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Response Action Contract
Contract No. 68-W-98-228

EPA United States Environmental Protection Agency

REGION 10

FINAL DESIGN SUBMITTAL

- ☐ BASIS OF DESIGN REPORT
- ☐ DESIGN DRAWINGS
- ☐ SPECIFICATIONS
- ☐ CONSTRUCTION QUALITY ASSURANCE PLAN FOR RA1 THROUGH RA4

Pacific Sound Resources Superfund Site
Marine Sediment Unit
Seattle, Washington

URS
in association with
CH2M HILL
White Shield, Inc.

USEPA SF
1271291

FINAL DESIGN SUBMITTAL

- **Basis of Design Report**
- **Design Drawings**
- **Specifications**
- **Construction Quality Assurance Plan for RA1 Through RA4**

PACIFIC SOUND RESOURCES SUPERFUND SITE
MARINE SEDIMENT UNIT
SEATTLE, WASHINGTON

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Contract No. 68-W-98-228
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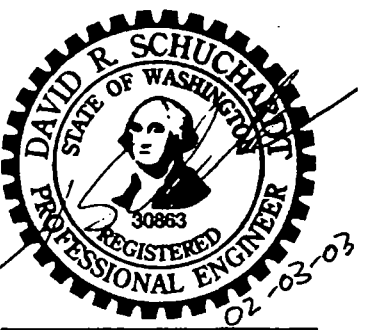

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PART II: DESIGN DRAWINGS

[bound separately]

PART III: SPECIFICATIONS

01000	Abbreviations and Acronyms
01110	Summary of Work
01115	Site Description
01140	Supplementary Requirements
01145	Site Specific Supplementary Requirements
01240	Cost and Performance Report
01270	Measurement and Payment
01320	Project Schedule
01330	Submittal Procedures
01351	Safety, Health, and Emergency Response
01355	Environmental Protection
01400	Remedial Action Management Plan
01450	Chemical Data Quality Control
01451	Contractor Quality Control
01500	Temporary Construction Facilities
01720	Surveying
01780	Record Drawings
01788	Project Closeout
02120	Transportation and Disposal of Hazardous and Non-Hazardous Materials
02325	Dredging
02483	Sediment Cap
02630	Storm Drainage
02940	Shoreline Restoration

PART IV: CONSTRUCTION QUALITY ASSURANCE PLAN FOR RA1 THROUGH RA4

ABBREVIATIONS AND ACRONYMS

ARARs	applicable or relevant and appropriate requirements
BA	biological assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
CPT	cone penetration testing
CQAP	construction quality assurance plan
CSL	cleanup screening level
CWA	Clean Water Act
cy	cubic yard
DMMO	Dredged Material Management Office
DMMP	Dredged Material Management Program
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
DOC	dissolved organic carbon
DRET	dredge elutriate test
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ft/sec	feet per second
FS	factor of safety
FSP	field sampling plan
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ID/IQ	indefinite delivery/indefinite quantity
L/kg	liter per kilogram
LNAPL	light nonaqueous-phase liquid
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
LWD	large woody debris
µg/kg	microgram per kilogram
µm	micrometer
mg/kg	milligram per kilogram
mg/L	milligram per liter
ml	milliliter
MCUL	minimum cleanup level
MHHW	mean higher high water

ABBREVIATIONS AND ACRONYMS (Continued)

MLLW	mean lower low water
m/sec	meter per second
MSU	Marine Sediment Unit
MTCA	Model Toxics Control Act
NAPL	nonaqueous-phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric turbidity unit
OMMP	operation, maintenance, and monitoring plan
O&M	operation and maintenance
OSI	organism sediment index
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
pcf	pounds per cubic foot
PGA	peak ground acceleration
PSDDA	Puget Sound Dredged Disposal Analysis
psf	pounds per square foot
PSR	Pacific Sound Resources
PSRMP	Pacific Sound Resources management plan
QA	quality assurance
QA/QC	Quality Assurance/Quality Control
RA	remediation area
RAC	Response Action Contract
RAMP	remedial action management plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
ROV	Remotely operated vehicle
RPD	redox potential discontinuity
SMS	Sediment Management Standards
SPI	sediment profile imaging
SQS	Sediment Quality Standard
STFATE	Short-Term Fate [of dredged material in the open water]

ABBREVIATIONS AND ACRONYMS (Continued)

SVPS	sediment vertical profiling system
TCLP	toxicity characteristics leaching procedure
T/E	threatened or endangered
TOC	total organic carbon
TSS	total suspended solids
UCL	Upper Confidence Limit
URS	URS Group, Inc.
USACE	United States Army Corps of Engineers
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administration Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WQC	water quality criteria

PART I

BASIS OF DESIGN

1.0 INTRODUCTION

This design document was prepared by URS Group, Inc. (URS) for the U.S. Environmental Protection Agency (EPA) as a part of the EPA Region 10 Response Action Contract (RAC). This design document presents the basis for the design of the selected remedial action for the Marine Sediment Unit (MSU) of the Pacific Sound Resources (PSR) Superfund site. The location of the site is shown in Figure 1-1.

Remedial actions selected by the EPA include capping and a slurry wall for the Upland Unit (which are not part of this design) and a subaqueous sediment cap for the MSU. These actions are identified in the Record of Decision (ROD) for the site (USEPA 1999). Active cleanup has been completed in the Upland Unit and the area redeveloped for use by the Port of Seattle. The primary elements of this design include a subaqueous sediment cap covering approximately 58 acres of Elliott Bay, along with limited dredging in an area of approximately 1 acre to maintain post-capping navigational depths.

This document presents the final (100 percent) design for the cleanup of the MSU. This design submittal is organized as follows:

Part I: Basis of Design

- Section 1 Introduction
- Section 2 General Design Considerations
- Section 3 Dredge Design
- Section 4 Cap Design
- Section 5 Short-term Water Quality Impacts During Construction
- Section 6 Regulatory Compliance Strategy
- Section 7 Habitat Considerations
- Section 8 Remedial Action Contracting Strategy
- Section 9 Remedial Design and Post-Construction Deliverables
- Section 10 Identification of Easement and Access Requirements
- Section 11 Construction Sequencing, Schedule, and Cost Estimate
- Section 12 References

Part II: Design Drawings

Part III: Specifications

Part IV: Construction Quality Assurance Plan for RA1 Through RA4

Technical analyses, model outputs, and additional design documentation are included as appendices to this document.

As discussed in Section 9, several other design-related documents are being prepared separately by the U.S. Army Corps of Engineers, Seattle District (USACE). These documents include the biological assessment (BA) and the Pacific Sound Resources Management Plan (PSRMP). The PSRMP contains the construction quality assurance plan (CQAP) for RA5; the operations, maintenance, and monitoring plan (OMMP); and the PSR Management Guidelines. This Final Design Submittal is also considered a part of the PSRMP.

1.1 PURPOSE, SCOPE, AND PROJECT ORGANIZATION

1.1.1 Purpose and Scope

This document presents the final design for the cleanup of the MSU. The body of this document is the basis of design, which presents a narrative discussion of the key technical parameters upon which the design is based. The other primary design components of this submittal are the specifications, design drawings, and the CQAP for RAs 1–4.

This document describes the design for the capping and dredging elements of the selected remedy for the MSU. The selected remedy also includes removal of several hundred treated wood piling and associated overhead structures from the MSU (collectively referred to as "piling removal"). The piling removal is being designed and constructed separately by the Port of Seattle and is not discussed in detail in this document. The timing of the piling removal is discussed in Section 11. Institutional controls are also a feature of the selected remedy and are discussed in Section 1.7.

1.1.2 Project Organization

Design activities at PSR are being performed under contract to EPA (Contract 68-W-98-228; Work Assignment 065-RD-RD-101L) by URS. Design activities are being completed in consultation with the USACE and in coordination with the Natural Resource Trustees.

Several pre-remedial design and draft design documents precede this submittal, as described below:

- Remedial design (RD) of the subaqueous capping system for the MSU required the collection and analysis of additional data. Data collection requirements were outlined in a data gaps analysis (USEPA 2001a).

- Specific data collection activities were defined in a field sampling plan (FSP) (USEPA 2001b). The FSP also defined quality assurance/quality control (QA/QC) and sampling and analysis procedures.

- The results of the remedial design field investigations were documented in the *Draft Technical Memorandum #1—Pre-Design Investigation Data Summary* that was submitted to EPA in February 2002 (USEPA 2002a). The pre-design investigation data summary was reviewed by the EPA and representatives of the Seattle District, USACE.

- The preliminary evaluation of pre-design investigation data and development of design criteria, were documented in the *Technical Memorandum #2—Conceptual Site Design* that was finalized in June 2002 (USEPA 2002b). The conceptual site design included design calculations, modeling, and other evaluations for establishing design criteria, and was reviewed by EPA, USACE, U.S. Fish and Wildlife Service (USFWS), Washington Department of Fisheries and Wildlife (WDFW), Washington Department of Ecology (Ecology), Washington Department of Natural Resources (WDNR), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Suquamish Tribal Fisheries Department, and the Muckleshoot Fisheries Department.

- The 30 Percent Design was submitted on July 26, 2002, and was reviewed by the same parties as described above. Comments received on the 30 percent Design were incorporated into the 90 percent Design Submittal.

- The 90 Percent Design was submitted on December 3, 2002, and was reviewed by the same parties as described above. Comments received on the 90 percent Design have been incorporated into this Final Design Submittal.

To facilitate design development and resolution of key technical issues, a number of stakeholder meetings were held following issuance of the 30 Percent Design and the 90 Percent Design. Key topics of these meetings included:

- Use of dredged material
- Loss of aquatic prism and gains in intertidal habitat
- Habitat enhancements
- Remedial construction scheduling
- Water quality certification
- Coordination with tribal fisheries

Meeting summaries are available and are included in project files. The summaries outline consensus decisions and agreements among reviewers that are reflected in this Final Design. Section 9 of this report summarizes the scope and status of the various documents associated with the remedial design and post-construction deliverables.

The USACE will be responsible for all dredging and cap construction activities, including procuring remedial construction contractors and administering construction and oversight contracts. USACE maintains a number of contracting vehicles to execute construction activities. Contracting strategy is discussed in Section 8.

1.2 SITE LOCATION AND DESCRIPTION

The PSR site, formerly known as the Wyckoff West Wood Treating Facility, is located on the south shore of Elliott Bay in Puget Sound, in Seattle, Washington (Figure 1-1). The site is divided into two operable units: the Upland Unit and the MSU. The Upland Unit consists of the former wood treating facility and occupied an area of approximately 25 acres; the MSU encompasses approximately 200 acres of Elliott Bay and approximately 2,000 feet of shoreline. Tidal elevations in the MSU range from extreme low water at -4 feet mean lower low water (MLLW) to extreme high water at +14.8 MLLW (USACE 2002, Nelson 1978). The relationship between various datum planes and tidal stages is shown in Table 1-1. All elevations in this design are based on the U.S. Survey MLLW vertical datum, and are given in feet.

Groundwater and soils contamination by creosote and other wood-treating waste products was present in the Upland Unit; an area of the MSU encompassing approximately 50 acres was reported to contain sediments with elevated levels of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) that present unacceptable risks to aquatic resources. During design, the size of the ROD-defined area of concern was determined to be 55 acres. (The cap design area encompasses approximately 58 acres as discussed in Section 2.2). A discussion of the nature and extent of contamination in the MSU as well as risk assessment results are presented in the remedial investigation report (USEPA 1998a).

1.3 SITE HISTORY AND NATURE OF CONTAMINATION

From 1909 to 1994, wood-treating operations were performed at the site. The wood-treating facility was originally a pile-supported facility over the Duwamish River estuary. The shoreline and intertidal area were filled in at various times throughout the last 100 years and the facility was eventually entirely located on approximately 25 acres of fill material that created an upland. This in-filling resulted in a steep riprap bank on the shoreline between the upland and off-shore area.

The southern portion of the facility (10 acres) was used primarily for treated wood storage and the northern part of the facility (15 acres) was used for processing. All retorts, product storage tanks and piping were located on the northern portion of the facility. Wood-treating chemicals used at the site included creosote, pentachlorophenol and various metals-based wood preservation solutions.

The MSU has been contaminated by discharge of used and waste creosote and wood-treating chemicals from the former wood-treating operations on the upland portion of the site. Chemicals of concern in the MSU include PAHs, phenolic compounds, dibenzofuran, polychlorinated dibenzo-p-dioxins and -furans, PCBs, and mercury (USEPA 1998a). PAHs have been detected in excess of screening levels to depths of 20 feet below the mudline at the site. Downward and lateral migration of nonaqueous-phase liquids (NAPL), transport of contaminated groundwater, and erosion of contaminated soils by stormwater runoff from the Upland Unit represent historical sources and transport pathways to the MSU. In addition, the former Longfellow Creek outfall historically contributed PCB contamination to the MSU, and mercury contamination appears to have migrated from a source to the east of the site.[1]

A conceptual site model is provided as Figure 1-2. As a result of cleanup actions in the Upland Unit, there are only three likely contaminant migration pathways to Elliott Bay remaining: (1) transport of dissolved contaminants via groundwater with subsequent partitioning to sediment; (2) dissolution of sediment-bound contaminants to the waters of Elliott Bay; and (3) longshore or downslope migration of contaminated surface sediment in the MSU. The transport of free- and dissolved-phase NAPL in shallow groundwater to Elliott Bay has been inhibited by the slurry wall and light NAPL (LNAPL) recovery trench that were constructed as part of the upland source control activities. However, some dense NAPL (DNAPL) is present

[1]Flow from Longfellow Creek has since been rerouted to the West Waterway of the Duwamish River. The outfall remains functional and receives local storm drainage as well as overflow of peak flows from Longfellow Creek.

seaward of and deeper than the slurry wall. The DNAPL constitutes an ongoing, however minor, source to the bay via dissolved phase groundwater transport (USEPA 1999).

1.4 GEOLOGICAL SETTING

1.4.1 Regional Geology

The PSR site lies near the center of the Puget Sound Basin between the Cascade Mountain Range and the Olympic Mountains. The geomorphology of the Puget Sound Basin has been shaped by several episodes of Pleistocene glaciation, which have resulted in a westward-sloping, gently rolling drift plain cut by many wide, steep-sided troughs.

These north-south trending troughs have been glacially scoured and are filled with marine water (i.e., Puget Sound) or large freshwater lakes (e.g., Lake Washington) or have been alluviated by streams and rivers (e.g., Duwamish Valley).

The Duwamish River is a major drainage of the western slope of the Cascade Mountain range, and enters Puget Sound from the south at Elliott Bay, a protected, deep-water harbor. The MSU cap design limits encompass approximately 58 acres of Elliott Bay adjacent to and offshore of the Upland Unit (Figure 1-1). The Elliott Bay shoreline has been extensively developed for urban, port, and industrial land uses; the area surrounding the site is principally used for water-dependent industries. The mouth of the Duwamish River's West Waterway is located approximately 0.3 mile east of the PSR MSU site.

Unconsolidated sediments dominate the project vicinity. The sedimentary bedrock of the Blakely Formation outcrops at Alki Point, about 1 mile west of the site, and at the west side of Beacon Hill, approximately 2 miles east of the site. No deep borehole explorations (past or current) have encountered bedrock at the PSR site, but the Blakely Formation is expected to underlie the site at approximately 340 to 680 feet based on regional data from geophysical surveys and nearby soil borings (Yount and Holmes 1992).

1.4.2 Site Geology

The upland area of the site lies in an estuary that was filled to create usable land for industrial development (USEPA 1998a). The upland fill is variable in nature and underlain by, in lithological sequence, native estuarine deposits, deltaic deposits, and glacial deposits. The fill in the upland area is typically 20 to 45 feet thick and consists of dredged sand and silt, construction debris and predominantly granular sediment, riprap, and wooden bulkhead debris. Estuarine

deposits consist of silty sand and sandy silt with interbedded silt, clay and sand, and minor peat, wood, organic fragments and shells. The lower deltaic unit is medium dense to dense sand, and silty sand with some silt interbeds. Silt and clay lenses up to 10 feet thick have been observed and indicate a seaward dip of about 5 to 10 degrees. Dense glacial deposits were not encountered in the upland borings installed as part of the remedial investigation, which penetrated approximately 100 feet below the ground surface (bgs), nor were they encountered in sediment explorations installed during the RI/FS and predesign investigations through depths of 80 feet below the mudline.

The sea-bottom slopes in the MSU are generally steeper nearshore and become flatter further offshore. The bottom slopes are variable, with nominal slopes up to about 20 to 25 percent (5H:1V to 4H:1V) from the shore to water depths of about -120 feet mean lower low water (MLLW), 15 percent (7H:1V) in the 120- to 150-foot MLLW depth, and about 6 to 15 percent (16H:1V to 7H:1V) below -150 feet MLLW. A flat embayment area is present at the Crowley Marine Services pier in a water depth of about 40 feet.

Surface deposits of anthropogenic contaminated fill material overlie native sediments throughout the MSU. For consistency with the ROD, this contaminated fill material in the MSU is referred to as the Marine Sediments Unit fill, or simply "fill." Side-scan sonar (USGS 1996) and core samples (USEPA 1998a) indicate as much as 20 feet of fill consisting of contaminated sand and silty sand with organics and occasional wood debris.

The presence of thin layers of contaminated sediments in water depths up to 200 feet suggest that some fill material may have flowed down the submarine slopes due to uncontrolled placement (USGS 1996). Bathymetric data indicate that landslides have also historically occurred as subaqueous landslide features. Settling of turbidity plumes may also have contributed to the thin deposits of contaminated sediments. Ongoing sediment resuspension and transport during storm events could also explain the occurrence of contaminated sediments in deeper offshore areas.

Seattle is located in a seismically active area. In addition to documented earthquakes throughout the Northwest region, the project site is located adjacent to the Seattle fault. Current research by the U.S. Geological Survey (USGS) indicates that the Seattle fault may have produced a Magnitude 7 earthquake about 1,100 years ago.

1.5 REMEDIAL ACTION OBJECTIVES

The ROD (USEPA 1999) identified the following remedial action objectives for cleanup in the MSU:

- Minimize human exposure through seafood consumption
- Minimize benthic community exposure to site contaminants

Attainment of these overall objectives, as specified in the ROD, will be measured by compliance with the Washington State Sediment Management Standards (SMS) (WAC 173-204). The SMS establish a narrative standard with specific biological effects criteria and numerical chemical concentrations for Puget Sound sediment. Under the SMS, the cleanup of a site should result in the elimination of adverse effects on biological resources and any health threats to humans. The Sediment Quality Standards (SQS) correspond to this narrative for ecological effects. Under the SMS, site-specific cleanup standards are established from a range of concentrations based on environmental effects, feasibility, and cost; they are to be as close as practicable to the SQS and no greater than the minimum cleanup levels (MCULs). The MCULs are equivalent to the cleanup screening levels (CSLs).

The CSL for PAHs serves as the trigger for remediation of the MSU; the SQS for PCBs is the trigger for active remediation of sediments in the nearshore environment (shallower than –10 feet MLLW). The marine sediment cap is the primary component to achieve CSLs and SQSs in the MSU. The ROD identified the cap boundaries based on these triggers, as shown in Figure 1-3. The capping material will at least meet the SQS, resulting in SQS or lower concentrations throughout the capped area.

1.6 THE SELECTED REMEDY

The selected remedy for the MSU is described in the ROD (USEPA 1999) and generally consists of the following elements:

- Confinement of contaminated marine sediments by placement of a sediment cap that covers approximately 50 acres. (Acreage estimate from ROD has since been refined to 55 acres of required capping area. The cap as designed covers approximately 58 acres.)

- Dredging approximately 3,500 cubic yards of contaminated sediment from the area north of Crowley Marine Services, to allow capping while maintaining current navigational depths (dredge quantity estimate from ROD)
- Removal of unused piling prior to capping
- Implementation of institutional controls to restrict use of boat anchors
- Development and implementation of both a short- and long-term monitoring and management plan to ensure that the cap is placed as intended and is performing the basic confinement functions

The capping and dredging activities are described in detail in this basis of design. Piling removal is being accomplished by the Port of Seattle and is not discussed further in this document. The institutional control for anchoring is further discussed in Section 1.7. The monitoring and management plans are discussed in Section 9.

1.7 INSTITUTIONAL CONTROLS

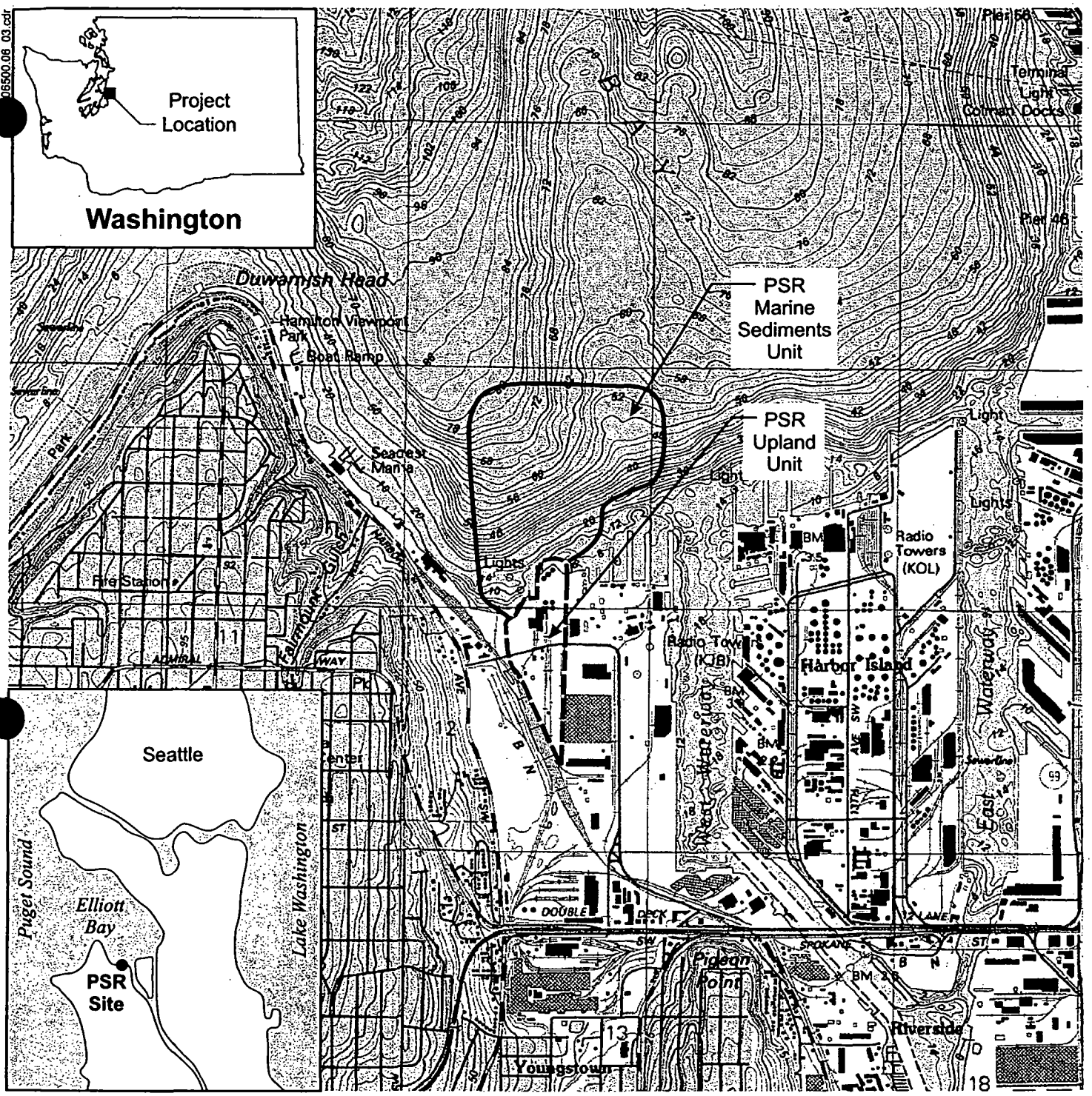
The ROD requires that the entire capped area be designated as a "no-anchor" zone. The no-anchor designation will apply to commercial vessels using the large "whale-tail" type anchors that have the capacity to break through the cap and expose contaminated sediment. Figure 1-4 illustrates the area to be covered by the "no-anchor" designation.

Institutional controls may be employed at sites as a critical component of the cleanup process, whose purpose is to ensure both the short- and long-term protection of human health and the environment. The use of institutional controls is governed by both EPA guidance (OSWER 9355.0-74FS-P) and MTCA regulation (WAC 173-340-440).

Land use restriction is the primary institutional control to be employed at PSR. The restriction will be placed on anchor use over the sediment cap, to limit the potential for cap disturbance and subsequent release of contaminated sediments. The land use restriction will be in the form of promulgation of a regulatory amendment that designates the entire sediment cap as a "no-anchor" zone. In consultation with the WDNR, EPA, and the USACE, the U.S. Coast Guard (USCG) will develop an additional section to USCG regulation 33 CFR Part 165, Regulated Navigation Areas and Limited Access Areas. This new section will prohibit commercial vessels from using large "whale-tail" anchors in the no-anchor zone. The rule-making will be subject to public comment.

The development and enforcement of the no-anchor zone will meet the requirements of WAC 173-340-440(8), which typically requires that property owners include institutional controls in restrictive covenants on their properties. However, restrictive covenants are not required of a government landowner if it implements an effective alternative system (such as the no-anchor zone). The level of protection provided by promulgation of a federal regulation written specifically for the PSR cap area is high. First, the regulation is a legal requirement enforceable by the USCG. Second, the regulation provides long-term protection, since it can only be modified or terminated through the federal rulemaking process. For the USCG to modify or terminate the regulation, it would have to publish the proposed regulatory change in the *Federal Register* for public (and agency) comment and then take any comments into account before finalizing a change. Thus, MTCA institutional controls requirements will be met.

The institutional control described above will remain in place as long as the cap is needed to contain subsurface contaminated sediments.



Map created with TOPO!™ © 1997 Wildflower Productions, www.topo.com, based on USGS topographic map

Note: Contours shown in meters

Figure 1-1

PSR Upland and Marine Sediments Unit Location Map

Job No. 53-F4006500.06

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

F4006500.06_07.cdr

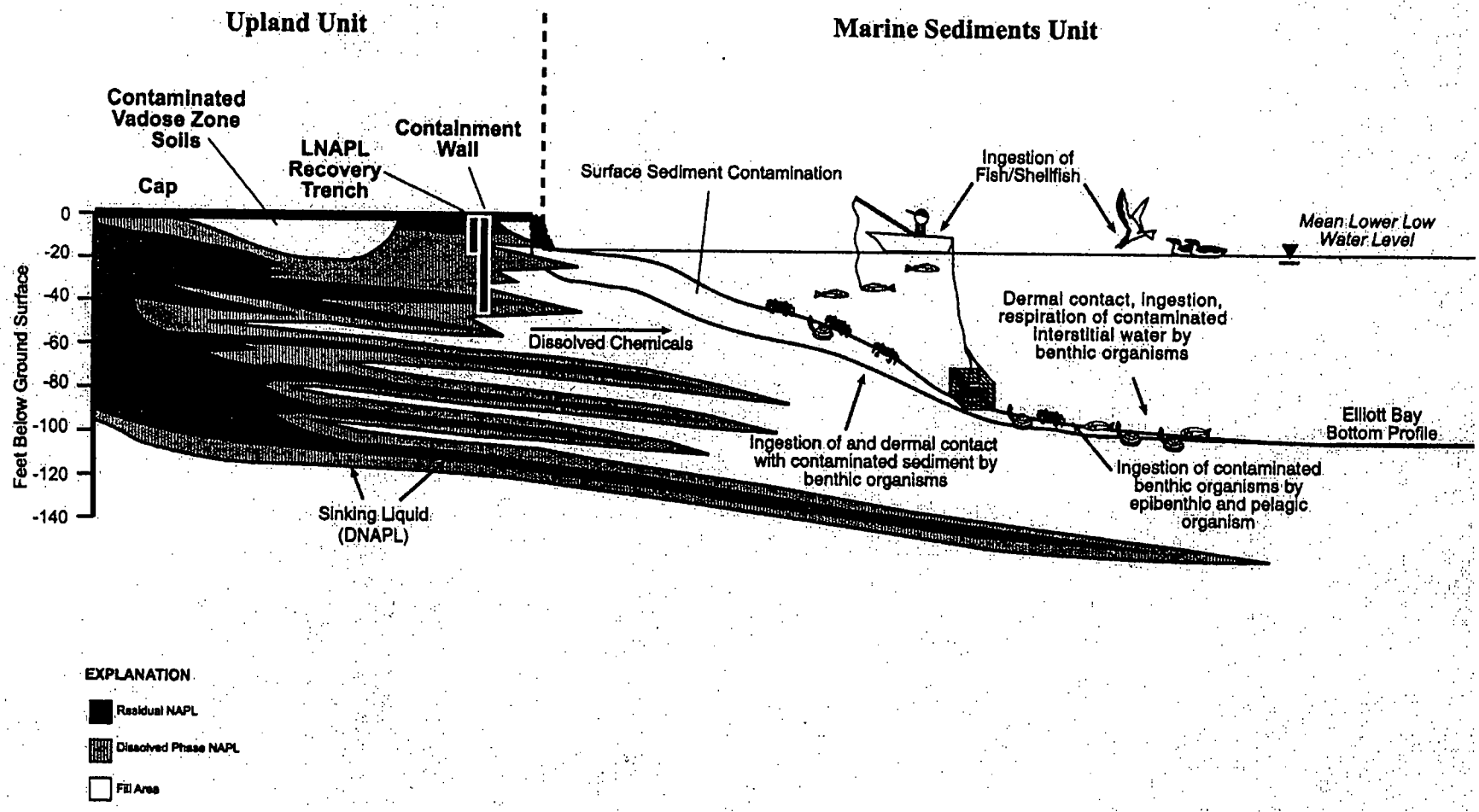


Figure 1-2

PSR Conceptual Site Model of Receptors and Exposure Pathways in the Marine Sediments Unit Post-upland Cleanup

Job No. 53-F4006500.06

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

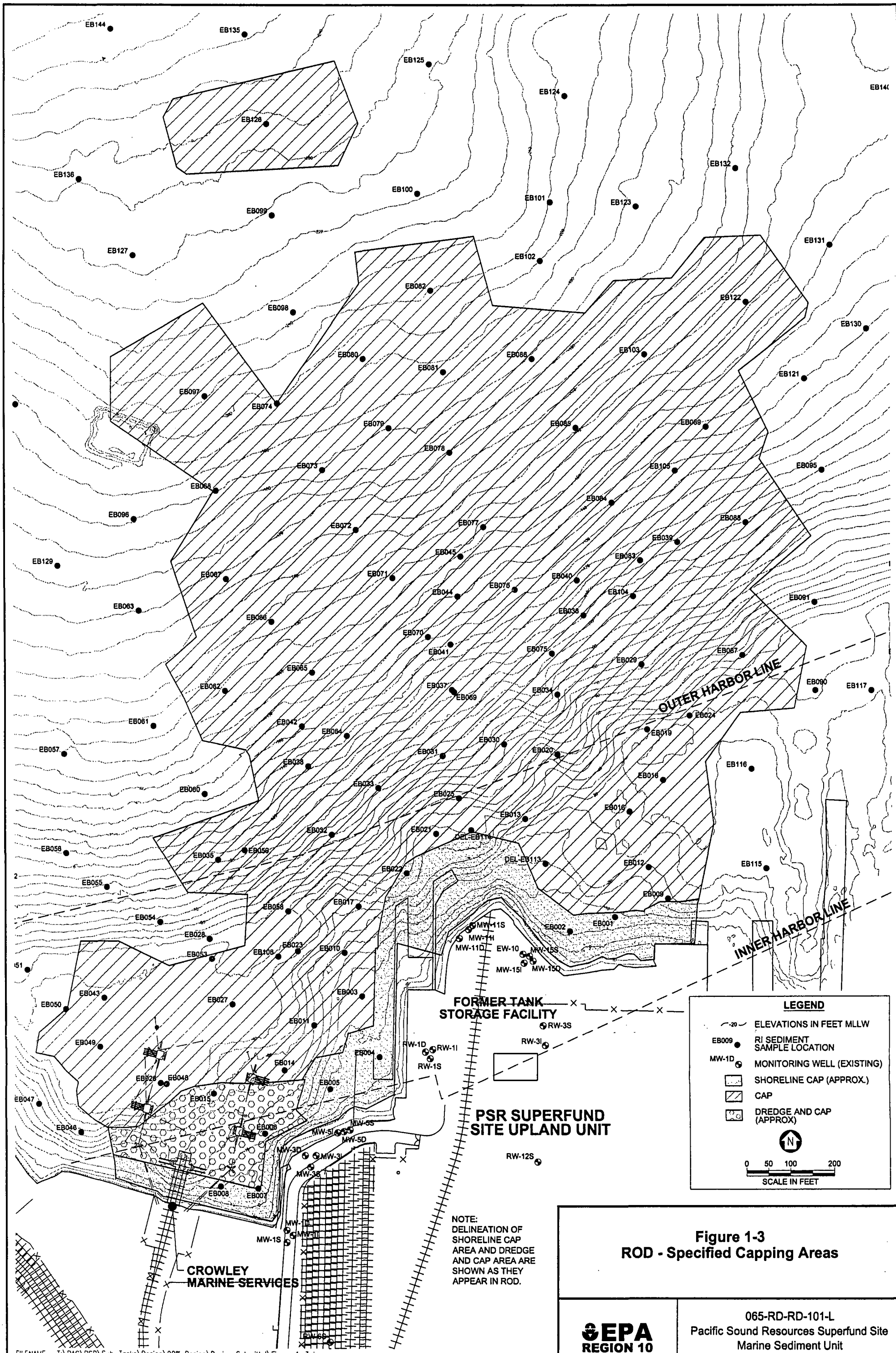


Figure 1-3
ROD - Specified Capping Areas

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

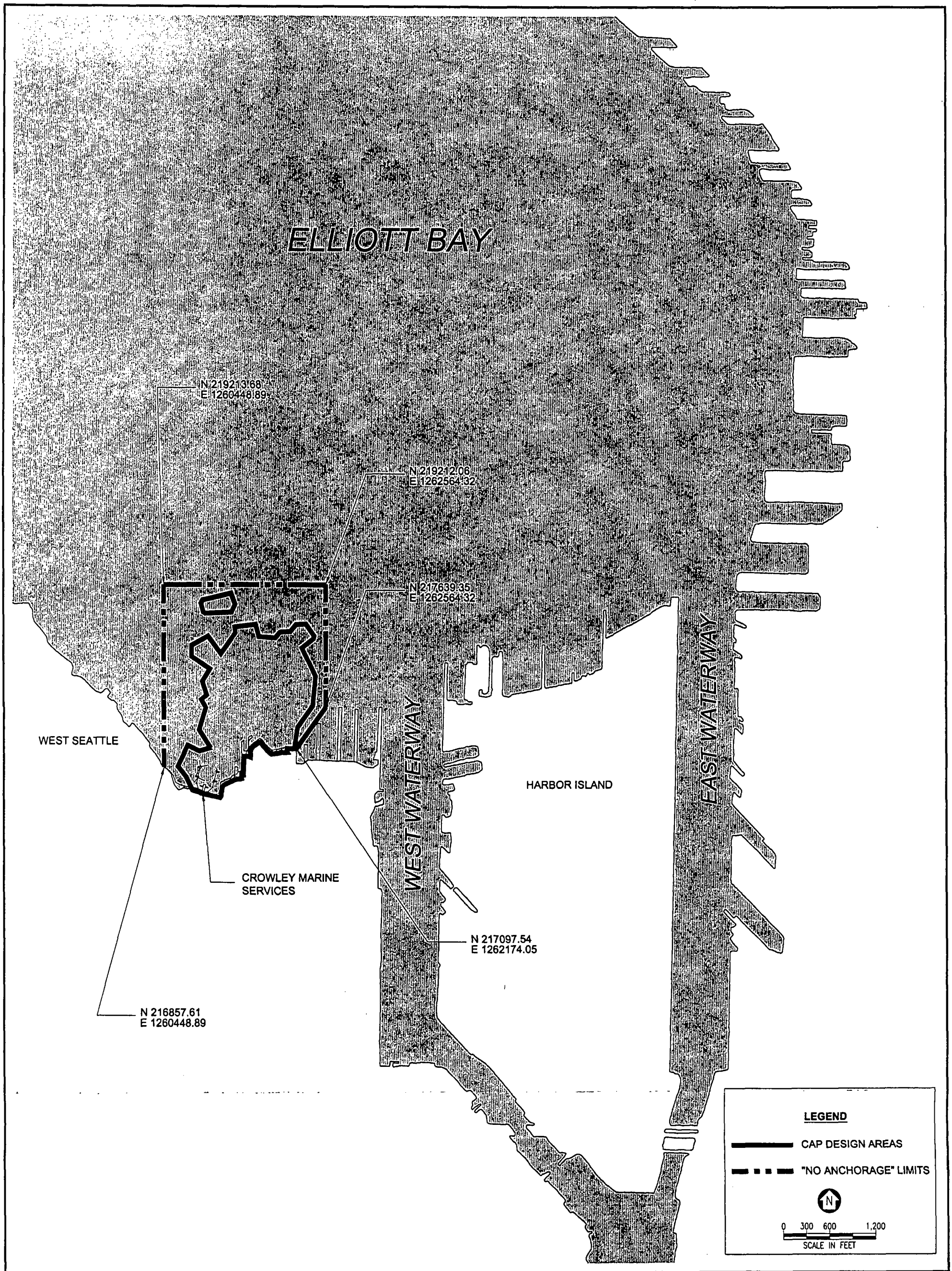


Figure 1-4
Area of "No Anchor Zone"
Institutional Control

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

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Table 1-1
Tidal Datums at PSR Superfund Site

Relationship Between Various Datum Planes (ft)					
Datum Plane	MLLW	NGVD	NAVD88	USACE	City
Highest Observed Tide	14.8	8.7	12.3	15.7	2.6
Mean Higher High Water	11.2	5.13	8.69	12.08	-1.03
Mean High Water	10.3	4.23	7.79	11.18	-1.93
Mean (Half) Tide Level	6.55	0.48	4.04	7.43	-5.68
NGVD	6.07	0.00	3.56	6.95	-6.16
Mean Low Water	2.80	-3.27	0.29	3.68	-9.43
Mean Lower Low Water	0.00	-6.07	-2.51	0.88	-12.23
Lowest Estimated Tide	-4.5 +/- 0.5	-10.6 +/- 0.5	-7.0 +/- 0.5	-3.6 +/- 0.5	-16.7 +/- 0.5

Notes:
MLLW - mean lower low water
NAVD88 - North American Vertical Datum 1988
NGVD - National Geodetic Vertical Datum
USACE - U.S. Army Corps of Engineers

Source: USACE 2002, Nelson 1978

2.0 GENERAL DESIGN CONSIDERATIONS

To provide an overview of the design approach, general design considerations are discussed in the following subsections. Key design issues include compliance with the conditions of the ROD, extent and boundary of remediation area, capping material sources and availability, dredging methods, cap placement techniques, cap monitoring and verification, and construction scheduling to minimize impacts on aquatic resources and navigation. A summary of these issues is provided in this section, and specific design elements are developed in Sections 3 through 11.

