported per Truck:	18	tons		
Amount of Large Debris Transported per Truck:	22.5	tons		
Amount of SOF Debris Transported per Truck:	22.5	tons		
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile		
Weight per cubic foot of sediment[7]:	100	lb/cf =	2,700	lb/cy
Weight per cubic foot of large debris[7]:	109	lb/cf =	2,943	lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[9]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in IN	0.009217468
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D29 - Emission Estimates from Truck Traffic
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] No activity data provided in FFS. Assume truck trip = 50 miles one way.

[9] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in IN, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D30 - Emission Estimates from Thermal Incineration
Remedial Alternative 3, DMM Scenario C

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	180,000	7,000	126,000	39	--	137,640	1,507

Emission Factors

GHG	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D30 - Emission Estimates from Thermal Incineration
Remedial Alternative 3, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed June 2014).

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4* , Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory and applied $PM_{2.5}$ to PM_{10} factor.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

Table D31 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	295	1.4E-02	0.22	1.4E-02	0.22
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	1,140	190	5.4E-03	2.4E-02	192		0.15		0.15	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	396	66	1.9E-03	8.4E-03	67		5.1E-02		5.1E-02	
Testing & Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	958	2.7E-02	0.12	969	4,845	0.73	3.7	0.73	3.7
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	11,520	3,831	0.11	0.49	3,876		2.9		2.9	
Dredging	Channel Dredgers	2	--	--	896		51%	11,520	7,996	0.23	1.0	8,092	10,534	5.24	6.9	5.24	6.9
	Dredge Tenders	2	--	--	687		38%	3,456	1,370	4.0E-02	0.18	1,387		0.90		0.90	
	Survey Boats	2	--	--	224		38%	2,304	298	8.6E-03	3.9E-02	301		0.20		0.20	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	3	2.5	7.3E-05	3.3E-04	2.5		1.6E-03		1.6E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	3	6.7E-02	5.4E-07	2.7E-06	6.7E-02		3.5E-04		3.5E-04	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	763	724	2.1E-02	9.4E-02	733		0.47		0.47	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	763	19	1.6E-04	7.8E-04	19		0.10		0.10	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	6,848	6,496	0.19	0.85	6,574	13,919	4.3	10	4.3	10
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	6,848	172	1.4E-03	7.0E-03	173		0.91		0.91	
	Channel Dredgers - backfill	2	--	--	896		51%	5,580	3,873	0.11	0.51	3,919		2.5		2.5	
	Dredge Tenders - backfill	2	--	--	687		38%	1,674	664	1.9E-02	8.7E-02	672		0.44		0.44	
	Survey Boats - backfill	2	--	--	224		38%	1,116	144	4.2E-03	1.9E-02	146		9.5E-02		9.5E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	22	6.3E-04	2.8E-03	22		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	677	643	1.9E-02	8.4E-02	650		0.42		0.42	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	677	17	1.4E-04	6.9E-04	17		9.0E-02		9.0E-02	
	Channel Dredgers-armor	2	--	--	896		51%	552	383	1.1E-02	5.0E-02	388		0.25		0.25	
	Dredge Tenders - armor	2	--	--	687		38%	166	66	1.9E-03	8.6E-03	66		4.3E-02		4.3E-02	
	Survey Boats - armor	2	--	--	224		38%	110	14	4.1E-04	1.9E-03	14		9.4E-03		9.4E-03	
	Mudflat Scow Tug Boat - main	1	--	--	1,836	--	68%	762	723	2.1E-02	9.4E-02	732		0.47		0.47	
	Mudflat Scow Tug Boat - aux	1	--	--	--	210	43%	762	19	1.6E-04	7.8E-04	19		0.10		0.10	
	Channel Dredgers-mudflat	2	--	--	896		51%	621	431	1.2E-02	5.6E-02	436		0.28		0.28	
	Dredge Tenders - mudflat	2	--	--	687		38%	186	74	2.1E-03	9.6E-03	75		4.8E-02		4.8E-02	
	Survey Boats - mudflat	2	--	--	224		38%	124	16	4.7E-04	2.1E-03	16		1.1E-02		1.1E-02	
Pre-Construction of CAD	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	12	2.0	5.7E-05	2.6E-04	2.0	16	1.5E-03	1.2E-02	1.5E-03	1.2E-02
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	72	12	3.4E-04	1.5E-03	12		9.2E-03		9.2E-03	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	12	2.0	5.7E-05	2.6E-04	2.0		1.5E-03		1.5E-03	

ENVIRON

Table D31 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario A

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	GHG Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[16]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
CAD Excavation	Channel Dredgers	4	--	--	896		51%	1,789	2,484	7.2E-02	0.32	2,513	10,943	1.6	8.0	1.6	8.0
	Dredge Tenders	4	--	--	687		38%	537	426	1.2E-02	5.6E-02	431		0.28		0.28	
	Survey Boats	4	--	--	224		38%	358	93	2.7E-03	1.2E-02	94		6.1E-02		6.1E-02	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	10	9.5	2.7E-04	1.2E-03	10		6.2E-03		6.2E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	10	0.25	2.0E-06	1.0E-05	0.25		1.3E-03		1.3E-03	
	Cont. Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	270	256	7.4E-03	3.3E-02	259		0.17		0.17	
	Cont. Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	270	6.8	5.5E-05	2.8E-04	6.8		3.6E-02		3.6E-02	
	Uncont Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	4,794	4,548	0.13	0.59	4,602		3.0		3.0	
	Uncont Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	4,794	121	9.8E-04	4.9E-03	121		0.64		0.64	
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	5,760	1,915	5.5E-02	0.25	1,938		1.5		1.5	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	2,880	479	1.4E-02	6.1E-02	484		0.37		0.37	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	2,880	479	1.4E-02	6.1E-02	484		0.37		0.37	
CAD Closure	Cap Material Scow Tug Boat - main	1	--	--	1,836	--	68%	663	629	1.8E-02	8.2E-02	636	1,125	0.41	0.81	0.41	0.81
	Cap Material Scow Tug Boat - aux	1	--	--	--	210	43%	663	17	1.4E-04	6.8E-04	17		8.8E-02		8.8E-02	
	Channel Dredgers - backfill	2	--	--	896		51%	540	375	1.1E-02	4.9E-02	379		0.25		0.25	
	Dredge Tenders - backfill	2	--	--	687		38%	162	64	1.9E-03	8.4E-03	65		4.2E-02		4.2E-02	
	Survey Boats - backfill	2	--	--	224		38%	108	14	4.0E-04	1.8E-03	14		9.2E-03		9.2E-03	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	60	10	2.8E-04	1.3E-03	10		7.7E-03		7.7E-03	
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	24	4.0	1.1E-04	5.1E-04	4.0		3.1E-03		3.1E-03	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	1,440	479	1.4E-02	6.1E-02	484	3,848	0.37	2.9	0.37	2.9
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,600	599	1.7E-02	7.7E-02	606		0.46		0.46	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	7,758	1,290	3.7E-02	0.17	1,305		1.0		1.0	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	8,640	1,437	4.1E-02	0.18	1,453		1.1		1.1	
Total									**44,996**	**1.3**	**5.8**	**45,526**		33		33	

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

ENVIRON

Table D31 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario A

Harbor Craft Hours of Operation[12]

Project Phase	Vessel Type					
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel
Pre-Construction	108	1,140	--	108	396	--
Testing and Monitoring During Dredging and Backfilling	5,760	--	11,520	--	--	--
Dredging	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--
Pre-Construction of CAD	12	72	--	--	12	--
CAD Excavation[13]	2,880	2,880	5,760	--	--	--
CAD Closure	24	60	--	--	--	--
Annual O&M[14]	3,600	7,758	1,440	--	--	8,640

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[15]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,17]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[17]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D31 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario A

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Dredge rate of clay[1]:	5,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to CAD[6]:	5.3 river miles		
Hours of operation per roundtrip:	1.3 hours		
Amount of large debris removed[1]:	2,000 tons =	36,697 cubic feet =	1,359 cubic yards
Amount of sediment removed[1]:	1,021,000 cubic yards		
Amount of sediment barged[1]:	1,584,000 cubic yards		
Number of large debris trips (total)[8]:	2		
Number of sediment trips (total):	576		
Dredged Material from CAD			
Distance to Upland Disposal Area:	20 river miles		
Distance to HARS:	47 river miles		
Hours per roundtrip to UDA:	5 hours		
Hours per roundtrip to HARS:	12 hours		
Amount of large debris removed[1]:	200 tons =	3,670 cubic feet =	136 cubic yards
Amount of sediment removed (CAD cell)[1]:	148,000 cubic yards		
Amount of sediment removed to HARS[1]:	1,121,000 cubic yards		
Time to dredge sediment (per vessel):	75 days =	1,789 hours	
Number of large debris trips (total)[8]:	2		
Number of sediment trips to UDA[10]:	54		
Number of sediment trips to HARS:	408		

Backfill/Engineered Cap Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 river miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	930,000 cubic yards	
Number of trips (total):	338 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	233 days =	5,580 hours
Armor Material		
Amount of armor material[1]:	92,000 cubic yards	
Number of trips (total):	33 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	23 days =	552 hours
Mudflat Cap/Mudflat Reconstruction		
Amount of backfill[1]:	103,500 cubic yards	
Number of trips (total):	38 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	26 days =	621 hours
CAD Cap Material		
Amount of Cap Material[1]:	90,000 cubic yards	
Number of trips (total):	33 per scow	
Cap Material placement rate/vessel[1]:	2,000 cy/day	
Time to place Cap Material (total):	23 days =	540 hours

Table D31 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] From mid-point of 8-mile study area (Figure 1-1 of FFS) to mid-point of CADs in Newark Bay (Figure 4-1 of FFS)

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Only for sediment removed from first cell.

[12] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[13] Water survey vessel assumed to operate 24 hours/day.

[14] Assuming 30 years of annual O&M.

