DRAFT REMEDIAL ALTERNATIVES MEMORANDUM
SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

U.S. Environmental Protection Agency, Region 6

On behalf of

McGinnes Industrial Maintenance Corporation

International Paper Company

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

January 2012

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Appendix A Draft Dioxin Treatability Study Literature Review

LIST OF ACRONYMS AND ABBREVIATIONS

^{137}Cs	cesium-137
^{210}Pb	lead-210
AC	activated carbon
ADCP	acoustic doppler current profiler
Anchor QEA	Anchor QEA, LLC
APEG/KPEG	Modified Alkaline/Potassium Polyethylene Glycolate
ARAR	Applicable or Relevant and Appropriate Requirement
BCD	Base-Catalyzed Decomposition
bgs	below ground surface
BMP	best management practice
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm/yr	centimeters per year
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
CWA	Coastal Water Authority
cy	cubic yard
DDT	dichloro-diphenyl-trichloroethane
EMNR	Enhanced Monitored Natural Recovery
FS	Feasibility Study
GLO	General Land Office
GPS	global positioning system
GRA	General Response Action
HGAC	Houston-Galveston Area Council
HSC	Houston Ship Channel
I-10	Interstate Highway 10
Integral	Integral Consulting Inc.

IPC	International Paper Company
IPTD	In-Pile Thermal Desorption
LiDAR	light detection and ranging
LLDPE	linear low density polyethylene
MHHW	mean higher high water
MHW	mean high water
MIMC	McGinnes Industrial Maintenance Corporation
MLLW	mean lower low water
MLW	mean low water
MNR	Monitored Natural Recovery
MSL	mean sea level
MTL	mean tide level
NAVD88	North American Vertical Datum of 1988
NAV	navigation
NCP	National Contingency Plan
ng/kg	nanograms per kilogram
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NS	nearshore
NSR	net sedimentation rate
O&M	operations and maintenance
OCDD	octachlorodibenzo-p-dioxin
OMMP	Operations, Monitoring, and Maintenance Plan
ounce	oz
OW	open-water
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
pg/g	picograms per gram
pg/L	picograms per liter
PIC	product of incomplete combustion
PHA	Port of Houston Authority

POTW	publically owned treatment works
ppt	parts per trillion
PRG	preliminary remediation goal
PSCR	Preliminary Site Characterization Report
RACR	Removal Action Completion Report
RAL	remedial action level
RAM	Remedial Alternatives Memorandum
RAO	Remedial Action Objective
RDF	Regional Disposal Facility
REV	reference envelope value
RG	remediation goal
RI/FS	Remedial Investigation/Feasibility Study
River	San Jacinto River
ROD	Record of Decision
ROW	right-of-way
S/S	solidification/stabilization
SAP	Sampling and Analysis Plan
SET	Solvated Electron Technology™
Site	San Jacinto River Waste Pits Superfund Site
SJRF	San Jacinto River Fleet, LLC
SJRWP	San Jacinto River Waste Pits
SMA	sediment management area
SVOC	semivolatile organic compound
SWAC	Surface Weighted Average Concentration
sy	square yards
T½	half-life
TBC	to be considered
TCDF	2,3,7,8-tetrachlorodibenzofuran
TCEQ	Texas Commission for Environmental Quality
TCRA	time critical removal action
TDSHS	Texas Department of State Health Services
TEF	toxicity equivalency factor
TEQ	toxicity equivalent

TEQ_{DF}	TEQ concentration calculated using only dioxin and furan congeners
TMDL	total maximum daily load
T_{MZ}	mixing-zone layer thickness
TSS	total suspended solids
TxDOT	Texas Department of Transportation
UAO	Unilateral Administrative Order
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1 INTRODUCTION

This Draft Remedial Alternatives Memorandum (RAM) was prepared as part of a Remedial Investigation/Feasibility Study (RI/FS) for the San Jacinto River Waste Pits (SJRWP) Superfund Site (Site) in Harris County, Texas (Figure 1-1). The RAM was prepared on behalf of International Paper Company (IPC) and McGinnes Industrial Maintenance Corporation (MIMC) (collectively referred to as the Respondents for the Site). This document develops and screens an appropriate range of preliminary remedial alternatives for the SJRWP Site in relation to Remedial Action Objectives (RAOs), and results will be carried forward for further consideration in the Site Feasibility Study (FS). It should be noted that the Baseline Ecological and Human Health Risk Assessments for the Site are ongoing; the results of those assessments will play an important role in determining the final range of remedial alternatives in the FS.

1.1 Background and Regulatory Framework

On March 19, 2008, the U.S. Environmental Protection Agency (USEPA) listed the Site on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. On November 20, 2009, USEPA issued a Unilateral Administrative Order (UAO), Docket No. 06-03-10, to IPC and MIMC (USEPA 2009a). The 2009 UAO directs IPC and MIMC to conduct an RI/FS for the Site. The UAO describes in its findings of fact a basic history of the Site, but it addresses only the impoundments that are located on the north side of Interstate Highway 10 (I-10). USEPA has subsequently required investigation of soil in an area to the south of I-10, citing historical documents indicating possible waste disposal activities in that area.

This memorandum satisfies the requirement in the Statement of Work in the UAO for the RI/FS to submit a draft RAM following receipt of USEPA approval of the draft Preliminary Site Characterization Report (PSCR)[1] (Integral Consulting Inc. [Integral] and Anchor QEA, LLC [Anchor QEA] 2011a).

[1] USEPA provided conditional approval of the draft PSCR on December 9, 2011. The final is in preparation at the time of this submittal, and will be completed in February 2012.

The RI/FS will ultimately lead to a proposed remedial action plan for the Site. The remedial action plan will be incorporated into a USEPA Record of Decision (ROD) that outlines cleanup actions to address threats to human health and the environment at the Site.

1.2 Time Critical Removal Action

A time critical removal action (TCRA) was implemented, under an Administrative Settlement Agreement and Order on Consent for Removal Action: CERCLA Docket No. 06-12-10, to stabilize pulp waste and sediments within the original 1966 perimeter berm of the impoundments north of I-10 to prevent the release of dioxins and furans and other chemicals of potential concern (COPCs) to the environment (Anchor QEA 2010; Anchor QEA 2011b).

1.2.1 Time Critical Removal Action Components

The area within the original 1966 perimeter was separated into three distinct areas: 1) the Eastern Cell, 2) the Western Cell, and 3) the Northwestern Area (Figure 1-2). In general, the TCRA design included an armor rock cap placed atop a geotextile bedding layer in all but the Northwestern Area. Additionally, the Western Cell received a geomembrane cover layer prior to armor rock installation.

Four different armor rock gradations were specified for the cap material. The armor cap layout is provided in Figure 1-2. Each of the armor rock types and minimum thicknesses are provided in Table 1-1, along with the final in-place quantities for each type.

Table 1-1
TCRA Armor Cap Rock Components

Material	Stone Size D_{50} (inches)	Minimum Thickness (inches)	Installed Quantity (tons)
Armor Cap A	3	12	13,500
Armor Cap B/C	6	12	11,300
Armor Cap C	6	12	10,100
Armor Cap D, D_{24}	8	18, 24	23,900
		Total:	58,800

Notes: All quantities have been rounded to the nearest 100 tons.

Both land- and water-based equipment were used to complete the TCRA construction. Land-based construction equipment included long-reach excavators, dozers, and front-end loaders. Water-based construction operations occurred via barge. A long-reach excavator was mounted on a material placement barge and was used to install armor cap materials directly atop the deployed geotextile layer. The water-based geotextile as-built drawing is provided in Figure 1-3.

Prior to geotextile, geomembrane, and armor rock installation in the Western Cell, the low-lying areas were stabilized using an 8 percent by weight Portland cement admixture. A total of 430 tons of Portland cement were used to complete the stabilization. The surface was then graded and received three geosynthetic layers: 12-ounce (oz) geotextile; 40-millimeter linear low density polyethylene (LLDPE) geomembrane; and 16-oz geotextile. The Western Cell geotextile and geomembrane as-built drawing is provided in Figure 1-4. The total quantities of geotextile and geomembrane installed during the TCRA are 79,000 square yards (sy) and 15,400 sy, respectively.

A full description of the TCRA implementation is provided in the Draft Removal Action Completion Report (RACR) (Anchor QEA 2011b).

1.3 Objectives of the Remedial Alternatives Memorandum

The objectives of the RAM are:

- Identify and screen remedial alternatives and related technologies that may be applicable to the Site.
- Develop preliminary RAOs for the Site.
- Identify and screen potential disposal alternatives for removed contaminated sediment and eliminate disposal process options that are not practical to implement.
- Identify and screen remedial technologies (such as monitored natural recovery, sediment containment, or sediment treatment) to eliminate candidate remedial technologies that cannot be implemented or that may be limited in their applicability due to technical or other constraints at the Site.

- Following the screening to narrow the range of remedial technologies, assemble the retained technologies into potential remedial alternatives to be considered (TBC) for detailed analysis in the FS.

The preliminary RAOs to be developed for the Site are narrative statements that are medium- or area-specific goals for protecting human health and the environment (USEPA 1988). The RAOs address the primary exposure pathways, receptors, and risk drivers, based on the current understanding of the Site. The RAOs also describe in general terms what the sediment cleanup will accomplish for the Site, help focus the development of remedial alternatives, and form the basis for establishing preliminary remediation goals (PRGs).

The purpose of screening remedial technologies, screening disposal sites, and developing preliminary RAOs is to efficiently eliminate remedial technologies, disposal options, and alternatives that are not practicable so the FS can focus on viable remedial alternatives. This approach is consistent with USEPA RI/FS guidance (USEPA 1988) and contaminated sediment remediation guidance (USEPA 2005). Site-specific conditions at the SJRWP and existing and future uses of the San Jacinto River (River) may limit the remedial alternatives that are feasible, and this preliminary evaluation will factor Site-specific conditions into the evaluation of potential remedial alternatives and disposal sites.

After completion of the preliminary screening of technologies by this RAM, a detailed evaluation of the retained technologies will occur as part of the FS Report. The FS will refine potential remedial alternatives as necessary, analyze the alternatives against CERCLA evaluation criteria, and compare the alternatives against one another.

1.4 Remedial Alternatives Memorandum Assumptions

The following assumptions apply to the preliminary screening of remedial alternatives for the Site conducted as part of this RAM:

- Dioxins and furans is the indicator chemical group, and are the primary COPCs; the primary exposure pathway that is amenable to remediation of this indicator chemical group is direct or indirect contact with sediments and associated floodplain soils within USEPA's preliminary Site perimeter on the River. This indicator chemical

group is appropriate because the concentrations of dioxins and furans relative to risk-based screening values are high in sediments from the Site. The degree to which they exceed risk-based screening levels in source materials at the Site relative to that of other COPCs is also high, indicating that they are likely to be the most important risk driver at the Site (Anchor QEA and Integral 2010). For these reasons, dioxins and furans are the chemicals most relevant to the preliminary screening of remedial alternatives and are, therefore, the focus of this document.

- Potential remedial areas were developed using dioxins and furans as an appropriate indicator chemical group for the RI/FS.
- The preliminary screening relies on the current understanding of physical conditions that affect sediment stability and the distribution of surface and subsurface sediment contamination. The baseline dataset, upon which this understanding is based, is identified and described in the PSCR (Integral and Anchor QEA 2011a) and the draft Exposure Assessment Memorandum (Integral 2012).
- The data collection phase of the remedial investigation for the impoundments north of I-10 is largely complete. Although one additional study is anticipated for the northern impoundments (i.e., to evaluate the effectiveness of the TCRA cap), the CSM for the northern impoundment and surrounding aquatic environment is sufficiently well developed to perform the screening of alternatives. In contrast, additional data collection to describe the nature and extent of contamination in the vicinity of the impoundment south of I-10 is ongoing. As a result, the CSM for the south impoundment is not as well developed. Because of existing uncertainties and data gaps relating to the southern impoundment, and in the context of the existing information for that area (addressed further in Section 4.3), both the preliminary RAOs, and the screening of remedial alternatives for that area are not as extensively developed in this document for the south impoundment.
- Cleanup levels for dioxins and furans, remedial action levels (RALs), and sediment management areas (SMAs) have not yet been defined. Baseline risk assessments have not yet been submitted to USEPA nor finalized. Although preliminary RAOs are described in this RAM, they will be refined and finalized in the FS report. This document uses a “knee of the curve” analysis (Section 3) using prospective SMA boundaries as a surrogate for RALs to identify potential remedial areas. This approach provides a consistent basis for developing and evaluating conceptual remedial action

alternatives independent of the final cleanup decisions. Appropriate RALs and final SMAs for dioxins and furans will be addressed in the FS report.

The assumptions identified above are necessary to perform the screening described in this RAM. Although the remedial footprint, which will be developed in the FS, is not available at this time, it is not anticipated that decisions to eliminate certain disposal technologies, remedial technologies, and remedial alternatives evaluated in this RAM will need to be revisited during the FS.

1.5 Document Organization

This remainder of the RAM includes the following major sections:

- Section 2 describes the Site characteristics and conceptual site model that form the basis of the evaluation for screening remedial alternatives.
- Section 3 presents preliminary RAOs, and describes the basis for remedial action, including development of remedial action levels and Applicable or Relevant and Appropriate Requirements (ARARs).
- Section 4 identifies and screens remedial and disposal technologies.
- Section 5 identifies and screens Site-specific remedial alternatives.
- Section 6 provides the conclusions and recommendations of this RAM.
- Section 7 provides a list of references.
- Appendix A – Draft Dioxin Treatability Study Literature Review.

2 BASIS FOR THE EVALUATION

This section provides descriptions of the physical and chemical characteristics of the Site as determined during the Site remedial investigation studies completed to date. Particular attention is given to physical features within USEPA's preliminary Site perimeter that may affect the choice of remedial alternatives that can be considered across the Site.

2.1.1 Physical Description of the Site

The "Site", as defined above in Section 1, includes the area within the preliminary Site perimeter, or RI/FS Site perimeter, established by the USEPA and shown on Figure 2-1. Important features within and adjacent to the Site are displayed on Figure 2-1. The I-10 Bridge transects the USEPA's preliminary Site perimeter, defining northern and southern areas of the Site. The peninsula south of the I-10 Bridge is utilized by several businesses for marine construction and maintenance activities. The peninsula south of I-10 is the location of another former waste impoundment (the South Impoundment); further discussion of the upland soil conditions in the South Impoundment is provided in Section 2.3.3.3. The peninsula is bordered by two adjacent waterways: 1) Old River to the west, and 2) the San Jacinto River to the east. Both continue south and join the Houston Ship Channel (HSC). North of the I-10 Bridge, the River continues to Lake Houston dam.

The waste impoundments stabilized by the TCRA are located within the northern portion of the Site. To the west of the TCRA Site is the San Jacinto River Fleet, LLC (SJRF) operations location. On the western bank of the River beyond the Site perimeter to the north is the off-site TCRA equipment mobilization area (LaBarge Property).

2.1.2 Bathymetry and Topography

The bathymetry and topography of the Site were developed using data from the following sources:

- Bathymetry
  - National Oceanic and Atmospheric Administration (NOAA) nautical charts (electronic bathymetry data [NOAA 1995])

  - Multi-beam bathymetry data collected in the vicinity of waste impoundments during 2008
  - Single-beam bathymetry data collected along transects upstream and downstream of the study area during 2011
  - Baseline bathymetric survey collected in 2011 as part of the TCRA Operations, Monitoring, and Maintenance Plan (OMMP)
- Topography
  - Houston-Galveston Area Council (HGAC) light detection and ranging (LiDAR) dataset from 2008
- Baseline topographic survey collected in 2011 as part of the TCRA OMMP

2.1.2.1 Navigation and Berthing Elevations

Water depths at the Site range from relatively shallow in intertidal areas (2 feet or less) to relatively deep in the main channel of the River (about 30 feet); see Figure 2-2. Depths in Figure 2-2 are referenced to the North American Vertical Datum of 1988 (NAVD88). Berthing areas at the shipyard located on the southern peninsula range from -15 feet NAVD88 to -5 feet NAVD88. Areas identified as "barge mooring" locations on the NOAA National Ocean Service (NOS) nautical chart (NOS Nautical Chart 11329, Figure 2-3) in the Old River display the same variability in depth; however, the mooring location on the northeastern side of the Old River tends to be more shallow based on the recent bathymetric data shown on Figure 2-2. According to the source data on Chart 11329 the depth soundings are from partial bottom coverage NOS surveys from 1990 to 1996. As a result, depth soundings on the northern portion of the Site on Chart 11329 (referenced to the mean lower low water [MLLW] datum[2]) do not reflect water depths associated with dredging that occurred between the TCRA Site and the SJRF area in the late 1990s through 2002. The deeper water areas that currently exist in this area are properly shown by the more recent data on Figure 2-2.

[2] Based on the NOAA Tides and Currents gauge at Battleship Texas State Park, the conversion from MLLW to NAVD88 is -0.05 feet; therefore, general comparisons of channel bathymetry between these two sources are possible.

There is no federally authorized navigation channel in either the River or Old River; however, both support a variety of shallow-draft marine commerce. For purposes of this RAM, elevations of -12 feet NAVD88 and deeper were selected to define the limits of active navigation areas based on the draft requirements of vessels and barges typically operating in the Site area.

2.1.2.2 Upland Topography

The LiDAR data from the HGAC were used to generate a high-resolution digital elevation model of the upland area of the Site (Figure 2-4). This is the most recent LiDAR survey available and provides 5-foot horizontal pixel resolution with 0.22-foot vertical resolution.

The highest ground surface elevations on the Site are associated with the elevated areas beneath and adjacent to the I-10 corridor. Ground surface elevations of the peninsula area south of I-10 range from 0 feet mean sea level (MSL) at the shoreline, to nearly 13 feet above MSL. Ground surface elevations of the area north of I-10 range from 0 feet MSL at the shoreline, to approximately 11 feet above MSL. Linear drainage ditches are apparent in several areas – these appear to be primarily associated with roadways. Figure 2-4 does not include the recent changes in topography resulting from the implementation of the TCRA. The TCRA OMMP baseline survey (Figure 2-5), performed in September 2011, provides the most recent elevation data for the TCRA Site and its surrounding area. The baseline survey indicates that the upland area stabilized by the TCRA varies from +10 feet NAVD88[3] along the crest of the central berm to 0 feet NAVD88 along the western border of the impoundments (Figure 2-5).

2.1.3 Sediment Characteristics

Four distinct types of sediment particles are found in varying proportions in the sediment bed at the Site: 1) clay (particle diameter less than 2 microns), 2) silt (particle diameter 2 to 62 microns), 3) sand (particle diameter 62 to 2,000 microns), and 4) gravel (particle diameter

[3] Based on the NOAA Tides and Currents gauge at Battleship Texas State Park, the conversion from MSL to NAVD88 is -0.86 foot; therefore, general comparisons of upland topography between these two sources are possible.

greater than 2,000 microns). The range of organic carbon in sediments is correlated with grain size, and varies between the TCRA Site and areas outside of the TCRA Site. For sediment samples that are predominantly silt and clay sized, the organic content ranges from approximately 1 to 2 percent. For samples with very little silt and clay, the average organic content is approximately 0.1 percent. In addition, the sediment bed may be separated into two distinct categories (or bed types): 1) non-cohesive, and 2) cohesive. A non-cohesive bed is primarily composed of sand and gravel, with relatively small amounts of clay and silt. Non-cohesive (sandy) bed areas are usually found in locations with relatively high hydrodynamic energy, such as the main channel of the River. A cohesive bed is primarily composed of clay, silt, and fine sand (very fine to fine sand particle diameter range is 62 to 250 microns), with relatively small amounts of coarse sand and gravel. Cohesive (muddy) bed areas generally occur in locations with relatively low hydrodynamic energy, such as shallower areas that are adjacent to the main channel.

2.2 Waterway Uses

The River is utilized on a daily basis by both commercial and recreational vessel traffic. Various commercial industries exist throughout the area and depend on the River for transport and receipt of cargo. Additionally, both permitted facilities and the local stormwater infrastructure direct outfalls into the area upstream of the Site for industrial and stormwater run-off, respectively. The following sections discuss the waterway uses identified for the Site.

2.2.1 Navigation

Navigation conditions in the Site are displayed on the NOAA NOS Chart 11329[4] (Figure 2-3). Areas outside of the prescribed channel are generally very shallow; some regions of the waterway are marked as “Foul Areas”, which indicates “an area of numerous unidentified dangers to navigation which are not individually located” (IHB 1996). Additionally, as displayed on the chart, an area approximately 1 mile north of the I-10 Bridge in the River channel is identified as having an obstruction that may affect watercraft traversing the area. One aid for navigation is located in the channel near the southern perimeter of the Site; the

[4] Digital, georeferenced navigation charts are available from: http://www.charts.noaa.gov/.

navigation chart designates it is as a general nun-type buoy that is placed on the starboard side of the channel to direct vessel traffic entering from the HSC.

As described in Section 2.1.2, there are three sections of the waterway designated for barge mooring areas within the southern portion of the preliminary Site perimeter. A review of the bathymetry, described in Section 2.1.2 and displayed in Figure 2-2, indicates that the depth in these barge mooring areas is shallower than in the channel but is not prohibitive to vessel access. The SJRF property shown on Figure 2-1 also supports barge fleeting operations. Barge fleeting and mooring areas extend from the SJRF property to the navigation channel north of the small islands, located approximately one-third mile north of the TCRA Site.

The I-10 Bridge, which is a fixed structure not equipped for rotation or lifting of the bridge deck (i.e., a drawbridge), crosses the River at one of the narrowest portions of the waterway within the Site. The clearances for vessels passing under the Bridge are 166 feet in the horizontal direction and 22 feet in the vertical direction at high tide. The vertical clearance limits the size of the vessels that are capable of passing under the Bridge. Additionally, an area near the waste impoundment area, parallel to the I-10 Bridge, is designated as a pipeline area on Figure 2-3. Drawings received from the ExxonMobil Pipeline Company indicate that two pipe bundles transect the River channel within this boundary. One bundle consists of three pipes: 1) 8-inch liquefied petroleum gas, 2) 10-inch products pipeline, and 3) 20-inch crude pipeline. The second bundle has identically sized pipes, with the 10- and 20-inch pipelines listed as spare. Both pipeline bundles cross the River underground well below the existing River bottom, with estimated depths of 55 and 93 feet below the channel bottom based on these drawings.

2.2.2 Adjacent Facilities and Infrastructure

A combination of residential, commercial, industrial, and other land uses occurs adjacent to the River within the Site, in the surrounding areas, and upstream (Figure 2-6). Generally, development is more intense near the River and HSC to the south. The majority of residential land use within 0.5 miles of the Site is on the eastern bank of the River, although

some residential properties occur within 0.5 miles west of the Site (TDSHS 2011). Several industrial facilities are present upstream of the Site, adjacent to the River.

2.2.3 Existing Structures

Existing structures within the preliminary Site perimeter have supported various industrial and commercial activities. A boat slip with a concrete slab dock and sheet pile bulkhead is located on the current SJRF property (shown on Figure 2-1) in the northern portion of the Site; photos of the structure are provided in Figure 2-7.

Currently, the peninsula on the southern side of I-10 is utilized by a barge towing company, a shipbuilding company, and an active shipyard, all of which have developed structures, including bulkheads, piers, wharves, boat slips and other shoreline structures to support their operations. The shipyard and shipbuilding facilities include: cranes, storage tanks, warehouse space, and docking facilities, which are utilized for vessel dry docking and restoration. Additionally, there is a marine facility at the southern end of the peninsula, which supports barge transport operations.

Facilities outside of, but adjacent to the Site on the eastern side of the River, include two tanks owned by a packaging, blending, and distributions company on a parcel of land north of the I-10 Bridge. Two recycling companies also operate from the eastern bank of the River north of I-10. It is not known how much vessel traffic is generated by either company; however, said traffic must pass through the Site to access the HSC. Portions of the shoreline at these facilities are protected with riprap or bulkhead (Figure 2-8).

Several facilities with discharge permits are located on lands upstream and downstream of the Site. Permitted facilities discharge to water quality segment 1001, which extends upstream from the Site to a point just south of Lake Houston. These facilities are part of the National Pollution Discharge Elimination System (NPDES), which assigns effluent limitations for a variety of chemical constituents but does not address dioxins and furans. Those for which sludge or effluent sampling was performed by the Texas Commission for Environmental Quality (TCEQ) HSC total maximum daily load (TMDL) project to determine

if dioxins and furans are associated with in sludges or effluents at those facilities are listed in Table 2-1. The facility locations and TMDL sampling locations are provided in Figure 2-9.

Table 2-1

NPDES-Permitted Facilities Upstream of the Site

	Facility Name	NPDES Permit ID	Notes	A Sludge or Effluent Sample was Collected and Dioxins and Furans Were Found
1	NEWPORT MUD WWTP	TX0023230	Upstream Permitted Discharger	X
2	EQUISTAR CHANNELVIEW COMPLEX	TX0003531	Upstream Permitted Discharger	X
3	LYONDELL CHEMICAL CHANNELVIEW	TX0069493	Upstream Permitted Discharger	X
4	HARRIS COUNTY WCID NO. 1 WWTP	TX0023311	Upstream Permitted Discharger	X
5	BAYTOWN WEST 1	TX0072834	On-Site Permitted Discharger	X

In addition to the NPDES-permitted facilities upstream and downstream of the Site, the Site includes elements of a stormwater network that conveys run-off to permitted wastewater outfalls in the River (Figure 2-10), and additional NPDES-permitted outfalls. One of these, the Baytown West 1 location, has also been sampled for the TMDL program, confirming the presence of dioxins and furans in effluent from this outfall. In total, there are seven permitted outfalls on the Site, and at least one stormwater conveyance system that leads to the waters of the Site. These facilities and permitted outfalls are discussed in Section 2.2.3 of the RI/FS Work Plan (Anchor QEA and Integral 2010) and Section 3.5.1 of the PSCR (Integral and Anchor QEA 2011a), respectively.

2.2.4 Aquatic Land Ownership

Aquatic lands of Texas are permanently reserved to the state and encompass those areas of submerged coastline and River and lake bottoms of navigable waterways (Lang and Haigh 2011). Specifically, state ownership is inclusive of all lands ranging from mean high water (MHW) to three marine leagues (MCA 2011). The Texas General Land Office (GLO) owns and manages the tracts of state submerged lands, including lands leased for oil and gas exploration. The GLO maintains a database of all the surveyed submerged lands in the offshore and coastal inland waters of Texas. All of the lands for which they retain records are state owned and can be leased through the GLO. Figure 2-11 displays the submerged lands data publically available through the GLO website[5]. The Site intersects three separate tracts of land. Tracts 15 and 16 represent the areas of the River on the south and north sides of the I-10, respectively. The other tract (Tract A) is part of Old River and is on the western side of the Site, south of I-10. Additionally, Figure 2-11 displays all lands in the vicinity of the Site that are currently leased for oil and gas exploration. None of the lands in close proximity to the Site have been leased for these purposes.

In addition to the GLO, the role and authority of the Port of Houston has a significant impact on the acquisition of submerged lands in Harris County. Beginning in 1922, the Port Authority took the lead on both the operations and maintenance (O&M) of the Port's facilities and work relating to the navigation channel, and in 1927, the state of Texas transferred ownership of "…all submerged lands lying and being situated under the waters of … [list of bayous and rivers] … and all other streams within Harris County Navigation District tributary to the HSC, so far up said streams as the State may own the same…" to the Port Authority (PHA 2011). By 1958, the Port's role had become more defined. It now operates as a navigation district whose boundaries are coterminous with Harris County, and operations are defined under Article XVI, Section 59 of the Texas Constitution, pursuant to Chapter 117, Acts of the 55th Legislature, Regular Session, 1957, which provides power:

> *"… to acquire, purchase, construct, enlarge, extend, repair, maintain, operate or develop channels and turning basins, wharves, docks, warehouses, grain*

[5] http://www.glo.texas.gov/

> *elevators, bunkering facilities, railroads, floating plants and facilities, lightering facilities and towing facilities, bulk handling facilities, and everything appurtenant thereto, together with all other facilities or aids incident to or useful in the operation or development of the District's ports and waterways or in aid of navigation and commerce thereon"*

While there are still privately owned submerged lands along the waterway, the Port still retains its power to exercise its authority over the water bottom in Harris County as it sees fit (PHA 2011).

2.2.5 Recreational

Commercial and recreational fishing industries along the Texas coast and inland bays are common. Within the Site, despite current consumption advisories for fish and crab (discussed in Section 2.3.7.5 of the RI/FS Work Plan [Anchor QEA and Integral 2010]), fishing activity has been observed, and fishers in this area are reported to collect whatever they catch (Beauchamp 2010, personal communication). The Texas Department of State Health Services (TDSHS) has issued shellfish harvest maps[6] that designate approved or conditionally approved harvest areas. Waters within the Site are not included on these maps; however, the TDSHS prohibits the consumption of molluscan shellfish harvested from public fresh water areas (TPWD 2009).

Prior to the erection of fencing to limit access to the public for areas near the TCRA Site and areas across the River from the TCRA Site on the eastern bank of the River, fishing activities were observed under and adjacent to the I-10 Bridge. Areas south of the I-10 Bridge are industrialized and have limited access; also, the Hog Island area, located at the southeast corner of the Site (Figure 2-3), consists largely of submerged sand bars, which limits fishing activity (Beauchamp 2010, personal communication). Other points of fishing access within the Site include RV trailer parks on the east side of the River north of I-10, bridges and roadside areas on Market Street south of I-10, and Meadowbrook Park, west of the Site has residential areas on the River and a public access boat ramp.

[6] http://www.dshs.state.tx.us/seafood/classification.shtm#maps

2.2.6 Ecological Functions

The Site is located in a low gradient, tidal estuary near the confluence of the River and the HSC. The surrounding area includes Lynchburg Reservoir to the southeast and the Lost Lake sediment management area on the island in the center of the River west of Lynchburg Reservoir (Figure 2-12). Upland natural habitat adjacent to the River in the Site vicinity is generally low-lying, displaying little change in elevation, and consists primarily of clay and sand that supports loblolly pine-sweetgum, loblolly pine-shortleaf pine, water oak-elm, pecan-elm, and willow oak-blackgum forest communities along the River's banks (TSHA 2009).

Wildlife habitats on the northern portion of the Site include shallow and deep estuarine waters, and shoreline areas occupied by estuarine vegetation. A sandy intertidal zone is present along the shoreline throughout much of the Site (Figure 2-12). Minimal habitat is present in the upland terrestrial area of the Site west of the impoundments, as demolition of this former industrial area, and current operations in support of barge fleeting have created a denuded upland with a covering of crushed cement and sand. The sandy shoreline of this area has scattered riprap, other metal debris, and piles of cement fragments.

The tidal portions of the River and upper Galveston Bay provide rearing, spawning, and adult habitat for a variety of marine and estuarine fish and invertebrate species. Species known to occur in the vicinity of the Site include clams and oysters, blue crab (*Callinectes sapidus*), black drum (*Pagonius cromis*), southern flounder (*Paralichthys lethostigma*), hardhead (*Ariopsis afelis*) and blue catfish (*Ictalurus furcatus*), spotted sea trout (*Cynoscion nebulosis*), and grass shrimp (*Paleomonetes pugio*) (Gardiner et al. 2008; Usenko et al. 2009). An estimated 34 acres of estuarine and marine wetlands are found within the Site.

2.3 Nature and Extent of Contamination

This section describes the horizontal and vertical extent of paper mill waste-related contamination on the Site that will be considered in the selection of appropriate remedial technologies and strategies for the Site.

As outlined in Section 1.4, dioxins and furans are used as the indicator chemical group in surface sediment and soils, subsurface sediment and soils, and groundwater collected as part of the RI, and surface water and sediment data collected by URS Corporation (URS) (2010) for TCEQ. Although dioxins and furans are the focus of the text, tables with summary statistics and discussions presented in the PSCR (Integral and Anchor QEA 2011a) include results for other chemicals analyzed. Much of the discussions in the following sections were extracted directly, or modified, from text previously presented in the PSCR.

2.3.1 Surface Sediment Data

Surface sediment samples from 0 to 6 inches below ground surface (bgs) were collected at 145 locations. USEPA has required that sediments from three additional locations be sampled in the northern extent of the Old River, south of I-10. The related sampling plan is in review at the time this memorandum is published. Results will be included in the RI Report.

The distribution of dioxins and furans in intertidal sediment and soil samples, expressed as toxicity equivalent (TEQ) concentrations in nanograms per kilogram (ng/kg) calculated using only dioxin and furan congeners (TEQ_{DF}), is shown for the Site in Figure 2-13. Figure 2-14 shows TEQ_{DF} concentrations in surface sediment throughout the Site, and Figure 2-15 provides a detailed illustration of TEQ_{DF} concentrations at the surface of the impoundments north of I-10 prior to implementation of the TCRA, and in surface sediments surrounding the impoundments. TEQ_{DF} values in upstream background areas are shown as dry weight concentrations in Figure 2-16.

With this dataset, the extent of dioxin and furan contamination in surface soils and sediments is well defined. Dioxin and furan concentrations in surface sediments, expressed as TEQ_{DF} concentrations, are substantially higher within the 1966 perimeter of the northern impoundments than elsewhere on the Site. Within the 1966 perimeter, TEQ_{DF} concentrations in surface sediments are highest in the Western Cell (Figures 2-13 and 2-15). TEQ_{DF} concentrations in surface sediment outside of the northern impoundment are typically 3 to 4 orders of magnitude lower than within the impoundment, even in areas directly adjacent to the 1966 impoundment perimeter.

Surface sediment TEQ_{DF} concentrations upstream and downstream of the northern impoundment are lower than within the north impoundment footprint (Figures 2-13 and 2-14). The highest TEQ_{DF} concentrations in surface sediments north of I-10 and outside the north impoundment footprint (Figure 2-14) are located in the eastern side of the SJRF operations area, approximately 1,000 feet northeast of the northern impoundment. TEQ_{DF} concentrations downstream of the northern impoundment (Figure 2-14) are lowest along the eastern cutbank side of the River south of I-10; the next lowest concentrations are within the Old River to the west of the peninsula south of I-10, and thalweg portions of the River. In the sediments along the southern perimeter of the Site, surface sediment TEQ_{DF} concentrations are highest along a line running west to east, perpendicular to the southern tip of the peninsula (Figure 2-14) where surface sediment values range from 49.3 to 52.6 ng/kg.

Surface sediment TEQ_{DF} concentrations in the upstream background area (Figure 2-16) are comparable to the lowest concentrations in surface sediments on the Site. All TEQ_{DF} concentrations collected in the upstream background area in May 2010 are less than 6 ng/kg, with the highest measured TEQ_{DF} concentration in samples collected in 2010 (5.72 ng/kg dry weight), to the west of the Site. Additional sediment data from upstream were collected in October 2011 to address DQOs outlined in Addendum 1 Sediment Sampling and Analysis Plan (SAP) (Integral and Anchor QEA 2011b), and results have been included in the RI dataset. The updated dataset was provided to USEPA on January 10, 2012. The maximum TEQ_{DF} of all upstream data, including the October 2011 data, is 6.54 ng/kg dw.

2.3.2 Subsurface Sediment Data

Subsurface sediment samples are those samples collected from intervals greater than 6 inches bgs. Subsurface sediment samples were collected for chemical analysis at 22 locations (Figure 2-17), resulting in 124 subsurface sediment samples. The distribution of dioxins and furans in deep subsurface sediments, expressed as TEQ_{DF}, are shown in Figure 2-17. It should be noted that the northern impoundment was recently capped by the implementation of the TCRA, as described in Section 1.2.

The highest TEQ_{DF} concentration (31,600 ng/kg) occurs in the upper 2-foot interval of the core from Station SJGB014, the boring located in the north-central portion of the impoundment (Figure 2-17), but cores surrounding it to the north, east, and southeast show much lower concentrations at all intervals, even where they occur within the 1966 impoundment perimeter. Cores within the Western Cell tend to show higher TEQ_{DF} concentrations throughout the upper core increments. TEQ_{DF} concentrations in most cores decrease from their maximum with depth within a given core, indicating that the peak concentrations have been located in the vertical dimension. TEQ_{DF} is below 7 ng/kg in the lower most interval measured in all but three borings. The three exceptions occur in the western portion of the northern impoundment, where TEQ_{DF} concentrations within the bottom interval range from 25.2 to 17,700 ng/kg.

Subsurface sediment TEQ_{DF} concentrations in one location east of the impoundments (SJNE026) are slightly elevated relative to their surface sediment counterparts (Figures 2-14 and 2-17).

The highest subsurface sediment TEQ_{DF} concentrations north of I-10 and outside the 1966 impoundment perimeter are in a core located in the eastern side of the SJRF property, in the 3- to 4-foot bgs (349 ng/kg) and 5- to 6-foot bgs (339 ng/kg) intervals (Figure 2-17). TEQ_{DF} concentrations in sediments downstream of the northern impoundment, south of I-10 (Figure 2-17), are generally much lower than elsewhere on-site, except at the station just south of the peninsula, where the maximum subsurface TEQ_{DF} concentration (51.1 ng/kg) occurs at the 3- to 4-foot depth interval. In other sediment cores south of I-10, the maximum subsurface sediment TEQ_{DF} concentration was 7.41 ng/kg.

2.3.3 Evaluation of Vertical Extent of Contamination

2.3.3.1 Soils

For soils, summary statistics were developed in the PSCR (Integral and Anchor QEA 2011a) within four areas. These areas are shown on Figure 2-18 and are described below:

1. Area 1 is the denuded portion of the upland sand separation area, where historical aerial photographs suggest that sediment handling took place, and the area surrounding the road that provides access in and out of this upland area.

2. Area 2 is the portion of the Site beneath I-10, in the Texas Department of Transportation (TxDOT) right-of-way (ROW) that was sampled for the TCRA (Anchor QEA 2010).
3. Area 3 is the area of the impoundments north of I-10.
4. Area 4 is the area of soil investigation south of I-10.

Text and figures in this section focus on dioxins and furans. Summary statistics for other chemicals of interest in surface and subsurface soils are presented in the PSCR.

The distribution of dioxins and furans in surface and shallow subsurface soils, expressed as TEQ_{DF}, is shown in Figure 2-13 for areas north of I-10 and Figure 2-19 for the peninsula south of I-10. Figure 2-20 shows the distribution of TEQ_{DF} at depth for soils at the peninsula south of I-10.

Because the sampling designs were substantially different south of I-10 than north of I-10, the nature and extent of dioxins and furans in soils are discussed separately for these two areas. Additional data collection for the area south of I-10 is anticipated for February 2012, and the ultimate RI dataset will include results of that sampling effort.

2.3.3.2 North of I-10

2.3.3.2.1 Surface

North of I-10, in Areas 1 to 3, the highest averages of dioxin and furan concentrations in surface soils prior to implementation of the TCRA occurred in Area 3 (Table 2-2), which encompasses the northern impoundments. The maximum TEQ_{DF} concentration in surface soils (11,200 ng/kg) occurred in the southern portion of the Western Cell of the impoundments at Station SJ6B009. The highest average congener concentration in this area was for 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) at 5,480 ng/kg (Table 2-2).

Average TEQ_{DF} concentrations in surface soils in Areas 1 and 2 are much lower than those that existed within the northern impoundments prior to implementation of the TCRA (Table 2-2). The maximum TEQ_{DF} values in Areas 1 and 2 were 27.2 ng/kg and 66.1 ng/kg at Stations SJTS010 and TXDOT005, respectively. Unlike Area 3, where the predominant

congener is 2,3,7,8-TCDF, in Areas 1 and 2, octachlorodibenzo-p-dioxin (OCDD) has both the highest average and the highest maximum of all the congeners.

2.3.3.2.2 Subsurface

In subsurface soils north of I-10, the highest average concentration of dioxins and furans in Areas 1 to 3 occurs in Area 3 (Table 2-3). In Area 3, the highest TEQ_{DF} value in subsurface soils (16,200 ng/kg) occurs in the southern portion of the Western Cell (Figures 2-13 and 2-15), also at Station SJGB009. Consistent with surface soils within Area 3, the highest average congener concentrations was for 2,3,7,8-TCDF at 15,300 ng/kg (Table 2-3).

Subsurface soil TEQ_{DF} values in Areas 1 and 2 are generally lower than those within the northern impoundments (Table 2-3). The maximum TEQ_{DF} concentration in subsurface soils of Area 1 was 195 ng/kg and occurs in the northeastern corner of the upland sand separation area, in the vicinity of surface and subsurface sediment samples with relatively elevated TEQ_{DF} concentrations. In Area 2, the TxDOT ROW, the maximum TEQ_{DF} of the two subsurface soil samples was 1.22 ng/kg. The congener with the highest concentrations in subsurface soils in Areas 1 and 2 is OCDD, which is consistent with patterns in the surface soils from these areas.

2.3.3.3 South of I-10

Soil samples were collected from the south impoundment area in March 2011. USEPA has required additional soil sampling in this area, and the sampling approach and DQOs are in review at the time of this publication. Additional soil sampling will include both surface soil and soil cores. The RI Report will describe the nature and extent of soil contamination south of I-10, inclusive of samples to be collected in February 2012.

2.3.3.3.1 Surface

Dioxin and furan analyses were conducted on surface soils at 13 locations (ten soil bores and three surface soil stations) in soil investigation Area 4, south of I-10 (Table 2-2). Results are discussed in the following section. Summary statistics for other chemicals of interest in surface soils in Area 4 are presented in the PSCR (Integral and Anchor QEA 2011a).

Dioxin and furan concentrations in surface and shallow subsurface soils in Area 4, south of I-10, are presented as TEQ_{DF} in plan view on Figure 2-19.

TEQ_{DF} values in surface soils south of I-10 are generally much lower than surface soils in Area 3 north of I-10. The highest TEQ_{DF} value (31.1 ng/kg) in surface soil in Area 4 is located in the northwestern portion of that area (Figure 2-19). The average TEQ_{DF} concentration in Area 4 surface soils was 10.5 ng/kg. The highest average congener concentrations were for OCDD (10,100 ng/kg) (Table 2-2).

2.3.3.3.2 Subsurface

Dioxins and furans were analyzed in 81 samples collected from ten soil cores and three surface soil stations in Area 4. Dioxin and furan concentrations in subsurface cores are presented as TEQ_{DF} (ng/kg dry weight), in plan view on Figure 2-20. In some cases, the soil intervals could not be retrieved because the soil lacked cohesiveness. When this occurred (e.g., SJSB005, SJSB007, and SJSB009), the next deeper recovered interval may contain material from the interval above.

Summary statistics for dioxin and furan concentrations in subsurface soils are presented in dry weight measurement in Table 2-3 and normalized to organic carbon in Table 2-4.

Subsurface soil dioxin and furan concentrations, expressed as TEQ_{DF}, are substantially lower in the area of soils investigation south of I-10 than in the Western Cell of the impoundment north of I-10. Unlike the northern impoundments, where high TEQ_{DF} values were located in the shallow intervals of certain borings, the highest TEQ_{DF} concentrations in cores south of I-10 are located at least 6 feet bgs throughout Area 4. The highest concentration reported (1,880 ng/kg) occurs between 6 and 8 feet bgs in the southwestern portion of the investigation area, at Station SJSB008 (Figure 2-20). Elevated subsurface TEQ_{DF} concentrations are more deeply buried in the northern end of Area 4 (at least 8 feet) than in the southern end of Area 4.

TEQ_{DF} values decrease from their maximum value with depth within each of the soil cores, indicating that the peak values have been located in the vertical dimension in all but two

borings (SJSB001 and SJSB007). This could be an indication that the lower extent of the contamination has not been identified in those two locations, or that material from the interval above has mixed with soils from the more competent interval below.

The average concentrations of congeners in subsurface soils in Area 4 are lower than averages in Area 3 (Tables 2-3 and 2-4). The highest average congener concentrations in subsurface soils south of I-10 are for OCDD at 5,370 ng/kg TEQ_{DF} and OCDF at 560 ng/kg TEQ_{DF}. The average TEQ_{DF} in subsurface soils south of I-10 was 92.9 ng/kg.

2.3.3.4 Groundwater

Monitoring well sampling was conducted in December 2010 through January 2011, from three well pairs situated on the berms of the northern impoundment, prior to implementation of the TCRA (Figure 2-21). The study design provided for three well pairs, with one of each pair screened in the alluvial groundwater, and the other in the deeper aquifer; a fourth well was placed within the waste materials in the Western Cell of the northern impoundments (SJMWS04). The sampling yielded a total of eight groundwater samples (including one duplicate), consistent with the approved Groundwater SAP (Anchor QEA and Integral 2011). Water was collected in samples from deep and shallow water-bearing units below the waste materials, and one sample was collected from very shallow perched water conditions within the waste materials. One sample was collected from each monitoring well shown on Figure 2-21, and the duplicate was collected from SJMWS02. In addition, real-time groundwater quality data (i.e., measurements of water characteristics such as pH and specific conductance) were collected during well development and sampling activities. Groundwater sample data are provided in Table 2-5. Groundwater quality data are provided in Table 2-6. USEPA has required that groundwater samples be collected in the area south of I-10; no groundwater data for that area are currently available. Data collection is anticipated to occur in February 2012. The sampling plan is under review at the time of publication of this memorandum. Complete results of the groundwater study, including results of upcoming sampling, will be presented in the RI Report.