2.1 ROD-SPECIFIED DESIGN REQUIREMENTS

Consistent with the ROD and USACE guidance (Palermo et. al 1998a and b), the primary component of the selected remedy, a marine sediment cap, has been designed to accomplish the following:

- Reduce the chemical flux from contaminated sediments and groundwater, and chemically isolate these sources from benthic organisms;
- Physically isolate the contaminated sediments and provide a clean habitat for benthic organisms;
- Maintain stability under static loads and have an acceptable reliability under design seismic loads;
- Resist erosion, suspension, and transport of cap materials and underlying contaminated sediments by waves, tidal, and wind-induced currents, and propeller wash.

The design is based on achieving remedial action objectives in a cost-effective manner, consistent with the requirements of the ROD, applicable or relevant and appropriate requirements (ARARs), and standard engineering practice.

Site conditions limit the ability to ensure cap stability under extreme seismic loads, such as earthquakes that are projected to occur at return periods of greater than 100 years. Construction of engineered features to improve long-term seismic stability throughout the MSU is not considered practicable and would represent a very large capital expenditure. Rather, the design deals with potential long-term seismic damage to the cap by establishing future maintenance

requirements. The design documentation includes an OMMP in which procedures associated with cap repair and maintenance are identified. (Additional information on seismic stability is presented in Section 4.2.)

The cap design, including cap thickness and material specifications, has been conducted in accordance with the *Guidance for In Situ Subaqueous Capping of Contaminated Sediments* (USEPA 1998b). The ROD also specifies the following design parameters for the cap:

- The minimum cap thickness shall be 5 feet in the intertidal area.
- Capping material shall be at least as clean or cleaner than the SQS and, according to the ROD, will originate from routine maintenance dredge projects in local rivers. (Note: It is necessary, however, to use upland materials for capping certain areas of the site to enhance cap stability and allow for construction activities to be completed within specific time periods such that impacts to aquatic resources are minimized.)
- Capping material shall be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to this area.

Additional engineered features will be used as necessary to maintain the thicker cap in the intertidal area.

Materials specifications are generally discussed in Section 4; detailed specifications are provided in Part III of this document.

The ROD discusses the potential existence of a region of the MSU (termed the Intermediate Groundwater Discharge Zone) where recontamination of cap material by groundwater transport was suspected. This suspected area of concern was identified based on preliminary modeling in the Remedial Investigation/Feasibility Study (RI/FS). The pre-design efforts (USEPA 2002a, 2002b) included specific investigations of groundwater discharge and porewater contaminant concentrations to evaluate the potential for cap recontamination in the Intermediate Groundwater Discharge Zone and elsewhere in the MSU. Based on the results of these studies, no enhanced potential for recontamination exists in the Intermediate Groundwater Discharge Zone, and this region of the MSU is therefore not referred to as a unique region in this design.

As discussed in Section 1.7, the ROD also specifies that the entire capped area be designated a "no-anchor" zone. Other regulatory programs will address the capped contaminated sediment that may be potentially exposed by future dredging projects that might be proposed within the

capped area. Such projects may be associated with currently unplanned future development scenarios. Permitting requirements under Section 404 of the federal Clean Water Act and the Washington State Shoreline Management Act will address such scenarios and will require appropriate design elements, such as requirements for handling and disposal of contaminated sediments, restoration of the cap following dredging, or dredging to remove all sediments above the SQS. Additional regulatory considerations for this project are discussed in Section 6.

2.2 REMEDIATION AREAS

The ROD specifies the portions of the MSU that require capping. These boundaries are shown in Figure 2-1. To facilitate construction of the remedy, simplified remediation area (RA) boundaries have been established in nearshore portions of the site, as shown on Figure 2-1. These simplified RA boundaries will result in limited overplacement of capping material outside the irregular ROD-required capping boundaries, but the simplified boundaries have been designed to minimize overplacement while improving constructability.

The irregular cap area boundaries were not modified in the deep offshore areas of the site. Based on the cap placement methods specified for these areas of the site, the irregular boundary does not pose constructability concerns. However, the placement methods and depths in the deep offshore areas result in broad deposits of capping material, and hence significant amounts of capping material will be deposited outside the ROD-required capping boundaries.

Based on the defined RA boundaries, the cap design area totals approximately 58 acres, versus the ROD-required capping area of 55 acres (which was reported as 50 acres in the text of the ROD). Further discussion of the site boundaries and areas affected by cap material deposition is provided in Section 4.8.4.

For engineering purposes, the individual RA boundaries were developed according to specific site conditions and operational considerations that require different cap designs, cap materials specifications, or construction methods (Figure 2-1). The MSU is divided into the following RAs:

- **RA1: Intertidal/Shallow Subtidal Area.** The RA1 boundaries are defined to extend from the top of the bank, offshore a sufficient distance to construct the required grade transitions to the adjacent offshore RAs. According to the ROD, a minimum 5-foot cap thickness is required for capping contaminated sediments in the intertidal area. (The term "intertidal area" as used in this document includes areas with sediment at existing mudline elevations from –10 feet MLLW to

+14.8 feet MLLW, the maximum tidal elevation [Nelson 1978]. The 5-foot cap thickness is required over existing sediments within these elevations, but not over existing riprap within these elevations. This definition allows placement of a minimum 5-foot-thick cap to achieve final elevations within the intertidal elevations of –4 feet MLLW to +14.8 feet MLLW. This is discussed further in Section 4.3.) Erosive forces due to surface waves, propeller wash, and cross-shore sediment transport processes determine the particle size of capping material in RA1. Design elements include intertidal habitat enhancement and establishment of beach areas. Engineered features such as specific materials, specific slopes, and riprap slope caps are necessary for physical cap stability in RA1. Due to the complex topography in RA1, significantly different slope profiles are required along various segments of the shoreline.

- **RA2: Shallow Nearshore Areas.** RA2 consists of two discrete nearshore areas, RA2a and RA2b, which extend from approximately -15 to -50 feet MLLW. RA2a and RA2b are characterized by relatively flat areas or shallow slopes, with localized steepened areas. Conditions in this area are analogous to conditions at other capping projects in the Puget Sound region, such as Eagle Harbor. Erosive forces due to propeller wash determine the particle size of capping material in RA2a. Erosive forces are not anticipated to be significant in RA2b.

- **RA3: Crowley Marine Services Area.** It is necessary to maintain navigational depths in this area for barges, tugs, and other vessels. Because sediment contamination in this area extends to depths of 8 to 10 feet below the mudline and because of the need to maintain navigational access, a cap cannot be constructed in the area of Crowley Marine Services without first removing materials through dredging. The capping material in this area must also resist erosive forces from propeller wash.

- **RA4: Sloping Offshore Area.** This area extends from approximately -50 to -140 feet MLLW and includes relatively steep slopes with approximately 15 percent to 25 percent grades. Stability of these soft/loose sediment slopes and the potential for failure during cap placement requires specific controlled cap placement methods.

- **RA5: Deep Offshore Areas.** RA5 consists of sub-areas RA5a and RA5b. These areas extend from approximately -140 to -240 feet MLLW and include slopes with approximately 4 percent to 15 percent grades. Placement of cap material in

RA5 can be accomplished in the most cost-effective manner by instantaneous bottom-dump placement of clean dredged material from other dredging projects.

Engineering analyses (see Appendix D) were used to define the RA4/RA5 boundary with consideration of the material types and placement methods to be used. Key parameters that were used to define this boundary are the load-bearing strength of the existing sediments and the modeled mound geometry for instantaneous bottom-dump placement. The RA4/RA5 boundary was located such that mound heights from instantaneous bottom-dump placement do not exceed the load-bearing strength of the sediments.

2.3 MATERIALS SOURCES AND AVAILABILITY

The engineering analyses in this document are used to develop the materials specifications for capping. One objective of the cap design process was to develop materials specifications that can be satisfied using available borrow sources or dredged material, while minimizing the need to manufacture material to meet the various specifications (e.g., particle size distributions, organic carbon content). As previously discussed, the ROD requires capping material to be at least as clean or cleaner than the SQS. All capping material used on this project will be tested to verify its suitability for use. Testing protocols depend on the material to be used for capping and are outlined in the CQAP.

Cap materials sources generally fall into two categories: dredged material and upland material. It is known that the remedial action at PSR will be performed concurrently with several other remedial actions at other contaminated sediment sites in Puget Sound. Thus, there may be competing demands for cap materials, which could limit the availability of dredged materials and potentially increase the costs of upland materials. EPA is conducting programmatic planning of these supply/demand issues to better define the potential implications to the various cleanup projects.

2.3.1 Upland Material

In areas where dredged material cannot satisfy the material specifications required for the cap, and areas where logistical or contractual requirements preclude special placement techniques using dredged material, upland sources will be used. Based on material specification requirements to minimize erosion and other engineering property requirements for material gradation, upland material will be required to construct the cap in RA1, RA2a, and RA3. EPA has determined that upland materials will also be used for construction of the caps in RA2b and

RA4 (further discussion of the decision for use of upland material in RA2b and RA4 is provided in the following subsection).

The specifications do not identify the source of the upland materials, but include soil gradation and verification testing requirements. In preparing the upland material specifications, materials that are commonly available at local quarries and satisfy the minimum engineering requirements of the cap design have been identified. Potential suppliers of upland materials have been identified and have indicated that the required material quantities that meet minimum materials specifications are available. It is not anticipated that the ability of the material supplier to provide sufficient material quantities will impact the project schedule. To minimize rehandling costs, limit road traffic, and facilitate in-water construction, it is expected that the materials will be transported to the site by the contractor in barges supplied by the contractor. Barges will be loaded by the material supplier at its facility and the materials transported by the contractor.

Alternative sources for supply of upland material may be identified by the contractor. Potential sources may include major ongoing infrastructure projects such as Sound Transit, transportation mega-projects (I-405, Alaskan Way), the Brightwater Wastewater Treatment Plant, and large material suppliers in the area. The contractor will be responsible for selecting the source(s) of upland materials and verifying that the materials meet the specifications.

2.3.2 Dredged Material

Dredged material is less costly than upland material, and its beneficial use is encouraged. Further, the ROD states that dredged material will be used to construct the cap. Consequently, dredged material will be used to the extent practicable, provided it meets the materials specifications, is available in suitable quantities within allowable periods for in-water work and the anticipated project schedule, and can be placed according to the requirements of the specifications.

The EPA has tasked the Seattle District, USACE to develop a Pacific Sound Resources Management Plan (the PSRMP) that defines the strategies and procedures for use of dredged material for the cap. Section 9 contains further discussion of the PSRMP. The PSRMP provides a basis for EPA and USACE to utilize material from federal channel navigation and restoration dredging, as well as nonfederal navigation and restoration dredging projects for beneficial use as capping material at PSR.

Dredged material properties will vary according to the source of the material. For the purposes of the engineering analyses presented in this document, the properties of dredged material from the Duwamish River and the Snohomish River (as provided by the USACE) are used to represent

typical dredged material properties; however, potential sources of dredged material are not limited to the Duwamish River and the Snohomish River. The materials specification for dredged material to be used at PSR (termed "dredged cap material" in the specifications - see Appendix F), however, precludes the use of certain sources of dredged material (such as cohesive materials).

Engineering analyses presented in the conceptual design (USEPA 2002b) and included in Appendix D have indicated that dredged material can be used to construct the cap in RA5 through instantaneous-release bottom-dump placement.

Dredged material could potentially meet the materials specifications for construction of the cap in RA4 and RA2b; however, special placement methods are required in these areas. A value engineering analysis for use of dredged material in RA2b and RA4 is provided in Appendix E and summarized in Section 2.3.6. After considering contracting requirements, logistics, costs, and potential impacts to the project schedule, EPA has determined that it is most practicable to use upland material to construct the cap in RA2b and RA4. Thus, dredged material will be used for cap construction only in RA5.

Section 8 of this document outlines the remedial action contracting strategy, which is largely influenced by where dredged material is to be used. For example, in RA5, it is anticipated that the USACE will modify its contracts with maintenance/navigation dredgers to allow these dredgers to place the dredged material with bottom-dump barges at prescribed coordinates in RA5.

2.3.3 Basis for Dredged Material Specifications

Any dredged material used for capping at PSR must meet the materials specifications for "dredged cap material," which are included in Appendix F. The bases for these specifications are discussed in general terms below, and include requirements for SQS compliance, Dredged Material Management Program (DMMP) suitability determination, debris, gradation, total organic carbon (TOC), and non-cohesive properties. USACE will be responsible for determining whether dredged material meets the materials specifications.

SQS Compliance and DMMP Suitability Determination

Based on the ROD requirements, all cap material must meet the SQS. Dredged material from off-site sources that may be used for cap material must first be determined to be suitable for open water disposal under the DMMP. USACE considers SQS compliance and DMMP suitability

determination to be a two-step process. The DMMP requirements for evaluation of dredged material for open water disposal include four tiers, as follows:

- Tier I – no or limited testing (determination made on existing information)
- Tier II – chemical testing
- Tier III – biological toxicity testing
- Tier IV – bioaccumulation testing

If a Tier I evaluation finds that more testing is necessary before a suitability determination can be made, chemical testing (Tier II) is required. If chemical testing detects chemicals of concern over screening levels, Tier III toxicity testing is necessary before a determination of suitability can be made. Tier IV bioaccumulation testing is required if a determination of suitability cannot be made with tests from the first three tiers.

None of these tiers directly corresponds to the SQS chemical requirements of WAC 173-204-320(2). The Tier III biological testing is substantially equivalent to the SQS biological requirements of WAC 173-204-320(3); however, there are different interpretive guidelines. Appendix F presents specific acceptance criteria for use of dredged material at PSR, based on the SQS requirements and the DMMP suitability determinations.

Debris

Based on DMMP requirements, all dredged material must be able to pass a 2-foot by 4-foot mesh to remove large debris. Because this requirement is already imposed by the Dredged Material Management Office (DMMO) for any dredged material that may be placed at the DMMP sites, no additional requirements for debris are established in the dredged material specifications.

Gradation

The primary gradation requirement is fines content. Based on USACE experience, the fines content of the cap material (silt and clay, passing U.S. No. 200 sieve) should be limited to no more that 30 percent by weight for controlled placement operations (USACE 2000). However, in RA5, instantaneous bottom-dump placement will be used, and dredged material with fines

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USACE has further defined the procedures for making a suitability determination in the PSRMP and will identify instances where best professional judgement may be required in making the determination.

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content exceeding 30 percent may potentially be appropriate for use in RA5. The following factors must be considered if dredged material with higher fines content is used in RA5:

- Greater quantities of dredged material will be required to accomplish the desired cap thickness, because more fine material will be transported outside the cap boundaries.
- The areal extent and thickness of off-site cap material deposition will be greater.
- Greater allowances for cap consolidation thickness (T_c) may be required.
- Short-term turbidity impacts may extend for greater distances and may be manifested higher in the water column (the currently modeled turbidity impacts are limited to near-bottom depths - see Appendix D).

The USACE will consider using dredged material with fines content exceeding 30 percent on a case-by-case basis, and the fines content will be treated as an operational parameter during construction.

Cohesiveness

All dredged material would be mechanically dredged and mechanically placed, and is therefore required to be non-cohesive. This requirement will be satisfied by material with a plasticity index less than 10, which represents the upper limit of a low-plasticity soil. The reasons for this requirement are described below.[2]

- During placement, cohesive material would impact the bottom in clumps. If placed directly atop existing contaminated materials, these clumps would likely resuspend contaminated sediments. This resuspension would be detrimental to water quality and could potentially release sheens. The resuspended contaminated material may then deposit on, and recontaminate, adjacent capped areas.
- Cohesive material placed atop layers of clean cap material may resuspend the in-place cap material on impact, compromising the cap integrity around the deposited clumps.

[2]Appendix D includes modeling of the deposition of cohesive material in RA5.

- Placement of cohesive material results in greater mound heights and higher impact forces (of clumps) on the capping surfaces, and more concentrated static stresses (from "tighter" mound geometry) placed near the RA5/RA4 boundary, cohesive materials would have a greater potential for causing bearing capacity failures and landsliding.

- The cohesive material would contribute little to the required cap thickness in areas away from the tight mounds and clumps, and thus may not reduce the required volume of non-cohesive capping material. There may therefore be little to no cost or schedule benefits in using cohesive material.

- The greater variability in capping thickness associated with cohesive clumps could make interpretation of construction monitoring and long-term monitoring results more difficult and potentially increase the costs of monitoring.

From an aquatic habitat perspective, the presence of clumps of cohesive material (clay) would change the existing unconsolidated silt and sand substrate to a mosaic of unconsolidated substrate (silt and sand) and consolidated substrate (clay clumps distributed through substrate and clay mounds) and the existing community of benthic organisms would not be able to colonize areas of the cap where the majority of the substrate surface is composed of hardpan or mounds of clay. A hard bottom, combined with structure created by mounds of clay, would likely attract a different assemblage of demersal fish, including rockfish, greenlings, and lingcod.

The majority of subtidal marine habitat in the Puget Sound is an unconsolidated substrate and as a result, the benthic organisms and demersal fish associated with an unconsolidated substrate are relatively abundant. Benthic organisms and demersal fish associated with consolidated substrates and bottom structure tend to be relatively rare and occur in highly localized populations, which are highly susceptible to harvest by sports and commercial fisheries.

The USACE will consider using dredged material with a plasticity index greater than 10 on a case-by-case basis, and the plasticity index will be treated as an operational parameter during construction.

TOC Content

In general, dredged material placed as a cap does not need to contain a minimum TOC content. However, USACE, through its PSRMP, will direct any material with TOC content significantly lower than 1 percent to be placed in the upper cap horizons and reserve materials with higher TOC for the lower cap horizons, just above the existing substrate. Use of materials with higher

TOC in the lower horizons of the cap provides additional contaminant isolation and may provide additional protection from long-term contaminant breakthrough and subsequent contamination of the newly placed cap. Controlling placement of materials as a function of TOC should be relatively straightforward, as barges containing dredged material with lower TOC can simply be directed to dump at coordinates where higher-TOC material has already been placed. However, it is not considered practical to alter the sequencing of offsite dredging projects, and engineering decisions may be required during construction to best meet the intent of this TOC criterion.

2.3.4 Required Volumes of Cap Material

This section summarizes the estimated capping volumes that will be required. The capping volumes were estimated for each RA as described in Section 4. The estimates are based on the following:

- The defined area of each RA;
- The required cap thicknesses for each RA;
- The overplacement allowances;
- The anticipated spread of capping materials outside of the defined RAs during cap placement (discussed in detail in Section 4.8.4);
- Allowances for consolidation of cap material in RA5;
- Allowances for consolidation of native material in RA1;
- A volume contingency of 10 percent, typical in capping projects.

The estimated cap volumes for each RA are summarized in Table 2-1, along with the potential material sources (upland or dredged material) required in each RA. The total estimated cap volume is 542,000 cubic yards (cy) for all material types. Because granular upland materials are to be used, the as-supplied volume is assumed to be the same as the volume placed. That is, "fluff factors" have not been included in the upland materials volume estimates. Dredged cap material volume is expressed in barge-measure volume bulk.

2.3.5 Schedule of Dredged Material Availability

Engineering analyses of material requirements have indicated that dredged material can be used to construct the cap in RA5, using instantaneous-release bottom-dump placement. Four potential sources of dredged material, identified by USACE as being available for beneficial use projects, have been considered. Table 2-2 summarizes currently identified dredged material sources. This information was provided by USACE and provides the best estimate of availability of dredged material and data necessary to assess material suitability for use at PSR. However, the information presented in Table 2-2 is subject to change. Table 2-2 also presents the estimated material quantities that meet the gradation, cohesion, and SQS requirements for construction of the cap. For materials from these sources, the primary material specifications that may limit their suitability for use at PSR include SQS compliance and fines content.

In addition, the availability of dredged material for capping is also affected by other factors including construction schedule, availability of dredged material, dredging and dredged material placement rates, contractual considerations, and competition for dredged material from other similar projects.

- **Construction Schedule.** The construction schedule developed for the remedy must be such that the greatest ecological benefits are attained as early in the schedule as possible so the impact to aquatic resources is minimized. The resultant construction schedule and sequence may not be consistent with that developed for the dredging projects.

- **Dredging.** Only a fraction of the dredged material at some of the dredged material source locations is expected to be suitable for use in the cap construction due to failure of some materials to meet gradation requirements. The time at which suitable material is available will depend on the approach taken by the USACE dredging contractor and may vary considerably from one contractor to another.

- **Dredging and Dredged Material Placement Rates.** In RA5, where instantaneous-release bottom-dump placement is acceptable, the rate of material placement can match the rate of dredging (see Section 2.4 for explanation of placement techniques). Further, because the placement method does not require any specialized equipment, material from several different sources can be placed simultaneously.

- **Contractual Considerations.** USACE contracts for navigational dredging specify disposal at DMMP open water sites. These contracts will require modifications to accommodate placement of dredged material as part of the PSR remedy. No major modification of the work methodology will be required for placement of dredged material in RA5. Rather, the location of the material disposal will be changed.

- **Competition for the Available Resources.** Other projects with similar requirements for dredged material, such as those in Commencement Bay, may be scheduled for construction at the same as the PSR remedy. This competition for the finite quantity of dredged material available each year may limit the amount that is available for use at PSR. The PSRMP addresses these issues.

2.3.6 Results of Value Engineering Analysis for Cap Materials Sources

Appendix E provides value engineering analyses for several design elements. One of the analyses in Appendix E compares the options for using dredged material versus upland material in locations other than RA5 where dredged material may meet the materials specifications, specifically RA4 and RA2b. Two alternatives were considered:

- Under Alternative 1, dredged material would only be used in RA5
- Under Alternative 2, dredged material would be used in RA2b, RA4, and RA5

This analysis considers the amount of materials required, dredged material availability and impact on project schedule, materials cost, and the ability to place the materials using controlled methods.

A key assumption of this analysis is that the cost of placement of materials in RA4 and RA2b is largely independent of the material type. That is, the use of upland materials and/or dredged materials in RA4 and RA2b is not expected to significantly impact the material placement cost in this areas.

Key outcomes of this analysis are:

- With the exception of a minor allowance for consolidation of dredged material, the quantity of material required to construct the cap in RA4 and RA2b is independent of the material type.

- Under Alternative 1, because of the unlimited supply of upland material for use in RA4 and RA2b, it is estimated that construction would be completed over 3 years (in two construction sessions), between 2003 and 2005.

- The use of dredged material in RA4 and RA2b (Alternative 2) will double the duration of the construction schedule compared to Alternative 1. It is estimated that construction under Alternative 2 would be completed over 6 years, between 2003 and 2008. This time includes one year, 2007, during which no construction would be possible because no dredging is currently scheduled for that year.

- The schedule impacts were analyzed under the assumptions that dredged material becomes available on schedule as USACE anticipates, that all of the suitable dredged material can be diverted to PSR, and that any timing and/or contracting issues can be overcome to allow controlled placement in RA2b and RA4. If any of these assumptions are not valid, the schedule for Alternative 2 could be significantly extended.

- The cost of purchasing and delivering upland material for use in RA4 and RA2b (Alternative 1) is higher than the corresponding cost of delivering dredged material in the same areas (Alternative 2). Specifically, the cost of using upland materials is estimated to be $1,400,000 greater than that for using dredged materials (roughly 10 percent of the construction costs). This additional cost considers only the cost of the materials delivered to the site. Factors such as lengthened project schedule, and attendant increased construction monitoring and administrative costs, will significantly erode the potential cost advantage of Alternative 2.

As described above, use of dredged material in RA4 and RA2b may extend construction from 3 years to 6 years, and would include 1 year where construction activities are not being completed because no dredging is scheduled for that year. Contract management and administration as well as the extended duration of required construction monitoring and verification may add $100,000 to $250,000 per year of construction. A delay of 3 years may increase project costs by as much as $750,000, reducing the cost differential between use of dredged or upland material to $650,000.

After considering contracting requirements, logistics, costs, and potential impacts to the project schedule, EPA has determined that it is most practicable to use upland material to construct the cap in RA2b and RA4.

2.4 CAP PLACEMENT TECHNIQUES

Cap placement techniques potentially applicable to PSR can generally be categorized as: (1) instantaneous releases from bottom-dump barges and (2) controlled placement techniques that employ either surface or subsurface discharge. Each technique has advantages and disadvantages relative to placement accuracy, turbidity control, impacts on bottom sediments, availability of equipment, placement rate, contracting strategy, and unit costs. Descriptions of equipment and placement techniques provided below are adapted from EPA and USACE guidance (USEPA 1998b).

2.4.1 Instantaneous Release from Bottom-dump Barge

Description

The relatively rapid release of dredged material from split-hull bottom dump barges is termed "instantaneous release" for the purposes of this design. This method of placement is used for disposal of suitable dredged material at DMMP disposal sites in Puget Sound. Typically, a split-hull barge is towed to the target area, the hull is opened, and within about two minutes the dredged material drops from the barge in one mass. The dredged material then falls through the water column under the influence of gravity (convective descent). At the DMMP sites, the contractor and the USCG log the times and positions of the barge at the beginning and end of the disposal event.

Point discharges from barges are not normally applicable for in situ capping of soft, fine-grained contaminated sediments such as those at PSR (USEPA 1998b). The surface placement of capping material from barges results in a faster descent, tighter mound, and less water column dispersion compared to surface discharge of hydraulically placed capping material from a pipeline. In the shallower waters typical of most in situ capping projects, an instantaneous release would not be amenable to placement of a uniform cap and may cause bearing capacity failures (see Section 4.2.2) and unacceptable resuspension of contaminated sediments on impact. At PSR, bearing capacity failures during placement on steep slopes could trigger landsliding. However in the deeper portions of the MSU (RA5), modeling has indicated that for non-cohesive materials, dispersion during descent through the water column is sufficient to allow a relatively thin, uniform lift of material to be placed by instantaneous bottom-dump from barges. This modeling is presented in Appendix D.

Implications for Design and Contracting

Because no special operational controls are needed (other than coordinating the sequencing and positioning of the barge dumps), this method can readily be accomplished in RA5 using USACE dredging contracts. This design specifies those areas where instantaneous release from bottom-dump barges is allowed, and designates the barge positioning and the amount of material to be placed at each target location.[3] Because a number of contractors may be used to accomplish this placement over (potentially) several construction seasons, the individual contractors cannot be responsible for meeting the requirements of the final cap design.

USACE will ensure that the cap is ultimately placed as designed in RA5. Cap verification techniques (discussed in the RA5 CQAP) will be used to verify proper placement. USACE may need to modify the number or locations of placement events to accomplish the final cap thickness throughout RA5. If the verification monitoring indicates that instantaneous releases from bottom-dump barges are resulting in unacceptable cap placement, then controlled placement methods may need to be implemented in portions of RA5.

2.4.2 Controlled Placement Methods

Description

In the shallower depths of RAs 1 through 4, more controlled placement methods are needed to accomplish uniform cap placement and reduce the potential for bearing capacity failures. Several surface discharge methods have been successfully employed for in situ cap placement. Alternatively, the use of submerged discharge methods may provide additional control and accuracy during placement, thereby reducing water quality impacts and potentially reducing the volume of capping material required. Typically, submerged placement of capping materials is more costly, but if the placement of the capping materials by surface discharge results in unacceptable water column impacts, or if the anticipated degree of spreading and water column dispersion is unacceptable, submerged discharge is a potential control measure. Controlled surface and subsurface placement methods that could potentially be used at the site include the following:

- **Spreading by Barge Movement.** Capping material can be placed using a bottom-dump barge with selected control of the opening and the barge movement.

[3] The boundaries of RA5 are defined by the areas where instantaneous release from bottom-dump barges is considered acceptable.

Implications for Design and Contracting

Because no special operational controls are needed (other than coordinating the sequencing and positioning of the barge dumps), this method can readily be accomplished in RA5 using USACE dredging contracts. This design specifies those areas where instantaneous release from bottom-dump barges is allowed, and designates the barge positioning and the amount of material to be placed at each target location.[3] Because a number of contractors may be used to accomplish this placement over (potentially) several construction seasons, the individual contractors cannot be responsible for meeting the requirements of the final cap design.

USACE, using the PSRMP, will ensure that the cap is ultimately placed as designed in RA5. Cap verification techniques (discussed in the RA5 CQAP) will be used to verify proper placement. USACE may need to modify the number or locations of placement events to accomplish the final cap thickness throughout RA5. If the verification monitoring indicates that instantaneous releases from bottom-dump barges are resulting in unacceptable cap placement, then controlled placement methods may need to be implemented in portions of RA5.

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- **Spreading by Barge Movement.** Capping material can be placed using a bottom-dump barge with selected control of the opening and the barge movement.

[3] The boundaries of RA5 are defined by the areas where instantaneous release from bottom-dump barges is considered acceptable.

A conventional split-hull barge can be opened slowly over a period of tens of minutes, depending on the barge size and site conditions. This technique is particularly successful when placing coarse-grained, sandy capping materials. The gradual opening of the split-hull or multi-compartmented barges allows the capping material to be released slowly from the barge. Tugs may be used to slowly move the barge during the release. This method was employed successfully at the Eagle Harbor/Wyckoff Superfund Site Area 1. Multiple barge loads are used to cap large areas in an overlapping manner. This method is not suitable in the shallow depths of RA1, because of barge draft requirements, potential interference of near shore structures, and propeller wash from the tug boats.

- **Direct Mechanical Placement.** Surface discharge of capping material using conventional equipment such as a clamshell bucket results in the rapid descent of the capping material to the bottom as a dense jet with minimal short-term losses to the overlying water column. The use of conventional equipment, such as conveyors or clamshell buckets, can be considered for placement of capping material if the bottom spread and water column dispersion resulting from such a discharge are acceptable. Direct mechanical placement using a clamshell or conveyor is considered the most appropriate method for sand and gravel in RA1. A skip box may be used to mechanically place larger materials in RA1, such as filter rock, quarry spalls, or riprap. Spreading and grading of material using dozers at low tide is potentially applicable to RA1. Direct mechanical placement using a clamshell could also be used in RAs 2a, 2b, and 3, however a very methodical approach would be required similar to the grid system used for a recent capping project at Puget Sound Naval Shipyard. This approach was very successful in placing uniform lifts of sand cap material at a rate of about 1,600 cy/day (U.S. Navy 2002).

- **Hydraulic Washing.** Granular capping materials such as sand can be transported to a site in flat-topped barges and washed overboard with high-pressure hoses. This technique produces a gradual buildup of cap material and prevents any sudden discharge of a large volume of material. A relatively uniform layer of cap material was placed by hydraulic washing at the Eagle Harbor/Wyckoff Superfund Site where mudline elevations ranged from –10 to –55 feet MLLW.

- **Pipeline with Baffle Plate or Sand Box.** Cap placement and spreading could also be performed using a hydraulic pipeline and an energy-dissipating device such as a baffle plate or sand box attached to the end of the pipeline. A baffle

plate decreases the velocity of the capping slurry and reduces the potential of the discharge to erode contaminated sediments or capping materials already in place. The sand box is a diffuser box with baffles and sideboards to dissipate the energy of the discharge. The bottom and sides of the box are constructed as an open grid or with a pattern of holes so that the discharge is released through the entire box. This equipment can be used in capping operations to place thin layers of material over large areas. The cap would be gradually built up to the required cap thickness by making several passes.

- **Submerged Diffuser.** A submerged diffuser provides additional control for hydraulic pipeline discharge. The diffuser, which is used to reduce the velocity of the slurry during placement, is mounted to the end of the discharge pipeline. A small discharge barge positions the diffuser and pipeline vertically in the water column, several feet above the bottom to isolate the capping materials from the upper water column and reduce resuspension of bottom sediments. Movement of the discharge barge assists in spreading the discharge to cap larger areas. The diffuser can be used with any hydraulic pipeline operation including hydraulic pipeline dredges, pump-out from hopper dredges, and reslurried pump-out from barges.

- **Gravity-Fed Downpipe (Tremie).** Tremie equipment can be used for submerged discharge of either mechanically or hydraulically dredged material. The equipment consists of a large-diameter conduit extending vertically from the surface through the water column to some point near or above the bottom. The conduit provides isolation of discharge from the upper water column and improves placement accuracy. However, because the conduit is a large-diameter straight vertical section, there is little reduction in momentum or impact energy over conventional surface discharge. A telescoping feature of the tremie can allow placement at greater depths. Anchor and winch systems may be used to swing the barge from side to side and forward so that larger areas can be capped, similar to the sand spreader barge. A tremie is not likely to be used at PSR because placement accuracy is not as important as using techniques that minimize the potential for bearing capacity failure.

Implications for Design and Contracting

For RA1 through RA4, the project specifications identify an acceptable method of cap placement to be used by the contractor, and allow a "contractor's option" for cap placement methods to be proposed.

As discussed in Section 8.2, one or more contractors will be procured to construct the caps in RA1 through RA4, using upland material and controlled placement techniques. (In this document, the contractor(s) responsible for construction of RA1 through RA4 is (are) referred to as the "contractor.") Final equipment selection will be the contractor's responsibility. Regardless of equipment or methods, the construction specifications require the contractor to meet performance requirements for capping (including placement rates and/or limitations on individual lift heights, final cap thickness, and compliance with water quality criteria). The contractor may propose to use any of the methods presented above or an alternative method. The contractor's proposals will be evaluated by USACE based on the experience of the contractor and whether the proposed capping method(s) meets the objectives identified in the specifications. The contractor will be required to fulfill the requirements of the specifications and to modify placement methods if performance requirements are not being met. (See Section 8 for contracting strategy.)

A number of marine contractors in the Puget Sound region could accomplish the capping in RA1 through RA4 using mechanical placement. A limited number of Puget Sound-based contractors have had experience with sand washing, spreading by barge movement, tremie, or hydraulic methods of cap placement.

2.5 CAP PLACEMENT VERIFICATION

The cap will be placed in a series of relatively thin uniform lifts to achieve the final cap thickness. A number of techniques are available to perform the following tasks:

- Measure the thickness and extent of cap placement;
- Verify placement techniques are producing acceptable lift height and uniformity;
- Assess the degree to which contaminated sediments may become intermingled with the cap during placement.

The CQAP for RA1 through RA4 (included as Part IV of this design package) identifies the specific techniques and testing frequency that will be used to verify that the cap is being placed in accordance with the plans and specifications. For RA1 through RA4, the construction contractor will implement the required testing and reporting specified in the CQAP, and will be required to take necessary corrective actions (including modifications of placement methods) to ensure compliance.

The RA5 CQAP serves the same functions as described above. However, the quality control requirements (e.g., sampling, surveys) will be implemented by an oversight contractor, and potential corrective actions will be implemented through new or modified construction contracts to successfully complete the cap in RA5.

Long-term monitoring of the cap will be covered under the OMMP. Refer to Section 9 for discussions of the OMMP and the RA5 CQAP.

2.6 CONSTRUCTION WINDOW

The Washington State Hydraulic Code Rule - Saltwater Technical Provisions set forth prohibited work times in saltwater areas (WAC 220-110-271). For Tidal Reference Area 5, in which the MSU is located, in-water work is prohibited from March 15 through June 14 for protection of juvenile salmon migration. However, additional timing restrictions will apply for protection of other species. Requirements for additional timing restrictions have been identified through consultation with the natural resource agencies, as part of the informal Endangered Species Act (ESA) consultation. These additional constraints are site- and activity-specific. The natural resource agencies identified the following restrictions:

- **Dredging** - prohibited from February 14 through August 16
- **Capping** - prohibited from February 14 through July 16

The above restrictions on capping and dredging are used for developing the project schedule presented in Section 11. It is possible that the prohibited times could be modified through extraordinary measures, such as on-site monitoring for the presence of species of concern during in-water work during prohibited periods.