[15] Average PM_{10} emission factor for Tier 1 Engines

[16] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[17] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D32 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	1,140	1.2	9.6E-06	4.8E-05	1.2	1.2	6.3E-03	6.3E-03	6.3E-03	6.3E-03
Pre-Construction of CAD	Vibracoring Equipment	10	0.025	50%	72	7.5E-02	6.1E-07	3.0E-06	7.5E-02	7.5E-02	4.0E-04	4.0E-04	4.0E-04	4.0E-04
CAD Excavation	Vibratory Pile Driver - Containment System	228	0.58	50%	1,720	41	3.3E-04	1.6E-03	41	41	0.22	0.22	0.22	0.22
CAD Closure	Sheet Pile Remover - vibratory equipment	10	0.025	50%	1,720	1.8	1.4E-05	7.2E-05	1.8	1.8	9.5E-03	9.5E-03	9.5E-03	9.5E-03
Annual O&M	Vibracoring Equipment	10	0.025	50%	7,758	8.0	6.5E-05	3.3E-04	8.1	8.1	4.3E-02	4.3E-02	4.3E-02	4.3E-02
Total						**52**	**4.2E-04**	**2.1E-03**	**52**		0.27		0.27	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	1,140
Pre-Construction of CAD	Vibracoring Equipment	72
CAD Excavation	Sheet Pile Driver[3]	1,720
CAD Closure	Sheet Pile Removal[6]	1,720
Annual O&M	Vibracoring Equipment	7,758

Table D32 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[6] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D33 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[8]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Fugitive Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	396	--	20	--	--	20	43	8.8E-03	1.8E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	135	--	7.0	--	--	7.0		3.0E-03		--	
Pre-Construction of CAD	Drill Rig - USF Geotechnical	1	206	43%	10	--	0.52	--	--	0.52	1.1	2.2E-04	4.9E-04	--	--
	Barge-Auger	1	206	43%	12	--	0.6	--	--	0.6		2.7E-04		--	
CAD Excavation	Sheet Pile Driver Crane - Containment System	1	226	29%	1,720	--	66	--	--	66	66	1.3E-02	1.3E-02	--	--
Upland Support Facility	Rubber-tired Dozers	4	255	40%	104	--	25	--	--	25	752	7.9E-03	0.71	2.2E-02	2.2E-02
	Tractors/Loaders/ Backhoes	10	97	37%	1,714	--	470	--	--	470		0.57		--	
	Excavators	1	162	38%	64	--	2.3	--	--	2.3		8.4E-04		--	
	Graders	1	174	41%	64	3.4	2.7	--	--	2.7		1.1E-03		1.5E-05	
	Cranes	1	226	29%	1,610	--	62	--	--	62		1.2E-02		--	
	Forklifts	3	89	20%	1,840	--	64	--	--	64		1.8E-02		--	
	Generator Sets	1	84	74%	1,840	--	74	--	--	74		5.6E-02		--	
	Welders	1	46	45%	1,840	--	29	--	--	29		3.1E-02		--	
	Pavers	2	125	42%	144	--	8.9	--	--	8.9		3.7E-03		--	
	Paving Equipment	2	130	36%	144	--	8.0	--	--	8.0		3.6E-03		--	
	Rollers	2	80	38%	144	--	5.7	--	--	5.7		3.3E-03		--	
CAD Closure	Sheet Pile Remover - Crane	1	226	29%	1,720	--	66	--	--	66	66	1.3E-02	1.3E-02	--	--
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	160	--	6.2	--	--	6.2	43	4.2E-03	1.7E-02	--	3.3E-02
	Excavators	3	162	38%	160	--	17	--	--	17		6.3E-03		--	
	Rubber-tired Dozers	2	255	40%	160	--	19	--	--	19		6.1E-03		3.3E-02	
Total							**970**	**0**	**0**	**970**		**0.77**		**5.5E-02**	

ENVIRON

Table D33 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[8] (lb/VMT)	$PM_{2.5}$[8] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Barge-Auger	396
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	135
Pre-Construction of CAD	Drill Rig - Upland Support Facility	10
	Barge-Auger	12
CAD Excavation	Sheet Pile Driver[3]	1,720
CAD Closure	Sheet Pile Removal[9]	1,720

USF Site Area[1]: 5 acres

ENVIRON

Table D33 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	5	Rubber Tired Dozers	3	8
		Tractors/ Loaders/ Backhoes	4	8
Grading	8	Excavators	1	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Tractors/ Loaders/ Backhoes	3	8
Building Construction	230	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/ Loaders/ Backhoes	3	7
		Welders	1	8
Paving	18	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	20	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D33 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario A

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 25,150 sf of General Light Industrial on 5-acre site; Climate Zone 1; Urban

[8] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

[9] Assume same amount of time to remove sheet piling as to install it.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D34 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario B

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	295	1.4E-02	0.22	1.4E-02	0.22
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	1,140	190	5.4E-03	2.4E-02	192		0.15		0.15	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	396	66	1.9E-03	8.4E-03	67		0.05		0.05	
Testing and Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	958	2.7E-02	0.12	969	4,845	0.73	3.7	0.73	3.7
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	11,520	3,831	0.11	0.49	3,876		2.9		2.9	
Dredging	Channel Dredgers	2	--	--	896		51%	11,520	7,996	0.23	1.0	8,092	11,203	5.2	7.4	5.2	7.4
	Dredge Tenders	2	--	--	687		38%	3,456	1,370	4.0E-02	0.18	1,387		0.90		0.90	
	Survey Boats	2	--	--	224		38%	2,304	298	8.6E-03	3.9E-02	301		0.20		0.20	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	5	4.7	1.4E-04	6.2E-04	4.8		3.1E-03		3.1E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	5	0.13	1.0E-06	5.1E-06	0.13		6.7E-04		6.7E-04	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	1,440	1,366	4.0E-02	0.18	1,382		0.90		0.90	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	1,440	36	2.9E-04	1.5E-03	36		0.19		0.19	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	6,848	6,496	0.19	0.85	6,574	13,938	4.3	10	4.3	10
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	6,848	172	1.4E-03	7.0E-03	173		0.91		0.91	
	Channel Dredgers - backfill	2	--	--	896		51%	5,580	3,873	0.11	0.51	3,919		2.5		2.5	
	Dredge Tenders - backfill	2	--	--	687		38%	1,674	664	1.9E-02	8.7E-02	672		0.44		0.44	
	Survey Boats - backfill	2	--	--	224		38%	1,116	144	4.2E-03	1.9E-02	146		9.5E-02		9.5E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	40	1.1E-03	5.1E-03	40		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	677	643	1.9E-02	8.4E-02	650		0.42		0.42	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	677	17	1.4E-04	6.9E-04	17		0.09		0.09	
	Channel Dredgers-armor	2	--	--	896		51%	552	383	1.1E-02	5.0E-02	388		0.25		0.25	
	Dredge Tenders - armor	2	--	--	687		38%	166	66	1.9E-03	8.6E-03	66		4.3E-02		4.3E-02	
	Survey Boats - armor	2	--	--	224		38%	110	14	4.1E-04	1.9E-03	14		9.4E-03		9.4E-03	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	762	723	2.1E-02	9.4E-02	732		0.47		0.47	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	762	19	1.6E-04	7.8E-04	19		0.10		0.10	
	Channel Dredgers- mudflat, etc. backfill	2	--	--	896		51%	621	431	1.2E-02	5.6E-02	436		0.28		0.28	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	186	74	2.1E-03	9.6E-03	75		4.8E-02		4.8E-02	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	124	16	4.7E-04	2.1E-03	16		1.1E-02		1.1E-02	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maintenance Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**31,569**	**0.91**	**4.1**	**31,942**		**24**		**24**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	1,140	--	108	396	--	--
Testing and Monitoring During Dredging and Backfilling	5,760	--	11,520	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	2,000 tons =	36,697 cubic feet =	1,359 cubic yards
Amount of sediment removed[1]:	1,021,000 cubic yards		
Amount of sediment barged[1]:	1,584,000 cubic yards		
Number of large debris trips (total)[8]:	2		
Number of sediment trips (total):	576		

Backfill/Engineered Cap Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	930,000 cubic yards	
Number of trips (total):	338 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	233 days =	5,580 hours
Armor Material		
Amount of armor material[1]:	92,000 cubic yards	
Number of trips (total):	33 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	23 days =	552 hours
Mudflat/Mudflat Reconstruction		
Amount of backfill[1]:	103,500 cubic yards	
Number of trips (total):	38 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	26 days =	621 hours

Table D34 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D35 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	1,140	1.2	9.6E-06	4.8E-05	1.2	1.2	6.3E-03	6.3E-03	6.3E-03	6.3E-03
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**8.0**	**6.5E-05**	**3.2E-04**	**8.0**		**4.2E-02**		**4.2E-02**	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	1,140
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D35 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D36 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	396	--	20	--	--	20	43	8.8E-03	1.8E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	135	--	7.0	--	--	7.0		3.0E-03		--	
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	52	--	2.7	--	--	2.7	2.7	1.2E-03	1.2E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	520	--	125	--	--	125	1,611	3.9E-02	1.4	0.11	0.11
	Tractors/Loaders/ Backhoes	9	97	37%	3,600	--	888	--	--	888		1.1		--	
	Excavators	2	162	38%	360	--	26	--	--	26		9.5E-03		--	
	Graders	1	174	41%	360	18	15	--	--	15		5.9E-03		7.9E-05	
	Scrapers	2	361	48%	360	--	74	--	--	74		2.1E-02		--	
	Cranes	1	226	29%	3,080	--	118	--	--	118		2.3E-02		--	
	Forklifts	3	89	20%	3,520	--	123	--	--	123		3.5E-02		--	
	Generator Sets	1	84	74%	3,520	--	142	--	--	142		0.11		--	
	Welders	1	46	45%	3,520	--	56	--	--	56		5.9E-02		--	
	Pavers	2	125	42%	280	--	17	--	--	17		7.1E-03		--	
	Paving Equipment	2	130	36%	280	--	15	--	--	15		7.0E-03		--	
	Rollers	2	80	38%	280	--	11	--	--	11		6.4E-03		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	36,000	--	2,959	--	--	2,959	24,321	3.6	8.7	--	--
	Skid Steer	1	65	37%	36,000	--	660	--	--	660		0.86		--	
	Excavator	1	162	38%	36,000	--	1,308	--	--	1,308		0.47		--	
	Dump Truck	4	400	38%	36,000	--	12,929	--	--	12,929		2.5		--	
	Water Truck	1	400	38%	36,000	--	3,232	--	--	3,232		0.62		--	
	Street Sweeper	1	400	38%	36,000	--	3,232	--	--	3,232		0.62		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	240	--	9.3	--	--	9.3	64	6.4E-03	2.5E-02	--	5.0E-02
	Excavators	3	162	38%	240	--	26	--	--	26		9.5E-03		--	
	Rubber-tired Dozers	2	255	40%	240	--	29	--	--	29		9.1E-03		5.0E-02	
Total							**26,041**	**0**	**0**	**26,041**		**10.1**		**0.16**	

ENVIRON

Table D36 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	1,140
	Barge-Auger	396
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	135
Pre-Construction of UPF	Drill Rig - Upland Support Facility	52
UPF Operations[8,9]	All	36,000

USF Site Area[1]: 26 acres

ENVIRON

Table D36 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	20	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	45	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	440	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	35	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	30	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D36 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Walker's Building Estimator's Reference Book* , *26th Edition* , Frank R. Walker Company, 1999. Ten 30' long steel sheet piles can be driven per day. Assume 12-hour days.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D37 - Emission Estimates from Rail Transport
Remedial Alternative 4, DMM Scenario B

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[10]
Processing and Disposal	Rail Cars Hauling Sediment from UPF to Incinerator	30,000	4,556	4,031	1.4E-02	1.3E-07	4,036	70,578	1.3	1.3
	Rail Cars Hauling Sediment from UPF to Landfill	600,000	3,086	54,613	0.13	1.6E-05	54,651		18	18
	Rail Cars Hauling Large Debris from UPF to Landfill	82,404	4,556	11,073	3.8E-02	9.7E-07	11,085		3.6	3.6
	Rail Cars Hauling SOF from UPF to Landfill	6,000	4,556	806	2.8E-03	5.1E-09	807		0.26	0.26
Total				**70,524**	**0.18**	**1.7E-05**	**70,578**		**23**	**23**

Distance by Rail[3]

Trip	Roundtrip Distance (miles)
From UPF to Clive Transfer Facility[4]	4,556
From UPF to Avard Transfer Facility[5]	3,086

Assumptions

Amount of Sediment Incinerated[1]:	30,000	tons		
Amount of Sediment Landfilled[1]:	600,000	tons		
Amount of Large Debris Landfilled[1]:	56,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	6,000	tons		
Fuel Economy of Trains[8]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		
Amount of Sediment per Container[3]:	22.5	tons		
Amount of Large Debris per Container:	22.5	tons		
Amount of SOF Debris per Container:	22.5	tons		
Emission factor conversion[9]:	1 g/gal =		0.048	gal/bhp-hr
Weight per cubic foot of large debris[6]:	109	lb/cf =	2,943	lb/cy

ENVIRON

Table D37 - Emission Estimates from Rail Transport
Remedial Alternative 4, DMM Scenario B

Emission Factors[7,8]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[4] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Clive Transfer Facility is 2,261 driving miles.