Consistent with the Groundwater SAP, groundwater samples were analyzed for dioxins and furans (USEPA Method 1613B), metals on the COPC list, including mercury, semivolatile organic compounds (SVOCs: acenaphthene, fluorene, naphthalene, phenanthrene, phenol,

and carbazole), polychlorinated biphenyls (PCBs) such as Aroclors, and total suspended solids (TSS). All samples were analyzed on an unfiltered basis to determine total concentrations. Metals and mercury (referred to collectively in this document as metals) were also analyzed as dissolved concentrations in each groundwater water sample, following sample filtration (i.e., samples were filtered during collection using a 0.45 micron in-line filter). All groundwater results are shown in Table 2-6.

This section provides a brief overview of the data for dioxins and furans and conventional analytes, with details for other chemicals in each sample provided in Table 2-6. No dioxin and furan congeners were detected in five of the seven monitoring wells at the Site: two shallow wells (SJMWS01 and SJMWS03) and all three deep wells (SJMWD01, SJMWD02, and SJMWD03).

Two dioxin and furan congeners were detected in SJMWS02. Two of these congeners were detected at estimated concentrations (OCDD [3.6 picograms per liter (pg/L), and 2,3,7,8-TCDF [1.89 pg/L]); both of these are qualified as estimated by the laboratory because concentrations were below the method reporting limit. 2,3,7,8-TCDD was not detected in this groundwater sample.

All but three of the 17 dioxin and furan congeners were detected or estimated from 14 to 9,100 pg/L in the perched water collected from SJMWS04. This well was screened within the upper 2.5 feet of waste material in the former impoundment (Figure 2-21). 2,3,7,8-TCDD was detected at a concentration of 2,700 pg/L (Table 2-6).

2.4 Physical Conceptual Site Model

The physical conceptual site model (CSM) that will be used in the FS is currently under development. This section presents the current understanding of the physical process in the area north of I-10 and within the River. Once data collection and analysis is complete, the updated CSM for the aquatic environment will be presented as part of the Fate and Transport Modeling Report that is scheduled for submittal to USEPA as a draft report in February 2012. For the purposes of the CSM, the modeling study area is much larger than the Site so that appropriate boundary conditions could be accounted for in the modeling effort. The modeling study area is defined as the River from the Lake Houston Dam to the confluence of

the River with the HSC and Galveston Bay, an approximately 18-mile reach (Figure 2-22). The modeling study area also includes the 20-mile reach of the HSC.

2.4.1 Waterway Hydrodynamics

The typical tidal range in the River is about 1 to 2 feet. Tidal range varies over a 14-day cycle, with neap and spring tide conditions corresponding to minimum and maximum tidal ranges, respectively. Tropical storms and wind storms from the north can have significant effects on water levels at the Site. Tropical storms can cause storm surges with water levels that are significantly higher than typical tidal elevations. Storms with strong winds from the north can cause water to be transported out of the Galveston Bay system, which can result in water levels that are much lower than low tide elevations. Table 2-7 presents a summary of the tidal elevations at the gauge that was historically nearest the Site for the 1983 to 2001 tidal epoch, relative to NAVD88.

Table 2-7
Tidal Relationships for Battleship Texas State Park Gauge (Station ID: 8770743)

Datum	Elevation (feet)
NAVD88	0.0
Mean Lower Low Water (MLLW)	0.05
Mean Low Water (MLW)	0.22
Mean Tide Level (MTL)	0.83
Mean Sea Level (MSL)	0.86
Mean High Water (MHW)	1.43
Mean Higher High Water (MHHW)	1.52

Note: Primary benchmark 0743 A 2002 at elevation 11.54 feet NAVD88.

Flow rates in the River in the vicinity of the Site are partially controlled by the Lake Houston dam, which is located about 9.5 miles northwest and upstream of the waste impoundments. The average flow rate in the River is 2,200 to 2,600 cubic feet per second (cfs), based on a flood frequency analysis conducted using two datasets: U.S. Geological

Survey (USGS) stage height data and the Coastal Water Authority (CWA) rating curve at the Lake Houston dam for the 16-year period from 1996 through 2010 (Dataset 1); and summation of six USGS gauges located upstream of Lake Houston for the 24-year period from 1985 to 2009 (Dataset 2 - Integral and Anchor QEA 2011). Table 2-8 presents a range of reasonable estimates for in-river flows under different flow conditions. For comparative purposes, published San Jacinto River flood flows have been previously estimated at 254,000 cfs for the 100-year event, and 422,000 cfs for the 500-year event in the vicinity of Highway 90 at Sheldon (RUST, 1994).

Table 2-8
Flow Range Estimates

Flow Condition	Estimated Flow Rate (cfs)	
	Dataset 1 (1996 to 2010)	Dataset 2 (1985 to 2009)
Average	2,200	2,600
2-Year Flood	30,300	38,400
5-Year Flood	58,500	82,100
10-Year Flood	80,100	126,000
25-Year Flood	121,000	202,000
50-Year Flood	155,000	277,000
100-Year Flood	195,000	372,000

Floods in the River primarily occur during tropical storms (e.g., hurricanes) or intense thunderstorms. Extreme flood events (return intervals of 25 years or more) have flow rates of 200,000 cfs or greater. An October 1994 flood had a peak discharge of 360,000 cfs. River stage height during the October 1994 flood had a maximum value of 27 feet above MSL. Previous studies have indicated that average salinity ranges from 2 to 20 parts per thousand.

Current velocity data were collected in the vicinity of the waste impoundments north of I-10 during June and July 2010. Both water surface elevation and current velocity data are shown on Figure 2-23. In this figure, the bottom three panels present the following information related to the current velocity data: 1) east–west component of total velocity; 2) north–south component of total velocity; and 3) total velocity. During low-flow conditions, when current velocities are dominated by tidal effects, maximum velocities were about 1 foot per second, with typical velocities of 0.5 feet per second or less during most of the tidal cycle. A

high-flow event (maximum flow rate in the River of about 20,000 cfs) occurred during the first week of July 2010. Maximum current velocities during this high-flow event ranged between about 2 and 2.5 feet per second.

An acoustic doppler current profiler (ADCP) was installed in the River in May 2011, at a location to the north of the Site, to collect additional current velocity data for input into the CSM. The ADCP was retrieved in December 2011, and data from this deployment will be presented in the Fate and Transport Modeling Report.

2.4.2 Erosion Potential

To assess potential for erosion of bed sediments in the River within the RI/FS preliminary Site perimeter, Sedflume data was collected in May 2011. Sediment cores were collected from 15 locations within the River; five cores were collected at locations in the immediate vicinity of the waste impoundments north of I-10; and five each were collected upstream and downstream from the waste impoundments.

The analysis of the Sedflume data are ongoing and predicted bed-shear stress and critical-shear stress are not yet available. Predicted bed-shear stress and critical-shear stress will be included in the Fate and Transport Modeling Report.

Near-bed velocities generated by episodes of propeller wash are expected to be significantly higher than those due to tidal and riverine currents in areas of the River that are subjected to large vessel operations (e.g., at the SJRF operations). Bed-shear stress due to vessel operations is expected to be significantly greater than bed-shear stress due to natural forces and may have the potential to disturb sediments in these vessel operation areas.

2.4.3 Net Sedimentation

A bed property study was also completed in March 2011, and a radioisotope coring study was completed in May 2011 in the RI/FS preliminary Site perimeter to evaluate net sedimentation rates. Analysis of the data obtained from these studies and incorporation of the data into the CSM is ongoing.

For the bed property study, sediment probing was completed at 98 locations (55 upstream and 43 downstream, within approximately 3 miles of the waste impoundments). Sediment probing was completed to evaluate the spatial distribution of cohesive (muddy) and non-cohesive (sandy) bed areas. In addition, a subset of 30 surface sediment samples was analyzed for grain size distribution and dry density.

For the radioisotope coring study, 3-inch diameter sediment cores were collected from cohesive sediment bed areas at ten locations: two locations upstream of the impoundments, four locations in the vicinity of the Site, and four locations downstream of the impoundments. The cores were submitted for laboratory analysis of lead-210 (^{210}Pb) and cesium-137 (^{137}Cs). The results of the radioisotope coring study will be used to estimate net sedimentation rates for the sediment transport model.

Analysis of the bed property and radioisotope coring studies is not complete and the CSM is still in development. However, the majority of the sediments observed during the bed property study consisted of cohesive materials, suggesting that most (though not all) of the sediments in the study area are net depositional. Preliminary evaluation of the radioisotope coring data and previous experience on similar projects in the HSC suggest that the net sedimentation rate (NSR) is approximately 0.5 to 2 centimeters per year (cm/yr).

This estimate of the NSR is preliminary and subject to change as the CSM is developed. The CSM will be included in the draft Fate and Transport Modeling Report (February 2012) and will contain an analysis of which portions of the River are net depositional and a calculation for the NSR for these areas.

2.4.4 Contribution of Solids from Lateral Sources

Although other sources of dioxins and furans are known to occur both upstream of the Site and on the Site (Section 2.2.3), an estimate of contaminant mass loading from lateral sources is not incorporated into the CSM at this time. The CSM that will be included in the Fate and Transport Modeling Report will specify contaminant mass loading from outfalls (i.e., point sources) as well as stormwater run-off loads. These loads were quantified as part of the *Total*

Maximum Daily Loads for Dioxins in the Houston Ship Channel (University of Houston and Parsons 2008).

3 BASIS FOR REMEDIAL ACTION

This section describes the development of preliminary RAOs and provides discussion of prospective RALs against which the various remedial alternatives will be evaluated. This information, combined with the development of SMAs and considerations of ARARs, form the basis for evaluating remedial actions for the Site.

3.1 Preliminary Remedial Action Objectives

RAOs, under the National Contingency Plan (NCP), are established in the RI/FS to specify "contaminants and media of concern, potential exposure pathways, and remediation goals" (40 Code of Federal Regulations [CFR] §300.430(e)(2)(i)). According to USEPA guidance (1999, 2005), RAOs "describe what the proposed Site cleanup is expected to accomplish." They should be clearly tied to the CSM, address the significant exposure pathways and Site-specific risks to human health and the environment, and provide the basis for more specific remediation goals (RG). RAOs may differ for different parts of the Site, regardless of whether such different areas constitute different operable units. RAOs provide a foundational consideration in the process of comparing remedial alternatives and help to focus the development and evaluation of alternatives. Because this memorandum is the first step in the identification of remedial alternatives, a set of RAOs for the Site is provided below as the basis for the preliminary screening of alternatives. However, RAOs typically evolve over the course of the RI/FS and only become final when the ROD is signed.

RAOs support the initial development and refinement of PRGs during the RI/FS process, and the selection of final RGs in the ROD. These terms are defined in the NCP and supporting guidance and are used in this document as follows:

- A PRG is a specific expression of a cleanup level (e.g., a sediment concentration or risk level) that is protective of human health and the environment for each exposure pathway. Initially, PRGs may be defined using ARARs or generic cleanup levels, but they are often re-evaluated during the RI/FS process as the CSM is refined and Site-specific studies, including the baseline risk assessments and the characterization of background conditions, become available. PRGs may be represented as a range of values corresponding to an acceptable risk range.
- Final RGs (or final cleanup levels) are established in the ROD and may take into

account additional considerations, such as the uncertainty in the risk assessments or models used to characterize the Site, and additional factors and tradeoffs (e.g., future Site use, remediation timeframes, cost-effectiveness, and short-term community and environmental impacts associated with the cleanup) that are identified based on the remedy selection criteria specified under the NCP (40 CFR §300.430(e)(9)(iii)).

At many sites, attaining the final RG or cleanup level will not be achieved solely by active remediation and will rely in whole or part on natural processes occurring over time. There are also circumstances in which RG can be attained on the basis of a Site-wide average or exposure unit average by cleaning up hotspots of contamination with concentrations that exceed a defined action level. For these reasons, the concept of RALs, which are distinct from RGs, has been recognized in some remedy decision documents (e.g., USEPA 2002). RALs are generally understood to represent levels of contamination in environmental media above which active remedial measures, such as treatment, capping, or removal, will be implemented.

RAOs provide the first step in the process to define the contaminants and media to be addressed by the cleanup, address specific exposure pathways and receptors, and provide the basis for defining PRGs. The initial RAOs for the Site are provided below. These RAOs emphasize objectives for the impoundments north of I-10 and surrounding aquatic environment. As noted in Section 1.2, data gaps exist for the south impoundment area, and the CSM for that area is currently under development. Revised RAOs that specifically address the south impoundment area will be presented in the RI Report, when the south impoundment investigation is complete. RAOs for the south impoundment area are anticipated to be similar to those expressed below.

3.2 Source Control

RAO 1: Eliminate loading of dioxins and furans from the former paper mill waste impoundments north of I-10 to sediments and surface waters of the San Jacinto River.

Consideration of this RAO requires a review of the Site history and CSM, as follows. The Site history provided in the RI/FS Work Plan describes a set of impoundments approximately

14 acres in size, built in the mid-1960s for disposal of paper mill wastes. The set of impoundments is located on a partially submerged parcel of land, on the western bank of the River, north of I-10. The impoundments north of I-10 were constructed by forming berms within the estuarine marsh. Regional subsidence of land in the area in the 1970s and 1980s, and sand mining within the River and marsh to the west of the impoundments, resulted in partial submergence of the impoundments north of I-10 and exposure of the contents of the impoundments to surface waters. Based on review of U.S. Army Corps of Engineers (USACE) approved dredging permits, dredging by third parties has occurred in the vicinity of the perimeter berm at the northwest corner of these impoundments. Sediment samples indicate that dioxins and furans are present in some nearby sediments at levels higher than levels in background areas nationally (USEPA 2000), and higher than levels upstream (Integral and Anchor QEA 2011a). A source analysis presented in the draft PSCR (Integral and Anchor QEA 2011a) indicates that some of the sediments within a defined area near the impoundments include dioxin and furan mixtures characteristic of the waste materials. Regional subsidence and local dredging are shown in the CSM (updated in the draft PSCR) as primary release mechanisms of the dioxin and furan source material from the impoundments north of I-10. The CSM for the impoundments north of I-10 and surrounding aquatic environment also shows that other regional sources, including other upstream and on-site sources of dioxins and furans, are present; the source evaluation has demonstrated that dioxins and furans from these other sources are also found in sediments on the Site.

Achieving RAO 1 requires elimination of the three major transport pathways shown in the CSM: 1) transport and dispersal of wastes, 2) processing of dredged material, and 3) sediment re-suspension due to storms. Transport and dispersal of wastes no longer occur at the Site, as this is not an active disposal facility. In addition, one of the primary release mechanisms for dioxin-contaminated wastes (dredging in the impoundment area), and related secondary transport processes, no longer occur. With the cessation of regional groundwater withdrawal, the major source of subsidence has also been eliminated in the Site area, and implementation of the TCRA at the Site has eliminated the associated secondary transport mechanisms resulting from erosion due to the River flowing over the wastes and due to storm-related sediment resuspension. Therefore, as a result of the TCRA, RAO 1 has been achieved.

3.3 Pathway Elimination

RAO 2: Reduce human exposures to Site-derived dioxins and furans from consumption of fish and shellfish by remediating sediments affected by paper mill wastes to appropriate cleanup levels.

Although the human health risk assessment has not yet been conducted, it is likely that dioxins and furans originating in the wastes deposited in the impoundments will be identified as chemicals of concern (COCs) and will be a risk driver for people who could visit the Site and collect fish and shellfish for consumption. To the extent that human exposures to Site-derived COCs caused by eating fish and shellfish from the Site results in a lifetime excess cancer risk greater than $1x10^{-4}$, or a non-cancer hazard index greater than 1, sediment remedial actions will be required to reduce or eliminate the pathways linking hazardous materials derived from the waste impoundments to fish and shellfish consumed by people.

RAO 3: Reduce human exposures to Site-derived dioxins and furans from direct contact with intertidal sediment by remediating sediments affected by paper mill wastes to appropriate cleanup levels.

People may become exposed to COCs from the waste impoundments when visiting the Site and wading or otherwise having direct contact with sediments in the intertidal zone. If potential exposures to Site-derived COCs through direct contact with intertidal sediments result in a lifetime excess cancer risk greater than $1x10^{-4}$, or a non-cancer hazard index greater than 1, sediment remedial actions will be required to reduce or eliminate these exposures.

RAO 4: Reduce exposures of fish, shellfish, reptiles, birds, and mammals to Site-derived dioxins and furans by remediating sediment affected by paper mill wastes to appropriate cleanup levels.

Ecological receptors may become exposed to COCs from the waste impoundments through direct contact with sediments and through ingestion of bioaccumulative chemicals (including dioxins and furans originating from the waste impoundments) while foraging on or inhabiting the Site. If exposure to Site-derived COCs by ingestion of sediment and biota, or

by respiration of pore water or surface water results in unacceptable risks to ecological receptors, sediment remedial actions will be required to reduce or eliminate the exposure pathways contributing to unacceptable ecological risks. Remediation of sediments is expected to reduce COC concentrations in sediments, water, and biota, with which ecological receptors may have contact, and will thereby reduce or eliminate the pathways linking ecological receptors to hazardous materials derived from the waste impoundments.

3.4 Remedial Action Level Development

As described in Section 1, RALs will be defined during development of the FS. However, some surrogate for actual RALs is necessary to facilitate assembly and screening of remedial action scenarios for purposes of the RAM. To evaluate surrogate prospective RALs for TEQ_{DF}, a "knee of the curve" analysis was performed to consider the resulting Surface Weighted Average Concentration (SWAC) for TEQ_{DF} by varying the area of the Site remediated under a variety of prospective RAL scenarios. This section describes the methods used to calculate SWAC TEQ_{DF} using Thiessen polygons.

3.4.1 Data Use Rules

A Thiessen polygon is defined as the area around a sampling location that includes all points in space that are closer to that sampling location than they are to any other sampling location. Area-weighting of surface sediment concentrations using Thiessen polygons is a well-established method of accounting for different spatial sampling densities within and across sampling programs. For the screening evaluation of remedial alternatives, Thiessen polygons were generated using the surface sediment data points for TEQ_{DF} calculated with non-detects calculated at U=1/2 and using the 2005 World Health Organization Mammalian toxicity equivalency factors (TEFs) (van den Berg et al. 2006). Samples from the top 6 inches (approximately 15 centimeters) were considered to be surface chemistry data.

3.4.2 GIS Generation of Thiessen Polygons

The surface TEQ_{DF} concentration data was plotted using the northing and easting coordinates provided in North American Datum 1983 State Plane Texas South Central Zone, U.S. Survey Feet.

Samples inside the TCRA boundary were considered separate from the other areas, such that the Thiessen polygon from a sample outside the TCRA boundary could not straddle the TCRA boundary. Samples were divided into two groups: 1) those inside the TCRA boundary, and 2) those outside the TCRA boundary. Those created from points inside the TCRA were clipped using the TCRA boundary. Those created from points outside the TCRA boundary were clipped using the RI/FS preliminary Site boundary, and the areas from these Thiessen polygons falling within the TRCA Site boundary were removed from the resulting dataset. In this way, the space left behind after this clipping was characterized using those samples in group 1 – the nearest available sample within the TCRA boundary. These two sets of polygons were then merged together to create a seamless Thiessen polygon dataset characterizing the surface concentrations for the entire project area.

A polygon dataset of the shoreline was used to remove those portions of Thiessen polygons located in upland areas. Final cleanup and editing of the Thiessen polygons was performed to make sure polygons were not separated by land masses. Most notably, this is visible in the final polygon in the upper end of the Old River, just south of I-10. In these cases, polygons were merged and edited so that they were attributed to the nearest point forming a contiguous, discreet polygon rather than attributing a small portion of a polygon with a disconnected area located on the other side of an upland land mass (Figure 3-1).

3.4.3 Area/Surface Weighted Average Concentration Curve

Using the resulting array of Thiessen polygons, the area in square feet and the TEQ_{DF} concentration for each polygon were compiled. To evaluate the impact on the SWAC from each of several different hypothetical remediation scenarios, SWACs representing the potential results of increasingly large areas of remediation were developed. The analysis was performed to compute a new SWAC for each incremental increase in the level of effort applied to remediation, as follows: initially, the SWAC was calculated for the entire Site assuming the TCRA had not been implemented in order to establish a baseline for comparative analysis. Subsequently, the SWAC was calculated for a scenario in which only the TCRA Site is addressed; and following these calculations, the SWAC resulting from the TCRA plus remediation of any Thiessen polygons with concentrations above 1,000 was calculated; then the SWAC following the TCRA Site plus any Thiessen polygons with concentrations greater than 200 ppt (parts per trillion) was calculated, etc. The final result

was a series of SWACs reflecting the TCRA plus additional incremental increases in the level of effort to address polygons with concentration of 100, 90, 80, 70, 60, 50, 40, 30, 20, and 10 ppt. For the purposes of this exercise, each of these concentrations represents a hypothetical RAL. Resulting SWACs allowed consideration of the effect each of these RALs, and the resulting elimination of the exposure pathways to dioxins and furans in sediment in those areas that would be addressed by some sort of remedial action. In each of these scenarios, the "remediated" areas (i.e., polygons with a concentration above the threshold RAL for that scenario) were considered to have post-remediation concentrations equivalent to the reference envelope value (REV) of 7 ppt TEQ_{DF}, identified in the PSCR (Integral and Anchor QEA 2011a). Pre- and post-remediation concentrations, along with the acreage of each Thiessen polygon, were used to calculate the SWACs of TEQ_{DF} for the Site under each of the hypothetical remediation scenarios using the following algorithm.

The entire dataset of Thiessen polygon areas and post-remediation concentrations were multiplied and averaged over the entire area of the Site to calculate the post-remediation SWAC. For each Thiessen polygon in the dataset, the post-remediation concentration either remained the same (where no action would occur) or was replaced with the REV (where remediation was assumed to occur). The area of the Thiessen was multiplied by this post-remediation concentration, and then the sum of all these multiplied areas and concentrations was normalized by the entire Site area to generate the SWAC TEQ_{DF} as follows:

$$SWAC\ TEQ_{DF} = \frac{\sum(Area_{Thiessen} \times Concentration_{Thiessen})}{Area_{Site}} \qquad 3\text{-}1$$

Areas were rounded to the nearest 100 square feet and then converted to acreages, and resulting SWACs were rounded to three significant digits during calculation.

The results of this analysis show the incremental improvement (i.e., lowering) of the SWAC with each additional level of remedial effort. Figure 3-2 depicts the result of this analysis as a plot of SWAC for TEQ_{DF} versus area of active remediation. As depicted in this figure, the significant "knee" of the curve occurs between a prospective RAL of 1,000 and 200 ppt TEQ_{DF}, which corresponds to an active remediation area of approximately 10 acres. This indicates that the most significant benefit to SWAC TEQ_{DF} occurs for RALs between 200 and

1000 ppt dw. A RAL lower than 200 ppt TEQ_{DF} does not significantly reduce the SWAC when compared to the remedial area increases. For lower RALs, the increasing areas of remediation have comparatively small improvements in the SWAC for TEQ_{DF}.

3.5 Sediment Management Areas

Prospective SMAs were developed as a necessary component of this memorandum to facilitate the evaluation of potential remedial alternatives. SMAs are used to subdivide the Site into smaller areas with common characteristics. These common characteristics may affect the performance of certain remedial technologies. For example, a remedial approach like containment might not be appropriate for consideration in navigation channels if a required water depth must be maintained. Thus, one criterion for developing SMA boundaries is based on water depth. SMAs will be used for screening remedial alternatives in the FS.

Table 3-1 lists the prospective SMA classifications developed for this memorandum.

Table 3-1
SMA Definitions

SMA Name	Description
NAV	"Navigation" Deep water areas that can support vessel navigation; typically -12 feet MLLW and deeper, or areas with known active navigation uses such as the barge fleeting areas north and south of I-10.
NS	"Nearshore" Shallow areas with limited construction equipment access; typically -2 feet MLLW and shallower.
ST	"Fixed Structures" Areas beneath the footprint of fixed structures.
TCRA	Time Critical Removal Action footprint.
OW	"Open-Water" All other areas within the project footprint that are not covered by the descriptions above.

Figure 3-3 depicts the location of these SMAs within the boundaries of the Site. Considerations related to potential remedial actions within each type of SMA are discussed in more detail in Section 4.

3.6 Sediment Bed Stability

The stability of the sediment bed is an important factor for considering natural recovery processes and to evaluate remedial alternatives for deeply buried deposits of sediment that might exceed prospective RALs. Under the RI/FS and to be reported in the Fate and Transport Modeling Memorandum, the Respondents are evaluating bed stability through development of a hydrodynamic model of the Site. The draft report describing the model and its results is being developed and submitted to USEPA concurrent with this RAM.

For purposes of evaluating alternatives for addressing buried deposits for the RAM, the hydrodynamic model was run for a 100-year flow event[7] at locations where core samples at depth (below the 6-inch depth interval) exceed 25 ppt TEQ_{DF} and where surface sediment sample (0 to 6-inch depth) concentrations are lower than 25 ppt TEQ_{DF}. Core locations SJNE007, SJNE026, and SJNE033 meet these criteria (see Figure 2-17 for core locations). Under these flow conditions, accretion is predicted at locations SNJE007 and SNJE026, and erosion is predicted at SNJE033. The implications of these modeling results are further discussed in Section 5. Figure 3-4 depicts the results of the bed stability evaluation.

3.7 ARARs

The development and evaluation of remedial alternatives will include an assessment of the ability of the remedial alternatives to address ARARs of environmental laws and other standards or guidance TBC. Table 3-2 provides a broad summary of potential ARARs and TBCs that will be considered in the FS. The compliation of Site ARARs is ongoing and will be completed for the RI. The list in Table 3-2 includes certain citations that are not applicable to the Site so as to document the basis for eliminating these regulations, standards, or guidelines from consideration. Many of the ARARs and TBCs in Table 3-2 will be

[7] This flow event corresponds to historic records for flows at the site during October 1994.

relevant to only some of the remedial alternatives, but all of the requirements that may be relevant to any of the remedial alternatives are identified in the list.

Once a remedial action is selected, a detailed review of ARARs specific to the selected remedial action will be conducted and included in the Design Analysis Report for the selected action.

4 IDENTIFICATION AND SCREENING OF REMEDIAL AND DISPOSAL TECHNOLOGIES

This section identifies and describes the General Response Actions (GRAs), remedial and disposal technologies, and process options TBC at the Site. Each of these elements is considered in the screening of remedial alternatives and is defined below:

- **GRAs** – Major categories of cleanup activities that could be applied to manage COCs (i.e., dioxins and furans) in sediments. GRAs include no further action, natural recovery, institutional controls, containment, removal, treatment, and disposal. GRAs for the Site apply to sediment and may be used singly or in combination to satisfy the RAOs developed for the Site.
- **Remedial and Disposal Technologies** – General categories of technologies within a GRA that describe a means for achieving the RAOs. For example, removal is a GRA that can be achieved using dry excavation or dredging technologies, while treatment is a GRA that can be achieved using physical, biological, or chemical technologies. Innovative technologies will also be evaluated during the FS, as required per USEPA guidance (USEPA 1988). Further description of technologies capable of successfully treating dioxin- and furan-contaminated materials is provided in Appendix A, the draft *Dioxin Treatability Study Literature Review* (Anchor QEA 2011a).
- **Process Options** – Specific processes within each technology type. Process options are selected based on the characteristics of the medium (e.g., sediment), Site conditions, and availability of technologies to address the medium or Site conditions. For this RAM, a range of process options are identified to illustrate the variety of process options that could be implemented by a contractor during remedial construction. At this conceptual-level screening phase, eliminating certain process options may inadvertently limit potential remedial technologies from consideration in the FS or the remedial design phase. Therefore, the RAM primarily focuses its screening at the remedial and disposal technologies level, with some detailed discussion on process options where it is important to note critical factors for specific process options. Some process options are identified and screened out where critical factors make the process option infeasible.

Following CERCLA guidance, cleanup technologies are organized under GRAs that represent different conceptual approaches to remediation and include:

- No Further Action
- Institutional Controls
- Monitored Natural Recovery (MNR) and Enhanced Natural Recovery
- In Situ Containment
- In Situ Treatment
- Removal Technologies
- Ex Situ Treatment
- Disposal Technologies

Table 4-1 describes the GRAs, technology types, and process options potentially appropriate to the Site sediments. Applicable technologies for the treatment of dioxin-contaminated soils and sediments have been reviewed by Anchor QEA (2011a; Appendix A). These form the basis of the in situ and ex situ treatment sections. Additional technologies for each of the above GRAs are included alongside these treatment options to provide a comprehensive screening assessment for the methods applicable to the Site. Each of the elements identified is discussed in subsequent sections of the RAM. Remedial technologies are described in Section 4.4, and disposal technologies are described in Section 4.5.

Table 4-1
Identification of General Response Actions, Technology Types, and Process Options Potentially Appropriate for the San Jacinto River Waste Pits RI/FS

GRA	Technology Type	Process Option	Section
Institutional Controls	Administrative and Legal Controls	Waterway use restrictions and maintenance agreements	4.4.1 Institutional Controls
		Access and property use restrictions	
		Informational devices (e.g., signage and fish consumption advisories)	

GRA	Technology Type	Process Option	Section
Natural Recovery	Monitored Natural Recovery	Sedimentation	4.4.2 Monitored Natural Recovery and Enhanced Natural Recovery
		Placement of thin layer of clean cover	
In situ Containment	Cap	Conventional Cap	4.4.3 In Situ Containment (Capping)
		Low-permeability Cap	
In situ Treatment	Physical-Immobilization	Adsorptive Amendments	4.4.4 In Situ Treatment
		Solidification/Stabilization (S/S)	
Removal	Dry Excavation	Excavator	4.4.5 Removal
	Dredging	Mechanical Dredging	
		Hydraulic Dredging	
Ex situ Treatment	Thermal	Incineration	4.4.6 Ex Situ Treatment Technologies
		In Pile Thermal Desorption	
	Chemical	Solvated Electron Technology™ (SET)	
		Base-Catalyzed Decomposition	
Disposal/Reuse	Aquatic Disposal	Confined Aquatic Disposal (CAD)	4.5.1 Aquatic Disposal
		Nearshore Confined Disposal Facility	
		Open-water Disposal	
	Off-Site Upland Disposal	Confined Disposal Facility/Landfill	4.5.2 Upland Disposal
		Beneficial Use	4.5.3 Beneficial Use

The identification and screening of remedial technologies and process options generally follows the USEPA's *Guidance for Conducting RI/FSs* (USEPA 1988, 2005). This evaluation

includes only those technologies and process options applicable to the contaminants present, their physical matrix, and relevant Site characteristics; therefore, only applicable technologies will be carried forward into the assembly of alternatives.

The screening in this section will be based on three evaluation criteria: 1) implementability, 2) effectiveness, and 3) cost. The screening process determines those technologies that will not be carried forward for further Site-specific evaluation. After the identification and screening steps are completed, the retained technologies (and representative process options) are assembled into a focused set of Site-wide alternatives in accordance with CERCLA guidance. Potentially applicable technologies are identified and then eliminated or retained in this section, while assembly and evaluation of Site-specific remedial alternatives are provided in Section 5. Retained remedial alternatives from Section 5 will be further refined and evaluated in the FS.

4.1 Evaluation Criteria

The technology screening process described in the following sections is based on the guidance provided in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988) and 40 CFR §300.430(f)(7). The following technology evaluations provide, to the extent practicable, an appropriate level of detail to allow a balanced screening level assessment. The evaluations are based on an appropriate level of reasoning, experience, and professional judgment for conceptual-level studies. A more rigorous approach to technology assessment will be performed, where appropriate, during the FS for those alternatives carried forward.

4.1.1 Implementability

This evaluation criterion is based on two aspects of a given technology's feasibility: 1) technological, and 2) administrative. Specifically, technological feasibility refers to both the short-term (i.e., construction, operation, and completion of the remedial action) and long-term (i.e., O&M, replacement, and monitoring post-remedial action completion) aspects of an alternative. Administrative feasibility refers to the necessary agency coordination prior to on-site execution of an alternative. Additionally, the associated components of a given

technology (e.g., equipment or off-site storage availability) are also evaluated as part of the administrative feasibility.

4.1.2 Effectiveness

The evaluation of the effectiveness of a given technology focuses on its ability to reduce the toxicity, mobility, or volume of a contaminant within a specified matrix; all of these characteristics point to the ability of a technology to effectively minimize or eliminate the risk associated with a particular contaminant. Additionally, as discussed for a given technology's implementability, the short-term and long-term aspects of its effectiveness must also be evaluated. Short-term aspects of effectiveness focus on the duration of construction and implementation and long-term evaluations consider the period beyond construction.

4.1.3 Cost

An assessment of the construction or implementation costs associated with a particular alternative is also required as part of the screening evaluation. The referenced guidance indicates that adequate information for each screened technology is necessary to perform "comparative estimates" that can be carried forward for further evaluation in the subsequent detailed analyses in the FS; therefore, only a certain degree of alternative refinement is necessary at this stage of the evaluation. Cost assessments for the presented technologies are provided on a unit price basis, providing a simplified metric for technology evaluation.

4.2 Critical Site Restrictions

As discussed in Section 3.5, different SMAs were developed for the Site to facilitate remedial alternatives screening. Existing Site conditions were used to define these areas, and in certain instances, these conditions could affect one or more of the criteria listed above. For example, areas with limited access that require specialized equipment for implementation of a certain technology may have higher costs than those areas with unrestricted access. The following sections provide a discussion of restrictions imposed by on-site conditions within the SMAs.

4.2.1 Structural Restrictions

Areas within the Site that have fixed structures may preclude the successful implementation of certain remedial design technologies listed in Table 4-1. Areas in both the northern and southern regions of the Site have docking facilities that are immovable and within areas that may be recommended for remedial action. These facilities are active and have a high vessel departure and arrival rate. A thorough evaluation of these areas, which includes coordination with facility owners and operators, must be made prior to final remedy selection, as implementation of certain remedial actions would likely disrupt on-site operations. In addition, removal GRAs could have fatal-flaw issues related to structures as removal of sediment can reduce the structural capacity of pile foundations. The extent to which this could be an issue is unknown and will be evaluated in more detail during the FS, as appropriate to the final alternatives considered.

4.2.2 Use, Habitat, and Water Depth Considerations

The River is an active waterway, utilized for both recreational and industrial purposes. Facilities within the Site generate significant amounts of vessel traffic. Also, open-water areas adjacent to these facilities are used regularly as temporary barge mooring locations. Based on the wetlands information gathered from the U.S. Fish and Wildlife Service (USFWS)[8] (Figure 2-11), the majority of the areas within the Site are estuarine and marine deepwater. These areas provide habitat for fish and invertebrate species described in Section 2.2.6. Table 4-2 provides a description of the use, habitat, and water depth considerations for each of the SMAs.

[8] http://www.fws.gov/wetlands/data/Mapper.html

Table 4-2
SMA Critical Site Restrictions

SMA Name	Use, Habitat, and Water Depth Considerations
Navigation (NAV)	The navigation channel is utilized frequently by shallow and deep draft vessels operating on the San Jacinto River. Portions of this SMA are also utilized for barge mooring, particularly on the western side of the southern peninsula, and in the SJRF operations area. Recreational fishing has been observed in some areas along the navigation channel; however, these activities are limited by increased vessel traffic. Water depths in the navigation channel may preclude the implementation of certain remedial technologies.
Nearshore (NS)	Likely the only vessels that are capable of accessing the majority of the NS areas are small recreational craft. This SMA includes areas with shallow water depth. As identified on the NOS navigation chart (No. 11329), "Foul Areas" are located within this SMA. Recreational fishing has been observed in the NS SMA.
Fixed Structures (ST)	Fixed structures associated with the shipyard and shipbuilding facilities located on the southern peninsula are accessed on a daily basis. It is likely that operations are rarely discontinued for any significant time period. The I-10 Bridge is a heavy-use structure for vehicular traffic. The dock structures on the northeastern side of the Site are likely used infrequently for launching private recreational vessels. The Bridge is protected by several dolphins constructed on the northeastern side of the Bridge, and a fender-type structure on the western side of the San Jacinto River. No habitat or water depth considerations for fixed structures have been identified at this time.
TCRA	Implementation of the TCRA at the northern impoundments of the Site was completed in July 2011. Construction included the stabilization of a portion of the Western Cell and the installation of geosynthetic and/or granular armor cap layers across the entirety of the northern impoundments. The cap has effectively contained all of the material within the northern impoundment area, thus accessing the contaminated material for removal or treatment options would require the removal of all construction elements associated with the TCRA. No use or habitat considerations for the TCRA SMA have been identified at this time. Figure 2-4 displays the final baseline survey of the TCRA SMA post-implementation. Relative to the other SMAs identified, there is significant variation in elevation, as this SMA includes both upland and submerged areas.
Open-Water (OW)	Traffic associated with the SJRF, shipyard, and shipbuilding operations traverses portions of the OW SMA to access the navigation channel. Certain areas may experience higher use than others. Recreational fishing has been observed in the OW SMA.

4.3 Media and Extent of Contamination

Soils in Areas 1, 2, and 4 (Figure 2-18) are not included in the SMAs developed for the Site. TEQ_{DF} concentrations present in surface soils evaluated to date in these areas (Section 2.3.3.3) are below the USEPA draft interim PRGs for industrial soils of 950 ng/kg TEQ_{DF}.[9] As a result, none of the remedial or disposal technologies will be screened for this area. The two alternatives considered for application at these areas are the No Further Action and Institutional Controls alternatives; these alternatives will be retained for further evaluation in the FS. Additional soil testing is planned for the area south of I-10 with data collection anticipated for February 2012. Results will be presented and analyzed in the RI Report, following completion of the soil investigation south of I-10, soil may be added as an appropriate media of concern to consider for active remediation in the FS if results of the study indicate that soil contamination results in a significant exposure pathway of Site-derived COPCs to human or ecological receptors in that area.

Soils in Area 3 (Figure 2-18, the TCRA Site) are not included in the SMAs developed for the Site. Surface soils were effectively contained by construction of the TCRA. As a result, none of the remedial or disposal technologies were screened for TCRA soils. The two alternatives that will be considered for application to Area 3 soils are the No Further Action and Institutional Controls alternatives, which will be retained for further evaluation in the FS. Additional discussion and support for the selection of these alternatives will be provided in the FS.

Concentrations of dioxins and furans in shallow and deep groundwater wells within the northern impoundment were below applicable groundwater quality criteria for dioxins and furans, with the exception of perched groundwater collected from a shallow well that was screened within waste materials of the western impoundment. The area from which this sample was collected was stabilized as part of the TCRA. The two alternatives that will be considered for application to groundwater are the No Further Action and Institutional Controls alternatives; these alternatives will be retained for further evaluation in the FS for

[9] USEPA is expected to endorse a reference dose (RfD) for 2,3,7,8-TCDD (also applicable to TEQ) in the near future. The statement that TEQ concentrations in surface soils at the Site are below USEPA's interim PRG for soils remains factual, even if the draft interim PRG is revised using the expected update to the RfD.

this media. Additional groundwater testing is planned for the area south of I-10 and groundwater may be added as an appropriate media of concern to consider for active remediation in the FS if those evaluations indicate groundwater presents a significant exposure pathway of Site-derived COPC to human or ecological receptors in that area.

4.4 Remedial Technologies

The following sections develop screening evaluations for remedial technologies applicable for the Site. Each of the technologies will be evaluated on the criteria discussed in Section 4.1.

4.4.1 Institutional Controls

Institutional controls are non-engineered instruments, such as administrative and legal controls, that may be included as part of a response action to minimize the potential for human exposure to sediment contamination and ensure the long-term integrity of the remedy. CERCLA guidance prohibits the use of institutional controls as the primary mechanism for achieving RAOs unless active remedial measures, such as removal or containment, are not feasible. The two major types of institutional controls considered are proprietary controls and informational devices.

Proprietary controls may include:

- Waterway use restrictions and maintenance agreements
- Access and property use restrictions

Informational devices may include:

- Monitoring and notification of waterway users
- Seafood consumption advisories, public outreach, and education
- Enforcement tools
- Site registry

4.4.1.1 Implementability

Institutional controls are technically implementable. The administration of institutional controls would need to be coordinated with stakeholder groups, such as Harris County, the

Port of Houston Authority (POH), and regulatory agencies, as well as commitment from the public. Several institutional controls have already been implemented for the Site, including:

- Consumption advisories, issued by the TDSHS, for certain species of fish or crab.
- Warning signs have been installed around the impoundments to inform the public of the fish and crab consumption advisories.
- Perimeter fencing has been installed around the impoundments and on the east bank of the River, intended to restrict public access to the impoundments.
- No trespassing signs have been installed around the impoundments to warn the public against trespassing on the impoundments.

When using institutional controls alone, implementability is considered to have a moderate rank.

4.4.1.2 Effectiveness

Institutional controls alone are not considered to be a proven and reliable technology at achieving RAOs and protecting human health and the environment. Institutional controls are most often used in conjunction with remedial technologies that isolate contaminated sediments in place or in circumstances where concentrations of contaminants in fish or crab are expected to post risks to human health for some time in the future (USEPA 1997). However, such actions do not reduce the toxicity, mobility, or volume of contaminants. In addition, despite current consumption advisories for fish and crab, fishing activity has been observed within the Site, and fishers in this area are reported to collect whatever they catch (Beauchamp 2010, personal communication). Breaches in the Site perimeter fence have been observed and repaired on more than one occasion. These incidents indicate that enforcement of the existing institutional controls is likely to be challenging.

Institutional controls, such as deed restrictions, can be effective for maintaining appropriate land uses for low-levels of dioxins and furans in soils; however, because institutional controls alone do not reduce the toxicity, mobility, or volume of contaminants, and because enforcement of institutional controls with members of the public is likely to be challenging, effectiveness is considered to have a moderate ranking.

4.4.1.3 Cost

Costs are expected to be low for the institutional controls alternative. Costs are primarily related to administrative and legal costs, community education and engagement, construction and maintenance of fencing and warning signs, as well as potential long-term monitoring costs.

Estimated costs related to administrative, legal, and community engagement have not been calculated at this time. Previous fencing installed as part of the TCRA cost approximately $50 per linear foot to install; this included all materials, equipment, and labor, including a post-installation survey.

4.4.1.4 Summary

Institutional controls are retained as a remedial technology (Table 4-3).

Table 4-3
Institutional Controls Screening Summary

GRA	Technology Type	Process Options	Implementability	Effectiveness	Cost	Screening Decision
Institutional Controls	NA	NA	Moderate	Moderate	Low	Retained

4.4.2 Monitored Natural Recovery and Enhanced Monitored Natural Recovery

As outlined in USEPA's *Sediment Remediation Guidance* (USEPA 2005b), MNR is a remedy for contaminated sediment that typically uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. MNR may rely on a wide range of naturally occurring processes to reduce risk to human and ecological receptors. These processes may include: 1) physical, 2) biological, and 3) chemical mechanisms that act together to reduce the risk posed by the contaminants. Depending on the contaminants and the environment, this risk reduction may occur in a number of different ways, including destruction (degradation or transformation) of chemicals, reduced mobility or toxicity, burial, or dispersion. A variation of MNR is enhanced MNR (EMNR)

where one of the driving mechanisms (usually burial) is accelerated. A common method of EMNR is the placement of a thin layer of sediment over the affected area.

4.4.2.1 Implementability

MNR and EMNR are technically and administratively implementable for all SMAs at the Site. The River at the location of the Site is generally depositional in nature, and MNR of dioxins and furans is a natural process that occurs when clean sediment particles are deposited over contaminated materials within the Site. Decreases in surface sediment concentrations were documented for all dioxin and furan congeners between 2005 and 2010 datasets within the Site in the *Chemical of Potential Concern Technical Memorandum* (Integral 2011). There would not be any short- or long-term impacts related to the implementation of the remedial action for MNR and very modest potential short-term impacts from the implementation to an EMNR remedial action. MNR and EMNR scenarios would also not involve maintenance costs associated with the implementation; however, MNR and EMNR scenarios would involve a monitoring component to assure the predicted rates of recovery are realized. There are no ARARs associated with implementing a MNR/EMNR remedial action.

4.4.2.2 Effectiveness

The rate of natural recovery in the well-mixed layer[10] of the sediment bed is primarily controlled by: 1) initial chemical bed concentration, 2) chemical concentration on depositing particles, and 3) NSR. The temporal change in chemical concentration in the mixing-zone layer of the bed due to deposition may be approximated by an idealized model, as shown on Figure 4-1. This idealized model assumes continuous deposition with no erosion and, thus, chemical concentration will decrease at an exponential rate, which is expressed mathematically (Thomann and Mueller 1987):

$$C_b(t) = C_{b,o}\, e^{-\lambda(t-t_o)} + C_w\left(1 - e^{-\lambda(t-t_o)}\right) \qquad 4\text{-}1$$

[10] The degree to which the layer will be "well-mixed" is affected by bioturbation processes, which are being considered for the Site. Bioturbation will be evaluated in more detail in the forthcoming chemical fate and transport modeling report.

where:

C_b	=	chemical concentration in the mixing-zone layer
$C_{b,o}$	=	initial bed concentration at time t_o
C_w	=	chemical concentration on sediment particles being deposited
t	=	time
λ	=	the decay rate coefficient with units of inverse time (e.g., year^{-1})

The decay rate coefficient depends on the ratio of NSR and mixing-zone layer thickness (T_{MZ}):

$$\lambda = NSR/T_{MZ} \qquad 4\text{-}2$$

As the value of the decay rate coefficient increases, the rate at which C_b declines will increase. As time progresses, bed concentration asymptotically approaches the concentration of depositing particles (C_w). Half-life (i.e., time needed for a 50 percent reduction of C_b in the mixing-zone layer) is a convenient measure of the rate of decrease of chemical concentration. Half-life ($T_{1/2}$) is calculated using:

$$T_{1/2} = -ln\left[\frac{0.5C_{b,o}-C_w}{C_{b,o}-C_w}\right]/\lambda \qquad 4\text{-}3$$

where:

$ln[X]$	=	natural logarithm of X

A geochronology analysis was conducted of radioisotope data obtained from ten sediment cores that were collected within the Site during 2011. The results of the geochronology analysis indicate that reasonable lower- and upper-bound limits for NSR values within the study area are 0.5 and 1.5[11] centimeters per year (cm/yr), respectively. If it is assumed that the T_{MZ} is 10 cm, then lower- and upper-bound limits of the decay rate coefficient are 0.05 and 0.15 yr^{-1}, respectively.