2.7 COORDINATION OF VESSEL TRAFFIC

All in-water work will require coordination of vessel traffic to minimize any impediments to navigation in the project vicinity. Particular care will be required in coordinating remedial activities (dredging and capping) near Crowley Marine Services (i.e., work in RA3, RA2a, and the western portions of RA1). Accommodations for tribal fishing activities may also be required. Water access issues are further discussed in Section 10.

The specifications require the contractor to plan the construction activities to minimize conflict with these commercial operations. Where such conflicts cannot be avoided, the required

coordination will be effected through EPA and/or USACE. The contractor will be required to describe vessel management procedures as part of its remedial action management plan, including the numbers and types of vessels to be used, berthing/tie-up areas, and vessel routes.

Where dredged material is to be used as cap material and placed under other USACE contracts (in RA5), USACE will include any vessel management requirements in those contracts.

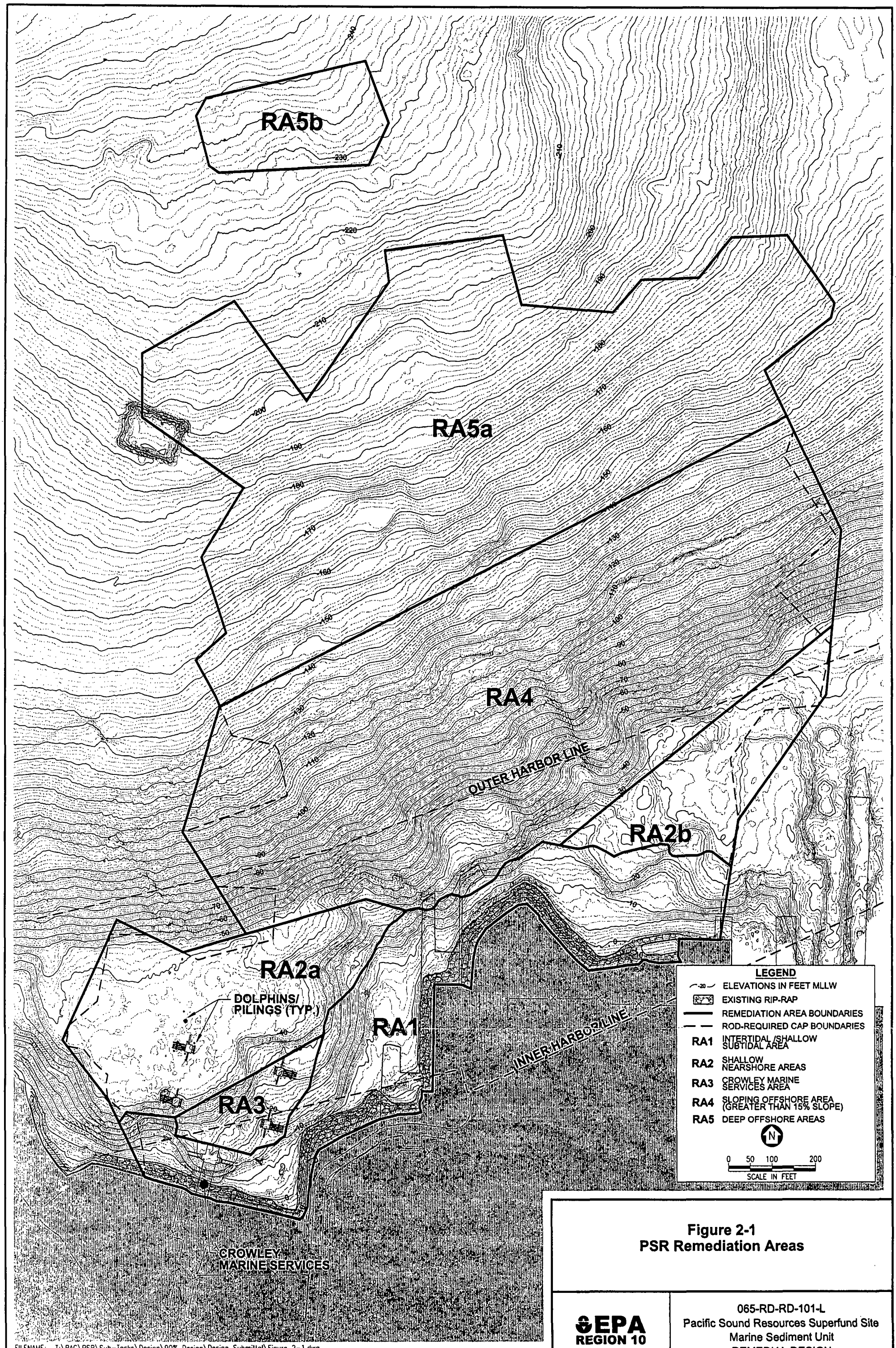

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Figure 2-1
PSR Remediation Areas

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

Table 2-1
Estimated Cap Material Volumes and Sources

RA	Total Estimated Cap Volume (CY)	Estimated Volumes by Material Type (CY)	
		Dredged Cap Material	Upland Materials
1	96,165	0	96,165
2a	43,638	0	43,638
2b	18,238	0	18,238
3	7,750	0	7,750
4	159,157	0	159,157
5a and 5b (a)	217,250	217,250	0
TOTAL	**542,199**	**217,250**	**324,949**

Notes:
CY - cubic yards
a - Dredged Cap Material expressed in barge-measure volume.
All volumes include 10% contingency
See specifications for required properties of materials types

Table 2-2
USACE Maintenance Dredging Schedule and Material Suitability

Project[a]	Estimated Quantities (cy)			Dredging History		Future Dredging		
	Total	Suitable for Cap[b]	Cycle	Last Dredged	Disposal Site	Year	Month[c]	Rate[d] (cy/mo)
Duwamish River Upstream Basin	100,000	38,000	2	2002	Elliott Bay	2004 2006 2008	Aug. To Jan.	62,000
Snohomish River Downstream Basin	250,000	0	3	2002	Port Gardner	2005 2008	Aug. To Jan.	228,000
Snohomish River Upstream Basin	250,000	250,000	3	2002	Riverside	2005 2008	Aug. To Jan.	228,000
Swinomish Channel / La Conner	35,000	35,000	2	2002	Rosario Strait	2004 2006 2008	Aug. To Jan.	32,000

[a]Other projects could potentially generate suitable dredged material in the timeframe of interest. This table presents recent available information and each project is subject to change.
[b]Material suitability based on an assessment of available grain size data for each site.
[c]The fish window, during which dredging is restricted, may vary and may not correspond to the fish windows for PSR.
[d]The estimated rate of dredging is based on historical data from previous dredging operations at each site.

Note:
cy - cubic yards
cy/mo - cubic yards per month

Source: USACE 2002.

3.0 DREDGE DESIGN

3.1 DESIGN OBJECTIVES AND CONSIDERATIONS

Sediments will be dredged from the Crowley Marine Services Area (RA3) and adjacent portions of RA1 to make room for the cap. The ROD states, "The purpose of dredging this material is to maintain current navigational depths and access to Crowley Marine Services." The ROD estimated 3,500 cubic yards of material require dredging.

3.1.1 Design Criteria

The areas of tug operations and required operational depths were presented in the feasibility study (USEPA 1998c). Based on input from Crowley Marine Services, these boundaries have been modified slightly, and are shown in Figure 3-1. The currently available operational depth depends on tidal elevations. The "desired mudlines" shown in Figure 3-1 illustrate mudline elevations that would be required to achieve the operational depth requirements during extreme low tide (–4 feet MLLW). The existing mudline elevations are higher than the desired mudlines and do not meet the operational depth requirements during low tide, particularly in the southwest portion of this area. Crowley Marine Services has indicated that the existing mudline elevations are not ideal, but work well for their operations 98 to 99 percent of the time (Hannuksela 2002).

Based on the ROD requirements and the information provided by Crowley, the design criterion for the final elevations is to maintain the existing mudline elevations in the area designated in Figure 3-1. This criterion, along with the design cap thickness and slopes, is used to design the dredge cuts in RA3.

3.1.2 Design of Dredge Cuts

The area to be dredged is a sloping, irregular, crescent-shaped area. Designing a uniform, flat-bottomed dredge prism in this area would require dredging more than 15 feet of material near the southeast dolphin, with a substantial slope cutback towards shore for slope stability. Given the desire to minimize dredge volumes, the need to match slopes and grades with the RA1 cap, and the potential for deep dredge cuts to compromise the integrity of the dolphin, a uniform dredge prism is not desirable. Therefore, the RA3 dredge design is based on a performance requirement to remove a specified minimum thickness of material in the designated area, with cutbacks at specified slopes.

The minimum thickness of material to be removed is 5 feet in the area designated in Figure 3-1. This is based on placement of a minimum 3.5-foot-thick cap in RA3, with a 1-foot cap overplacement allowance and a 0.5-foot buffer.

The design drawings show limited additional dredging that is required to accommodate the former Longfellow Creek outfall extension located on the southwest shoreline, west of the viewing pier. The existing 84-inch-diameter outfall will need to be extended to facilitate completion of the intertidal cap.

The contractor will be required to ensure that the specified minimum amount of material is removed and specified slope cutbacks are attained. Because of dredging inaccuracies, the contractor may remove, on average, an additional 12 inches beyond the required removal thickness, to address any sloughing that may occur and ensure specified depths are achieved. Therefore, in all dredge areas, a 1-foot dredge overdepth allowance has been specified.

3.1.3 Constructability Issues

The large dolphins in RA3 are over-water structures supported by piling. Navigation does not occur under the dolphins, and dredging is required only for maintaining navigational depths. Consequently, dredging will not be attempted under dolphins. Adjacent to dolphins, the contractor will be required to remove the specified depth of material to within 5 feet of the dolphin to facilitate navigation following cap placement.

The Crowley Marine Services pier includes dolphins supporting the pontoon system for raising and lowering the pier. No under-pier dredging is feasible to allow construction of a thick cap in RA1 under the pier. This is discussed further in the RA1 cap design, Section 4.3.

Dredging in the vicinity of Crowley Marine Services will be required prior to cap placement. In RA1, cap placement should follow dredging within a relatively short timeframe (less than 1 month) to minimize sloughing of dredged slopes. For the Longfellow Creek outfall extension, temporary slope protection will immediately follow dredging to prevent sloughing into the trench.

Around Station 9+00, capping will be required as soon as possible after dredging is complete, for slope stability. This is further discussed in Section 4.2.3.

3.2 DREDGE QUANTITIES

Based on the minimum 5-foot dredge depth and specified slope cutbacks, the neatline dredge volume is 8,040 cubic yards. With the 1-foot dredge overdepth allowance, the overdepth quantity is 1,810 cubic yards. The total estimated dredge quantity is 9,850 cubic yards. All quantities are expressed as in-place volumes.

3.3 DREDGE METHODS AND MATERIAL HANDLING

Use of mechanical dredging equipment is specified as it is anticipated to be more cost effective and has fewer associated dewatering logistical concerns than hydraulic dredges. Dredging performance requirements are set forth in the specifications, and verification of the dredge cuts and compliance with water quality criteria are addressed in the CQAP. These requirements include, for example, allowable overdepth for dredging, bathymetric survey requirements, and water quality sampling requirements. An evaluation of the short-term water quality impacts associated with mechanical dredging is presented in Section 5.

As described in the pre-design investigation data summary (USEPA 2002a), the material to be dredged was physically characterized from a composite sample of cores from three sampling locations in the area of Crowley Marine Services. The results of this characterization will be included in the bid packages for the contractor to evaluate. This material should be readily dredged and should not pose special difficulties in handling.

The contractor is required to submit a Remedial Action Management Plan (RAMP) that describes the equipment, procedures, materials, methods, disposal location, and personnel to be employed for dredging work. The requirements for the RAMP are set forth in the specifications. Dredged sediments will be allowed to gravity-drain on barges on site for several hours to minimize free draining liquids, prior to being loaded for off-site transportation and disposal.

3.4 WASTE HANDLING, TRANSPORTATION AND DISPOSAL

Disposal of dredged sediments will be at an established upland solid waste landfill, in accordance with the ROD. Piling or other debris encountered during the remediation will be managed in accordance with the substantive provisions of state regulations (WAC 173-304-200), and will be either recycled or sent to a permitted solid waste facility. Also, all off-site treatment, storage, and disposal of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waste will occur at facilities that are acceptable under EPA's Off-Site Rule.

The design specifications set forth the performance requirements for accomplishing waste transportation and disposal such as handling and dewatering requirements. The contractor's RAMP will discuss the specific equipment and logistics. If barges are to be used for transport of material dredged from the MSU, they will be subject to requirements for leakage and overflow that are commonly used in sediment remediation. Through communications with one local landfill, it is known that at least one dedicated rehandling/offloading facility will exist within a few miles of the site, to accomplish the transfer of dredged material from barge to lined rail cars. The contractor will contract with the handling and disposal facilities and will identify these facilities and haul routes in the RAMP.

As described in the pre-design investigation data summary (USEPA 2002a), the results of the bulk chemical analysis and toxicity characteristic leaching procedure (TCLP) analysis of sediment in the dredging area indicate that the material will not be designated as dangerous waste, and thus can be disposed of in a Resource Conservation and Recovery Act (RCRA) Subtitle D landfill. The specifications do not identify the landfill, but specify the disposal requirements. The contractor will be responsible for any additional sampling and analysis of dredged material (or other waste) that may be required by the landfill.

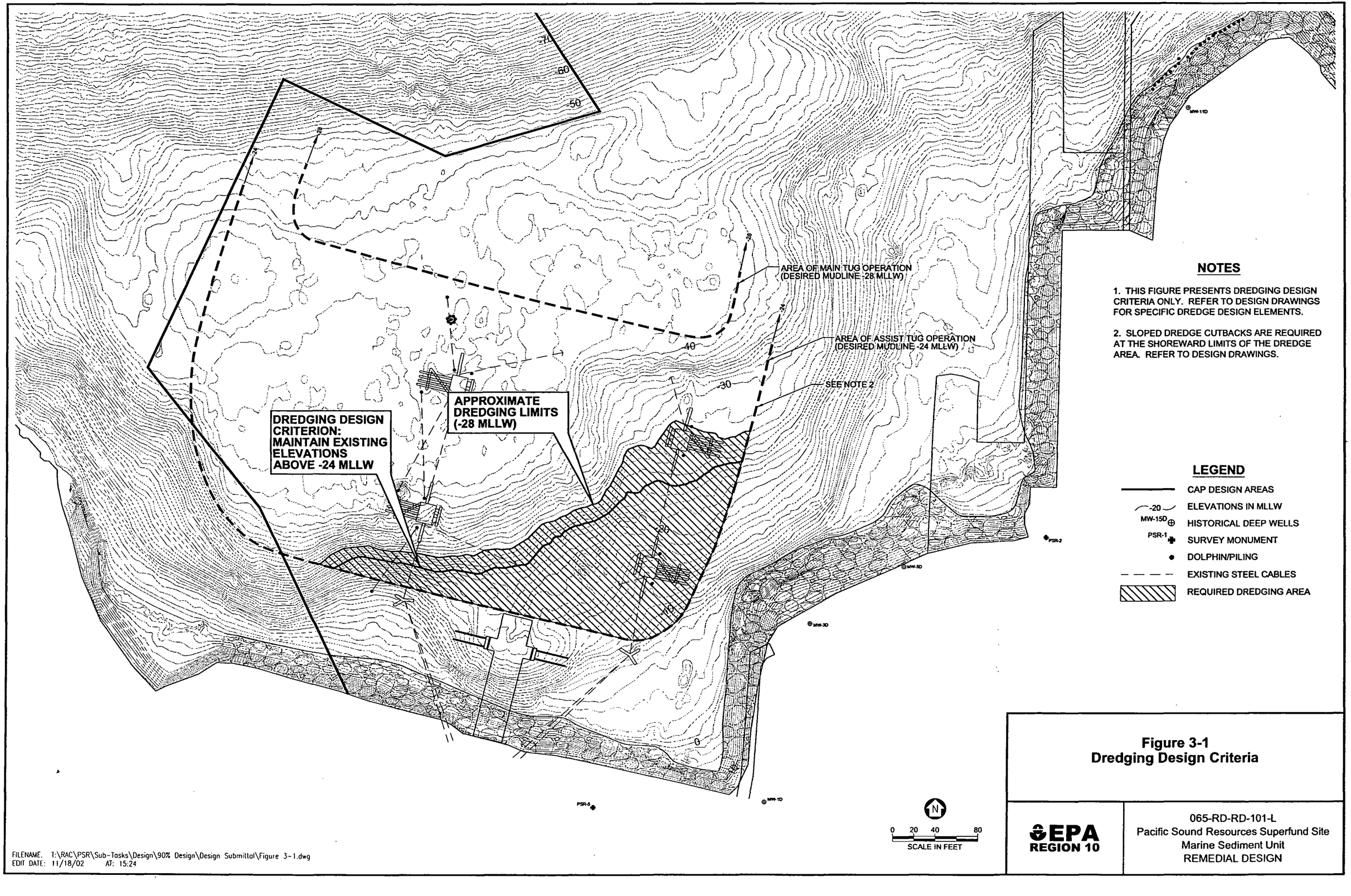

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Figure 3-1
Dredging Design Criteria

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

4.0 CAP DESIGN

This section presents an overview of the cap design process, slope stability analysis and geotechnical considerations in the cap design, the basis of the cap design for each RA, and an evaluation of impacts to areas outside of the capping boundary resulting from cap material deposition during cap placement.

4.1 CAP DESIGN PROCESS

The composition and thickness of the components of a cap can be referred to as the cap design. The cap thickness is based on a series of additive layers that perform the various functions of the cap. The cap thickness is determined as follows:

$$T_t = T_b + T_e + T_c + T_i + T_o$$

where:

T_t = total cap thickness
T_b = thickness for bioturbation
T_e = thickness for erosion
T_c = thickness for cap consolidation
T_i = thickness for chemical isolation
T_o = thickness for operational considerations

Figure 4-1 depicts the function of these cap components, which are discussed in the following subsections. Cap design parameters for each of the RAs are presented in Table 4-1. Typical cap sections are presented in the drawings. Considerations in determining cap component thicknesses are described below; detailed cap designs for each RA are presented in later subsections.

4.1.1 Evaluation of Bioturbation Thickness

Evaluation of the required bioturbation thickness is based on a review of existing information. The biologically active zone is generally taken to be the top 10 cm of sediment, and compliance with the Washington State Sediment Management Standards (SMS) (WAC 173-204) is based on samples from 0 to 10 cm. However, it is well known that some burrowing animals may exist at greater depths. Most benthic species live in the oxic (i.e., oxygenated) sediment zone, which in

the Puget Sound region commonly extends only about 10 cm into the sediment. However, under favorable conditions, some benthic species are known to burrow as deep as 6 feet. Deep-burrowing species either use siphons to draw oxygenated water from overlying water, or live in burrows connected to the overlying water, which can provide a microhabitat of oxygenated conditions. Deep-burrowing species include the geoduck (*Panope abrupta*) and ghost shrimp (*Neotrypaea spp.*), both of which can be found as deep as 30 inches (75 cm). Members of the polychaete worm family *Chaetopteridae* live in tubes that can extend to depths up to 6 feet (2 meters) in sandy sediment.

The benthic infauna survey performed for the remedial investigation at PSR (USEPA 1998a, Appendix K) provides a comprehensive list of the benthic species present at PSR. Ghost shrimp and *Chaetopteridae* were found in sediments at the site. Geoducks were not found at PSR but are known to be present near the mouth of Elliott Bay. Bent-nosed clams (*Macoma nasuta*) are present at PSR, and can be found as deep as 6 inches (15 cm) at other locations within Puget Sound.

The majority of species and abundance of individuals at PSR are shallow-burrowing organisms that inhabit the oxic top 4 inches (10 cm) of the sediment. To allow an additional degree of protection, the thickness of the bioturbation layer (T_b) in RAs 2 through 5 is 6 inches (15 cm). This value is consistent with the design bioturbation thickness selected for the Eagle Harbor cap. Although some burrowing species may extend deeper than this, 6 inches is considered to be conservative given the presence of other cap layers, the additivity of the equation for cap thickness determination, and the potential multiple functions provided by the other thickness components[4]. Also, the species present at PSR that are found deeper than 10 cm in sediment at other locations within Puget Sound are generally either species with siphons that can draw water from at or slightly above the sediment-water interface, or are species that live in burrows connected to the overlying water, which can provide a microhabitat of conditions different from the conditions found at depth within sediment.

Ghost shrimp prefer intertidal to shallow subtidal habitats, and sandy silt to silty sand substrates. It is under these conditions that high densities of ghost shrimp burrows tend to exist, which could potentially result in deeper horizons of significant bioturbation (Stivers 2002). At PSR, the cap in the intertidal and shallow subtidal elevations will be relatively thick and composed of gravels

[4]In particular, the operational layer thickness will provide, on average, several inches of additional clean capping material for potentially deeper-burrowing benthic species. The chemical isolation layer thickness will consist of clean capping material in which a contaminant front slowly advances over a period of several decades, and so the upper portion of the chemical isolation layer thickness will remain uncontaminated until the end of the cap's design life.

and sands, which will tend to both decrease burrow density and provide sufficient cap thickness in the unlikely event of deeper bioturbation.

In deeper subtidal areas, dense beds of ghost shrimp are unlikely to develop, and deeper bioturbation by ghost shrimp should be minimal. The presence of burrowing organisms at depths greater than 6 inches (15 cm) would have no effect on chemical transport, as long as the organisms do not penetrate into the bottommost, chemical isolation horizon of the cap. If the deeper-burrowing organisms such as ghost shrimp do penetrate into the chemical isolation layer (or into the underlying contaminated sediments), then little in the way of sediment mixing is expected to occur. Some facilitated diffusion of contaminants may occur, as contaminants diffuse from the porewater, into the macroscopic burrows, and then out through the sediment cap. However, during the predesign investigation it was determined that the contaminant concentrations in the porewater of the contaminated sediments are generally below water quality criteria, and as previously noted, circulation of water within the burrows creates a microhabitat that would further decrease contaminant concentrations in the burrows. Such facilitated diffusion is therefore not expected to significantly affect the cap life.

A T_b equal to 6 inches is considered adequate to prevent burrowing aquatic organisms from displacing the isolation barrier and reworking the surface of the sediments. A more conservative value was selected for the surface of RA1 (T_b of 12 inches) to qualitatively account for potential human disturbances of the cap in the intertidal area, through such activities as shellfish harvesting or other recreational digging.

4.1.2 Evaluation of Erosion Thickness

Appendix A presents an evaluation of erosive forces acting on the cap. This analysis includes an evaluation of wind and tidally-driven waves, propeller wash, and cross-shore sediment transport. The approach taken in this design is to develop materials specifications for cap material particle sizes that resist the calculated erosive forces, rather than design an additional thickness to accommodate erosion of finer material.

Because the cap materials specifications are designed to resist erosion, modeling of long-term rates of erosion (e.g., with LTFATE) was not necessary. In most areas, T_e will be equal to 0 inches. However, to account for potential reshaping of the intertidal areas by wave action, or potential extreme propeller wash in the Crowley Marine Services area, nonzero values of T_e are specified in these high-energy areas, such that limited erosion or reshaping of the beach does not necessitate maintenance.

4.1.3 Evaluation of Cap Consolidation Thickness

Evaluation of cap consolidation thickness (T_c) is based on the properties of cap materials, which will generally consist of granular materials. The specified granular upland materials are essentially self-consolidating in a short timeframe, and no additional cap thickness is needed to allow for long-term consolidation of the capping material itself. Thus, T_c is equal to 0 inches for areas in which upland material is used. A nonzero value of T_c is specified for RA5 where dredged material is used.

It is noted that underlying sediments will consolidate under the cap load, and this consolidation is evaluated in Appendix C.

4.1.4 Evaluation of Chemical Isolation Thickness

The chemical isolation thickness (T_i) considers the movement of contaminants upward into the cap over time through long-term diffusion, advection, and dispersion, as well as short-term expression of contaminated porewater into the cap after placement. Appendix B presents the chemical isolation analysis used to specify the values of T_i for the various remediation areas. Specifications for required organic carbon content of the cap materials are based on this analysis.

4.1.5 Evaluation of Operational Thickness

The operational thickness (T_o) component of the cap is primarily related to the ability to place a relatively uniform, thin cap layer. Any placement technique will result in some unevenness of the cap, and subaqueous caps cannot be constructed to the tolerances typical of those in terrestrial earthwork projects. The value allowed for T_o in the design is based on:

- The placement technique used (e.g., bottom-dump barge placement, hydraulic washing of sand, towed split-hull barge)
- Water depths
- Cap material properties
- Bottom roughness and slopes

Appendix D presents the results of cap placement modeling (using the USACE STFATE model) that accounts for these factors and provides representative mound geometries for instantaneous

bottom-dump placement of capping material in RA5, where the predicted mound geometries are used to establish T_o.

For RA1 through RA4, a different approach is used for including T_o into the cap thickness design. For the purposes of developing plans and specifications, T_o is not added to the required cap thickness, but rather is included as an "overplacement allowance." Thus, the contractor will be required to achieve the minimum cap thickness in all locations, and will be paid for overplacement of material only up to a thickness of T_o. T_o in RA1 through RA4 is specified based on engineering judgment for conditions at the site, and experience at other sites. Overplacement allowances account for potential inaccuracies and unevenness of cap construction and provide a degree of assurance that the entire capping area will be covered with at least the minimum required thickness necessary for cap function.

Another operational concern is vessel anchoring. The selected remedy includes a no-anchor zone over the cap design area to prevent damage from commercial vessels using large, whale-tail-type anchors. While recreational vessels may anchor on the cap, the area impacted by these anchors is very small, and penetration depth is typically limited to 1 to 2 feet (Palermo et al. 1998). When the anchors are removed, the disturbed area is quickly filled. Thus, no additional operational thickness for recreational vessel anchoring is required.

4.2 SLOPE STABILITY EVALUATION

Appendix C provides the detailed geotechnical evaluations used in the cap design. The results are summarized below.

4.2.1 Summary of Static and Seismic Stability

Static Stability

The existing slopes at the site are stable under static conditions. Slope stability analyses indicate static factors of safety (FS) greater than 3 for general slope conditions in the MSU, under both existing and post-capping conditions. Static FSs greater than 1.5 are indicated for localized oversteepened areas, under both existing and post-capping conditions. Thus, it is concluded that proper placement of the cap will not result in unstable slopes for static loading conditions.

Seismic Stability

The occurrence of the February 2001 magnitude 6.8 Nisqually earthquake, combined with bathymetric data collected before and after the earthquake, provided a unique opportunity to calibrate the seismic stability analysis to the observed response of the slopes to seismic loads. Pre-Nisqually earthquake bathymetric data suggest the presence of at least five features in the MSU that are interpreted as past landslides, most likely the result of historic earthquakes. Examination of the post-Nisqually bathymetry indicates that the existing slopes appear to have remained stable during the Nisqually earthquake.

As a basis for design, a conservative assumption was made that the Nisqually earthquake brought the sediments to just below the trigger point of liquefaction, i.e., the FS of liquefaction was approximately 1.0. A peak ground acceleration (PGA) corresponding to the liquefaction-triggering value of 0.13g computed from CPT back-analysis was therefore identified as the seismic design parameter.

Using the calculated submarine PGA of 0.13g, the pseudo-static analysis indicated seismic FSs greater than 1.3 for general slope conditions in the MSU. Seismic FSs less than 1.0 were computed for a representative local over-steepened slope along the margin of an existing landslide feature, indicating that local failures may be expected in steepened zones of the sediments similar to the Nisqually seismic event. The extent of the predicted failure for the local steepened zones is relatively small and involves mainly the upper cap material and few feet of the upper silt layer for a distance of about 100 feet in the direction of the maximum slope gradient.

Design Parameters

The slope stability analyses (based on the calibrated site response to the Nisqually earthquake) indicate that moderate-sized earthquakes like the Nisqually event will not cause large-scale landslides, but could cause instability at localized over-steepened areas that can be found at the edges of some of the old landslide features. Such moderate seismic events would typically occur at 30- to 50-year intervals, and potentially cause minor or localized cap damage.

Larger earthquakes with return periods of roughly 100 years or more (with an associated submarine PGA of at least 0.18g) will likely cause substantial liquefaction that will result in large-scale landslides of size and shape similar to the historic slides evident in the pre-Nisqually earthquake bathymetric data. Such slides would typically involve individual slide masses roughly 20 feet deep, 100 feet wide and several hundred feet long, which would "run out" to distances of at least several hundred feet beyond the toe of the slide zone.

The slope failures that may result from these seismic events do not pose human health risks but will cause short-term disruption to the benthic community in the affected slide zone. As discussed in the OMMP, such cap damage will be repaired by placement of additional cap material as part of the long-term operation and maintenance (O&M) of the remedy. The estimated O&M costs associated with such seismic damage are based on this analysis.

4.2.2 Bearing Capacity and Implications for Cap Placement

This subsection discusses the short-term slope stability effects of cap loading during placement. These results apply to the cap placement methods and performance requirements during placement, but do not apply to the long-term slope stability analysis discussed above.

Description

As the cap is placed on the existing sediments, the vertical pressure applied to the sediments will cause consolidation settlement of the sediments as the skeletal structure of the sediments is compressed and pore water is expelled. If the applied vertical pressure is too high, a bearing capacity failure and associated shearing deformations and slumping will occur within the sediments. These deformations may be both vertical and lateral near the edge of a loaded area, and may take the form of a rotational failure and/or "mud wave." In relatively flat areas, such a bearing failure may result in some intermingling of sediments with cap material and the need for a thicker cap. However, in steep areas, bearing failures may induce larger slides and transport of material downslope. Thus, in RA4 and near the top of the slope (in portions of RA1, RA2a and RA2b), careful placement is considered essential to minimize any bearing capacity failures that may trigger larger slides.

To avoid a bearing capacity failure, the magnitude of the vertical pressure applied at the surface of the sediments should be limited to the "allowable" bearing pressure of the sediments. This same principle is used to design shallow footings for structures, and to design roadway embankments on soft ground. The allowable bearing pressure equals the "ultimate" bearing pressure (i.e., the pressure that directly causes shear failure of the sediments) divided by an appropriate factor of safety.

As reported in a previous technical memorandum (USEPA 2002b) and as presented in Appendix C, the organic silt sediments will consolidate and the undrained shear strength of the sediments will increase under the pressure applied by the first lift (layer) of capping material. The consolidation and the strength increase of the organic silt sediments will be completed in approximately 5 days. Because of the strength increase in the organic silt sediments, the allowable bearing pressure for the second and subsequent capping lifts will be higher than for the

initial lift. Sequencing of the capping operation is designed based on the concept of progressive increases in the allowable bearing pressure as the capping proceeds.

Key Parameters

The following key parameters affect the calculation of allowable lift heights for each RA:

- **Undrained Shear Strength.** In RA1 through RA4, the undrained shear strength of the organic silt sediments has been measured as low as 10 pounds per square foot (psf) from pre-design investigation vane shear testing. While this value is variable and higher shear strengths were measured in other locations in these areas, use of this low value is considered appropriate as it is not possible to map all areas where the least competent sediments may exist. This value is also appropriate for the shallower portions of RA5, from approximately -175 feet MLLW and shallower. In the deeper portions of RA5, where the organic silt layer is absent or more competent, the undrained shear strength in the upper 2 to 4 feet of sediments has been estimated in the range of 200 psf to 500 psf using CPT data.

- **Factor of Safety (FS).** Selection of an appropriate FS for cap placement in each RA is based on consideration of the placement methods and the consequences of bearing capacity failure. In RA1 through RA3, controlled placement methods will be used and the consequences of a bearing capacity failure would generally be limited to a greater intermingling of sediments with cap material and the potential need for a thicker cap in localized areas. Thus, an FS of 1.0 is used in RA1 through RA3. In RA4, controlled placement methods will be used, however the consequences of a bearing capacity failure could be significant landsliding, potentially resulting in the need to re-cap large areas. Thus, a more protective FS of 2 is used in RA4. In RA5, instantaneous bottom-dump placement will be used and the cap material may actually be applying an impact load to the surface of the sediments. Thus, a higher FS of 3.0 is used in RA5.

- **Buoyant Unit Weight.** The buoyant unit weight of the specific cap materials proportionately affects the allowable lift heights. A buoyant unit weight of 50 pounds per cubic foot (pcf) is used to represent upland cap materials placed in RA1 through RA4. A buoyant unit weight of 50 pcf is also used to represent dredged materials placed in RA4 and RA5. This estimate is based on STFATE-modeled dredged material mound heights and the USACE-suggested void ratios

for long-term mound configurations. The buoyant unit weight calculations are shown in Appendix D.

Methods of Analysis

The method of analysis of the bearing capacity of the cap lifts was complicated by the following considerations:

- The existing "foundation" consists of layers of both "cohesive" soil (shear strength consisting of cohesion but no friction angle) and "granular" soil (shear strength consisting of a friction angle but no cohesion) layers.

- The actual load applied by each successive cap lift is very wide, and it is nonuniform in thickness, increasing from negligible values around the edges of the lift to a maximum value at the center of the lift.

These considerations led to two separate approaches to the analysis.

Approach 1. The bearing capacity of the cap materials placed on the existing sediment was initially examined using the traditional general bearing capacity equations as presented in Terzaghi and Peck (1967) where a uniform load is applied over a well defined area of width "B", and the ultimate value of bearing pressure q(ult) is a function of the weight and shear strength of the soil as well as the B dimension. For the special case of loads applied to the surface of a homogeneous cohesive foundation soil, i.e., a soil with shear strength defined only by the cohesion component, the general bearing capacity equation reduces to a single term:

$$q(ult) = c\,(N_c)$$

where c = cohesion (undrained shear strength)
and N_c = constant ranging from 4 to 6

However, this simple equation applies only to the case where the bearing capacity failure zone is limited to the thickness of the cohesive foundation soil thickness. For the case of a layered foundation soil with both cohesive and granular layers (including the first lifts of the cap material) the general bearing capacity equations cannot be applied directly, and a limit analysis slope stability approach is commonly adopted. Where it is present, the surficial 3.5-foot-thick layer of very soft organic silt tends to produce the lowest FS for bearing capacity, and hence limits the lift thickness values for the desired FS of 3. The analysis for the first lift, assumed to be at least 10 feet wide and capable of failing anywhere within that 10-foot dimension, was

performed using the single term equation above. The analysis for later lifts was performed using the commercially available slope stability software SLOPE/W by Geoslope Limited. The values of cohesion (undrained shear strength) for the surficial organic silt layer ranged from 10 psf, which was the lowest value recorded during in situ vane shear tests, to 35 psf, which was used for the slope stability analysis based on back-computation from observed stable slope configurations.

Approach 2. A second examination of bearing capacity was performed assuming that the dimensions of the lifts can be approximated from the results of STFATE modeling of the cap mounds in RA5. The STFATE mound widths originally calculated at approximately 600 feet were reduced to 100 feet to represent the steepest part of the mound slope and to represent a locally possible but near-worst-case situation. The bearing capacity analysis was then performed using SLOPE/W.

Results

Table 4-2 summarizes the allowable cap lift thicknesses. Appendix C presents the calculations of these thicknesses. Table 4-2 also presents the calculated placement rates (tons per acre) that are based on achieving these lift thicknesses and are used in developing the performance requirements in the specifications.

For RA5, the resulting allowable lift thickness value using Approach 2 (1.3 feet) is substantially greater than that from the Approach 1 analysis (0.3 foot) for the same soil parameters and safety factors, as reflected in Table 4-2. This result underscores the degree of uncertainty in these calculations.

The thicknesses shown in Table 4-2 are used to define performance requirements for the controlled cap placement methods that will be used by the contractor in RAs 1 through 4. In addition, the allowable cap lift thicknesses for RA5 have been used in conjunction with STFATE modeling to define the RA4 / RA5 boundary, such that instantaneous bottom-dump placement in RA5 is not expected to result in bearing capacity failures. The RA4/RA5 boundary analysis is presented in Appendix D.

In RA1 and RA4, a best management practice has been adopted to minimize the potential for load bearing failure and cap material movement on slopes. Cap construction will proceed from deeper areas to shallower areas; therefore the slope loading will begin at the bottom of the slopes and move upward. This will create, in effect, a buttress to the slope and enhance slope stability. This "bottom up" approach is shown on the plans.

4.2.3 Slope Stability Considerations for RA1

General Revetment Design

Guidance on coastal protection (for example Allsop and McConell 2000 and USACE 1995b) indicates that protective material (revetment or riprap) on shoreline slopes should consist of an armor layer, a filter layer, and toe protection. From the geotechnical perspective, the revetment must be designed to resist slope failure and slumping, and must not induce failure of the slope on which it may be placed. Excessive differential settlement can lead to local failure zones within the revetment. Settlement and slumping can be induced by washing out of filter material and or existing sediment due to wave action.

To address these issues, revetment slopes, materials sizing, and toe berm and key design were conducted in accordance with USACE guidance (USACE 1995b). Significant wave heights for the design 50-year wave were calculated and used to size the riprap and an appropriate filter material. These calculations are shown in Appendix A.