[5] Distance from Dundee Dam to Brills Yard Transfer Facility is 17 rail miles; distance from Brills Yard Transfer Facility to Avard Transfer Facility is 1,526 driving miles.

[6] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[7] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[8] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[9] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[10] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D38 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario B

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Sediment from Transfer Facility to Incinerator	1,334	20	51	1.4E-04	1.5E-04	51	4,390		0.13
	Trucks Hauling Ash from Thermal Incinerator Site to Landfill	334	105	67	1.9E-04	2.0E-04	67			0.17
	Trucks Hauling Sediment from Transfer Facility to Landfill	26,667	60	3,037	8.5E-03	9.0E-03	3,040			7.5
	Trucks Hauling Large Debris from Transfer Facility to Landfill	3,663	52	362	1.0E-03	1.1E-03	362			0.91
	Trucks Hauling Small Organic Fraction from Transfer Facility to Landfill	267	52	26	7.3E-05	7.8E-05	26			6.6E-02
	Trucks Hauling Sand for Beneficial Use	4,445	100	844	2.3E-03	2.5E-03	844			0.25
Total				**4,386**	**1.2E-02**	**1.3E-02**	**4,390**			**9.1**

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from Transfer Facility to Incinerator Site[4,8]	20
Distance from Incinerator Site to Landfill[4,7]	105
Distance from Transfer Facility to Landfill[4,10]	60
Distance from Transfer Facility to Landfill - Large Debris[4,11]	52
Distance from Transfer Facility to Landfill - Small Organic Fraction Debris[11]	52
Distance from UPF to Beneficial Use Site[13]	100

ENVIRON

Table D38 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario B

Assumptions

Ash Production Rate by weight[3]:	20%			
Amount of Sediment Incinerated[1]:	30,000	tons		
Amount of Ash Disposal:	6,000	tons		
Amount of Sediment Landfilled[1]:	600,000	tons		
Amount of Large Debris Landfilled[1]:	56,000	cubic yards		
Amount of SOF Debris Landfilled[1]:	6,000	tons		
Amount of Sand transported for Beneficial Use[1]:	100,000	tons		
Amount of Sediment Transported per Truck[4,9]:	22.5	tons		
Amount of Ash Transported per Truck:	18	tons		
Amount of Large Debris Transported per Truck:	22.5	tons		
Amount of SOF Debris Transported per Truck:	22.5	tons		
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile		
Weight per cubic foot of large debris[12]:	109	lb/cf =	2,943	lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[14]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in UT	0.009558856
Truck transfer in OK	0.009422301
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D38 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Aragonite Incinerator, Utah to Grassy Mountain Subtitle C Landfill, Utah

[8] Clive Transfer Facility, Utah to Aragonite Incinerator, Utah

[9] 22.5 tons of sediment per container

[10] Avard Transfer Facility, OK to Lone Mountain Subtitle C Landfill Facility, OK

[11] Clive Transfer Facility, Utah to Grassy Mountain Subtitle C Landfill, Utah

[12] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[13] No activity data provided in FFS.

[14] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in OK and UT, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D39 - Emission Estimates from Thermal Incineration
Remedial Alternative 4, DMM Scenario B

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	30,000	7,000	21,000	6.5	--	22,940	251

Emission Factors

Pollutant	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D39 - Emission Estimates from Thermal Incineration
Remedial Alternative 4, DMM Scenario B

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed June 2014).

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4* , Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory and applied $PM_{2.5}$ to PM_{10} factor.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

Table D40 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario C

Phase[1]	Emission Source[1]	Number of Vessels	Number of Engines[2] (per Vessel)		Engine Power[2] (kW)		Load Factor	Activity per Vessel[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[13]	
			Main	Auxiliary	Main	Auxiliary			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18	295	1.4E-02	0.22	1.4E-02	0.22
	Video Survey Vessel	1	1.8	0.6	275.9	55.7	43%	108	18	5.1E-04	2.3E-03	18		1.4E-02		1.4E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	1,140	190	5.4E-03	2.4E-02	192		0.15		0.15	
	Barge-Auger	1	1.8	0.6	275.9	55.7	43%	396	66	1.9E-03	8.4E-03	67		5.1E-02		5.1E-02	
Testing and Monitoring During Dredging and Backfilling/Capping	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	958	2.7E-02	0.12	969	4,845	0.73	3.7	0.73	3.7
	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	11,520	3,831	0.11	0.49	3,876		2.9		2.9	
Dredging	Channel Dredgers	2	--	--	896		51%	11,520	7,996	0.23	1.0	8,092	11,203	5.2	7.4	5.2	7.4
	Dredge Tenders	2	--	--	687		38%	3,456	1,370	4.0E-02	0.18	1,387		0.90		0.90	
	Survey Boats	2	--	--	224		38%	2,304	298	8.6E-03	3.9E-02	301		0.20		0.20	
	Large Debris Scow Tug Boat - main	1	--	--	1,836	--	68%	5	4.7	1.4E-04	6.2E-04	4.8		3.1E-03		3.1E-03	
	Large Debris Scow Tug Boat - aux	1	--	--	--	210	43%	5	0.13	1.0E-06	5.1E-06	0.13		6.7E-04		6.7E-04	
	Sediment Scow Tug Boat - main	1	--	--	1,836	--	68%	1,440	1,366	4.0E-02	0.18	1,382		0.90		0.90	
	Sediment Scow Tug Boat - aux	1	--	--	--	210	43%	1,440	36	2.9E-04	1.5E-03	36		0.19		0.19	
Backfill and/or Engineered Cap	Backfill Scow Tug Boat - main	1	--	--	1,836	--	68%	6,848	6,496	0.19	0.85	6,574	13,938	4.3	10	4.3	10
	Backfill Scow Tug Boat - aux	1	--	--	--	210	43%	6,848	172	1.4E-03	7.0E-03	173		0.91		0.91	
	Channel Dredgers - backfill	2	--	--	896		51%	5,580	3,873	0.11	0.51	3,919		2.5		2.5	
	Dredge Tenders - backfill	2	--	--	687		38%	1,674	664	1.9E-02	8.7E-02	672		0.44		0.44	
	Survey Boats - backfill	2	--	--	224		38%	1,116	144	4.2E-03	1.9E-02	146		9.5E-02		9.5E-02	
	Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	240	40	1.1E-03	5.1E-03	40		3.1E-02		3.1E-02	
	Armor Scow Tug Boat - main	1	--	--	1,836	--	68%	677	643	1.9E-02	8.4E-02	650		0.42		0.42	
	Armor Scow Tug Boat - aux	1	--	--	--	210	43%	677	17	1.4E-04	6.9E-04	17		9.0E-02		9.0E-02	
	Channel Dredgers-armor	2	--	--	896		51%	552	383	1.1E-02	5.0E-02	388		0.25		0.25	
	Dredge Tenders - armor	2	--	--	687		38%	166	66	1.9E-03	8.6E-03	66		4.3E-02		4.3E-02	
	Survey Boats - armor	2	--	--	224		38%	110	14	4.1E-04	1.9E-03	14		9.4E-03		9.4E-03	
	Mudflat, etc. Backfill Scow Tug Boat -main	1	--	--	1,836	--	68%	762	723	2.1E-02	9.4E-02	732		0.47		0.47	
	Mudflat, etc. Backfill Scow Tug Boat -aux	1	--	--	--	210	43%	762	19	1.6E-04	7.8E-04	19		0.10		0.10	
	Channel Dredgers-mudflat, etc. backfill	2	--	--	896		51%	621	431	1.2E-02	5.6E-02	436		0.28		0.28	
	Dredge Tenders - mudflat, etc. backfill	2	--	--	687		38%	186	74	2.1E-03	9.6E-03	75		4.8E-02		4.8E-02	
	Survey Boats - mudflat, etc. backfill	2	--	--	224		38%	124	16	4.7E-04	2.1E-03	16		1.1E-02		1.1E-02	
Annual O&M	Water Quality Vessels	2	1.8	0.6	275.9	55.7	43%	720	130	3.8E-03	1.7E-02	131	1,552	0.18	2.2	0.18	2.2
	Geophysical Vessel	1	1.8	0.6	275.9	55.7	43%	3,240	292	8.5E-03	3.8E-02	296		0.41		0.41	
	Small Vibracoring Vessel	1	1.8	0.6	275.9	55.7	43%	6,570	592	1.7E-02	7.7E-02	599		0.84		0.84	
	SPI Vessel	1	1.8	0.6	275.9	55.7	43%	5,760	519	1.5E-02	6.8E-02	525		0.73		0.73	
Annual Maintenance Activities	Ice Scour	1	1.8	0.6	275.9	55.7	43%	1,200	108	3.1E-03	1.4E-02	109	109	0.15	0.15	0.15	0.15
Total									**31,569**	**0.91**	**4.1**	**31,942**		**24**		**24**	

ENVIRON

Default Vessel Specifications

Vessel Category	Load Factor	Number of Engines (per Vessel)		Engine Power (kW)		Model Year		Number per dredge	Percent operating time while dredge operating
		Main	Auxiliary	Main	Auxiliary	Main	Auxiliary		
Work Boat[2]	43%	1.8	0.6	275.9	55.7	1989	1986	--	--
Harbor Tug[2]	--	1.9	1.5	711.4	55.7	1990	1990	--	--
Tug Boat[2]	31%	--	--	--	--	--	--	--	--
Dredge Tenders[2]	69%	--	--	--	--	--	--	--	--
Other Categories[2]	43%	--	--	--	--	--	--	--	--
Other Auxilliaries[2]	43%	--	--	--	--	--	--	--	--
Channel Dredging[3]	51%	--	--	896		--	--	--	--
Dredge Tender[3]	38%	--	--	687		--	--	1	30%
Survey Boat[3]	38%	--	--	224		--	--	1	20%
Tug Boat-main[3]	68%	--	--	1,836	--	--	--	--	--
Tug Boat-auxiliary[3]	43%	--	--	--	210	--	--	--	--