[11] Sedimentation rates of up to 2 cm/yr were observed at the Site; the 1.5 cm/yr NSR value was chosen as a conservative upper bound for this preliminary analysis. A detailed evaluation of NSR and the effect of natural recovery over the Site will be completed with the fate and transport model being developed for the Site.

The half-life of chemical concentrations in the mixing-zone layer within the Site was calculated as follows. The concentration of total dioxin/furan TEQ_{DF} on depositing particles (C_w) was assumed to be 7 ng/kg or ppt – this is the approximate REV discussed in the draft PSCR (Integral and Anchor QEA 2011a); the REV will change as a result of the upstream sediment sampling conducted in October 2011. The spatial distribution of total dioxin/furan TEQ_{DF} concentration in the mixing-zone layer was determined from Site data (see Figure 4-2). Spatial distributions of lower- and upper-bound half-lives of total dioxin/furan TEQ_{DF} concentration were generated by using decay rate coefficients of 0.05 and 0.15 yr^{-1}, C_w of 7 ppt, and the local value of $C_{b,o}$ in Equation 4-3. In general, Equation 4-3 provides valid half-life results for values of $C_{b,o}$ greater than two times C_w; therefore, for the purposes of this evaluation, half-life values are not calculated for areas where $C_{b,o}$ is less than or equal to 14 ppt. This process produced the spatial distributions of half-life for total dioxin/furan TEQ_{DF} concentrations corresponding to lower-limit (Figure 4-3) and upper-limit (Figure 4-4) decay rate coefficients. For the lower-limit distribution, half-lives are generally greater than 10 years. Half-lives are shorter for the upper-limit distribution, with the typical range being 5 to 15 years. Lower- and upper-bound limits of total dioxin/furan TEQ_{DF} concentration in the mixing-zone layer at times corresponding to 10 and 20 years in the future were estimated using Equation 4-1 (see Figures 4-5 through 4-8). As expected, the total dioxin/furan TEQ_{DF} concentrations decrease at a faster rate when the NSR is at the upper limit (1.5 cm/yr).

The analysis presented above indicates that MNR and EMNR will effectively lower surface concentrations of dioxins and furans in sediments within the Site at varying time scales across different areas of the Site. The effectiveness of MNR and EMNR is directly proportional to the NSR for the area under consideration. Other factors that may influence the effectiveness of these technologies include potential impacts from marine vessel operations (propeller wash), and the effect of episodic changes to the sediment bed areas that can have erosional and depositional characteristics, depending on changing flow conditions within the River.

4.4.2.3 Cost

MNR and EMNR each involve monitoring the shallow sediment to demonstrate a reduction in the concentration of dioxins and furans over time. Sediment samples representative of

initial conditions would be collected in areas where MNR or EMNR remedial action is chosen as the preferred alternative. The samples would be analyzed for dioxin and furan congeners. Subsequent monitoring would involve collecting surface grab samples in essentially the same locations using the same collection methods and analyzing the samples for the same constituents. Monitoring schedules can vary, but would typically include collecting samples annually for 5 years and then once every 5 years thereafter for a total of 30 years (for a total of ten rounds of sampling) – the sampling schedule could be modified with USEPA approval if the results of the monitoring indicated that more or less monitoring was needed or if some disturbance of the sediment was suspected due to a change in flow conditions or some other event.

This technology may also involve implementing administrative controls, such as posting signs advising against dredging or disturbing sediment in the impacted area. Implementation cost associated with EMNR would be similar to the installation of a 6-inch to 9-inch sand cap described in Section 4.4.3 and would be expected to range from approximately $70,000 to $100,000 per acre. The actual cost of EMNR would depend on the source of EMNR material and the thickness of the cover materials. The relative cost of MNR or EMNR compared to other active remedial technologies would be low, and low to moderate, respectively.

4.4.2.4 Summary

MNR and EMNR are retained as a remedial technology (Table 4-4). The FS will assess the degree and spatial extent to which MNR or EMNR can be expected to be a suitable remedy that meets the RAOs. This will involve modeling of chemical fate and transport within and around the Site to determine how quickly and to what level chemical concentrations in surface sediments to which organisms and people are exposed can be expected to decrease over time. The chemical fate and transport model being developed will be used to assist with MNR modeling. To the extent that this model is not available, other models or estimation methods may be employed. This modeling will be supported by a thorough evaluation of empirical information, such as the comparison between 2005 and 2010 datasets discussed in Section 4.4.2.2 above, to determine whether MNR has occurred historically. This information may include (but is not limited to) evaluations of sediment samples taken over

time and evaluations of concentration profiles in cores. The timeframes for acceptable MNR or EMNR will be set to be consistent with appropriate guidance.

Table 4-4
MNR and EMNR Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Natural Recovery	Monitored Natural Recovery	Sedimentation	High	High	Low	Retained
		Placement of thin layer of clean cover	Moderate to High	High	Low to Moderate	Retained

4.4.3 In Situ Containment (Capping)

In situ containment refers to the placement of an engineered subaqueous covering or cap of clean material on top of contaminated sediment that will remain in place. A cap would be designed to effectively contain and isolate contaminated sediments from the biologically active surface zone. As described in *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005), in situ caps can quickly reduce exposure to contaminants and typically requires less infrastructure than ex situ technologies (e.g., dredging, dewatering, treatment, and disposal). Since capping leaves contaminated sediments in place, long-term monitoring is typically a component of in situ containment to ensure that the cap is stable (i.e., not eroding) and continues to effectively isolate contaminants, or sufficiently attenuate contaminant mobility through the cap (USEPA 2005).

In situ caps isolate contaminated sediments from the environment by use of natural (e.g., sand) or constructed (e.g., geosynthetic) products. Depending on the proposed remedial design for a site, a cap can consist of a single sediment layer to isolate contaminants or can be designed as a multi-layered system consisting of a combination of sediment, geosynthetic, and armor layers. Such a design was installed as part of the implementation of the TCRA at the northern impoundments within the Site.

Detailed guidance manuals for in situ containment for contaminated sediments have been developed by USACE and USEPA (Palermo et al. 1998; USEPA 1998b). The RAM intends to provide a general overview of in situ containment technology and refers the reader to USACE and USEPA guidance manuals for detailed information on cap design for contaminated sediments.

The main component of an in situ containment design is the chemical isolation layer. This portion of the cap reduces the flux of the solids and dissolved contaminants to the overlying water column to acceptable levels. The chemical isolation component is typically made of naturally occurring sands or gravels. Additives, such as organoclay or other products (e.g., AquaBlok), have been used to help sequester more mobile dissolved contaminants; this application is discussed in the following section. Depending on the Site conditions (e.g., low erosion potential), this layer may be installed as a single system over the affected area. For the purposes of the RAM, a nominal sand cap thickness of 1 foot is evaluated for the cost assessment. Based on further design considerations presented in the FS, this thickness may be adjusted down or up based on the characteristics of a particular SMA. Other components (e.g., geosynthetic materials) may be added to the chemical isolation layer to create a low-permeability cap. Both geomembrane and geotextile layers were utilized in the TCRA implementation (Figures 1-3 and 1-4); however, each type of material has unique implementability issues when used below water, particularly in flowing River environments.

If Site conditions include areas with high energy or erosion potential, an erosion protection component can be installed over the chemical isolation layer. The erosion protection layer can be constructed from either naturally occurring gravels or boulders or manufactured products (e.g., processed recycled concrete). The gradation and thickness of this layer would be designed to resist potential erosive forces such as currents, waves, or propeller wash. Further evaluation of the propeller wash in the SMAs with increased vessel traffic will be required during the FS to assess the need for an armor stone layer atop the sediment cap. In addition an evaluation of the natural variations in the River currents and their potential scouring effects will be addressed in the FS.

Placing sand- and gravel-sized materials in a controlled fashion is relatively easy to do under suitable on-site conditions (e.g., low currents, calm sea state, lack of physical restrictions, and relatively flat bottoms), and can be accomplished with a variety of equipment such as:

- Controlled discharge from hopper barges.
- Hydraulic pipeline delivery of a sand slurry through a floating spreader box or submerged diffuser.
- Physical dispersion of barge stockpile capping materials by dozing, clamming, conveying, or hydraulic spraying of stockpiled material off the barge and into the water column.
- Mechanically fed tremie tube to limit the lateral spread of the cap material as it is placed with the tube opening near the bottom of the water column.

Sand and gravel placement can often be accomplished in more difficult access areas through the use of conveyors or hydraulic pipeline discharge. However, steep side slopes are a critical limitation to cap placement due to the ability of cap material to be placed and maintain stability, especially for larger stones (e.g., riprap). Placement of an armor layer made of riprap is somewhat more complicated than sand and gravel placement. The placement equipment for rock is typically limited to mechanical equipment since hydraulic pipelines and conveyors are limited to the size of material they can effectively transport.

4.4.3.1 Implementability

In situ containment methods can be successfully implemented in most of the SMAs at the Site. Work during the TCRA demonstrated the successful implementability of armored cap construction in both deep and shallow water.

The construction of in situ containment caps is subject to short-term technological feasibility issues. Specifically, since a portion or all of the construction activities will take place water-side, the on-site hydrodynamic conditions are a significant factor. Periods of high flow could impact the installation of cap layers by causing unwanted transport of lighter-weight materials during placement. This can be mitigated by monitoring flow conditions during construction and adjusting procedures accordingly. Also, the Site is within a tidal reach of the River, and periods during low tide could delay cap installation in shallow water

and nearshore areas due to water depth requirements for marine-based construction equipment.

For this RAM, it is assumed that capping within NAV areas is infeasible. The surface of the cap will need to be 1 to 2 feet below the deepest future dredge depth. In addition, material will need to be dredged in order to place the total thickness of the cap (isolation and armor components) to ensure that the top is 1 to 2 feet below future dredge depths. Because the area is directly below barge traffic, thicker armor layers would likely be required to resist propeller wash. With the required dredging necessary to fit an engineered cap, the impacted sediment will likely be removed. This will be confirmed during remedial design if remedial actions are required in NAV areas.

Low-permeability caps using geomembranes are significantly more difficult to construct than conventional caps since working with either liners require specialized equipment and/or methods to place. Geomembrane caps have not been proven to be technically implementable for sites with deep water depths and accessibility issues. The use of materials like AquaBlok have been demonstrated in similar site conditions. However, the presence of brackish water may affect the effectiveness of these materials.

The deepest areas of the TCRA Site did not receive a geotextile layer before armor cap installation (Figure 1-3) because of implementability concerns. The deepest portions of the Site are part of the NAV SMA and would not receive cap layers, as discussed above. Therefore, implementability of low-permeability caps using geomembranes or regular granular caps utilizing geotextiles is considered to be low for the open-water (OW) SMA because of the construction issues associated with placing geosynthetic materials in deeper flowing water.

The long-term technological feasibility of in situ containment is supported by OMMP actions that are developed during the remedial design. Such plans present criteria that trigger additional monitoring and repairs, as needed, for the areas where caps have been installed.

Administrative feasibility of in situ containment is dependent on the material and equipment necessary for installation and potential access issues prior to and resulting from

implementation. In situ containment caps consist of readily available materials and can be installed with conventional construction equipment. Depending on the access capabilities, capping in the nearshore areas may be accomplished via track-mounted excavators operating from the shoreline. Remaining submerged areas could be capped using barge-mounted equipment. In situ capping operations would be similar to the implementation of the TCRA at the northern waste impoundments. Installation of cap layers around and under existing water-side structures (ST type SMAs) within the Site can be accomplished through pumping or conveyor methods, as the maneuverability of conventional construction equipment may be limited in these areas.

Water-side mobilization would require berthing and loading/unloading facilities for the equipment and cap material. A location to store or stockpile the cap material until installation is also required for implementation. The property owned by LaBarge Realty, LLC, used for the implementation of the TCRA at the northern waste impoundments is a candidate location to mobilize the water-side equipment necessary for remedial action.

Equipment operators and on-board technology must both meet required standards to install the design thickness of the cap. On-board technology (e.g., bucket global positioning system [GPS]) provides an additional means for the operator to track material placement. Best management practices (BMPs) are necessary during construction to mitigate resuspension of contaminated material, and could include either operational or engineered controls. Also, turbidity monitoring, both qualitative and quantitative, can be implemented during construction to track water quality conditions.

Depending on the location of the capping operations, coordination with the business operations within or adjacent to the Site may be necessary to completely install the caps. The water depth in areas that receive sediment or composite cap layers as part of the remedial action at the Site would be altered. Based on the design thickness of the cap layer, installation in navigable waters may affect vessel passage. Also, changes in the water depth could affect flood stage for areas within the Site. Modeling would be conducted during the FS to evaluate the resultant hydrodynamics for post-remedy conditions at the Site.

4.4.3.2 Effectiveness

In situ containment methods have been demonstrated in previous applications to effectively sequester COCs, particularly for highly sorbed contaminants such as dioxins and furans. Depending on the contaminant, the addition of a reactive component (e.g., activated carbon (AC) could provide additional reduction in mobility.

Short-term effectiveness of this technology relies on the initial coverage of the contaminated material immediately following installation of the cap. Migration or erosion of the contaminant isolation layer during placement may create areas with differential thickness beyond what is preferred for remedial design. Understanding the variability of on-site conditions and incorporating it into the design is a necessity. Once the contaminant isolation cap layer has been installed, the contaminants are effectively sequestered. Benthos living in contaminated sediments beneath the capped area may be temporarily lost, but they will quickly recolonize the surface of the cap, likely within months of cap placement. Since capping disturbs relatively little in situ contaminated sediment, capping technology is considered to have relatively few other environmental impacts during construction.

The long-term effectiveness of in situ containment methods depends on the stability of the cap components. As discussed above, on-site conditions may necessitate an additional cap armor layer to mitigate the effects of erosive forces. Also, cap design thickness should consider the potential for groundwater migration, which could transport contaminated material to the surface water. However, the risk of groundwater transport for dioxins and furans as dissolved constituents is low, because of the very low solubility of these compounds in water.

4.4.3.3 Cost

As discussed above, an average 1.5 foot thickness was assumed for the development of an initial order of magnitude cost range. The upper 6 inches of the cap is assumed to be armor rock similar to the Type A rock utilized for the implementation of the TCRA (Anchor QEA 2011b). The remaining 12 inches consists of a sand layer. The cost range for this application is estimated to be $130,000 to $160,000 per acre. The installation of a geotextile layer similar

to the shallow water portions of the TCRA implementation would increase this range to approximately $520,000 to $650,000 per acre.

4.4.3.4 Summary

In situ containment through single- and multi-layer cap systems is a well-demonstrated technology for sequestering COCs, particularly dioxins and furans. This remedial design method can be successfully implemented in both shallow and deep water portions of the Site. However, the resultant alterations in water depth may impact flood conditions in the surrounding area if cap thicknesses were much greater than 1 foot. There will be some consolidation of underlying sediments with the cap placement to offset this impact. As discussed above, erosional forces associated with propeller wash may preclude the installation of cap layers in high to moderate vessel traffic areas. Erosion resistant layers in the vessel traffic areas (NAV and OW SMAs) may prove effective in resisting propeller wash, but the thickness required may increase vessel draft restrictions. Also, as discussed in Section 4.4.3.1, the RAM assumes that capping in NAV areas is not practical at this time.

SMAs that experience net sedimentation, but may not meet the required remediation timeline by MNR alone, are candidate areas for in situ containment; however, routine maintenance dredging for navigation purposes must be considered prior to implementation in the NAV SMA. Additionally, with design consideration of the erosive forces, SMAs that experience net erosion are also candidate areas for implementing in situ containment. As a result, this technology has been retained for further evaluation in the FS (Table 4-5).

Table 4-5
In Situ Containment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
In Situ Containment	Capping	Conventional	Moderate	High	Moderate	Retained
		Low-Permeability	Low	High	Moderate to High	Retained

4.4.4 In Situ Treatment

In situ sediment treatment technologies include sequestering agents (e.g., AC), biological or chemical degradation, immobilization, and other potentially appropriate treatment technologies to reduce levels or mobility of sediment contaminants while leaving sediments in place. Applicable in situ treatment options for dioxin/furan-contaminated sediments are reviewed in the draft *Dioxin Treatability Study Literature Review* (Anchor QEA 2011a; Appendix A) and are screened as part of the RAM. As noted in USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, "…for the majority of sediment removed from Superfund sites, treatment is not conducted prior to disposal, generally because sediment sites often have widespread low-level contamination, which the National Contingency Plan acknowledges is more difficult to treat" (USEPA 2005).

Solidification/stabilization (S/S) and adsorbent amendments are evaluated as candidate in situ technologies for remedial action at the Site. Both have been demonstrated in previous applications as successful technologies for consideration during remedial design; however S/S likely has limited use for submerged sediments and would only be appropriate for consideration for intertidal nearshore sediments.

4.4.4.1 Solidification/Stabilization

S/S is a category of treatment technologies that involves blending the affected medium, such as contaminated soil or relatively dry sediment, with a material that binds it into a solid matrix, which increases the material's strength and reduces its permeability and mobility. Contaminants are encapsulated in the solidified sediment, meaning that the mobility of the contaminants is controlled both by reducing the potential for the treated material to be eroded and reducing the flow of water through the treated material (permeability), thereby reducing advective transport of contaminants. Stabilization refers to treatment whereby contaminants, typically metals and more polar nonmetals, are also chemically bound to the solidified matrix (USEPA 2006).

Application of S/S will not be considered for submerged sediments based on expected limitations associated with the free water. To the extent that the use of S/S is considered in

the FS, it would be limited to cases where relatively dry application could be employed, such as for intertidal sediments.

4.4.4.2 Adsorptive Amendments

The USEPA has recently supported in situ application of amendments as an in situ treatment. Two adsorptive materials, organoclay and AC, have been well-demonstrated for removing organic compounds from water. This type of in situ treatment is most applicable to sediment in the biologically active zone (i.e., approximately the upper 0 to 10 cm of sediment). Both materials have been effectively used as amendments to contaminated soil and sediment, or as amendments to granular caps or standard ENR sand cover layers. The latter is similar to an in situ containment application, as discussed in Section 4.4.3. The mechanism by which each of these amendments removes contaminants from water differs.

Because the active adsorption occurs on the surface of AC and the activation process creates very large active surface areas on micropores in a unit mass or volume of the material, AC is particularly well suited to removing trace amounts of contaminants from water (125 acres of active surface per pound of AC[12]). AC has been shown to be an effective adsorptive amendment for polycyclic aromatic hydrocarbons (PAHs), PCBs, dioxins/furans, dichloro-diphenyl-trichloroethane (DDT), and mercury, when directly mixed into sediment (USEPA 2011; Ghosh et al. 2011).

Organoclay is produced from bentonite clay modified with quaternary amines. The nitrogen in the amine reacts with the clay mineral, and the organic ends of the amine molecules attract organic contaminants. Organoclay is less subject to fouling than AC in the presence of nonaqueous-phase liquids and has been shown to reduce the bioavailability for non-soluble organics and potentially other contaminants; however, nonaqueous-phase liquids have not been observed in the sediments at the Site and are not expected to inhibit the effectiveness of AC at this Site.

[12] http://www.calgoncarbon.com/carbon_products/faqs.html

4.4.4.3 Implementability

The implementation of in situ treatment methods is subject to short-term technology feasibility issues similar to those presented for in situ containment. Specifically, since a portion or all of the construction activities will take place water-side, the on-site hydrodynamic conditions are a significant factor for both in situ treatment methods. Periods of high flow could impact the installation of adsorbent amendments by causing unwanted transport of lighter-weight materials (e.g., bulk AC) during placement. This can be mitigated by monitoring flow conditions during construction and adjusting procedures accordingly. Certain construction methods have been developed for the direct application of amendments to surface sediments via tilling or injection, which minimizes the interaction of the amendment and the surface water.

The long-term technological feasibility of in situ treatment technologies is supported by OMMP activities that would be developed during the remedial design. Such plans present criteria that trigger additional monitoring and repairs, or enhancement, as needed, for the areas where these methods have been applied. Specifically for adsorbent amendments, excessive erosion could result in areas requiring additional material.

Administrative feasibility of this remedial alternative is dependent on the material and equipment necessary for installation. Materials required for in situ treatment are available; although, depending on the material, may need to be manufactured outside the area and shipped to the Site. Adsorbents range from proprietary materials that can be coated on aggregate to bulk materials that can be blended or injected into the sediment; they can also be added as a component to geotextile mat layers or mixed with a thin layer of sand, which can provide additional uniformity to a remedial design, depending on site conditions.

The application of treatment technologies requires similar implementability measures to those presented for in situ containment, with the potential need to utilize specialized equipment for tilling, mixing, or injecting the amendment into the sediment.

In situ treatment may be accomplished using conventional excavators[13] or specialized tillers or augers. In addition, both methods require an understanding of the appropriate quantity of material necessary to successfully implement a remedial design; therefore, bench-scale testing may be required to determine the appropriate mix ratios for on-site conditions. The implementability of both in situ treatment technologies is ranked moderate to high. The moderate ranking comes largely from the specialized equipment that may be necessary for applications in certain SMAs at the Site.

4.4.4.4 Effectiveness

S/S is a well-demonstrated technology that has been used for numerous Superfund remedial actions (USEPA 2000). The treatment binds fine sediment grains into a solid material that resists resuspension by erosive forces. The permeability of treated sediment is reduced and contaminants are encapsulated in the solid matrix, further reducing the mobility and bioavailability of the contaminants. Chloride ion attack can result in decomposition of the solid sediment matrix; however, the mobility of the contaminants will still be controlled so that the release would be negligible. S/S is given a high effectiveness rating for application at the Site when considered for intertidal applications where the S/S amendment can be added to relatively dry sediments.

Organoclay and AC have both been demonstrated to be effective and reliable for passively removing organic contaminants from water. AC is particularly effective for removing trace amounts of organic compounds from water. Organoclay is very effective for removing nonaqueous-phase liquids from water and is also effective for dissolved contaminants; although, it may be less effective than AC for removing already very low concentrations of organic contaminants from water (Reible et al. 2008). Also, the effectiveness of any adsorptive material relies on its ability to remain in place. An armor layer may be necessary to protect the adsorptive amendments from erosive forces induced by tidal fluctuations and propeller wash.

[13] Conventional excavators were used to stabilize approximately 5,500 cy of soft materials in the western waste impoundment at the Site, to provide a stable surface for geomembrane and cap installation during the TCRA.

4.4.4.5 Cost

Costs for the application of S/S and adsorptive amendments to sediments at the Site are provided in the draft *Dioxin Treatability Study Literature Review* (Anchor QEA 2011a; Appendix A). Treating sediments to a nominal depth of 3 feet was estimated to cost between $240,000 and $290,000 per acre for S/S. This estimate was based on previous project experience. Deep-mixing or other specialty equipment would likely increase the upper end of this range.

A generic order of magnitude unit cost estimate for an application of adsorptive amendments to a sand cap layer was developed for this document. The adsorptive amendment material would be blended into the sand prior to placement. The initial unit cost estimate range for this application is $110,000 to $290,000 per acre for the bulk adsorbent material alone, and would be additive to the in situ cap costs presented in Section 4.4.3. The range includes pricing for the two amendment materials discussed in this section, and considers two different application quantities (3 percent by weight and 6 percent by weight). Other applications of in situ treatment include adding aggregate coated with adsorptive materials the surface sediments (e.g., AquaBlok), placing geotextile mats with a reactive core layer (e.g., AC) atop the surface sediments, or tilling in adsorptive materials into the surface sediments. Costs for the application of these technologies typically range from $265,000 to $835,000 per acre.

4.4.4.6 Summary

S/S and adsorptive amendments are both well-demonstrated technologies for immobilizing and sequestering dioxins and furans. S/S, where considered, would be applicable in relatively dry applications. Addition of adsorptive amendments can be successfully implemented in both shallow and deep water portions of the Site. Erosion resistant layers in the vessel traffic areas may prove effective in resisting propeller wash, but the thickness required may increase vessel draft restrictions. Also, areas in the NAV SMA where potential dredging could be required to maintain the channel depth could not be effectively treated for long-term remediation, as dredging events may encounter solidified sediments or remove the adsorptive amendment layer.

SMAs that experience net sedimentation, but may not meet the required remediation timeline by MNR alone, are candidate areas for in situ treatment; however, potential maintenance dredging for navigation purposes must be considered prior to implementation in the NAV SMA. As a result, this technology has been retained for further evaluation in the FS (Table 4-6).

Table 4-6
In Situ Treatment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
In Situ Treatment	Physical-Immobilization	Solidification/ Stabilization	Moderate to High[1]	High[1]	Moderate	Retained[1]
		Adsorptive Amendments	Moderate to High	High	Moderate	Retained

1. Ranking only applies for dry application, such as in use for intertidal sediments.

4.4.5 Removal

The two most common technologies for removing contaminated sediment from a water body are excavation and dredging (USEPA 2005). In this context, excavation refers to removal activities that are performed in the dry, after water has been diverted or drained from the removal area; dredging refers to removal activities that are performed while the sediment remains submerged. Both removal technologies, along with several associated process options, are discussed in more detail in this section.

Contaminated sediment removal can result in the least uncertainty with respect to the effectiveness of contaminant mass reduction of a remedy (USEPA 2005) and can usually provide increased flexibility in future uses of the waterway. However, removal results in greater short-term environmental impacts from contaminated sediment loss and resuspension than other remedial technologies. Removal can result in short-term water quality impacts from dredging releases that can increase fish and shellfish tissue concentrations (Bridges et al. 2010), and there are often post-dredging surface contamination issues associated with residual materials on the surface of the remediated area (NRC 2007). Contaminated sediment removal evaluations should also consider site

restrictions associated with existing structures that can limit the ability to remove all contaminated sediment within the waterway (USEPA 2005).

Contaminated sediment that has been removed requires processing that may include dewatering, offloading, transport, treatment, and disposal, each of which involves additional costs and the potential for further releases.

This RAM intends to provide a general overview of removal technologies. Detailed guidance manuals for environmental dredging of contaminated sediments have been developed by the USACE (2008b), the USEPA (2005), and the National Research Council (NRC 2007); the reader is referred to those documents for detailed information on environmental dredging for contaminated sediments.

4.4.5.1 Dry Excavation

Sediment excavation involves the use of excavators, backhoes, and other conventional earth moving equipment to remove contaminated sediment after water has been diverted or drained from the removal area (i.e., "in the dry" removal).

Diversion of water from the excavation area can be facilitated through the installation of temporary cofferdams, sheet piling, or other water management structures, followed by removal of surface water within the excavation area, which generally occurs via pumping. Following dewatering of the area, equipment can be positioned on the sediment bed within the excavation area or immediately adjacent to the dewatered excavation area.

Dry excavation in river systems has significant limitations that have been well documented (USEPA 2005; USACE 2008b; Bridges et al. 2010; Connolly et al. 2007) and it is not considered feasible for deep water areas in the River, particularly in the navigational channel with water depths that can extend deeper than 30 feet. The River also is an active navigation area for deep draft container ships and other shallower draft vessels. There may be limited areas near open shorelines where dry excavation potentially could be used, but for purposes of the RAM, dry excavation will not be evaluated further. However, it will be addressed in

more detail in the FS as a potential removal technology that may have limited application within the Site.

4.4.5.2 Dredging

Dredging is a method of excavation that allows the removal of sediments without water diversion or draining (i.e., "in the wet" removal). Hydraulic or mechanical dredging is generally accomplished using floating equipment.

Regardless of the dredging method and use of dredging BMPs, short-term water quality impacts and residual contamination post-dredging are inherent to the dredging process and require mitigation planning (USACE 2008a). Short-term water quality impacts from dredging releases can lead to increased fish and shellfish tissue concentrations. Dredging BMPs that are typically employed to help comply with water quality criteria include operational controls, barriers such as silt curtains, specialized dredging equipment such as closed buckets, and water quality monitoring.

All dredging projects result in some degree of resuspension, release, and residuals (NRC 2007). Residual contamination is defined as both contaminated sediment that remains un-dredged due to the inability to be 100 percent accurate in delineating all of the contaminated sediment, or contaminated sediment that was resuspended during dredging and that could not be fully captured (i.e., due to removal equipment limitations in preventing loss of sediment during the action of dredging). The need to address residual contamination post-dredging depends upon the concentrations and thicknesses of residuals remaining. However, empirical data from numerous sediment remediation projects indicate that residual contamination is a common occurrence and that sites with high concentrations are unlikely to achieve RALs with dredge technology alone (Patmont and Palermo 2007; NRC 2007).

Placing a thin clean sediment cover as a final step in the remediation process has been successfully used to manage residuals to achieve cleanup levels on the surface post-construction. For purposes of this RAM, the dredging alternative will assume that a residuals management cover would be placed in all areas where dredging occurs. In concept, this

would entail placement of a nominal 6-inch thickness of clean sand over areas that require residuals management.

4.4.5.2.1 Mechanical Dredging

Mechanical dredges have been used in the HSC and nearby waterways for sediment remediation projects; they are widely available. A barge-mounted crane can use different types of buckets or attachments to dredge or assist with demolition activities. Mechanical dredges can work in difficult-to-access areas and are relatively easy to reposition, thus reducing the potential impact to other waterway uses. However, mechanical dredges cannot effectively work under low clearance overwater structures to remove sediment and require several feet of water to provide sufficient draft for the floating equipment.

Mechanical dredges are designed to remove sediment at or near in situ density (USEPA 2005), though some amount of excess water is typically entrained in the dredge bucket as it closes and is lifted up through the water column. The quantity of water generated using mechanical dredging is orders of magnitude less than water generated with hydraulic dredging. Mechanical dredges can effectively remove consolidated sediment, debris, and other materials such as piling and riprap. Following removal, the mechanically dredged sediment typically requires processing. A typical "treatment or process train" for mechanical dredging (assuming landfill disposal) is shown below:

1. Dredge contaminated sediment
2. Place contaminated sediment in a haul barge
3. Passive dewatering on the barge
4. Transport contaminated sediment to either an on-site or off-site offloading/staging area
5. Offload sediment to a stockpile area for either passive or active dewatering
    - Dewatering methods may include working the sediment with standard earthmoving equipment, additives, filter or belt presses, hydrocyclones, or other methods
6. Treat effluent water from the stockpile and discharge to receiving waters or approved publically owned treatment works (POTW)

7. Transport contaminated sediment over land by truck or rail, or over water by barge
8. Dispose contaminated sediment at a landfill facility

Mechanical dredging is considered feasible for open-water areas because of its ability to effectively remove consolidated sediment, debris, and other materials such as piling and riprap and its ability to easily relocate during construction, thus reducing the potential impact to other waterway uses.

4.4.5.2.2 Hydraulic Dredging

Hydraulic dredging typically involves using a cutterhead or similar equipment to remove sediments from the sediment bed in a sediment/water slurry. This slurry is pumped through the dredge and transported via pipeline to a processing or disposal facility. Hydraulic dredging has been implemented at many contaminated sediment sites.

Relative to mechanical dredging, a significantly greater volume of water is entrained with the sediment slurry removed by the dredge and must be subsequently separated from the sediment solids and treated and discharged (USEPA 2005). The solids content of hydraulically dredged slurries typically averages about 5 to10 percent by weight, but it can vary considerably depending on sediment characteristics (i.e., specific gravity, grain size, and moisture content) and the depth and thickness of the dredge cut. In general, hydraulic dredges cannot remove rocks and large debris.

The hydraulically dredged slurry can be transported via piping directly to a staging/processing area that is typically land based. The hydraulic transport pipeline is typically a floating pipeline, which can interfere with vessel navigation. The staging area is ideally in close proximity to the dredge area due to the difficulties in placing, operating, and maintaining long distances of pipeline and may require a large footprint depending on the dredging production rate, as well as options used to dewater, process, stockpile, transload, and transport the dredged sediment. Limited space is available in the upland area close to the SMAs for the dewatering, rehandling, and transloading operations associated with hydraulic dredging.

Dewatering of hydraulically dredged sediments is required prior to transport and disposal of the sediment. Hydraulically dredged sediments can be dewatered using passive or active methods; this typically requires use of a large area for passive settling basins or geotextile tubes due to the relatively large volume of water added for slurry transport. Active dewatering methods may include filter or belt presses, hydrocyclones, or other methods; additives may be used to enhance dewatering by these methods.

The Lost Lake sediment management area is a large upland confined disposal facility operated by the PHA and the Galveston District USACE that would have sufficient space to manage a hydraulic dredging process. Current guidance for disposal of sediments from the Site and surrounding areas was developed by USEPA, USACE, and TCEQ (2009), and states the following:

- If sample >1000 ppt TEQ_{DF}, then disposal of sample's representative volume (or dredged materials) shall be in a hazardous waste landfill.
- If sample >33 ppt TCDD organic carbon normalized and <1000 TEQ_{DF}; or, >0.45 ppt TCDD non-organic carbon normalized and <1000 TEQ_{DF}, then disposal of sample's representative volume (or dredged materials) shall be in a hazardous waste landfill or upland confined disposal area.
- If sample <33 ppt TCDD organic carbon normalized; or, <0.45 ppt TCDD non-organic carbon normalized, then no restrictions on disposal location of sample's representative volume (or dredged materials).

There are not any sediment samples (surface or subsurface) outside of the TCRA Site that exceed 1000 ppt TEQ_{DF}; therefore, the Lost Lake upland confined disposal facility is technically available for disposal of hydraulically or mechanically dredged sediments from the Site. Access and other issues would need to be addressed with the PHA and the USACE.

4.4.5.3 Implementability

Dredging as a primary removal technology is considered to be technically implementable at the Site. However, tidal fluctuation may preclude dredging in nearshore areas that experience significant decrease in water surface elevation. Such impacts were observed during the implementation of the TCRA and affected armor cap installation (Anchor QEA

2011b). Mechanical and hydraulic dredging, as primary process options, are technically implementable in most of the SMAs. Most of the Site is unrestricted OW, and it is feasible to use conventional mechanical and hydraulic dredging equipment to dredge those areas. Areas with fixed structures may require a separate remedial technology.

For areas beneath the footprint of fixed structures, dredging using diver-assisted methods may be technically implementable, though this approach would present significant design and construction issues and would need to be evaluated in more detail during the FS. Dredging may need to be restricted adjacent to existing structures and slopes to avoid adversely impacting their stability. Table 4-2 summarizes critical site restrictions within the Site SMAs that may impact the ability to fully remove all contaminated sediment.

From an administrative standpoint, removal by dredging is considered to be implementable. The navigation channel has minimum water depths that dredging would help maintain. Removal by dredging has been accepted as a primary remedial technology on numerous contaminated sediment sites throughout the United States. Removal by dredging is considered to have a moderate rank for implementability, depending upon the various process options and due to critical site restrictions that may limit its use in certain SMAs. In addition, residuals management strategies are expected to be necessary in conjunction with dredging.

4.4.5.4 Effectiveness

Removal has been proven to be an effective technology for achieving cleanup goals when used in combination with residuals management. Each process option discussed above can be effective given the appropriate site conditions and must consider critical site restrictions. Removal technologies will not remove 100 percent of the contaminated sediment, leaving behind contaminated residuals. The residual sediment limits the risk-reduction of the remedy, and consequently, reduces the effectiveness of the dredging remedy (NRC 2007). Research has shown that residual sediment remaining on the post-dredge surface (typically ranging from 2 to 11 percent of the remaining contaminated sediment mass prior to the final production dredge pass) have been observed during most environmental dredging projects, particularly when targeted sediments overlie a layer of hard material (e.g., rock or till) and

where rocks/cobbles, logs, or other debris are present on the River bottom (USACE 2008a). Management of potential post-removal residuals, either by placement of a residuals management cover (sand, gravel, or stone) or natural recovery, is commonly considered in the evaluation of excavation or dredging as a removal technology. For all removal technologies, effectiveness is improved by application of a residuals management cover, and this RAM assumes that a residuals management cover will be placed in all dredged areas.

Removal by dredging can handle the estimated volume of contaminated sediment to achieve the surrogate RALs. Dredging is also considered to be a proven and reliable remedial technology and suitable for use for the Site. Dredging does result in release of contaminants during construction (i.e., dissolved or sorbed to suspended sediment particles) to the water column, and potential sediment transport will likely result in water quality impacts during dredging, even if the removal area is enclosed by turbidity control devices or other dredging BMPs are used. Whereas sediment turbidity impacts in the removal area can be minimized in certain applications through the use of BMPs, such as silt curtains, such BMPs have been demonstrated to be generally ineffective in areas with large tidal excursions and in generally reducing the release of dissolved contaminants from any site. Therefore, dredging technology is considered to have a ranking between moderate and high for effectiveness.

4.4.5.5 Cost

Dry excavation is not feasible for the entire Site, but potentially may be used in some nearshore areas. The cost for removal by dredging, both hydraulic and mechanical, is high. Removal costs include the cost of dredging and also all of the ancillary construction elements that are part of the overall "treatment or process train." These ancillary construction elements may include: 1)pre-dredge debris removal, 2) staging and stockpile area preparation, 3) dewatering, 4) water treatment, 5) sediment stabilization, 6) transport, 7) landfill disposal tipping fees (or other disposal technology costs), and 8) environmental monitoring.

Order of magnitude dredging costs were developed for the draft *Dioxin Treatability Study Literature Review* (Anchor QEA 2011a; Appendix A) and were included as part of the unit cost for ex situ treatment options. The "treatment or process train" costs evaluated included

mechanical dredging, monitoring, dewatering, and transloading; the total unit cost estimated was $73 to $87 per cubic yard (cy), not including off-site transport and tipping. In the case of hydraulic dredging, the total cost of dredging is highly dependent on the volume of material being dredged, and the process option selected for dewatering the dredged sediments. Hydraulic dredging of small volumes of sediment has a relatively high unit cost due to the mobilization and setup of the hydraulic dredge and pipeline. At larger volumes, the efficiency of the hydraulic dredge results in lower unit costs. For a conceptual 12-inch diameter hydraulic dredge pumping 70,000 to 500,000 cy of material to the Lost Lake site, the unit cost is estimated to range from $20 to $26 per cy including the measures that would be taken at the Lost Lake site to dewater the dredge material. Based on recent local contractor estimates for smaller volumes of material (30,000 cy or less), the unit cost could range from $60 to over $300 per cy for hydraulic dredging.

4.4.5.6 Summary

Sediment removal by dry excavation (in limited areas) or by dredging is retained as a potential remedial technology (Table 4-7) with the above-noted limitations.

Table 4-7
Removal Options Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Removal	Dry Excavation	Soil Excavators	Low	Moderate to High (in areas where it is implementable)	High	Not Retained
	Dredging	Mechanical Dredging	Moderate	Moderate to High	High	Retained
		Hydraulic Dredging	Moderate	Moderate to High	High	Retained

4.4.6 Ex Situ Treatment Technologies

Ex situ treatment describes those methods that require excavation of contaminated materials prior to immobilization, transformation, or destruction of COCs. Applicable treatment

technologies for the Site are discussed in the draft *Dioxin Treatability Study Literature Review* (Anchor QEA 2011a; Appendix A). The two classes of treatment technologies evaluated by the RAM are thermal treatment and chemical degradation. The following sections provide brief descriptions of the information presented in Appendix A, but focus largely on the screening of the candidate technologies. The reader is referred to Appendix A for full descriptions of the technologies.

4.4.6.1 Thermal Treatment

Thermal treatment technologies remove contaminants from soil and sediment by heat application at standard or negative pressure to volatilize contaminants. Volatized contaminants are then chemically altered under high temperatures by oxidation (combustion) or pyrolysis (thermal decomposition without oxidation). Thermal technologies are commonly used to treat contaminated waste. Advancements in the technologies have increased the safety and effectiveness of thermal treatment. The RAM reviews two technologies for application at the Site: 1) incineration, and 2) thermal desorption.

4.4.6.1.1 Incineration

Incineration of dioxin contaminated material requires high temperatures (in excess of 1200°F) of sufficient residence time (30 to 90 minutes) (USEPA 1998a). Air mixed with the volatilized organic contaminants undergoes an oxidation reaction to form carbon dioxide and water vapor. Incomplete oxidation of contaminants may produce other harmful byproducts if sufficient temperatures and residence times are not achieved; however, operating conditions (temperatures, residence times, contaminant inflow, and excess air flow) are carefully controlled to maximize the destruction of contaminants and minimize the generation of products of incomplete combustion (PICs). Any portion of the material that cannot be incinerated (fly ash) is removed from the system; off-gases are captured and treated by a scrubber system prior to atmospheric release.

Both the ash material produced and the off-gas released from the incinerator system are assessed for contaminant content. To be permitted, an incinerator facility must meet local, state, and federal requirements for emissions standards. This technology can be applied both on-site with a portable incinerator and off-site at a dedicated facility.

4.4.6.1.2 Thermal Desorption

In-Pile Thermal Desorption (IPTD) technology uses a heated negative pressure system to treat excavated/dredged contaminated soils and sediments. Reduced pressure lowers the temperature at which contaminants desorb and volatilize from the contaminated material. Excavated material is placed in piles or "cells" for treatment. Each cell is constructed above ground with a foundation, containment berms, insulating walls and cover, and treatment wells, which are used to heat and ventilate the cell.

Most dioxins are removed in-pile from the affected media by oxidation, pyrolysis, and volatilization. Dioxins begin to decompose at temperatures as low as 300°C to 400°C in a reduced-oxygen environment; therefore, a minimum temperature of 335°C is suggested for the treatment of dioxin-contaminated soils and sediments. Previous research indicates that thermal desorption is capable of removing 95 percent to 99 percent (or more) of the contaminant from the soil/sediment (Baker et al. 2006). The IPTD process has been proven to achieve a destruction and removal efficiency of greater than 99.9999 percent for dioxin-contaminated sites (Baker et al. 2009). Any other volatilized contaminants are extracted and treated outside of the piles.

4.4.6.2 Chemical Degradation

Chemical degradation technologies apply chemical and thermal processes to break down dioxins in contaminated soil and sediment. Treatment is achieved either through dechlorination by removing chlorine atoms from the dioxin molecules or through decomposition or volatilization of the contaminants (FRTR 2008). All of these technologies are applied to the contaminated media ex situ and require pre- and post-treatment to complete the process (e.g., dewatering, thermal desorption, debris removal, or reagent removal).

Anchor QEA (2011a; Appendix A) describes several chemical degradation technologies that may be considered for the Site: 1) Modified Alkaline/Potassium Polyethylene Glycolate (APEG/KPEG), 2) Solvated Electron Technology™ (SET), 3) Base-Catalyzed Decomposition (BCD), and 4) Photolysis; Appendix A concludes that both APEG/KPEG and Photolysis treatment technologies are infeasible for treating dioxin-contaminated sediments excavated

from the Site. As a result, these two technologies are not included in the alternatives screening. Based on the available information, neither chemical dehalogenation treatment technology (SET or BCD) appears to be currently available for full-scale implementation in the United States. As a result, these two process options are also not retained for further evaluation.

4.4.6.3 Implementability

Ex situ treatment operations for all process options requires a sizable on- or off-site treatment area to facilitate material handling, staging, treatment, and transport of excavated contaminated material. Space is limited at the Site as there are no berthing facilities or suitable locations for developing such facilities. As a result, a permitted off-site facility would be necessary to receive and dewater dredged sediments and allow for material transfer to truck or rail for transport to the treatment facility. The establishment of an on-site mobile treatment facility is not considered technically feasible, as the Site is located within a floodplain and there is a minimal amount of open space. Moreover, there are residential areas adjacent to the Site.

For technologies with no facility in the vicinity[14], an off-site facility would need to be established for treatment. The administrative feasibility of land acquisition and permitting may disqualify certain ex situ technologies. Several acres would be required to accommodate the treatment facility and ancillary operations, including stockpiles for untreated and treated soil, equipment storage, and off-gas treatment. Site access and security are also considerations for any treatment effort. Cooperation from local and state agencies would be necessary to create awareness of the treatment and to coordinate appropriate emergency contingency planning.

Implementation of ex situ treatment options requires dredging or excavation prior to treatment. As a result, the entire armor cap from the TCRA SMA would require complete

[14] An off-site incinerator facility capable of processing the sediments from the Site is located in Port Arthur, Texas, approximately 72 miles from the Site.

removal for the implementation of ex situ treatment of sediments in the footprint of this SMA.

Post-treatment processing and handling of decontaminated material or treatment byproducts require proper disposal or, if appropriate, placement as part of beneficial use programs. Water content of the sediments will affect the time and energy required for treatment. Therefore, dewatering the material prior to treatment may be necessary. This additional time constraint must be considered in light of the excavation production rate; the staging area required for dewatering the material, if necessary; and the amount of treatment cells capable of fitting on the treatment Site.