Slope Stability Analyses in RA1

Revetments inclined at a slope of 2H:1V are typically expected to be stable where the slope above and below the revetment is reasonably flat. However, a detailed slope stability analysis was performed to assess cases where a 2H:1V revetment is placed above existing slopes that are inclined at more than approximately 10 degrees (roughly 6H:1V slope). Also, where dredge cutbacks extend to the toe of the existing riprap revetment, a detailed slope stability analysis was performed. Static and seismic analyses were conducted for the following sections (refer to design drawings for section locations):

- **Station 9+00:** This station is considered a worst-case condition of dredge cutbacks that may potentially undermine existing riprap. To accommodate the cap in RA3, the dredge cutback in this region extends to the toe of the existing riprap at a 2H:1V slope. The calculated static safety factor for the design cutback is 1.55 in this area, indicating the design cut is expected to be stable. Seismic evaluations are not applicable here, as the cutback condition is temporary and the final slope configuration is considered more stable than the two other sections evaluated below. While the temporary cut slope is expected to be stable, the contractor will be required to avoid over-cutting and to limit the duration the cut is left open before installing the cap.

- **Station 16+50:** The RA1 cap configuration was evaluated at Station 16+50 because this area represents revetment construction on one of the steepest sections of the existing nearshore mudline. This area appears to include a historic submarine slide, and transects the viewing pier. For the design cap configuration, the static FS is 1.82 and the seismic FS is greater than 1.07. The seismic FS was obtained by assuming that the 1.5-foot thick layer of "upper silt" (typical un-improved undrained shear strength of 100 psf) gets mixed with or displaced by a suitable subgrade rock material and has a final "improved" shear strength represented by a friction angle of 35 degrees. This assumption is based on placement of crushed rock as the first two feet of fill. The industry–standard seismic FS target for slopes associated with civil works projects is 1.1. Slopes that are configured similar to those at Stations 16+50 and 18+85 cannot achieve that target seismic FS unless rock fill is used as the initial lift(s) to strengthen or replace the existing Upper Silt and to improve the upper portion of the Intermediate Silt layer. Finally, the liquefaction potential of the RA1 cap material was evaluated using LiquefyPro software. The sand layer of the fill is marginally liquefiable, but the residual strength of the fill provides a static FS of at least 1.1.

- **Station 17+85:** The RA1 cap configuration was evaluated at Station 17+85 because this area represents revetment construction on another of the steepest sections of the existing nearshore mudline. The results at this station were very similar to those at station 16+50, with acceptable static and seismic FS.

In summary, the RA1 cap design includes placement of 2 feet of crushed rock as the first fill layer to improve the slope stability under seismic loads. The crushed rock is required between stations 9+25 and 18+00, and above the daylight of the dredge cuts west of Station 9+25. The crushed rock is not required where the thick slope cap revetment is not used (i.e., between stations 18+00 and 24+00) or where the upper silt layer is being dredged out (i.e., in the dredge cuts between stations 3+50 and 9+25).

Analysis of Design Slopes of Thick Slope Cap

The design revetment slope for the Thick Slope Cap of 2H:1V is a typical design for revetments in Puget Sound and elsewhere. Analyses were performed to evaluate the potential for increasing the design revetment slope to steeper than 2H:1V. Using a simple "infinite slope" approach and data on the properties of loose sand, the analysis indicates that the reasonably well graded sand can be placed underwater using backhoe or similar bucket methods to achieve a relative density that would be associated with an angle of repose of approximately 30 to 31 degrees. Placing this material on a 2H:1V slope (26.5 degree angle) will result in a temporary FS of approximately 1.2.

This situation is adequate until placement of overlying materials (filter material and rip rap) further densifies the cap subgrade to its final assumed friction angle of 33 degrees. Placing the cap subgrade sand at angles steeper than 2H:1V would result in a high likelihood of local sloughing and instability before the filter material and riprap are placed.

The design drawings show the thick slope cap slopes constructed at 2H:1V. The specifications require the contractor to correct any sloughing that may occur prior to placing the filter material and riprap. In no locations can the final constructed slope above the toe berm exceed 1.75H:1V (30 degrees).

Analysis of Downdrag at Viewing Pier

Construction of the cap in RA1 will result in a variable amount (0-10 feet) of fill material being placed around the existing friction piling that support the viewing pier. To bracket the possible response of the piles to the placement of as much as 10 feet of fill, two separate possible soil profiles were examined:

- Profile 1: 3.5 ft of highly compressible silt overlying at least 30 feet of compressible silt and sand mixture.

- Profile 2: 3.5 ft of highly compressible silt, underlain by 16.5 ft of compressible silt and sand mix, underlain by at least 20 ft of medium dense sand.

As the actual length of the piles is unknown, an embedment of 30 feet below the mudline was assumed. The actual embedment may be considerably greater, and thus the settlement predicted in this analysis may be greater than the actual settlement.

For Soil Profile 1, the pile tip is embedded in compressible soil and is expected to settle with the soil by an amount approximately equal to 20 inches. This maximum amount of settlement would occur at the location of the thickest fill, and settlement at the entrance to the pier and at the end of the pier would be very small.

For Soil Profile 2, the pile tip is embedded in a medium dense low compressibility sand that will settle only a small amount from the effects of the future fill placement, and will offer resistance to downdrag loads applied to the pile. Overall, the pile settlement is expected to be approximately 2 inches.

In conclusion, under the worst-case scenario, the piles near the center of the pier could settle approximately 20 inches. It is also likely that a small amount of downslope lateral deformation

of the piles on the steepest portion of the slope could occur during fill placement. It is recommended that the viewing pier be closed to the public while cap construction is occurring within 100 feet of the pier. The Port of Seattle will be responsible for evaluating any settlement impacts to the pier and making any repairs that may be necessary prior to reopening the pier.

Consolidation of MSU Sediments in RA1

The existing very soft Upper Silt layer and Intermediate and Lower Silt layers will compress as a result of the placement of cap material in RA1. The amount of settlement will be variable depending on the local thicknesses of the cap and the very soft Upper Silt layer, and may range from about 17-23 inches. The contractor is required to construct the RA 1 cap to the final grades shown (within the specified overplacement and underplacement allowances). The quantity estimates for RA1 include additional quantities to account for an estimated 20 inches average overall settlement of the existing subgrade.

Consolidation Evaluation For Outfall Extension

The 84-inch, reinforced-concrete pipe extension of the Longfellow Creek Overflow will pass through the cap in RA1, as shown on the Drawings. To accommodate this extension, existing sediments must be dredged along the alignment. This dredging is anticipated to remove all highly compressible sediments from the pipeline alignment, and the Drawings and CQAP include provisions for additional dredging if required to remove all highly compressible sediments. After installation of the extension and capping, the consolidation along the pipeline is estimated be on the order of 2 inches. This consolidation is considered acceptable given the allowable deflection at each joint of the pipeline.

4.3 RA1 CAP DESIGN

Because of topographic variations in the intertidal area, navigational depth requirements, and the need to transition between the minimum 5-foot intertidal cap and the off-shore caps, the RA1 cap design as discussed in the following sections is composed of two parts:

- A gravel cap constructed to moderate slopes at finished elevations in the intertidal zone. The gravel cap provides a stable cap of a thickness necessary to provide for nearshore habitat. The gravel cap is used to the maximum extent practical; however, in many locations the grades of the gravel cap cannot match the steeply sloping existing mudlines.

- A thick slope cap constructed to slopes of up to 2H:1V. This cap generally is used at subtidal elevations, to allow grade transition between RA1 and the offshore caps in the other RAs. In some locations, the existing nearshore mudlines are sufficiently steep that the thick slope cap must extend upward into intertidal elevations.

4.3.1 Cap Thickness

Intertidal Elevations

The thickness of each component of the RA1 cap at intertidal elevations (i.e., finished grade above -4 feet MLLW) is described below:

- The bioturbation thickness, T_b, is specified at 12 inches. As described in Section 4.1.1, a T_b equal to 6 inches is considered adequate to prevent burrowing aquatic organisms from disrupting the isolation barrier through reworking of the surface sediments. However, the intertidal areas in RA1 may also be subject to human disturbances through recreational use of the beach, and thus a more conservative value is used at intertidal elevations in RA1.

- The erosion thickness, T_e, is specified at 12 inches. The cap in RA1 is subject to erosive forces from wind and tidally-driven waves, as well as propeller wash. Further, cap material placed at intertidal elevations may be subject to cross-shore transport. The specified cap material is designed to resist the calculated erosive forces. However, because this is a relatively high-energy area, the specified value of T_e will allow limited erosion or reshaping of the beach without triggering the need for maintenance.

- The consolidation thickness, T_c, is specified at 0 inches. The RA1 capping material will be granular and is expected to undergo negligible consolidation.

- The chemical isolation thickness, T_i, is specified at 24 inches. This thickness was determined based on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 120 years.

- The operational thickness, T_o, is specified at 12 inches. This additional allowance accounts for the potential inaccuracies and unevenness of cap construction, and

ensures that the entire capping area will be covered with at least the minimum required thickness needed for the above-described cap functions.

Based on the cap components described above, the minimum required capping thickness for intertidal areas of RA1 is:

$T_t = 12 + 12 + 0 + 24 = 48$ **inches minimum required**, plus 12 inches (T_o) overplacement allowance.

As discussed in Section 4.1.2, cap material specifications were developed to provide for a particle size that resists erosive forces rather than designing an additional thickness to accommodate erosion. Because the ROD specifies that a minimum of 5 feet (60 inches) of capping material be placed in the intertidal area and because the intent of the ROD is that a 60-inch thickness be maintained in the intertidal area over time, both the erosion thickness and overplacement allowance are added to the 60-inch ROD requirement. This will provide a measure to account for potential reshaping of the area by wave action or by extreme propeller wash such that limited erosion or reshaping of the beach does not necessitate maintenance. The final specified capping thickness for the intertidal areas of RA1 is:

$T_t = 60 + 12 = 72$ **inches minimum required,** plus 12 inches (T_o) overplacement allowance.

Subtidal Elevations

Below a finished grade of -4 feet MLLW, the ROD does not require a minimum cap thickness. Subtidal portions of RA1 will consist of either a gravel cap that tapers to the thickness of the cap in the adjacent offshore RA (either RA2a, RA2b, RA3, or RA4), or a thick slope cap. The thickness of each component of the thick slope cap is described below:

- The bioturbation thickness, T_b, is specified at 6 inches (Section 4.1.1).
- The erosion thickness, T_e, is specified at 12 inches. The thick slope cap is subject to erosive forces from wind and tidally-driven waves, as well as propeller wash. The specified value of T_e will allow limited erosion without triggering the need for maintenance.
- The consolidation thickness, T_c, is specified at 0 inches. The capping material will be granular and is expected to undergo negligible consolidation.

- The chemical isolation thickness, T_i, is specified at 24 inches. This thickness was determined based on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 120 years.

- The operational thickness, T_o, is specified at 12 inches.

Based on the cap components described above, the minimum required thickness of the thick slope cap for subtidal areas of RA1 is:

$T_t = 6 + 12 + 0 + 24 = 42$ inches minimum required, plus 12 inches (T_o) overplacement allowance.

4.3.2 Cap Materials and Quantities

Cap Material Types

The following design elements influence the materials specifications for both cap types used in RA1:

- **Chemical Isolation.** The chemical isolation analysis is based on a cap material total organic carbon (TOC) content of 0.5 percent within the specified 2-foot chemical isolation thickness. This minimum TOC requirement only applies to the bottom 2 feet of the cap (i.e., a separate material is specified for the bottom 2 feet of cap).

- **Erosion.** Wave scour and cross-shore transport are important mechanisms for all of RA1, and propeller wash is significant in the western portions of RA1. In general, fine gravel (D_{50} = 10 mm) will resist wave-induced currents throughout RA1, and fine gravel (D_{50} = 18 mm) will resist propeller wash. More significantly, analysis of equilibrium beach profiles and the desire to minimize any cross-shore transport influences the particle size requirements throughout RA1. For the gravel cap to resist cross-shore sediment transport, intertidal slopes should not exceed 7:1. A fine-to-coarse gravel (D_{50} of at least 18 mm) is required for the gravel cap to maintain these slopes. This erosion-resistant material is required within the top 18 inches of the cap.

- **Placement.** Non-cohesive materials are required to allow controlled placement of the cap material in even lifts.

- **Slope Stability**. The thick slope cap will be constructed to grades of up to 2:1 to allow transition from the elevations in intertidal areas to the elevations in subtidal areas. Consistent with USACE guidance (USACE 1995), this cap will include a sandy gravel filter layer overlain by a light riprap armor layer. In addition, the slope stability analyses of the RA1 cap (Section 4.2.3 and Appendix C) indicate that improvement of the shear strength of the existing upper silt layer is needed where 2:1 slopes are to be constructed. To improve the upper silt layer, 2 feet of crushed rock will be placed over the existing sediments to form a foundation where the thick slope cap is specified. The crushed rock foundation is expected to intermingle to a great extent with the upper silt layer as it is placed and then compacted by subsequent lifts of cap material.

- **Habitat**. The ROD requires that capping material be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to this area. The natural resource agencies in coordination with EPA have identified the size and gradation of intertidal capping material to maximize habitat value. These preferences have been incorporated into the materials specifications for "habitat mix" material which will be placed over the armor layer and gravel cap materials in the littoral zone.

To satisfy the above requirements, the gravel cap in RA1 consists of:

- A 2-foot-thick layer of gravel mix foundation (in locations shown on the drawings).

- A base layer of a well-graded, medium to coarse sand with trace gravel and fines, with average 0.5 percent or greater TOC ("sand cap mix"). The base layer will be a minimum of 2 feet thick.

- An intermediate layer of a well-graded, sandy gravel with a D_{50} of approximately 18 mm and a maximum particle size of approximately 64 mm (2.5 inches) ("gravel mix"). The gravel layer will be constructed to within 6 inches of the grades shown on the drawings.

- A top course of 6 inches of habitat mix.

Final grading of the gravel cap to the lines and grades shown on the drawings will accomplish the minimum 72-inch total cap thickness. A 12-inch overplacement allowance is included for the entire cap thickness.

The thick slope cap in RA1 is a typical armored slope design for the region, and consists of:

- A filter layer of a well-graded, sandy gravel ("filter material"). Where the thick slope cap sits directly on a dredge cut, the filter material will be a minimum of 2 feet thick and will have an average 0.5 percent or greater TOC. This requirement will necessitate use of an amended product.

- An armor layer of a graded, angular broken stone ("riprap"). The armor layer will be a minimum 24 inches thick.

- The armor layer will be constructed to the final grades shown on the drawings, with a 12-inch overplacement allowance for the final surface.

- A riprap "key" or toe berm constructed at the base of the slope to provide support to the overlying riprap.

- Habitat mix (a well-graded sandy gravel) placed over the armor layer to fill the voids in the riprap. The habitat mix will be applied at 3 tons per 100 square feet, which is designed to fill the voids and leave an average 3-inch-thick layer of habitat mix on top of the riprap. Habitat mix will be applied to the final surfaces of all new and existing riprap in the littoral zone, between the elevations of -10 feet MLLW and +13 feet MLLW.

Materials Sources

The cap materials will be obtained from upland sources to meet the materials specifications.

Cap Quantities

The estimated quantities of cap materials in RA1 are summarized in Table 4-3. A total of 93,000 cubic yards of material will be required for this area. These quantities include the overplacement allowance, an allowance for consolidation of the underlying sediments, and include tapering of cap edges outside the cap boundaries. Due to the complex geometry of the cap in RA1, the volume estimates are made electronically by generating triangulated irregular network (TIN) surfaces.

4.3.3 Cap Slopes and Elevations

Several design criteria relate to the final grades and elevations of the cap in the intertidal area, as discussed below:

- The ROD requires confinement (through capping) of contaminated marine sediments. For the intertidal area, the primary design criterion evolving from this requirement is that the cap requirements must be met over the existing sediment mudline, but not over the shoreline riprap which is not "contaminated sediment."

- The existing riprap provides slope stabilization and erosion protection for the existing upland features, at their present locations and elevations. Therefore, the existing riprap will not be removed, or cut back, to create new intertidal areas and loss of uplands.

- According to the ROD, a minimum of 5 feet of capping material will be placed over the intertidal area. The RA1 cap design includes an additional 12-inch erosional thickness and a 12-inch overplacement allowance. Thus, the minimum specified capping thickness is 6 feet plus up to 1 foot of overplacement, at all locations where the finished elevation is above -4 feet MLLW.

- During and following placement, underlying sediments will consolidate. Up to 23 inches of consolidation may be expected in some locations (Appendix C). The contractor will place additional cap material in RA1 to compensate for this consolidation and attain the grades shown on the drawings.

- Actual intertidal elevations at the site are –4 to +14.8 feet MLLW. Following placement of the cap, the sediment elevation at any given location will be raised by the cap thickness. Thus, the new mudline elevations will be at least 6 feet above the existing mudline, representing a substantially larger area of intertidal habitat than existed prior to capping.

- The existing toe of the riprap occurs at elevations ranging from approximately –5 to +5 feet MLLW, and the riprap generally extends to the top of the bank above the intertidal zone. However, on the far eastern portion of the shoreline (near station 21 + 50), a beach exists on a bench between two riprap slopes. Because potentially contaminated sediments are present on this bench, the full cap thickness will be extended over the bench.

- Above –10 feet MLLW, the maximum allowable slope of the gravel cap is 7H:1V for the design gravel mix. Where cap material tapers into the riprap bank, a slope of 7H:1V is generally used to extend the cap grade to meet the riprap. Slopes less than 7H:1V are specified where possible, typically in areas where the existing slope is less than 7H:1V.

- Below –10 feet MLLW, cross-shore sediment transport is not anticipated to be significant, and the design slope of the gravel cap is 4H:1V for the design gravel mix. This slope is consistent with existing submarine slopes at the site that have been determined to be stable.

- To avoid exceeding the maximum allowable grades, placement of greater thickness of cap material will be required in some locations.

- A thick slope cap is specified in areas where steep slopes of up to 2H:1V are required. This cap generally is used at subtidal elevations, to allow grade transition between RA1 and the offshore caps in the other RAs. In some locations, the existing nearshore mudlines are sufficiently steep that the thick slope cap must extend upward into intertidal elevations.

- A natural resource preservation goal is to maximize the areas of the cap that fall within certain intertidal elevations (-4 to +4 feet MLLW) that are deemed the most critical and productive habitat for salmonids. To this end, and consistent with the design criteria described above, efforts have been made to minimize the presence of the relatively steep, armored thick slope cap between -4 to +4 feet MLLW and maximize the use of flatter slopes at these elevations. Section 7 presents further information on this and other habitat enhancements.

Overall, the design grades, slopes, and materials selection are intended to realize the greatest benefits in habitat quality and minimize the need for long-term maintenance. Because the intertidal gravel cap geometries are based on slopes at or shallower than the calculated equilibrium profile, the beach should be in equilibrium with the existing energy environment and reshaping of the beach by wave action should be minimal. However, localized areas of erosion and accretion may develop, and some perturbations to the constructed profile should be expected over time as a result of seasonal variations in wave energies. It is expected that periodic renourishment of some beach areas may be required as part of the long-term O&M for the site. Because beaches are dynamic, the OMMP includes criteria for evaluating the need for management actions (repair or nourishing) in RA1.

4.3.4 Additional Physical Features and Constraints

Additional physical features affecting the intertidal cap design are discussed below.

Piling and Viewing Pier

It is anticipated that the majority of the existing piling in RA1 will be removed by the Port of Seattle prior to capping. However, the viewing pier (a pile-supported structure) will remain in RA1, and capping is therefore required beneath this pier. Cap material will be cast under the pier using mechanical equipment or simply mechanically graded into place at higher beach elevations. The cap material will be as specified elsewhere in RA1, and thus there are no additional erosion resistance considerations for this material. Additional costs have been included in the cost estimate to account for difficulties in placing cap material beneath the pier.

Eastern Pier

A small wooden pier (approximately 40 feet by 60 feet) is present at station 24+00. Cap material will be cast under the pier in this area.

Crowley Marine Services Pier

The area under the Crowley Marine Services pier has little available clearance in which to accommodate a cap (see design drawings). The pier structure and pontoon dolphin assemblies require their approximate existing clearances for their low tide positions. Further, existing sediment slopes beneath the existing riprap revetment are 2H:1V, and any dredging may destabilize the slopes or undermine the revetment. Finally, any dredging under the pier would require diver-operated hydraulic dredging which can be an extremely high-risk activity. For these reasons, it is not considered practicable to dredge under the pier and a thick cap cannot be constructed under the pier. However, a thin layer of capping material can be cast under and around the pier to provide some capping and confinement of potentially contaminated sediments. Therefore, a thin layer (6 inches) of gravel mix capping material will be placed under the pier either hydraulically or with a conveyor. The thickness of the gravel mix will be 18 inches in the region between the outer edges of the pier and the toe of the RA1 thick slope cap, as shown on the drawings.

Outfalls. Three outfalls have been identified along the shoreline and will be addressed as follows:

- **Former Longfellow Creek Overflow**. This outfall is a historic remnant of the original Longfellow Creek. It currently receives overflow drainage from the existing Longfellow Creek and is not a salmon migration pathway. The outfall also serves as a local stormwater drain, receiving drainage from as far south as the Birmingham Steel property. This outfall is present approximately 140 feet east of the Crowley pier. Based on survey information and field observations, the outfall partially daylights with approximately half of its diameter below the mudline. Based on field observations, the outfall appears to be anchored in place with chains and concrete blocks. As-builts of this outfall have been obtained and indicate 84-inch (7-ft) inside diameter, 8-inch thick, reinforced concrete pipe (RCP), with the invert of the pipe at approximately −7.6 feet MLLW. An engineered extension of this pipe is required to accommodate the cap in this area. The cap will also require scour protection at the outfall, consisting of a riprap splash pad.

- **Crowley Storm Drain Outfall.** This former outfall was located approximately 155 feet east of the Crowley pier. Based on review of drawings for Public Access Construction, a new manhole was installed just south of the public access park, and the 15-inch concrete storm drain pipe was plugged and abandoned north of the manhole (to the outfall). The new manhole includes a pipe connecting the 15-inch concrete storm drain line to the 84-inch former Longfellow Creek outfall. Because the Crowley storm drain outfall is not functional and could not be located, it is not considered to be of concern in the cap design.

- **Unidentified East Outfall.** This outfall is a dilapidated 12-inch steel pipe at approximately +8 feet MLLW, on the eastern portion of the shoreline near the elevated bench. No flow has been observed from this pipe. As-builts of this outfall could not be obtained. The pipe will be grouted with concrete and the cap in this area will be placed over the pipe.

Shoreline Access

No specific design elements are currently included in this design to increase public accessibility to the capped intertidal areas. Access ways may be required for cap construction and may be completed by the construction contractor to allow beach access.

Habitat Enhancement

Significant modifications of the existing shoreline will result from cap placement. Section 7 presents the net changes in habitat areas resulting from the cap. In coordination with the Natural Resource Trustees, additional habitat enhancements have been included in the RA1 cap in areas where the finished cap surface is at upper intertidal elevations. The goals of these enhancements are to create a more natural and stable upper intertidal area, to enhance the recruitment and retention of fines, to introduce native plant species and discourage establishment of invasive species, and to accelerate the natural evolution of the upper intertidal area. The habitat enhancements include the following elements, which are shown on the drawings:

- Placing temporary large woody debris (LWD) along approximately 250 feet of shoreline: The design of the temporary LWD has been developed based on engineering considerations and in coordination with the Natural Resource Trustees. Over time, additional LWD is expected to naturally accumulate at upper intertidal elevations in these locations. However, natural sources of LWD in Elliott Bay are diminished from historical baseline conditions. The goal of placing the LWD is to enhance the recruitment and retention of fines and to allow for more rapid establishment and increased survival of vegetation. The LWD is considered "temporary" because it was not engineered to withstand, for example, a 50-year-storm condition. Rather, the LWD is designed to last for several years (potentially decades) and to leave minimal anthropogenic debris on the beach when the LWD eventually deteriorates. The temporary LWD consists of partially buried durable native log species (cedar or fir) with rootwads, cabled to buried concrete anchors. The temporary LWD is installed at elevations between +12 feet MLLW and +14 feet MLLW, which is the elevation range expected to naturally recruit additional LWD over time. At these relatively high intertidal elevations (above mean higher high water [MHHW]), there is less potential for severe wave action to dislodge the LWD. When the LWD eventually deteriorates, minimal cleanup (e.g., cutting exposed cable sections) may be desired to remove anthropogenic material.

- Placing a top course of beach sand in areas around the LWD: The beach sand consists of a well-graded sand with significant fines content and is intended to provide a suitable substrate for vegetative growth.

- Planting native salt-tolerant vegetation: The planting plans include beach grasses and gumweed in the beach sand areas (between +12 and +14 feet MLLW) and willows above approximately +15 feet MLLW. In the designated locations, riprap

interstices will be amended with topsoil to support growth of the willows. The planting plans have been developed considering input from natural resource agencies and other parties involved in shoreline restoration projects in the Puget Sound area. Native species typically found in undisturbed beach areas have been selected, and the plantings are targeted to specific elevations appropriate for those species. As with any comparable nearshore revegetation project, there is some uncertainty regarding the long-term survival of the plants. The planting specifications (Appendix H) include measures to enhance the establishment of the plants and to establish target survival rates during the first year after planting.

It is noted that there is no planned long-term monitoring, maintenance, or adaptive management specific to the vegetation or temporary LWD. It is anticipated that the areas of habitat enhancements will undergo changes over time due to natural processes.

4.3.5 Placement Techniques

Cap material may be placed and graded in RA1 mechanically from a barge, or by other method(s) proposed by the contractor and approved by USACE. It is anticipated that land-based equipment such as dozers will be used for final cap grading in RA1. Equipment such as conveyors may be used to place materials under the Crowley Marine Services pier and the viewing pier.

The allowable lift heights are summarized in Table 4-2. Construction monitoring, described in the CQAP (Part IV of this design), will verify that the cap is being placed according to specifications. The contractor will be required to modify the placement methods if the monitoring results are not acceptable (e.g., if cores show excessive mixing of cap material with underlying sediments).

4.4 RA2a AND RA3 CAP DESIGN

The RA2a and RA3 cap designs differ only in the gradation of the erosion-resistant top layer of cap material, and are described together.

4.4.1 Cap Thickness

The thickness of each component of the RA2a and RA3 cap is described below:

- The bioturbation thickness, T_b, is specified at 6 inches.
- The erosion thickness, T_e, is specified at 12 inches. The cap in RA2a and RA3 is subject to significant erosive forces from propeller wash. Because this is a relatively high energy area, the specified value of T_e will allow limited erosion without triggering the need for maintenance. While 12 inches is highly conservative for T_e, the total thickness of erosion-resistant material should be at least 18 inches, which corresponds to the sum of T_b and T_e in this area.
- The consolidation thickness, T_c, is specified at 0 inches. The RA2a and RA3 capping material will be granular and is expected to undergo negligible consolidation.
- The chemical isolation thickness, T_i, is specified at 24 inches. This thickness was determined based on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 120 years.
- The operational thickness, T_o, is specified at 12 inches.

Based on the cap components described above, the minimum required capping thickness in RA2a and RA3 is:

$T_t = 6 + 12 + 0 + 24 = 42$ inches minimum required, plus 12 inches (T_o) overplacement allowance for a maximum cap thickness of 54 inches.

4.4.2 Cap Materials and Quantities

Cap Material Types

The following design elements influence the materials specifications for RA2a and RA3:

- **Chemical Isolation**. The chemical isolation analysis is based on a cap material TOC content of 0.5 percent within the specified chemical isolation thickness.

This minimum TOC content requirement only applies to the bottom 24 inches of the cap (i.e., a separate material is specified for the bottom 24 inches of cap).

- **Erosion**. Propeller wash is the dominant erosive force in these areas. In RA2a, coarse sands (D_{50} = 4.75 mm) will resist the erosive forces of propeller wash. In RA3, a fine-to-coarse gravel (D_{50} = 18 mm) is required to resist the erosive forces of propeller wash. This erosion-resistant material is required within the top 18 inches of the cap.

- **Placement**. Non-cohesive materials are required to allow controlled placement of the cap material in even lifts.

- **Habitat**. The ROD requires that capping material be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to the area. The materials required to resist erosion are coarser than the existing substrate, however it is possible that this material may be overlain over time with deposits of sands or silts.

To satisfy the above requirements, the cap material in RA2a and RA3 will consist of:

- A base layer of sand cap mix. The base layer will be a minimum of 24 inches thick.

- In RA2a, a top layer of a well-graded, gravelly sand with a D_{50} of approximately 5 mm ("coarse sand"). The top layer will be a minimum of 18 inches thick.

- In RA3, a top layer of gravel mix. The top layer will be a minimum of 18 inches thick.

- In RA2a and RA3, there is a 12-inch overplacement allowance for the final cap surface.

Materials Sources

The cap materials will be obtained from upland sources to meet the materials specifications.

Cap Quantities

The estimated quantities of cap materials in RA2a and RA3 are summarized in Table 4-2. A total of 43,600 cubic yards of material will be required for RA2a and 7,700 cubic yards of material will be required for RA3. These quantities include the overplacement allowance, a 10 percent contingency, and include tapering of cap edges outside the cap boundaries. The quantities were calculated by multiplying the plan view area by the total cap thickness and adding the calculated edge taper volume.

4.4.3 Additional Physical Features

The dolphins in RA3 are pile-supported structures. Cap material will be cast under the dolphins using mechanical equipment or hydraulic washing. The cap material will be as specified elsewhere in RA3, and thus there are no additional erosion resistance considerations for this material.

Several steel cables are strung between the dolphins and the Crowley Marine Services pier. Coordination with Crowley will be required to temporarily remove the cables during construction.

4.4.4 Placement Techniques

The base layer of sand cap mix in RA2a and RA3 may be placed mechanically or by hydraulic washing from a barge, and the top layers of coarse sand and gravel mix may be placed mechanically. Other method(s) may be proposed by the contractor and may be approved by USACE. Equipment such as conveyors may be used to place materials under the pier and dolphins.

The allowable lift heights are summarized in Table 4-2. To achieve uniform lifts that do not exceed the allowable lift heights, the specifications establish limits on the volume of cap material placed per unit area. Construction monitoring, described in the CQAP, will verify that the cap is being placed according to specifications. The contractor will be required to modify the placement methods if the monitoring results are not acceptable.

4.5 RA2b CAP DESIGN

4.5.1 Cap Thickness

The thickness of each component of the RA2b cap is described below:

- The bioturbation thickness, T_b, is specified at 6 inches.
- The erosion thickness, T_e, is specified at 0 inches. The cap in RA2b is not anticipated to be subject to significant erosive forces from propeller wash or other bottom currents.
- The consolidation thickness, T_c, is specified at 0 inches. RA2b capping material will be granular and is expected to undergo negligible consolidation.
- The chemical isolation thickness, T_i, is specified at 24 inches. This thickness was determined on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 120 years.
- The operational thickness, T_o, is specified at 12 inches. The 12-inch operational thickness is based on a total 12-inch overplacement allowance for the multiple cap lifts that will be required.

Based on the cap components described above, the minimum required capping thickness in RA2b is:

$T_t = 6 + 0 + 0 + 24 = 30$ inches minimum required, plus 12 inches (T_o) overplacement allowance for a maximum cap thickness of 42 inches.

4.5.2 Cap Materials and Quantities

Cap Material Types

The following design elements influence the materials specifications for RA2b:

- **Chemical Isolation**. The chemical isolation analysis is based on a cap material TOC content of 0.5 percent within the specified chemical isolation thickness.

Because one material type is used for the cap in this area, the entire cap thickness will meet this minimum TOC requirement.

- **Erosion**. The erosion analysis indicates bottom currents in this area are below the threshold velocity for initiation of motion, even for fine-grained materials. Therefore, erosion considerations do not influence the material specification in this area.

- **Placement**. Non-cohesive materials are required to allow controlled placement of the cap material in even lifts.

- **Habitat**. The ROD requires that capping material will be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to this area. The cap materials used in this area will be similar to the existing substrate and will satisfy this requirement.

To satisfy the above requirements, the cap material in RA2b will consist of:

- A single layer of sand cap mix. The cap will be a minimum of 30 inches thick plus a 12-inch overplacement allowance.

Materials Sources

The sand cap mix will be obtained from upland sources.

Cap Quantities

The estimated quantities of cap materials in RA2b are summarized in Table 4-3. A total of 18,200 cubic yards of material will be required for this area. This quantity includes the overplacement allowance, a 10 percent contingency, and includes tapering of cap edges outside the cap boundaries. The quantities were calculated by multiplying the plan view area by the total cap thickness and adding the calculated edge taper volume.

4.5.3 Placement Techniques

Cap material in RA2b may be placed mechanically or by hydraulic washing from a barge, or by other method(s) proposed by the contractor and approved by USACE.

The allowable lift heights are summarized in Table 4-2. To achieve uniform lifts that do not exceed the allowable lift heights, the specifications establish limits on the volume of cap material placed per unit area. Construction monitoring, described in the CQAP, will verify that the cap is being placed according to specifications. The contractor will be required to modify the placement methods if the monitoring results are not acceptable.

4.6 RA4 CAP DESIGN

4.6.1 Cap Thickness

The thickness of each component of the RA4 cap is described below:

- The bioturbation thickness, T_b, is specified at 6 inches.
- The erosion thickness, T_e, is specified at 0 inches. The cap in RA4 is not anticipated to be subject to significant erosive forces from propeller wash or other bottom currents.
- The consolidation thickness, T_c, is specified at 0 inches. RA4 capping material will be granular and is expected to undergo negligible consolidation.
- The chemical isolation thickness, T_i, is specified at 24 inches. This thickness was determined based on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 120 years.
- The operational thickness, T_o, is specified at 12 inches. The 12-inch operational thickness is based on a total 12-inch overplacement allowance for the multiple cap lifts that will be required.

Based on the cap components described above, the minimum required capping thickness in RA4 is:

$T_t = 6 + 0 + 0 + 24 = 30$ inches minimum required, plus 12 inches (T_o) overplacement allowance for a maximum cap thickness of 42 inches.

4.6.2 Cap Materials and Quantities

Cap Material Types

The following design elements influence the materials specifications for RA4:

- **Chemical Isolation**. The chemical isolation analysis is based on a cap material TOC content of 0.5 percent within the specified chemical isolation thickness. Because one material type is used for the cap in this area, the entire cap thickness will meet this minimum TOC requirement.

- **Erosion**. The erosion analysis indicated bottom currents in this area are below the threshold velocity for initiation of motion, even for fine-grained materials. Therefore erosion considerations do not influence the material specification in this area.

- **Placement**. Non-cohesive materials are required to allow controlled placement of the cap material in even lifts.

- **Habitat**. The ROD requires that capping material will be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to this area. The cap materials used in this area will be similar to the existing substrate and so will satisfy this requirement.

- **Slope Stability.** The material specification for sand cap mix includes angularity requirements to achieve the design friction angle of 32 degrees.

To satisfy the above requirements, the cap material in RA4 will consist of:

- A single layer of sand cap mix. The cap will be a minimum of 30 inches thick plus a 12-inch overplacement allowance.

Materials Sources

The sand cap mix will be obtained from upland sources.

Cap Quantities

The estimated quantities of cap materials in RA4 are summarized in Table 4-3. A total of 159,000 cubic yards of material will be required for this area. This quantity includes the overplacement allowance, a 10 percent contingency, and includes the estimated deposition of cap material, both outside the cap boundaries and into RA5 (from STFATE mound geometry; see Appendix D). The quantities were calculated by multiplying the plan view area by the total cap thickness and adding the calculated mound apron volumes.

4.6.3 Placement Techniques

Cap material may be placed in RA4 by hydraulic washing from a barge, or by other method(s) proposed by the Contractor and approved by USACE.

The allowable lift heights are summarized in Table 4-2. RA4 has the most restrictive lift height requirements (to avoid bearing capacity failures and potential landsliding) and thus the placement will be monitored intensively. To achieve uniform lifts that do not exceed the allowable lift heights, the specifications establish limits on the volume of cap material placed per unit area. Construction monitoring, described in the CQAP, will verify that the cap is being placed according to specifications. The Contractor will be required to modify the placement methods if the monitoring results are not acceptable.

4.7 RA5 CAP DESIGN

4.7.1 Cap Thickness

The thickness of each component of the RA5 cap is described below:

- The bioturbation thickness, T_b, is specified at 6 inches.
- The erosion thickness, T_e, is specified at 0 inches. The cap in RA5 is not anticipated to be subject to significant erosive forces from propeller wash or other bottom currents.
- The consolidation thickness, T_c, is specified at 3 inches. The RA5 capping material will be dredged material and is expected to consolidate up to this amount in the months following placement.

- The chemical isolation thickness, T_i, is specified at 18 inches. This thickness was determined based on the results of the chemical isolation analysis (Appendix B). The associated design life for chemical isolation is conservatively estimated at 140 years.

- The operational thickness, T_o, is specified at 13 inches. The 13-inch operational thickness is based on the results of STFATE modeling of cap deposition for multiple, instantaneous releases of cap material from bottom-dump barges (Appendix D).

Based on the cap components described above, the required capping thickness in RA5 is:

$T_t = 6 + 0 + 3 + 18 = 27$ inches minimum required, plus 13 inches (T_o) overplacement allowance for a maximum (short-term) cap thickness of approximately 40 inches.