Harbor Craft Hours of Operation[10]

Project Phase	Vessel Type						
	Geophysical Vessel	Vibracoring Vessel	Water Survey Vessel	Video Survey Vessel	Barge-Auger	SPI Vessel	Ice Scour Vessel
Pre-Construction	108	1,140	--	108	396	--	--
Testing and Monitoring During Dredging and Backfilling	5,760	--	11,520	--	--	--	--
Dredging	--	--	--	--	--	--	--
Backfill and/or Engineered Cap	--	240	--	--	--	--	--
Annual O&M[11]	3,240	6,570	720	--	--	5,760	--
Annual Maintenance Activities[11]	--	--	--	--	--	--	1,200

Emission Factors for Main Harbor Craft Engines[2]

Engine Type	Minimum Power (kW)	Correction Factor[4]	CO_2 (g/kWh)	N_2O (g/kWh)	CH_4 (g/kWh)	PM_{10} (g/kWh)[12]
Tier 0, 1, 2 engines	37-1,000, Cat 2	1	690	0.02	0.09	--
Tier 1 engines	37-1,000, Cat 2	1	--	--	--	0.45

Emission Factors for Auxiliary Engines[5,14]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[14]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[5]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Dredged Material Disposal Assumptions

Hopper Scow Capacity[1]:	2,750 cubic yards		
Speed of tug boat[3]:	8 knots		
Dredge rate of sediment[1]:	2,000 cy/day/vessel		
Weight per cubic foot of large debris[7]:	109 lb/cf		
Weight per cubic foot of sediment[7]:	100 lb/cf		
Dredged Material from 8-mile study area			
Distance to USF[6]:	10 river miles		
Hours of operation per roundtrip:	2.5 hours		
Amount of large debris removed[1]:	2,000 tons =	36,697 cubic feet =	1,359 cubic yards
Amount of sediment removed[1]:	1,021,000 cubic yards		
Amount of sediment barged[1]:	1,584,000 cubic yards		
Number of large debris trips (total)[8]:	2		
Number of sediment trips (total):	576		

Backfill Assumptions

Scow Capacity[1]:	2,750 cubic yards	
Distance from Quarry[9]:	81 ntcl miles	
Speed of tug boat[3]:	8 knots	
Hours of operation per roundtrip:	20.25 hours	
Backfill/Engineered Cap		
Amount of backfill/engineered cap material[1]:	930,000 cubic yards	
Number of trips (total):	338 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	233 days =	5,580 hours
Armor Material		
Amount of armor material[1]:	92,000 cubic yards	
Number of trips (total):	33 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	23 days =	552 hours
Mudflat/Mudflat Reconstruction		
Amount of backfill[1]:	103,500 cubic yards	
Number of trips (total):	38 per scow	
Backfill placement rate[1]:	2,000 cy/day/vessel	
Time to place backfill (total):	26 days =	621 hours

Table D40 - Harbor Craft Emission Estimates
Remedial Alternative 4, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014. [FFS]

[2] *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report* , prepared by USEPA, April 2009.

[3] *Port of Oakland 2012 Seaport Air Emissions Inventory,* prepared by ENVIRON International Corporation, November 5, 2013.

[4] Correction Factor for onroad diesel and ultra low sulfur diesel with respect to offroad diesel.

[5] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[6] Assume 5 river miles to Upland Processing Facility. Mid-point of distance ranges evaluated in Table 3-3 of the FFS.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 201

[8] Assuming that at least one large debris disposal event occurs per year/mobilization.

[9] Clinton Point Quarry; *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[10] Unless otherwise specified, assume support vessels operate 12 hours/day, 6 days/week, 40 weeks/year.

[11] Assuming 30 years of annual O&M.

[12] Average PM_{10} emission factor for Tier 1 Engines

[13] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

[14] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours

Table D41 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Stationary Combustion Source Emission Estimates

Phase[1]	Emission Source[1]	Engine Size		Load Factor	Activity[1] (total hours)	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)[5]	
		hp	MMBtu/hr			CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Vibracoring Equipment	10	2.5E-02	50%	1,140	1.2	9.6E-06	4.8E-05	1.2	1.2	6.3E-03	6.3E-03	6.3E-03	6.3E-03
Annual O&M	Vibracoring Equipment	10	0.025	50%	6,570	6.8	5.5E-05	2.8E-04	6.8	6.8	3.6E-02	3.6E-02	3.6E-02	3.6E-02
Total						**8.0**	**6.5E-05**	**3.2E-04**	**8.0**		**4.2E-02**		**4.2E-02**	

Engine Size Assumptions

Source	Engine Size (hp)	Load Factor	Reference
Vibracoring Equipment	10	50%	Alpine Ocean Seismic Survey, Alpine Model E Electric Vibracore; http://www.alpineocean.com/Vibracore.html# (Accessed June 2014). No info on load factor; used mid-point.
Vibratory Pile Driver	228	50%	Hammer & Steel, Excavator Mounted Vibratory Pile Driver HVR-100; http://www.hammersteel.com/abi-excavator-mounted-vibratory-pile-driver.html (accessed June 2014). No info on load factor, used mid-point.

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	1,140
Annual O&M	Vibracoring Equipment	6,570

Emission Factors for Engines[2,4]

Engine Type	CO_2 (kg/MMBtu)	N_2O (kg/MMBtu)	CH_4 (kg/MMBtu)	PM_{10} (lb/hp-hr)[4]
Distillate Fuel Oil No. 2/Petroleum	73.96	6.0E-04	3.0E-03	2.20E-03

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D41 - Stationary Combustion Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] AP-42, Chapter 3.3 (Gasoline and Diesel Industrial Engines), USEPA, October 1996.

[5] All PM from harbor craft is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D42 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Off-Road Mobile Source Emission Estimates

Phase[1]	Emission Source[1]	Quantity	Engine Size (hp)	Load Factor	Activity[1] (total hours)	VMT[10]	Emissions (total tons)					DPM Emissions (total tons)		$PM_{2.5}$ Emissions (total tons)	
							CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	By Emission Source	By Phase	By Emission Source	By Phase
Pre-Construction	Barge-Auger	1	206	43%	396	--	20	--	--	20	43	8.8E-03	1.8E-02	--	--
	Drill Rig - Borrow Site Pre-Screening	1	206	43%	300	--	16	--	--	16		6.7E-03		--	
	Drill Rig - Borrow Material Characterization	1	206	43%	135	--	7.0	--	--	7.0		3.0E-03		--	
Pre-Construction of UPF	Drill Rig - Geotechnical Investigation	1	206	43%	72	--	3.7	--	--	3.7	3.7	1.6E-03	1.6E-03	--	--
Upland Sediment Processing Facility Construction	Rubber Tired Dozers	4	255	40%	840	--	202	--	--	202	2,685	6.4E-02	2.3	0.17	0.17
	Tractors/Loaders/ Backhoes	9	97	37%	6,020	--	1484	--	--	1,484		1.8		--	
	Excavators	2	162	38%	600	--	44	--	--	44		1.6E-02		--	
	Graders	1	174	41%	600	25	25	--	--	25		9.8E-03		1.1E-04	
	Scrapers	2	361	48%	600	--	123	--	--	123		3.5E-02		--	
	Cranes	1	226	29%	5,180	--	198	--	--	198		3.8E-02		--	
	Forklifts	3	89	20%	5,920	--	207	--	--	207		5.9E-02		--	
	Generator Sets	1	84	74%	5,920	--	239	--	--	239		0.18		--	
	Welders	1	46	45%	5,920	--	93	--	--	93		9.9E-02		--	
	Pavers	2	125	42%	440	--	27	--	--	27		1.1E-02		--	
	Paving Equipment	2	130	36%	440	--	24	--	--	24		1.1E-02		--	
	Rollers	2	80	38%	440	--	18	--	--	18		1.0E-02		--	
Upland Sediment Processing Facility Operations	Front End Loaders	3	97	37%	14,400	--	1,183	--	--	1,183	9,728	1.4	3.5	--	--
	Skid Steer	1	65	37%	14,400	--	264	--	--	264		0.34		--	
	Excavator	1	162	38%	14,400	--	523	--	--	523		0.19		--	
	Dump Truck	4	400	38%	14,400	--	5,172	--	--	5,172		1.0		--	
	Water Truck	1	400	38%	14,400	--	1,293	--	--	1,293		0.25		--	
	Street Sweeper	1	400	38%	14,400	--	1,293	--	--	1,293		0.25		--	
Upland Support Facility Site Decommissioning	Concrete/ Industrial Saws	1	81	73%	400	--	16	--	--	16	107	1.1E-02	4.2E-02	--	1.8E-03
	Excavators	3	162	38%	400	--	44	--	--	44		1.6E-02		--	
	Rubber-tired Dozers	2	255	40%	400	--	48	--	--	48		1.5E-02		1.8E-03	
Total							**12,568**	**0**	**0**	**12,568**		**5.9**		**0.18**	

ENVIRON

Table D42 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Engine Characteristics and Emission Rates

Source	Engine Size[4] (hp)	Load Factor[4]	CO_2 Emission Factor[5] (g/hp-hr)	$PM_{exhaust}$[5] (g/hp-hr)	$PM_{2.5}$[10] (lb/VMT)	$PM_{2.5}$[10] (lb/hr)
Concrete/Industrial Saw	81	73%	595.14	0.41	--	--
Excavator	162	38%	535.98	0.19	--	--
Rubber Tired Dozer[6]	255	40%	536.14	0.17	--	0.41
Tractor/Loader/ Backhoe	97	37%	693.05	0.84	--	--
Grader	174	41%	536.25	0.21	8.8E-03	--
Forklift	89	20%	595.67	0.17	--	--
Generator Set	84	74%	588.77	0.44	--	--
Welder	46	45%	692.56	0.73	--	--
Paver	125	42%	536.20	0.22	--	--
Paving Equipment	130	36%	536.08	0.24	--	--
Roller	80	38%	595.35	0.34	--	--
Scraper	361	48%	536.29	0.15	--	--
Bore/Drill Rig	206	43%	530.00	0.23	--	--
Cranes	226	29%	530.44	0.10	--	--
Off-Highway Truck	400	38%	536.36	0.10	--	--
Skid Steer	65	37%	692.29	0.90	--	--

Hours of Operation

Project Phase	Source	Hours
Pre-Construction	Vibracoring Equipment	1,140
	Barge-Auger	396
	Drill Rig - Borrow Site Pre-Screening	300
	Drill Rig - Borrow Material Characterization	135
Pre-Construction of UPF	Drill Rig - Upland Support Facility	72
UPF Operations[8,9]	All	14,400

USF Site Area[1]: 36 acres

ENVIRON

Table D42 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Equipment Type by Construction Phase[7]

Phase	Duration (days)	Equipment Type	Unit Amount	Hours/Day
Site Prep	30	Rubber Tired Dozers	3	8
		Tractors/Loaders/ Backhoes	4	8
Grading	75	Excavators	2	8
		Graders	1	8
		Rubber Tired Dozers	1	8
		Scrapers	2	8
		Tractors/Loaders/ Backhoes	2	8
Building Construction	740	Cranes	1	7
		Forklifts	3	8
		Generator Sets	1	8
		Tractors/Loaders/ Backhoes	3	7
		Welders	1	8
Paving	55	Pavers	2	8
		Paving Equipment	2	8
		Rollers	2	8
Demolition	50	Concrete/ Industrial Saws	1	8
		Excavators	3	8
		Rubber Tired Dozers	2	8

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

ENVIRON

Table D42 - Off-Road Mobile Source Emission Estimates
Remedial Alternative 4, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[4] CalEEMod.2013.2.2, default horsepower ratingsand load factors.