4.4.6.4 Effectiveness

All ex situ treatment technologies require removal of the contaminated material from the Site prior to treatment. The RAOs discussed in Section 3 would be achieved by the removal of the sediment from the aquatic environment. The effectiveness of ex situ treatments then refers to the ability of the technology to immobilize, transform, or destroy a contaminant prior to landfilling or final placement.

Incineration is capable of removing dioxins from contaminated media and chemically altering the dioxin to harmless constituents. Incinerators operating in compliance with environmental permits have been shown to effectively and safely treat soil, sediment, and debris contaminated with dioxin and related compounds.

The IPTD treatment is capable of destroying the dioxin present in the sediment. The treated sediment could be beneficially reused, unless there are additional contaminants that are resilient to thermal desorption, such as heavy metals (Baker 2011b). This technology has been successfully applied to four dioxin-contaminated sites: 1) Yamaguchi, Japan; 2) Alhambra, California; 3) Cape Girardeau, Missouri; and 4) Ferndale, California. The Cape Girardeau, Missouri, and Yamaguchi, Japan, sites were demonstration-scale tests, while the remaining two were full-scale applications (Baker 2011a). The maximum average pre-treatment TEQ concentration in picograms per gram (pg/g) for these four sites was 18,000 pg-TEQ/g (Alhambra, California), which was reduced to an average concentration of 110 pg-

TEQ/g (Baker 2011a). Treatment at this site achieved the target concentration levels, and post-treatment, the California Department of Toxic Substances Control issued a No Further Action letter and did not place any restrictions on the land usage (Baker et al. 2007; Baker 2011b).

4.4.6.5 Cost

Treatment costs for incineration were obtained from the Veolia facility. The waste would be transported to the facility in roll-off boxes. The unit cost for incineration is $900 per ton, and the roll-off boxes must meet a minimum requirement of $5,000 per shipment (Stringer 2011). Treatment costs for water removed from the sediment were also obtained from Veolia. If the water contains less than 5 percent solids, it can be delivered in a vacuum tanker truck and the treatment cost is approximately $300 to $500 per ton (Stringer 2011). Water containing greater than 5 percent solids, along with sludge material, can be transported to the facility in a vacuum box, which would have a unit cost of $900 per ton (Stringer 2011).

Treatment costs for IPTD are estimated based on information provided by TerraTherm. The estimated cost to treat dioxin-contaminated sediments is $250 to $500 per cy (Baker 2011b). If a unit weight of 1.4 tons per cy were assumed for the material, then the unit cost range would be $350 to $520 per ton. These figures are a generalization and do not represent an actual quote for services. The unit cost provided is a “turnkey” cost, which includes design, equipment, and implementation.

Additional costs for dredging, decontaminating, dewatering, offloading, rehandling, and transport of the material are not included in this unit cost. Also, the costs for establishing an intermediary transloading facility and an off-site treatment location for IPTD have not been included in the above-noted unit costs.

4.4.6.6 Summary

On-site treatment processes are limited by space and lack of infrastructure. Ex situ operations require additional upland treatment facilities. Ex situ treatment technologies address the risks associated with the contaminated sediment by removing the sediment from the aquatic environment and transferring the risk to upland operations in the subsequent

transport, handling, and treatment of the contaminated material. Incineration is a viable ex situ treatment option that has been shown to effectively and safely treat soil, sediment, and debris contaminated with dioxin and related compounds (Table 4-8). In general, these technologies are applicable for any of the SMAs at the Site where dredging operations can occur.

Table 4-8
Ex Situ Treatment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Ex Situ Treatment	Thermal	Incineration	Moderate	High	High	Retained
		Thermal Desorption	Low	High	High	Not Retained
	Chemical Dehalogenation	SET	Low	Moderate	High	Not Retained
		BCD	Low	High	High	Not Retained

4.5 Preliminary Disposal Technologies

One or more disposal technologies would be required if sediment is removed from the River. Disposal may follow ex situ treatment or untreated sediment may be placed into a secure disposal site to control exposure to COCs and to address RAOs. Disposal technologies are divided into three broad categories: 1) aquatic disposal, 2) upland disposal, and 3) beneficial reuse—that are discussed and evaluated in the following sections.

4.5.1 Aquatic Disposal

Aquatic disposal includes those technologies that involve placing sediment in an engineered containment unit in the water, as well as uncontained in-water disposal. Confined aquatic disposal (CAD) facilities and nearshore confined disposal facilities (CDF) are engineered containment units designed to resist erosion and other forces that could lead to the release of confined sediment. The design of such facilities also includes an evaluation of potential migration of COCs from the confined sediment to groundwater and surface water. Enhanced confinement can be designed into the disposal unit if necessary to control the release of COCs. Because of the limited surface area of the potential on-site CAD and nearshore CDF,

which limits the retention time for solids to settle out of the dredged slurry, these disposal technologies would be coupled with mechanical dredging, which would place the disposed material at a lower rate and with a higher solids content. Solids would likely not have enough surface area necessary to settle out if the disposal sites are filled hydraulically.

4.5.1.1 Confined Aquatic Disposal

CAD facilities are constructed in water with the completed surface of the cap of the facility below water. Dredged sediments are placed in a naturally occurring depression, in an excavated cell, or in an area segregated from surrounding surface waters by a submerged berm or other containment structure. The CAD is capped with clean material and an erosion-resistant layer, if needed, after the contaminated sediment is placed.

For the purpose of this screening evaluation, a hypothetical CAD facility concept was developed in the deep water to the northwest of the TCRA SMA. The location of the hypothetical CAD facility is shown on Figure 4-9. This concept is illustrated in plan view in Figure 4-10 and in the section view in Figure 4-11. The CAD facility would be developed by constructing a containment berm in the location shown on Figure 4-10 to create a disposal cell. After placing dredged sediment to an elevation of approximately -6 feet NAVD88, a 5-foot-thick cap consisting of an isolation layer, an armor layer, and a habitat layer would be placed over the confined sediment, resulting in a final elevation of approximately -1 feet NAVD88. The volumetric capacity of the hypothetical CAD would be approximately 160,000 cy ignoring potential capacity gained by consolidation settlement of the native sediment. The surface of the CAD would be planted with wetland vegetation to enhance habitat quality and enhance the erosion resistance of the cap.

4.5.1.2 Nearshore Confined Disposal Facility

Nearshore CDFs are similar to CAD facilities except that the surface of the cap is completed above the waterline. For nearshore CDFs, a disposal cell is created by building a berm or other barrier from the shoreline to isolate the cell from adjacent surface water. The cell is then filled with contaminated material up to the water line. Following the placement of contaminated sediment, a cap of clean material is placed to a final elevation that is above the water line.

A hypothetical new CDF concept was developed for this screening evaluation. The location of the hypothetical new CDF is shown on Figure 4-12 and is essentially the same footprint as the CAD facility described in the previous section. The difference between these two concepts is that for the CDF, dredged sediment would be placed to an elevation of -3 feet NAVD88, increasing the capacity of the facility by approximately 60,000 cy. The dredged sediment would be covered with an isolation layer consisting of 2 feet of clean sand and an armor layer consisting of 1 foot of stone sized to resist erosive forces. A typical section of the hypothetical CDF is shown in Figure 4-13. The volumetric capacity of the hypothetical CDF would be approximately 225,000 cy, ignoring potential capacity gained by consolidation settlement of the native sediment.

4.5.1.3 Open-Water Disposal

Open-water disposal involves placing dredged sediment in water without creating a disposal cell and without placing a cap to contain the sediment. This form of disposal is used for disposal of uncontaminated sediment, such as sediment from maintenance dredging. Open-water disposal is generally inappropriate for managing contaminated sediment. As the remedial action is not expected to include dredging uncontaminated sediment, open-water disposal has been screened from further consideration and will not be carried forward into the FS.

4.5.1.4 Implementability

CAD options are generally readily implemented, provided that appropriate locations are available near the location to be dredged. Appropriate locations for CAD facilities have sufficient water depth to accommodate the volume of sediment requiring confinement plus a protective cap while being able to accommodate flow and navigation, as appropriate. Areas that require periodic dredging to maintain a channel depth may be inappropriate for siting a CAD. Areas that do not require maintenance dredging can be appropriate locations for a CAD, and the completed CAD may provide shallow-water or wetland habitat that is environmentally beneficial. Agency approval may be more readily obtained for a CAD facility located on-site because of the waiver from permitting and other administrative requirements contained in Section 121(e) of CERCLA for on-site response actions.

The River has been identified as a waterway that is subject to flooding, and regulations are in place to restrict the placement of fill in the River. Dredging from one part of the River and disposing of sediment in another part of the River may be accomplished with no significant loss of hydraulic capacity for flood water. A hydrologic evaluation may be necessary to evaluate the potential impacts of creating an aquatic disposal facility. Regulatory approvals would be required for dredging and filling.

As discussed above, the Lost Lake sediment management area is an existing and permitted nearby upland CDF that could be utilized for disposal of material with TEQ_{DF} concentrations that are less than 1000 ppt if approved by the PHA and USACE.

4.5.1.5 Cost

A preliminary cost estimate for in-water disposal was prepared considering the costs to develop the in-water CAD illustrated in Figures 4-9 and 4-10, place dredged sediment in the CAD, and close the CAD with the multilayer cap shown schematically in Figure 4-10. The cost estimate includes costs to monitor water quality during the operation of the CAD. The estimated unit cost for in-water CAD disposal is $50 to $75 per ton, assuming the full capacity of 160,000 cy is used. A similar estimate was developed for the nearshore CDF concept assuming the full volume of 225,000 cy is used. The estimated unit cost for nearshore CDF disposal is $40 to $60 per ton.

4.5.1.6 Effectiveness

CADs and CDFs can effectively contain contaminated sediment and COCs. The design of the facility would consider hydrodynamic forces that may erode containment berms and caps, and materials of construction would be selected to prevent erosion. Potential long-term movement of COCs in groundwater would be evaluated to confirm that the confined sediment would have no significant impacts on groundwater or surface water quality. Techniques for building the containment facility, placing dredged sediment, and closing the facility would be evaluated to select methods of construction and operation that would minimize short-term water quality impacts. BMPs would be used to minimize impacts on water quality and, if necessary, to mitigate for unavoidable impacts.

4.5.1.7 Summary

In-water disposal, in a CAD or CDF, is a well-established and viable method for secure, long-term containment of dredged sediment. The effectiveness of this technology has been demonstrated on many contaminated sediment sites. Prior to implementing a remedy involving in-water disposal, evaluations may be required to demonstrate that the disposal unit will effectively contain COCs and will not adversely affect flooding, and that exterior surfaces of the disposal unit (e.g., cap or containment berms) will effectively resist erosion. In-water disposal offers several advantages compared to other disposal methods, including shorter transportation from the dredge location to the disposal site and not having to transfer sediment from barges to upland transportation.

4.5.2 Upland Disposal

There are two types of upland disposal considered. The first is a licensed municipal landfill. The second is an upland CDF, such as Lost Lake. As discussed in Section 4.4.5.2.2, the Lost Lake sediment management area operated by the PHA and USACE is a nearby upland CDF that could be used for sediment disposal from the Site under current guidance. Upland disposal at a municipal landfill would involve dewatering the sediment and trucking it to a landfill for secure disposal in a lined engineered cell that would be capped upon completion. Landfills are designed to prevent the release of COCs into soil, groundwater, and surface water, and groundwater near landfills is monitored to confirm that groundwater quality is protected. Landfill operators are required to obtain permits issued by state agencies; materials from CERCLA sites can be taken only to landfills operated in compliance with their permits (Off-Site Rule, 40 CFR 300.440).

4.5.2.1 Landfill Disposal

Sediment dredged from the Site would be taken by barge to a processing and transloading facility where the sediment would be dewatered and loaded onto trucks. If disposal at a more distant landfill than the two discussed in this document is necessary, then rail transport may be more cost-effective than truck transport. Loading sediment onto rail cars would require more space at a transfer facility and may require the extension of a rail spur to a dock. Therefore, this option would be feasible only if a large volume of sediment is to be disposed of at a landfill remote from the Site.

The sediment could be dewatered on barges and loaded directly onto trucks if space is not available at an upland facility to stage and dewater the sediment. Dewatering would consist of draining the water that readily separates from the sediment and then amending the sediment to absorb sufficient residual moisture to allow transportation and disposal of the sediment without releasing potentially contaminated water. A variety of amendments have been used for dewatering sediment, including Portland cement, fly ash, diatomaceous earth, and a variety of cellulose-based materials. The water that would be drained from the sediment in the first stage of dewatering could be treated, if necessary, and released to surface water in compliance with a permit or collected and transported to a permitted wastewater treatment facility. One of the disadvantages of amendments is that it increases the weight (and therefore cost) or material to be disposed.

During TCRA construction two landfills were used to dispose of debris from the Site. In addition to these potential landfills, other upland permitted landfill facilities will be evaluated for use as potential disposal sites in the FS. Potential disposal sites will have to be properly permitted and approved by the USEPA prior to use.

4.5.2.2 Upland CDF Disposal

Dredged sediment could be transported by barge to the Lost Lake facility and transferred from barges into the disposal cell using a high-solids pump. Alternatively, for a hydraulic dredging process option, the dredged material would be pumped via pipeline from the dredge area directly to the disposal area, using a booster pump, if necessary. Unlike disposal in a commercial landfill, disposal in the upland CDF would not require the transportation of sediment from the Site on public roadways.

4.5.2.3 Implementability

Upland disposal in a landfill or a CDF is a very common method for disposal of dredged sediment. Several landfills are located within a short distance of the Site, and two facilities that are permitted to accept material from CERCLA response actions have already received debris and vegetation from the Site during the TCRA. It will need to be determined during the FS whether these facilities have internal administrative limitations on their acceptance of dioxin-contaminated sediment. The challenging aspect of upland disposal for this Site will

be identifying and permitting a transfer station for offloading sediment from barges, dewatering sediment, and loading sediment onto trucks for transportation to the landfill. The transload facility will need to have a dock with sufficient water depth to accommodate barges of sediment and sufficient upland area for staging dewatering amendment, dewatering sediment, loading trucks, managing truck traffic, containing decant water and, potentially, treating the water for discharge. Transloading would not be necessary for disposal at the upland CDF. As discussed in Section 4.4.5.2.2, the Lost Lake sediment management area is already approved to accept most sediment that might be removed from the Site.

4.5.2.4 Cost

A preliminary cost estimate for upland disposal was prepared considering the costs to develop the transfer facility, offload sediment from barges, dewater the sediment, and transload the dewatered material to trucks for transportation and disposal. The cost estimate includes costs to monitor water quality during the operation of the transfer facility. The estimated unit cost for transportation and upland disposal at a commercial landfill is $80 to $100 per ton. Transport and disposal at an upland CDF, such as Lost Lake, is discussed as part of, and included in, the unit cost for hydraulic dredging described in Section 4.4.5.5.

4.5.2.5 Effectiveness

Landfills provide secure, permanent containment of waste. The effectiveness of liners and leachate collection systems have been well documented and the COCs in the sediment from the Site have low mobility that will be further reduced by dewatering the sediment. The effectiveness of landfill containment systems is monitored as stipulated in landfill operating permits.

The transportation of sediment from the dredge site to the landfill has potential for short-term impacts associated with release of COCs due to accidental spills of material, additional truck traffic on roads from the transload facility to the landfill, and emissions from trucks and other equipment used to load and transport sediment. BMPs can be used at all stages of transportation to reduce the potential for accidental releases of contaminated material. Some examples of potential BMPs are:

- Sealing transport barges to contain water and sediment.

- The use of a spill apron between the dock and barge to catch material dropped from transfer buckets and direct spills back to the barge or into the contained upland facility.
- The use of pavement and curbing in the truck loading area, entrance, and exit to provide secondary containment for material in the transload facility.
- The use of an enclosed box to provide primary containment of contaminated material in the transload facility and a location for mixing sediment with dewatering amendment.
- Inspection of trucks for spilled material on the exterior of the truck body or on tires, and tires and the use of a wheel wash, if necessary, before the truck leaves the transload facility.
- Regular sweeping and washing of the truck loading area and approaches to remove spilled material and minimize the potential for such material being picked up and spread by tires.

CDFs provide effective containment of sediment and COCs. The waste acceptance criteria developed for the Lost Lake facility determined that sediments such as those that may be removed from the Site can be effectively contained in the facility. Since disposal in the upland CDF would not require transloading sediment from barges onto trucks or transporting sediment on public highways, many of the considerations discussed in the preceding paragraph would not apply to remedial alternatives that would incorporate disposal at the Lost Lake sediment management area.

4.5.2.6 Summary

Upland disposal in a commercial landfill or an upland CDF is a well-established and viable method for secure, long-term containment of dredged sediment. Upland disposal would occur in an existing permitted facility; therefore, a new disposal site would not need to be developed before remedial action could begin, and the disposal site owner would be responsible for long-term maintenance and monitoring of the facility.

For landfill disposal, a transfer facility would need to be developed to transload sediment from barges to trucks, but an existing facility (such as the LaBarge facility used during the

TCRA) may be adapted for this purpose provided that the facility has sufficient available space to accommodate operations. The transfer facility would be decontaminated and closed at the end of the remedial action, so there would be no need for long-term maintenance or monitoring. Upland disposal would require trucking dredged sediment from the Site to the disposal facility, which would increase short-term risks associated with increase truck traffic, exhaust emissions, and potential release of contaminated material on public roads.

4.5.3 Beneficial Use

Dredged sediment is sometimes used as fill in the aquatic environment, such as for beach or wetland renourishment, or in upland areas where fill is needed to achieve desired topographic contours. Sediment for beneficial use must meet certain criteria for soil type (e.g., grain size) and contaminant concentrations depending on where and how the fill is proposed to be used. The sediment that may be dredged from the Site is not expected to meet criteria for beneficial use. Therefore, this disposal technique has been screened from further consideration in the FS.

4.5.4 Summary of Retained Remedial and Disposal Technologies

Remedial alternatives that include sediment removal will require one or more disposal technologies for permanent placement of the sediment. In-water and upland disposal options are both potentially feasible and will be evaluated in the FS. In-water disposal options offer advantages associated with close proximity to the sediment-removal location: 1) fewer handling steps (no transload to upland transportation), 2) reduced fuel use and emissions associated with transportation, and 3) less potential for releases of contaminated material in transportation. The upland disposal options offer the advantages of essentially unlimited capacity, not having to build a disposal facility, and long-term monitoring being performed by the commercial landfill that would accept the sediment. Additional considerations that may need to be evaluated in the selection or design of disposal options are the potential for in-water disposal units to affect the flow in the River, potential erosive forces that in-water disposal unit would need to resist, and the ability of in-water disposal units to contain COCs. Table 4-9 provides a summary of the preliminary disposal options screening.

Table 4-9
Disposal Options Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Disposal/ Reuse	Aquatic Disposal	Confined Aquatic Disposal (CAD)	Moderate	Moderate to High	Low to Moderate	Retained
		Nearshore Confined Disposal Facility (CDF)	Moderate	Moderate to High	Low to Moderate	Retained
		Open-Water Disposal	N/A	N/A	N/A	Not Retained
	Off-Site Upland Disposal	Confined Disposal Facility/Landfill	Moderate	High	Moderate to High	Retained
		Beneficial Use	N/A	N/A	N/A	Not Retained

4.6 Summary of Remedial and Disposal Technology Screening

Table 4-10 provides an overall summary of the remedial technology and disposal option screening results discussed in this section. The retained technologies and options will be used to assemble alternatives for further evaluation, and ultimately for more detailed consideration during the FS and remedial design.

Table 4-10
Remedial Technology and Disposal Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Institutional Controls	NA	NA	Moderate	Moderate	Low	Retained
Natural Recovery	Monitored Natural Recovery	Sedimentation	High	High	Low	Retained
		Placement of thin layer of clean cover	Moderate to High	High	Low to Moderate	Retained
In Situ	Capping	Conventional	Moderate	High	Moderate	Retained

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Containment		Low-Permeability	Low	High	Moderate to High	Retained
In Situ Treatment	Physical-Immobilization	Solidification/ Stabilization	Moderate to High[1]	High[1]	Moderate	Retained[1]
		Adsorptive Amendments	Moderate to High	High	Moderate	Retained
Removal	Dry Excavation	Soil Excavators	Low	Moderate to High[2]	High	Not Retained
	Dredging	Mechanical Dredging	Moderate	Moderate to High	High	Retained
		Hydraulic Dredging	Moderate	Moderate to High	High	Retained
Ex Situ Treatment	Thermal	Incineration	Moderate	High	High	Retained
		Thermal Desorption	Low	High	High	Not Retained
	Chemical De-halogenation	SET	Low	Moderate	High	Not Retained
		BCD	Low	High	High	Not Retained
Disposal/ Reuse	Aquatic Disposal	Confined Aquatic Disposal (CAD)	Moderate	Moderate to High	Low to Moderate	Retained
		Nearshore Confined Disposal Facility (CDF)	Moderate	Moderate to High	Low to Moderate	Retained
		Open-Water Disposal	N/A	N/A	N/A	Not Retained
	Off-Site Upland Disposal	Confined Disposal Facility/Landfill	Moderate	High	Moderate to High	Retained
		Beneficial Use	N/A	N/A	N/A	Not Retained

1. Retained for consideration for relatively dry intertidal areas, but not for submerged sediments.
2. In areas where implementable.

5 IDENTIFICATION AND SCREENING OF SITE-SPECIFIC REMEDIAL ALTERNATIVES

This section provides descriptions of the various preliminary remedial alternatives, including considerations related to process options for each alternative. Where appropriate, alternatives are screened from further detailed consideration in the FS. The discussion developed in this section is focused on sediment because, as previously discussed, both soil and groundwater media alternatives are limited to NFA and Institutional Controls at this time. Additional information under development for the RI will be considered in the final evaluation of alternatives.

A more detailed evaluation of remedial alternatives will be performed for the FS, including a comparative evaluation of alternatives. This detailed evaluation will include consideration of CERCLA Threshold Criteria of: 1) overall protection, 2) compliance with ARARs, 3) balancing criteria of long term effectiveness, 4) reduction of toxicity, mobility, or volume, 5) short-term effectiveness, 6) implementability, 7) cost and modifying criteria 8) state acceptance, and 9) community acceptance per 40 CFR Section 300.430(e)(9). As part of the short term effectiveness evaluation, USEPA Region 6 Clean and Green Policy (USEPA 2009b), as well as potential impacts to worker health and safety will be considered for each alternative.

5.1 Preliminary Remedial Alternatives Development

Preliminary remedial alternatives were developed based on the prospective RALs identified in Section 3, and the resulting SWAC associated with each RAL. Broadly, for each SWAC, two preliminary remedial alternatives were developed: 1) one that is removal-focused, and 2) one that is integrated-focused.

Removal-focused alternatives emphasize sediment removal, where practicable, and the disposal of the sediments using one of the options described in Section 4. The removal-focused alternatives include selective containment of certain sediment, as necessary, depending on Site-specific factors, such as infeasibility of removal in certain areas. Integrated-focused alternatives will primarily consider containment of sediments, where practicable, with selective removal, as necessary, depending on Site-specific factors.

5.1.1 Removal-Focused Alternatives

Removal-focused alternatives assume the following:

- For areas where sediments need to be addressed in the surface interval only, removal where practicable would entail dredging of a nominal 6-inch thick layer of sediments.
- Where subsurface sediments need to be addressed, removal would target the deepest interval necessary to achieve the SWAC of interest.
- Residuals management would be performed, where necessary, by placing a nominal 6-inch thick layer of clean sediment on the surface of the dredge prism.

Preliminary volumes were developed using the Thiessen polygons to determine the removal area, and multiplying the area by the thickness of removal. A 1-foot overdredge was assumed for all dredge areas. This volume was further scaled up by a factor of 1.3 as a contingency to account for potential additional volume related to side slopes and engineering factors that would be considered during the design phase. The FS may recommend additional data collection for final design work of any alternatives that are carried forward into the ROD.

5.1.2 Integrated-Focused Alternatives

Integrated-focused alternatives assume the following options would be carried forward into the FS:

- Natural recovery/enhanced natural recovery, which may entail placement of a thin layer of clean sediment over the existing surface to accelerate the rate of natural recovery.
- Containment capping, which would entail placement of a suitable thickness of clean sediment over the existing surface to isolate and contain contaminants. This alternative may entail the use of a surface armor layer of larger-sized aggregate for areas where current or propeller wash forces need TBC.
- Treatment, which would entail the use of AC or other similar measures, as either an amendment to cap substrate, or in direct application to sediments to reduce the bioavailability of contaminants.

For containment capping, the required thickness of the cap would be determined during remedial design based on standard methods developed by USEPA (USEPA 1998b). The use of thick caps over broad areas would need to be evaluated relative to net changes in the floodplain and potential resulting impacts to flood elevations in areas where the cap might not induce significant settlement of surface sediments (and thus would potentially raise the bed elevation in the River).

AC treatment has been demonstrated to be effective across a broad range of sediment contaminant concentrations and as such may be considered for use for both lower- and higher-concentration areas. The appropriate selection and application of a technology such as AC would be more fully evaluated during the FS.

5.1.3 Buried Deposit Locations

In some locations, buried sediments exceed prospective RALS. In some cases, these locations are covered by clean sediment, whereas other locations are coincident with surface TEQ_{DF} concentrations that would need to be addressed to achieve the target SWAC. This section describes the specific considerations that were identified for these locations when assembling potential alternatives. The locations of these cores are depicted on Figure 5-2 through 5-4 for the alternatives where they would be considered.

Core SJNE007. TEQ_{DF} concentrations at this core location exceed the 25 and 50 ppt prospective RAL at depths of 5 and 4 feet below mudline, respectively (Figure 2-17). Based on the sediment transport modeling described in Section 3, this area is net depositional. However, this is a NAV SMA due to the barge fleeting that occurs in the area. Thus, capping was not considered under the RAM in this location due to potential navigation conflicts. More detailed consideration of location SJNE007 would be performed during the FS and design to identify water depth requirements and potential cap thickness requirements to evaluate whether dredge and cap alternatives might be appropriate.

Core SJNE026. TEQ_{DF} concentrations at this core location exceed the 25 and 50 ppt prospective RAL at depths from 2 to 3 and 0 to 2 feet below mudline, respectively (Figure 2-17). However, the TEQ_{DF} concentration in the 0 to 6 inch grab of surface sediments at this

location do not exceed prospective RALs (Figure 2-15). The sediment transport model predicts that this area is net depositional, and this location is not within active navigation corridors. Because deposits are buried at this location and the surface is clean and predicted to be stable, active remediation measures were not considered under either the removal or the integrated focused scenarios.

Core SJNE032. TEQ_{DF} concentrations at this core location exceed the 100 ppt prospective RAL at a maximum depth of 6 feet (Figure 2-17). The surface sediment also needs to be addressed to achieve post-remedy SWACs TEQ_{DF} of 11 or lower. This area is predicted to be net depositional; however, in cases where surface sediments need to be addressed, active management is considered necessary to also address buried deposits. Further evaluation of dredge and cap alternatives will be performed during the FS and design at this location. For purposes of the RAM, removal was assumed to a depth of 6 feet under removal-focused alternatives where surface sediments are also being addressed. Under integrated management-focused alternatives, capping was assumed for this area.

Core SJNE033. TEQ_{DF} concentrations at this core location exceed the 25 and 50 ppt prospective RALS from 2 to a maximum depth of 8 feet. The top 2 feet of surface sediment contain less than 25 ppt TEQ_{DF}, but this area is predicted to be net erosional. Thus, active management is considered necessary to address buried deposits. Further evaluation of potential depth of scour will be performed during the FS to determine whether natural recovery or capping would be sufficient measures to address sediments at this location. For purposes of the RAM, removal was assumed to a depth of 8 feet under removal-focused alternatives. Under the integrated-focused alternatives, capping was assumed for this area.

Cores SJGB013, 014, and 016. These cores were located in the footprint of the TCRA Site. These locations were subject to a TCRA and, as such, warrant special consideration. For example, prior to the TCRA, these areas may have been net erosional; however, post-TCRA they are not subject to erosion because of the placement of the engineered cap. In addition, the TCRA resulted in a clean surface at these locations. Specific additional considerations for preliminary remedial alternatives in the TCRA SMA are discussed in Section 5.2. These considerations apply to buried deposits within the TCRA SMA. Therefore, this area is considered stable and active remediation is not required.

Table 5-1 summarizes the location-specific considerations for buried deposits.

Table 5-1
Considerations for Buried Deposit Locations

Location	Clean Surface	Net Depositional	Net Erosional	Navigation Area	Considerations
SJNE007	Note 1	✓		✓	Consider removal only for the RAM when prospective RAL is exceeded. Evaluate dredge and cap opportunities during FS and design.
SJNE026	✓	✓			No active management assumed for RAM.
SJNE032		✓			Address surface impacts, as necessary. For removal scenarios, remove to depth of impact. Evaluate dredge and cap opportunities during FS and design. For integrated management scenarios, cap.
SJNE033	✓		✓		Address surface impacts, as necessary. For removal scenarios, remove to depth of impact. Evaluate dredge and cap opportunities during FS and design. For integrated management scenarios, cap.
SJGB013, 014, and 016	TCRA Site – see text				

1. Surface sediments at location SJNE007 would require active management under Alternative 1, but not under Alternatives 2, 3, or 4.

5.1.4 Time Critical Removal Action Site Remedial Alternatives

There are several alternatives that could be considered for further remediation of materials contained within the footprint of the TCRA, if it is found that post-TCRA Site conditions warrant such action. In situ treatment of materials isolated by the armored cap could involve adding adsorptive media, such as AC, to the armor cap, to limit the potential transport of dissolved COPCs. This treatment method may require placement of additional materials on top of the armored cap.

Ex situ treatment of the contaminated materials at the TCRA Site would require the removal of all installed TCRA stabilization components (i.e., geotextile, geomembrane, and armor rock material), in addition to the potentially contaminated material beneath the armored

cap. It is anticipated that the means and methods necessary for the satisfactory deconstruction and removal of the TCRA armor cap would be similar to the construction methods described in the RACR (Anchor QEA 2011b). During the course of removal operations, especially water-based, implementation of best management practices (BMPs) would be needed to prevent the resuspension and release of contaminated materials from the work area. Because of the high concentrations of some of the materials beneath the armored cap, it is likely that any excavation of those materials could involve removal in dry conditions. This would involve installation of temporary sheet piles, dewatering, and potential water treatment prior to, and during removal. Additionally, prior to off-site transport, the removed TCRA stabilization components may require temporary storage in lined containers or barges suitable for storing and transporting contaminated materials.

As discussed in Section 1.2, a portion of the Western Cell was stabilized prior to installing the armor cap. The stabilization was performed to reinforce the upper layers of soft soils, which allowed construction equipment to access the interior portion of the cell. The stabilization treatment also likely reduced the mobility of the contaminants by reducing the overall permeability of the materials; although, testing was not performed to determine the degree of immobilization that was achieved.

If the TCRA armor cap and associated geotextile and geomembrane are removed from the Site, each would require proper disposal or treatment. As part of the removal operations, it would be necessary to establish an off-site facility for staging and decontamination areas to receive and process the armor rock. The staging and decontamination areas would be constructed to capture run-off generated by drainage and decontamination operations. Additionally, as a protective measure, containment berms lined with polyethylene sheeting could be used to contain rinsate spillage. The staging and decontamination facility would have adequate dock space for equipment to unload the armor rock, sufficient interior space to allow for equipment to manage segregated stockpiles, before and after treatment, and a loading area for trucks transporting the material to off-site disposal.

Proper methods for decontaminating the armor rock are not presented in this evaluation. Depending on the facility's containment capabilities, high-pressure washing or low-pressure flushing may be appropriate methods for decontaminating armor stone. The run-off would

require proper handling (e.g., vacuum trucks) and treatment. Following decontamination, the armor rock may be placed in an approved landfill for disposal if it could not be reused at the Site.

Depending on the method selected (i.e., in situ or ex situ), the contaminated material would either receive treatment on-site, or be excavated for treatment at an approved off-site facility. Section 3 describes both types of treatment implementation methods.

5.1.5 Technology Summary

Section 4 screened different technologies with Table 4-11 presenting the technologies carried forward for the alternatives development. This section further refines the technologies by SMA allowing development of the remedial alternatives. Below, removal and containment limitations in some SMAs are further discussed. The section concludes by summarizing technologies by SMA.

5.1.5.1 Natural Recovery Constraints by SMA

Natural recovery is an ongoing process occurring at the Site, as described in Section 4.4.2. As such, MNR is a technology that is applicable for all areas of the Site and is not constrained by SMA type. EMNR entails the placement of a thin layer of clean material to accelerate the natural recovery process. Placement of EMNR material is not expected to be compatible with active navigation areas that may be subject to propeller wash forces, because loss of the material would occur and preclude the effectiveness of the clean material. Thus, EMNR would not be considered in SMAs identified as NAV.

5.1.5.2 Removal Constraints by SMA

Due to implementability issues, removal is not a practicable alternative for all areas of the Site. Areas beneath fixed structures (ST SMAs) are typically very difficult to access and might require complete demolition and replacement of the structure to facilitate removal. Alternatively, removal might compromise the structural integrity of structures as sediment is removed and passive resistance for foundation elements is reduced. Thus, for SMAs delineated as ST, removal would be impracticable and capping would be selected instead.

The TCRA SMA has unique effectiveness and implementability issues associated with removal, as discussed in Section 5.1.4. As part of the TCRA, an armored cap was constructed over the TCRA SMA by placing a geotextile and varying thickness of processed concrete or rock aggregate (Anchor QEA 2011b). Thus, removal in this area would require excavating this rock and geofabric to access the underlying sediments. Such an excavation is expected to be problematic for a number of reasons:

- Short-term environmental impacts related to removal would be significant. As was demonstrated during the TCRA (Anchor QEA 2011b), effective containment of surface water through the use of silt curtains is difficult to achieve in the River[15]. Loss of high-concentration sediments from the TCRA SMA could potentially spread contamination well beyond the area of work.
- The effectiveness of removal in the TCRA footprint would be limited, at best. Significant residuals could be expected from this type of excavation. As has been reported in the remedial design guidance (USEPA 2005; USACE 2008a, 2008b), and in NRC (2007), a relatively high residuals loss can be expected when encountering hard bottom conditions or conditions where the dredge bucket cannot fully close (such as when excavating rock).
- Implementability challenges would be expected. Excavation would be difficult due to the dense nature of the rock, and access to the shallow water areas in the TCRA footprint would be limited. The dense rock would potentially require larger marine equipment that could only work during high tide periods, which would substantially increase the overall duration of the work, and the duration over which potential environmental and safety risks would be incurred.
- At the edges of the excavation footprint, the TCRA cap would need to be repaired, and provisions to protect the newly exposed cap edge from scour would need TBC.
- The overlying rock would require disposal, which would entail additional material handling and transport, and the management issues associated with this additional volume of material.

[15] The experience using silt curtains during the TCRA is consistent with that reported at many other sites. Limitations on the use of engineered barriers such as silt curtains for containment in river systems has been well documented and is discussed in Bridges et al. (2010), Connolly et al. (2007), and USEPA (2005), among others.

Because of the significant effectiveness and implementability issues, removal within the TCRA SMA is not considered practicable and will not be carried forward for further consideration as part of the RAM.

Nearshore (NS SMAs) areas are potentially out of reach for large marine-based equipment and have implementability issues for both dredging and capping. These areas would TBC on a case-by-case basis to determine whether dredging or capping is a more appropriate technology for a given location and whether specific implementability issues exist.

5.1.5.3 Containment Constraints by SMA

Due to effectiveness and implementability issues, containment is not a practicable alternative for all areas of the Site. Areas that are highly erosive (due to currents or propeller wash) may not be suitable for containment because of the need for armoring. Furthermore, areas with minimum depth-of-water requirements (such as navigation channels or berthing areas) might not be suitable for capping because the cap would potentially create a shallow condition. Thus, for SMAs delineated as NAV, containment would not be used and removal would be selected instead. As previously mentioned, the use of containment caps over broad areas of the Site would need to consider any potential changes in flood elevations.

5.1.5.4 Summary of Technologies by SMA

Table 5-2 summarizes technologies suitable for each SMA based on the analyses provided in Sections 4 and 5.1.

5.2 Description of Preliminary Remedial Alternatives

The following is a description of each of the alternatives considered in this RAM, as well as specific considerations related to the various types of SMAs that would be included under each alternative. Table 5-3 is a graphical presentation of the technologies assumed for each SMA for each alterative described below.

5.2.1 Alternative 1 – No Further Action

As required by CERCLA, a No Action or No Further Action alternative will be developed, carried forward, and included as part of the FS evaluation of remedial technologies for the Site.

This alternative provides the baseline against which other remedial technologies will be evaluated. The No Further Action alternative can include monitoring at a given site to identify future risks to the environment or human health; however, means taken to mitigate the exposure of receptors (e.g., engineering or institutional controls) are not included as part of this alternative (USEPA 1988). The selection of the No Further Action alternative depends on whether the site in question continues to pose an environmental or human health risk subsequent to the implementation of the initial action.

Alternative 1 will be retained in the FS for sediments, as well as for soils and groundwater, as previously described in Section 4.

5.2.2 Alternative 2a – Surface Weighted Average Concentration of 12.5 Parts per Trillion – Removal Focused

Alternative 2a considers active removal measures to achieve a post-remedy SWAC of 12.5 ppt TEQ_{DF} where practicable. Figure 5-1 presents the location of areas requiring active remediation to achieve a SWAC of 12.5 ppt TEQ_{DF}, all of which are located within the footprint of the TCRA SMA. An estimated 6.8 acres of the Site would need to be addressed to achieve this SWAC. As previously described under Section 5.1.5.2 for the TCRA SMA, removal is not a practicable approach. Thus, Alternative 2a is screened out from further consideration and will not be carried forward as part of the FS.

5.2.3 Alternative 2b – Surface Weighted Average Concentration of 12.5 Parts per Trillion – Integrated Focused

Alternative 2b focuses on integrated management of sediments to achieve a post-remedy SWAC of 12.5 ppt TEQ_{DF}. As shown on Figure 5-1, all of these sediments are located within the TCRA SMA. Thus, this alternative would focus on any efforts that might be necessary to demonstrate the effectiveness of the TCRA cap as a long-term remedy and provide for

ongoing operations, monitoring, and maintenance of the armor cap in this SMA. Alternative 2b will be retained for further consideration in the FS.

5.2.4 Alternative 3a – Surface Weighted Average Concentration of 11 Parts per Trillion – Removal Focused

Under Alternative 3a, sediments would be targeted for removal to the maximum extent practicable to achieve an overall SWAC of 11 ppt. Removal and disposal would be achieved using one of the process options described in Section 4.

Considerations related to the TCRA SMA described under Section 5.1.5.2 are also applicable for Alternative 3a. Alternative 3a does not include any NS or ST SMAs.

Figure 5-2 depicts areas that would be addressed under Alternative 3a. This includes areas where surface sediments need to be addressed, as well as subsurface removal at core location SJNE032. Based on a review of surface and subsurface data, and considering implementability factors, an estimated 69,000 cy of material would be removed for Alternative 3a. This alternative includes 7.4 acres of capping where removal is not reasonably implementable, and 9.0 acres of residuals management in removal areas.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 3a will be retained for consideration in the FS.

5.2.5 Alternative 3b – Surface Weighted Average Concentration of 11 Parts per Trillion – Integrated Focused

Under Alternative 3b, sediments would be targeted for integrated management to the maximum extent practicable to achieve a SWAC of 11 ppt. Integrated management in the form of containment would be achieved using one of the process options described in Section 4.

Considerations related to the NAV SMAs described under Section 5.1.5.3 are also applicable for Alternative 3b. There is a small intersection of potential NAV area in the location of the SJRF operations that would need to be more fully evaluated during the FS or remedial design to determine whether this area is subject to navigation considerations or should be treated as an OW SMA.

Figure 5-2 depicts areas addressed under Alternative 3b. This includes areas where surface sediments need to be addressed, as well as subsurface sediments, the latter of which would be accomplished through containment at location SJNE032. Based on a review of surface and subsurface data, and considering implementability and effectiveness factors, an estimated 16 acres of the Site would be capped by engineered means and/or natural recovery processes for Alternative 3b. This alternative includes 600 cy of dredging where capping is not reasonably implementable or effective (at the SJRF operations) and 0.2 acres of residuals management in this removal area.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 3b will be retained for consideration in the FS.

5.2.6 Alternative 4a – Surface Weighted Average Concentration of 8 Parts per Trillion – Removal Focused

Under Alternative 4a, sediments would be targeted for removal to the maximum extent practicable to achieve an overall SWAC of 8 ppt. Removal and disposal would be achieved using one of the process options described in Section 4.

Considerations related to the TCRA SMA described under Section 5.1.5.2 are also applicable for Alternative 4a. For Alternative 4a, the NS SMA adjacent to the TCRA Site is sufficiently shallow and potentially out of reach of marine equipment so that specialized process options would need TBC to implement removal for this alternative. While the RAM considers removal under Alternative 4a, containment may be determined to be more practicable during the FS in these types of limited access areas.

Alternative 4a does not include any ST SMAs.

Figure 5-3 depicts areas that would be addressed under Alternative 4a. This includes areas where surface sediments need to be addressed, as well as subsurface removal at core locations SJNE007, SJNE032, and SJNE033. Based on a review of surface and subsurface data, and considering implementability factors, an estimated 445,000 cy of material would be removed for Alternative 4a. This alternative includes 7.4 acres of capping where removal is not reasonably implementable, and 72.6 acres of residuals management in removal areas.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 4a will be retained for consideration in the FS.

5.2.7 Alternative 4b – Surface Weighted Average Concentration of 8 Parts per Trillion – Integrated Focused

Under Alternative 4b, sediments would be targeted for integrated management to the maximum extent practicable to achieve a SWAC of 8 ppt. Integrated management in the form of containment would be achieved using one of the process options described in Section 4.

Considerations related to the NAV SMAs described under Section 5.1.5.3 are also applicable for Alternative 4b.

Figure 5-3 depicts areas addressed under Alternative 4b. This includes areas where surface sediments need to be addressed, as well as subsurface sediments, the latter of which would be accomplished through subsurface removal at core location SJNE007 and through containment at locations SJNE032 and SJNE033. Based on a review of surface and subsurface data, and considering implementability and effectiveness factors, an estimated 28 acres of the Site would be capped by engineered means and/or natural recovery processes for Alternative 4b. This alternative includes 275,000 cy of dredging where capping is not considered implementable or effective and 52 acres of residuals management in these removal areas.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 4b will be retained for consideration in the FS.

5.2.8 Alternative 5a – Surface Weighted Average Concentration of 6 Parts per Trillion – Removal Focused

Under Alternative 5a, sediments would be targeted for removal to the maximum extent practicable to achieve an overall SWAC of 6 ppt. Removal and disposal would be achieved using one of the process options described in Section 4.

Considerations related to the TCRA SMA described under Section 5.1.5.2 and NS SMAs described under Alternative 4a are also applicable for Alternative 5a.

Figure 5-4 depicts areas that would be addressed under Alternative 5a. This includes areas where surface sediments need to be addressed, and there would be subsurface removal at core locations SJNE007, SJNE032, and SJNE033. Based on a review of surface and subsurface data, and considering implementability factors, an estimated 540,000 cy of material would be removed for Alternative 5a. This alternative includes 7.5 acres of capping where removal is not reasonably implementable and 86 acres of residuals management in removal areas.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 5a will be retained for consideration in the FS.

5.2.9 Alternative 5b – Surface Weighted Average Concentration of 6 Parts per Trillion – Integrated Focused

Under Alternative 5b, sediments would be targeted for integrated management to the maximum extent practicable to achieve a SWAC of 6 ppt. Integrated management in the form of containment would be achieved using one of the process options described in Section 4.

Figure 5-4 depicts areas addressed under Alternative 5b. This includes areas where surface sediments need to be addressed, as well as subsurface sediments, the latter of which would be accomplished through subsurface removal at core location SJNE007 and through containment at locations SJNE032 and SJNE033. Based on a review of surface and subsurface data, and considering implementability and effectiveness factors, an estimated 33 acres of the Site is assumed to be capped by engineered means and/or natural recovery processes for Alternative 5b. This alternative includes 360,000 cy of dredging where capping is not considered implementable or effective, and 61 acres of residuals management in these removal areas.

For those sediments removed, disposal options would include those process options described in Section 4.

Alternative 5b will be retained for consideration in the FS.

5.3 Conclusions

A variety of alternatives have been developed for the RAM that address sediments to achieve a specific post-remedy Site-wide SWAC TEQ_{DF} for each alternative. Ongoing natural recovery processes are expected to continue to reduce the Site-side SWAC over time after remedy construction has been completed. Alternatives are either removal – focused, or integrated -focused, and have been developed with specific effectiveness and implementability considerations for SMA characteristics and process option opportunities and constraints.

Table 5-4 summarizes each alternative, and the estimated acreage of each SMA type that would need to be addressed under the alternative. Table 5-5 provides a summary of estimated dredge volumes and cap areas for each alternative.