Following consolidation, the cap will be a minimum of 24 inches thick and the average cap thickness is anticipated to be approximately 30 inches.

4.7.2 Cap Materials and Quantities

Cap Material Types

The following design elements influence the materials specifications for RA5:

- **Chemical Isolation**. The chemical isolation analysis is based on a cap material TOC content of 1 percent, which is an average value of dredged material characteristics from the Snohomish River.

- **Erosion**. The erosion analysis indicated bottom currents in this area are below the threshold velocity for initiation of motion, even for fine-grained materials. Therefore erosion considerations do not influence the material specification in this area.

- **Placement.** Non-cohesive materials are required to allow controlled placement of the cap material in even lifts.

- **Habitat**. The ROD requires that capping material be selected and placed in such a way as to provide appropriate habitat for the marine organisms natural to this

area. The cap materials used in this area will be similar to the existing substrate and so will satisfy this requirement.

To satisfy the above requirements, the cap material in RA5 will consist of:

- A single layer of sandy dredged cap material. Following consolidation, the cap will be a minimum of 24 inches thick.

The dredged cap material must meet the materials specifications identified in Appendix F. The basis of these specifications is discussed in Section 2.3. In general, all dredged material placed as a cap in RA5 does not need to contain a minimum TOC content. However, USACE, through its PSRMP, will direct material with TOC content significantly lower than 1 percent to be placed in the upper cap horizons. This should be relatively straightforward, as barges containing dredged material with lower TOC can simply be directed to dump at coordinates where higher TOC material has already been placed.

Cap Quantities

The estimated quantities of cap materials in RA5 are summarized in Table 4-3. A total of 217,000 cubic yards of material will be required for this area. This quantity includes off-site deposition, the operational thickness, a 10 percent contingency, and is based on the STFATE modeling results for instantaneous bottom-dump placement on regular 200-foot grids. The modeling indicates that up to 54 percent of the RA5 cap material will be transported outside the RA5 boundaries. This transport is a result of dispersion of the dredged material in the water column.

Note on RA5 Quantity Estimates: All quantity estimates are based on a hypothetical dredged material whose properties represent an "average" gradation of materials from the Snohomish and Duwamish Rivers. The quantities are based on **barge-measure** cubic yards, with an assumed 55 percent water content in the barge. The barge-measure material includes entrained water from the dredging process, and is estimated to have a volumetric "fluff" factor of about 20–25 percent over the volume of in situ material. For example, a 1,000 cy barge load of dredged material may represent approximately 800 cy of in situ material in the Duwamish. The USACE typically measures sandy dredged material based on barge-measure volumes, so no fluff factor corrections should be needed. However, if measurement and payment is made based on in-situ volume, the measurement for placement at PSR will have to be appropriately adjusted to barge volume to achieve the desired cap thickness. It is stressed that actual dredged material properties will vary from the assumed properties. The ultimate attainment of the cap thickness in RA5 will be

verified as described in the RA5 CQAP, and placement volumes may be modified during construction to attain the design cap thickness.

As mentioned in the RA4 discussion, some of the material placed in RA4 will deposit in RA5a (estimated at 18,000 cubic yards; see Appendix D) . This has been accounted for in the RA5a cap placement design by appropriately positioning RA5a target locations as discussed below.

4.7.3 Placement Techniques

Cap material will be placed in RA5 by instantaneous bottom-dump placement at regularly spaced target locations. USACE, through its PSRMP, will require each contractor to dump each barge load within 100 feet of the prescribed coordinates of a target location. The RA5 design drawings (Appendix F) show the cap placement design for RA5, including target location coordinates and the required volume of dredged material to be placed at each target location. Each of the target locations is within the ROD-specified capping boundary.

As discussed in Appendix D, STFATE was used to simulate multiple placement events for the buildup of several lifts to achieve the required cap thickness. The modeling indicates that a minimum of 4,500 cubic yards are required to be placed at each target location. The target locations are spaced at regular 200-foot intervals. All STFATE runs are based on the long-term, post-consolidation properties of the deposited cap material. Thus, the model results are evaluated against the required post-consolidation minimum cap thickness of 24 inches.

Figure 4-2 depicts the resulting long-term mound geometry for an idealized 800-foot by 800-foot capping area (roughly half the size of RA5a). This simulation shows that a relatively uniform cap averaging 30 inches thick can be accomplished with instantaneous bottom dump placement on the design target location spacing. The outer target locations of the grid exhibit slightly diminished cap thicknesses because they do not experience the additive effects of mound aprons beyond the defined grid. Thus, one additional disposal event is specified around the RA5 cap perimeter to compensate for these edge effects (i.e., 5,500 cubic yards of material is specified at perimeter target locations). The outer edge of the cap (as seen on transect A-A' in Figure 4-2) would extend approximately 350 feet beyond the defined placement grid, before tapering off to less than about a 1-inch thickness (see further discussion of off-site transport in Section 4.8).

The capping scheme includes an extra margin of safety in the event that placement is not as uniform as STFATE predicts. It is assumed that mound height variability may be up to three times the modeled variability, to account for differences in such factors as actual loaded volume in each barge, varying accuracy in releasing the material at the target locations, the properties of the materials within each barge, varying depths and tidal elevations associated with each grid

node at each point in time, and prevailing currents. T_o is therefore set equal to three times the variability in modeled mound height. Thus, the average 30-inch cap (which as modeled, varies from 29 to 33 inches) may actually vary from about 24 to 37 inches.

These modeling results suggest that the minimum required 24-inch thickness (post-consolidation) can readily be met and exceeded with the specified placement plan. Also, the predicted STFATE mound geometries do not account for up to 3 percent of the deposited material, which had not yet settled out within the modeled timeframe. Much of this material is expected to settle within RA5, further adding to the cap thickness.

As noted previously, some RA4 cap material will deposit into RA5 during placement. To account for this, target locations along the RA5/RA4 boundary are offset 100 feet into RA5. Appendix D includes the calculation used to determine this offset.

Construction monitoring, described in the RA5 CQAP (see Section 9), will verify that the cap is being placed according to specifications. Specific construction monitoring and management considerations for RA5 include the following:

- If monitoring shows the required cap thickness has not been achieved, USACE may direct additional dredged material to be placed at certain target locations.

- Excessive mound heights in the shallower and steeper portions of RA5 (within about 300 feet of the RA5/RA4 boundary) could potentially induce bearing capacity failures and landsliding. Modeling of bottom-dump placement in RA5 indicates maximum mound heights are not expected to exceed the allowable lift height in this area. To verify the modeled results, monitoring of mound heights from individual dumps will be required for the target locations within 300 feet of the RA5/RA4 border. As an adaptive management approach, USACE will require other operational controls (such as limiting loaded barge volumes) if the monitoring results are not acceptable near the RA5/RA4 border.

- Monitoring will also be used to adjust the required number of disposal events along the RA5/RA4 boundary, since some RA4 cap material will deposit in RA5.

4.8 EVALUATION OF OFF-SITE CAP MATERIAL DEPOSITION DURING CAP PLACEMENT

This section provides an evaluation of the amount of cap material that is expected to be transported outside the capping boundaries during placement, and the associated area that is affected by the cap material deposition. This analysis is important for assessing the amount of cap material required, and also for estimating the areal extent of short-term disturbances to the benthic community outside the capping area. This evaluation is based on the STFATE results and monitoring results from the nearby Elliott Bay PSDDA disposal site. The PSDDA monitoring results provide real data for conditions analogous to the RA5 capping at PSR.

Table 4-4 and Figure 4-4 summarize the results of this analysis.

It is important to note that the MSU capping area boundaries are defined by CSL exceedances, and existing sediments generally exceed the SQS for several hundred feet outside the capping boundaries. Thus, the off-site cap material deposition will improve sediment quality through enhanced natural recovery in these marginally contaminated areas. While this enhanced natural recovery will be brought about by the capping, it is not part of the selected remedy and will not be monitored as an "enhanced natural recovery action."

4.8.1 RA1, RA2a, RA2b, RA3

In RA1, deposition of cap material outside the cap boundaries will be limited to the design cap tapers shown on the drawings.

In RA2a and RA2b, there is no design requirement for the cap tapering. The contractor is required to meet the required cap thickness up to the RA boundaries, and the actual taper outside the boundary will vary according to the local water depths, material types, and placement methods. The actual taper may vary from close to the angle of repose of the material (i.e., about 2H:1V) to a broader taper of about 10H:1V. Conservatively assuming a 10H:1V taper, an estimated 35 to 45 feet outside these cap boundaries will be affected by cap material deposition.

Because RA3 is bounded by the other RAs, no off-site deposition is associated with RA3.

4.8.2 RA4

RA4 represents a transition between the shallow nearshore areas and the deep offshore areas. As a result, cap deposition outside the capping boundaries (i.e., on the eastern and western borders of RA4) will vary according to depth. The distance of off-site transport in RA4 is therefore

estimated to vary linearly from 100 feet on the shoreward boundary of RA4 to approximately 400 feet at the RA4/RA5 boundary.

It is noted that some cap material placed in RA4 will be deposited into RA5. This accounted for in the RA4 volume estimates and RA5 placement design, but is not relevant to this analysis of off-site deposition.

4.8.3 RA5

RA5 represents the deep off-shore areas. Instantaneous bottom-dump placement of dredged material will be used in cap construction in this area. Deposition of capping material outside of the RA5 boundaries was estimated using STFATE modeling and evaluation of depositional data from the Elliott Bay PSDDA site.

STFATE Results

The extent of deposition of capping material outside the RA5 capping boundaries was approximated using STFATE modeling. This modeling suggests an apron of diminishing thickness will be deposited up to several hundred feet outside the capping area boundaries. This apron diminishes to less than 0.1 foot in thickness within about 350 feet of the cap boundary. However, this modeling result may underestimate off-site cap material deposition, for the following reasons:

- Within the modeled timeframe of one hour following placement, 97 percent of the material will be deposited on the bottom. The remaining suspended material is not accounted for in the STFATE mound geometry. Thus, a broader area would be expected to receive an additional very thin deposit over time as the fine-grained material continues to settle out of the water column. While much of this material would likely settle within the desired capping area, a portion of the fines may be transported off site.

- STFATE cannot model the additional bottom shear stresses caused by a sloping bottom, and hence some additional lateral downslope movement of the deposited material is expected. This effect is anticipated to be greatest in RA4, leading to deposition of RA4 cap material into RA5. To a lesser extent, this effect may contribute to deposition of RA5 cap material outside the RA5 capping boundaries.

As a result of these factors, the lateral extent of off-site transport directly predicted by the STFATE mound geometries (350 feet) is considered a lower bound estimate for RA5.

Monitoring Results for the Elliott Bay PSDDA Disposal Site

Results. In dredging year 1999 (DY99), 414,794 cubic yards of dredged material was placed at the Elliott Bay PSDDA disposal site. This site is a 6,200-foot by 4,000-foot ovoid with a 1200 foot-diameter target area in which disposal occurs. Water depths in the target area are 300 to 350 feet. From June 21 to July 11, 2000, WDNR conducted a monitoring study of the site (WDNR 2000). One of the objectives of that study was to evaluate whether the 1999 dredged material was being transported outside the site boundaries. Sampling consisted of a sediment vertical profiling system (SVPS) survey, followed by benthic infauna, sediment, and *Molpadia* sea cucumber collections.

The distribution of recently deposited dredged material at the Elliott Bay PSDDA site identified using SVPS is mapped in Figure 4-3. The dredged material deposit is centered over the 600-foot diameter target area and recently deposited dredged material was not found beyond the site perimeter. Key findings of the 2000 SVPS survey are:

- Recently deposited dredged material observed in Elliott Bay consists of mixed layers of dark gray medium to fine sands and dark to light gray silt-clays. Six stations at or near the site center showed the presence of dredged material greater than SVPS camera prism penetration (Figure 4-3). This largely un-recolonized dredged material extends from 0 feet to approximately 700 feet outside the target area, averaging about 400 feet outside the target area.

- Outside this main dredged material deposit, several stations showed the presence of discontinuous layers of apparent dredged material mixed below high reflectance sediments of ambient quality. The surface sediments at these stations are light gray, well mixed, and fine grained, similar to ambient sediments. The subsurface sediments believed to be dredged material are layers of dark gray silt-clays similar in character to known dredged material present at the site center. This sedimentary sequence suggests that enough time has elapsed in these areas for bioturbation of the upper sediment column (infauna transporting sediments upward to the sediment/water interface), or that the sediment may be related to non-recent (historical) dredged material deposits with subsequent natural sedimentation. A discrete measurement of dredged material thickness is not possible at these stations. Therefore, the measurement is indicated as the prism penetration depth followed by an asterisk (Figure 4-3). This area of recolonized dredged material extends from 500 feet to a maximum of approximately 2,000 feet outside the target area, averaging about 1,200 feet outside the target area.

- Thin, discrete layers of recent dredged material were not measured at the Elliott Bay site during the 2000 SVPS survey. The last disposal of dredged material at the Elliott Bay PSDDA site occurred on March 1, 2000, approximately 4 months prior to the SVPS survey. It is possible that enough time had passed for the resident benthos to bioturbate very thin layers of recent dredged material present on the sediment surface, thus obscuring its optical signature.

More recent monitoring of the Elliott Bay PSDDA site in 2002 yielded similar results. Deposits of recent dredged material greater than 10 cm thick extended from 0 feet to approximately 900 feet outside the target area. Deposits between 1 cm and 10 cm thick extended 400 to 1,500 feet outside the target area. Traces of freshly deposited material were detected up to 2,900 feet outside the target area.

Interpretation. The water depths at the Elliott Bay PSDDA site are 300 to 350 feet, substantially deeper than the depths of 140 to 240 feet in RA5. Thus, greater dispersion and material deposition outside the target area is expected at the PSDDA site than at PSR. Also, it is possible that some historical PSDDA material (in particular the relict, bioturbated material) could have been released outside the current target area, increasing the footprint of the relict dredged material.[5] Using the 2000 and 2002 Elliott Bay PSDDA site data as conservative benchmarks, the following can be implied for PSR:

- Significant thicknesses (greater than 10 cm) of capping material are expected to be deposited to distances from 400 to 700 feet outside the RA5 capping boundaries. The 400-foot distance is taken as the best estimate for cross-slope deposition. The 700-foot estimate is taken as the best estimate for downslope deposition.

- Beyond 700 feet from the RA5 capping boundaries, any deposits are expected to rapidly recolonize (within several months).

- Thinner deposits (from 1 cm to 10 cm) of capping material could be deposited to distances averaging about 1,200 feet outside the RA5 capping boundaries. However, rapid recolonization (within several months) is expected for these

[5]In Figure 4-3, the southwestern shaded region that extends outside the disposal site boundary is a separate disposal of PCB-contaminated sediments conducted by the USACE in the 1970s (USACE 1978). The PCB-contaminated sediments were capped with clean material.

thinner deposits. The 2000 PSDDA monitoring data indicated that deposits at these distances had already recolonized by the time the monitoring was conducted.

- Beyond approximately 2,000 feet from the RA5 capping boundaries, any deposits of capping material would be so thin as to be undetectable after several months.

4.8.4 Estimated Areas and Quantities of Cap Deposition

Figure 4-4 depicts the generalized footprint of off-site cap material deposition. Table 4-4 summarizes the estimated lateral extent and volume of off-site cap material deposition, as interpreted from both the STFATE and PSDDA monitoring data. In addition to the design cap area of 58 acres, approximately 65 acres outside the cap boundaries are anticipated to be affected by deposition of cap material. The bulk of this off-site depositional area (58 acres) is associated with RA5.

The total capping volume for the MSU is 542,000 cubic yards (this includes a 10 percent volume contingency). An estimated 123,000 cubic yards of this capping material will deposit outside the cap boundaries.

In RA5, the total volume of material specified for placement is 198,000 cubic yards.[6] Based on the STFATE mound geometry, 90,000 cubic yards will be deposited in RA5, and 108,000 cubic yards (54 percent of the placed material) will be deposited outside the RA5 boundary.

As previously discussed, sediments in areas outside of the ROD-specified and design capping boundaries are known to exceed SQS for selected chemicals of concern. Deposition of capping material outside of the boundaries will therefore reduce exposure of aquatic resources to areas with elevated concentrations of site-related contaminants. Near the RA boundaries, relatively thick (>10 cm) off site deposits of capping material will occur and will essentially function as a sediment cap. In these areas, near-complete isolation of underlying contaminated sediments is expected. Farther outside the RA boundaries, thinner deposits (<10 cm) will occur and will essentially function as enhanced natural recovery. In these areas, many of the existing benthic organisms will survive the deposition and rework the newly-deposited sediments into the biologically active layer. For example, deposition of 1 inch (2.5 cm) of clean cap material in off-site areas may effect an approximate 25 percent reduction in contaminant concentrations in the

[6] For cost estimating purposes, a 10 percent contingency (equaling 19,800 cubic yards) is added to the specified volume for a total estimated volume of 217,000 cubic yards. Because it is unknown whether this extra material will be required or where in RA5 it would be placed, the percentage of this extra material that may travel offsite has not been estimated.

top 10 cm of sediment, assuming a 10 cm biologically active zone. The areas of off-site cap deposition will not, however, be monitored as a long-term capping or enhanced natural recovery remedy.

4.9 SUMMARY OF CAP QUANTITIES

Table 4-3 summarizes the estimated capping volumes that will be required. All cap volumes are expressed as bulk, barge-measure, and include the overplacement allowance, and the total cap volume includes a 10 percent contingency on the baseline estimated volume. A total of 542,000 cubic yards of material is estimated to be required, including 325,000 cubic yards of upland material and 217,000 cubic yards of dredged material.

6500.06_08.CDR

POTENTIAL PHYSICAL CHANGES IN CAP THICKNESS

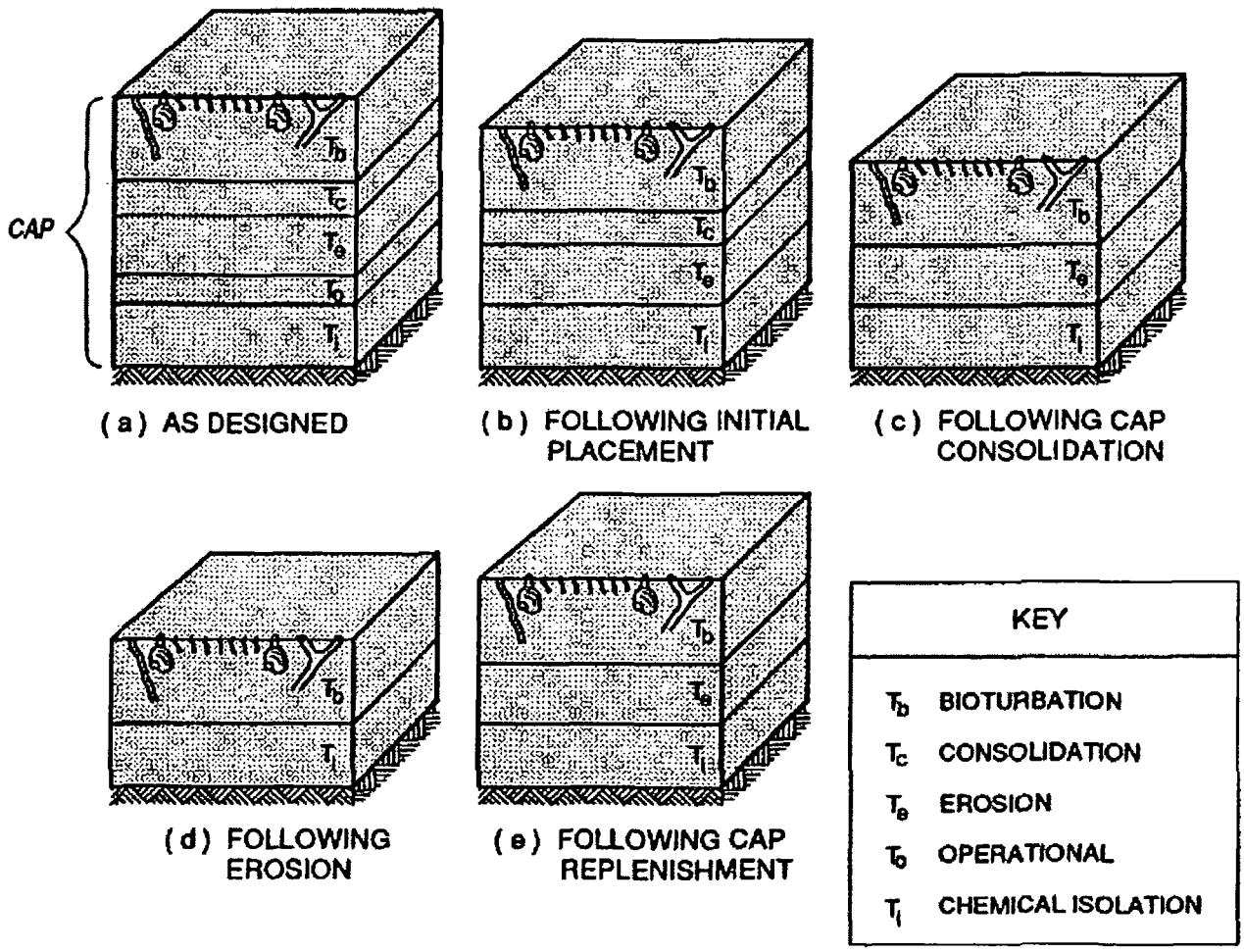


Figure 4-1

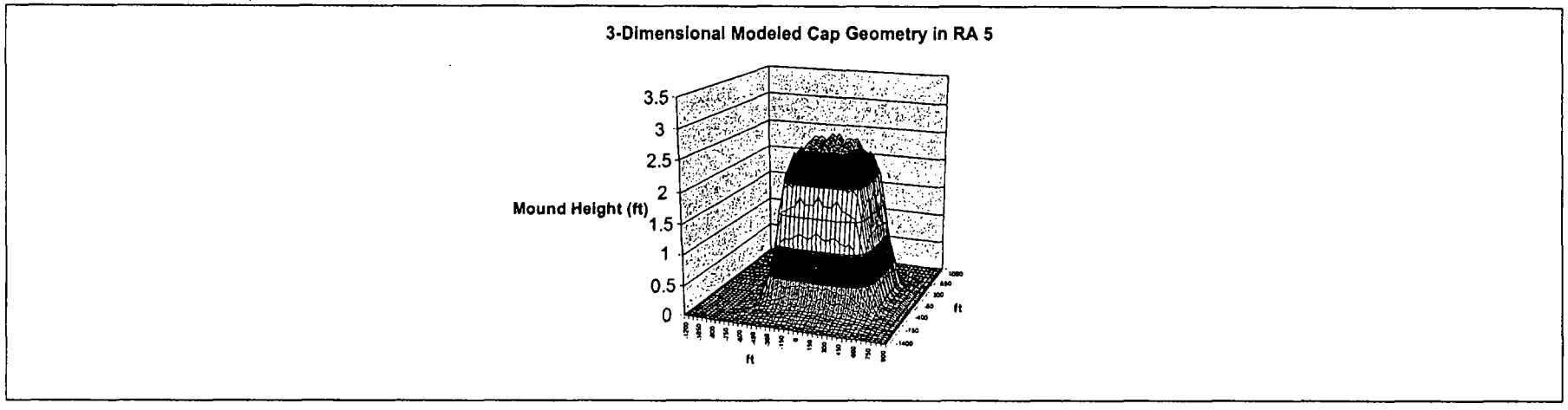
Cap Thickness Design Components

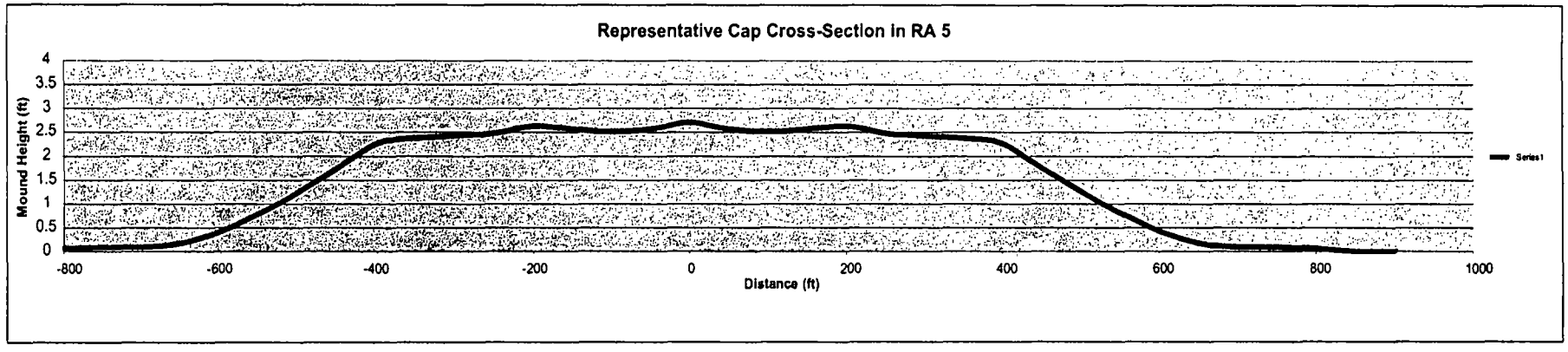
Job No. 53-F4006500.06

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

33755206-2



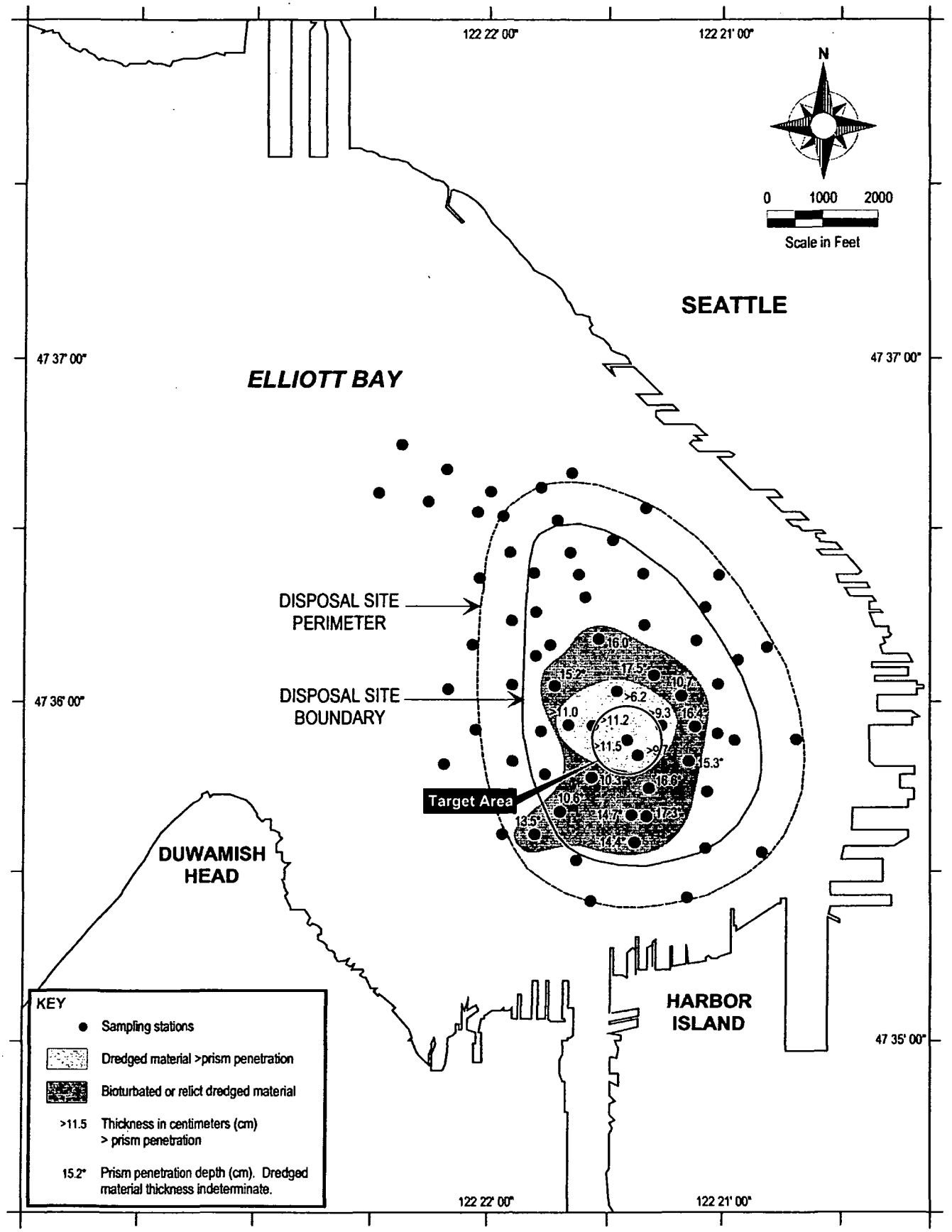


Job No. 33755206.08000

Figure 4-2
Modeled Cap Geometry in RA 5

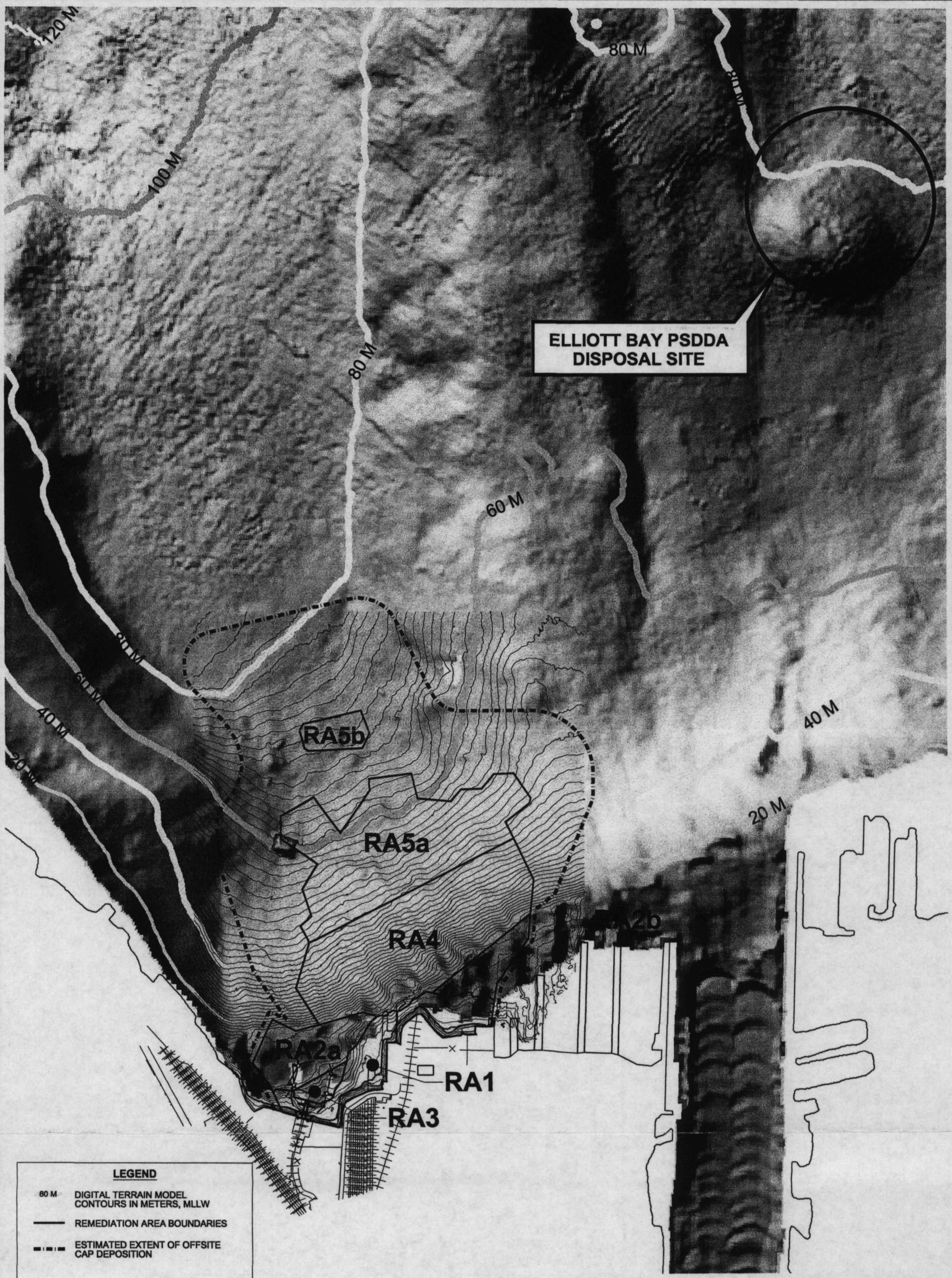
EPA REGION 10

065-RD-RD-101L
PSR Superfund Site



Source: DNR 2000

Figure 4-3
PSDDA Dredged Material Footprint Measured During 2000 Elliott Bay SVPS Survey



LEGEND

80 M — DIGITAL TERRAIN MODEL CONTOURS IN METERS, MLLW

——— REMEDIATION AREA BOUNDARIES

- - - - ESTIMATED EXTENT OF OFFSITE CAP DEPOSITION

TOTAL DESIGN CAP AREA = 58.3 ACRES

AREA OF POTENTIAL OFFSITE CAP DEPOSITION = 65 ACRES

NOTE: DIGITAL TERRAIN MODEL IMAGE AND CONTOURS FROM NOAA.

N

0 150 300 600

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Figure 4-4
Estimated Extent of Offsite Cap Deposition

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

Table 4-1
Summary of Cap Thickness Requirements by Area

RA	Thickness (in inches)						
	Bioturbation T_b	Erosion T_e	Consolidation T_c	Chemical Isolation T_I	Minimum Required Cap Thickness[a]	Overplacement Allowance T_o	Total T_t
1 (intertidal)	12	12	0	24	72[b]	12	84
1 (subtidal)	6	12	0	24	42	12	54
2a	6	12	0	24	42	12	54
2b	6	0	0	24	30	12	42
3	6	12	0	24	42	12	54
4	6	0	0	24	30	12	42
5	6	0	3	18	27	13	40

[a] RA5 minimum required cap thickness is 24 inches when measured after consolidation

[b] ROD requires minimum 60 inches. T_e is added to the ROD minimum

Table 4-2
Allowable Lift Heights for Cap Placement

Remediation Area	Cap Material	Placement Method Type	Buoyant Unit Weight (pcf)	Undrained Shear Strength[f] (psf)	Design Factor of Safety	Lift Number	Maximum Allowable Thickness of Cap Lift (ft)	Allowable Placement Rate (TON/acre) (b)
1, 2, 3	Upland sands/ gravels	Controlled	50	10	1	1 2 3[e]	1 2 5	2100 4200 4200
4	upland sands	Controlled	50	10	2	1 2 3, 4	0.5 0.75 1.75	1200 1800 4000
5 (above -175 feet MLLW)	dredged material	Instantaneous Bottom-dump	35 - 50[a]	10	3	All	0.3 - 1.3[c]	[d]
5 (below -175 feet MLLW)	dredged material	Instantaneous Bottom-dump	35 - 50[a]	200	3	1	>3	[d]

[a] Buoyant Unit weight for dredged material is calculated from STFATE deposition modeling (Appendix D).
Associated allowable thicknesses are based on modeled long-term mound heights and long-term Buoyant Unit Weight of 50 pcf.
Allowable short-term mound heights (within the first week of placement) are approximately 50% greater.

[b] Contractor performance requirement for RA2-4. RA1 performance requirement is based on lift thickness.

[c] Calculated range of lift heights used to define RA4/RA5 boundary. See Appendix D.

[d] Placement rate not applicable to instantaneous bottom dump placement

[e] For RA1 up to 5 feet may be placed in the 3rd lift.

[f] Representative values.