[5] NONROAD 2008a model, model year 2015.

[6] Used General Construction Equipment default factor for load factor

[7] CalEEMod.2013.2.2, Assumptions: 243,936 sf of General Heavy Industrial; 280,150 sf of General Light Industrial; 27.5 total acreage; Climate Zone 1; Urban

[8] 24 hours/day, 6 days/week, *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013. Distance measured using Google Earth to mid-point of 8-mile study area.

[9] Assume 50 weeks/year for 11 years

[10] CalEEMod.2013.2.2, Appendix A Assumptions for Fugitive Emissions; references AP-42, Chapter 11.9 (Western Surface Coal Mining), USEPA.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 acre =	43,560	sf
1 mile =	5,280	ft

Table D43 - Emission Estimates from Rail Transport
Remedial Alternative 4, DMM Scenario C

Emission Estimates from Rail Transport

Phase[1]	Emission Source[1]	Amount Hauled (tons)	Roundtrip Distance[3] (miles)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$[7]
Processing and Disposal	Rail Cars Hauling SOF from Brill Yard Transfer Station to Subtitle C Landfill	6,000	1,480	262	2.9E-04	1.8E-10	262	262	8.6E-02	8.6E-02
Total				**262**	**2.9E-04**	**1.8E-10**	**262**		**8.6E-02**	**8.6E-02**

Assumptions

Amount of SOF Debris Landfilled[1]:	6,000	tons		
Fuel Economy of Trains[5]:	337	Btu/ton-mile =	2.6E-03	gal/ton-mile
Emission factor conversion[9]:	1 g/gal =	0.048	gal/bhp-hr	
Heating Value of U.S. Conventional Diesel:	128,450	Btu/gal		

Emission Factors[4,5,6]

GHG	EF (g/gallon)	EF (g/ton-mile)	EF (g/bhp-hr)
CO_2	10,208	27	--
CH_4	0.8	2.1E-03	--
N_2O	0.26	6.8E-04	--
PM_{10}	3.3	--	0.16

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River*, prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE

[2] *Mandatory Greenhouse Gas Reporting*, Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] Distance from Brills Yard Transfer Facility to Roachdale, IN is 740 driving miles one way.

[4] CO_2 emission factor from *Emission Factors for Locomotives, Technical Highlights, EPA-420-F-09-025,* USEPA, April 2009

[5] CH_4 and N_2O emission factors for diesel fuel locomotives; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[6] PM_{10} emission factor, CY 2015 from *Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories, Final Report,* prepared by USEPA, April 2009.

[7] All PM from locomotives is DPM; assume $PM_{10} = PM_{2.5}$; based on AP-42 Chapter 3.3, which states that all PM is assumed to be less than 1 µm in diameter.

ENVIRON

Table D43 - Emission Estimates from Rail Transport
Remedial Alternative 4, DMM Scenario C

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D44 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario C

Emission Estimates from Truck Traffic

Phase[1]	Emission Source[1]	Number of trucks	Roundtrip Distance (VMT)	Emissions (total tons)						
				CO_2	N_2O	CH_4	CO_2e	CO_2e (by phase)	DPM	$PM_{2.5}$
Processing and Disposal	Trucks Hauling Thermally Treated Sediment for Beneficial Reuse	333	100	63	1.8E-04	1.9E-04	63	9,854		1.8E-02
	Trucks Hauling Washed Sediment for Beneficial Reuse	42,600	100	8,086	2.3E-02	2.4E-02	8,093			2.4
	Trucks Hauling Amended Sediment for Beneficial Reuse	489	100	93	2.6E-04	2.7E-04	93			2.7E-02
	Trucks Hauling Decontaminated Medium-Sized Debris	3,662	100	695	1.9E-03	2.1E-03	696			0.20
	Trucks Hauling SOF to Brills Yard Transfer Station	267	28	14	3.9E-05	4.2E-05	14			4.1E-03
	Trucks Hauling SOF from Transfer Station to Roachdale Subtitle C Landfill	267	100	51	1.4E-04	1.5E-04	51			0.12
	Trucks Hauling Sand for Beneficial Use	4,444	100	844	2.3E-03	2.5E-03	844			0.25
Total				**9,845**	**2.7E-02**	**2.9E-02**	**9,854**			**3.0**

Vehicle Miles Traveled (VMT)

Trip	Roundtrip VMT
Distance from UPF to Beneficial Use - Thermally Treated Sediment[8]	100
Distance from UPF to Beneficial Use - Washed Sediment[8]	100
Distance from UPF to Beneficial Use - Amended Sediment[8]	100
Distance from UPF to Medium-Size Debris Landfill[8]	100
Distance from UPF to Brills Yard Transfer Station[4]	28
Distance from Transfer Station to Roachdale Subtitle C Landfill[8]	100
Distance from UPF to Sand Beneficial Use Site[8]	100

ENVIRON

Table D44 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario C

Assumptions

Ash Production Rate by weight[3]:	20%			
Amount of Sediment Incinerated[1]:	30,000	tons		
Amount of Ash Beneficially Reused:	6,000	tons		
Amount of Washed Sediment[1]:	710,000	cubic yards =	958,500	tons
Amount of Amended Sediment[1]:	11,000	tons		
Amount of Medium-Sized Debris[1]:	56,000	cubic yards =	82,404	tons
Amount of SOF Debris Landfilled[1]:	6,000	tons		
Amount of Sand transported for Beneficial Use[1]:	100,000	tons		
Amount of Sediment Transported per Truck[4]:	22.5	tons		
Amount of Ash Transported per Truck:	18	tons		
Amount of Large Debris Transported per Truck:	22.5	tons		
Amount of SOF Debris Transported per Truck:	22.5	tons		
Fuel Economy Values for Diesel Trucks[6]:	0.169	gal/mile		
Weight per cubic foot of sediment[7]:	100	lb/cf =	2,700	lb/cy
Weight per cubic foot of large debris[7]:	109	lb/cf =	2,943	lb/cy

GHG Emission Factors[5]

GHG	EF (kg/gallon)	EF (g/mile)
CO_2	10.21	--
CH_4	--	0.0051
N_2O	--	0.0048

PM Emission Factors[9]

Source	$PM_{2.5}$ EF (lb/VMT)
Truck transfer in IN	0.009217468
Truck transfer in NJ	0.001108796

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D44 - Emission Estimates from Truck Traffic
Remedial Alternative 4, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] The amount of ash generated ranges from 15-25 percent by weight of the MSW processed; picked mid-point of range. From *Wastes - Nonhazardous Waste - Municipal Solid Waste Basic Information* , USEPA; http://www.epa.gov/osw/nonhaz/municipal/wte/basic.htm (accessed June 2014).

[4] *Final Construction Report - Phase I Removal Action, CERCLA Non-Time-Critical Removal Action - Lower Passaic River Study Area,* prepared by Tierra Solutions, Inc., March 20, 2013.

[5] Mobile combustion, diesel fuel, diesel medium- and heavy-duty vehicles; *Emission Factors for Greenhouse Gas Inventories,* USEPA Climate Leadership, Last Modified: April 4, 2014.

[6] Diesel Highway Vehicles, Combination Trucks; *Direct Emissions from Mobile Combustion Sources,* USEPA Climate Leaders, May 2008.

[7] Density of debris set equal to trap rock, broken; density of sediment set equal to earth, wet, excavated. Source: Reade; http://www.reade.com/resources/reference-charts-particle-property-briefings/89-weight-per-cubic-foot-and-specific-gravity-metals-minerals-organics-inorganics-ceraqmics (accessed on June 22, 2014).

[8] No activity data provided in FFS. Assume truck trip = 50 miles one way.

[9] AP-42, Section 13.2.1 (Paved Roads), USEPA, revised January 2011. Assumptions: empty trailer = 30,000 lbs; full trailer = 80,000 lbs; ADT <500 in IN, ADT 5,000-10,000 in NJ.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr

Table D45 - Emission Estimates from Thermal Incineration
Remedial Alternative 4, DMM Scenario C

Emission Estimates from Thermal Incineration

Phase[1]	Emission Source[1]	Throughput[1] (tons)	Waste Gas Volume[3] (m^3/Mg of Waste)	Emissions (total tons)				
				CO_2	N_2O	CH_4	CO_2e	$PM_{2.5}$
Processing and Disposal	Thermal Incineration	30,000	7,000	21,000	6.5	--	22,940	251

Emission Factors

GHG	EF[3] (Mg of GHG/Mg of Waste)	EF[3] (mg/m^3)	EF[7] (lb/ton)
CO_2[4]	0.7	--	--
CH_4[5]	0	0	--
N_2O[6]	--	31	--
$PM_{2.5}$	--	--	16.7417

GHG Global Warming Potentials[2]

GHG	GWP
CO_2	1
CH_4	25
N_2O	298

Table D45 - Emission Estimates from Thermal Incineration
Remedial Alternative 4, DMM Scenario C

Notes:

[1] *Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River* , prepared by The Louis Berger Group, Inc. in conjunction with Battelle and HDR/HydroQual for USEPA Region 2 and USACE, Kansas City District, 2014.

[2] *Mandatory Greenhouse Gas Reporting* , Tables A-1, C-1, and C-2, 40 CFR Part 98, USEPA, last amended November 29, 2013.

[3] *Emissions from Waste Incineration, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* International Panel on Climate Change; http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed June 2014).

[4] CO_2 emission factor ranges from 0.7 to 1.2 Mg/Mg of MSW. Assumed that MSW contains more carbon than contaminated sediment. Selected lower value in range.

[5] Under the oxidative combustion in waste incineration, it is assumed that methane is not present in the waste gas.

[6] Mid-range of N_2O emission factor from hazardous waste incinerators of 30-32 mg/m^3.