Table 5-4
Acreage of Surface Sediment Exceeding RALs for Each SMA Type

Alternative	Post-remedy SWAC (ppt TEQ_{DF})	Submerged Area in TCRA SMA (acres)	Area in ST SMA (acres)	Area in NAV SMA (acres)	Area in NS SMA (acres)	Area in OW SMA (acres)
1	No Action	N/A	N/A	N/A	N/A	N/A
2a/2b	12.5	6.8	0	0	0	0
3a/3b	11	7.4	0	0.2	0.2	8.6
4a/4b	8	7.4	0	34.4	1.0	15.1
5a/5b	6	7.4	0.1	61.0	2.3	18.8

Table 5-5
Summary of Alternative Volumes and Areas

Alternative	Post-remedy SWAC (ppt TEQ_{DF})	Dredge Volume (cubic yards)	Cap Area (acres)
2a	12.5	Screened from further consideration. See text.	
2b		0	6.8
3a	11	69,000	7.4
3b		600	16.2
4a	8	445,000	7.4
4b		275,000	28.0
5a	6	540,000	7.5
5b		360,000	33.1

6 CONCLUSIONS AND RECOMMENDATIONS

This RAM was prepared by the Respondents under the UAO for RI/FS for the SJRWP Site. The intent of this document is to perform preliminary screening of alternatives to focus on concepts, process options, and assemblies of alternatives that will be carried into detailed screening during the FS. The Baseline Ecological and Human Health Risk Assessments for the Site are ongoing and the results of those assessments will play an important role in determining the final range of remedial alternatives in the FS.

The following general conclusions and considerations were made in regards to identifying the range of remedial alternatives that will be carried forward and considered in the FS. These recommendations are based on the current understanding of the extent and distribution of contamination at the Site. New information that may be developed at the Site during the course of completing the RI Report (e.g., the cap monitoring study) may result in revisions to the proposed range of alternatives. Additional data collection to describe the nature and extent of contamination in the south impoundment area and to refine the CSM for that area is also in progress. Results could affect the range of remedial alternatives considered for the south impoundment in the FS.

6.1 Media-Specific Conclusions

As discussed in Section 4.3, soils in Areas 1, 2, 3, and 4 are not included in the SMAs developed for the Site. The extent of contamination present in surface soils evaluated to date in Areas 1, 2, and 4 is below the USEPA draft interim industrial screening standard for soils of 950 ng/kg TEQ_{DF}, while soils that exceeded that screening standard in Area 3 were stabilized as part of the TCRA implementation. Unless new data are developed in the interim that would suggest active remediation of soils should be considered, the two alternatives that will be retained in the FS for application to soils are the No Further Action and Institutional Controls.

As discussed in Section 4.3, concentrations of dioxins and furans in shallow and deep groundwater wells are generally below applicable groundwater quality criteria with one exception. Unless new data are developed in the interim that would suggest active remediation of groundwater should be considered, the two alternatives that will be retained

in the FS for application to groundwater are the No Further Action and Institutional Controls.

Concentrations in Site sediments exceed prospective RALs for the various scenarios considered. Removal-focused and integrated-focused alternatives will be carried into the FS for more detailed consideration for Site sediments.

6.2 Sediment Surface Weighted Average Concentration Reduction Conclusions

The pre-TCRA sediment SWAC was approximately 62 ppt TEQ_{DF}. The post-TCRA SWAC for submerged sediments at the Site is approximately 12.5 ppt TEQ_{DF} representing an approximate 80 percent reduction in SWAC due to the source control measures implemented in the TCRA. As shown in Section 3, and demonstrated under the assembly of alternatives, achieving a post-remedy SWAC of 6 to 8 ppt TEQ_{DF} requires significantly more dredging or capping compared to achieving a post-remedy SWAC of 11 to 12.5 ppt TEQ_{DF}.

The range of background concentrations assumed for the Site is less than 1.0 to 6.54 ppt TEQ_{DF} based on upstream sampling results. To achieve background conditions another 10 percent reduction in the post-TCRA SWAC would be required. To achieve this additional 10 percent reduction beyond the 80 percent reduction accomplished by the TCRA would require removal of approximately 540,000 cy of material, or 33 acres of in situ containment under those respective scenarios. The completion of the Baseline Ecological and Human Health Risk Assessments will provide information needed to determine if there is an appropriate reduction in risks associated with the implementation of any of the remedial options. The final selected remedy will be developed based on the implementability, effectiveness, and cost considerations outlined in this document, and will also consider if the ecological disruptions associated with some of the more active potential remedial actions are commensurate with the predicted level of risk reduction associated with those actions.

Upon completion of any active remedy construction, ongoing natural recovery processes are predicted to further reduce the Site-wide SWAC TEQ_{DF} by one half over a 5- to 20-year time frame, depending on location. As directed in USEPA sediment management guidance

(USEPA 2005), the effectiveness of natural recovery processes will be considered as part of any active remediation strategy. The FS will consider a range of alternatives using the SWAC reduction process options and alternatives described in Section 5 of this document.

6.3 Sediment Process Options Conclusions

Multiple process options are available for removal, integrated management, and disposal. Most of these process options will be retained for detailed consideration during the FS. However, for reasons described in Section 4, the following process options have been screened from further consideration and will not be evaluated during the FS:

- For ex situ treatment technologies, chemical dehalogenation by SET and BCT have been screened from further consideration
- For in situ treatment technologies, S/S has been screened from further consideration for submerged sediments
- For aquatic disposal alternatives, open-water disposal has been screened from further consideration
- Beneficial reuse of dredged sediment has been screened from further consideration

Table 5-2 presents a summary of technologies suitable for each SMA based on the screening completed.

6.4 Conclusions of Preliminary Screening of Remedial Alternatives

As described in Section 5, removal options within the TCRA footprint are not practicable due to effectiveness and implementability issues. Therefore, removal within the TCRA footprint has been screened from further consideration and will not be included in the FS. However, additional in situ treatment, and/or additional engineered cap technologies will be considered depending on the results of the future cap evaluations being performed under the RI/FS. Assemblies of alternatives will evaluate integrated management options for the TCRA Site as the strategy for managing sediments in this location. Table 5-3 presents a summary of technologies considered for each SMA for each alternative.

This RAM has provided a relatively simple approach to delineating SMAs and focused alternatives assemblies for the purposes of describing the concepts and considerations that

will be carried forward for more detailed evaluation during the FS. It is anticipated that the SMA definitions will be refined, and footprints will be accordingly modified for the FS alternatives assemblies. In addition, the FS will consider alternatives such as dredge and cap and treatment in more detail than discussed in this RAM.

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TABLES

Table 2-2
Summary Statistics for Dioxin and Furan Concentrations in Surface Soil Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
Area 1							
2,3,7,8-TCDD	ng/kg	31	13	42%	0.318	6.58	1.05
1,2,3,7,8-PeCDD	ng/kg	31	10	32%	0.159	1.96	0.294
1,2,3,4,7,8-HxCDD	ng/kg	31	18	58%	0.0802	2.5	0.585
1,2,3,6,7,8-HxCDD	ng/kg	31	24	77%	0.381	16.3	2.97
1,2,3,7,8,9-HxCDD	ng/kg	31	25	81%	0.169	8.03	2.03
1,2,3,4,6,7,8-HpCDD	ng/kg	31	31	100%	0.829	1,010	117
OCDD	ng/kg	31	31	100%	17.1	35,400	3,670
2,3,7,8-TCDF	ng/kg	31	22	71%	0.506	26	5.28
1,2,3,7,8-PeCDF	ng/kg	31	9	29%	0.114	4.91	0.483
2,3,4,7,8-PeCDF	ng/kg	31	14	45%	0.248	7.68	0.828
1,2,3,4,7,8-HxCDF	ng/kg	31	28	90%	0.071	29.2	3.07
1,2,3,6,7,8-HxCDF	ng/kg	31	16	52%	0.155	11.2	1.11
1,2,3,7,8,9-HxCDF	ng/kg	31	3	10%	0.0974	0.868	0.138
2,3,4,6,7,8-HxCDF	ng/kg	31	17	55%	0.119	4.42	0.834
1,2,3,4,6,7,8-HpCDF	ng/kg	31	29	94%	0.0805	103	16.2
1,2,3,4,7,8,9-HpCDF	ng/kg	31	19	61%	0.18	19.8	1.89
OCDF	ng/kg	31	30	97%	0.93	700	94.4
TEQ_{DF}	ng/kg	31	31	100%	0.456	27.2	5.7
Area 2							
2,3,7,8-TCDD	ng/kg	10	7	70%	0.55	46.5	7.63
1,2,3,7,8-PeCDD	ng/kg	10	7	70%	0.153	1.03	0.438
1,2,3,4,7,8-HxCDD	ng/kg	10	7	70%	0.297	1.65	0.754
1,2,3,6,7,8-HxCDD	ng/kg	10	9	90%	0.829	7.88	3.47
1,2,3,7,8,9-HxCDD	ng/kg	10	10	100%	0.701	5.47	2.51
1,2,3,4,6,7,8-HpCDD	ng/kg	10	10	100%	22.4	319	121
OCDD	ng/kg	10	10	100%	518	6,870	2,710
2,3,7,8-TCDF	ng/kg	10	9	90%	0.581	161	28.4
1,2,3,7,8-PeCDF	ng/kg	10	8	80%	0.19	5.47	1.17
2,3,4,7,8-PeCDF	ng/kg	10	8	80%	0.264	3.73	1.05
1,2,3,4,7,8-HxCDF	ng/kg	10	10	100%	0.677	6.12	2.82
1,2,3,6,7,8-HxCDF	ng/kg	10	8	80%	0.266	1.82	1.05
1,2,3,7,8,9-HxCDF	ng/kg	10	0	0%	na	na	0.0664
2,3,4,6,7,8-HxCDF	ng/kg	10	10	100%	0.219	2.94	1.28
1,2,3,4,6,7,8-HpCDF	ng/kg	10	10	100%	1.87	61.1	19.6
1,2,3,4,7,8,9-HpCDF	ng/kg	10	9	90%	0.347	4.29	1.56
OCDF	ng/kg	10	10	100%	6.39	347	99.7
TEQ_{DF}	ng/kg	10	10	100%	1.73	66.1	14.7
Area 3							
2,3,7,8-TCDD	ng/kg	11	11	100%	0.575	8,650	1740
1,2,3,7,8-PeCDD	ng/kg	11	9	82%	0.369	57.2	14.6
1,2,3,4,7,8-HxCDD	ng/kg	11	5	45%	0.163	1.53	0.363
1,2,3,6,7,8-HxCDD	ng/kg	11	6	55%	0.829	6.54	1.69

Table 2-2
Summary Statistics for Dioxin and Furan Concentrations in Surface Soil Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
1,2,3,7,8,9-HxCDD	ng/kg	11	10	91%	0.151	3.62	1.18
1,2,3,4,6,7,8-HpCDD	ng/kg	11	11	100%	3	191	57.6
OCDD	ng/kg	11	11	100%	118	3,700	1100
2,3,7,8-TCDF	ng/kg	11	11	100%	2.88	20,600	5480
1,2,3,7,8-PeCDF	ng/kg	11	10	91%	1.6	959	257
2,3,4,7,8-PeCDF	ng/kg	11	10	91%	1.53	465	128
1,2,3,4,7,8-HxCDF	ng/kg	11	11	100%	0.207	2,110	545
1,2,3,6,7,8-HxCDF	ng/kg	11	10	91%	1.68	498	122
1,2,3,7,8,9-HxCDF	ng/kg	11	6	55%	0.359	25.5	6.91
2,3,4,6,7,8-HxCDF	ng/kg	11	9	82%	0.593	69.7	19.8
1,2,3,4,6,7,8-HpCDF	ng/kg	11	10	91%	2.11	668	157
1,2,3,4,7,8,9-HpCDF	ng/kg	11	9	82%	0.685	244	59.8
OCDF	ng/kg	11	10	91%	3.74	363	101
TEQ_{DF}	ng/kg	11	11	100%	1.02	11,200	2420
Area 4							
2,3,7,8-TCDD	ng/kg	13	8	62%	0.544	24.3	3.8
1,2,3,7,8-PeCDD	ng/kg	13	9	69%	0.216	0.992	0.515
1,2,3,4,7,8-HxCDD	ng/kg	13	10	77%	0.186	3.25	0.782
1,2,3,6,7,8-HxCDD	ng/kg	13	12	92%	0.72	6.38	2.62
1,2,3,7,8,9-HxCDD	ng/kg	13	13	100%	0.627	10.9	2.63
1,2,3,4,6,7,8-HpCDD	ng/kg	13	13	100%	19.6	379	99.5
OCDD	ng/kg	13	13	100%	376	50,800	10,100
2,3,7,8-TCDF	ng/kg	13	10	77%	0.237	45.9	9.58
1,2,3,7,8-PeCDF	ng/kg	13	6	46%	0.29	2.82	0.632
2,3,4,7,8-PeCDF	ng/kg	13	9	69%	0.18	1.71	0.603
1,2,3,4,7,8-HxCDF	ng/kg	13	13	100%	0.16	6.73	1.89
1,2,3,6,7,8-HxCDF	ng/kg	13	8	62%	0.229	1.76	0.588
1,2,3,7,8,9-HxCDF	ng/kg	13	4	31%	0.0696	0.181	0.0667
2,3,4,6,7,8-HxCDF	ng/kg	13	6	46%	0.258	1.41	0.446
1,2,3,4,6,7,8-HpCDF	ng/kg	13	13	100%	0.87	22.2	8.38
1,2,3,4,7,8,9-HpCDF	ng/kg	13	8	62%	0.204	2.24	0.63
OCDF	ng/kg	13	13	100%	3	105	36.3
TEQ_{DF}	ng/kg	13	13	100%	1.35	31.1	10.5

Notes

na = not applicable, no detected values.
Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

Table 2-3
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Soils Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
Area 1							
2,3,7,8-TCDD	ng/kg	39	19	49%	0.268	144	5.18
1,2,3,7,8-PeCDD	ng/kg	39	17	44%	0.139	2.58	0.331
1,2,3,4,7,8-HxCDD	ng/kg	39	21	54%	0.118	3.11	0.529
1,2,3,6,7,8-HxCDD	ng/kg	39	31	79%	0.179	18.2	2.79
1,2,3,7,8,9-HxCDD	ng/kg	39	26	67%	0.291	8.34	1.86
1,2,3,4,6,7,8-HpCDD	ng/kg	39	39	100%	1.33	1,080	114
OCDD	ng/kg	39	39	100%	32.5	30,700	4,500
2,3,7,8-TCDF	ng/kg	39	32	82%	0.306	459	18.6
1,2,3,7,8-PeCDF	ng/kg	39	17	44%	0.154	10.8	0.862
2,3,4,7,8-PeCDF	ng/kg	39	20	51%	0.264	7.44	0.853
1,2,3,4,7,8-HxCDF	ng/kg	39	29	74%	0.188	21.5	2.63
1,2,3,6,7,8-HxCDF	ng/kg	39	26	67%	0.108	8.25	1.01
1,2,3,7,8,9-HxCDF	ng/kg	39	4	10%	0.0711	0.522	0.0981
2,3,4,6,7,8-HxCDF	ng/kg	39	23	59%	0.0707	6.69	0.864
1,2,3,4,6,7,8-HpCDF	ng/kg	39	36	92%	0.118	129	13.4
1,2,3,4,7,8,9-HpCDF	ng/kg	39	21	54%	0.201	12.9	1.33
OCDF	ng/kg	39	35	90%	0.229	777	73.2
TEQ_{DF}	ng/kg	39	39	100%	0.357	195	11.3
Area 2							
2,3,7,8-TCDD	ng/kg	1	1	100%	0.547	0.547	0.547
1,2,3,7,8-PeCDD	ng/kg	1	0	0%	na	na	0.0580
1,2,3,4,7,8-HxCDD	ng/kg	1	0	0%	na	na	0.102
1,2,3,6,7,8-HxCDD	ng/kg	1	1	100%	0.476	0.476	0.476
1,2,3,7,8,9-HxCDD	ng/kg	1	0	0%	na	na	0.170
1,2,3,4,6,7,8-HpCDD	ng/kg	1	1	100%	18.6	18.6	18.6
OCDD	ng/kg	1	1	100%	484	484	484
2,3,7,8-TCDF	ng/kg	1	1	100%	1.74	1.74	1.74
1,2,3,7,8-PeCDF	ng/kg	1	0	0%	na	na	0.0434
2,3,4,7,8-PeCDF	ng/kg	1	0	0%	na	na	0.0470
1,2,3,4,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0565
1,2,3,6,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0390
1,2,3,7,8,9-HxCDF	ng/kg	1	0	0%	na	na	0.0493
2,3,4,6,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0382
1,2,3,4,6,7,8-HpCDF	ng/kg	1	0	0%	na	na	0.198
1,2,3,4,7,8,9-HpCDF	ng/kg	1	0	0%	na	na	0.0407
OCDF	ng/kg	1	1	100%	2.83	2.83	2.83
TEQ_{DF}	ng/kg	1	1	100%	1.22	1.22	1.22
Area 3							
2,3,7,8-TCDD	ng/kg	10	10	100%	0.547	11,300	4,100
1,2,3,7,8-PeCDD	ng/kg	10	8	80%	0.781	85.5	35.3
1,2,3,4,7,8-HxCDD	ng/kg	10	4	40%	0.657	1.15	0.464
1,2,3,6,7,8-HxCDD	ng/kg	10	8	80%	0.333	12.9	3.39

Table 2-3
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Soils Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
1,2,3,7,8,9-HxCDD	ng/kg	10	6	60%	0.321	3.49	1.51
1,2,3,4,6,7,8-HpCDD	ng/kg	10	10	100%	5.41	475	102
OCDD	ng/kg	10	10	100%	202	4,310	1,310
2,3,7,8-TCDF	ng/kg	10	10	100%	1.74	43,000	15,300
1,2,3,7,8-PeCDF	ng/kg	10	9	90%	0.544	1,450	577
2,3,4,7,8-PeCDF	ng/kg	10	8	80%	5	735	314
1,2,3,4,7,8-HxCDF	ng/kg	10	8	80%	12.6	3,060	984
1,2,3,6,7,8-HxCDF	ng/kg	10	9	90%	0.256	691	231
1,2,3,7,8,9-HxCDF	ng/kg	10	7	70%	0.296	43.2	12.5
2,3,4,6,7,8-HxCDF	ng/kg	10	7	70%	2.71	92.7	37.4
1,2,3,4,6,7,8-HpCDF	ng/kg	10	9	90%	0.737	782	274
1,2,3,4,7,8,9-HpCDF	ng/kg	10	8	80%	1.1	296	101
OCDF	ng/kg	10	10	100%	1.43	412	166
TEQ_{DF}	ng/kg	10	10	100%	1.22	16,200	5,910
Area 4							
2,3,7,8-TCDD	ng/kg	81	56	69%	0.157	1,410	66.8
1,2,3,7,8-PeCDD	ng/kg	81	52	64%	0.0825	12.4	1.25
1,2,3,4,7,8-HxCDD	ng/kg	81	53	65%	0.0594	17.5	1.11
1,2,3,6,7,8-HxCDD	ng/kg	81	67	83%	0.172	53.4	4.72
1,2,3,7,8,9-HxCDD	ng/kg	81	71	88%	0.154	52	3.47
1,2,3,4,6,7,8-HpCDD	ng/kg	81	80	99%	1.92	1,450	146
OCDD	ng/kg	81	81	100%	30.8	59,300	5,370
2,3,7,8-TCDF	ng/kg	81	75	93%	0.375	3,850	170
1,2,3,7,8-PeCDF	ng/kg	81	57	70%	0.119	121	6.27
2,3,4,7,8-PeCDF	ng/kg	81	61	75%	0.095	88	4.50
1,2,3,4,7,8-HxCDF	ng/kg	81	72	89%	0.109	251	13.4
1,2,3,6,7,8-HxCDF	ng/kg	81	54	67%	0.123	64.1	3.83
1,2,3,7,8,9-HxCDF	ng/kg	81	22	27%	0.0567	3.48	0.191
2,3,4,6,7,8-HxCDF	ng/kg	81	43	53%	0.0763	15	1.45
1,2,3,4,6,7,8-HpCDF	ng/kg	81	78	96%	0.115	223	28.9
1,2,3,4,7,8,9-HpCDF	ng/kg	81	57	70%	0.101	31.1	2.77
OCDF	ng/kg	81	75	93%	1.26	11,300	560
TEQ_{DF}	ng/kg	81	81	100%	0.163	1,880	92.9

Notes

na = not applicable, no detected values.
Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

Table 2-4

Summary Statistics for OC-Normalized [a] Concentrations of Dioxins and Furans in Subsurface Soils Samples

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
Area 1							
2,3,7,8-TCDD	ng/kg	39	19	49%	21.6	97,800	3,300
1,2,3,7,8-PeCDD	ng/kg	39	17	44%	11.1	194	62.8
1,2,3,4,7,8-HxCDD	ng/kg	39	21	54%	4.57	216	69.7
1,2,3,6,7,8-HxCDD	ng/kg	39	31	79%	18.9	1,220	284
1,2,3,7,8,9-HxCDD	ng/kg	39	26	67%	24.1	681	212
1,2,3,4,6,7,8-HpCDD	ng/kg	39	39	100%	686	51,200	11,400
OCDD	ng/kg	39	39	100%	15,500	3,890,000	535,000
2,3,7,8-TCDF	ng/kg	39	32	82%	13.3	312,000	11,000
1,2,3,7,8-PeCDF	ng/kg	39	17	44%	7.83	7,330	288
2,3,4,7,8-PeCDF	ng/kg	39	20	51%	5.38	5,050	228
1,2,3,4,7,8-HxCDF	ng/kg	39	29	74%	7.29	10,600	546
1,2,3,6,7,8-HxCDF	ng/kg	39	26	67%	6.1	2,400	163
1,2,3,7,8,9-HxCDF	ng/kg	39	4	10%	5.7	41.3	29.3
2,3,4,6,7,8-HxCDF	ng/kg	39	23	59%	2.74	530	101
1,2,3,4,6,7,8-HpCDF	ng/kg	39	36	92%	51.2	6,110	1,350
1,2,3,4,7,8,9-HpCDF	ng/kg	39	21	54%	17.4	1,020	155
OCDF	ng/kg	39	35	90%	156	36,800	6,160
TEQ Dioxin/Furans Mammal 1/2 DL	ng/kg	39	39	100%	29.4	132,000	4,910
Area 3							
2,3,7,8-TCDD	ng/kg	9	9	100%	550	253,000	78,200
1,2,3,7,8-PeCDD	ng/kg	9	8	89%	104	2,610	732
1,2,3,4,7,8-HxCDD	ng/kg	9	4	44%	11.6	33.7	16.8
1,2,3,6,7,8-HxCDD	ng/kg	9	7	78%	11.8	141	78.0
1,2,3,7,8,9-HxCDD	ng/kg	9	6	67%	29.8	102	51.3
1,2,3,4,6,7,8-HpCDD	ng/kg	9	9	100%	279	4,540	2,220
OCDD	ng/kg	9	9	100%	3,880	83,400	40,000
2,3,7,8-TCDF	ng/kg	9	9	100%	2,580	1,220,000	314,000
1,2,3,7,8-PeCDF	ng/kg	9	9	100%	90.1	37,700	11,200
2,3,4,7,8-PeCDF	ng/kg	9	8	89%	668	23,700	6,440
1,2,3,4,7,8-HxCDF	ng/kg	9	8	89%	1,360	67,200	19,100
1,2,3,6,7,8-HxCDF	ng/kg	9	9	100%	42.4	15,400	4,480
1,2,3,7,8,9-HxCDF	ng/kg	9	7	78%	14.4	698	231
2,3,4,6,7,8-HxCDF	ng/kg	9	7	78%	132	2,010	704
1,2,3,4,6,7,8-HpCDF	ng/kg	9	9	100%	122	21,700	5,670
1,2,3,4,7,8,9-HpCDF	ng/kg	9	8	89%	162	7,700	2,020
OCDF	ng/kg	9	9	100%	237	14,000	4,200
TEQ_{DF}	ng/kg	9	9	100%	863	394,000	115,000
Area 4							
2,3,7,8-TCDD	ng/kg	81	56	69%	33.7	79,100	6,370
1,2,3,7,8-PeCDD	ng/kg	81	52	64%	12.4	2,270	153
1,2,3,4,7,8-HxCDD	ng/kg	81	53	65%	7.9	4,090	153
1,2,3,6,7,8-HxCDD	ng/kg	81	67	83%	18.5	12,500	567

Table 2-4

Summary Statistics for OC-Normalized [a] Concentrations of Dioxins and Furans in Subsurface Soils Samples

					Detected Data		All Data
Analyte	**Units**	**Number of Samples**	**Number of Detected Measurements**	**Detection Frequency**	**Minimum**	**Maximum**	**Mean**
1,2,3,7,8,9-HxCDD	ng/kg	81	71	88%	5.18	12,100	463
1,2,3,4,6,7,8-HpCDD	ng/kg	81	80	99%	49.7	339,000	16,600
OCDD	ng/kg	81	81	100%	797	5,390,000	581,000
2,3,7,8-TCDF	ng/kg	81	75	93%	17.9	189,000	15,600
1,2,3,7,8-PeCDF	ng/kg	81	57	70%	13.4	9,920	654
2,3,4,7,8-PeCDF	ng/kg	81	61	75%	6.5	5,550	480
1,2,3,4,7,8-HxCDF	ng/kg	81	72	89%	12.1	20,400	1,470
1,2,3,6,7,8-HxCDF	ng/kg	81	54	67%	8.44	5,170	431
1,2,3,7,8,9-HxCDF	ng/kg	81	22	27%	5.06	171	35.7
2,3,4,6,7,8-HxCDF	ng/kg	81	43	53%	7.11	3,500	207
1,2,3,4,6,7,8-HpCDF	ng/kg	81	78	96%	12	52,100	3,060
1,2,3,4,7,8,9-HpCDF	ng/kg	81	57	70%	8.33	3,270	300
OCDF	ng/kg	81	75	93%	111	638,000	41,400
TEQ_{DF}	ng/kg	81	81	100%	4.23	100,000	8,920

Notes

na = not applicable, no detected values.

Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

a - Only samples with total organic carbon data are presented. OC-Normalized data not available for all samples measured.

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWS01	1/11/11	11:00	2.78	0.00	0.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:05	2.76	0.00	0.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:10	3.13	5.00	5.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:12	2.94	0.00	5.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:19	3.11	7.00	12.00	7.42	20.37	9.85	—	—	—	7,384
SJMWS01	1/11/11	11:22	3.14	3.00	15.00	7.41	20.46	9.90	—	—	—	7,426
SJMWS01	1/11/11	11:25	3.16	3.00	18.00	7.37	20.66	10.29	—	—	—	7,718
SJMWS01	1/11/11	11:28	3.15	3.00	21.00	7.34	20.67	10.47	—	—	—	7,853
SJMWS01	1/11/11	11:31	3.17	3.00	24.00	7.33	20.66	10.49	—	—	—	7,868
SJMWS01	1/11/11	11:40	2.86	3.00	27.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:43	3.05	3.00	30.00	7.19	20.60	12.71	—	—	—	9,533
SJMWS01	1/11/11	11:46	3.15	3.00	33.00	7.12	20.73	13.25	—	—	479.00	9,938
SJMWS01	1/11/11	11:50	2.93	0.00	33.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	11:53	3.12	3.00	36.00	7.06	20.65	13.58	—	—	208.00	10,185
SJMWS01	1/11/11	11:56	3.13	3.00	39.00	7.03	20.74	13.76	—	—	128.00	10,320
SJMWS01	1/11/11	12:05	2.90	0.00	39.00	—	—	—	—	—	—	—
SJMWS01	1/11/11	12:08	3.15	3.00	42.00	6.98	20.54	14.05	—	—	71.20	10,538
SJMWS01	1/11/11	12:11	3.12	3.00	45.00	6.96	20.28	14.08	—	—	7.09	10,560
SJMWS01	1/11/11	12:14	3.11	3.00	48.00	6.95	20.38	14.15	—	—	4.71	10,613
SJMWS01	1/11/11	12:17	3.13	3.00	51.00	6.95	20.42	14.19	—	—	4.03	10,643
SJMWS01	1/11/11	12:20	3.14	3.00	54.00	6.94	20.53	14.25	—	—	2.87	10,688
SJMWS01	1/11/11	12:23	3.13	3.00	57.00	6.94	20.64	14.30	—	—	2.32	10,725
SJMWS01	1/11/11	12:26	3.12	3.00	60.00	6.93	20.69	14.35	—	—	1.92	10,763
SJMWS01	1/11/11	12:29	3.11	3.00	63.00	6.93	20.72	14.36	—	—	1.51	10,770
SJMWS01	1/11/11	12:32	3.12	3.00	66.00	6.93	20.75	14.38	—	—	1.24	10,785
SJMWS01	1/11/11	12:35	3.11	3.00	69.00	6.92	20.81	14.42	—	—	1.38	10,815
SJMWS01	1/11/11	12:36	3.13	1.00	70.00	6.92	20.82	14.43	—	—	1.26	10,823
SJMWS01	1/11/11	12:37	3.11	1.00	71.00	6.92	20.83	14.43	—	—	1.32	10,823
SJMWS01	1/11/11	12:38	3.11	1.00	72.00	6.92	20.82	14.44	—	—	1.27	10,830
SJMWS01	1/11/11	12:39	3.12	1.00	73.00	6.92	20.79	14.46	—	—	1.29	10,845
SJMWS01	1/11/11	12:40	3.13	1.00	74.00	6.92	20.78	14.46	—	—	1.22	10,845
SJMWS01	1/11/11	12:40	—	0.00	74.00	—	—	—	—	—	—	—
SJMWS01	1/12/11	8:30	3.29	0.00	74.00	6.10	19.73	14.43	-22.30	3.00	—	10,823
SJMWS01	1/12/11	8:33	3.29	0.08	74.08	6.29	19.68	14.66	-53.30	2.60	0.79	10,995
SJMWS01	1/12/11	8:36	3.29	0.08	74.16	6.50	19.83	15.22	-79.00	2.08	0.68	11,415
SJMWS01	1/12/11	8:39	3.30	0.08	74.24	6.61	19.94	15.14	-90.90	1.99	0.62	11,355
SJMWS01	1/12/11	8:42	3.30	0.08	74.32	6.63	20.00	15.41	-94.70	2.08	0.63	11,558
SJMWS01	1/12/11	8:45	3.30	0.08	74.40	6.65	19.99	15.41	-97.90	2.02	0.48	11,558
SJMWS01	1/12/11	8:48	3.30	0.08	74.48	6.66	20.04	15.47	-99.20	1.99	0.53	11,603
SJMWS01	1/12/11	8:51	3.30	2.72	77.20	6.67	20.00	15.45	-100.60	2.05	0.62	11,588
SJMWS02	1/4/11	15:00	9.70	0.00	0.00	—	—	—	—	—	—	—
SJMWS02	1/4/11	15:20	9.70	0.00	0.00	—	—	—	—	—	—	—
SJMWS02	1/4/11	15:35	9.80	5.00	5.00	—	—	—	—	—	—	—
SJMWS02	1/4/11	15:45	9.88	5.00	10.00	6.96	20.82	8.68	—	—	—	6,511
SJMWS02	1/4/11	16:00	9.95	5.00	15.00	7.02	20.91	8.78	—	—	—	6,587

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWS02	1/4/11	16:10	10.01	5.00	20.00	7.06	20.88	8.70	—	—	—	6,522
SJMWS02	1/4/11	16:10	—	0.00	20.00	—	—	—	—	—	—	—
SJMWS02	1/5/11	8:40	—	0.00	20.00	—	—	—	—	—	—	—
SJMWS02	1/5/11	8:50	8.82	0.00	20.00	—	—	—	—	—	—	—
SJMWS02	1/5/11	9:05	8.97	5.00	25.00	6.65	20.73	11.08	—	—	—	8,310
SJMWS02	1/5/11	9:05	8.97	0.00	25.00	—	—	—	—	—	—	—
SJMWS02	1/5/11	9:20	9.03	5.00	30.00	6.68	20.51	11.84	—	—	495.00	8,880
SJMWS02	1/5/11	9:30	8.95	0.00	30.00	—	—	—	—	—	—	—
SJMWS02	1/5/11	9:40	9.32	5.00	35.00	6.72	20.83	12.35	—	—	52.50	9,263
SJMWS02	1/5/11	9:50	9.32	5.00	40.00	6.66	20.85	12.56	—	—	23.70	9,420
SJMWS02	1/5/11	10:00	9.37	5.00	45.00	6.66	21.12	12.51	—	—	14.60	9,383
SJMWS02	1/5/11	10:10	9.39	5.00	50.00	6.75	19.66	12.63	—	—	5.61	9,473
SJMWS02	1/5/11	10:20	—	0.00	50.00	—	—	—	—	—	—	—
SJMWS02	1/15/11	12:30	9.52	0.00	50.00	—	—	—	—	—	—	—
SJMWS02	1/15/11	12:33	9.55	0.32	50.32	6.60	21.83	14.17	-81.00	—	40.10	10,628
SJMWS02	1/15/11	12:36	9.56	0.31	50.63	6.59	21.82	14.16	-80.60	—	37.70	10,620
SJMWS02	1/15/11	12:39	9.58	0.32	50.95	6.63	21.58	14.03	-80.90	2.57	19.70	10,523
SJMWS02	1/15/11	12:42	9.58	0.32	51.27	6.59	21.59	13.95	-83.30	2.44	18.80	10,463
SJMWS02	1/15/11	12:45	9.58	0.32	51.59	6.57	21.59	13.90	-84.50	2.32	19.20	10,425
SJMWS02	1/15/11	12:48	9.58	0.31	51.90	6.56	21.58	13.87	-85.30	2.18	18.80	10,403
SJMWS02	1/15/11	12:51	9.58	0.32	52.22	6.55	21.59	13.86	-85.70	2.12	15.90	10,395
SJMWS02	1/15/11	12:54	9.58	0.32	52.54	6.55	21.58	13.83	-86.70	1.96	15.10	10,373
SJMWS02	1/15/11	12:57	9.59	0.31	52.85	6.55	21.58	13.81	-87.30	1.89	14.70	10,358
SJMWS02	1/15/11	13:00	9.62	0.32	53.17	6.55	21.60	13.82	-88.60	1.70	13.90	10,365
SJMWS02	1/15/11	13:03	9.60	0.32	53.49	6.55	21.62	13.79	-89.00	1.62	8.67	10,343
SJMWS02	1/15/11	13:04	9.62	0.10	53.59	6.55	21.62	13.78	-89.60	1.56	8.65	10,335
SJMWS02	1/15/11	13:05	9.62	0.11	53.70	6.55	21.62	13.78	-89.70	1.49	8.48	10,335
SJMWS02	1/15/11	13:06	9.63	0.10	53.80	6.55	21.61	13.77	-89.90	1.51	7.84	10,328
SJMWS02	1/15/11	13:14	9.61	0.85	54.65	6.55	21.59	13.73	-90.90	1.23	6.98	10,298
SJMWS02	1/15/11	13:16	9.65	0.21	54.86	6.55	21.60	13.73	-91.10	1.22	6.79	10,298
SJMWS02	1/15/11	13:18	9.67	0.21	55.07	6.55	21.59	13.73	-91.20	1.21	6.67	10,298
SJMWS03	1/7/11	11:30	3.63	0.00	0.00	—	—	—	—	—	—	—
SJMWS03	1/7/11	11:50	3.63	0.00	0.00	—	—	—	—	—	—	—
SJMWS03	1/7/11	12:01	13.21	3.00	3.00	6.77	21.61	2.68	—	—	—	2,011
SJMWS03	1/7/11	12:17	11.75	3.00	6.00	6.69	21.65	2.78	—	—	—	2,084
SJMWS03	1/7/11	12:28	11.77	1.50	7.50	6.32	21.62	9.55	—	—	—	7,165
SJMWS03	1/7/11	12:34	12.65	1.50	9.00	6.33	22.48	11.87	—	—	—	8,903
SJMWS03	1/7/11	12:42	14.50	1.50	10.50	6.41	21.91	12.50	—	—	—	9,375
SJMWS03	1/7/11	12:50	13.79	1.50	12.00	6.39	22.01	13.69	—	—	—	10,268
SJMWS03	1/7/11	12:54	11.73	0.00	12.00	—	—	—	—	—	—	—
SJMWS03	1/7/11	13:07	14.69	3.00	15.00	6.77	22.40	14.12	—	—	859.00	10,590
SJMWS03	1/7/11	13:27	13.49	3.00	18.00	6.61	21.79	14.42	—	—	264.00	10,815
SJMWS03	1/7/11	13:47	14.47	3.00	21.00	6.31	21.83	14.57	—	—	89.20	10,928
SJMWS03	1/7/11	14:07	15.14	3.00	24.00	6.32	21.69	14.60	—	—	39.60	10,950

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWS03	1/7/11	14:27	15.10	3.00	27.00	6.37	21.39	14.64	—	—	37.90	10,980
SJMWS03	1/7/11	14:45	14.77	3.00	30.00	6.43	21.46	14.70	—	—	30.60	11,025
SJMWS03	1/7/11	14:53	9.35	0.24	30.24	6.24	21.84	14.50	-48.30	4.31	107.80	10,875
SJMWS03	1/7/11	14:56	9.64	0.24	30.48	6.20	21.82	14.75	-42.30	4.45	22.10	11,063
SJMWS03	1/7/11	14:59	9.66	0.23	30.71	6.19	21.70	14.80	-39.70	4.66	15.10	11,100
SJMWS03	1/7/11	15:02	9.66	0.24	30.95	6.18	21.68	14.80	-40.30	4.42	12.30	11,100
SJMWS03	1/7/11	15:05	9.68	0.24	31.19	6.18	21.66	14.80	-40.80	4.50	13.40	11,100
SJMWS03	1/7/11	15:08	9.67	0.24	31.43	6.18	21.65	14.79	-41.20	4.49	13.30	11,093
SJMWS03	1/7/11	15:11	9.68	0.23	31.66	6.18	21.59	14.80	-42.00	4.55	9.18	11,100
SJMWS03	1/7/11	15:14	9.66	0.23	31.89	6.18	21.54	14.80	-42.70	4.61	7.86	11,100
SJMWS03	1/7/11	15:17	9.65	0.24	32.13	6.17	21.60	14.81	-42.70	4.60	8.70	11,108
SJMWS03	1/7/11	15:20	9.61	0.20	32.33	6.18	21.59	14.79	-43.10	4.54	7.01	11,093
SJMWS03	1/7/11	15:23	9.59	0.28	32.61	6.17	21.59	14.79	-43.30	4.62	7.62	11,093
SJMWS03	1/7/11	15:26	9.58	0.07	32.68	6.17	21.57	14.80	-43.20	4.52	7.08	11,100
SJMWS04	1/2/11	9:15	3.16	0.00	0.00	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:22	5.45	0.13	0.13	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:30	5.45	0.07	0.20	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:36	3.91	0.00	0.20	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:37	5.45	0.06	0.26	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:55	3.18	0.00	0.26	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:57	3.18	0.00	0.26	—	—	—	—	—	—	—
SJMWS04	1/2/11	9:59	5.45	0.07	0.33	—	—	—	—	—	—	—
SJMWS04	1/2/11	10:30	3.16	0.00	0.33	—	—	—	—	—	—	—
SJMWS04	1/2/11	10:32	5.45	0.07	0.40	—	—	—	—	—	—	—
SJMWS04	1/2/11	10:50	3.19	0.00	0.40	—	—	—	—	—	—	—
SJMWS04	1/2/11	10:53	5.45	0.06	0.46	—	—	—	—	—	—	—
SJMWS04	1/2/11	11:12	3.17	0.00	0.46	—	—	—	—	—	—	—
SJMWS04	1/2/11	11:15	5.45	0.07	0.53	6.85	15.05	15.78	-251.70	—	—	11,835
SJMWS04	1/2/11	11:37	3.16	0.00	0.53	—	—	—	—	—	—	—
SJMWS04	1/2/11	11:39	5.45	0.06	0.59	—	—	—	—	—	—	—
SJMWS04	1/2/11	11:57	3.18	0.00	0.59	—	—	—	—	—	—	—
SJMWS04	1/2/11	12:00	5.45	0.07	0.66	—	—	—	—	—	—	—
SJMWS04	1/2/11	12:20	3.17	0.00	0.66	—	—	—	—	—	—	—
SJMWS04	1/2/11	12:23	5.75	0.13	0.79	7.03	14.01	15.70	-336.30	-0.97	26.80	11,775
SJMWS04	1/2/11	12:30	—	0.00	0.79	—	—	—	—	—	—	—
SJMWS04	1/2/11	12:55	3.16	0.00	0.79	—	—	—	—	—	—	—
SJMWS04	1/2/11	13:00	5.45	0.08	0.87	7.06	15.30	15.60	-286.60	3.73	18.20	11,700
SJMWS04	1/2/11	14:10	—	0.26	1.13	—	—	—	—	—	—	—
SJMWS04	1/2/11	15:00	—	0.26	1.39	—	—	—	—	—	—	—
SJMWS04	1/2/11	15:45	—	0.26	1.65	—	—	—	—	—	—	—
SJMWS04	1/2/11	16:30	—	0.26	1.91	—	—	—	—	—	—	—
SJMWS04	1/3/11	13:45	—	0.13	2.04	—	—	—	—	—	—	—
SJMWS04	1/3/11	14:30	—	0.13	2.17	—	—	—	—	—	—	—
SJMWS04	1/3/11	15:00	—	0.00	2.17	6.87	16.73	15.91	-232.80	4.06	—	11,933

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWD01	1/11/11	8:30	8.44	0.00	0.00	—	—	—	—	—	—	—
SJMWD01	1/11/11	9:00	56.11	20.00	20.00	5.32	18.39	16.80	—	—	—	12,600
SJMWD01	1/11/11	9:10	8.80	5.00	25.00	6.28	18.64	16.99	—	—	—	12,743
SJMWD01	1/11/11	9:20	9.50	10.00	35.00	6.57	19.62	16.60	—	—	—	12,450
SJMWD01	1/11/11	9:25	10.76	5.00	40.00	6.70	19.40	15.33	—	—	—	11,498
SJMWD01	1/11/11	9:35	11.27	10.00	50.00	—	18.66	—	—	—	—	—
SJMWD01	1/11/11	9:45	8.56	0.00	50.00	—	—	—	—	—	—	—
SJMWD01	1/11/11	9:55	11.19	10.00	60.00	6.84	20.04	17.06	—	—	38.80	12,795
SJMWD01	1/11/11	10:05	11.29	10.00	70.00	6.89	20.45	16.95	—	—	14.20	12,713
SJMWD01	1/11/11	10:15	11.36	10.00	80.00	6.97	20.80	16.36	—	—	—	12,270
SJMWD01	1/11/11	10:25	10.13	10.00	90.00	7.06	20.69	15.22	—	—	7.38	11,415
SJMWD01	1/11/11	10:30	8.05	5.00	95.00	7.05	20.71	15.02	—	—	4.31	11,265
SJMWD01	1/11/11	10:35	10.03	5.00	100.00	7.06	20.65	14.88	—	—	3.25	11,160
SJMWD01	1/12/11	9:20	9.13	0.00	100.00	6.96	20.71	13.71	-127.30	1.62	—	10,283
SJMWD01	1/12/11	9:23	9.15	0.08	100.08	6.97	20.82	13.65	-132.50	1.64	0.33	10,238
SJMWD01	1/12/11	9:26	9.15	0.08	100.16	7.00	20.75	13.57	-140.50	1.65	1.36	10,178
SJMWD01	1/12/11	9:29	9.16	0.08	100.24	6.83	20.73	16.99	-141.60	1.57	1.57	12,743
SJMWD01	1/12/11	9:32	9.16	0.08	100.32	6.82	20.80	17.03	-106.50	2.05	1.52	12,773
SJMWD01	1/12/11	9:35	9.16	0.08	100.40	6.80	20.76	17.18	-101.80	2.12	0.17	12,885
SJMWD01	1/12/11	9:38	9.16	0.08	100.48	6.80	20.76	17.21	-99.40	2.05	0.16	12,908
SJMWD01	1/12/11	9:41	9.16	0.07	100.55	6.79	20.75	17.25	-97.80	2.02	0.60	12,938
SJMWD01	1/12/11	9:44	9.16	0.08	100.63	6.79	20.82	17.29	-94.70	2.14	0.23	12,968
SJMWD01	1/12/11	9:47	9.16	0.08	100.71	6.78	20.81	17.30	-92.30	2.18	0.08	12,975
SJMWD01	1/12/11	9:50	9.16	0.08	100.79	6.78	20.78	17.30	-91.60	2.22	0.10	12,975
SJMWD01	1/12/11	9:53	9.16	0.08	100.87	6.78	20.82	17.31	-90.90	2.22	0.12	12,983
SJMWD02	1/4/11	12:15	15.40	0.00	0.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	12:15	15.40	0.00	0.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	12:50	50.00	20.00	20.00	6.96	21.46	4.27	—	—	—	3,206
SJMWD02	1/4/11	13:15	66.20	0.00	20.00	7.02	21.46	4.30	—	—	—	3,223
SJMWD02	1/4/11	13:15	—	0.00	20.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	13:30	68.40	5.00	25.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	13:30	—	0.00	25.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	13:40	—	0.00	25.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	13:50	66.00	5.00	30.00	6.96	20.83	7.08	—	—	4,451.00	5,312
SJMWD02	1/4/11	13:55	42.00	0.00	30.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	14:05	69.00	5.00	35.00	7.19	20.97	7.51	—	—	14,468.00	5,630
SJMWD02	1/4/11	14:20	45.00	0.00	35.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	14:30	54.40	5.00	40.00	7.18	21.06	8.27	—	—	2,904.00	6,199
SJMWD02	1/4/11	14:40	61.05	5.00	45.00	7.31	20.57	8.13	—	—	—	6,101
SJMWD02	1/4/11	14:45	—	0.00	45.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	14:45	53.80	0.00	45.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	15:10	70.10	10.00	55.00	7.23	21.41	8.88	—	—	450.00	6,661
SJMWD02	1/4/11	15:20	—	0.00	55.00	—	—	—	—	—	—	—
SJMWD02	1/4/11	15:50	40.72	0.00	55.00	—	—	—	—	—	—	—
SJMWD02	1/5/11	8:15	16.98	0.00	55.00	—	—	—	—	—	—	—

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWD02	1/5/11	8:30	16.97	0.00	55.00	—	—	—	—	—	—	—
SJMWD02	1/5/11	9:10	23.02	5.00	60.00	7.07	20.40	9.36	—	—	4.65	7,020
SJMWD02	1/5/11	9:40	23.19	5.00	65.00	7.12	19.64	9.41	—	—	3.14	7,054
SJMWD02	1/5/11	10:10	23.30	5.00	70.00	7.32	19.55	9.40	—	—	2.83	7,053
SJMWD02	1/5/11	10:30	23.30	2.50	72.50	7.22	19.87	9.45	—	—	1.66	7,091
SJMWD02	1/5/11	11:30	23.90	7.50	80.00	7.09	21.77	9.45	—	—	4.15	7,089
SJMWD02	1/5/11	12:00	26.45	12.50	92.50	7.16	20.92	9.57	—	—	3.62	7,175
SJMWD02	1/5/11	12:15	26.45	0.00	92.50	—	—	—	—	—	—	—
SJMWD02	1/5/11	14:15	17.51	0.00	92.50	—	—	—	—	—	—	—
SJMWD02	1/5/11	14:20	18.40	0.13	92.63	7.10	21.88	9.72	-68.20	2.05	—	7,289
SJMWD02	1/5/11	14:25	19.07	0.13	92.76	7.06	21.69	9.51	-55.30	1.77	2.91	7,131
SJMWD02	1/5/11	14:30	19.45	0.14	92.90	7.04	21.30	9.45	-49.20	1.73	3.10	7,085
SJMWD02	1/5/11	14:35	19.90	0.13	93.03	7.04	21.58	9.47	-54.50	1.63	3.17	7,104
SJMWD02	1/5/11	14:50	20.90	0.39	93.42	7.04	21.52	9.56	-66.20	1.57	3.19	7,167
SJMWD02	1/5/11	14:53	20.92	0.08	93.50	7.04	21.63	9.62	-68.90	1.57	3.20	7,211
SJMWD02	1/5/11	14:56	20.90	0.08	93.58	7.05	21.58	9.67	-70.10	1.53	2.92	7,253
SJMWD02	1/5/11	14:59	20.86	0.08	93.66	7.06	21.23	9.69	-75.00	1.50	3.00	7,270
SJMWD02	1/5/11	15:02	20.87	0.08	93.74	7.06	21.24	9.70	-75.40	1.48	3.48	7,274
SJMWD02	1/5/11	15:05	20.88	0.08	93.82	7.07	21.22	9.75	-75.90	1.47	3.53	7,312
SJMWD02	1/5/11	15:08	20.89	0.08	93.90	7.07	21.23	9.75	-76.10	1.44	3.41	7,310
SJMWD03	1/7/11	9:30	4.02	0.00	0.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	9:40	4.02	0.00	0.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	9:50	35.64	10.00	10.00	8.10	19.99	0.50	—	—	—	373
SJMWD03	1/7/11	10:00	59.73	10.00	20.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	10:10	61.70	10.00	30.00	8.01	20.10	0.58	—	—	—	431
SJMWD03	1/7/11	10:22	58.20	0.00	30.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	10:35	50.49	0.00	30.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	10:45	46.49	0.00	30.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	10:50	45.10	0.00	30.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	10:55	44.02	0.00	30.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	11:00	—	3.00	33.00	8.02	19.43	0.61	—	—	—	460
SJMWD03	1/7/11	11:05	—	0.00	33.00	—	—	—	—	—	—	—
SJMWD03	1/7/11	16:00	53.34	0.00	33.00	—	—	—	—	—	—	—
SJMWD03	1/10/11	11:14	26.16	0.13	33.13	6.85	18.23	3.11	174.20	2.98	181.00	2,333
SJMWD03	1/10/11	11:24	26.80	0.05	33.18	6.97	18.33	3.12	166.20	2.80	99.50	2,339
SJMWD03	1/10/11	11:34	27.54	0.06	33.24	7.10	18.51	3.14	153.80	2.53	27.50	2,354
SJMWD03	1/10/11	11:44	27.60	0.05	33.29	7.24	18.38	3.16	137.60	2.44	16.10	2,366
SJMWD03	1/10/11	11:54	27.77	0.05	33.34	7.28	18.50	3.16	132.30	2.39	11.70	2,369
SJMWD03	1/10/11	12:04	28.63	0.06	33.40	7.36	18.46	3.16	117.90	2.27	7.26	2,372
SJMWD03	1/10/11	12:14	29.30	0.05	33.45	7.40	18.65	3.16	106.60	2.25	6.65	2,369
SJMWD03	1/10/11	12:24	29.56	0.05	33.50	7.42	18.66	3.16	103.90	2.25	6.05	2,373
SJMWD03	1/10/11	12:34	29.90	0.05	33.55	7.42	18.64	3.16	99.10	2.27	5.12	2,369
SJMWD03	1/10/11	12:44	30.24	0.06	33.61	7.43	18.60	3.16	94.80	2.24	4.80	2,369
SJMWD03	1/10/11	12:54	30.55	0.05	33.66	7.44	18.59	3.16	91.00	2.27	4.42	2,369
SJMWD03	1/10/11	12:59	30.80	0.03	33.69	7.44	18.60	3.15	88.90	2.33	4.66	2,360

Table 2-5
Well Development and Sampling Data
Groundwater Quality Parameters

Well	Date	Time	DTW (TOC)	Incremental Vol. Removed (gal)	Cum. Vol. Removed (gal)	pH	Temperature (°C)	Spec. Cond. (MS/cm^2)	ORP	DO	NTU	Estimated TDS (calculated from Spec. Cond.) [a]
SJMWD03	1/10/11	13:04	30.80	0.02	33.71	7.45	18.62	3.15	88.10	2.36	4.58	2,363
SJMWD03	1/10/11	13:09	30.79	0.03	33.74	7.45	18.66	3.15	86.60	2.35	4.64	2,363

Notes

DO = dissolved oxygen
DTW = depth to water
gal = gallon
mS/cm^2 = millisiemens per square centimeter
NTU = nephelometric turbidity unit
ORP = oxidation/reduction potential
TDS = total dissolved solids
TOC = top of casing

a - Estimated TDS calculated as TDS = 0.75 * C where C is specific conductance in microsiemens (Freeze and Cherry 1979).