Notes:
MLLW - mean lower low water
pcf - pound per cubic foot
psf - pound per square foot

Table 4-3
Estimated Capping Volumes

RA	Area (Acres)	Minimum Required Cap Thickness (inches)	Over-placement Allowance (inches)	Estimated Cap Volume (CY)		Estimated Volumes by Material Type (CY)									
							Upland Materials (d, f)								
				Estimated	With Contingency (e)	Dredged Material (a)	Sand Cap Mix	Coarse Sand	Beach Sand	Gravel Mix	Filter Material #1	Filter Material #2	Rip Rap	Habitat mix	TOTAL UPLAND
1	7.02	72 (c)	12	96,165	96,165	0	18,184		603	60,911	466	2,057	9,350	4,594	96,165
2a	5.08	42	12	39,671	43,638	0	21,819	21,819							43,638
2b	2.68	30	12	16,580	18,238	0	18,238								18,238
3	0.97	42	12	7,046	7,750	0	3,875			3,875					7,750
4	20.62	30	12	144,688	159,157	0	159,157								159,157
5a and 5b	21.95	24 (b)	13	197,500	217,250	217,250									0
Subtotal				501,650	542,199	217,250	221,273	21,819	603	64,786	466	2,057	9,350	4,594	324,949
Contingency (10%)				40,549											
TOTAL	58.3			542,199	542,199	217,250	221,273	21,819	603	64,786	466	2,057	9,350	4,594	324,949

Notes:
a - Dredged Material cap volume in barge-measure cubic yards
b - Post-consolidation thickness
c - Tapers to match adjacent RAs at elevations below -4 feet MLLW
d - See specifications for required properties of materials types. Volumes by material type include contingency
e - Volume contingency for RA 2a, 2b, 3, and 4 is a provision for greater than expected offsite transport or potential additional placement to correct thin areas
f - In-place and bulk volumes are assumed to be equal for all materials

	Volume	Basis
RA1 Volume =	96,165 CY	LanDevelopment software estimate + overplacement allowance +consolidation
RA2a Volume =	39,671 CY	Area x cap thickness +overplacement allowance + offsite transport
RA2b Volume =	16,580 CY	Area x cap thickness +overplacement allowance + offsite transport
RA3 Volume =	7,046 CY	Area x cap thickness +overplacement allowance
RA4 Volume =	144,688 CY	Area x cap thickness +overplacement allowance + offsite transport + deposition into RA5
RA5a/b Volume =	197,500 CY	STFATE grid placement modeling

Table 4-4
Anticipated Extent of Offsite Cap Material Deposition

Remediation Area	Source of Estimate	Distance Outside Cap Boundary (ft)	Affected Area Outside Cap Boundary (Acres)	Volume of Material Deposited Outside Cap Boundary (CY)	Comments
RA1	Based on design cap taper	varies	0.16	977	Cap taper readily controlled
RA2a	Based on assumed 10:1 cap taper	45	0.77	2,813	Cap taper will be a function of placement methods
RA2b	Based on assumed 10:1 cap taper	35	0.52	1,475	Cap taper will be a function of placement methods
RA3	None	0	0.00	0	RA3 is bound by other RAs
RA4	Transition from RA2b to RA5; STFATE Results	150 - 400	5.84	10,436	Area based on assumed linear transition; volume estimate from bottom-dump modeling, likely overpredicted
RA5	STFATE Results	>350	N/E	107,552	Area potentially under-predicted; best estimate of volume
	PSDDA Monitoring Results (a)	400 - 700	57.9	N/E	Estimated area with significant deposition
	PSDDA Monitoring Results (Average of Recolonized)	1200	N/E	N/E	Possible thin deposits; rapid recolonization
TOTAL OFFSITE DEPOSITION			**65**	**123,253**	Area based on 400 - 700-foot distance for RA 5

Notes:
N/E - Volume or area not evaluated from this source
a - PSDDA-observed average of 400 ft used for cross-slope deposition;
PSDDA-observed maximum of 700 ft used for downslope deposition

Calculation of Offsite Deposition from RA5 Placement:

Placed Volume	197,500 cy
Deposition in Cap area	89,948 cy
Offsite Volume	**107,552** cy
Percent Transported Outside RA5:	**54%**

5.0 SHORT-TERM WATER QUALITY IMPACTS DURING CONSTRUCTION

In this section, potential short-term losses of chemicals and suspended particulates to the waters of Elliott Bay are analyzed. Potential impacts to water quality could include elevated chemical concentrations and/or turbidity associated with dredging, and elevated turbidity associated with capping operations.

5.1 WATER QUALITY CRITERIA

5.1.1 State Criteria

During construction, Washington state water quality criteria will need to be attained at a specified point of compliance. These criteria include general water use and criteria classes (WAC 173-201A-030) for turbidity, dissolved oxygen (DO), and toxic conditions, and the numerical toxic substances criteria (WAC 173-201A-040).

A temporary mixing zone will be established during the in-water construction activities, and the point of compliance set at the boundary of this mixing zone. EPA will designate the allowable mixing zone and has typically approved 300-foot mixing zones in Puget Sound. Water quality will be monitored at the point of compliance, and the contractor will be required to modify its placement methods, if required to ensure compliance.

Elliott Bay is a "Class A" water body. The following water quality standards (WAC 173-201A-030) apply to Elliott Bay, except in the indicated temporary mixing zones:

- **Turbidity Criteria.** Turbidity shall not exceed 5 nephelometric turbidity units (NTUs) over background turbidity when the background turbidity is 50 NTUs or less, or when there is more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTUs.

- **Dissolved Oxygen.** Dissolved oxygen shall exceed 6.0 mg/L. When natural conditions, such as upwelling, occur, causing the dissolved oxygen to be depressed near or below 6.0 mg/L, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human-caused activities.

- **Toxic Conditions.** Toxic concentrations must be "below those which have the potential either singularly or cumulatively to adversely affect characteristic water

uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department."

In accordance with anticipated short-term water quality certification, temporary mixing zones are established in the specifications. If water quality becomes a problem, in-water construction operations will cease until testing at the mixing zone boundary falls within the required parameters and operational controls as necessary will be implemented.

5.1.2 Assessment of Turbidity Criterion with TSS Results

The following subsections focus on modeling to assess the predicted turbidity impacts associated with remedial actions (dredging and capping). These assessments are intended to serve as preliminary indications of the extent of turbidity plumes and the potential need for operational controls to prevent excessive turbidity. The model outputs are expressed in terms of incremental total suspended solids (TSS) above background. A correlation is therefore needed to estimate the TSS value associated with the state turbidity criterion of an incremental 5 NTU over background.

There is no universal correlation of turbidity with TSS; however, several studies of this correlation for Puget Sound sediments have yielded similar results. Table 5-1 summarizes these correlations and the TSS value that corresponds to 5 NTUs at the various sites. From these studies, a range of 5 to 50 mg/L TSS corresponds to 5 NTUs. This range is consistent with correlations reported in the literature in other regions (Thackston and Palermo 2000). The correlations in Table 5-1 include an intercept associated with background turbidity. For the purposes of this analysis, the maximum slope of the correlations in Table 5-1 is used to assess incremental turbidity; that is, 1.7 mg/L TSS is assumed to increase turbidity by 1 NTU. Thus, it is assumed that a TSS of approximately 8 mg/L over background is required to produce a turbidity of 5 NTU over background.

While the above correlation is needed to interpret the modeling results, actual confirmation of the turbidity criterion during construction will be accomplished with direct-reading turbidity meters that provide results in NTUs. Modification of construction procedures will be required if turbidity impacts exceed state criteria at the mixing zone boundaries.

5.2 WATER QUALITY IMPACTS DURING DREDGING

5.2.1 Contaminants Released During Dredging

During the pre-design investigation, a dredge elutriate test (DRET) was conducted on a composite sample from RA3 . The results of this testing, reported in the pre-design investigation data summary (USEPA 2002a), indicate that chemical concentrations are not expected to exceed either the acute or chronic water quality criteria in WAC 173-201A-040. Thus, no further modeling of chemical releases from dredging is required, and no monitoring of chemical constituents in the water column is needed during dredging.

Although the samples collected for characterization of dredged material showed no indication of NAPL, highly contaminated oily sediments are present in the MSU, and it is possible that oily sediments could be encountered at some location(s) within the dredge prism. The contractor is required to contain any sheens with containment booms and remove any sheen with sorbent pads or by other means.

5.2.2 Resuspended Sediment Released During Dredging

The TSS concentrations resulting from dredging were estimated using the DREDGE Module software developed by the USACE (Hayes and Je 1997). Based on site-specific input parameters, the DREDGE Module predicts a plume of suspended sediment emanating from the dredge operation. DREDGE Module output includes TSS concentration values at specific locations relative to the dredge operation, and a representation of the extent of the predicted TSS plume.

Selected Inputs

The input parameters used for the designed dredge cuts are summarized in Table 5-2. This analysis assumes that dredging will be accomplished by open bucket dredging, with a relatively small bucket size (8 m^3), and a 60-second cycle time. The use of closed "environmental" buckets or increased cycle times would be expected to reduce the TSS concentrations predicted by this analysis.

Engineering characteristics of the sediment to be dredged were selected based on the grain-size analysis of sediment sample 207comp, collected during the pre-design investigation from within the area to be dredged, and on the measured saturated density and water content of another site sediment sample (from B6-9) classified as a sand. The in situ dry density of the sediment to be dredged (1,387 kg/m^3) was based on this measured saturated density and water content. The

sediment fraction smaller than 74 micrometer (μm; equal to the No. 200 sieve size) was selected as 27.8 percent from the grain size distribution report for sample 207comp. The sediment fraction smaller than the size associated with the critical resuspension velocity (R_0 = 17%) was estimated based on the methodology described in the DREDGE Module. The specific gravity of the sediment was selected based on a typical value for sand of 2.65 (note that this is conservative compared to the value of 2.68 measured for sample B6-9).

The settling velocity of the sediment to be dredged (0.00066 m/sec) was calculated based on the median grain size of the sediment fraction passing the No. 200 sieve (i.e., particles with diameters less than 74 μm. This median grain size was estimated from the grain size distribution curve for sample 207comp at 31 μm. The calculated settling velocity was manually entered into the DREDGE Module, overriding the automatic calculation provided (which resulted in a less conservative 0.000759 m/sec settling velocity). Calculations for dry density and settling velocity are included in Appendix G.

Input parameters for the near-field and far-field models within the DREDGE Module were selected based on the Module recommendations (as modified by USACE comments on the 30% Design), along with an expected average water depth during dredging of 6 meters. Site characteristic input parameters included the ambient water velocity (0.03 m/sec), which was selected based on the vertical profile of current velocities measured during the predesign investigations by the current meter CM-2 (USEPA 2002c).

Program Output

DREDGE module output is summarized in Table 5-3 and included in Appendix G. At 150 feet directly downgradient of the dredging location, DREDGE predicts a maximum TSS concentration of approximately 12 mg/L. At 300 feet, DREDGE predicts a TSS concentration of approximately 7.3 mg/L. The downgradient extent of the plume (where TSS concentration drops below 1 mg/L) is estimated as 1,300 feet, with a maximum lateral extent of approximately 350 feet to either side of the source.

The modeled TSS concentration at 300 ft (7.3 mg/L) is slightly below the 8 mg/L concentration that may result in a turbidity of 5 NTU above background. These model results indicate that neither special operational controls nor use of a closed bucket should be required during dredging to meet the turbidity criterion in WAC 173-201A. However, because the modeled value is near the maximum allowable turbidity, the specifications indicate that the dredging contractor should be prepared to modify operational parameters (such as increasing dredge cycle time) based on actual turbidity monitoring results.

5.3 WATER QUALITY IMPACTS DURING CAPPING

The STFATE analysis described in Appendix D was used to evaluate TSS concentrations during cap placement. Table 5-4 summarizes the TSS plumes at different points in the water column at 3,600 seconds following placement. As expected, the greatest TSS concentrations are encountered near the bottom, as the deposited material collapses. The results are summarized as follows:

- **Run 1.** In RA2b, use of dredged material results in a TSS greater than 8 mg/L (i.e., NTU more than 5 over background) at a distance between 350 and 400 feet from the dump location, at near-bottom depths. TSS at the shallower depth intervals did not exceed 8 mg/L (i.e., NTU more than 5 over background). While bottom-dump placement may not be used in this location, the results may approximate turbidity impacts from other placement methods.

- **Run 2.** In RA2b, use of upland medium sand results in a TSS greater than 8 mg/L (i.e., NTU more than 5 over background) at a distance between 300 and 350 feet from the dump location, at near-bottom depths. TSS impacts are less than Run 1 due to the lower silt content. While bottom-dump placement may not be used in this location, the results may approximate turbidity impacts from other placement methods.

- **Run 3.** In RA2a, use of upland coarse sand results in a TSS greater than 8 mg/L (i.e., NTU more than 5 over background) at a distance between 150 and 200 feet from the dump location, at near-bottom depths. While bottom-dump placement may not be used in this location, the results may approximate turbidity impacts from other placement methods.

- **Run 4.** STFATE did not produce TSS output for this simulation of RA4, due to input errors related to water density.

- **Run 5.** In RA5, use of dredged material results in a TSS greater than 8 mg/L (i.e., NTU more than 5 over background) at a distance of approximately 250 feet from the dump location, at both a mid-water-column depth of 50 feet and a near-bottom depth of 150 feet. STFATE did not encounter the sediment clouds at the closer bottom depth of 165 feet; however, turbidity impacts are anticipated to extend significantly further at this near bottom depth.

Model runs were not attempted for RA1 and RA3 because placement in these areas will likely be accomplished with mechanical equipment and STFATE is not an appropriate model for these areas. In general, turbidity impacts in RA1 and RA3 will be less than in other areas, due to shallow depths and the granular construction materials used. In RA1 through RA4, placement specifications are performance based, and water quality monitoring will be performed during all construction activities. The contractor will be required to modify the construction methods if turbidity or dissolved oxygen falls outside applicable state criteria.

5.4 SUMMARY

The results of the DRET analysis indicate that chemical concentrations are not expected to exceed either the acute or chronic water quality criteria during dredging. DREDGE model results indicate that special operational controls or use of a closed bucket are not expected to be required during dredging to meet the turbidity water quality criterion. During capping, STFATE results indicate that turbidity exceedances are confined to near-bottom depth intervals. At near-bottom depths, mixing zones of up to 400 feet from the dump location may be required to attain water quality standards for turbidity. Higher in the water column, turbidity impacts should be below water quality criteria well within the mixing zone. The STFATE TSS results for RA2a, RA2b, and RA4 are based on modeled instantaneous bottom-dump placement, which is not the placement method to be used in these areas. For these areas, the STFATE results are considered a qualitative yardstick for predicting the turbidity impacts of the actual capping operations.

Water quality will be monitored at the point of compliance established in accordance with applicable regulations and as specified in the CQAP, and the contractor will be required to modify its construction methods if turbidity or dissolved oxygen impacts exceed state criteria at the mixing zone boundaries. The toxic conditions standard under WAC 173-201A-030 will be addressed by visually monitoring the work area for signs of distressed or dying fish or wildlife.

Table 5-1
Correlations of TSS and Turbidity in NTUs

Source	Correlation	Estimated TSS Corresponding to 5 NTU (mg/L)	Reference
Middle Waterway, Commencement Bay	TSS = 1.0556 (NTU)	5.27	MWAC 2001
Hylebos Waterway, Commencement Bay	TSS = 1.689(NTU) + 20.149	28.6	Hart Crowser 2001
Puget Sound Naval Shipyard, Sinclair Inlet	(not given)	50	Hart Crowser 1999
Puget Sound stream	ln (TSS) = 1.32 ln(NTU) + 0.15	9.7	Packman, Comings, and Booth 2000
Mean	–	23	–
Geometric mean	–	16	–

Notes:
mg/L - milligrams per liter
NTU - nephelometric turbidity unit
TSS - total suspended solids
– - not applicable

Table 5-2
DREDGE Module Input Parameters

Data Field Name	Selected Input Value	Rationale for Input Value
Dredge Mechanism		
Type of mechanism	Open bucket	Only other model choice is hydraulic, which is unlikely to be used at site
Bucket size	5 m^3	Low end of range of bucket sizes available in Puget Sound area
Cycle time	60 sec	Mid-range of typical values recommended by DREDGE Module User's Guide
Settling velocity	0.00066 m/sec	Calculated based on Stokes Law, for a particle size of 31 µm and a particle density of 2.65 mg/m^3.
In situ dry density of sediment	1,387 kg/m^3	Value for sandy sediment sample from site investigation – sample B6-9
Near Field Model		
TGU	5,580 g/m^3	From table provided in program, this value corresponds to sediments with d<74 µm = 27.7%, which is remarkably close to the value of 27.8% for d<74 µm from the grain-size curve from sample 207 comp.
Dredge depth	6 m	Representative water depth in area planned for dredge cuts
Bucket raise time	30% of total time	Typical value given in DREDGE Module User's Guide
Above-water time	48% of total time	Typical value given in DREDGE Module User's Guide
Bucket fall time	22% of total time	Typical value given in DREDGE Module User's Guide
User selected values for Source Strength and % loss	0.39 kg/sec and 0.21%	Source strength value selected as average of TGU and Correlation method values. DREDGE Module calculated the 0.21% value when 0.39 kg/sec was manually entered.

Table 5-2
DREDGE Module Input Parameters (Continued)

Data Field Name	Selected Input Value	Rationale for Input Value
Far-Field Model		
Lateral diffusion coefficient	3,500 cm^2/sec	Mean value of range recommended by USACE in 30% Design review comments.
Vertical diffusion coefficient	5 cm^2/sec	Mid-range of values recommended by DREDGE Module User's Guide
Settling velocity	0.00066 m/sec	Calculated based on Stokes Law, for a particle size of 31 µm and a particle density of 2.65 mg/m^3. DREDGE Module calculated a less conservative value of 0.000759 m/sec.
Downstream locations	1,000 m	Distance needed to show TSS concentrations below 0.1 mg/L
X-step	25 m	Convenient increment for display purposes
Lateral locations	250 m	Distance needed to show TSS concentrations below 0.1 mg/L
Y-Step	25 m	Convenient increment for display purposes
Desired water depth	6 m	Representative water depth in area planned for dredge cuts
Site Characteristics		
Water depth	6 m	Representative water depth in area planned for dredge cuts
Ambient water velocity	0.03 m/sec	Representative water velocity selected based on water velocity profile from CM-2. Discounts higher water velocities measured near water surface.
Mean particle size for sediment fraction passing the No. 200 sieve (diameters smaller than 74 µm)	31 µm	Based on grain-size curve from sample 207 comp., collected within proposed dredge area
Specific gravity of sediment	2.65	Typical value for sand
R_{74}	27.8%	From grain-size curve from sample 207 comp.

Table 5-2
DREDGE Module Input Parameters (Continued)

Data Field Name	Selected Input Value	Rationale for Input Value
R_0	17%	Based on the methodology described in the DREDGE module, which references Nakai (1978). R_0 is based on the estimated particle size whose critical resuspension velocity is the ambient current velocity (3 cm/s for the PSR site). This methodology gives a particle size of approximately 0.034 mm. Based on the grain size curve from sample 207 comp., fraction of the sediment less than this grain size is 17%.

Notes:
cm^2/sec - square centimeter per second
g/m^3 - gram per cubic meter
kg/m^3 - kilogram per cubic meter
kg/sec - kilogram per second
m - meter
m^3 - cubic meter
m/sec - meter per second
µm - microgram
mg/L - milligram per liter
mg/m^3 - milligram per cubic meter
mm - millimeter
R_0 - fraction of particles smaller than particles with a critical settling velocity
R_{74} - fraction of particles less than 74 microns
sec - second
TGU - turbidity generation unit

Table 5-3
Predicted Total Suspended Solids (mg/L) in Water Column During Dredging (From DREDGE)

Downstream Distance, m

Lateral Distance From Dredge, m	25	50	75	100	125	150	175	200	225	250	275	300
-250	0	0	0	0	0	0.001	0.002	0.004	0.007	0.011	0.016	0.021
-225	0	0	0	0	0.001	0.003	0.008	0.014	0.023	0.032	0.041	0.05
-200	0	0	0	0.001	0.006	0.015	0.029	0.045	0.062	0.079	0.094	0.106
-175	0	0	0.001	0.009	0.029	0.057	0.09	0.123	0.152	0.177	0.195	0.208
-150	0	0.001	0.014	0.054	0.115	0.182	0.244	0.294	0.33	0.354	0.367	0.371
-125	0	0.014	0.097	0.235	0.374	0.487	0.566	0.614	0.636	0.638	0.627	0.607
-100	0.003	0.156	0.485	0.783	0.981	1.088	1.127	1.121	1.086	1.034	0.972	0.907
-75	0.142	1.018	1.694	2.001	2.078	2.032	1.926	1.791	1.648	1.505	1.368	1.239
-50	2.063	3.886	4.137	3.908	3.55	3.176	2.823	2.503	2.219	1.967	1.745	1.549
-25	**10.29**	**8.678**	7.069	5.841	4.896	4.151	3.552	3.06	2.652	2.31	2.019	1.771
0	**17.583**	**11.344**	**8.451**	6.678	5.45	4.539	3.834	3.272	2.815	2.437	2.12	1.852
25	**10.29**	**8.678**	7.069	5.841	4.896	4.151	3.552	3.06	2.652	2.31	2.019	1.771
50	2.063	3.886	4.137	3.908	3.55	3.176	2.823	2.503	2.219	1.967	1.745	1.549
75	0.142	1.018	1.694	2.001	2.078	2.032	1.926	1.791	1.648	1.505	1.368	1.239
100	0.003	0.156	0.485	0.783	0.981	1.088	1.127	1.121	1.086	1.034	0.972	0.907
125	0	0.014	0.097	0.235	0.374	0.487	0.566	0.614	0.636	0.638	0.627	0.607
150	0	0.001	0.014	0.054	0.115	0.182	0.244	0.294	0.33	0.354	0.367	0.371
175	0	0	0.001	0.009	0.029	0.057	0.09	0.123	0.152	0.177	0.195	0.208
200	0	0	0	0.001	0.006	0.015	0.029	0.045	0.062	0.079	0.094	0.106
225	0	0	0	0	0.001	0.003	0.008	0.014	0.023	0.032	0.041	0.05
250	0	0	0	0	0	0.001	0.002	0.004	0.007	0.011	0.016	0.021

Notes:

Bold entry - value exceeds 8mg/L, which may potentially be associated with turbidity greater than 5 NTU above background

Dredge Type - Open Clamshell

Near-Field Model - User Input

Far-Field Model - Kuo's Model

Resuspended Material Selected - TSS, mg/L

Table 5-4
Predicted Total Suspended Solids in mg/L in Water Column During Cap Placement (From STFATE)

RA No.	Run No.	Depth (ft.)	Distance from Center Point of Cloud (ft)										
			0	50	100	150	200	250	300	350	400	450	500
2b	1	15	0.35	0.32	0.23	0.14	.07	.02	<.01	<.01	<.01	<.01	0
2b	1	25	654	590	439	271	143	67	29	11.3	4.2	1.56	0.52
2b	2	25	214	197	153	101	58	30	14	5.8	0	0	0
2a	3	20	24	14	2.7	0.22	<0.01	0	0	0	0	0	0
2a	3	38	217	167	80	26	5.9	1.0	0.13	0.01	0	0	0
4	4	35	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
4	4	65	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
5	5	50	69.4	61.36	43.26	23.14	10.06	3.42	0.95	0.21	.03	<.03	<.03
5	5	150	47.89	43.83	34.67	24.48	14.29	7.65	3.47	1.43	0.51	<.51	<.51
5	5	165	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E

Notes:
N/E - Not evaluated; STFATE did not encounter the sediment clouds in the RA4 and RA5 simulations at the specified depths
STFATE runs were not conducted for RA1 and RA3, as discussed in text.

6.0 REGULATORY REQUIREMENTS FOR REMEDIAL ACTION

The ROD (USEPA 1999) for the MSU requires that remedial actions comply with the applicable or relevant and appropriate requirements (ARARs). These regulatory requirements are discussed below as they pertain to the remedial actions represented in this design. Also, requirements that are legally applicable to off-site actions (e.g., material transportation, dredge material disposal) are presented. For each ARAR, the manner in which the remediation is designed to meet these requirements is discussed.

For CERCLA sites such as PSR, agency permits or approvals are not required for on-site actions, but on-site actions must be conducted in a manner that meets the substantive provisions of applicable requirements. Actions that take place off site are subject to all applicable requirements, including any administrative (e.g., permit/approval or reporting) requirements.

6.1 FEDERAL REQUIREMENTS

Federal regulatory requirements for dredging and cap construction, and how they are being met by the project design, are described below.

6.1.1 Sections 401 and 404 of the Federal Clean Water Act – Water Quality Certification and Dredge and Fill Requirements (33 USC 1340, 1344; 33 CFR Parts 320 through 330 and 40 CFR Parts 230 and 231)

Sections 401 and 404 of the Clean Water Act set forth requirements for water quality certification, and for dredging and placing fill materials into the waters of the United States, respectively, and are applicable to in-water actions at the MSU. Because these actions will take place on site, only substantive requirements of these programs apply.

Section 401 requires that a certification of water quality be issued by the responsible government authority to state that remedial actions will not violate applicable water quality standards. EPA and Ecology are examining the remedial design and as a result of that review, will make a determination regarding the ability of the project to meet water quality criteria. Based on the information and analyses presented in Section 5 of this design report, EPA anticipates that this certification is achievable. Further discussion of the specific state water quality criteria is presented in Section 6.2 of this design report. EPA will issue the water quality certification for this remedial action.

As stated in the ROD, a Section 404(b)(1) evaluation was completed for the project and it determined that the in-water remediation work complied with the requirements of Clean Water Act Section 404. Specifically, the work, as planned, complies with the substantive requirements of Nationwide Permit No. 38, Cleanup of Hazardous and Toxic Wastes. The requirements pertinent to the MSU are summarized as follows:

- **Navigation.** Activity cannot cause more than a minimal adverse impact.
- **Proper Maintenance.** Any fill must be properly maintained.
- **Erosion and Sediment Controls.** Appropriate erosion and sediment controls must be used and maintained in effective operating condition during construction, and all exposed soil and other fills, as well as any work below the ordinary high water mark or high tide line, must be permanently stabilized at the earliest practicable date.
- **Aquatic Life Movements.** Activity may not substantially disrupt the necessary lifecycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water.
- **Heavy Equipment.** Measures must be taken to minimize soil disturbance.
- **Tribal Rights.** No activity may impair reserved tribal rights.

The design specifics are intended to satisfy these requirements.

40 CFR Part 230 sets forth specific standards to implement Clean Water Act Section 404(b)(1) requirements for evaluation and testing of dredged or fill material placed into navigable waters of the U.S. The PSR capping actions include two distinct types of actions subject to these requirements:

- **Placement of Dredged Material.** Dredged material from off-site, non-CERCLA dredging projects will be used to construct the cap in RA5. Because these dredging projects occur primarily off site, they are subject to all substantive and administrative requirements of the CWA. Specifically, these projects must fulfill the requirements of DMMP testing guidelines (which are specific guidelines developed under CWA authority for management of dredged material in Puget Sound). The projects must demonstrate that dredged material proposed for

placement at PSR is suitable for open-water disposal, and the project proponents must satisfy the substantive and administrative requirements of DMMO suitability determination. The PSRMP includes procedures for verifying that all dredged material placed at PSR meets the substantive and administrative requirements of DMMO suitability determination.

- **Placement of Upland Fill Material.** Placement of fill material at PSR from upland sources is considered a CERCLA on-site action and, hence, the substantive requirements of 40 CFR Part 230 must be met. EPA will meet the requirements of 40 CFR Parts 230.60 and 230.61 (Evaluation and Testing) through consideration of such factors as the nature of material being placed, experience, and the results of import material tests that are required by the specifications. The specific requirements of DMMP testing guidelines are not applicable, as they are developed for the unique aspects of management of dredged material.

The design specifics are intended to satisfy these requirements.

6.1.2 Section 10 of the Rivers and Harbors Appropriations Act (33 USC 403; 33 CFR Part 320, 322)

Section 10 of this statute prohibits the unauthorized obstruction or alteration of any navigable waters of the United States, which includes the subject area. Procedures set forth by USACE in 33 CFR Parts 320 and 322 require an examination of the impact of the action, in this case in situ capping, on the public interest. The requirements of Section 10 have been addressed by USACE at the same time it addressed the requirements of Section 404 of the Clean Water Act.

6.1.3 Federal Clean Water Act – Water Quality Criteria (33 USC 1251-1376)

The ROD specifies that acute marine criteria set forth under the federal Clean Water Act are relevant and appropriate requirements for discharge to marine surface water during sediment dredging, dewatering, and cap placement. Therefore, dredging and cap placement must not cause exceedances of these criteria in the water outside the mixing zone.

These chemical criteria are not expected to be exceeded outside the mixing zone, as discussed in Section 5 of this design report. The mixing zone applicable to the MSU is described under the Washington State Clean Water Act in Section 6.2 of this design report.

6.1.4 Endangered Species Act (16 USC 1531 et seq.; 50 CFR Parts 17, 200, 402)

Section 7 of the Endangered Species Act (ESA) requires that federal agencies consider the effect of proposed actions on federally threatened or endangered (T/E) species. As noted in Section 7 of this design report, several T/E wildlife and fish species may be present in the site area. EPA has been consulting informally with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) about the potential effects of remedial activities and ways to minimize those effects. A biological assessment has been prepared for this project by USACE.

Once the biological assessment is complete, the USFWS and NMFS will issue a biological opinion as to whether the activity as proposed would jeopardize the existence of the listed species. If so, the NMFS may suggest project modifications that if followed, would reduce adverse project effects below the "jeopardy" threshold and allow the activity to proceed. If a no jeopardy opinion is issued by the USFWS and NMFS, the activity may be conducted as planned. Based on ongoing consultation, allowable periods of in-water work have been identified and specific habitat enhancement measures have been included in the design. The biological opinion may include additional conservation measures (such as restrictions on allowable work periods in certain areas, or monitoring for presence of listed species) that are intended to minimize impacts on listed species. The design reflects the identified conservation measures.

6.1.5 Fish and Wildlife Coordination Act (16 USC 661 et seq.)

This statute establishes criteria to protect fish and wildlife that could be affected by proposed or authorized federal projects involving "impounding, diverting, or controlling waters." EPA is consulting with the USFWS and the WDFW regarding the potential effects of the project on fish and wildlife and measures that would minimize or mitigate those impacts. Also, the statute requires that adequate provision be made for the conservation, maintenance, and management of fish and wildlife resources and their habitats. The ESA consultation described above will also satisfy the requirements of the Fish and Wildlife Coordination Act.

6.1.6 Resource Conservation and Recovery Act (Subtitle C) Hazardous Waste Program [42 USC 6921 through 6939(e)] and Regulation [40 CFR 261.4(g)]

In 1998, EPA exempted dredged contaminated sediments subject to Clean Water Act Section 404 requirements from regulation as a hazardous waste, in terms of disposal within water or on land where there is discharge back to surface water. The disposal of dredged sediments in an upland facility where there is no connection to surface water is not exempt from regulation. However, testing of the sediments using toxicity characteristics leaching procedure (TCLP) and other

chemical analyses indicates that the sediments dredged for off-site disposal will not designate as a hazardous waste (USEPA 2002b).

6.1.7 Resource Conservation and Recovery Act (Subtitle D) Nonhazardous Solid Waste Program [42 USC 6941 through 6949(a)] and Regulations (40 CFR Parts 257, 258)

The upland disposal of dredged contaminated sediments is not exempt from federal and state solid waste management requirements. The requirements of the federal regulations have been incorporated into Ecology's solid waste regulations, which are presented in Section 6.2.

6.1.8 Native American Graves Protection and Repatriation Act (NAGPRA), 25 USC. § 3001 et seq., 43 CFR Part 10

It is possible that disturbance of Native American materials from earlier times may occur as a result of sediment dredging. NAGPRA and implementing regulations are intended to protect Native American graves from desecration through the removal and trafficking of human remains and "cultural items" including funerary and sacred objects. To protect Native American burials and cultural items, the regulations require that if such items are inadvertently discovered during excavation, the excavation must cease and the affiliated tribes notified and consulted. The specifications require the dredging contractor to cease excavation, should such items be observed in the materials being loaded onto the barges. Such materials are not known to exist at the site.

6.1.9 National Historic Preservation Act (NHPA), 16 USC §470f, 36 CFR Parts 60, 63, and 800

If Native American or other cultural materials are unearthed as part of the dredging process, NHPA and implementing regulations require that federal agencies consider the possible effects on historic sites. If an agency finds a potential adverse effect on historic sites or structures, the agency must evaluate alternatives to "avoid, minimize, or mitigate" the impact, in consultation with the State Historic Preservation Officer (SHPO). The specifications require the dredging contractor to cease excavation, should such materials be observed in the materials being loaded onto the barges.

6.1.10 Archaeological Resources Protection Act (ARPA), 16 U.S.C. § 470aa et seq., 43 CFR Part 7

Should cultural materials be discovered in dredged sediments, the requirements of ARPA and its implementing regulations may apply. This program prohibits the unauthorized disturbance of archaeological resources on public and Indian lands. Archaeological resources are "any material remains of past human life and activities which are of archaeological interest," including pottery, baskets, tools, and human skeletal remains. The unauthorized removal of archaeological resources from public or Indian lands is prohibited, and any archaeological investigations at a site must be conducted by a professional archaeologist. The specifications require the dredging contractor to cease excavation, should such items be observed in the materials being loaded onto the barges.

6.1.11 Magnuson-Stevens Fishery Conservation and Management Act, 16 USC 1801 et seq., 50 CFR Part 600

Consideration of the effects of federal actions on Essential Fish Habitat (EFH) for species such as salmon is required under the Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801 et seq.) and its implementing regulations (50 CFR Part 600), finalized January 17, 2002. Typically state or federal agencies planning actions that might adversely affect an EFH-managed species must formally consult with NMFS regarding the action. Under 50 CFR 600.920(f), however, existing environmental review procedures for federal actions may meet EFH consultation requirements, if three criteria are met:

- The existing process must provide NMFS with timely notification of actions that may adversely affect EFH.
- Notification must include an assessment of the impacts of the proposed action on EFH.
- NMFS must make a finding that the existing environmental review process satisfies the statutory requirements (see 50 CFR 600.920(e)(3)).

NMFS has found for a number of other federal projects that an existing ESA environmental review process (such as the one being followed at PSR) satisfies the requirements of the Magnuson-Stevens Fishery Conservation and Management Act. It is expected that NMFS will issue such a finding via a letter to the federal PSR parties, although it may include certain specific stipulations.

6.2 STATE REQUIREMENTS

Washington State regulatory programs promulgated by Ecology and the WDNR contain design requirements that are ARARs for work within the MSU, and legally applicable requirements for off-site disposal. These regulatory requirements, and how they are being met by the project design, are described below.

6.2.1 Solid Waste Management Act (Ch. 70.95) and Regulations

The regulations implementing this act (Ch. 173-304 WAC, Minimum Functional Standards for Solid Waste Handling; Also Proposed Regulation Ch. 173-350 WAC, Solid Waste Handling Standards, Which When Final, Will Replace Ch. 173-304 WAC; and Ch. 173-351 WAC, Criteria for Municipal Solid Waste Landfills) are applicable to disposal of dredged material. Because the disposal of the dredged sediments will take place in a permitted solid waste landfill that is outside the site boundaries, both substantive and administrative requirements of applicable regulations must be met for this activity. Sediments and potentially debris will be removed from the site as part of the RA, and disposed of in a permitted solid waste landfill.

The off-site rule (40 CFR 302.440) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requires that solid and hazardous waste off-site landfills to which CERCLA hazardous substances are being sent must be acceptable to EPA. The project specifications require the contractor to obtain EPA approval of the proposed disposal facility.

In practical terms, the requirements for disposal of MSU dredged sediments will be found in the permit of the landfill that agrees to accept the waste. For example, the Roosevelt Regional Landfill's permit allows it to accept sediments that, while dewatered, do not need to pass the paint filter test (to limit free-draining liquids) before disposal.

6.2.2 Model Toxics Control Act Regulations (WAC 173-340-440)

These regulations contain a section addressing the use of institutional controls at cleanup sites. The institutional controls (ICs) identified in the PSR ROD (primarily anchoring restrictions) will be implemented in accordance with these regulations. ICs are also required for maintaining the integrity of engineered controls at the site (caps, monitoring).

The institutional control for anchoring will be implemented through federal rule-making as described in Section 1.7.

6.2.3 Water Quality Standards for Surface Waters (Ch. 90.48 and 90.54 RCW; Ch. 173-201A WAC)

Elliott Bay has been designated by Ecology as a "Class A" water body, meaning that it is of "excellent" quality. WAC 173-201-030(2) sets forth water quality standards that must be met in Class A waters. The most important standards for sediment capping and dredging activities as previously discussed, are turbidity, dissolved oxygen, and toxic substances limits.

The location where these water quality standards must be met is outside the boundary of the mixing zone, which for "oceanic waters" (the category into which the MSU fits), extends up to 300 horizontal feet plus the depth of water over the discharge point (WAC 173-201A-100).

Based on the information in Section 5 of this design report, toxic substance limits are not anticipated to be exceeded outside the mixing zone. Water quality monitoring during construction will include dissolved oxygen and turbidity. The specifications require the contractor to modify operations if exceedances of these criteria occur at the mixing zone boundary. EPA will determine the final mixing zone boundaries consistent with the requirements of Section 401 of the federal Clean Water Act.

6.2.4 Point Source Discharges to Surface Water (Ch. 90.48 and Ch. 90.54 RCW) and Regulations (Ch. 173-220 WAC)

These regulations govern the point source discharge of pollutants to surface water. The dredged sediments will be dewatered on site, on a barge, during the course of the dredging activities. Therefore, the substantive requirements of the state National Pollutant Discharge Elimination System (NPDES) program will be satisfied by the water quality monitoring described above. That is, the discharge must not cause a violation of surface water quality standards outside the established mixing zone. The activity will be conducted so as to meet applicable water quality standards at the mixing zone boundary.

6.2.5 Construction Projects in State Waters (Ch. 77.55 RCW) and Hydraulics Project Approval Regulations (Ch. 220-110 WAC)

This state program administered by the WDFW sets forth requirements for projects that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state. The purpose of this program is to minimize project-specific and cumulative impacts to fish life in a particular water body.

Technical provisions of the regulation pertaining to saltwater projects are found in WAC 220-110-220 through 220-110-330. Technical provisions regarding use restrictions for bed materials, siltation minimization, debris disposal, and other miscellaneous criteria are provided in WAC 220-110-270. Work within juvenile salmonid migration, feeding, and rearing areas such as the project area is prohibited from March 15 to June 14 each year (WAC 220-110-271). Additional restrictions on the dates and types of in-water work that will be allowed will be identified in consultation with the agencies (see Section 2.6 of this design report).