[7] *Air Quality Operating Permit Application, General Incinerator Operating Permit, Section 4* , Nebraska Department of Environmental Quality, revised April 2014. For MSW incinerators; based on NDEQ's annual emissions inventory and applied $PM_{2.5}$ to PM_{10} factor.

Conversions:

1 lb =	454	g
1 ton =	2,000	lbs
1 kW =	3,415	Btu/hr
1 kg =	2.2	lbs
1 MMBtu =	1,000,000	Btu
1 kW =	1.34	hp
1 cubic yard =	27	cubic feet
1 hour =	60	minutes
1 day =	24	hours
1 hp =	2,547	Btu/hr
1 Mg =	1.102	tons
1 Mg =	1.0E+09	mg

Joseph Nicolette

Principal
Environ
Atlanta, Georgia
678 388 1665
jnicolette@environcorp.com

PROFILE SUMMARY

Joseph Nicolette has over 29 years of experience in the environmental consulting field and serves as ENVIRON's Global Ecosystem Services Director. His experience has focused on net environmental benefits analysis (NEBA), natural resource damage assessments (NRDA), risk evaluation and management (ecological and human health), site remedial alternative evaluations, site restoration and mitigation, oil spill response and planning, and land asset management. He provides strategic advice and oversight for projects to help balance the risks, benefits and tradeoffs associated with competing alternatives (e.g., response/remedial actions). His experience (U.S. and International) includes strategies involving the use of natural resource economic valuation and risk assessment for quantifying the potential impacts and/or benefits to ecological and human use services associated with actions that affect the environment. His experience includes litigation support related to NRDA, ecosystem service valuation models, and oil/chemical releases. He has made demonstrated contributions in developing what is known as the net environmental benefits analysis (NEBA) and net ecosystem service analysis (NESA) approaches. The NEBA and NESA approaches are comparative risk management frameworks for social, environmental and economic valuation of actions that affect the environment. These approaches incorporate risk projections and resource equivalency analysis approaches. His expertise includes NRDA, NEBA, NESA, risk management and resource equivalency (i.e., service to service) analysis. Mr. Nicolette is a Certified Fisheries Scientist with the American Fisheries Society.

EDUCATION

University of Minnesota	Fisheries Management	M.S.	1983
Pennsylvania State University	Environmental Resources Management	B.S.	1980

EXPERIENCE

Distinguishing Qualifications

- He is recognized for his contributions in developing the NEBA and the evolving NESA approaches, which support the development of response strategies that provide the greatest net environmental benefit to the public while managing site risks and costs.
  - Joseph co-authored the first formalised NEBA framework recognized by the National Oceanic and Atmospheric Administration (NOAA) and the USEPA Science Advisory Board. The framework was co-authored with risk assessors from Oak Ridge National Laboratory and the United States Environmental Protection Agency (USEPA).
  - Conducted NEBA applications for over 24 years, focusing on remedial and response action evaluations.
  - Used resource equivalency approaches prior to being codified into damage assessment regulations in the U.S. and now in the ELD.
  - He has made demonstrated contributions to the development of NEBA and NRDA approaches in the U.S. and Internationally. This includes the conduct of recent international presentations and workshops (Germany, Great Britain, Italy, Malaysia, Norway, Scotland, South Africa, Thailand, etc.) related to NEBA, risk management, resource equivalency, and damage assessment.
  - Joseph's success in this area also includes:
    - A chapter regarding NEBA that was integrated into Interstate Technical Regulatory Council Guidance (ITRC 2006).
    - Pilot studies evaluating appropriate metrics for NEBA for site cleanup and remediation on behalf of the US Environmental Protection Agency.
    - Guidance for the Energy Institute (2009 and 2010, London) on the Environmental Liability Directive and on establishing ecological baselines (pre-incident) using NEBA concepts.

    - Multiple published papers related to NEBA (2001-2013).
    - Multiple client projects using NEBA approaches to address remedial/response risk issues.
- He is the lead author of a book chapter (published in March of 2013 by the Oxford Press) that provided an overview of the U.S. natural resource damage assessment regulations and the development of resource equivalency analysis approaches. The book was entitled *The E.U. Liability Directive: A Commentary*. He led Chapter 9 that was entitled "Experience with Restoration of Environmental Damage". The chapter also discusses the similarities and differences of the U.S. NRDA rules in relation to the ELD.
- Joseph has participated in natural resource damage/impact assessments since 1990. He has been involved in the conduct of impact assessments for over 50 hazardous releases. These include assessments associated with oil and chemical releases (including petroleum products, PCB, DDT, dioxin, metals, etc.) and damage assessments associated with releases under US NRDA regulations and the EU Environmental Liabilities Directive (ELD).
- Joseph has also worked with several law firms to provide technical and/or expert witness support in environmental litigation cases, typically focused on subject matter related to natural resource damage assessments (NRDAs) and the effects of contaminant releases on the environment. He has provided written affidavits to support his technical findings and has been deposed.
- He has managed several large oil spill and chemical related NRDA projects and has been involved in 50+ NRDA related liability projects. Joseph's experience includes client strategy development regarding natural resource injury and environmental assessment, risk management, mitigation and remedial planning, valuation and restoration planning, NRDA/remedial allocation modeling, agency negotiations, technical assessment design, and technical data review, assessment, and interpretation.
- Participated in the conduct of numerous assessments associated with the potential adverse environmental impacts of oil spills on the environment. Experience includes pre-spill planning support (e.g., tactical plans, contingency plans, drill participation, identification of environmentally sensitive areas and baseline assessment); emergency response support (e.g., ephemeral data collection, baseline assessment and resource protection strategies) and post-incident support (e.g., injury and compensatory restoration evaluation, fate and transport modeling and site remediation). He has contributed to the incorporation of NEBA/NESA considerations into the pre-spill, emergency response and post-incident support phases of hazardous releases and has worked within the Incident Command Structure (ICS) on behalf of multiple clients.
- In addition, he has worked on evaluating the potential environmental impact associated with new project construction, including appropriate mitigation and permitting efforts.
- Joseph has provided PRP identification and remedial/NRDA liability allocation support for clients.
- He has served as the Project Coordinator on behalf of the responsible party, at multiple Superfund (CERCLA) sites. These sites were primarily related to PCB releases to soil, sediment, and groundwater.
- Joseph has served on the Planning and Steering committees for the ACES Conferences (*A Community of Ecosystem Services*), working with the United States Geological Survey Conference leaders since 2008.

RECENT PUBLICATIONS

- **Nicolette, J.**, Burr, S., and Rockel, M. (2013). A Practical Approach for Demonstrating Environmental Sustainability and Stewardship through a Net Ecosystem Service Analysis. *Sustainability 2013*, 5, 2152-2177; doi:10.3390/su5052152, Published May 10, 2013.
- **Nicolette, J.**, Goldsmith, B., Wenning, R., Barber, T., and Colombo, Fabio (2013). Experience with Restoration of Environmental Damage. Chapter 9 in *The E.U. Liability Directive: A Commentary*, L. Berkamp and B. Goldsmith, eds. Oxford Press. Pages 181-219 (March 14, 2013).

Voltaggio Consulting, LLC
A Limited Liability Company
1529 Chalet Drive Cherry Hill New Jersey 08003
Telephone: 856-745-1488 Facsimile: 856-673-0243
Email: tom@voltaggioconsulting.com Web: www.voltaggioconsulting.com

Report
of
Thomas C. Voltaggio

Policy Issues Raised by the Proposed Plan Issued for the Lower Passaic River

Signed:

Dated:

August 12, 2014

Prepared For:

Maxus Energy Corporation
10333 Richmond Avenue
Houston, TX 77042

Tierra Solutions, Inc.
2 Tower Center Blvd., 10th Floor
East Brunswick, NJ 08816

1 - The Use of an FFS for Remedy Determination for the Lower 8 Miles of the Lower Passaic River ("LPR") Is Inconsistent with the National Contingency Plan

An FFS is a tool used by EPA to expedite CERCLA cleanups when a presumptive remedy or interim action will be employed. As explained in more detail below, FFSs have been used in limited circumstances where there are few technical issues surrounding a remedial action or to implement interim remedies while a detailed environmental investigation is completed. A remedy of the scale contemplated by the LPR FFS—some combination of dredging and capping eight miles of river, at a cost estimated to range between $400 million and $3.5 billion or more, to be implemented over the course of many years—should be evaluated and selected through CERCLA's well-established RI/FS process, rather than characterized as an "interim remedy" subject only to an abbreviated FFS process. The scale of two of the three remedial alternatives (the only alternatives considered in the draft FFS in 2007) being considered by Region 2 goes far beyond anything ever developed through an FFS process. If implemented, either of those two proposed alternatives would constitute one of the largest, if not the largest, sediment remedy ever selected by USEPA. Region 2's proposed course reflects a misuse of the FFS process, which was conceived and intended for truly focused work, not to prematurely select what is effectively the final remedy for eight miles of an urban river immediately prior to the scheduled completion of an RI/FS that has been under preparation for 20 years, a testament to the need for extensive data collection and analysis at the Site. That it has taken Region 2 seven years to finalize the FFS underscores the complexity of developing remedial alternatives for the LPR, the unsuitability of an FFS to do so, and the need for EPA to comply with the NCP.

There is no precedent for Region 2's decision to proceed with an FFS for the lower eight miles of the Passaic. In fact, an examination of the origin of the FFS and USEPA's past practice in using an FFS as part of a CERCLA cleanup demonstrates that the use of an FFS in the lower Passaic is inconsistent with USEPA's policy and practice. For a cleanup as large and complex as that being contemplated for the Passaic, a full RI/FS is necessary before a remedial action may be selected. As explained below, the FFS is a tool of USEPA's invention that is not governed by the NCP. Region 2's use of an FFS in the lower eight miles of the Passaic appears to be an attempt to advance Region 2's preferred remedy of dredging without thorough consideration of the data being collected in the ongoing RI/FS, thereby circumventing the requirements of the NCP. This consideration is particularly salient given the uncertainties surrounding the question of how much to dredge and where; what risks will be associated with re-entrainment of contaminated sediment; and the apparent absence of sufficient evaluation of natural attenuation, costs, and disposal option difficulties.

The term "focused feasibility study" is not found in the NCP. The first use of the concept appears to be in USEPA's 1994 Guidance on Accelerating CERCLA

Environmental Restoration at Federal Facilities. This guidance memorandum was intended to support the "accelerat[ion] and develop[ment of] streamlined approaches to the cleanup of hazardous waste" at federal facilities. The guidance memorandum encourages the development of presumptive remedies as standardized methods to approach similar or recurring contamination problems. The guidance states that "[f]ollowing site characterization, a focused Feasibility Study (FS) or Engineering Evaluation/Cost Analysis (EE/CA) may be sufficient when employing the presumptive remedy approach." Notably, the USEPA's 1994 Guidance was issued to provide specific guidance for federal facilities as a companion to the earlier OSWER Directive 9203.1-03 for privately-owned facilities (USEPA, 1992). This earlier directive mentions neither presumptive remedies nor the use of an FFS.