Table 2-6
Groundwater Chemical of Potential Concern Sampling Data

	GWBU	C	C	C	A	A	A	B
	study_loc_id	SJMWD01	SJMWD02	SJMWD03	SJMWS01	SJMWS02	SJMWS03	SJMWS04
	sample_date	1/8/2011	1/5/2011	1/7/2011	1/8/2011	1/5/2011	1/7/2011	12/28/2011
	x	3216668.348	3217045.488	3217179.409	3216654.641	3217048.206	3217163.239	3216943.21
	y	13857340.83	13857702.27	13857082.67	13857356.47	13857716.27	13857082.92	13857673.38
	TRRP GW_{Class3} PCL							
PhysChem (mg/L)								
TSS		2.5 U	**6.5**	2.5 U	2.5 U	**42**	**23**	**14**
Metals (mg/L)								
Aluminum	7,300	**0.056**	**0.12**	**0.17**	**0.043 J**	**0.205**	**0.12**	**0.48**
Arsenic	1	**0.0092**	**0.005**	**0.0016**	**0.0086**	**0.0073**	**0.0063**	**0.0075**
Barium	200	**0.15**	**0.52**	**0.45**	**0.19**	**0.21**	**3.8**	**0.47**
Cadmium	0.5	**0.0016 J**	0.001 U	0.001 U	0.001 U	**0.00265 J**	0.001 U	**0.0029 J**
Chromium	10	0.001 U	0.001 U	0.001 U	0.001 U	**0.0016 J**	**0.005 J**	**0.022**
Cobalt	2.2	**0.0017**	**0.002**	**0.00026**	**0.00038**	**0.00165**	**0.0031**	**0.0033**
Copper	130	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	**0.0037 J**
Lead	1.5	**1.7E-05 J**	**8.40E-05**	**0.00011**	**2.4E-05 J**	**0.000245**	**0.00015**	**0.0032**
Magnesium	--	**490**	**210**	**38**	**350**	**330**	**330**	**370**
Manganese	1,000	**1.9**	**1.4**	**0.12**	**1.7**	**2**	**4.4**	**2**
Mercury	0.2	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	**0.00017 J**
Nickel	150	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	**0.078**
Thallium	0.2	5E-06 U	**5.30E-05**	**1.9E-05 J**	5E-06 U	**0.00022**	8E-06 U	5E-06 U
Vanadium	0.51	3E-05 U	**0.0005**	**0.0015**	6E-05 U	**0.000595**	**0.0024**	**0.0011**
Zinc	2,200	0.0004 UJ	**0.0054 J**	0.0004 UJ	0.0004 UJ	0.0041 U	0.0004 UJ	**0.14**
Dissolved Metals (mg/L)								
Aluminum	--	**0.05 J**	**0.048 J**	0.015 U	**0.037 J**	**0.058**	**0.031 J**	**0.052**
Arsenic	--	**0.0095**	**0.0049**	**0.0019**	**0.0085**	**0.00695**	**0.0072**	**0.0073**
Barium	--	**0.15**	**0.56**	**0.45**	**0.19**	**0.215**	**3.8**	**0.45**
Cadmium	--	0.001 U	0.001 U	0.001 U	0.001 U	**0.0026 J**	**0.002 J**	**0.0022 J**
Chromium	--	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	**0.0028 J**	0.001 U
Cobalt	--	**0.0017**	**0.0019**	**0.00025**	**0.00035**	**0.00155**	**0.0031**	**0.0007**
Copper	--	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U
Lead	--	5.5E-06 U	**2.4E-05 J**	5E-06 U	5E-06 U	**2.1E-05 J**	**3E-05 J**	**1.9E-05 J**
Magnesium	--	**490**	**210**	**37**	**350**	**330**	**330**	**370**
Manganese	--	**2**	**1.5**	**0.11**	**1.7**	**2**	**4.4**	**2**
Mercury	--	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 UJ	1E-05 U
Nickel	--	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	**0.0093 J**
Thallium	--	5E-06 U	9.5E-06 U	8.5E-06 U	5.5E-06 U	1.1E-05 U	5.5E-06 U	5E-06 UJ
Vanadium	--	3E-05 U	**0.0002 J**	**0.0014**	3E-05 U	3E-05 U	**0.0022**	**0.00023 J**
Zinc	--	0.0004 UJ	0.0004 UJ	0.0004 UJ	0.0004 UJ	0.0004 UJ	0.0004 UJ	0.0004 UJ
Semivolatile Organic Compounds (µg/L)								
Acenaphthene	440,000	0.013 U	0.013 U	0.013 U	0.013 U	0.013 U	0.013 U	0.013 U
Fluorene	290,000	0.014 U	0.014 U	0.014 U	0.014 U	0.014 U	0.014 U	**0.03 J**
Naphthalene	150,000	**0.031 J**	0.011 U	0.011 U	**0.025 J**	**0.0295 J**	**0.033 J**	**0.046 J**
Phenanthrene	220,000	0.011 U	**0.029 J**	0.011 U	0.011 U	0.011 U	0.011 U	**0.099 J**
Bis(2-ethylhexyl)phthalate	600	0.065 U	0.065 U	0.065 U	0.065 U	**0.0975 J**	0.065 U	**0.49 J**
Phenol	2,200,000	0.032 U	**0.07 J**	**0.14 J**	0.032 U	**0.0795 J**	0.032 U	**1.1**
Carbazole	10,000	0.009 U	0.009 U	0.009 U	0.009 U	**0.018 J**	0.009 U	**0.054 J**

Table 2-6
Groundwater Chemical of Potential Concern Sampling Data

	GWBU	C	C	C	A	A	A	B
	study_loc_id	**SJMWD01**	**SJMWD02**	**SJMWD03**	**SJMWS01**	**SJMWS02**	**SJMWS03**	**SJMWS04**
	sample_date	**1/8/2011**	**1/5/2011**	**1/7/2011**	**1/8/2011**	**1/5/2011**	**1/7/2011**	**12/28/2011**
	x	**3216668.348**	**3217045.488**	**3217179.409**	**3216654.641**	**3217048.206**	**3217163.239**	**3216943.21**
	y	**13857340.83**	**13857702.27**	**13857082.67**	**13857356.47**	**13857716.27**	**13857082.92**	**13857673.38**
	TRRP GW_{Class3} PCL							
PCBs (pg/L)								
Aroclor 1016	--	480 U	480 U	2,400 U	480 U	480 U	480 U	40,000 U
Aroclor 1221	--	480 U	480 U	20,000 U	480 U	480 U	480 U	95,000 U
Aroclor 1232	--	480 U	480 U	4,800 U	480 U	480 U	480 U	85,000 U
Aroclor 1242	--	480 U	480 U	2,900 U	480 U	480 U	480 U	75,000 U
Aroclor 1248	--	480 U	480 U	2,700 U	480 U	480 U	480 U	28,000 U
Aroclor 1254	--	480 U	480 U	480 U	480 U	480 U	480 U	31,000 U
Aroclor 1260	--	480 U	480 U	480 U	480 U	480 U	480 U	19,000 U
Aroclor 1262	--	480 U	480 U	480 U	480 U	480 U	480 U	480 U
Aroclor 1268	--	480 U	480 U	480 U	480 U	480 U	480 U	480 U
Total PCBs (Aroclor sum)	50,000,000	2,200 U	2,200 U	17,000 U	2,200 U	2,200 U	2,200 U	190,000 U
Dioxin/Furans (pg/L)								
2,3,7,8-TCDD	3,000	0.44 U	0.58 U	0.51 U	0.52 U	0.44 U	0.37 U	**2,700**
1,2,3,7,8-PeCDD	--	0.42 U	0.42 U	0.47 U	0.41 U	0.41 U	0.39 U	**25 J**
1,2,3,4,7,8-HxCDD	--	0.34 U	0.36 U	0.32 U	0.32 U	0.31 U	0.28 U	0.31 U
1,2,3,6,7,8-HxCDD	--	0.47 U	0.52 U	0.45 U	0.43 U	0.46 U	0.4 U	0.48 U
1,2,3,7,8,9-HxCDD	--	0.38 U	0.41 U	0.36 U	0.35 U	0.36 U	0.32 U	0.37 U
1,2,3,4,6,7,8-HpCDD	--	0.37 U	0.49 U	0.4 U	0.44 U	0.41 U	0.35 U	**25 J**
OCDD	--	1.1 U	0.79 U	0.62 U	0.55 U	**3.6 J**	7.2 U	**390**
2,3,7,8-TCDF	--	0.5 U	0.52 U	0.45 U	0.54 U	**1.89 J**	0.43 U	**9,100**
1,2,3,7,8-PeCDF	--	0.34 U	0.54 U	0.36 U	0.41 U	0.32 U	0.37 U	**270**
2,3,4,7,8-PeCDF	--	0.31 U	0.5 U	0.34 U	0.39 U	0.31 U	0.34 U	**170**
1,2,3,4,7,8-HxCDF	--	0.22 U	0.32 U	0.23 U	0.25 U	0.26 U	0.3 U	**520**
1,2,3,6,7,8-HxCDF	--	0.22 U	0.31 U	0.23 U	0.25 U	0.26 U	0.3 U	**110**
1,2,3,7,8,9-HxCDF	--	0.3 U	0.43 U	0.31 U	0.34 U	0.34 U	0.4 U	2.5 U
2,3,4,6,7,8-HxCDF	--	0.23 U	0.33 U	0.25 U	0.26 U	0.27 U	0.31 U	**14 J**
1,2,3,4,6,7,8-HpCDF	--	0.27 U	0.41 U	0.32 U	0.35 U	0.34 U	0.32 U	**120**
1,2,3,4,7,8,9-HpCDF	--	0.48 U	0.66 U	0.54 U	0.58 U	0.51 U	0.51 U	**50**
OCDF	--	0.55 U	0.69 U	0.67 U	0.68 U	0.57 U	0.7 U	**81 J**
TEQ_{DF}		1.24 U	1.5 U	1.37 U	1.35 U	2.64 J	1.17 U	3770

Notes

Detected concentration is greater than GW_{Class3} screening level. See Section 4.2.1.2 of the text for a discussion of the determination of site groundwater classification and standard selection.

Bold = Detected result

-- = No Standard

J = Estimated value

U = Compound analyzed, but not detected above detection limit

UJ = Compound analyzed, but not detected above estimated detection limit

Samples SJMWS02-D1 & SJMWS02-D1 are averaged.

If values are both ND, the lower detection limit is used.

If one value is ND, that detection limit is used.

Table 3-2
Potential ARAR Screening for the San Jacinto River Waste Pits Superfund Site, Remedial Alternatives Memorandum

Potential ARARs[1]	Citation	Summary	Comment
Federal			
Clean Water Act (CWA): Criteria and standards for imposing technology-based treatment requirements under §§ 309(b) and 402 of the Act	33 U.S.C. §§ 1319 and 1342 (implementing regulations at 40 CFR Part 125 Subpart A)	Both on-site and off-site discharges from CERCLA sites to surface waters are required to meet the substantive CWA (National Pollutant Discharge Elimination System) NPDES requirements (USEPA 1988).	On-site discharges must comply with the substantive technical requirements of the CWA but do not require a permit (USEPA 1988). Off-site discharges would be regulated under the conditions of a NPDES permit (USEPA 1988). Standards of control for direct discharges must meet technology-based requirements. Best conventional pollution control technology (BCT) is applicable to conventional pollutants. Best available technology economically achievable (BAT) applies to toxic and non-conventional pollutants. For CERCLA sites, BCT/BAT requirements are determined on a case-by-case basis using best professional judgment. This is likely to be a potential requirement only if treated water or excess dredge water is discharged during implementation.
CWA Sections 303 and 304: Federal Water Quality Criteria	33 U.S.C. §§1313 and 1314 (Most recent 304(a) list as updated to issuance of ROD)	Under §303 (33 U.S.C. §1313), individual states have established water quality standards to protect existing and attainable uses (USEPA 1988). CWA §301(b)(1)(C) requires that pollutants contained in direct discharges be controlled beyond BCT/BAT equivalents (USEPA 1988). CERCLA §121(d)(2)(B)(i) establishes conditions under which water quality criteria, which were developed by USEPA as guidance for states to establish location-specific water quality standards, are to be considered relevant and appropriate. Two kinds of water quality criteria have been developed under CWA §304 (33 U.S.C. §1314): one for protection of human health, and another for protection of aquatic life. These requirements include establishment of total maximum daily loads (TMDL).	The FS will consider the ability of remedial alternatives to satisfy established water quality criteria. Best management practices (BMPs) would be established for remedial actions and applied during construction. Water quality would also be monitored during construction and additional BMPs may be implemented if necessary to protect water quality. Where water quality state standards contain numerical criteria for toxic pollutants, appropriate numerical discharge limitations may be derived for the discharge and considered (USEPA 1988). Where state standards are narrative, either the whole-effluent or chemical-specific approach may generally be used as a standard of care (USEPA 1988).
CWA Section 307(b): Pretreatment standards	33 U.S.C. §1317(b)	CERCLA §121(e) states that no federal, state, or local permit for direct discharges is required for the portion of any removal or remedial action conducted entirely on-site (the aerial extent of contamination and all suitable areas in close proximity to the contamination necessary for implementation of the response action) (USEPA 1988).	If off-site discharges from a CERCLA response activity were to enter receiving waters directly or indirectly, through treatment at a Publicly Owned Treatment Works (POTWs), they must comply with applicable Federal, State, and Local substantive requirements and formal administrative permitting requirements (USEPA 1988). This requirement may be triggered by disposal methods for waste.
CWA Section 401: Water Quality Certification	33 U.S.C. §1341	Requires applicants for Federal permits for projects that involve a discharge into navigable waters of the U.S. to obtain certification from state or regional regulatory agencies that the proposed discharge will comply with CWA Sections 301, 302, 303, 306, and 307.	Proposed activities that are on-site would not require a Federal permit. Therefore, certification is not legally required for on-site actions. Certification would be required for off-site actions. For on-site or off-site actions, certification should occur as part of the state identification of substantive state ARARs (USEPA 1988). Compliance with water quality criteria is discussed under CWA Sections 303 and 304.

[1] ARARs are applicable or relevant and appropriate requirements of Federal or state environmental laws and state facility siting laws. CERCLA section 121(d) requires that remedial actions generally comply with ARARs. The USEPA has stated a policy of attaining ARARs to the greatest extent practicable on remedial or removal actions (USEPA 1988). USEPA also stated that certain nonpromulgated Federal and state advisories or guidelines would be considered in selecting remedial or removal actions; these guidelines are referred to as TBCs, or "to be considered."

Potential ARARs[1]	Citation	Summary	Comment
CWA Section 404 and 404(b)(1): Dredge and Fill	33 U.S.C. §1344 (b)(1) (implementing regulations at 33 CFR 320 and 330; 40 CFR 230)	Discharges of dredged and fill material into waters of the U.S. must comply with the CWA §404 (33 U.S.C. 1344) guidelines and demonstrate the public interest is served (USEPA 1988).	The San Jacinto site is a water of the U.S. (USEPA 2007). Dredge and fill permits are applicable to dredging, in-water disposal, capping, construction of berms or levees, stream channelization, excavation and/or dewatering within waters of the U.S. (USEPA 1988). Permits are not required, however, for on-site CERCLA actions. Under the 404(b)(1) guidelines, efforts should be made to avoid, minimize, and mitigate adverse effects on the waters of the U.S. and, where possible, select a practicable (engineering feasible) alternative with the least adverse effects. The substantive requirements of Section 404 will be considered in the development and evaluation of remedial alternatives to minimize adverse impacts to waters of the U.S.
Safe Drinking Water Act	42 U.S.C. §300f (implementing regulations at 40 CFR Part 141, et seq.)	The Safe Drinking Water Act is applicable to public drinking water sources at the point of consumption ("at the tap"). Maximum contaminant levels (MCLs) have been established for certain constituents to protect human health and to preserve the aesthetic quality of public water supplies.	Safe Drinking Water Act standards are applicable to public drinking water sources. The San Jacinto River is not a public water supply and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Federal Drinking Water Regulations (Primary and Secondary Drinking Water Standards)[2]	40 CFR 141 and Part 143	USEPA has established two sets of drinking water standards: one for protection of human health (primary) and one to protect aesthetic values of drinking water (secondary) (USEPA 1988). MCLs are applicable to public drinking water sources at the point of consumption.	Safe Drinking Water Act standards are applicable to public drinking water sources. The San Jacinto River is not a public water supply and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Resource Conservation And Recovery Act (RCRA): Hazardous Waste Management	42 U.S.C. §§6921 et seq. (implementing regulations at 40 CFR Parts 260 – 268)	RCRA is intended to protect human health and the environment from the hazards posed by waste management (both hazardous and nonhazardous). RCRA also contains provisions to encourage waste reduction. RCRA Subtitle C and its implementing regulations contain the Federal requirements for the management of hazardous wastes.	This requirement would apply to certain activities if the affected sediments contain RCRA listed hazardous waste or exhibit a hazardous waste characteristic. RCRA requirements are applicable only if waste is managed (treated, stored, or disposed of) after effective date of RCRA requirement under consideration or if CERCLA activity constitutes treatment, storage, or disposal as defined by RCRA. The sludge and sediment at the site are not listed hazardous waste, do not contain listed hazardous waste, and do not meet any of the characteristics of hazardous waste. Therefore, the RCRA rules for hazardous waste are neither applicable nor relevant and appropriate.
RCRA: General Requirements for Solid Waste Management	42 U.S.C. §§6941 et seq. (implementing regulations at 40 CFR 258)	Requirements for construction for municipal solid waste landfills that receive RCRA Subtitle D wastes, including industrial solid waste. Requirements for run-on/run-off control systems, groundwater monitoring systems, surface water requirements, etc.	This requirement would be relevant if a landfill was constructed for the disposal of non-hazardous solid waste. There are no specific Federal requirements for non-hazardous waste management; state regulations provide specific applicable requirements for siting, design, permitting, and operation of landfills.
Clean Air Act (CAA)	42 U.S.C. §§7401 et seq.	Would apply if dredging and/or excavation activities generate air emissions sufficient to require a permit, greater than 10 tons of any pollutant per year under the CAA operational permit (USEPA 2009).	None of the remedial alternatives is expected to trigger an operational permit.
Rivers And Harbors Act of 1899: Obstruction of navigable waters (generally, wharves; piers, etc.); excavation and filling-in	33 U.S.C. §401	Controls the alteration of navigable waters (i.e., waters subject to ebb and flow of the tide shoreward to the mean high water mark). Activities controlled include construction of structures such as piers, berms, and installation of pilings as well as excavation and fill. Section 10 may be applicable for any action that may obstruct or alter a navigable waterway.	No permit is required for on-site activities. However, substantive requirements might limit in-water construction activities.

[2] Underground injection is not anticipated as a part of the potential remedial action. Furthermore, the site is not located in a sole-source aquifer (USEPA 2008). It is also assumed that no wellhead protection area is located near the study area.

Potential ARARs[1]	Citation	Summary	Comment
Endangered Species Act	16 U.S.C. §§ 1531 et seq.	Federal agencies must ensure that actions they authorize, fund, or carry out are not likely to adversely modify or destroy critical habitat of endangered or threatened species. Actions authorized, funded, or carried out by federal agencies may not jeopardize the continued existence of endangered or threatened species as well as adversely modify or destroy their critical habitats.	If Federally listed threatened or endangered (T&E) species or their critical habitat are present on the site or utilize areas in the vicinity of the site, this requirement is potentially relevant to determination of cleanup areas/volumes, preliminary remediation goals, and determination of removal alternatives. Based on review of USFWS and NMFS maps, no critical habitat is present at the site. Based on a review of photos and aerial images of the site and lists of federal T&E species and their habitats, it is unlikely that T&E species are present at the site. NMFS includes endangered sea turtles in Trust resources impacted by contaminated surface water and sediments that may have been transported from the site. A qualified biologist will perform a site visit prior to construction to confirm the absence of T&E species and critical habitat. Pursuant to CERCLA 121(e) and USEPA policy, separate consultation with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) is not required and permits are not required. USEPA will consult with the resource agencies.
Fish and Wildlife Coordination Act	16 U.S.C. §§661 et seq., 16 U.S.C. §742a, 16 U.S.C. § 2901	Requires adequate provision for protection of fish and wildlife resources. This title has been expanded to include requests for consultation with USFWS for water resources development projects (Mueller 1980). Any modifications to rivers and channels require consultation with the USFWS, Department of Interior, and state wildlife resources agency[3]. Project-related losses (including discharge of pollutants to water bodies) may require mitigation or compensation.	Applicable to any action that controls or modifies a body of water.
Bald and Golden Eagle Protection Act	16 U.S.C. §668a-d	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any bald or golden eagle, nest, or egg. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, trapping and collecting, molesting, or disturbing.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests bald or golden eagles frequent the project area; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that bald and golden eagles do not frequent the project area.
Migratory Bird Treaty Act	16 U.S.C. §§703-712 (implementing regulations at 50 CFR §10.12)	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any migratory bird. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, and trapping and collecting.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests migratory birds frequent the project area, and aerial photography of the site suggests no suitable nesting or stopover habitat is present; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that migratory birds do not frequent the project area.
Coastal Zone Management Act	16 USC §§1451 et seq. (implementing regulations at 15 CFR 930)	Federal activities must be consistent with, to the maximum extent practicable, State coastal zone management programs. Federal agencies must supply the State with a consistency determination (USEPA 1989).	The San Jacinto River lies within the Coastal Zone Boundary according to the Texas Coastal Management Plan (TCMP) prepared by the General Land Office (GLO). The FS will consider whether the remedial alternatives would affect (adversely or not) the coastal zone, the lead agency is required to determine whether the activity will be consistent with the State's CZMP (USEPA 1989). More information regarding the state requirements is provided under Texas Coastal Coordination Council (TCCC) Policies for Development in Critical Areas.
FEMA (Federal Emergency Management Agency), Department of Homeland Security (Operating Regulations)	42 U.S.C. 4001 et seq. (implementing regulations at 44 CFR Chapter 1)	Prohibits alterations to river or floodplains that may increase potential for flooding.	This requirement is relevant to CERCLA activities in floodplains and in the river because the project area is within a designated flood zone. The FS will include an assessment of the potential impacts of remedial alternatives on the floodplain.
National Flood Insurance Program (NFIP) Regulations	42 U.S.C. subchapter III, §§4101 et seq.	Provides federal flood insurance to local authorities and requires that the local authorities not allow fill in the river that would cause an increase in water levels associated with floods.	A hydrologic evaluation will be performed to determine if remedial alternatives would have a significant impact on the water level during a flood.

[3] Texas Parks and Wildlife Department.

Potential ARARs[1]	Citation	Summary	Comment
Title 40: Protection of the Environment - Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR Part 6 App. A; Executive Orders (EO) 11988 and 11990	Requires federal agencies to conduct their activities to avoid, if possible, adverse impacts associated with the destruction or modification of wetlands and occupation or modification of floodplains. Executive Orders 11988 and 11990 require federal projects to avoid adverse effects and minimize potential harm to wetlands and within flood plains. The EO 11990 requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative (USEPA 1994).	This requirement is potentially relevant to disposal or treatment activities in the upland as well as any in-water facilities that might displace floodwaters. The waste pits are located within the floodway and Zone AE, or the 1% probability floodplain. Effects on the base flood, typically the 100-year or 1% probability flood, should be minimized to the maximum extent practicable (Code of Federal Regulations 1985 as amended). The agency also adopted a requirement that the substantive requirements of the Protection of Wetlands Executive Order must be met (USEPA 1994). Unavoidable impacts to wetlands must be mitigated (USEPA 1994)[4].
National Historic Preservation Act	16 U.S.C. §§ 470 et seq. (implementing regulations at 36 CFR 800)	Section 106 of this statute requires Federal agencies to consider effects of their undertakings on historic properties. Historic properties may include any district, site, building, structure, or object included in or eligible for the National Register of Historic Places (NRHP), including artifacts, records, and material remains related to such a property.	According to the San Jacinto River Waste Pits Remedial Investigation/Feasibility Study (RI/FS) cultural resources assessment, "no NRHP-eligible properties are documented in the area of concern. Because of the extensive disturbance to the site and minimal ground disturbance that will likely occur for the project, it is not likely that NRHP-eligible historic properties will be affected by RI/FS or eventual site remediation activities" (Anchor QEA 2009).
Noise Control Act	42 U.S.C. §§ 4901 et seq. (implementing regulations at 40 CFR Subchapter G §201 et seq.	Noise Control Act remains in effect but unfunded (USEPA 2010).	Noise is regulated at the state level. See Texas Penal Code under state ARARs.
Hazardous Materials Transportation Act	49 U.S.C. §§1801 et seq. (implementing regulations at 49 CFR. Subchapter C)	Establishes standards for packaging, documenting, and transporting hazardous materials.	This requirement would apply to remedial alternatives that involve transporting hazardous materials off-site for treatment or disposal.

[4] Each agency is expected to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when implementing actions such as CERCLA sites (President of the United States 1977). If §404 of the Clean Water Act is considered an ARAR, then the 404(b)(1) guidelines established in a Memorandum of Understanding (MOU) between USEPA and Department of Army should be followed (USEPA 1994). When habitat is severely degraded, a mitigation ratio of 1:1 may be acceptable (USEPA 1994). However, any mitigation would be at the discretion of the agency and the USEPA may elect to orient mitigation towards "minimizing further adverse environmental impacts rather than attempting to recreate the wetlands original value on site or off site" (USEPA 1988).

Potential ARARs	Citation	Summary	Comment
State			
30 Texas Administrative Code (TAC) Part 1: Industrial Solid Waste and Municipal Hazardous Waste General Terms	30 TAC §§335.1 – 335.15	General Terms: Substantive requirements for the transportation of industrial solid and hazardous wastes; requirements for the location, design, construction, operation, and closure of solid waste management facilities.	Guidelines to promote the proper collection, handling, storage, processing, and disposal of industrial solid waste or municipal hazardous waste in a manner consistent with the purposes of Texas Health and Safety Code, Chapter 361. Solid nonhazardous waste provisions are applicable if material is transported to an upland disposal facility.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Notification	30 TAC Chapter 335 Subchapter P	Requires placement of warning signs in contaminated and hazardous areas if a determination is made by the executive director of the Texas Water Commission a potential hazard to public health and safety exists which will be eliminated or reduced by placing a warning sign on the contaminated property.	Warning signs and fencing were placed around the site as part of the Time Critical Removal Action. The FS will consider the need for additional warning signs and fencing as part of remedial alternatives.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Generators	30 TAC Chapter 335, Subchapter C	Standards for hazardous waste generators either disposing of waste on-site or shipping off-site with the exception of conditionally exempt small quantity generators. The definition of hazardous involves state and federal standards.	The sludge and sediment at the site are not listed hazardous waste, do not contain listed hazardous waste, and do not meet any of the characteristics of hazardous waste. Therefore, the rules for hazardous waste are neither applicable nor relevant and appropriate.
Texas Surface Water Quality Standards	30 TAC §307.4-7, 10	These state regulations provide: • General narrative criteria • Anti-degradation Policy • Numerical criteria for pollutants • Numerical and narrative criteria for water-quality related uses (e.g., human use) • Site specific criteria for San Jacinto basin	Surface water quality standards are potentially relevant to the determination of risks, but should not override any site-specific toxicity values or risks determined through the risk assessment process. It is also relevant to the identification of potential sources and the short-term and long-term effectiveness of removal alternatives.
Texas Water Quality: Pollutant Discharge Elimination System (TPDES)	30 TAC §279.10	These state regulations require stormwater discharge permits for either industrial discharge or construction-related discharge. The State of Texas was authorized by USEPA to administer the NPDES program in Texas on September 14, 1998 (Texas Commission on Environmental Quality 2009).	The FS will evaluate the need for a discharge permit for off-site remedial actions.
Texas Water Quality: Water Quality Certification	30 TAC §279.10	These state regulations establish procedures and criteria for applying for, processing, and reviewing state certifications under CWA, §401. It is the purpose of this chapter, consistent with the Texas Water Code and the federal CWA, to maintain the chemical, physical, and biological integrity of the state's waters.	The development and evaluation of remedial alternatives will include consideration of potential water-quality impacts, relevant to the Water Quality Certification in Texas. Although permits are not required for on-site CERCLA actions, water quality certification is relevant as part of identification of substantive state ARARs (USEPA 1988).
Texas Risk Reduction Program	30 TAC §350	Activated upon release of Chemicals of Concern (COC). The Risk Reduction Program uses a tiered approach incorporating risk assessment techniques to help focus investigations, to determine appropriate protective concentration levels for human health, and when necessary, for ecological receptors. Includes protective concentration levels.	Risk assessment is being performed as part of the remedial investigation, and permanent risk reduction would be accomplished through the potential remedial action.
Natural Resources Code, Antiquities Code of Texas	Texas Parks and Wildlife Commission Regulations 191.092-171	Requires that the Texas Historical Commission staff review any action that has the potential to disturb historic and archeological sites on public land. Actions that need review include any construction program that takes place on land owned or controlled by a state agency or a state political subdivision, such as a city or a county. Without local control, this requirement does not apply.	Assessment of historical resources during the TCRA produced no known eligible properties and determined that disturbance of any archaeological or historic resources is unlikely within the TCRA Site. Depending on the magnitude and specific boundaries of ground disturbance determined during the FS for the overall site, this ARAR will need to be re-evaluated relative to CERCLA activities outside of the TCRA boundaries. (Anchor QEA 2009).
Practice and Procedure, Administrative Code of Texas	13 TAC Part 2, Chapter 26	Regulations implementing the Antiquities Code of Texas. Describes criteria for evaluating archaeological sites and permit requirements for archaeological excavation.	This requirement is only applicable if an archaeological site is found.

Potential ARARs	Citation	Summary	Comment
State of Texas Threatened and Endangered Species Regulations	31 TAC 65.171 - 65.176	No person may take, possess, propagate, transport, export, sell or offer for sale, or ship any species of fish or wildlife listed as threatened or endangered.	No readily available information suggests endangered or threatened species in the project area. NMFS includes endangered sea turtles in Trust resources impacted by contaminated surface water and sediments likely transported from the site. The presence or absence of state T&E species will be documented for the site as part of the FS.
TCCC Policies for Development in Critical Areas	31 TAC §501.23	Dredging in critical areas is prohibited if activities have adverse effects or degradation on shellfish and/or jeopardize the continued existence of endangered species or results in an adverse effect on a coastal natural resource area (CNRA)[5]; prohibit the location of facilities in coastal natural resource areas unless adverse effects are prevented and /or no practicable alternative. Actions should not be conducted during spawning or nesting seasons or during seasonal migration periods. Specifies compensatory mitigation.	The FS will evaluate the potential effects of remedial alternatives on Coastal Natural Resource Area (CNRAs), which includes coastal wetlands (Railroad Commission of Texas n.d.).
Texas Coastal Management Plan Consistency	31 TAC, §506.12	Specifies Federal actions within the CMP boundary that may adversely affect CNRAs; specifically selection of remedial actions.	The San Jacinto River lies within the Coastal Zone Boundary (GLO TCMP). The FS will evaluate whether remedial alternatives may affect (adversely or not) the coastal zone and will provide a technical basis for the lead agency to determine whether the activity will be consistent with the State's CZMP (USEPA 1989).
Texas State Code – obstructions to navigation	Natural Resources Code § 51.302 Prohibition and Penalty	Prohibits construction or maintenance of any structure or facility on land owned by the State without an easement, lease, permit, or other instrument from the State.	The FS will evaluate whether the remedial alternatives include construction on state-owned land.
Noise Regulations	Texas Penal Code Chapter 42, Section 42.01	The Texas Penal Code regulates any noise that exceeds 85 decibels after the noise is identified as a public nuisance.	Noise abatement may be required if actions are identified as a public nuisance. Due to the isolation of the site, its location adjacent to a freeway with high volumes of traffic during normal working hours, and the industrial nature of the nearest properties, noise from construction activity associated with a potential remedial action is unlikely to constitute a public nuisance. Noise associated with truck traffic to and from the site should be considered.
Local			
Harris County Floodplain Management Permit[6]	Regulations of Harris County, Texas for Flood Plain Management	All development occurring within the floodplain of unincorporated Harris County requires a permit from Harris County; provide land use controls necessary to qualify unincorporated areas of Harris County for flood insurance under requirements of the National Flood Insurance Act of 1968, as amended, to protect human life and health (Harris County 2007).	Floodplain management is addressed under the Federal requirements for floodplains.

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[5] A CNRA is a coastal wetland, oyster reef, hard substrate reef, submerged aquatic vegetation, tidal sand, or mud flat.

[6] Harris County authorization is based upon Texas Local Government Code Section 240.901, as amended; Texas Transportation Code Sections 251.001 - 251.059 and Sections 254.001 - 254.019, as amended; the Harris County Road Law, as amended; and the Flood Control and Insurance Act, Subchapter I of Chapter 16 of the Texas Water Code, as amended.

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Table 5-2
Summary of Technology Implementability Screening Results by SMA Based on Site Uses and Physical Conditions[1]

Label	Feature	Description	MNR	EMNR	In Situ Treatment	Engineered and Active Capping	Full Removal	Ex Situ Treatment[2]
NAV	Navigation Channel	Areas within the active navigation channel, where barge fleeting operations are known to occur, or with water depths generally deeper than 12 feet.	YES	NO	NO	NO	YES	YES
NS[3]	Nearshore Area	Areas with water depths shallower than approximately 2 feet, which could constrain access for some process options	YES	YES	YES	YES	YES	YES
OW[3]	Open Water Area	Areas where there is no restrictions to dredging or capping equipment.	YES	YES	YES	YES	YES	YES
ST	Fixed Structure	Areas where access by water-based equipment is highly restricted and upland structures, utilities, and/or topography highly restrict access from shore.	YES	YES	YES	YES	NO	NO
TCRA	TCRA Site	Existing cap at TCRA Site.	YES	YES	YES	YES	NO	NO

Notes:
1 - All screening results in this table are for draft FS purposes only, and all technologies discussed here may be implementable under specific circumstances for specific SMAs as determined in remedial design.
2 - Ex situ treatment implementability is not typically controlled by the Site use and physical conditions in this table. Implementability issues related to removal before ex situ treatment are noted here.
3 - NS and OW SMAs generally can support all remedial technologies. However, there may be specific process option limitations due to access constraints in NS areas. Thus, the NS SMA has been defined to facilitate more detailed consideration of implementability during the FS.

Table 5-3

Application of Technologies by SMA Type for Comprehensive Alternatives

SMA Type	SMA Description	Removal Focused	Integrated Focused
NAV	Areas within the active navigation channel, where barge fleeting operations are known to occur, or with water depths generally deeper than 12 feet.	Removal	Removal
NS	Areas with water depths shallower than approximately 2 feet, which could constrain access for some process options	Removal	Cap
OW	Areas where there is no restrictions to dredging or capping equipment.	Removal	Cap
ST	Areas where access by water-based equipment is highly restricted and upland structures, utilities, and/or topography highly restrict access from shore.	Cap	Cap
TCRA	Existing cap at TCRA Site.	Cap	Cap

FIGURES

APPENDIX A

DRAFT DIOXIN TREATABILITY STUDY LITERATURE REVIEW

DRAFT DIOXIN TREATABILITY STUDY LITERATURE REVIEW
SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

McGinnes Industrial Maintenance Corporation

International Paper Company

U.S. Environmental Protection Agency, Region 6

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

October 2011

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LIST OF ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
AC	Activated Carbon
Anchor QEA	Anchor QEA, LLC
AOC	Administrative Order on Consent
APEG	Alkaline Polyethylene Glycolate
BCD	Base-Catalyzed Decomposition
BMPs	best management practices
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CETCO	Colloid Environmental Technologies Company
CF	cubic feet
CFR	Code of Federal Regulations
COI	Chemical of Interest
COPC	contaminant of potential concern
cy	cubic yard
FRTR	Federal Remediation Technologies Roundtable
I-10	Interstate Highway 10
IBTD	In-Barge Thermal Desorption
Integral	Integral Consulting Inc.
IPC	International Paper Company
IPTD	In-Pile Thermal Desorption
ISTD	In Situ Thermal Desorption
K_{oc}	organic carbon partitioning coefficient
K_{ow}	octanol/water partitioning coefficient
KPEG	Potassium Polyethylene Glycolate
LLDPE	linear low density polyethylene
MIMC	McGinnes Industrial Maintenance Corporation
ng/kg	nanograms per kilogram
NPL	National Priorities List
OTA	Office of Technology Assessment
PCB	polychlorinated biphenyl

PIC	products of incomplete combustion
ppm	parts per million
RACR	Removal Action Completion Report
RAWP	Removal Action Work Plan
RCRA	Resource Conservation and Recovery Act
RCM	Reactive Core Mat®
RI/FS	Remedial Investigation and Feasibility Study
River	San Jacinto River
S/S	Solidification/Stabilization
SET	Solvated Electron Technology™
sf	square foot
Site	San Jacinto River Waste Pits Superfund Site
SOW	Statement of Work
sy	square yard
TCRA	time critical removal action
TEQ	toxic equivalency
UAO	Unilateral Administrative Order
U.S.	United States
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
Veolia	Veolia Environmental Services

1 INTRODUCTION

1.1 Purpose

This document fulfills the requirement for a "Literature Survey and Determination of the Need for Treatability Testing" that is contained in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 106(a) Unilateral Administrative Order (UAO) issued by the U.S. Environmental Protection Agency, Region 6 (USEPA), Docket No. 06-03-10, to McGinnes Industrial Maintenance Corporation (MIMC) and International Paper Company (IPC). The requirement is part of Task 8 in the Statement of Work (SOW) of the UAO for the San Jacinto River Waste Pits Superfund Site (Site) Remedial Investigation and Feasibility Study (RI/FS). The SOW requires that the Respondents evaluate the performance, relative costs, applicability, removal efficiencies, operation and maintenance requirements, and implementability of treatment options and assess whether sufficient information about candidate technologies is available to evaluate them in the RI/FS or whether treatability studies are necessary to perform the evaluation.

This document does not contain an evaluation of remedial alternatives for the Site. The evaluation of remedial alternatives is the subject of the FS. Rather, the purpose of this evaluation is to identify treatment technologies that are potentially applicable as part of a remedy for the Site, and review currently available information about each treatment technology to determine whether the available information is sufficient for the needs of the FS. The FS will provide an evaluation of remedial alternatives that incorporate both treatment and non-treatment technologies to mitigate threats to human health and the environment from the Site, and is scheduled to be delivered to USEPA on February 21, 2013.

The FS will require sufficient information about the long- and short-term effectiveness, implementability, and cost of each treatment technology to evaluate the relative cost effectiveness of the remedial alternatives. Additional information on treatment technologies may be needed for application of the method, such as operational requirements and certain performance metrics. This type of detailed information may be obtained from treatability studies during the design phase, after the remedy is selected and may not be needed for the FS evaluation.