Although this CERCLA on-site action does not require permits (in this case a hydraulic project approval), the elements of the MSU remedial design include provisions to satisfy substantive requirements of this regulation. Further, coordination and consultation with USFWS, NMFS, and WDFW under the ESA, the Fish and Wildlife Coordination Act, and the Hydraulic Code will ensure that design elements meet the requirements for all these programs.

6.2.6 Shoreline Management Act (Ch. 90.58 RCW)

The purpose of the Shoreline Management Act (SMA) is to protect and manage shoreline environments. The MSU includes a shoreline of the state and thus is subject to the substantive requirements of the act and its regulations. A shoreline is defined in the statute as extending landward 200 feet from the ordinary high water mark.

According to SMA regulation WAC 173-27-060, federal agency actions within a coastal county such as King County must be consistent to the maximum extent practicable with the approved Washington state coastal zone management program, subject to certain limitations set forth in the Federal Coastal Zone Management Act, 16 U.S.C. 1451 et seq. (CZMA) and regulations adopted pursuant to it. The SMA is incorporated into the Washington state coastal zone management plan and, thereby, those direct federal actions occurring on lands subject to the act must be consistent to the maximum practicable extent with the act, with regulations adopted pursuant to the act, and with the local master program.

6.2.7 Aquatic Lands Management Laws (Ch. 79.90 through 79.96 RCW) and Regulations (Ch. 332-30 WAC)

The statutes and regulations pertaining to aquatic lands management are implemented by the DNR. The State owns these aquatic lands (tidelands, shorelands, harbor areas, and the beds of navigable waters) in fee and has delegated to the DNR the responsibility to manage these lands for the benefit of the public. Coordination and consultation with DNR will ensure that design elements meet the requirements for these regulations.

6.2.8 Washington State Sediment Management Standards (SMS) (Ch. 173-204 WAC)

The SMS establish a narrative standard with specific biological effects criteria and numerical chemical concentrations for Puget Sound sediment. Under the SMS, the cleanup of a site should result in the elimination of adverse effects on biological resources and any health threats to humans. The Sediment Quality Standards (SQS) correspond to this narrative for ecological effects. Under the SMS, site-specific cleanup standards are established from a range of concentrations based on environmental effects, feasibility, and cost; they are to be as close as practicable to the SQS and no greater than the minimum cleanup levels (MCUL). The MCUL are equivalent to the cleanup screening levels (CSL).

Attainment of the overall cleanup objectives, as specified in the ROD, will be measured by compliance with the SMS. The CSL for PAHs serves as the trigger for active remediation of the MSU; the SQS for PCBs is the trigger for active remediation of sediments in the nearshore environment (shallower than –10 feet MLLW). The marine sediment cap is the primary component to achieve CSL and SQS in the MSU.

All imported capping material (with the exception of coarse-grained rock such as riprap) will be sampled to establish that import material chemical concentrations are below the SQS. The final surface of the constructed cap will also be sampled to demonstrate that the cap has been successfully placed, resulting in SQS or lower concentrations throughout the capped area.

6.3 LOCAL REQUIREMENTS

6.3.1 Puget Sound Clean Air Agency Requirements

The Puget Sound Clean Air Agency (PSCAA) requires control of fugitive dust emissions generated by activities within its region. Specifically, Regulation I, Section 9.15 (Fugitive Dust Control Measures) prohibits visible emissions of fugitive dust unless reasonable precautions are employed to minimize these emissions. Examples of reasonable precautions are listed in the regulations.

Clean materials brought to the site to construct the sediment cap will be managed in accordance with the requirements of this regulation.

6.3.2 City of Seattle Noise Ordinance

The City of Seattle's noise ordinance (Seattle Municipal Code, Ch. 25.08, Noise Control) sets maximum noise emission levels for two time periods: one, for daytime (7 a.m. to 10 p.m.); and two, for weeknights (10 p.m. to 7 a.m.), and weekends and holidays (10 p.m. to 9 a.m.). Maximum permissible noise levels within the City of Seattle are listed in Tables 6-1 and 6-2.

The site and its immediate area are within the industrial zone. The contractor will control noise emissions such that they are no louder than the "industrial" sound sources in Tables 6-1 and 6-2.

6.3.3 City of Seattle's Shoreline Master Program

Activities within 200 feet of the shoreline must be consistent with allowable actions under the City of Seattle's Shoreline Master Program (see SMC Ch. 23.60, Shoreline District). The cleanup and shoreline habitat enhancements that are part of this design may ultimately allow public access to be restored to beach areas, consistent with the goals of the Shoreline Master Program.

Table 6-1
Daytime Permissible Noise Levels (Decibels)

District of Sound Source	District of Receiving Property		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

Note:
Applies 7 a.m. to 10 p.m. weekdays and 9 a.m. to 10 p.m. weekends/holidays

Table 6-2
Weeknight/Weekend/Holiday Permissible Noise Levels (Decibels)

District of Sound Source	District of Receiving Property		
	Residential	Commercial	Industrial
Residential	45	57	60
Commercial	47	60	65
Industrial	50	65	70

Note:
Applies weeknights (10 p.m. to 7 a.m.) and weekend/holiday nights (10 p.m. to 9 a.m.)

7.0 HABITAT CONSIDERATIONS

This section summarizes key information used in preparing the biological assessment (BA), including an overview of the ecological setting of the MSU, a list of the threatened or endangered species that may be affected by the cleanup, and a summary of the effects of the cleanup on the MSU habitat. As discussed in Section 9, the USACE has prepared the BA.

7.1 ECOLOGICAL SETTING

A detailed description of the ecological setting of the MSU, including habitats and biota, is provided in the ecological and human health risk assessment technical memorandum (USEPA 1998a, Appendix K). The following sections briefly summarize this information.

7.1.1 Intertidal and Subtidal Habitats

Uplands surrounding Elliott Bay have been developed for urban, port, and industrial land uses, resulting in the elimination of nearly all intertidal wetlands and shallow subtidal aquatic habitats (PTI and Tetra Tech 1988). Although estimated to be limited in area (the remedial investigation estimated about 2.3 acres) based on the lowest spring tides, intertidal habitats present in the MSU include mud- and sandflats, in addition to bulkheads, pilings, and riprap. Presently, the mudflats and sandflats exist as four small pocket beaches. The remaining intertidal mud or sand flats occur only as a thin strip at the toe of the riprapped banks and are exposed only at extreme low tides. Subtidal habitats in Elliott Bay primarily consist of sandy silts, and muddy and coarse sands, except at the mouth of the Duwamish River, where sandy substrates predominate (Dexter et al. 1981; PTI and Tetra Tech 1988). The MSU is located in a transition zone between the estuarine environment of the Duwamish River and the marine environment of Elliott Bay; as a result, the substrates and waters of the MSU contain habitat characteristics common to both environments.

7.1.2 Biota

Biota utilizing available habitat within the MSU include a variety of marine invertebrates, estuarine and marine fishes (including salmonids), birds, and marine mammals.

Common marine invertebrates on the piling surfaces, riprap, and bulkheads include barnacles, tube-dwelling worms, sea anemones, sponges, tunicates, and mussels. Marine invertebrates

documented or anticipated to utilize the offshore subtidal habitat of the MSU include a variety of polychaetes, clams, mussels, crab, and shrimp.

Habitats within the MSU provide nesting and adult forage areas on either a seasonal or year-round basis for numerous estuarine and marine species of fish, including Pacific herring, shiner perch, snake prickleback, Pacific tomcod, pile perch, Pacific sand lance, copper rockfish, Pacific staghorn sculpin, and various flatfish species, most notably English sole (Tetra Tech 1988; Dexter et al. 1981). The most abundant fish species collected during the remedial investigation fish trawling activities included English and slender sole, Pacific hake, and Pacific tomcod.

Salmonids represent the most important anadromous fish present in the vicinity of the MSU. Chinook, pink, and chum salmon are common, while coho and sockeye salmon, steelhead trout, bull trout, and cutthroat trout are less abundant. Multiple migratory runs of both native and hatchery reared salmonid stocks occur seasonally in Elliott Bay and Duwamish River (Warner and Fritz 1995). Returning adult salmon congregate at the mouth of the Duwamish River east of the MSU prior to upstream migrations, and juvenile salmonids may use the nearshore reaches of the MSU for physiological transition to marine waters.

The MSU provides habitat to a number of terrestrial and water-dependent birds, including loons, grebes, cormorants, scaups, mergansers, scoters, coots, and gulls. The majority of these birds utilize the water-column habitat in the vicinity of the MSU during their respective overwintering periods. Two state monitor species, the osprey and great blue heron, breed close to and possibly feed on fish within the MSU. However, the great blue heron utilizes primarily shallow water habitats that can be accessed by wading or perching on structures immediately next to or floating on the water surface. This type of habitat is extremely limited at the site and in some cases exists only under pier structures. In addition, two other state monitor species (the horned grebe and red-necked grebe), as well as five state candidate species (the western grebe, Brandt's cormorant, merlin, common murre, and Cassin's auklet), and two state sensitive species (the peregrine falcon and common loon) are also likely to forage or utilize surface waters in the MSU. The bald eagle (a state and federally listed threatened species) and the peregrine falcon (federal species of concern) have also been observed in the vicinity of the site. The bald eagle may feed on fish occurring in the area. However, the peregrine falcon feeds primarily on other birds (usually song or shore birds). Occurrence of these prey species at the site is habitat-limited, thus remedial activities will not likely impact these species. The marbled murrelet (state and federally threatened) depends on nesting in old growth and feeding in coastal marine environments. The murrelet is more common in northern Puget Sound. Other species that winter in Puget Sound and may be present in the project area include the brown pelican (state and federally endangered) and the harlequin duck (federal species of concern).

Marine mammals known to frequently forage in Elliott Bay include harbor seals and California sea lions. The harbor porpoise (historically common in south Puget Sound) is also seen infrequently and is a state candidate species. Harbor porpoise and harbor seals are year-round residents, while California sea lions utilize the area for winter feeding (Pfeifer 1991). Both the harbor seal and the California sea lion are state monitor species and have been observed hauled out on floating structures near the site.

The WDFW, USFWS, and NMFS have classified several species of special concern (i.e., requiring protective measures for their perpetuation due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance). Special-status fish and wildlife species with their corresponding federal and state status are listed in Table 7-1.

7.2 THREATENED OR ENDANGERED SPECIES

Species are listed under the ESA as either *endangered, threatened, proposed,* or *candidate.* Species listed as *threatened* or *endangered* receive federal protection. Species listed as *proposed* receive limited federal protection (i.e., are subject to the ESA Section 7 consultation requirement for federal actions). *Candidate* species are those that could become listed during the course of the project. Candidate species receive no mandatory federal protection under the ESA, but NMFS and USFWS encourage voluntary protection of the species.

7.2.1 ESA Threatened or Endangered Species

Federally threatened or endangered species that may be present in the vicinity of the project are listed in Table 7-2. A brief description of their occurrence in Elliott Bay is provided below. Consultation with the USFWS and the NMFS is required if the project will affect species listed under the ESA. The BA addresses the project impacts on those species as well as threatened and endangered species listed in Table 7-2. (Candidate species are not addressed in the BA.)

Chinook salmon, bull trout, bald eagles, and the marbled murrelet are common in Puget Sound year-round; however, the marbled murrelet is more common in northern Puget Sound. There are no breeding, haulout, or aggregation areas of Steller sea lions in Puget Sound or Elliott Bay. The California sea lion is very common (not federally listed) and seen at the Ballard locks and Shilshole Marina. However, only one or two Steller sea lions are thought to be in Puget Sound at any given time. One or two humpback whales have been sighted in Puget Sound (but none in Elliott Bay). The nearest sightings were near Alki Beach and Sinclair Inlet in 1999 and 2000, respectively. There were no sightings in 2001. There has been one sighting to date in Admiralty Inlet (March 2002). The leatherback sea turtle is common on the outer coast of Washington, but

may enter Puget Sound to forage on aggregations of jellyfish. There are no confirmed sightings in Elliott Bay to date. A few brown pelicans winter in Puget Sound every year.

7.2.2 ESA Proposed Species

There are no proposed species in the project area.

7.2.3 ESA Candidate Species

Puget Sound/Straight of Georgia coho salmon and Pacific hake are ESA candidate species.

7.3 ESSENTIAL FISH HABITAT (EFH) SPECIES

Chinook, coho, and Puget Sound pink salmon and marine fishes are EFH species. Consultation with NMFS under the Magnuson-Stevens Fishery Conservation and Management Act is required if a project will affect EFH.

7.4 SUMMARY OF HABITAT CHANGES RESULTING FROM REMEDIATION

7.4.1 Project Habitat Objectives

In addition to the overall remediation objectives, the design of the capping systems in the MSU is based on fulfilling the following overall habitat objectives:

- To select and place cap material in such a way as to provide appropriate habitat for native marine organisms
- To increase and enhance littoral habitat conditions for migration of juvenile salmonids, with an emphasis on maximizing habitat gains in the most productive target elevations of -4 to +4 feet MLLW
- To minimize (to the extent practicable) temporal loss of ecological functions that result from project implementation

7.4.2 Areas Affected by Capping

As discussed in Section 4, the cap design area totals 58 acres. The cap will result in habitat enhancement along approximately 2,000 feet of shoreline.

Approximately 65 acres outside the cap boundaries are anticipated to be affected by deposition of cap material. The bulk of this off-site depositional area (58 of the 65 acres) is associated with RA5, and occurs at depths below -150 feet MLLW.

7.4.3 Substrate Modifications

The primary substrate modification will be conversion of contaminated substrate (exceeding CSLs) to clean substrate in the 58-acre cap design area. Clean cap material will also cover the less-contaminated substrate outside the cap design area, and much of this area exceeds the SQS.

The sand cap mix and dredged cap material used in RA2b, RA4, and RA5 will be a silty sand material similar to the existing substrate, although potentially sandier. The coarse sand and gravels placed in RA1, RA2a, and RA3 (approximately 13 acres) will be considerably coarser than the existing substrate, but are required for erosion resistance. In areas where riprap is needed for slope stability in RA1, habitat mix will be placed over the riprap at elevations between -10 and +13 feet MLLW to enhance habitat value.

Additional substrate enhancement will be provided on the existing riprap bank at elevations above the cap design limits. Habitat mix will be placed over existing riprap at elevations above the point where the cap tapers into the riprap. The habitat mix is intended to fill the interstitial spaces between the riprap materials, enhancing the habitat for the benthos. Above approximately +15 feet MLLW and along approximately 550 feet of shoreline, the existing riprap will be amended with topsoil in the interstices to support vegetation.

7.4.4 Changes in Habitat Areas

The cap design for intertidal and littoral areas is based on maximizing the extent of gently sloping, clean gravel substrate. Placement of the cap will result in a net increase of 1.3 acres of littoral habitat by conversion of an equivalent area of sublittoral habitat, with no net change in area of existing waters of the United States. Table 7-3 summarizes the net habitat area changes resulting from the remediation.

Table 7-4 presents a breakdown of the habitat area changes within the littoral zone, which is entirely within RA1. In coordination with the Natural Resource Trustees, a project goal was

established to maximize the areas of the cap that fall within certain intertidal elevations (-4 to +4 feet MLLW) that are deemed the most critical and productive habitat for salmonids. To this end, and consistent with the other cap design criteria, efforts have been made to minimize the presence of the relatively steep, armored thick slope cap between -4 to +4 feet MLLW and maximize the use of flatter slopes at these elevations. The RA1 design results in a net gain of 0.64 acre of habitat between -4 and +4 feet MLLW.

7.4.5 Additional Habitat Enhancements

In coordination with the Natural Resource Trustees, specific habitat enhancements have been included in the RA1 design. These measures are described in Section 4.3.4 and shown on the drawings, and include soil amendments, plantings of riparian vegetation, and placement of LWD. These elements will add habitat complexity and an ongoing source of organic matter input in the newly constructed and expanded littoral habitat. As discussed in Section 4.3.4, there is a 1-year vegetation establishment period during which the vegetation will be monitored. There is no planned long-term monitoring, maintenance, or adaptive management specific to the vegetation or LWD.

Table 7-1
Special Status Wildlife and Fish That Occur in Puget Sound and May Occur Within the Vicinity of the MSU

Common Name	Scientific Name	Status		
		WDFW	USFWS	NMFS
Birds				
Osprey	*Pandion haliaetus*	M	None	None
Great blue heron	*Ardea herodias*	M	None	None
Horned grebe	*Podiceps auritus*	M	None	None
Red-necked grebe	*Podiceps grisegena*	M	None	None
Western grebe	*Aechmophorus occidentalis*	C	None	None
Brandt's cormorant	*Phalacrocorax penicillatus*	C	None	None
Merlin	*Falco clumbarius*	C	None	None
Common murre	*Uria aalge*	C	None	None
Cassin's auklet	*Ptychoramphus aleuticus*	C	SoC	None
Peregrine falcon	*Falco peregrinus*	S	SoC	None
Common loon	*Gavia immer*	S	None	None
Bald eagle	*Haliaeetus leucocephalus*	T	T	None
Marbled murrelet	*Brachyramphus marmoratus*	T	T	None
Brown pelican	*Pelecanus occidentalis*	E	E	None
Harlequin duck	*Histrionicus histrionicus*	None	SoC	None
Mammals				
Steller sea lion	*Eumetopias jubatus*	T	None	T
California sea lion	*Zalophus californianus*	M	None	None
Harbor seal	*Phoca vitulina*	M	None	None
Harbor porpoise	*Phocoena phocoena*	C	None	None
Orca whale	*Orcinus orca*	C	None	None
Gray whale	*Eschrichtius robustus*	S	None	None
Humpback whale	*Megaptera novaeangliae*	E	None	E

Table 7-1 (Continued)
Special Status Wildlife and Fish That Occur in Puget Sound and May Occur Within the Vicinity of the MSU

Common Name	Scientific Name	Status		
		WDFW	USFWS	NMFS
Fish				
Puget Sound chinook	*Oncorhynchus tshawytscha*	C	None	T
Bull trout	*Salvelinus confluentus*	C	T	None
Pacific cod	*Gadus macrocephalus*	C	None	None
Pacific hake	*Merluccius productus*	C	None	C
Walleye Pollock	*Theragra chalcogramma*	C	None	None
Brown rockfish	*Sebastes auriculatus*	C	None	None
Copper rockfish	*Sebastes caurinus*	C	None	None
Greenstriped rockfish	*Sebastes elongatus*	C	None	None
Widow rockfish	*Sebastes entomelas*	C	None	None
Yellowtail rockfish	*Sebastes flavidus*	C	None	None
Quillback rockfish	*Sebastes maliger*	C	None	None
Black rockfish	*Sebastes melanops*	C	None	None
China rockfish	*Sebastes nebulosus*	C	None	None
Tiger rockfish	*Sebastes nigrocinctus*	C	None	None
Bocaccio rockfish	*Sebastes paucispinis*	C	None	None
Canary rockfish	*Sebastes pinniger*	C	None	None
Redstripe rockfish	*Sebastes proriger*	C	None	None
Yelloweye rockfish	*Sebastes ruberrimus*	C	None	None
Puget Sound-Straight of Georgia coho salmon	*Oncorhynchus kisutch*	None	None	C
Pacific lamprey	*Entosphenus tridentatus*	None	None	SoC
Reptiles				
Leatherback sea turtle	*Dermochelys coriacea*	E	None	E

Source: WDFW

Explanation of status codes:
C = Candidate for listing as threatened or endangered
E = Endangered
M = Monitor
S = Sensitive
SoC = Species of Concern
T = Threatened

Table 7-2
Threatened or Endangered Species that May Occur in or Near the Vicinity of the MSU

Threatened	Endangered
Puget Sound chinook salmon	Humpback whale
Bull trout	Leatherback sea turtle
Bald eagle	Brown pelican
Marbled murrelet	
Steller sea lion	

Table 7-3
Total Habitat Area Changes Resulting From Remediation

RA	Areas in Acres					
	Existing Conditions		Post-Remediation		Net Change	
	Below -10 feet MLLW	-10 to +14.8 feet MLLW	Below -10 feet MLLW	-10 to +14.8 feet MLLW	Below -10 feet MLLW	-10 to +14.8 feet MLLW
1	2.97	4.05	1.68	5.34	-1.29	1.29
2a	5.08	0	5.08	0	0	0
2b	2.68	0	2.68	0	0	0
3	0.97	0	0.97	0	0	0
4	20.62	0	20.62	0	0	0
5a	20.00	0	20.00	0	0	0
5b	1.94	0	1.94	0	0	0
TOTAL	54.26	4.05	52.97	5.34	**-1.29**	**1.29**

Table 7-4
Littoral Zone Habitat Area Changes Resulting From Remediation

Elevations (ft MLLW)	Areas in Acres		
	Existing Conditions	Post-Remediation	Net Change
-10 to -4	1.69	0.85	-0.84
-4 to +4	1.39	2.03	0.64
+4 to +11.2	0.65	1.98	1.32
+11.2 to +14.8	0.32	0.49	0.17
Total: -10 to +14.8	4.05	5.34	**1.29**

Notes:
All changes in littoral habitat area occur in RA1
MHHW = +11.2 feet MLLW
RA1 area = 7.02 acres

8.0 REMEDIAL STRATEGY

Implementing a capping remedy in an area with varying site conditions, varying sources of materials, and potentially limited material availability necessitates the development of and adherence to a construction strategy that minimizes short-term impacts to the environment and to commercial marine related activities, while remaining cost effective. This section describes the construction and contracting strategies.

8.1 REMEDIAL CONSTRUCTION STRATEGY

The overall construction strategy has been developed with the following goals:

- Sequence the remediation to obtain the greatest ecological benefits as early as possible.
- Minimize logistical conflicts between multiple contractors.
- Minimize the short-term, construction-related impacts to aquatic resources and commercial marine related activities.
- Allow for the beneficial re-use of dredged material as capping material.
- Provide the greatest risk reduction as early as possible.
- Implement the design in a cost-effective manner.

The general approach to the major construction elements (in the general order of construction) is described below. Specific information on construction sequencing and scheduling is provided in Section 11. The construction schedule reflects the strategy described below, and emphasizes removing the piling and completing construction of the RA1 cap before the end of the first construction season (e.g., before February 14, 2004). It is stressed, however, that this schedule is subject to change as the construction contractor (for RA1 through RA4) will submit a construction schedule for USACE and EPA approval. The contractor's construction schedule will comply with restrictions on allowable periods for in-water work that are identified in the specifications and discussed in Section 11.

8.1.1 Piling Removal

Several hundred piles and associated overhead wooden structures in the nearshore area will be removed to facilitate placement of the nearshore capping system. Design and construction of the piling removal will be executed by the Port of Seattle and will be coordinated to minimize the impact on marine resources, Port and other marine navigation activities, public access to existing park facilities, nearshore capping construction, and the required dredging in RA3. The piling design will include extraction of the piles where practicable, or otherwise cutting the piling at the mudline and leaving the stubs in place, consistent with the ROD. EPA is coordinating with the Port of Seattle to accomplish the piling removal before capping and dredging activities begin.

8.1.2 Dredging in RA3

Dredging in the vicinity of Crowley Marine Services (including RA3 and nearby portions of RA1) can be completed independently of other remedial actions but will need to be coordinated with nearshore capping construction and piling removal activities. The dredging must precede capping in RA3 and adjacent RA1 and RA2a. To minimize potential logistical conflicts between contractors, the dredging will be accomplished under the same contract as the capping in RA1. The contractor will dewater the dredged material on barges in the dredge area to minimize any off-site discharges of dredged material and associated short-term impacts to aquatic resources. Dredging of RA3 and adjacent capping in RA1 will necessitate shutting down operations at Crowley Marine Services for approximately a 3 to 5 week period, likely in autumn 2003.

8.1.3 Capping in RA1 Through RA4

Upland material will be used to construct the cap in these areas. Construction considerations for RA1 through RA4 are described below.

- **Capping and Outfall Extension in RA1.** It is desired to complete all work in RA1 within the first construction season. The intertidal area is potentially the most ecologically sensitive area of the MSU and provides the greatest opportunity for habitat enhancement and beach establishment. RA1 also presents geotechnical challenges related to slope stability and specific materials are required for erosion resistance. Construction in RA1 will need to be coordinated to minimize the impact on marine resources, Port and Crowley marine navigation activities, tribal fishing, public access to existing park facilities, and piling removal and dredging activities. Placement of the outfall extension in RA1 will follow the dredging activities as soon as practical, as the dredged slopes for the outfall extension are temporary and could slough if left open for extended periods.

In the portions of RA1 where armor material is required (i.e., in thick slope cap areas), the filter layer and armor material will be placed as soon as possible following completion of the cap subgrades, to avoid erosion. Specific placement sequence notes are included in the drawings. The specifications require the contractor to place the riprap in sections along the slope, immediately after the slope has been dressed with graded filter layer material. This is intended to minimize any damage to the filter layer materials due to tidal fluctuations.

- **Capping in RA2a, RA2b, and RA3.** These areas are located in relatively shallow water and do not pose unusual construction concerns for a project of this type. However, RA2a and RA3 are potentially susceptible to prop scour, which (in their existing uncapped condition) may pose some risk of resuspension of contaminated material and recontamination of newly-capped adjacent areas. Therefore, RA2a and RA3 should be capped as soon as possible after RA1 is completed. Construction in RA2a and RA3 will need to be coordinated to minimize the impact on Port and other marine navigation activities, and will necessitate shutting down or limiting operations at Crowley Marine Services for an approximate 3- to 5-week period, likely in early summer 2004. Because the cap design in RA2a and RA3 includes a top layer of armor material, the armor material must be placed before tug navigation resumes in this area to avoid erosion of the sand cap mix. Capping of RA2b will follow RA2a and RA3.

- **Capping in RA4.** Placement of a cap in this area presents geotechnical challenges associated with steep slopes, relatively deep water, and the potential for triggering submarine landslides during cap placement. Specialized placement methods are required to minimize the potential for short-term and long-term slope instability. Capping in RA4 will begin in the second construction season (following RA2a, RA2b, and RA3) and is anticipated to be complete by the end of the second construction season. However, it is possible that production rates could be lower than anticipated and construction of RA4 could extend into a third construction season. To enhance slope stability during construction, cap placement in RA4 will occur in several segments (as shown on the drawings) and proceed from the bottom of the slope, working upward. Interference with marine navigation activities is not anticipated to be a major concern in this area, although coordination will be required.

8.1.4 Capping in RA5

Dredged material will be used to construct the cap in RA5. RA5 is amenable to more simplified cap placement measures, similar to bottom-dump disposal of dredged material that occurs at DMMP disposal sites. Capping will take place over a number of years as clean dredged material from other locations becomes available for use as capping material. Specific procedures and construction quality control provisions have been developed in coordination with the USACE. (The design drawings and specifications for RA5 are included in Appendix F of this document.)

The schedule of availability of suitable dredged material will largely dictate the sequencing of cap placement in RA5. Therefore, it is not possible (or necessary) to coordinate the sequencing of the RA5 capping with the construction activities in RA4. However, to the extent that dredged material can be placed in RA5 in such a way as to provide some buttress material for the upgradient RA4 cap, slope stability may be slightly improved in RA4. The drawings for RA5 include sequencing notes that were developed with this goal. Sequencing is further discussed in Section 11.1.

8.2 CONTRACTING STRATEGY

8.2.1 Contracting Entities

Piling removal will be designed and contracted by the Port of Seattle. Piling removal is anticipated to be completed in advance of the capping and dredging activities defined in this design.

USACE will be the contracting entity for all other dredging and cap construction activities, and will procure remedial construction contractors and administer all construction and oversight contracts. Contracting must meet all applicable provisions of the Federal Acquisition Regulations (FARs) and the Defense Acquisition Regulations (DFARs), including assurance of competition and due consideration for use of small, disadvantaged, and minority-owned businesses.

Primary factors affecting the contracting strategy are the sources of capping material and the types of contracting mechanisms available to USACE. For example, dredging contracts are routinely let for maintenance dredging activities in the region, and these contracts may be useful as a means of procuring and placing dredged materials as a cap in RA5. Similarly, USACE maintains a number of indefinite delivery/indefinite quantity (ID/IQ) contracts that may provide a contracting mechanism for construction monitoring and verification services. At this time, it is envisioned that construction contracts will include those described in following subsections.

8.2.2 Construction of RA1 through RA4

All construction in RA1 through RA4 will be bid competitively under one contract. The contract for these areas will include a base item that covers the first year's activities, and option items for subsequent activities. Thus, the contract would be organized as follows.

Base Items

The contract base items will include:

- Dredging and disposal of dredged material from the area of Crowley Marine Services and the former Longfellow Creek Outfall
- Construction of the cap in RA1
- Construction quality control, including water quality monitoring, sampling, land and bathymetric surveying, reporting, and other activities described in the RA1–4 CQAP

Option Items

The contract option items will include:

- Construction of the cap in RA2a and RA3
- Construction of the cap in RA2b and RA4

Each of the option items would include the associated construction quality control, including water quality monitoring, sampling, land and bathymetric surveying, reporting, and other activities described in the RA1–4 CQAP. If the USACE elects to award all of the options, the same contractor would construct all of RA1 through RA4. If the USACE does not elect to award all of these options, then another contractor will be procured through competitive bidding.

Vegetative Planting. Because planting must be accomplished in autumn and the plants must be maintained, the planting will be contracted separately. Existing USACE delivery order contracts are likely to be used for planting and maintaining the vegetation during a designated establishment period (e.g., 1 year). For this reason, the vegetative planting specifications are included separately in Appendix H.

8.2.3 Construction of RA5

The USACE regularly procures dredging services for maintenance dredging activities in the region. Future contracts with these dredgers will be designed to include additional clauses and requirements that will allow dredged material to be used in construction of the RA5 cap. The dredging contracts will direct the contractors to place clean dredged material (that meets specifications for capping) in specific areas of RA5, in accordance with the drawings in Appendix F. An example of such a contract specification is included in Appendix F. Dredging contractors will not be responsible for cap placement monitoring or construction verification in RA5.

In addition to USACE dredging contracts, other parties applying for PSDDA open-water disposal of suitable material may consider placement of their material at RA5. In this case, USACE will evaluate the material for suitability as capping material, and if suitable, USACE will set forth the requirements for placement at RA5. The third parties would place the material at PSR.

Placement monitoring and verification in RA5 will be performed under available USACE contracting options as described below.

8.2.4 Construction Monitoring and Quality Control in RA5

Services for construction monitoring, oversight, and verification in RA5 will likely be procured through existing USACE ID/IQ contracts. Monitoring and verification will include sampling, surveying, construction oversight, reporting, and other activities described in the RA5 CQAP. This contract will also include requirements for post-construction monitoring activities that will occur over the period in which the cap is completed in discrete areas, but is still being constructed in other areas, as described in the OMMP.

8.2.5 Post-Construction Monitoring and Maintenance

Post-Construction Monitoring

The requirements for post-construction monitoring for the entire MSU are described in the OMMP. USACE will likely procure services for post-construction monitoring using existing ID/IQ contracts. This would include short-term monitoring requirements (i.e., monitoring of completed cap areas while other areas are still under construction) and long-term monitoring until the remedy is proven to be operational and functional, at which time long-term monitoring will be turned over to the State. As previously mentioned, these services may be included in the contract for the construction monitoring and construction quality control in RA5.

Post-Construction Maintenance

As the need for physical maintenance of cap areas is identified over time, separate construction contracts will need to be developed by the USACE or the State to accomplish the required work.

9.0 REMEDIAL DESIGN AND POST-CONSTRUCTION DELIVERABLES

This document represents the final (100 percent) design for the project. This design builds on the information presented in the 30-percent design deliverable, which was submitted on July 26, 2002, the 90 percent design deliverable, which was submitted on December 3, 2002, and includes consideration of input provided by EPA, USACE, WDNR, NMFS, NOAA, WDFW, Ecology, the Muckleshoot Tribe, and the Suquamish Tribe.

Additional documentation associated with construction and regulatory compliance will be developed as the construction progresses. Key design and construction documents are discussed in the following subsections.

9.1 FINAL DESIGN

This final design package was prepared by URS on behalf of EPA and incorporates measures deemed necessary to minimize adverse impacts to marine resources and implement habitat enhancements identified through ESA consultation. Based on this final design, bid packages will be prepared by USACE for prospective construction contractors to bid the work.

This design submittal includes the basis of design, all construction drawings, and specifications. Companion documents prepared concurrently with this submittal include the OMMP, the CQAPs, the PSRMP, and the BA as discussed below.

9.2 BIOLOGICAL ASSESSMENT

To meet substantive and procedural requirements of the ESA, the BA identifies sensitive (rare, threatened and endangered) species and their habitat within the project area and the types of impacts that could be associated with remedial actions. Opportunities and approaches for mitigation of adverse impacts are also presented in the BA. The BA is being used by EPA to meet consultation requirements under Section 7 of the ESA.

The Final BA was prepared concurrently with the 90 percent design package and submitted by EPA to NMFS and USFWS for review and concurrence.

9.3 CONSTRUCTION QUALITY ASSURANCE PLANS

Because contracting and construction methods in RA1 through RA4 are different from those in RA5, separate CQAPs were developed for these areas.

The CQAP for RA1 through RA4 is included as Part IV of this design and is also considered a part of the PSRMP. The CQAP will guide the construction managers in the evaluation and confirmation of performance during construction, and was developed in conjunction with the contractor quality control requirements that are included in the specifications. The CQAP identifies the required inspections, surveys, monitoring, verification sampling, reporting mechanisms, and documentation, and outlines potential corrective actions. In general, the contractor for RA1 through RA4 will implement the required construction quality control procedures and be responsible for potential corrective actions. The USACE will use the CQAP as they manage the construction, to assure the quality of the work and direct the contractor to take any necessary corrective actions.

The CQAP for RA5 was prepared by the USACE and is a companion document to this design. The RA5 CQAP serves the same functions as described above. However, the quality control requirements (e.g., sampling, surveys) will be implemented by an oversight contractor, and potential corrective actions will be implemented through new or modified construction contracts. The RA5 CQAP is a part of the PSRMP.

9.4 OPERATIONS, MONITORING, AND MAINTENANCE PLAN

One comprehensive OMMP covers all RAs. The OMMP is a part of the PSRMP and covers post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy. The OMMP outlines performance expectations and describes potential courses of action that should be taken based on sampling results, the passage of time, the influence of marine activities including marine construction, or the occurrence of natural phenomena such as earthquakes or significant weather events.

The OMMP also covers short-term monitoring activities that will be required in completed cap areas during the period in which the cap in other areas is still being constructed. The following is a specific example of the mechanisms for implementing the short-term requirements of the OMMP:

> ***Example of short-term OMMP implementation:*** *The cap in RA1 may be constructed, verified in accordance with the CQAP, and determined to meet all acceptance criteria at the end of the first year of construction. The contractor that constructed RA1 will have completed the contracted work in this RA. The OMMP defines the monitoring and maintenance requirements for the completed portion of the cap in year 2 (for example), while construction of the cap in other RAs is ongoing. The USACE will maintain a separate monitoring contract to implement the OMMP monitoring. Should maintenance of the RA1 cap be required in year 2, such maintenance would be contracted separately, either with the original construction contractor or a different construction contractor.*

9.5 PSR MANAGEMENT PLAN

The EPA has tasked the Seattle District, USACE to develop the PSRMP to define the strategies and procedures for construction and maintenance of the remedy for the MSU. The PSRMP includes:

- All documentation in this Final Design Submittal, including the CQAP for RA1 through RA4
- The CQAP for RA5
- The OMMP that covers the entire MSU
- The Management Guidelines, which covers procedures for use of dredged material for the cap in RA5

The PSRMP provides a basis for EPA and USACE (as an agent of EPA and under its Clean Water Act Section 404 and Rivers and Harbors Act authority) to utilize material from federal channel navigation and restoration dredging as well as nonfederal navigation and restoration dredging projects for beneficial use as capping material at PSR.

The PSRMP describes the means by which EPA's construction at PSR will satisfy dredged material and land management agencies' and resource trustees' objectives for environmental restoration and beneficial uses of dredged material. The RA will be completed using several contractors managed by the USACE. It also deals with permitted activities of open-water

dredged material placement managed by the USACE's 404/Section 10 program administered by the Dredged Material Management Office. The PSRMP describes relationship of activities and identifies administrative procedures for dredged material testing and acceptance (similar in function to the two existing PSDDA management plans). As such, the PSRMP provides a comprehensive guide for applicants to determine requirements for placing dredged material at PSR. The PSR Management Guidelines contains a Document and Data Management Plan, describing how data will be acquired and managed and documentation and filing procedures.

9.6 BID PACKAGE

Following EPA's approval of the Final Design, the USACE will develop a bid package for the competitively-bid construction in RA1 through RA4. The bid package will include the plans and specifications, supporting documentation, and bidding and contract documents (e.g., instructions for contractors to bid the work).

9.7 REMEDIAL ACTION MANAGEMENT PLAN

Following award of the construction contract for RA1 through RA4, the contractor will prepare and submit a Remedial Action Management Plan (RAMP). The construction specifications require the contractor to submit a RAMP that describes the equipment, procedures, materials, methods, disposal location, vessel management procedures, and personnel to be employed in the work. The RAMP will also include such elements as an environmental protection plan, sampling plans, and a Contractor Quality Control (CQC) Plan. EPA must approve the RAMP prior to initiation of construction.