It does not appear that USEPA has issued any subsequent guidance on why and when it is appropriate to initiate an FFS rather than an FS. An evaluation of USEPA practice reveals that the use of the FFS process has grown over time to exceed the limited circumstances outlined in the USEPA's 1994 guidance memorandum. A review of USEPA's practice reveals three primary situations in which the FFS has been used:

1. Interim Remedial Actions: FFSs have been used to evaluate alternatives for interim remedial actions in situations where a full remedy will follow. However, when an FFS is used to implement an interim remedy, it is critical that any actions taken under the FFS be consistent with the broader RI/FS. It is clear, however, that the FFS does not properly qualify as an "interim remedy" under relevant EPA guidance. Such actions are properly "limited in scope"; "quick action; or "temporary measures";[1] the FFS is none of these things. Further, the FFS cannot be justified as some form of "early action"; actions that will take more than five years, as the proposed interim remedy certainly will, "should be done as long-term responses using remedial authority."[2]

2. Implementation of a Presumptive Remedy: The use of the FFS outlined in the original USEPA guidance memorandum was for the implementation of a presumptive remedy. Presumptive remedies are implemented at sites where there are not significant, site-specific technical issues that require evaluation before implementation of a remedy. EPA guidance definitively states that "there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk."[3] Thus, EPA cannot use an FFS at the Site under the theory that a presumptive remedy applies.

---

[1] EPA, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* (July 1999) at 8-2.
[2] EPA, *Early Action and Long Term Action under SACM – Interim Guidance 1* (Dec. 1992) at 2.
[3] EPA, Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites 7 (Feb. 12, 2002) (hereinafter "Sediment Principles"), *available at* http://www.epa.gov/superfund/policy/remedy/pdfs/92-85608-s.pdf.

3. Implementation of a Remedy at a Similar Operable Unit (OU) within a Larger Site: When significant amounts of data have been obtained and analyzed during previous RIs, Remedial Designs (RDs), or RI/FSs performed at other OUs at a site, an FFS may be used to implement a remedy at a newly-addressed, similar OU. In practice, an FFS will only be used at a later OU when a full RI/FS has already been conducted for the similar, earlier remediated OU. Because the RI/FS for the Site is not yet complete, EPA's use of an FFS at this Site is inappropriate under this rationale.

Each of these applications demonstrates that the FFS can be an important tool to increase efficiency and decrease costs when further data collection and analysis are not required to develop and choose among a set of remedial alternatives. However, this is not the case in the lower eight miles of the Passaic River. At this time, the ongoing RI/FS for the LPR has yet to resolve questions regarding the distribution of contaminated sediment, pathways for redistribution of contamination, or the remedial options that will most effectively address the contaminated sediment that is present in the environment. The NCP's definition of a "feasibility study" stresses the importance of incorporating RI data:

> Feasibility study (FS) means a study undertaken by the lead agency to develop and evaluate options for remedial action. The FS emphasizes data analysis and is generally performed concurrently and in an interactive fashion with the remedial investigation (RI), using data gathered during the RI. The RI data are used to define the objectives of the response action, to develop remedial action alternatives, and to undertake an initial screening and detailed analysis of the alternatives.[4]

Accordingly, several provisions of the NCP applicable to feasibility studies require that they reflect the scope and complexity of a site. For instance, the NCP requires that the "development and evaluation of alternatives shall reflect the scope and complexity of the remedial action under consideration and the site problems being addressed."[5] In that same Section, the NCP further requires that the "[d]evelopment of alternatives shall be fully integrated with the site characterization activities of the remedial investigation . . . ."[6] Similarly, Section 300.430(e)(2) requires that the "number and type of alternatives to be analyzed shall be determined at each site, taking into account the scope, characteristics, and complexity of the site problem that is being addressed."[7]

---

[4] 40 C.F.R. § 300.5.
[5] 40 C.F.R. § 300.430(e)(1)
[6] *Id.*
[7] 40 C.F.R. § 300.430(e)(2).

Because of the failure of EPA's FFS to consider the data and analysis associated with the RI/FS, the FFS does not appropriately consider the scope and complexity of the Site, as is required by the NCP. The complexities arising from the variable distribution of contaminated sediment, scope of the study area, contaminants from ongoing sources, and the magnitude of the remedies under consideration all lead to the conclusion that the Lower Passaic River is not the type of site where an FFS's more abbreviated analysis can be applied.

Furthermore, significant technical questions that will influence both the baseline risk assessment and ultimate remedy selection remain in the ongoing RI for the LPR. At the same time, Maxus and Tierra, on behalf of Occidental, have implemented interim remedial actions in the LPR. Given that the areas of greatest concern are already being addressed and significant technical issues remain unresolved, an FFS is not justifiable for the lower eight miles of the Passaic River. At least one of the alternatives being considered under the FFS may well not be consistent with the FS preferred remedy for the entire LPR, given that they involve bank-to-bank dredging and the FS remedy may involve targeted dredging. Additionally, the RI/FS remedy may require some form of upland or upriver actions to control ongoing sources of contamination that impact the lower eight miles of the River. An FFS performed before the RI/FS is completed for the entire LPR could obstruct the final process and is inconsistent with the NCP and USEPA guidance.

In addition, the FFS deprives the PRPs the opportunity to meaningfully participate in the RI/FS process as provided in the RI/FS guidance before selection of significant and costly remedial actions.

There is substantial risk that, if Region 2 acts on the basis of the abbreviated FFS process, it will select an alternative that will fail, partially or fully, to achieve the desired risk management objectives and/or will be inconsistent with the final remedy determined from the full RI/FS. These considerations suggest that Region 2 should allow the RI/FS process to continue on its schedule and not divert resources to the FFS that would later have to be amended to conform to the RI/FS. Rather than select a final remedy in the guise of an "interim action" based on an abbreviated process, Region 2 should develop a measured approach based on the full RI/FS, which will allow Region 2 to implement a logical, iterative action plan for the entire 17 miles of the River.

2 - Region 2 has not adequately considered the ability of dredging to meet risk-based goals or the alternative of monitored natural recovery.

Environmental dredging is a complex and expensive process that does not always meet- and may actually delay or impede environmental risk reduction goals. Based on the information provided in the FFS Summary, it is not clear that Region 2 has adequately considered the challenges associated with implementation of environmental dredging or the benefits of monitored natural recovery (MNR) as an alternative.

MNR consists of allowing natural processes to reduce sediment contamination below risk levels. Enhanced monitored natural recovery (EMNR) broadcasts coarse-grained materials over the sediment surface to accelerate the process of natural recovery. USEPA guidance states "[d]ue to the limited number of cleanup methods available for contaminated sediment, generally, project managers should evaluate each of the three potential remedy approaches (sediment removal, capping, and MNR) at every sediment site. At large or complex sites, project managers have found that alternatives that combine a variety of approaches are frequently cost effective (USEPA 2005).

Remedial alternatives that rely primarily on dredging to achieve risk-based goals have demonstrated limitations as a result of the effects of sediment resuspension and residuals (Bridges et al. 2010), and the timeframes for reaching acceptable risk levels at the site may span decades. These considerations must be accounted for in the development and evaluation of the alternatives. When a Feasibility Study is performed, each potential alternative must have a remedy-specific risk assessment to determine to what extent levels of risk will be reduced and/or <u>how long it will take to reach remediation goals.</u> Many sediment sites can reach targeted risk levels over time via MNR or enhanced MNR without the additional risks created by dredging and associated resuspension. The agency recognizes the use of MNR as an appropriate alternative for Superfund sites, especially where remediation costs are extremely high, as is the case here.

It is not clear that Region 2 accurately evaluated MNR as a stand-alone remedy that could avoid the challenges posed by environmental dredging. Rather, it determined that MNR is "a component of alternatives comprising active remedial measures."[8] However, review of the NCP criteria that guide the development and screening of remedial alternatives suggests that MNR should have been considered as a stand-alone remedy at the Site. The NCP states that effectiveness, implementability, and cost should guide the development and screening of remedial alternatives.[9] The FFS concedes that MNR satisfies each of these criteria at the Site such that EPA should has evaluated MNR as a stand-alone remedy:

[8] FFS at ES-5.
[9] 40 C.F.R. § 300.430(e)(7).

1. Effectiveness: Though Table 3-2 of the FFS states that MNR is "[n]ot effective by itself," the description of the remedy in that same table states, more accurately, that "MNR by itself may not be effective in reducing existing unacceptable human health and ecological risks to reach RAOs and PRGs *for several decades*."[10] Thus, EPA admits that MNR is effective at the Site, simply over a longer time period than other remedial alternatives. This finding is consistent with other EPA guidance authorities, which recognize that MNR remedies may take longer than active remedies to achieve remediation goals. For instance, EPA has stated that MNR "may be slower than predicted for dredging or in-situ capping."[11] Thus, "MNR should be considered when it would meet remedial objectives within a time frame that is reasonable compared to active remedies."[12] Nowhere in the FFS does EPA assess whether MNR as a stand-alone remedy would achieve remedial objectives in a timeframe that is reasonable when compared to the time needed to complete other active remedies under consideration. Nor does EPA guidance or the FFS suggest that MNR's slower rate of recovery renders it ineffective. To the contrary, EPA has included MNR as a component of several remedial alternatives at the Site in conjunction with active remedies, admitting its effectiveness.[13]

2. Implementability: Region 2 concedes in the FFS that MNR is "[r]eadily [i]mplementable."[14]

3. Cost: Region 2 similarly admits in the FFS that MNR has "relatively low" costs in both the short- and long-term.[15]

By improperly screening out MNR as a stand-alone remedy at the Site, Region 2 failed to follow EPA guidance, which instructs that "All remedies that may potentially meet the removal or remedial action objectives (e.g., dredging or excavation, in-situ capping, in-situ treatment, monitored natural recovery) should be evaluated prior to selecting the remedy."[16]

It is particularly important to consider MNR at the Site, because its advantages provide a meaningful contrast to the extensive and expensive remedies Region 2 evaluates in more detail in the FFS. Indeed, EPA guidance has recognized that "the two key advantages of MNR are its relatively low implementation cost and its non-invasive nature."[17] When selecting between alternatives, EPA is required to evaluate cost-effectiveness in a manner that addresses the proportionality of

---

[10] FFS at Table 3-2 (emphasis added).
[11] EPA, Contaminated Sediment Remediation Guidance for Hazardous Waste Sites 2-22 (Dec. 2005) (hereinafter "Sediment Guidance"), *available at* http://www.epa.gov/superfund/health/conmedia/sediment/pdfs/guidance.pdf.
[12] FFS at 4-12.
[13] *Id.* at Table 5-4.
[14] *Id.* at Table 3-2.
[15] *Id.*
[16] Sediment Principles at 7.
[17] Sediment Guidance at iii.

alternatives' overall effectiveness in relation to cost; the NCP states that "[a] remedy shall be cost-effective if its costs are proportional to its overall effectiveness."[18] This inquiry is intended to extend between alternatives in order to arrive at a preferred remedy that is a reasonable value. By improperly screening out MNR as a stand-alone remedy, Region 2 has not evaluated whether its preferred alternative is a reasonable value in light of the effectiveness and cost of MNR as a stand-alone remedy at the Site. As described above, though MNR many take more time to achieve the desired results than an active remedy, it would do so at a cost Region 2 admits is "relatively low." Comparing the additional length of time it would take for MNR to achieve results at the Site to the cost-savings of that approach when compared to active remedies is the exact analysis of trade-offs that the NCP is designed to facilitate. Region 2's failure to engage in that question in its FFS renders it inconsistent with the NCP.