Candidate technologies are identified in this document as 1) inapplicable to the Site (with the rationale provided), 2) applicable with sufficient information available to evaluate in the FS, or 3) potentially applicable with additional information required to complete the FS evaluation. As required by the UAO, and as appropriate, this document will only recommend the performance of treatability tests for technologies that fall into the third category (potentially applicable, but with insufficient information available to evaluate in the FS).

The following sections present information concerning available treatment methods and their applicability to the Site. This evaluation provides a review of technologies available for the treatment of sediment and sludge containing dioxins and other Site contaminants of potential concern (COPCs). Some of the methods described in this document are not supported with unit cost and other operational information derived from full-scale field implementation. Moreover, the cost information (if available) of laboratory and pilot-scale model tests more than likely would not translate dollar-for-dollar to actual full-scale remediation efforts. Several of the treatment methods are still in the research stage; success in the laboratory or in pilot-scale tests may not reliably indicate the effectiveness of the method in the field.

1.2 Background

On March 19, 2008, the Site was placed on the National Priorities List (NPL), and on November 20, 2009, MIMC and IPC (the Respondents) received the UAO requiring that the Respondents conduct an RI/FS at the Site. In addition, MIMC and IPC entered into an Administrative Order on Consent (AOC), Docket No. 06-12-10, in May 2010 to perform a time critical removal action (TCRA). The activities of the TCRA are outlined in the *Removal Action Work Plan* (RAWP), prepared by Anchor QEA, LLC, (Anchor QEA) in November 2010, and revised in February 2011[1]and the *Draft Removal Action Completion Report* (September 2011).

[1] The revised RAWP was submitted to the USEPA on February 23, 2011, and approved by the USEPA on March 3, 2011.

The Site consists of a set of impoundments, 15.7-acres in size, built in the mid-1960s for disposal of paper mill wastes, and the surrounding areas containing sediments and soils potentially contaminated with the waste materials that had been disposed of in the impoundments. A set of impoundments is located on a partially submerged 20-acre parcel on the western bank of the San Jacinto River, in Harris County, Texas, immediately north of the Interstate Highway 10 (I-10) Bridge over the San Jacinto River (Figure 1-1).

USEPA has information that indicates that an additional impoundment is located south of I-10. This information indicates the additional impoundment contains material similar to that disposed of in the two impoundments north of I-10. USEPA has not identified any evidence of releases or threatened releases from the additional impoundment; however, new data for this area was generated as part of the RI/FS soil sampling and analysis plan addendum (Integral and Anchor QEA 2011) and are currently being evaluated.

A full description of the Site history is provided in the RI/FS Work Plan (Anchor QEA and Integral 2010).

The RI/FS will determine the need for further remedial action at the Site, following the implementation of the TCRA. In their approval of the RI/FS Work Plan (November 2, 2010), USEPA provides RI/FS "process direction" stating that the waste impoundments north of I-10 are source material, to be considered principal threat wastes. At that time, USEPA also directed Respondents to make a determination in the RI as to whether "the Site's contaminated materials" (i.e., sediment and soil outside of the northern impoundments) are principal threat wastes or low level threat wastes. According to USEPA guidance, source materials constituting principal threat wastes may be contained or treated as part of the final remedy, but that treatment must be considered (USEPA 1991).

1.3 TCRA Implementation

The TCRA was implemented to stabilize pulp waste and sediments within the original 1966 perimeter berm of the impoundments north of I-10 to prevent the release of dioxins and furans and other COPCs to the environment (Anchor QEA 2010).

1.3.1 TCRA Components

The area within the original 1966 perimeter was separated into three distinct areas: the Eastern Cell, the Western Cell, and the Northwestern Area (Figure 1-2). In general, the TCRA design included an armor rock cap placed atop a geotextile bedding layer. The one exception is that the Northwestern Area did not receive a geotextile bedding layer. Additionally, the Western Cell also received a geomembrane cover layer prior to armor rock installation.

Four different armor rock gradations were specified for the cap material. The armor cap layout is provided in Figure 1-2. Each of the armor rock types and minimum thicknesses is provided in Table 1-1, along with the final in-place quantities for each type.

Table 1-1

TCRA Armor Cap Rock Components

Material	Stone Size D_{50} (inch)	Minimum Thickness (inch)	Installed Quantity (ton)
Armor Cap A	3	12	13,500
Armor Cap B/C	6	12	11,300
Armor Cap C	6	12	10,100
Armor Cap D, D_{24}	8	18, 24	23,900
		Total:	58,800

Notes:
All quantities have been rounded to the nearest 100 tons.

Both land- and water-based equipment were used to complete the TCRA construction. Land-based construction equipment included long-reach excavators, dozers, and front-end loaders. Water-based construction operations occurred via barge. A long-reach excavator was mounted on a material placement barge and was used to install armor cap materials directly atop the deployed geotextile layer. The water-based geotextile as-built drawing is provided in Figure 1-3.

Prior to geotextile, geomembrane, and armor rock installation in the Western Cell, the low-lying areas were stabilized using an 8 percent by weight Portland cement admixture. A total of 430 tons of Portland cement was used to complete the stabilization. The surface was then graded and received three geosynthetic layers: 1) 12-ounce (oz) geotextile, 2) 40-millimeter linear low density polyethylene (LLDPE) geomembrane, and 3) 16-oz geotextile. The Western Cell geotextile and geomembrane as-built drawing is provided in Figure 1-4. The total quantities for geotextile and geomembrane installed during the TCRA are 79,000 square yards (sy) and 15,400 sy, respectively.

A full description of the TCRA implementation is provided in the Draft Removal Action Completion Report (RACR) (Anchor QEA 2011).

1.3.2 TCRA Site Treatment

In situ treatment of materials isolated by the armored cap could involve adding adsorptive media, such as activated carbon, to the armor cap to limit the potential transport of dissolved COPC. This treatment method may require placement of additional materials on top of the armored cap.

Ex situ treatment of the contaminated materials at the TCRA Site would require the removal of all installed TCRA stabilization components (i.e., geotextile, geomembrane, and armor rock material). It is anticipated that the means and methods necessary for the satisfactory deconstruction and removal of the TCRA armor cap would be similar to the construction methods described in the RACR (Anchor QEA 2011). Additionally, prior to off-site transport, the removed TCRA stabilization components may require temporary storage in lined containers or barges suitable for storing and transporting contaminated materials. During the course of removal operations, especially water-based, implementation of best management practices (BMPs) would be needed to prevent the resuspension and release of contaminated materials from the work area.

As discussed in Section 1.3.1, a portion of the Western Cell was stabilized prior to installing the armor cap. The stabilization was performed to reinforce the upper layers of soft soils, which allowed construction equipment to access the interior portion of the cell. The stabilization treatment also likely reduced the mobility of the contaminants by reducing the

overall permeability of the materials; although testing was not performed to determine the degree of immobilization that was achieved.

If the TCRA armor cap and associated geotextile and geomembrane are removed from the Site, each would require proper disposal or treatment. As part of the removal operations, it would be necessary to establish an off-site facility for staging and decontamination areas to receive and process the armor rock. The staging and decontamination areas would be constructed to capture run-off generated by drainage and decontamination operations. Additionally, as a protective measure, containment berms lined with polyethylene sheeting could be used to contain rinseate spillage. The staging and decontamination facility would have adequate dock space for equipment to unload the armor rock, sufficient interior space to allow for equipment to manage segregated stockpiles before and after treatment, and a loading area for trucks transporting the material to off-site disposal.

Proper methods for decontaminating the armor rock are not presented in this evaluation. Depending on the facility's containment capabilities, high pressure washing or low pressure flushing may be appropriate methods for decontaminating armor stone. The run-off would require proper handling (e.g., vacuum trucks) and treatment. Following decontamination, the armor rock may be placed in an approved landfill for disposal if it could not be reused at the Site.

Depending on the method selected (i.e., in situ or ex situ), the contaminated material would either receive treatment on-site or be excavated for treatment at an approved off-site facility. Section 3 describes both types of treatment implementation methods.

2 SITE CHEMICALS OF POTENTIAL CONCERN

Appendix C of the RI/FS Work Plan (Anchor QEA and Integral 2010) describes the methods and rationale for the selection of Chemicals of Interest (COI) that are used as the basis for identification of COPCs for the RI/FS. The COIs were selected from the USEPA priority pollutants that meet the following criteria. To be selected as Site COIs, the chemicals were reported by one or more technical papers as potentially occurring in pulp mill solid wastes or leachate from solid waste landfills containing pulp mill wastes. Further, the chemicals would need to have chemical or physical properties, such as strongly partitioning to sediment organic carbon, which would make them likely to have persisted for more than 40 years in the Site environment. These COIs provided the starting list from which primary and secondary COPCs were identified.

Appendix C of the RI/FS Work Plan (Anchor QEA and Integral 2010) establishes the use of dioxins and furans as an indicator chemical group for the Site, a concept provided for USEPA guidance on performance of RI/FS at CERCLA sites (USEPA 1988). This designation was made because dioxins and furans are persistent, are likely the most toxic chemicals at the Site, and are likely to contribute most significantly to the overall risk at the Site. The use of dioxins and furans as indicator chemicals helps to focus the required analyses, reducing the time required to develop and evaluate remedial alternatives. Integral (2011) identifies additional Site COPCs:

- **Metals**
    - Aluminum
    - Arsenic
    - Barium
    - Cadmium
    - Chromium
    - Cobalt
    - Copper
    - Lead
    - Magnesium
    - Manganese
    - Mercury

  - Nickel
  - Thallium
  - Vanadium
  - Zinc
- **PCBs**
- **Semivolatile Organic Compounds**
  - Polychlorinated Biphenyls (PCBs)
  - Phenol
  - Carbazole
  - Bis(2-ethylhexyl)phthalate

Because dioxins and furans are designated as the indicator chemical group for the Site, this treatability study review is focused on treatment technologies for dioxins and furans in potentially contaminated soils and sediments. Many of the treatment technologies reviewed are also applicable to the semivolatile organic COPCs, and some are also applicable to treatment of the metal COPCs.

The physical and chemical properties of dioxins and furans are pertinent to the review of potential treatment technologies. Dioxins and furans are persistent in the environment. They adsorb strongly to soil and sediment, and they have low solubility in water, but the solubility may be increased significantly in the presence of high concentrations of other organic compounds (USEPA 1989). Table 2-1 provides some chemical properties for dioxins and furans; PCBs are included for comparison and further discussion in the Review of Treatment Methods section below.

Table 2-1

Chemical Properties of Dioxins, Furans, and PCBs (USEPA 2010)

Chemical	Water Solubility (mg/L)	Octanol/Water Partitioning Coefficient (Log K_{ow})	Organic Carbon Partitioning Coefficient (Log K_{oc})
PCB	0.42	5.60	>5,000†
2,3,7,8-TCDD	0.00193*	6.8*, 7.02-8.70	N/A (very low mobility in soil)
Furans	0.010	4.00-5.00	N/A (very low mobility in soil)

Notes:
*Values supplemented from the Technical Factsheet on: Dioxin (2,3,7,8-TCDD) (USEPA 2002a)
†Values supplemented from the Technical Factsheet on: Polychlorinated Biphenyls (PCBs) (USEPA 2002b)

3 REVIEW OF TREATMENT METHODS

This section presents a review of specific treatment technologies applicable for dioxins and dioxin-like compounds. The information provided represents an overview of potential treatments for paper mill wastes, contaminated sediment, and contaminated soil at the Site. Treatment technologies include those that reduce toxicity by destroying the dioxin molecule, and those that reduce the mobility and bioavailability of the dioxin by altering the physical or chemical properties of the affected material.

Each of the potentially available technologies was evaluated considering the likely long-term effectiveness, implementability, short-term effectiveness, and cost. This evaluation is similar to the screening evaluation of remedial alternatives described in 40 CFR 300.430 (e)(7) and will be applied to the development of remedial alternatives in the FS. Unlike the FS, however, the purpose of this evaluation is not to select a remedial alternative or to select treatment technologies. Rather, the purpose of this evaluation is to identify treatment technologies that may be applicable to one or more remedial alternatives at the Site and to assess whether treatability testing is needed prior to development of the FS, so that promising treatment technologies can be effectively included in the evaluation of remedial alternatives in the FS. The effectiveness evaluation for each technology considers a variety of factors, including: 1) the demonstrated performance of the technology, 2) the applicability of the treatment to the COPCs, 3) physical characteristics of the Site, and 4) the ability of the treatment method to efficiently remove or immobilize the COPCs. The implementability evaluation considers factors that include the operations and maintenance requirements. Each of the methods evaluated is subject to the implementability issues that would arise, should it be determined that treatment of the contaminated material within the TCRA Site is necessary. A description of the removal and decontamination of the TCRA stabilization components is provided in Section 1.3.2.

Where such information is available for an individual technology, the anticipated unit cost to treat contaminated materials is presented in this document. Current cost information for these treatment technologies was collected by contacting vendors and reviewing recently completed projects. A complete description of any remedial alternative, particularly one that includes ex situ treatment, such as incineration or chemical dehalogenation, will require

many other components (e.g., dredging, decontamination, stabilization, and transportation) that will be described by the FS. An initial order of magnitude estimate is provided for several ex situ treatment options in Section 4 – Summary and Conclusions. The costs for these additional components are not intended to represent complete pricing for any of the remedial alternatives listed; rather, the intended use is solely as an order of magnitude comparison among technologies included in this document. Should an ex situ method be recommended for evaluation in the FS, further analysis of costs associated with that technology will be provided in the development of costs for the remedial alternatives.

Order of magnitude cost information is not provided for ex situ treatment of the contaminated materials stabilized by the TCRA. As described in Section 1.3.2, ex situ treatment would require the removal of all installed geotextile (79,000 sy), geomembrane (15,400 sy), and armor rock material (58,800 tons). The cost for removing the TCRA components may exceed the estimated construction cost ($8.78 million) reported in the RACR (Anchor QEA 2011). Should the contaminated material within the TCRA Site require treatment, a thorough assessment of the implementation costs and associated risks would be required.

The purpose of this evaluation is to identify technologies that may be appropriate for consideration in the development of remedial alternatives, and to assess whether sufficient information is available to evaluate remedial alternatives that include these technologies in the FS. The outcome of this evaluation is to identify each of the potential technologies as falling in one of the following categories:

- Inapplicable to the remedial action for the Site (no treatability testing).
- Potentially applicable to the remedial action with sufficient information available to evaluate in the FS (no treatability testing).
- Potentially applicable to the remedial action but requiring additional information to evaluate in the FS (treatability testing required).

3.1 Thermal Treatment

Thermal treatment technologies remove contaminants from soil and sediment by applying sufficient heat, with or without reduced pressure, to volatilize the contaminants. Once the

contaminants are volatilized, they are chemically altered at high temperatures by oxidation (combustion) or pyrolysis (thermal decomposition without oxidation). There have been many applications of thermal treatment to contaminated waste sites, and advancements in the types of technologies have made the treatments safer and more effective. Two thermal technologies are reviewed in this document: incineration and thermal desorption.

3.1.1 Incineration

Incineration of environmental media or waste contaminated with dioxins requires high temperatures (greater than 1200°F) and relatively long residence times (30 to 90 minutes) (USEPA 1998). This method volatilizes the contaminants from the environmental matrix. The vapor containing air and organic contaminants reacts to form carbon dioxide and water vapor. Other contaminants are formed if oxidation is incomplete. Permits for incinerators strictly limit the allowable generation of products of incomplete combustion (PIC), and operating conditions (temperatures, residence times, contaminant inflow, and excess air flow) are carefully controlled to maximize the destruction of contaminants and minimize the generation of PICs. Based on the type of incinerator, multiple heating chambers may be necessary to achieve the residence time required to fully oxidize the contaminated material. The portion of the material that cannot be incinerated (fly ash) is removed from the system. As required by emissions permits, the off-gases are captured and treated by a scrubber system prior to release.

Both the ash material produced and the off-gas released from the incinerator system is scrutinized heavily for contaminant content. In order to be permitted, an incinerator facility must meet local, state, and federal requirements for emissions standards. This technology can be applied both on- and off-site; however, as will be discussed in Section 3.1.1.3, on-site incineration is not applicable for the Site.

An off-site incinerator is located at the Veolia Environmental Services (Veolia) facility[2] in Port Arthur, Texas, which is located approximately 72 miles from the Site. This facility is capable of treating wastes from the Site and has been used to treat some materials removed from the Site during the sampling for the RI/FS. A waste profile for the contaminated

[2] http://veoliaes-ts.com/Facilities/Port-Arthur-TX-information

material from the Site has already been compiled and approved for treatment at the Veolia facility. Veolia confirmed that the dioxin-contaminated soil and sediment can be incinerated at the facility, regardless of the concentration of dioxin. Soils and sediments would be delivered to the facility in roll-off boxes. Waste water generated by dewatering and decontamination activities can also be disposed of at this facility (Stringer 2011). Water with less than 5 percent solids can be transported via a vacuum tanker truck; sludge and water with greater than 5 percent solids can be transported in a vacuum box. Vacuum boxes require a processing time of 4 to 6 weeks; therefore, appropriate lead time is required when transporting waste using these containers.

3.1.1.1 Long-Term Effectiveness

Incineration is an ex situ treatment technology; therefore, removal of the source material from the Site is required prior to treatment. The risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment. As mentioned in Section 3.1.1, incineration is capable of removing dioxins from contaminated media and chemically altering the dioxin to harmless constituents. Incinerators operating in compliance with environmental permits have been shown to effectively and safely treat soil, sediment, and debris contaminated with dioxin and related compounds.

3.1.1.2 Short-Term Effectiveness

Incineration requires the removal of the contaminated source material prior to treatment. Dredging operations result in the resuspension of contaminated sediments into the water column. BMPs would be implemented to minimize the release of contaminated sediment from the work area. If dredging is selected as the remedial action in the navigation channel, coordination with commercial traffic would be required to mitigate the risks of collision with and/or contaminant release from the dredge, pipeline, and all other equipment incidental to sediment removal.

In addition to the upland treatment facility for dredged sediment, facilities would be required for unloading, dewatering (if required), and stockpiling sediment for transportation by truck or rail to the treatment facility. Transportation of the contaminated sediment to the

treatment facility would require planning and coordination with public safety authorities to minimize hazards associated with traffic and the potential release of contaminated material.

Water drained from the sediment would need to be treated at the dewatering location prior to release, or collected in tanks for treatment at another facility. Secondary containment and BMPs would be required to prevent releases from these operations to the environment.

3.1.1.3 Implementability

Although on-site, transportable incinerators have been used at Superfund sites; the Site is an unsuitable location for ex situ treatment for several reasons. There is limited space at the Site, there are no berthing facilities or suitable locations for developing such facilities; the entire surface of the impoundments north of I-10 was recently capped; the Site is located within a floodplain; and there are residential areas adjacent to the Site. For the same reasons, the Site is unsuitable for offloading dredged sediment from barges or for staging materials. Additionally, on-site incineration must meet the requisite local, state, and federal air emissions regulations; however, the proximity of the Site to the adjacent residential areas would be prohibitive to establishing the necessary air quality permits for operation.

To implement incineration, dredged sediment would need to be transported by barge to a suitable offloading facility, where the sediment could be dewatered, and transferred to truck or rail for transportation to a commercial incinerator, such as the Veolia facility, for treatment. Implementation of any ex situ treatment would require establishing an agreement with an intermediary facility for unloading barges and loading the sediment into trucks or rail cars. The offloading facility would also be required to obtain and operate in compliance with applicable permits.

3.1.1.4 Cost

Treatment costs for incineration were obtained from the Veolia facility. The waste would be transported to the facility in roll-off boxes. The unit cost for incineration is $900 per ton, and the roll-off boxes must meet a minimum requirement of $5,000 per shipment (Stringer 2011). Treatment costs for water removed from the sediment were also obtained from Veolia. If the water contains less than 5 percent solids, it can be delivered in a vacuum

tanker truck and the treatment cost is approximately $300 to $500 per ton (Stringer 2011). Water containing greater than 5 percent solids, along with sludge material, can be transported to the facility in a vacuum box, which would have a unit cost of $900 per ton (Stringer 2011). Additional costs for dredging, decontaminating, offloading, rehandling, and transport of the material are not included in this unit cost. Also, the cost for the establishment of an intermediary facility used for barge offloading and truck loading has not been included in the above unit costs.

3.1.1.5 Recommendations

Incineration has been proven to successfully destroy dioxins in contaminated media. Moreover, since investigation-derived waste from the Site has been treated by Veolia using incineration, treatability testing is not necessary for the FS. Further coordination and cost estimate development for the dredging, decontaminating, offloading, rehandling, and transport would be necessary to fully resolve the applicability of this method to the current Site conditions.

3.1.2 Thermal Desorption

The In Situ and In-Pile Thermal Desorption (ISTD and IPTD, respectively) technology uses a heated negative pressure environment to treat contaminated soils and sediments. A variant of the IPTD is the In-Barge Thermal Desorption (IBTD) (Baker et al. 2006), which could be applied to material at dockside locations; although, IBTD has not been applied to any of the researched demonstration- or field-scale tests presented below. Reduced pressure is used to lower the temperature at which contaminants desorb and volatilize from the affected soil or sediment. Thermal conduction heating is used to raise the temperature of the affected medium for residence times of up to several days—42 days for soil treatment at the Missouri Electric Works, a site with PCB and dioxin contamination (Stegemeier and Vinegar 2001). Most of the contaminants are destroyed in place by oxidation or pyrolysis; other volatilized contaminants are extracted and treated outside of the piles.

Dioxins begin to decompose at temperatures as low as 300°C to 400°C in a reduced-oxygen environment; therefore, a minimum temperature of 335°C is suggested for the treatment of dioxin contaminated soils and sediments. Dioxins are removed from the affected medium by

oxidation, pyrolysis, and volatilization. Previous research indicates that thermal desorption is capable of removing 95 percent to 99 percent (or more) of the contaminant from the soil/sediment (Baker et al. 2006). The IPTD process has been proven to achieve a destruction and removal efficiency of >99.9999 percent for dioxin contaminated sites (Baker et al. 2009).

IPTD was evaluated as a treatment for the dioxin-contaminated soil and sediment from the site. Differences between IPTD and the other treatment method variants are noted in the following discussion. As indicated by the IPTD name, excavated material is placed in piles or "cells" for treatment. Each "cell" is constructed above ground with a foundation, containment berms, insulating walls and cover, and treatment wells. Three types of wells used for IS/IP/IBTD treatment: 1) heater wells, 2) heater-vacuum wells, and 3) air inlet (injection) wells.

The following description of well construction and placement is summarized from Stegemeier and Vinegar (2001). The heater and heater-vacuum wells are constructed similarly. These wells are usually constructed first by making 6-inch diameter holes with an exterior and interior annulus of sand. The exterior annulus of sand is contained around the well casing with a size 10 to 20 mesh. The interior annulus is contained with a 4-inch to 4.5-inch diameter stainless steel slotted (0.032-inch by 2-inch) mesh liner (size 40 mesh). A 2.5-inch diameter "heater can," which is sealed at the bottom, is installed in the interior annulus.

The air-gap between the "heater can" and the stainless steel slotted mesh liner is used in the vacuum wells to evacuate air upward from the contaminated medium. The "heater can" contains nichrome wires that are used as the heater elements. The wires are threaded through ceramic insulators and extend the length of the "heater can." The top of the well is fixed by capping with concrete.

Air inlet or injection wells are placed near each heater well. These wells are similar to the others, but do not contain heater elements. Air is injected into the soil or sediment next to the heater to oxidize the organic contaminants in the affected medium.

The spacing and placement of wells is subject to the design constraints presented by a particular project. Research suggests that the spacing between the wells should not exceed

the total depth of contaminated soil/sediment. Wells are typically laid out in a hexagonal pattern, such that the heater-vacuum wells are located at the center of each hexagon. The wells may be oriented horizontally or vertically (Baker 2011a; Baker 2011b).

3.1.2.1 Long-Term Effectiveness

The IPTD treatment method is an ex situ technology; therefore, removal of the source material from the Site is required prior to treatment. The IPTD treatment is capable of destroying the dioxin present in the sediment. The treated sediment could be beneficially reused, unless there are additional contaminants that are resilient to thermal desorption, such as heavy metals (Baker 2011b). ISTD/IPTD has been successfully applied to four dioxin contaminated sites: Yamaguchi, Japan; Alhambra, California; Cape Girardeau, Missouri; and Ferndale, California. The Cape Girardeau, Missouri and Yamaguchi, Japan sites were demonstration-scale tests, while the remaining two were full-scale applications (Baker 2011a). The maximum average pre-treatment toxic equivalency (TEQ) concentration for these four sites was 18,000 pg-TEQ/g (Alhambra, California), which was reduced to an average concentration of 110 pg-TEQ/g (Baker 2011a). Treatment at this site achieved the target concentration levels, and post-treatment, the California Department of Toxic Substances Control issued a No Further Action letter and did not place any restrictions on the land usage (Baker et al. 2007; Baker 2011b).

3.1.2.2 Short-Term Effectiveness

As with all ex situ technologies, IPTD requires the removal of the contaminated source material prior to treatment. Risks of implementation associated with dredging contaminated sediment, managing the sediment in stockpiles, and transporting the sediment to a treatment facility are discussed in Section 3.1.1.2 and would be the same for thermal desorption.

3.1.2.3 Implementability

The Site is an unsuitable location for ex situ treatment, offloading dredged sediment from barges, or staging materials, as there is limited space, there are no berthing facilities or suitable locations for developing such facilities, the entire surface of the waste impoundments were recently capped, the Site is located within a floodplain, and there are residential areas adjacent to the Site.

Dredged sediment would need to be transported by barge to a suitable offloading facility where the sediment could be dewatered and transferred to truck or rail for transportation to a facility for ex situ treatment. Implementation of any ex situ treatment would require establishing an agreement with a facility for unloading barges and loading the sediment into trucks or rail cars.

Land would need to be acquired for the construction of the temporary treatment facility. Since the offloading and treatment facilities would be off-site, permits would be required for the construction and operation of these facilities. Several acres would be required to accommodate the treatment piles and ancillary operations, including stockpiles for untreated and treated soil, equipment storage, and off-gas treatment.

Site access and security are also considerations for any treatment effort. Cooperation from local and state agencies would be necessary to ensure that all parties concerned are aware of the requirements of the IPTD treatment method and that contractors and their sub-contractors, if applicable, can safely and adequately construct and manage the IPTD cells.

Based on the available information, the treatment time required for each batch of contaminated sediment can range from approximately 40 to 150 days; however, this treatment time is dependent on multiple factors, including the quantity and moisture content of the soil. While the IPTD method can handle a dredged slurry of contaminated sediments, the water content of the sediments will affect the time and energy required to heat the matrix (Baker 2011b). Therefore, it may be necessary to dewater the material prior to the IPTD treatment. The preferred dewatering agents are calcium carbonate or lime. Additionally, this time constraint must be considered in light of the excavation production rate, the staging area required for dewatering the material, if necessary, and the amount of treatment cells capable of fitting on the treatment Site.

3.1.2.4 Cost

Treatment costs are estimated based on information provided by TerraTherm. The estimated cost to treat dioxin-contaminated sediments is $250 to $500 per cubic yard (cy) (Baker 2011b). If a unit weight of 1.4 tons per cy were assumed for the material, then the unit cost

range would be $350 to $520 per ton. These figures are a generalization and do not represent an actual quote for services. The unit cost provided is a "turnkey" cost, which includes design, equipment, and implementation; however, it does not include the requisite cost for sediment excavation and dewatering, if necessary. Additionally, the costs for land acquisition and transportation to and from the off-site treatment piles are not included in the turnkey unit cost range.

3.1.2.5 Recommendations

The IPTD treatment technology has been field-tested and can successfully remove and destroy dioxins from contaminated soil and sediment matrices. As with any of the ex situ treatment technologies, a significant challenge will be identifying suitable locations for and acquiring the necessary permits for transloading sediment from barges to overland transportation and for the treatment facility. TerraTherm, a vendor that provides IPTD treatment, recommends performing site-specific testing on the material prior to selecting the IPTD method for treatment. This technology is viable for treating the sediment from the Site; although, it is subject to implementability challenges that would apply to all ex situ treatment technologies that would require temporary facilities, as discussed in Section 3.1.2.3. Previous experience, including full-scale demonstrations, indicates that the technology would effectively remove dioxin from the sediment. Therefore, treatability testing would not be necessary to evaluate this technology in the FS. If a remedial alternative is selected that includes IPTD, site-specific treatability testing would be needed as part of remedial design to determine the affect of sediment moisture content on the treatment time, which would affect the dimensions of the treatment cells and the cost of treatment.

3.2 Chemical Degradation

3.2.1 Dehalogenation

Dehalogenation treatments use chemical and thermal processes to break down dioxins in contaminated soil and sediment. Treatment is achieved either through the removal of chlorine (a halogen) atoms from the dioxin molecules or through decomposition or volatilization of the contaminants (FRTR 2008). All of these technologies are applied to the contaminated media ex situ and require pre- and post-treatment to complete the process

(e.g., dewatering, thermal desorption, debris removal, and/or reagent removal). Several methods have been applied as field-scale treatment operations and are described below.

The modified Alkaline/Potassium Polyethylene Glycolate (APEG/KPEG) method, APEG-PLUS, was developed by Galson Remediation Corporation, in the late 1980s. The technology uses a mobile treatment facility paired with a modified reagent, which uses potassium hydroxide and dimethyl sulfoxide to remediate contaminated soils and sediments. As outlined by the Office of Technology Assessment (OTA), this process takes a contaminated matrix, along with the APEG-PLUS reagents, and forms a slurry, which separates the chlorinated contaminants. The slurry is added to a reactor that heats the mixture and causes the polyethylene glycolate molecule to replace the chlorine atoms in a chlorinated dioxin molecule to form glycol ether, which can be readily broken down by the natural environment (U.S. Congress 1991). Reagents are separated from the soil matrix mixture by centrifuge; the soil is washed and the effluent is treated with activated carbon. Recent applications and vendors of this technology were not found while researching for this document; therefore, none of the polyethylene glycolate technologies will be evaluated any further.

The Solvated Electron Technology™ (SET) is a full-scale, ex situ chemical dehalogenation treatment process. The process involves mixing the contaminated soil or sediment with a solvated electron solution (alkali metal or alkaline earth metal mixed in liquid anhydrous ammonia) in a treatment vessel. Chlorine is removed from the chlorinated organic molecules, leaving the parent contaminant molecule (nonchlorinated dioxin in this case) and metal salts, such as sodium chloride. The vessel is then heated using hot water or steam to remove the ammonia for reuse. SET has been used to treat dioxin-contaminated sludge and oil from the New Bedford Harbor Sawyer Street site in Massachusetts and the McCormick and Baxter site in Stockton, California (Vijgen 2002b). The technology's patent holder, developer, and vendor is Commodore Advanced Sciences, Inc., and according to their website[3], five other sites with PCB contamination have been successfully treated. Only one of these sites, the Pennsylvania Air National Guard Site in Harrisburg, is listed by the USEPA (2010) as a full-scale application of SET for PCBs.

[3] http://www.commodore.com

Base-Catalyzed Decomposition (BCD) is another full-scale, ex situ technology that has been successfully applied in the U.S. and countries around the world. The patent holder of this technology in the U.S. is the USEPA. According to the USEPA (2010), this treatment technology requires pre-treatment via thermal desorption to remove the contaminants from the soil/sediment matrix by volatilization. The volatilized contaminants pass through a condenser and are fed into a liquid tank reactor, along with sodium hydroxide and a carrier oil. The mixture is then heated for 3 to 6 hours to temperatures above 326°C. The oil is tested post-treatment and the carbonaceous residues formed from the reaction are removed from the mixture; the carrier oil can then be reused for subsequent treatment applications (Vijgen 2002a; Vijgen and McDowall 2009[4]). The soil and sediment treated via thermal desorption can be reused as fill material. Vijgen (2002a; Vijgen and McDowall 2009) report that a full-scale application of this technology was conducted in 1997 in Binghamton, New York and treated 2,500 tons of dioxin contaminated waste. The most recent application of the BCD technology was in the Czech Republic, which began with treatment testing in 2003 to 2004; full-scale operations began in 2006.

3.2.1.1 Long-Term Effectiveness

The chemical dehalogenation treatment methods are ex situ technologies; therefore, removal of the source material from the Site is required prior to treatment. The risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment. Research indicates that dehalogenation is capable of reducing the concentration of dioxin in contaminated soil and sediment. Following treatment, the soil and sediment would likely require landfilling for ultimate disposal, which would limit the exposure point of ecological receptors to residual concentrations; thus the material would have a negligible long-term impact to the environment.

3.2.1.2 Short-Term Effectiveness

As with all ex situ technologies, chemical dehalogenation requires the removal of the contaminated source material prior to treatment. As outlined in Section 3.1.2.2,

[4] Vijgen and McDowall (2009) prepared an update to the existing 2002 fact sheet for BCD. The website source (www.ihpa.info) indicates, however, that this resource has not been peer-reviewed. As necessary, both resources are cited for completeness.

considerations for dredging at the Site include the resuspension and movement of source material; the interference with navigation channel traffic; and the establishment and maintenance of an off-site unloading, dewatering, and stockpiling facility.

The equipment necessary for the chemical dehalogenation treatment would need to be deployed at an off-site location because of restrictions on the use of the Site and the location of the Site in a floodplain; therefore, ex situ treatment on-site will not be discussed further. Transportation of the contaminated sediment to the established off-site treatment location would require planning and coordination with public safety authorities to minimize hazards associated with traffic and the potential release of contaminated material.

3.2.1.3 Implementability

As outlined in Section 3.1.2.3, the Site is located in a floodplain and is an unsuitable location for all stages of a removal and treatment effort, as the necessary facilities (i.e., berthing and staging/stockpiling) are not available; moreover, no suitable location is available for the establishment of such facilities. Additionally, a permitted off-site facility would be necessary to receive and dewater dredged sediments and allow for material transfer to truck or rail for transport to the temporary treatment facility. Land and the requisite permits would need to be acquired for the construction and operation of a treatment facility. Several acres would be required to accommodate the treatment equipment and ancillary operations, including stockpiles for untreated and treated soil, equipment storage, and off-gas treatment.

Site access and security are also considerations for any treatment effort. Cooperation from local and state agencies would be necessary to ensure that all parties concerned are aware of the requirements of the treatment method and those contractors and their sub-contractors, if applicable, can safely and adequately construct and manage the treatment equipment.

Based on the available information, neither treatment technology appears to be currently available in the U.S. According to Vijgen (2002a), the two technology providers responsible for previous applications of BCD to sites in the U.S. are no longer providing this treatment technology, and subsequent communication with the license distributor, BCD Group, Inc., indicates that no company is currently licensed to perform BCD treatment in the U.S.

(Opperman 2011). Additionally, no full-scale applications of the SET method for dioxin-contaminated waste are listed by either the USEPA (2010) or Vijgen (2002b).

3.2.1.4 Cost

As reported by Vijgen and McDowall (2009), current cost information for treatment at the facility in the Czech Republic is based on data from 2004; the reported unit cost range is €1,400 to €1,700 per ton. Assuming a 2004 conversion rate of $1.22[5] per euro, the unit cost range becomes $1,708 to $2,074 per ton. With the establishment of a permanent facility, the anticipated cost information for the treatment is €850 to €1,000 per ton. Again, assuming a 2004 conversion rate of $1.22 per euro the unit cost becomes $1,037 to $1,220 per ton. There is no cost information available in the research for the SET application to dioxin-contaminated wastes.

3.2.1.5 Recommendations

Chemical dehalogenation processes have been proven through field- and/or bench-scale testing to reduce dioxin concentrations to acceptable levels; therefore, no testing for these methods is required for the purposes of the FS. As with any of the ex situ treatment technologies, a significant challenge will be identifying suitable locations for and acquiring the necessary permits for transloading sediment from barges to overland transportation and for the treatment facility. This technology is viable for treating the sediment from the Site, although it is subject to implementability challenges that would apply to all ex situ treatment technologies that would require temporary facilities, as discussed in Sections 3.1.2.3 and 3.2.1.3. Treating the sediment with chemical dehalogenation would also cost considerably more than equally effective and more readily available methods. Additionally, vendors for chemical dehalogenation methods must be established prior to the selection of a chemical dehalogenation method. If a remedial alternative is selected that includes chemical dehalogenation, site-specific treatability testing would be needed as part of the remedial design to determine the reagent quantities necessary to reduce the dioxin concentration to an acceptable level.

[5] http://www.oanda.com/currency/converter/

3.2.2 Photolysis

Specific details regarding the affects of ultraviolet (UV) light on contaminated soil are summarized by Euro Chlor (2003). UV degradation breaks down contaminants through photolysis. Photolysis has been shown to be an effective method to transform dioxins in the upper layers of soil that can be penetrated by light. The transformation that typically occurs for dioxins is the dechlorination of the 1, 4, 6, and 9 positions, which is called peri-dechlorination (Euro Chlor 2003). The methods cited by Euro Chlor are all experimental and do not represent full-scale applications in the field. A limitation of this method results from the inability of sunlight to penetrate soil to a significant depth. Additionally, UV degradation requires a significant amount of space for the treatment. Information regarding the degradation rate of dioxins subjected to UV light has not been established for field-scale applications of this technology. Additionally, several studies presented by Euro Chlor indicate that the dechlorination of octachlorodibenzo-p-dioxin by photolysis would yield 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), which would increase the toxicity of the contamination. Based on the lack of field-scale applications and supporting data, along with the space limitations at the Site, this method is not recommended for further evaluation in the FS.

3.3 Biological Treatment

Bioremediation methods include those technologies that use microbes to metabolize contaminants present in the soil, sediments, and groundwater. These organisms require specific conditions for survival (for example, aerobic organisms require oxygen to survive and metabolize contaminants, whereas anaerobic organisms would be inhibited or poisoned by the presence of air). Under the wrong conditions, microbes could produce unwanted chemical by-products, reduce production, or die off. Bioremediation technologies are mostly in the research and development phase.

The dehalogenation capability of specific bacterial groups has been a long-standing research topic. Hieke (2008) presents a research effort that classifies a specific group of bacteria capable of dechlorinating dioxins: *Dehalococcoides*. These bacteria are anaerobes, indigenous to groundwater and freshwater systems, and are capable of dechlorinating various compounds. The products of dechlorination include less recalcitrant congeners of the parent

chlorinated molecules, which can be metabolized by other microorganisms. The Houston Ship Channel and surrounding waterways down to Galveston Bay were classified as the study area in the Hieke (2008) research. All of the sediment samples taken from the area were anoxic, thus providing suitable conditions for *Dehalococcoides* to survive. Of all the samples analyzed, there was an apparent trend for a minimum TEQ concentration of approximately 3 ng/kg dry weight necessary for the *Dehalococcoides* bacteria to be present, and the range of concentrations of dioxin TEQ in sediment providing the first detection of *Dehalococcoides* is from 2.98 to 30 ng/kg dry weight. Additionally, the age of the sediment samples indicated that there was an "establishment period" of approximately 2 years necessary for *Dehalococcoides* to appear. The overall age range for the sediment samples where *Dehalococcoides* made their first appearance is 2 to 7.12 years. Hieke (2008) indicates that this time frame be accounted for in future studies that plan to consider *Dehalococcoides* as a remediation option.

3.3.1 Long-Term Effectiveness

The research presented by Hieke (2008) and Brinkmeyer et al. (2010) demonstrates that *Dehalococcoides* is a naturally occurring bacterial group in the Houston Ship Channel and surrounding waters; therefore, it can be assumed that removal of dioxin from the source material via these organisms has already begun to occur. In situ biological treatment may effectively reduce dioxin concentrations in the long-term. However, the process of dehalogenation by native bacteria may be very slow, as is suggested by the continued presence of elevated TEQ concentrations decades after the waste materials were placed at the Site. In addition, the treatment by these organisms would seem to be limited to reducing the dioxin concentrations to approximately 3 ng/kg dry weight.

Ex situ treatment would, as stated for previous methods, eliminate the presence of the source material in the channel and surrounding waters through dredging. The research suggests that treatment of dredged sediment by *Dehalococcoides* would be unsuccessful. The dredging and subsequent handling of the sediment would introduce oxygen that would need to be eliminated before a colony of *Dehalococcoides* could be established. Anoxic conditions would need to be maintained for the duration of the treatment period, which would be

impractical considering the volume of sediment and the time required to achieve acceptable TEQ concentrations.

3.3.2 Short-Term Effectiveness

As noted in the previous section, the time required for *Dehalococcoides* to significantly reduce dioxin concentrations is considerably longer than the time that would be required for the other technologies reviewed in this evaluation. While the timeframe for in situ biological treatment may be reduced by adjusting conditions (such as adding nutrients or co-metabolites), additional research would be required to identify adjustments that would be effective and practical and to determine the degree to which such adjustments may accelerate the process and improve the final outcome.

3.3.3 Implementability

As discussed in the preceding sections, in situ biological treatment would be ineffective without some amendment of the sediment that would accelerate the process of dehalogenation. If research identifies amendments that would be effective and would not harm the environment, equipment is available for injecting reagents into the sediment or mixing reagents into the sediment. Agency approvals would be required for adding materials to the sediment.

3.3.4 Cost

Since this effort is a research-based initiative only, there is no unit cost information available for bioremediation using *Dehalococcoides*.

3.3.5 Recommendations

While Hieke (2008) presents a validation of the presence and activity of a bacterial species capable of dechlorinating dioxins, the evaluation of this technology indicates that it would not be suitable for remedial action. The treatment may not reduce concentrations of dioxin to acceptable levels, and even if the technology were effective in the long-term, the treatment period to achieve remedial goals may be much greater than the time to achieve

protection by other remedial technologies. Therefore, this technology is not suitable for remedial action and will not require site-specific treatability testing.

3.4 Adsorbent Technologies

Adsorbent technologies have been applied to sites contaminated with persistent organic pollutants to reduce their presence in the surface water, thereby decreasing the likelihood for bioaccumulation. As discussed in this section, adsorbent technologies are applicable to sites with submerged contaminated sediments and may be added directly to contaminated sediment or as a component of a sediment cap. As discussed in Section 2, 2,3,7,8-TCDD has low solubility in water and partitions strongly to organic carbon. These characteristics make dioxins particularly amenable to treatment with adsorbents.

Two adsorptive materials, organoclay and activated carbon (AC), have been well-demonstrated for removing organic compounds from water. Both materials have been effectively used as amendments to contaminated soil and sediment or as amendments to granular caps. The mechanism by which each of these amendments removes contaminants from water differs. Because the active adsorption sites are on the surface of AC and the activation process creates very large active surface areas on micropores in a unit mass or volume of the material, AC is particularly well suited to removing trace amounts of contaminants from water (125 acres of active surface per pound of AC[6]). AC is susceptible to fouling in mixtures of water and oil because the oil can coat granules or particles of AC, blocking the entrances of the micropores, rendering much of the surface area unavailable for the adsorption of contaminants. For this reason, AC is poorly suited to removing organic contaminants from water if an oil phase is present, as the oil coats, or fouls, the AC rendering it ineffective. Organoclay is produced from bentonite clay modified with quaternary amines. The nitrogen in the amine reacts with the clay mineral, and the organic ends of the amine molecules attract organic contaminants. Organoclay is less subject to fouling than AC in the presence of nonaqueous-phase liquids.

The majority of studies found while researching previous adsorbent amendment testing for the Site have used PCBs as the target contaminant. From the chemical characteristics listed

[6] http://www.calgoncarbon.com/carbon_products/faqs.html

in Table 2-1, PCBs serve as a conservative surrogate for dioxins in evaluating literature data. Compared to PCBs, dioxins have lower solubility and higher partitioning capability; therefore, adsorptive materials should be more effective at reducing concentrations of dioxins as compared to PCBs. Based on observed PCB reduction, some (Ghosh et al. 2004) have estimated the percent reduction in aqueous concentration of dioxins (2,3,7,8-TCDD specifically) to be approximately 85 percent in the presence of an AC adsorbent amendment; additionally, the reduction of 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) is estimated to be 95 percent. Moreover, a study by Goeyens et al. (2003) showed the ability of AC to adsorb a greater amount of dioxins than PCBs in contaminated dietary supplements consisting of marine oils. These studies indicate that AC is effective at removing PCBs from water and that AC may be at least as effective in removing dioxins from water.

Luthy et al. (2009) were responsible for field-testing the effects of AC when added to soils in situ. The study sought to affirm the validity of the AC treatment method and provide a field-scale test to assess the efficacy of this technology. The site chosen for the study was Hunters Point Shipyard in San Francisco, California, which was utilized from 1945 to 1974 by the U.S. Navy for ship maintenance and repair. For this remediation effort, AC was added to the upper 1 foot of sediments using two methods:

1. Mixing and tilling using Aquamog with rotovator attachment from Aquatic Environments, Inc.
2. Slurry injection using Compass Environmental, Inc. patented technology.

The tests proved that an AC amendment to PCB-contaminated soils would reduce the bioaccumulation of PCBs in a target species (bent-nosed clam; *Macoma nasuta*), reduce the PCB pore water concentration, and reduce the PCB-sediment desorption rate. The bioaccumulation was seen to decrease 30 to 50 percent in the target species, and the pore water concentrations were reduced 50 to 70 percent as a result of the AC amendment. In the laboratory setting, under more frequent mixing of the contaminated sediment with the AC amendment, samples displayed reductions of PCB partitioning greater than 95 percent.

Testing information for the performance of AC and organoclay to remove PCBs, specifically Aroclor 1260, from water is provided by Alther (2004). It should be noted that the Aroclor 1260 used in the experiment had a water solubility of 0.0027 mg/L. This value is similar to

the dioxin solubility (0.00193 mg/L) provided in Table 2-1; therefore, on this basis, the Aroclor 1260 used in these tests is an adequate surrogate for dioxin. Mini-column tests with spiked water samples were performed for three types of adsorbent amendments: organoclay blended with anthracite (70 percent and 30 percent, respectively), organoclay, and Bituminous AC. Results are presented as the sorbent loading at breakthrough (mg/g) for each amendment and indicate that both materials are capable of immobilizing Aroclor 1260 in water.

Manufacturers of the amendment materials provided lab results and technical data sheets for their products. This information provides clarity to the ability and applicability of a certain material to a given design. Colloid Environmental Technologies Company (CETCO) produces and tests various types of organoclay material used for the treatment of contaminated sediments. A laboratory experiment performed with their PM 199, 100 percent organoclay adsorptive material compared its removal capability for pentachlorophenol and dioxin (CETCO 2007). An isodrin stock solution of 12.4 parts per million (ppm) was used as a dioxin analog for the experiment. The results indicate that the organoclay is capable of removing dioxins from water. Communications with the vendor (Bullock 2011a) indicate that site-specific testing is warranted to establish actual values for removal efficiency.

In addition to the bulk product described above, CETCO manufactures a Reactive Core Mat® (RCM), which is a remediation product constructed of two exterior geotextile layers and an interior "reactive core" material layer. Reactive materials from CETCO include organoclay and AC. Active material in the RCMs is given as a mass of reactive material per square foot (sf) of mat. The RCM specifications listed on the CETCO website indicate that the organoclay and AC mats have 0.8 pounds per sf and 0.4 pounds per SF, respectively, of active material. RCMs are manufactured in rolls measuring 15 feet wide by 100 feet long. Implementability and unit cost information provided by CETCO is discussed in the following sections.

AquaBlok is another manufacturer of remediation and treatment technologies. Their organoclay and AC products are coated on the exterior of aggregate materials. This type of manufactured product allows for flexibility of design, as the amount of bulk material can be

varied on the exterior of the aggregate. By coating the aggregate with the adsorbent material, placement of the material becomes more precise than with bulk materials, as dispersal and amendment layer thickness are less controllable without the added weight of the aggregate. AquaBlok was consulted to assess the implementability of this technology and for the unit cost information provided in Table 3-1.

3.4.1 Long-Term Effectiveness

Organoclay and AC have both been demonstrated to be very effective and reliable for passively removing organic contaminants from water. AC is particularly effective for removing trace amounts of organic compounds from water; however, it is susceptible to fouling if exposed to high concentrations of organic contaminants, such as water mixed with nonaqueous-phase liquids. Organoclay is very effective for removing nonaqueous-phase liquids from water and is also effective for dissolved contaminants; although, it may be less effective than AC for removing already very low concentrations of organic contaminants from water (Reible et al. 2008). Dioxins have very low solubility in the water and partition strongly to the sediment. Therefore, AC may be a more suitable adsorptive material for the Site, given the need to reduce already low concentrations of dioxin in water passing from the sediment into the River. Other forms of organic carbon, such as agricultural byproducts, have also been added to contaminated sediment or cap material to increase the adsorptive capacity of the sediment or cap and reduce the concentration of organic contaminants in water. Such amendments may offer a more cost-effective alternative treatment, although the efficacy of such amendments would need to be demonstrated prior to their full-scale use.

The effectiveness of any adsorptive material relies on its ability to remain in place. Erosion of the adsorbent from any portion of the contaminated sediment area could cause resuspension of dioxin-contaminated materials into the surface water. The waters surrounding the Site are tidal and are prone to the daily fluctuation in stage and velocity; therefore, necessary means should be taken to ensure that the amendment material does not succumb to erosion. The FS will include an assessment of the need for an armor layer or cap to provide adequate protection against erosion of contaminated sediment and any adsorptive material. Also, any planned adjustments to the profile of the River bed would require further study to demonstrate that flood stage and navigation are not adversely affected.

3.4.2 Short-Term Effectiveness

The use of adsorbent technologies does not involve any particular hazards of implementation. Direct injection and shallow mixing techniques are available that minimize the resuspension of contaminated sediment. Amended cap materials may also be placed with minimal resuspension of contaminated sediment. The adsorptive materials would immediately begin removing dissolved contaminants from pore water that could migrate into the River through the sediment or a sediment cap.

Placement of materials, including adsorbent amendments, in the navigation channel, if required, would necessitate a coordinated effort between the contractor(s) and the vessel traffic anticipated along the River. As with the dredging operations described above for the ex situ treatment technologies, placement of the adsorptive material should be planned so as not to interfere with the navigation channel. Accurate placement is also a necessity; therefore, monitoring the flow in the channel and surrounding waters will be essential. Additionally, the RCM deployment should incorporate adequate overlap between panels. In the case of an adsorbent amendment, the material should be well-mixed with contaminated sediment or cap materials, and at application rates determined based on contaminant discharge rates and measured adsorptive kinetics.

3.4.3 Implementability

Adsorbent amendments are available from several vendors, and a variety of placement techniques are also available. Since the adsorbent amendments are applied in situ, the majority of the work will be water-side. Amendments could be added to affected sediment directly from barges. Amended cap materials would be blended prior to loading on barges and then placed mechanically or as a slurry. Luthy et al. (2009) describes that mixing or injecting an amendment material can achieve desirable reduction in contaminant concentration. Further evaluation of injection or direct mixing of amendments would be necessary prior to implementing this method for application at the Site.

AquaBlok materials can be placed with a stone-slinger telescopic articulated conveyor mechanism. Stone-slingers can be remote controlled and can spread aggregate or amendment material quickly over large areas; additionally, this equipment can operate land-

side or water-side depending on the placement application requirements. An excavator mounted on a barge can be used to distribute the material. Layers as thin as 6 inches can be achieved by both methods (AquaBlok 2011). Additionally, from the AquaBlok website[7], other placement methods are available: crane and clamshell bucket or bulk bag (funneled bag attached to excavator bucket). Since the AquaBlok material is coated on the exterior of the aggregate, adsorbent amendment layers can conform to irregular surfaces. Placing this type of material also reduces the susceptibility of the reactive cap to scour, in certain applications, without the need for an additional erosion-protection layer (Collins 2011). Additionally, depending on the remedial design criteria, the percent of the reactive material coated on the aggregate can be varied to increase treatment residence time (Collins 2011).

In addition to successful applications at dewatered contaminated sediment sites, RCMs can be deployed to sequester subaqueous contaminated sediments. Previous application methods have used the RCM in conjunction with a sand cap layer. According to CETCO, deployment of an RCM with an AC core in an aqueous environment may require a sand cap layer to act as a weight to prevent the mat from migrating during and after placement; RCMs with an organoclay core are heavier and can typically be deployed with better consistency (Bullock 2011b).

As described in Section 1.3.2, the TCRA included capping contaminated sediment in situ to sequester contaminated material. Should the capped material require treatment, an adsorbent technology can be applied in situ. The presence of the TCRA cap materials (geomembrane, geotextile, and armor rock) would preclude tilling adsorbent materials directly into the affected sediment. Direct injection of adsorbents without removing the TCRA cap may not be possible, as the equipment may not be capable of penetrating the armor cap layers. Direct injection of adsorbents through the TCRA cap may not be desirable, even if it is possible, as injecting adsorbents into the sediment would require breaching the TCRA cap, potentially releasing contaminated sediment into the surface water. A potential alternative method to implement in situ treatment with adsorbent materials is to blend bulk adsorbent amendment material with sand and install an augmented cap layer atop the TCRA cap. The placement of an adsorptive layer on top of the TCRA cap may require the

[7] http://www.aquablokinfo.com

installation of additional cap rock to protect the adsorptive material from erosion. This type of cap enhancement would require consideration of the potential effects of the action on floodplain elevations, per Harris County Flood Control guidance. The other adsorbent technologies presented in this section, AquaBlok and RCMs, can be installed directly atop the TCRA stabilization components and are limited by the implementability issues described above.

As discussed above, placement location is a key component to the level of success of this treatment method. Advanced global positioning systems can provide real-time location information to operators to ensure that total coverage of the contaminated areas is achieved. It is suggested that such equipment be evaluated prior to contractor selection.

The land-side work would include the coordination of the material delivery, stockpile, and loading areas. Staging areas for all the material and equipment would be essential for this method. The property owned by LaBarge Realty, LLC, which has a dock and stockpile area upstream of the Site, was used to stockpile and load capping materials for the TCRA. This facility may be appropriate for similar operations in a full-scale remedial action.

3.4.4 Cost

Communications with AquaBlok and CETCO provided these general estimates for the costs of the adsorbent materials. An organoclay-coated aggregate material with 30 percent active material by weight would range from $1,000 to $1,500 per ton (Collins 2011). Similarly, an activated carbon coated aggregate material with 5 percent active material by weight would cost $400 to $450 per ton (Collins 2011). Raw organoclay and AC material are similarly priced at $1.25 to $1.65 per pound (Bullock 2011c; Collins 2011). The RCMs with organoclay or AC core material are estimated to be $2.40 per sf and $3.00 per sf, respectively (Bullock 2011b).

Hypothetical remedial action scenarios were developed to provide a common basis for comparing the costs of the different methods identified above. In this assessment, summarized in Table 3-1, the costs are compared on the basis of cost per unit area.

Installation cost is not considered. The assumptions that were made in order to make these comparisons are as follows:

- AquaBlok Application
  - Organoclay and AC materials both have a bulk density of 85 pounds per cubic foot (CF) (Collins 2011).
  - Both materials are assumed to be placed with a minimum thickness of 6 inches.
- Amendment Using Raw Materials
  - Organoclay and AC have average bulk densities of 50 pounds per CF[8] and 32.5 pounds per CF[9], respectively.
  - Amendment layers for both materials are 12 inches thick.
  - Application ranges from 3 percent by weight to 6 percent by weight.
  - Unit costs for both the AC and organoclay range from $1.25 to $1.65 per pound (Bullock 2011c; Collins 2011).
  - A 1.5-foot thick amended sand cap layer is applied to the TCRA Site.
- RCM Application
  - A 1-foot thick sand cap layer is applied to AC core mat.

[8] http://www.cetco.com/RTG/technicaldatasheets/Organoclay.pdf
[9] http://www.calgoncarbon.com/carbon_products/faqs.html

Table 3-1

Areal Cost of Adsorbent Technologies

Adsorbent Technology	Material	Areal Cost ($ thousands/acre)
AquaBlok	AC	$370 to $420
	Organoclay	$930 to $1,400
Amended Cap	AC	$170 to $450
	Organoclay	$170 to $450
Amended Cap TCRA Site	AC	$220 to $510
	Organoclay	$220 to $510
Reactive Core Mat (RCM)	AC	$160 to $190
	Organoclay	$110 to $130

Complete assessments of the contaminated material location, quantity, and physical properties should be used to establish treatment unit costs that are more representative of the conditions at the Site. Additionally, none of the above costs include the delivery, management, and installation of the material. The cost for the stockpile, offloading, and loading facility are also not included. Should an armor or sand cap be necessary to prevent erosion of the adsorptive material, appropriate material, and placement costs should also be considered.

3.4.5 Recommendations

Adsorbents merit further evaluation in the FS as a potentially applicable technology for the remedial action at the Site. Based upon the research and performance data presented for dioxins and PCBs, site-specific treatability testing for the FS is not necessary to determine the effectiveness of the adsorptive materials. Upon selection as a remedial alternative, site-specific testing would be appropriate to assess specific design parameters of each material (e.g., removal capacity and efficiency).

Other materials that would add organic carbon to the sediment or to a cap material may also be effective and should not be excluded from consideration. One approach that would foster

innovation would be to demonstrate the effectiveness of materials, such as AC and organoclay, and set performance standards for remedial construction. Contractors would be invited to submit a proposal using one of the pretested materials with the option of proposing alternative materials. The alternative material could be shown to be more cost-effective if it is able to achieve the performance standard. If an adsorptive amendment technology is chosen for the remedial action, further modeling and coordination with suppliers would be necessary as part of remedial design to determine the thickness of the amendment layer and verify the necessity of an armor or sand cap atop the amended sediment.

3.5 Solidification/Stabilization

Solidification/stabilization (S/S) is a category of treatment technologies that involves blending the affected medium, such as contaminated soil or sediment, with a material that binds it into a solid matrix, increasing the strength and reducing the permeability and mobility of the material. Contaminants are encapsulated in the solidified sediment, meaning that the mobility of the contaminants is controlled both by reducing the potential for the sediment to be resuspended and reducing the flow of water through the sediment (permeability), thereby reducing advective transport of contaminants. Stabilization refers to treatment whereby contaminants, typically metals and more polar nonmetals, are also chemically bound to the solidified matrix (USEPA 2006). A variety of binders are available for S/S; although, the most common are pozzolanic reagents (e.g., Portland cement, fly ash, cement kiln dust), which are materials that react with lime in the presence of water to form rock-like solids.

S/S can be performed in situ or following dredging or excavation. In situ S/S may be accomplished using conventional excavators or specialized tillers or augers. Conventional excavators were used to stabilize approximately 5,500 cy of soft materials in the Western waste impoundment at the Site, to provide a stable surface for geomembrane and cap installation during the TCRA. Although sufficient water is essential for pozzolanic reactions, excess water can impede curing and result in a weaker final product. Proper mix ratios and equipment have been successfully used to solidify subaqueous sediment. The New Jersey Department of Transportation (Maher et al. 2005) successfully demonstrated the use of a

deep soil mixer, a specialized auger, for solidifying subaqueous sediment containing a variety of contaminants including dioxin.

3.5.1 Long-Term Effectiveness

S/S is a well-demonstrated technology that has been used for numerous Superfund remedial actions (USEPA 2000b). The treatment binds fine sediment grains into a solid material that resists resuspension by erosive forces. The permeability of treated sediment is reduced and contaminants are encapsulated in the solid matrix, further reducing the mobility and bioavailability of the contaminants. S/S has been used for remedial actions for more than 20 years and various forms of concrete have been used in construction for many more years, so the reliability of the treatment is expected to be very high. Over many years, chloride ions in brackish water will diffuse into concrete and weaken the solid matrix. Unlike structural concrete, however, the shear strength of solidified sediment is not critical to its performance. Assuming that chloride attack weakens the solidified sediment, the material may crack and break down into pieces that are erodible over many years, but the mobility of the contaminants will still be controlled, such that the release is negligible.

3.5.2 Short-Term Effectiveness

The implementation timeframe for S/S is among the shortest of the treatment technologies. After removing standing water, sediments may be treated in situ using a conventional excavator bucket to a depth of 10 feet or more, with treatment rates of greater than 400 cy per day. The stabilization performed for the TCRA was limited to the first 3 to 5 feet below grade, and the treatment rates were approximately 900 cy per day or greater. Specialized equipment, such as soil-mixing augers, can treat subaqueous sediment to greater depths, if necessary; the actual mixing time for a 10-foot-deep treatment was 10 minutes, and the volume of sediment treated in a single pass was approximately 5 cy (Maher et al. 2005). The mixed sediment and pozzolanic agents cure significantly over several days and reach full strength within weeks.

The principal hazard of implementation is associated with mobilizing contaminated sediment during treatment. For treatment using conventional excavators, the treatment area may be isolated from the surrounding surface water and standing water would be removed prior to

treatment, which effectively controls potential releases of contaminated sediment (Peckhaus 2011). Soil-mixing augers create minimal disturbance of shallow sediment. Extensive testing of turbidity and total suspended solids was performed during a demonstration of S/S using deep soil mixing augers in Newark Bay (Maher et al. 2005). The testing found no impacts in the top one-third of the water column. In the middle one-third of the water column, turbidity and suspended solids impacts were limited to within 125 feet of the deep soil mixing augers, and even in the bottom one-third of the water column, the water quality impacts were limited to within 135 feet of the augers.

S/S treatment by itself would control resuspension of contaminated sediment and desorption of dioxin from sediments. If dredging were required in the future, such as for navigation, S/S is also beneficial in that the treated sediment is less likely than untreated sediment to be resuspended during dredging. Short-term risks associated with implementing the technology are limited and readily monitored. Operations could be modified, if warranted, to further reduce short-term impacts.

3.5.3 Implementability

The materials required for S/S are readily available. Portland cement is a common construction material. Fly ash and cement kiln dust, which are often less expensive alternatives to Portland cement, are byproducts of electrical power production and cement production may be available. The use of specialized equipment, such as soil-mixing augers, may be the best option for implementing S/S in areas of the Site with deeper water, such as in the navigation channel. This equipment is not as readily available as conventional excavators.

Permits are not required for on-site CERCLA actions. The technical requirements of regulations for the protection of water quality would be met through the use of appropriate equipment and BMPs. Water-quality monitoring would be performed to detect impacts and adjust practices as needed.

3.5.4 Cost

The review of S/S use for Superfund remedial actions (USEPA 2000b) reported the average cost for 29 completed projects was more than $260 per cy and the average cost, excluding two projects with very high costs, was just under $200 per cy. The wording of the text in the report suggests that these figures are the quotient of the total project costs divided by the volume of material treated. The actual costs for S/S are less than these figures suggest. The costs for two recent Gulf Coast S/S projects were reviewed. The average unit cost to stabilize shallow material in the Western Cell during the TCRA using Portland cement was approximately $25 per cy. The cost for solidification using fly ash and conventional excavators on a Gulf Coast project completed in 2009 was also approximately $25 per cy. If a unit weight of 1.4 tons per cy were assumed for the sediments, the range of unit costs for these two projects is approximately $35 per ton. Costs for S/S using specialized equipment would be higher.

3.5.5 Recommendation

S/S is a potentially applicable technology for the remedial action at the Site. Sufficient information is available from investigations and full-scale remedial actions at other sites to evaluate remedial alternatives that incorporate this technology. Therefore, site-specific treatability testing is not necessary for the FS. If a remedy using S/S is selected, then site-specific treatability testing should be performed as part of the remedial design to identify appropriate solidification reagents and admixture ratios and to confirm the permeability and leaching characteristics of the treated sediment.

4 SUMMARY AND CONCLUSIONS

This document presents treatment technologies that are considered potentially applicable to the contaminated material detected at the Site. All ex situ treatment methods would require mechanical removal of the potentially contaminated materials, and the treatment itself would be performed off-site, as the Site is located within the River and adjacent floodplain. Depending on the method selected, there are additional facilities that would need to be established near the Site prior to execution of the treatment (e.g., berthing; loading and unloading; and material stockpiling and dewatering). The addition of such facilities would need to occur prior to implementation of the remedy, thus a method that would use these facilities would require sufficient construction lead-time factored into the implementation schedule. Additionally, ex situ treatment would require the establishment of appropriate facilities off-site, except in the case of incineration, for which a commercial facility that can treat material from the Site is available. The establishment of an off-site treatment facility would require acquiring land, obtaining permits, and building treatment and support facilities. Lastly, should the contaminated material within the TCRA Site require ex situ treatment, an assessment of the risks and costs associated with the removal, treatment, and disposal of the stabilization components would be necessary. As described in Section 1.3.2, these operations also require the establishment of an off-site location for transloading, staging, and decontaminating the armor rock material. The costs for these operations are not included in this evaluation.

Table 4-1 presents a summary of the evaluation of potential treatment technologies. The following technologies are potentially applicable to the Site:

- Incineration
- IPTD
- Chemical Dehalogenation (BCD and SET)
- Adsorbent Technologies (including AC and organoclay)
- S/S

Table 4-1
Treatment Technology Screening Matrix

Technology	Screening Criteria					Vendor Contacted[7,8]	Alternative Retained for Detailed Evaluation[9]
	Effectiveness[1,2]	Implementability[3]	Feasible Alternative	Relative Unit Cost[4,6]	Regulatory Requirements[5]		
Thermal Treatment							
Incineration	Yes - Incineration is a proven full-scale technology for dioxin destruction	Yes - Facility available for treatment of sediment, sludge, and water	Yes	$900/ton	Loading/unloading facility permits are necessary; Incineration permits retained by Veolia Environmental Services	Yes - Veolia Environmental Services	Yes
In-Pile Thermal Desorption	Yes - In-Pile Thermal Desorption is a proven full-scale technology for dioxin destruction	Yes - Equipment is available for application; Facility needs to be established for treatment	Yes	$350-$520/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Yes - TerraTherm, Inc.	Yes
Dehalogenation							
Polyethylene Glycolate	Uncertain - Polyethylene Glycolate reagents (Alkaline and Potassium) have been successfully applied to PCBs	No - Vendors and recent applications were not available	No	N/A	N/A	No	No
Solvated Electron Technology	Yes - Solvated Electron Technology has been successfully applied to PCBs and dioxins	Yes - Vendor is available and has tested the technology at pilot-scale; application to dioxins is certain	Yes	N/A	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Yes - Commodore Advanced Sciences, Inc.	Yes
Base-Catalyzed Decomposition	Yes - Base-Catalyzed Decomposition is a proven technology; no full-scale applications are currently being conducted conducted in the U.S.	No - Vendors listed in documentation are no longer available and no company is currently permitted to apply this technology in the U.S.; application to dioxins is certain	Yes	$1,037-$1,220/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	No	Yes
Degradation							
Photolysis (UV Degradation)	Uncertain - Complete degradation of dioxins by photolysis has not been documented	No - Equipment and personnel available for material distribution; area required for treatment would be excessive	No	N/A	N/A	No	No
Bioremediation							
Dehalococcides	Yes - *Dehalococcides* are proven effective in dehalogenating dioxins; bench-scale treatment has not been conducted	No - Equipment for treatment and testing has not been developed	No	N/A	N/A	No	No
Adsorbent Technologies							
Organoclay	Yes - Organoclay is effective in adsorbing dioxins; further site-specific testing is suggested	Yes - Equipment and personnel available for product application	Yes	$2.50-$31.90/sf	None	Yes - AquaBlok, CETCO	Yes
Activated Carbon	Yes - Activated Carbon is effective in adsorbing dioxins; further site-specific testing is suggested	Yes - Equipment and personnel available for product application	Yes	$3.70-$10.30/sf	None	Yes - AquaBlok, CETCO	Yes
Solidification/Stabilization							
Solidification/Stabilization	Yes - Solidification/Stabilization is a proven method to immobilize dioxins; necessary reagents would require further testing	Yes - Equipment and personnel available for method application; specialty equipment may be necessary for deep-water application	Yes	$35/ton	None	Yes - RECON Environmental, Inc.	Yes

Notes:
1. Those methods described as ex situ applications completely remove the contaminated source material by dredging; efficacy for these methods is considered to be complete.
2. PCB - polychlorinated biphenal.
3. Dredging operations must also consider the implementability in terms of coordinating with navigation channel traffic.
4. Treatment costs do not include the excavation of contaminated sediments, the establishment of the off-site unloading/loading facility, or transportation of the contaminated material. Additionally, these costs do not include the testing, design, and development of the treatment method.
5. Ex situ treatment will also require a permitted facility that is available to receive waste barged from the Site and that can accommodate equipment necessary to unload barges and load trucks or rail cars for delivery to the treatment site.
6. sf - square foot.
7. The license distributor, BCD Group, Inc. was contacted; however, they are not a vendor of the Base-Catalyzed Decomposition treatment technology.
8. CETCO - Colloid Environmental Technologies Company.
9. Further site-specific testing is suggested in the design phase of the project if this technology is carried forward from the Feasibility Study.

Incineration, as indicated in Section 3.1.1.5, is a full-scale technology that does not require testing for the purposes of the FS; moreover, since the facility evaluated in Section 3.1.1 has treated contaminated material from the Site, no site-specific testing would be required for evaluation of this treatment option in the FS.

The IPTD method is a full-scale technology that does not require treatability testing for the purposes of the FS; however, should IPTD be selected as a treatment option in the FS, testing the removal rate and efficacy of thermal desorption on small batches of contaminated material from the Site would be necessary as part of remedial design. Communications with TerraTherm have indicated that they can perform the necessary testing. Additionally, testing the efficacy of the IPTD treatment on materials that have been dewatered using different agents is also suggested.

The two chemical dehalogenation methods (BCD and SET) do not require treatability testing for the FS, as bench- and/or field-scale tests have proven the efficacy of these technologies to reduce dioxin concentrations in contaminated soils and sediments. While both methods may be capable of reducing dioxin concentrations in sediment to acceptable levels, the implementation of such treatment would be more difficult, and more expensive than other treatment methods that are at least as effective. If a remedial alternative that included chemical dehalogenation were selected, site-specific treatability testing would be required as part of the remedial design to determine the reagent quantity, treatment residence time, and other operating parameters necessary to reduce dioxin concentrations to acceptable levels.

Adsorbent technologies, both organoclay and AC, can effectively reduce the mobility of organic contaminants in water. No testing for the FS will be required. Should adsorbent technologies be selected as a treatment for the Site, site-specific testing will be necessary as part of a remedial design to gather performance data (e.g., removal capacity and efficiency) for each amendment.

Treatability testing for the FS is also not required for S/S, as the effectiveness of this technology has been demonstrated in successful full-scale treatment efforts and at the Site. If S/S is selected as a treatment for the remedial action, site-specific testing may be required during remedial design to determine the appropriate solidification reagents and admixture

ratios and to confirm the permeability and leaching characteristics of the treated sediment under different conditions.

Lastly, unit costs per acre for each of the methods listed above are provided in Table 4-2. The cost for technologies requiring the sediments to be treated ex situ includes a general assessment of typical costs associated with establishing a transloading facility, removing the sediments by mechanical dredging, dewatering and stabilization using Portland cement, and transporting the material to an off-site location. The cost information provided below is meant to aid in the overall assessment of the potential costs expected during certain phases of the removal and treatment processes; a complete cost analysis of each specific remedial alternative will be provided in the FS. These figures are not intended to represent actual cost estimates, as the dredging, transloading, and hauling operations have anticipated an ideal facility that only requires minimal renovations and whose location is near the assumed impacted area. Moreover, the cost of renovating said facility is not included in the unit costs provided in Table 4-2. Rather, it should be expected that if an ideal facility were chosen for the transloading area, then a lump sum cost of $500,000 to $700,000 could be assumed for renovations. Additionally, when assembling the dredging and treatment unit cost information, the depth of contaminated sediment was assumed to be 3 feet and the sediment unit weight was assumed to be 1.4 tons per cy. Lastly, a facility location was also assumed to be located within 50 miles of the transloading facility and the haul rate was assumed to be $0.55 per ton-mile.

Table 4-2

Cost Ranges for Applicable Treatment Technologies

Treatment Method	Application	Areal Unit Cost Range ($ thousands/acre)	
Incineration	Ex Situ	$6,500	$7,700
In-Pile Thermal Desorption (IPTD)	Ex Situ	$2,700	$3,900
Base-Catalyzed Dehalogenation (BCD)	Ex Situ	$7,400	$8,600
Adsorbent Technologies	In Situ	$110	$1,400
Solidification/Stabilization (S/S)	In Situ	$240	$290

The final remedy for the Site could involve one or more of the treatment technologies summarized above, combined with a variety of more conventional remediation technologies.

Ultimately, those decisions will be based on the development of the remedial action objectives and goals for the Site and the outcome of the FS.

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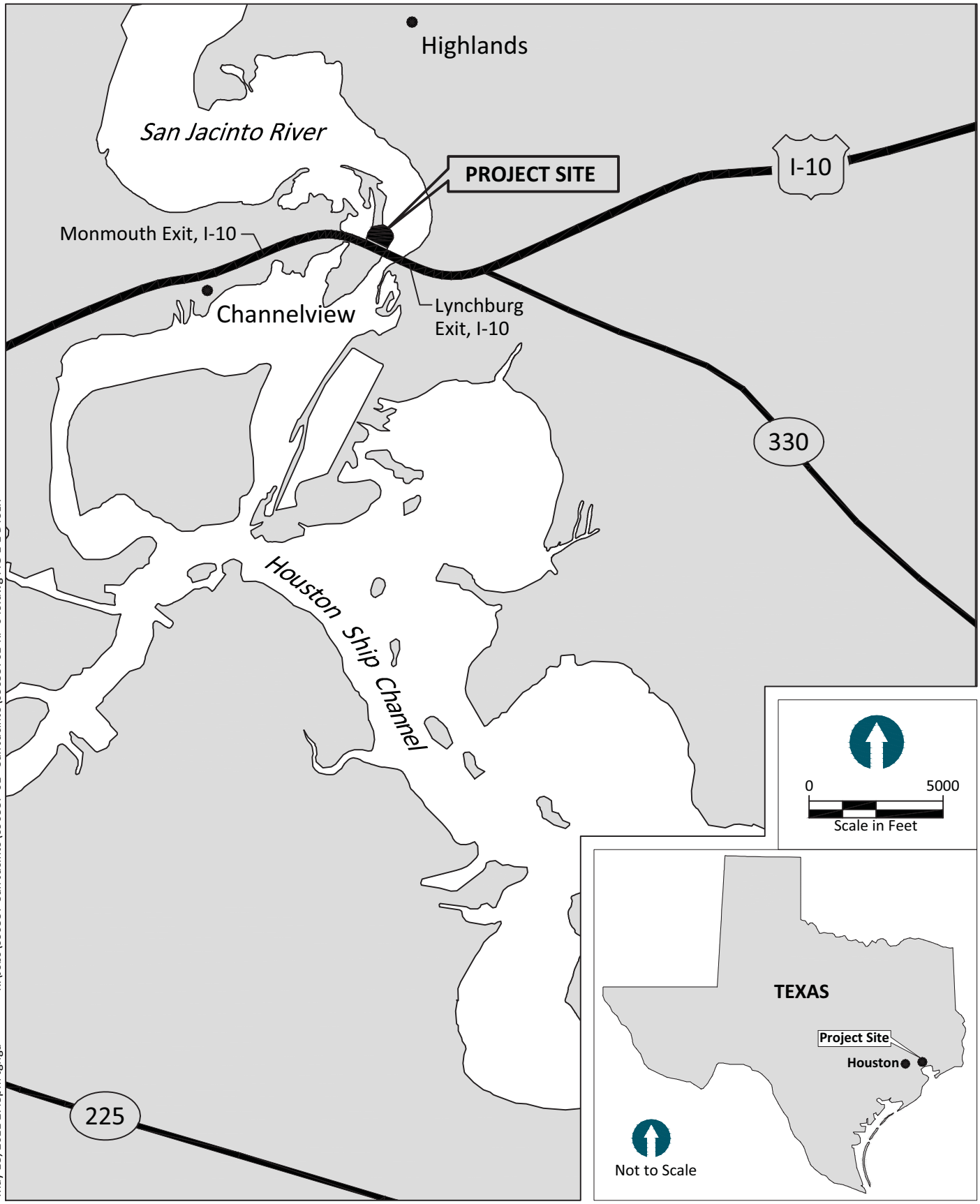
FIGURES



K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-049.dwg FIG 1-1 DTSLR

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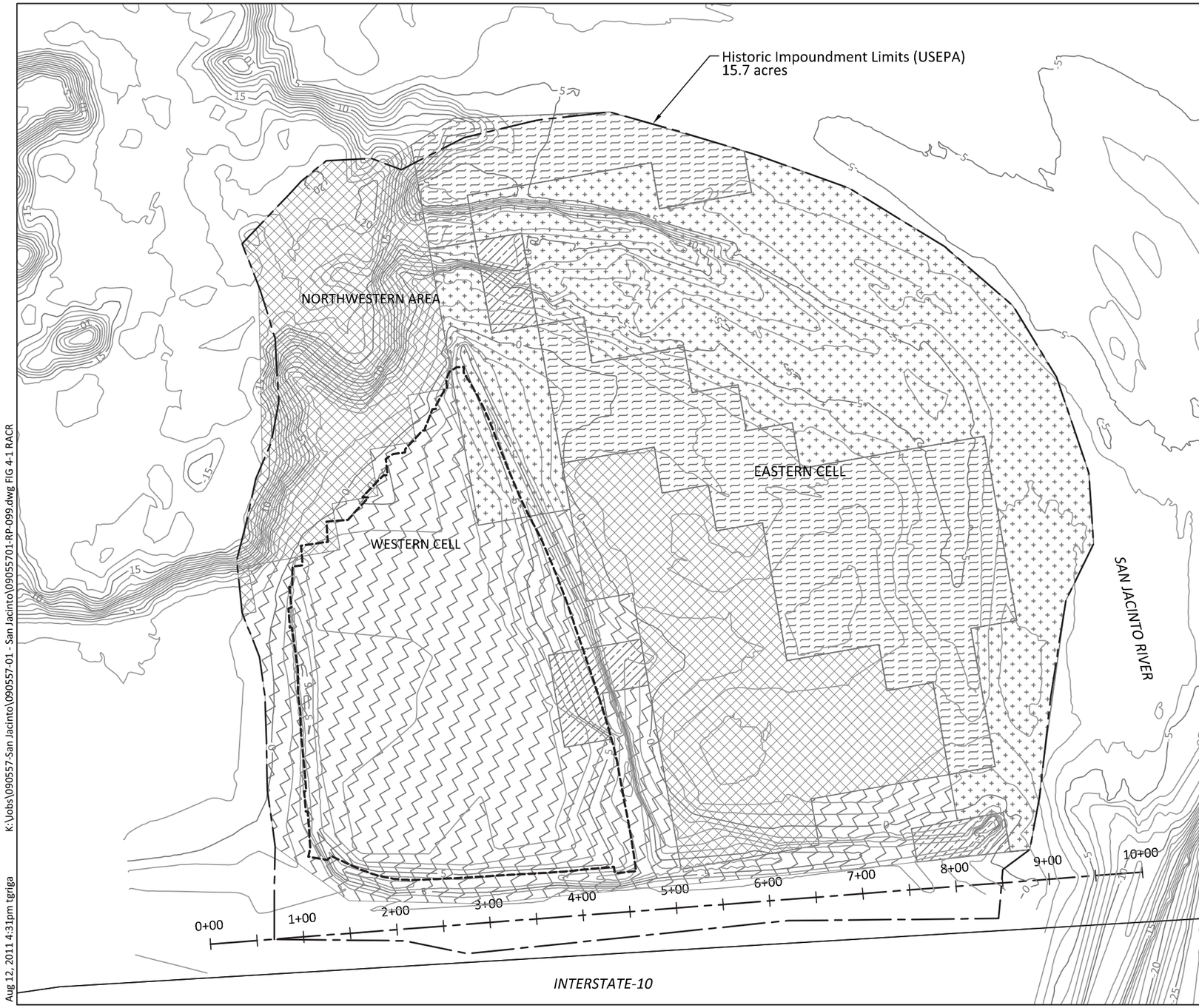
Figure 1-1
Vicinity Map
Draft Dioxin Treatability Study Literature Review
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

DRAFT



LEGEND:

Pre-Construction Contour, 6/12/10 (1-foot interval)

Historic Impoundment Limit (USEPA)

Armored Cap $A_{(P)}$ (Recycled)

Armored Cap $B/C_{(P)}$ (Recycled)

Armored Cap $C_{(N)}$ (Natural)

Armored Cap $D_{(N)}$ (Natural)

Armored Cap $D_{(N)}$ (Natural) (24"-Thick)

Surveyed Extent of Installed Geotextile and Geomembrane in Western Cell

HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.

VERTICAL DATUM: NAVD88.

0 120
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-099.dwg FIG 4-1 RACR

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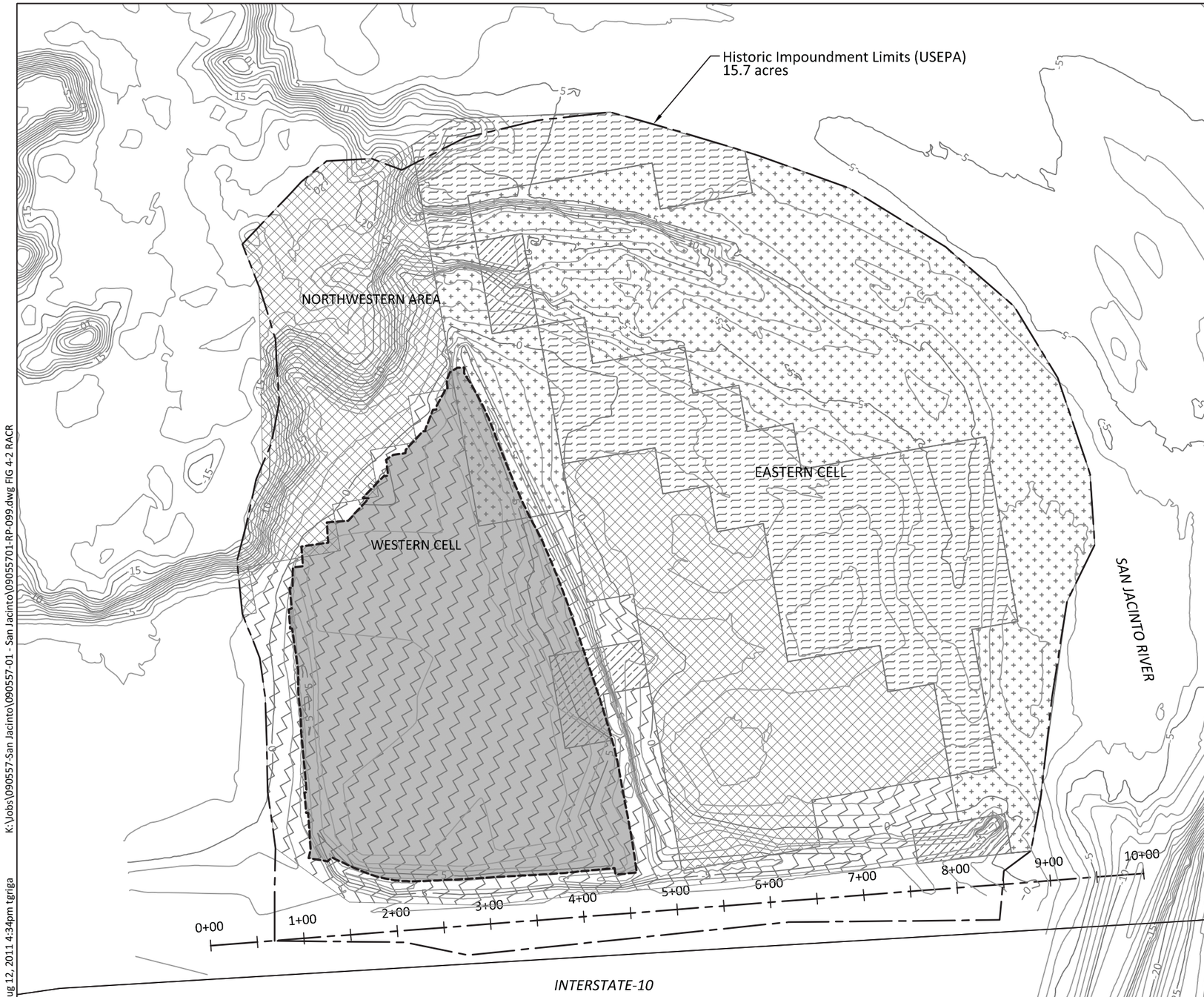
Figure 1-2
Armored Cap As-Built
Draft Dioxin Treatability Study Literature Review
San Jacinto River Waste Pits Superfund Site



LEGEND:

- Pre-Construction Contour, 6/12/10 (1-foot interval)
- Historic Impoundment Limit (USEPA)
- Armored Cap $A_{(P)}$ (Recycled)
- Armored Cap $B/C_{(P)}$ (Recycled)
- Armored Cap $C_{(N)}$ (Natural)
- Armored Cap $D_{(N)}$ (Natural)
- Armored Cap $D_{(N)}$ (Natural) (24"-Thick)
- Surveyed Extent of Installed Geotextile and Geomembrane in Western Cell

HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.

VERTICAL DATUM: NAVD88.

NOTE:

1. The shaded area indicates the area where a 12-oz geotextile, 40-mil LLDPE liner, and 16-oz geotextile were installed in the Western Cell.

0 120
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-099.dwg FIG 4-2 RACR
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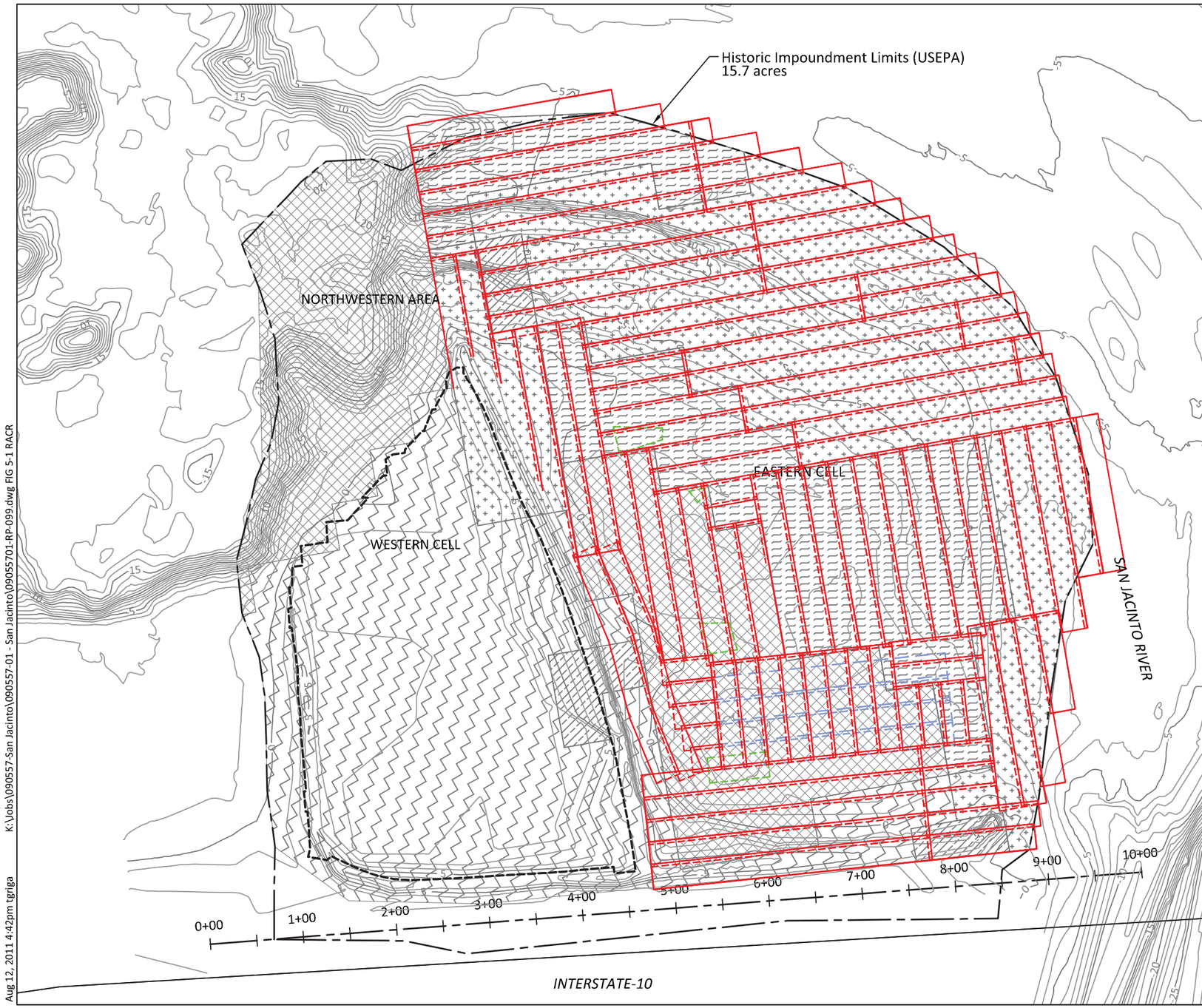
Figure 1-3
Western Cell Geotextile and Geomembrane As-Built
Draft Dioxin Treatability Study Literature Review
San Jacinto River Waste Pits Superfund Site



LEGEND:

- Pre-Construction Contour, 6/12/10 (1-foot interval)
- Historic Impoundment Limit (USEPA)
- Armored Cap $A_{(P)}$ (Recycled)
- Armored Cap $B/C_{(P)}$ (Recycled)
- Armored Cap $C_{(N)}$ (Natural)
- Armored Cap $D_{(N)}$ (Natural)
- Armored Cap $D_{(N)}$ (Natural) (24"-Thick)
- Final Geotextile Panels
- USA Installed Geotextile Panels (Underlay)
- USA Installed Geotextile Panels (Repair to Address Exposed Sediment)
- Surveyed Extent of Installed Geotextile and Geomembrane in Western Cell

HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.

VERTICAL DATUM: NAVD88.

NOTES:

1. Panel data from Sheet M8, titled Panel Configuration, by CRA, Inc. dated May 20, 2011.
2. The fabric panels depicted by this plat are based on information provided by the client and is not the result of an actual survey performed by CRA, Inc. The fabric panels shown are 27' wide by 300' long (maximum) with a 3' overlap along seams.
3. The berm area data shown on this plat reflect various Site conditions at the time of survey and are added for reference purposes. Please refer to specific berm survey plats for additional information.

0 120
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-099.dwg FIG 5-1 RACR
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Figure 1-4
Water-Based Geotextile As-Built
Draft Dioxin Treatability Study Literature Review
San Jacinto River Waste Pits Superfund Site