If many sediment remedies (even no further action) can result in achievement of remediation goals over time, the decision maker needs to balance the cost of different alternative remedies against the time it will take to achieve such goals. As there are no hard and fast rules governing the timing to achieve remediation goals, it becomes a judgment of the decision maker to decide how much money is too much to reduce the time it takes to meet remediation goals.

The issue to be considered is whether it is good public policy to require the expenditure of huge amounts of dollars for the deep dredging or bank-to-bank dredging and capping remedies to achieve remediation goals if it takes "x" years, when perhaps a much less costly MNR or EMNR remedy will only take "y" years longer? EPA has expressly stated that grossly excessive costs in comparison to benefits are sufficient reason to screen out an alternative as not implementable, although there is no evidence that Region 2 gave this important reality any consideration:

> Screening is to be performed to eliminate from further consideration those alternatives that are not effective, not implementable, <u>or whose costs are grossly excessive for the effectiveness they provide. This last category would include those situations where cost is so excessive that a remedy is virtually unimplementable</u> and is, therefore, impractical to consider.[19]

Further, Region 2 is required to "examine incremental cost differences in relation to incremental differences in effectiveness."[20] Again, this issue was neglected by Region 2.

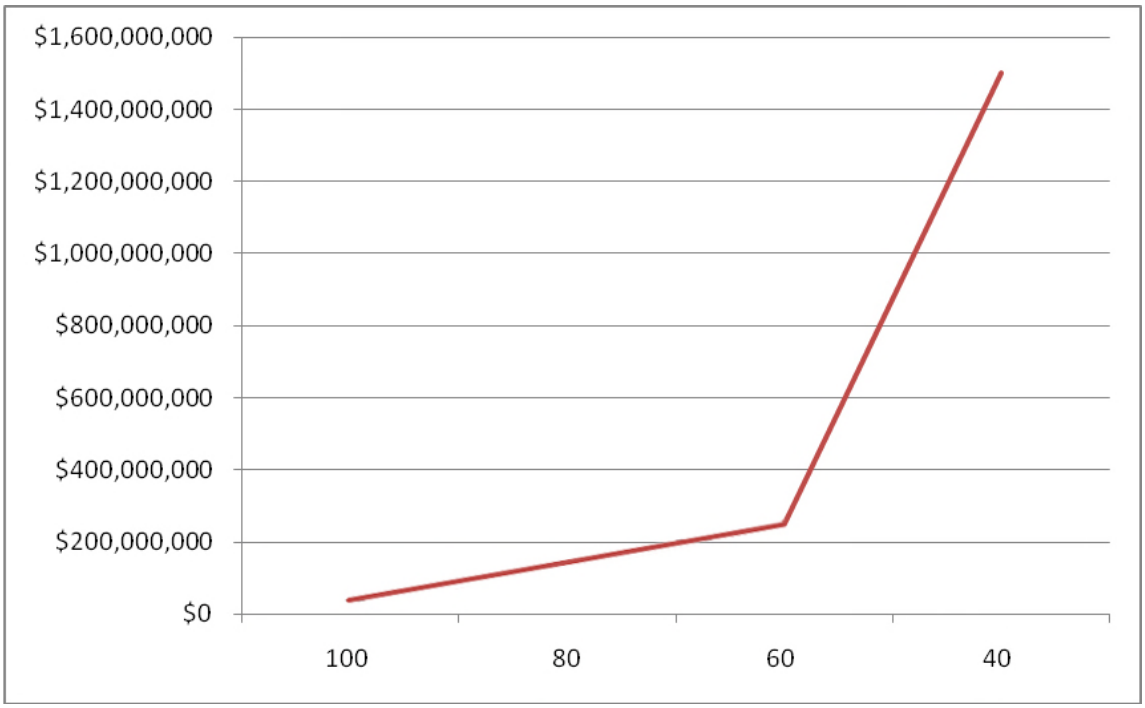
Below please find a **<u>hypothetical</u>** example of a type of analysis that would be useful to explore in a Feasibility Study for such a large remedy.

---

[18] 40 C.F.R. § 300.430(f)(1)(ii)(D).
[19] 55 Fed. Reg. 8714-15 (emphasis added).
[20] *Id.* at 8728.

Since there are no hard and fast rules governing the timing to achieve remediation goals, it becomes the reasoned judgment of the Superfund remedy decision maker in deciding the cost effectiveness of spending substantially more money in the hope of reducing the time to achieve remediation goals by x years.

The following chart illustrates this concept:



The x - axis depicts years to reach remediation goals. The Y axis is remedy cost beyond MNA cost. The $0 line is the MNA remedy. One can see that one will spend $250M more than MNA costs to shorten achievement of compliance 40 years (100-60 years), but must spend $1.25 Billion to shorten compliance achievement by another 20 years (60-40 years).

This type of analysis is crucial to sound decision-making for a complex, expensive and multi-year remedy.

Thomas C. Voltaggio

Chemical Engineer
Voltaggio Consulting, LLC
1529 Chalet Drive
Cherry Hill, NJ 08003
Phone: 856/745-1488 Fax: 856/673-0243
tom@voltaggioconsulting.com

PROFILE

Thirty five years of comprehensive experience in multiple aspects of environmental management at the federal level, including executive level leadership, scientific and technical management, budgeting and analysis, enforcement and compliance, biological and chemical environmental emergency response, hazardous waste site cleanup, homeland security terrorism response processes and operations and information management and technology. Seven years as principal and sole member of an independent consulting company with diverse clients, specializing in hazardous waste cleanup.

EDUCATION

Texas Christian University, Fort Worth	Management Science	M.Sc.	1971
City College of New York, NY	Chemical Engineering	B.S.	1968

ACHIEVEMENT SUMMARY

From its inception, and for more than 17 years, successfully directed the Superfund hazardous waste site cleanup program of the USEPA in the Middle Atlantic States through more than 500 complete cleanups by 1997. During this time, became a national expert and participated in legislative and regulatory development and national program planning.

Brought about dozens of resolutions of complex environmental issues in hazardous waste cleanup, air, and water fields with major corporations, state, local and federal governments through the use of detailed and profound knowledge of environmental programs and a well-developed skill in “getting to yes” environmental dispute resolution.

Member as gubernatorial appointee of New Jersey Tidelands Resource Council since 2008.

Most Recent EPA Experience:

- Acting Regional Administrator – 1/2001-7/2001
- Deputy Regional Administrator – 7/1998 - 1/2001; 7/2001-1/2006
- Director, Hazardous Waste Management Division – 1/1991-6/1998
- Chief, Superfund Branch – 2/1981-12/1990

CHRONOLOGICAL EPA CAREER HIGHLIGHTS

Joined USEPA in Region VI (Dallas) in 1971 and in 1973 relocated to EPA Region V (Chicago). In 1977, relocated to EPA Region III (Philadelphia).

In 1983 became responsible for implementation of the Superfund Remedial Program, including all Superfund remedial site identification, assessment, investigation design and cleanup. Beginning in 1984, responsible for all Superfund response activities including emergency and remedial response. With the addition of the emergency response activities, also responsible for overseeing all fund lead response actions in Region III. In 1989, assumed responsibility for entire Superfund Program, including all enforcement activities. With the addition of Superfund enforcement activities came responsibility for all programmatic facets of the Superfund program, including fund lead response, cost recovery, PRP searches and enforcement actions under Superfund. From 1991 to mid-1998 served as Director of the Hazardous Waste Management Division, responsible for all aspects of the Superfund, Resource Conservation and Recovery (RCRA), and Underground Storage Tank (UST) programs. With the addition of RCRA program responsibilities, directed all programmatic aspects of hazardous waste management

and remediation programs, supervising over 300 people, approximately 1/3 of the Region III office positions.

In July of 1998, became the Deputy Regional Administrator of EPA Region III. As the highest career executive, managed an annual budget of approximately $700M and directed a staff of 900+ technical, administrative and legal employees in the regional office to implement all federal environmental programs in the Middle Atlantic States. Major program responsibility included air, water, hazardous waste, enforcement, monitoring and inspections, budgeting finances and management, state relations and HQ coordination. From January through July of 2001, served as Acting Regional Administrator and reported directly to the Administrator of EPA in managing the Middle Atlantic regional office during the Presidential transition after the 2000 elections. Directed all regional operations and represented the administration in all public venues.

As a result of this experience, was called upon numerous times to consult with EPA Headquarters national program managers in national policy development and implementation. Utilized knowledge and experience of hazardous waste cleanup programs to provide assistance to foreign governments in the development of their hazardous site cleanup and Brownfields programs. These consultations started in 1986 and have continued throughout the period. The countries assisted include Italy, Hungary, Poland, Czech Republic, India, Japan, Taiwan, South Africa and China. In 1988, spent two months in Italy developing an environmental waste cleanup program for the Italian government. Over several years in the mid-1990's, assisted the Czech government in developing a risk assessment and an alternatives analysis for the reclamation of an abandoned steel mill site. Provided other waste site reclamation consultations for the Hungarian and South African governments as described below. In August 2001, resumed duties as Deputy Regional Administrator until retirement from EPA in January of 2006 after 34 ½ years of EPA service.

CONSULTING CAREER

In January of 2006, formed a single-person consulting firm and have assisted several dozen clients achieve solutions to environmental and homeland security problems.

SELECTED PRESENTATIONS

- Risk Management Strategies Used in Cleanup of Hazardous Waste Sites. James M. Seif and **Thomas C. Voltaggio**, March 1988. Presented in Philadelphia.
- The Ashland Oil Spill of January, 1988 - An EPA Perspective. Stanley L. Laskowski and **Thomas C. Voltaggio**, September 1988. Presented in Amsterdam, Holland, Washington DC, and San Antonio.
- A Model for the Development of an Abandoned Hazardous Waste Site Cleanup Program for the Republic of Italy. **Thomas C. Voltaggio** (1988). Presented in several venues in Italy between 1990 and 1993.
- The American Experience in Soil Contamination and Remediation – USEPA's Superfund Program. **Thomas C. Voltaggio**. Presented in numerous venues in Italy between 1990-2003.
- USEPA Cleanup of the Capitol Hill Anthrax Site. **Thomas C. Voltaggio** (2002). Presented at numerous national and international venues, from 2002 to the present.