9.8 POST-CONSTRUCTION DOCUMENTATION

The RA activities will be documented in several reports. The Contractor for RA1 through RA4 will submit a Cost and Performance Report (CPR) that will provide a narrative of the activities that occurred, document the modifications to the expected RA activities and the resulting cost implications, and list the quantities of material involved in the RA. The drawings will be modified to provide record drawings that reflect the actual site conditions at completion of construction. A post-construction survey will be included in the record drawings. The CPR will provide baseline information for the USACE to prepare a Remedial Action Report (RAR). The RAR will include the information presented in the CPR, along with results from the RA5

the Dredged Material Management Office. The PSRMP describes relationship of activities and identifies administrative procedures for dredged material testing and acceptance (similar in function to the two existing PSDDA management plans). As such, the PSRMP provides a comprehensive guide for applicants to determine requirements for placing dredged material at PSR. The PSR Management Guidelines contains a Document and Data Management Plan, describing how data will be acquired and managed and documentation and filing procedures.

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Following award of the construction contract for RA1 through RA4, the contractor will prepare and submit a Remedial Action Management Plan (RAMP). The construction specifications require the contractor to submit a RAMP that describes the equipment, procedures, materials, methods, disposal location, vessel management procedures, and personnel to be employed in the work. The RAMP will also include such elements as an environmental protection plan, sampling plans, and a Contractor Quality Control (CQC) Plan. EPA must approve the RAMP prior to initiation of construction.

9.8 POST-CONSTRUCTION DOCUMENTATION

The RA activities will be documented in several reports. The Contractor for RA1 through RA4 will submit a Cost and Performance Report (CPR) that will provide a narrative of the activities that occurred, document the modifications to the expected RA activities and the resulting cost implications, and list the quantities of material involved in the RA. The drawings will be modified to provide record drawings that reflect the actual site conditions at completion of construction. A post-construction survey will be included in the record drawings. The CPR will provide baseline information for the USACE to prepare a Remedial Action Report (RAR). The RAR will include the information presented in the CPR, along with results from the RA5 construction and construction monitoring. Separate RARs may be prepared for RA1 through RA4 and RA5.

construction and construction monitoring. Separate RARs may be prepared for RA1 through RA4 and RA5.

9.9 MONITORING AND MAINTENANCE REPORTS

Monitoring will be conducted according to the OMMP. Each monitoring event will be documented in a report that will record the reason the monitoring event was triggered, the methods that were used to perform the monitoring, and the results. The report will be concluded with a section that describes any necessary cap repair or additional monitoring activities.

10.0 IDENTIFICATION OF EASEMENT AND ACCESS REQUIREMENTS

10.1 WATER ACCESS

Contractor barge access to the site will be required over the 3- to 5-year construction activity. It is anticipated that most, if not all, import materials (dredged material and upland materials) will be brought to the site via barge. Barge access to the general site is not considered a difficulty. It is anticipated that existing nearshore marine structures can be used as a tie-up area.

A critical access concern relates to the dredging and capping construction activities in the vicinity of Crowley Marine Services. During activities in the vicinity of Crowley Marine Services, steel cables between the dolphins will need to be removed, mooring of vessels will not be possible, and access to the pier will be limited. In addition, modifications to the former Longfellow Creek outfall to accommodate cap placement will also impact operations at Crowley Marine Services. It is anticipated that these impacts will last for at least two discrete construction periods of:

- Dredging of RA3 and capping in adjacent areas of RA1: 3 to 5 weeks in autumn 2003
- Capping of RA3 and RA2a: 3 to 5 weeks in summer 2004

These are approximate estimates and will be refined based on the Contractor's RAMP submittal. EPA is coordinating with the Port of Seattle and Crowley regarding this access.

Water access will be coordinated with tribal fishing activities which are anticipated to occur in the vicinity of the site during construction activities. The Contractor may be required to modify construction sequencing or operations to accommodate tribal fishing.

10.2 LAND ACCESS

Road access to the site will be required, for construction equipment, field office, laydown areas, etc.

Contractor staging areas on the upland part of the site will be required for the contractor's parking, field office, equipment staging, and material stockpiling over the anticipated 2-year period in which upland material is used for cap construction. It is anticipated that most upland cap materials will be delivered by barge and placed directly from the barges into the MSU. However,

the contractor may elect to use the upland staging areas for stockpiling material. The contractor may also need to construct temporary access routes from the upland staging areas to the shoreline for transfer of equipment and materials. In general, the need for upland contractor staging areas will be greatest during the first season of construction, during which the RA1 cap and Longfellow Creek outfall are being constructed.

Land access will also be needed at the transloading facility, to accomplish the transfer of dredged material to rail cars. The contractor will identify the proposed transloading facility in the RAMP submittal.

Requirements for roadway access and staging areas are being coordinated with the Port of Seattle. Staging areas and haul routes have been identified and are shown on the drawings. EPA will coordinate with the Port of Seattle to finalize the acceptable staging areas and haul routes. The contractor responsible for construction of RA1 through RA4 will provide office space and access for USACE construction management personnel.

Public access areas currently transverse areas between the identified staging areas and the MSU. The public also currently has access to the viewing pier. EPA will coordinate with the Port of Seattle to identify any public access areas that will need to be restricted during the construction of RA1 through RA4.

No specific requirements for upland access are identified for construction of RA5. Dredged material will be brought into RA5 by barge and placed directly from barge, and the contractors placing the dredged material will not need land access. However, USACE construction management personnel may establish a field office if this is determined to be necessary.

10.3 EASEMENT AND LEASE REQUIREMENTS

No easement or lease requirements are anticipated for this project.

the contractor may elect to use the upland staging areas for stockpiling material. The contractor may also need to construct temporary access routes from the upland staging areas to the shoreline for transfer of equipment and materials. In general, the need for upland contractor staging areas will greatest during the first season of construction, during which the RA1 cap and Longfellow Creek outfall are being constructed.

Land access will also be needed at the transloading facility, to accomplish the transfer of dredged material to rail cars. The contractor will identify the proposed transloading facility in the RAMP submittal.

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Public access areas currently transverse areas between the identified staging areas and the MSU. The public also currently has access to the viewing pier. EPA will coordinate with the Port of Seattle to identify any public access areas that will need to be restricted during the construction of RA1 through RA4.

No specific requirements for upland access are identified for construction of RA5. Dredged material will be brought into RA5 by barge and placed directly from barge, and the contractors placing the dredged material will not need land access. However, USACE construction management personnel may establish a field office if this is determined to be necessary.

10.3 EASEMENT AND LEASE REQUIREMENTS

No easement or lease requirements are anticipated for this project.

11.0 CONSTRUCTION SEQUENCING, SCHEDULE, AND COST ESTIMATE

The following discussions of construction sequencing, schedule, and cost estimate are based on use of upland sources of cap material for RA1 through RA4, and the use of dredged cap material in RA5.

11.1 CONSTRUCTION SEQUENCING

Construction sequencing is based on the following logistical and design considerations (refer to the design drawings for locations of specific features):

- Piling removal (by others) is assumed to be completed prior to any other construction activities.

- RA1 through RA4 is assumed to be constructed by one contractor, working independently of construction in RA5.

- Construction of the cap in RA1 is anticipated to begin in the 2003 construction season and will take several months. RA1 construction should begin as early as possible to complete the intertidal habitat enhancement and achieve habitat benefits as early as possible. It will be necessary to construct the RA1 cap in segments to prevent erosion of placed material. Within each segment, the cap consists of individual lifts of material. Specific notes on sequencing the construction of the individual lifts in RA1 are included in the drawings. It is anticipated that the RA1 cap can be completed in the first construction season. However, due to fish window limitations, it is possible that a portion of the RA1 cap may need to be completed in the second construction season.

- Dredging in RA3 should begin roughly concurrently with initiation of the RA1 capping. Dredging in RA3 must be completed prior to construction of the cap in RA3 and the cap in adjacent portions of RA1 and RA2a. The dredging includes excavation of keys for the thick slope cap in a portion of RA1. The contractor will also excavate along the alignment of the required extension of the former Longfellow Creek outfall in RA1. This excavation will be armored to maintain the temporary slopes until the outfall extension is constructed.

- The extension of the former Longfellow Creek outfall must occur as soon as possible after dredging and before completion of the proximate portion of the RA1 cap.

- Vegetative planting in RA1 must occur after the RA1 cap is completed and must occur in the fall.

- RA3 will be capped following capping in RA1. RA3 has a higher priority than RA2a, RA2b, and RA4 because potentially contaminated sediments may remain in RA3 following dredging. Until they are capped, these sediments in RA3 may be subject to erosive forces from propwash and become a source of recontamination of adjacent areas.

- Capping in RA2a, RA2b, and RA4 will generally follow RA3.

- Capping in RA4 will generally occur in the same timeframe as capping in RA5. Specific sequencing within these RAs has been developed to minimize the potential for, and damage from, any potential slope failures that may occur during placement. Placement in RA4 will progress from deeper offshore areas and work upslope toward the nearshore areas. The cap in RA4 will be constructed in several segments, each segment constructed from the bottom of the slope working upward. In this way, if slope failures occur as the first segment is being constructed, construction methods can be modified in subsequent segments. The segments in RA4 will be constructed from east to west.

- Known sources of dredged material for placement in RA5 may first become available in 2004. Placement in RA5 will commence as soon as suitable dredged material becomes available and the associated environmental monitoring contracting is in place. Given the unknowns in dredged cap material availability, it is not possible to definitively link the sequencing of cap construction in RA5 relative to RA4. It is also desirable to maintain maximum flexibility for the USACE in specifying where individual bargeloads will be placed. In general, the slopes are shallower in RA5 and submarine landsliding caused by placement is less of a concern in RA5, compared to RA4. To the extent that landsliding is a concern in RA5, it is most likely near the RA4/RA5 boundary, where the slopes are about 15 percent and mound heights from bottom-dump placement are the greatest. For this reason, the shallower portions of RA5a (Phase 1, near the RA4/RA5 boundary) will be capped first, followed by the deeper portions of RA5a and RA5b (Phase 2). This approach will allow early identification of any landsliding problem in RA5,

and minimize damage to downgradient capped areas of RA5 in the event of sliding. Also, where Phase 1 of RA5a can be completed prior to construction of RA4, Phase 1 of RA5a will serve as a "buttress" to help support the RA4 cap. Thus, Phase 1 of RA5a will be constructed from east to west.

11.2 CONSTRUCTION SCHEDULE

Figure 11-1 presents the target construction schedule for implementing the remedy for the MSU. Construction of the remedy is estimated to be completed in 2006.

As noted in Section 2.6, the schedule has been developed with consideration of the fish windows identified by the Natural Resource Trustees in the course of ESA consultation.

For construction in RA1 through RA4, it is stressed that the target construction schedule has been developed using experience in production rates for similar work at other sites, assumptions regarding the number of working shifts and operations underway at any given time, and best professional judgement. One 12-hour working shift per day, Monday through Friday, was assumed for RA1, RA2a, RA2b, and RA3. Two working shifts per day were assumed for RA4. With these assumptions, and with the currently scheduled procurement process and mobilization dates, it is estimated that RA1 through RA4 can be completed by February 13, 2005. Contractors bidding the work will propose their own schedules, and will develop detailed schedules in their RAMP submittal. The actual schedule may vary depending on the means and methods the contractor uses.

Placement of dredged cap material in RA5 can be accomplished as quickly as suitable material becomes available. The RA5 schedule assumes that USACE dredging in the Duwamish River, Snohomish River, and Swinomish Channel all occur as currently projected by USACE, and that all suitable, sandy material that meets the PSR dredged cap material specifications can be diverted to PSR. Delays in these dredging projects, differing conditions of the dredged material, or competing demands on these resources may significantly delay the completion of the RA5 cap. Conversely, suitable material that may become available from other non-USACE projects could beneficially affect the schedule.

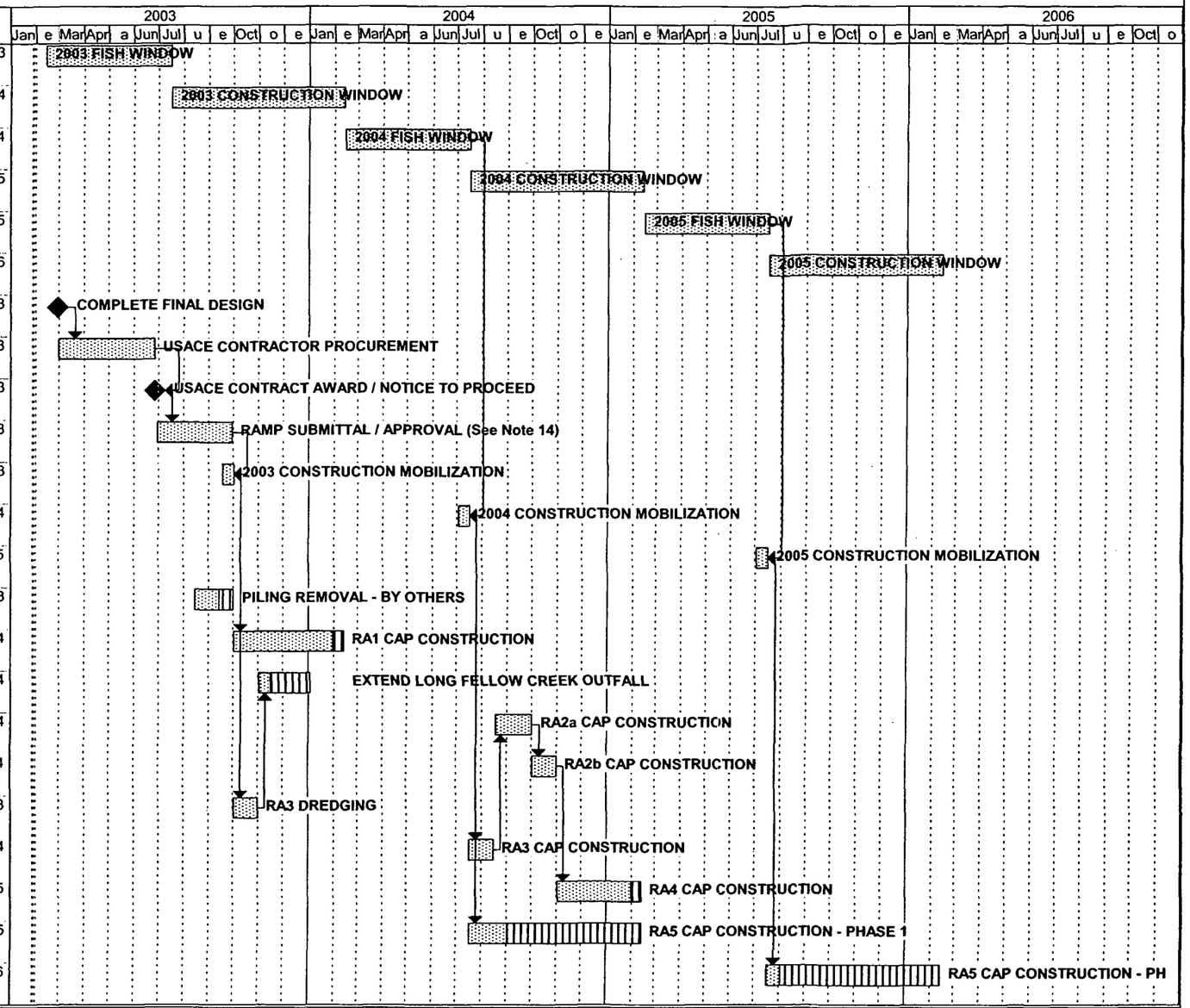
Certain elements of the work in RA1 will be tidally-sensitive, such as final grading of the intertidal cap surface and placement of large woody debris. The contractor's schedule (submitted in the RAMP) will indicate the daily work windows during which these activities will occur.

11.3 ENGINEER'S COST ESTIMATE

The Final Engineer's Cost Estimate is being prepared separately and will be submitted under separate cover.

FIGURE 11-1
PROPOSED CONSTRUCTION SCHEDULE

ID	Task Name	Duration	Start	Finish
1	2003 FISH WINDOW (ESA) (See Note 1)	152.38 edays	Fri 2/14/03	Wed 7/16/03
2	2003 CONSTRUCTION WINDOW (ESA)	211 edays	Thu 7/17/03	Fri 2/13/04
3	2004 FISH WINDOW (ESA) (See Note 1)	153 edays	Sat 2/14/04	Fri 7/16/04
4	2004 CONSTRUCTION WINDOW (ESA)	211 edays	Sat 7/17/04	Sun 2/13/05
5	2005 FISH WINDOW (ESA) (See Note 1)	152 edays	Mon 2/14/05	Sat 7/16/05
6	2005 CONSTRUCTION WINDOW (ESA)	211 edays	Sun 7/17/05	Mon 2/13/06
7	COMPLETE FINAL DESIGN	0 days	Fri 2/28/03	Fri 2/28/03
8	USACE CONTRACTOR PROCUREMENT	118 edays	Sat 3/1/03	Fri 6/27/03
9	USACE CONTRACT AWARD / NOTICE TO PROCEED	0 days	Fri 6/27/03	Fri 6/27/03
10	RAMP SUBMITTAL / APPROVAL (See Note 14)	92 edays	Mon 6/30/03	Tue 9/30/03
11	2003 CONSTRUCTION MOBILIZATION	14 edays	Wed 9/17/03	Wed 10/1/03
12	2004 CONSTRUCTION MOBILIZATION	14 edays	Fri 7/2/04	Fri 7/16/04
13	2005 CONSTRUCTION MOBILIZATION	14 edays	Sat 7/2/05	Sat 7/16/05
14	PILING REMOVAL - BY OTHERS (See Notes 3, 7)	47.38 edays	Fri 8/15/03	Wed 10/1/03
15	RA1 CAP CONSTRUCTION (See Notes 2, 3, 9, 12, 13)	134 edays	Thu 10/2/03	Fri 2/13/04
16	EXTEND LONG FELLOW CREEK OUTFALL	103 edays	Sun 11/2/03	Fri 2/13/04
17	RA2a CAP CONSTRUCTION (See Notes 9, 12, 13)	45 edays	Tue 8/17/04	Fri 10/1/04
18	RA2b CAP CONSTRUCTION (See Notes 9, 12, 13)	30 edays	Sat 10/2/04	Mon 11/1/04
19	RA3 DREDGING (See Notes 4, 8)	30 edays	Thu 10/2/03	Sat 11/1/03
20	RA3 CAP CONSTRUCTION (See Notes 4, 9, 12, 13)	30 edays	Sat 7/17/04	Mon 8/16/04
21	RA4 CAP CONSTRUCTION (See Notes 9, 12, 13)	103 edays	Tue 11/2/04	Sun 2/13/05
22	RA5 CAP CONSTRUCTION - PHASE 1 (See Notes 9, 10)	211 edays	Sat 7/17/04	Sun 2/13/05
23	RA5 CAP CONSTRUCTION - PHASE 2 (See Notes 9, 11)	211.38 edays	Sun 7/17/05	Mon 2/13/06



Project:
PSR CONSTRUCTION SCHEDULE
Date: Tue 1/28/03

Float | Task | Milestone | External Milestone | External Milestone | Deadline

Figure 11-1 (Continued)
Proposed Construction Schedule

NOTES FOR PROPOSED CONSTRUCTION SCHEDULE

The following notes and assumptions are associated with the proposed construction schedule.

1. The fish window, during which capping is not allowed, is between February 14 and July 16 (based on ESA) for all areas. The fish window, during which dredging and piling removal are not allowed, is between February 14 and August 16.

2. RA1 must be completed as quickly as practical to achieve habitat enhancements.

3. Removal of existing piles in RA1 must precede cap construction in RA1 (see Note 7).

4. Dredging in RA3 must precede construction of the cap in RA3 and adjacent parts of RA2a. The construction window for dredging is between August 17 and February 13.

5. RA3 cap construction will immediately follow completion of cap construction in RA1.

6. Assume 1 month equals 20 working days. Round all months up to the nearest 0.5 month. Assume a minimum duration of 1 month.

7. Assume a total of 600 piles will be removed at a rate of 30 piles per day. Assume piling removal must be completed outside the ESA fish window.

8. The dredge volume in RA3 is approximately 10,000 cubic yards. Assume an average dredging rate of approximately 600 cubic yards/day based on difficulties associated with work around the Crowley Pier. RA3 dredging duration equals 17 days, plus 7 days for survey and possible re-dredging, 1 month total duration.

9. Assume only one operation placing upland material at any given time. Assume one shift per day for all areas except RA4 (see Note 12). Assume placement of dredged material in RA5 is independent of other cap construction.

Figure 11-1 (Continued)
Proposed Construction Schedule

10. No dredged material is known to be available in 2003. During 2004, material is placed concurrently in RA5 from the following sources. Material could be available at any time during the 6-month dredging window.

    - 38,000 cubic yards placed from Duwamish, at same rate as dredged (62,000 cubic yards/month);
    - 35,000 cubic yards placed from Swinomish, at same rate as dredged (32,000 cubic yards/month).

11. During 2005, material is placed from the Snohomish Upstream Basin in RA5 at same rate as dredged (228,000 cubic yards/month). Material could be available at any time during the 6-month dredging window.

12. Assume average cap placement rates for upland material as follows.

    - Sand cap mix: 2,000 cubic yards/day for all applicable areas other than RA4. Assume a reduced rate of 1,300 cubic yards/shift for RA4, to account for steeper slopes. Assume two shifts per day or 2,600 cubic yards/day for RA4.
    - Coarse sand mix: 2,000 cubic yards/day for all applicable areas.
    - Gravel mix: 2,000 cubic yards/day for all applicable areas.
    - Filter layer: 1,000 cubic yards/day for all applicable areas. Reduced rate accounts for placement and grading on relatively steep slopes as part of revetment construction.
    - Rip rap: 500 cubic yards/day for all applicable areas. Reduced rate accounts for careful placement required for revetment construction.
    - Fishmix: 1000 cubic yards/day for all applicable areas. Reduced rate accounts for difficulty associated with placement over rip rap on revetment.

Figure 11-1 (Continued)
Proposed Construction Schedule

13. Upland material cap volumes (including contingency) and approximate duration of cap construction at assumed placement rates (see Notes 6 and 12) for each RA are as follows.

- RA1 cap volume is approximately 96,000 cubic yards, including sand cap mix, gravel mix, filter layer, rip rap and habitat mix. Total duration is approximately 4.0 months, based on 1 shift per day.

- RA2a cap volume is approximately 43,000 cubic yards, including sand cap mix and coarse sand. Total duration is approximately 1.5 months, based on 1 shift per day.

- RA2b cap volume is approximately 18,000 cubic yards of sand cap mix only. Total duration is approximately 1.0 month, based on 1 shift per day.

- RA3 cap volume is approximately 8,000 cubic yards of sand cap mix and gravel mix. Total duration is approximately 1.0 month, based on 1 shift per day and allowance for decreased productivity near Crowley.

- RA4 cap volume is approximately 160,000 cubic yards of sand cap mix only. Total duration is approximately 3 months, based on 2 shifts per day.

14. It is assumed that USACE will direct the Contractor to test, sample, and analyze proposed cap materials following submittal of the Draft RAMP, so that materials can be approved without delaying capping activities.

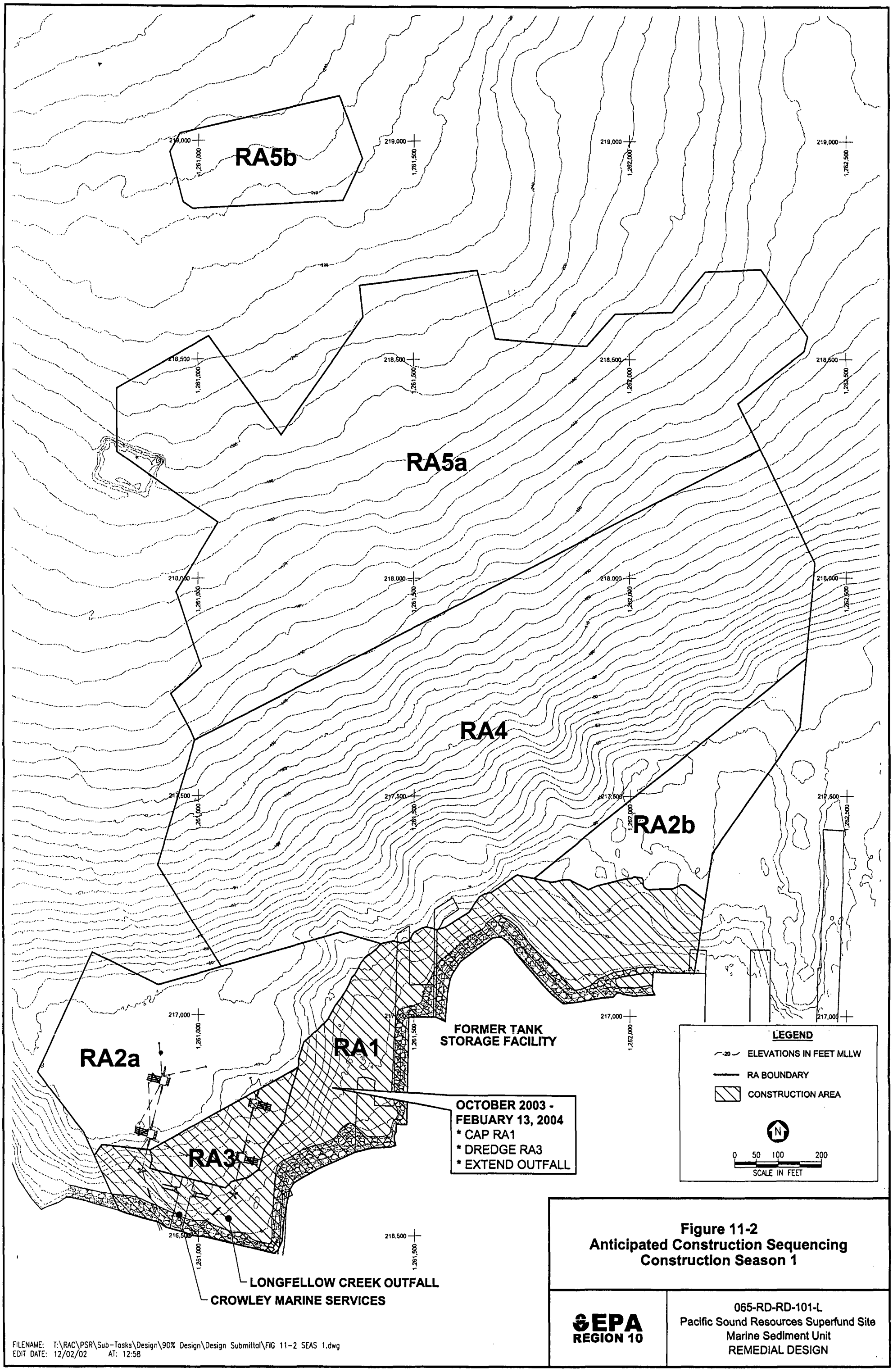


Figure 11-2
Anticipated Construction Sequencing
Construction Season 1

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

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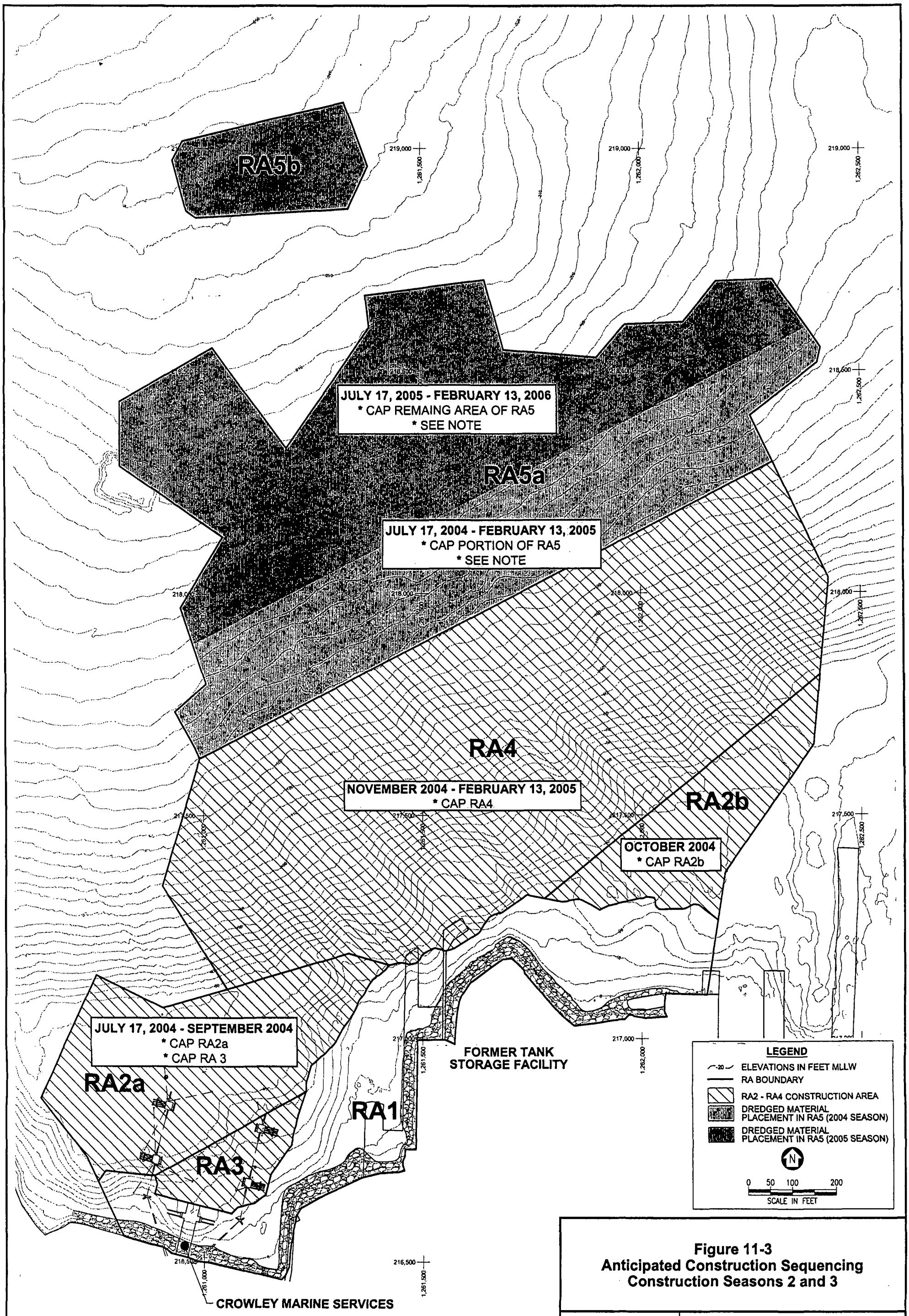

Figure 11-3
Anticipated Construction Sequencing
Construction Seasons 2 and 3

NOTE:
RA5 SCHEDULE SUBJECT TO DREDGED MATERIAL AVAILABILITY. ALL PLACEMENT OF DREDGED MATERIAL IN RA5 TO OCCUR OUTSIDE OF DESIGNATED FISH WINDOWS.

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

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Appendix A

APPENDIX A

EROSION ANALYSIS

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APPENDIX A

EROSION ANALYSIS

A.1 INTRODUCTION

This erosion analysis of the sediment cap considers the effects of water movement over the surface of the cap, including natural currents and propeller wash. The potential for other erosive mechanisms, such as subaqueous mass wasting (because of seismic loads, for example) are discussed in Appendix C.

Erosion can result from natural currents caused by winds, waves, tidal fluctuations, propeller wash, and other forces. Each of these mechanisms will induce water velocities at the surface of the cap with the potential to move the sediment particles used in the cap. This analysis evaluates the average particle size needed to resist the erosive forces expected at the site.

In general, one erosive mechanism is the controlling factor for design of the average particle size required for each area of the Marine Sediment Unit (MSU). For example, in the area around the Crowley Marine pier, propeller wash is the controlling erosive mechanism because higher water velocities are generated by propeller wash in this area than by currents. In the intertidal and shallow subtidal zones, away from vessel traffic, wind-generated wave action is typically the controlling erosive mechanism.[1] In deeper water, ambient currents control the potential for erosion.

Wind is the primary cause of waves and currents. The location of the MSU within Elliott Bay results in a great degree of protection from the prevailing winds and a relatively short fetch, compared to locations within greater Puget Sound. In particular, the PSR site is in the lee of the topographic high of West Seattle, with regard to the prevailing southwesterly winds. There is, however, a relatively narrow window (315° to 330° true azimuth) through which waves generated over a long fetch extending from Bainbridge Island may impinge on the site. Waves and currents generated over this fetch control the erosion design in the nearshore areas of RA1.

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[1]Based on input from Crowley, vessel traffic is not significant in the eastern portion of RA2. This erosion analysis does not consider potential future changes to waterway use that may increase propeller wash effects. Significant future changes in vessel traffic could necessitate future maintenance, such as additional placement of armor materials.

As reported in the pre-design investigation data summary (USEPA 2002a), currents were measured directly at two locations, one deep (CM-2) and one shallow (CM-1), within the area to be capped. Current data were collected over the time period September 7, 2001, to October 8, 2001, at 10-minute intervals. Data collected for use in this analysis included bottom-current speed and direction. Low bottom current speeds were measured, with mean speeds of 2 to 3 cm/sec. Current direction is highly variable and determined largely by tidal cycles.

Data for the evaluation of propeller wash erosion included the characteristics of the vessels using the Crowley Marine pier, the designated areas of vessel operation, the minimum water elevation in the area of the pier (–4 feet mean lower low water [MLLW] at extreme low tide), and the expected final bottom configuration after placement of the cap. Information regarding vessel characteristics and operating areas was obtained from Crowley Marine Services, who operate the largest vessels (heavy conventional tugs) using the pier.

A.2 SUBTIDAL AREAS (RA2b, RA4, RA5)

For the purposes of the erosion analysis, the subtidal areas of the MSU are defined as those areas outside the customary area of tug operation (as shown on Figure A-1) and at elevations at or below –19 feet MLLW. In these areas, the primary erosion mechanism is ambient current. To analyze erosion from ambient currents, the 99.9th percentile of the measured current speed from the current meter data was calculated and found to be 12 cm/sec for CM-2 and 8.7 cm/sec for CM-1. The 12 cm/sec velocity is below the threshold velocity for initiation of sediment motion, even for fine-grained sediments in shallow water (Palermo et al. 1998). The Puget Sound Dredged Disposal Analysis (PSDDA) Disposal Site Selection Technical Appendix reports that, based on empirical data, "the threshold speed [for resuspension of fine sediment] in Puget Sound apparently increases from 25 cm/sec for newly deposited materials to approximately 50 cm/sec after the material has been in place for some time" (USACE 1988). As discussed below, the current meter data were further evaluated to assess whether the measured current speeds are representative of maximum current speeds that could occur throughout the year at the site.

The potential direct effects of wind on currents at the site were evaluated by correlating the wind data to the current data. Measurements of wind speed and direction were obtained for the time period January 1999 through December 2001 from a wind measurement station operated by the Puget Sound Clean Air Agency. The wind station is located at 4752 E. Marginal Way South, approximately 2 miles southeast of the site. Although this wind station is inland of the site, it is situated at a similar low elevation, somewhat protected from the prevailing winds. The wind data used consisted of 1-hour averages of wind speed. Wind speeds that are sustained for less than one hour (such as instantaneous peak winds) do not generate substantive wave and current

action that could cause erosion. Scatter plots of current speed versus wind speed for equivalent times are included in Attachment A-1 to this appendix. The correlation factor between current speed and wind speed was 0.02 for current meter CM-1 and 0.04 for current meter CM-2. The low values of these correlation factors indicate no significant correlation between current speed and wind speed. The maximum 1-hour average wind speed recorded during the period January 1999 through December 2001 was 27 miles per hour. The maximum 1-hour average wind speed recorded during the 1-month deployment of the current meters was 11 miles per hour. Although stronger winds may occur during storm events, there is no correlation between current speed and wind speed and thus no indication that significant bottom currents would be induced during storm events. This result is consistent with the highly sheltered location of the site, within a protected embayment.

The potential for periodic site-wide current fluctuations was evaluated by correlating the data from the current meters with one another (see scatter plot in Attachment A-1). The correlation factor between the two data sets was 0.08, indicating no significant correlation. The possibility of a time lag between the response of the shallow and deep current meters to site-wide current fluctuations was also evaluated. The data from the deep current meter was shifted 30 minutes later than the data from the shallow meter, and the correlation coefficient between the resulting data sets was calculated. The deep current meter data was then shifted in 30-minute increments until the total time shift between the data sets was 120 minutes. The correlation coefficient was calculated for each 30-minute shift. To achieve a comprehensive evaluation, the reverse shift was also performed, with the data from the shallow current meter shifted in 30-minute increments later in time relative to the deep current meter data. In all cases, the greater the time lag introduced between the two data sets, the smaller the correlation coefficient.

The lack of significant correlation between the data sets from the deep and shallow current meters indicates that periodic site-wide current fluctuations are not present on the site. Overall, the correlation analysis between the two current meter data sets and between the current meter data and the wind data indicate that the bottom currents at the site are relatively independent of wind speed and direction, and are not controlled by site-wide oscillations. Based on this conclusion, the 99.9th percentile maximum current speed actually measured (12 cm/sec) was used to evaluate the cap material characteristics required to minimize erosion.

A screening-level analysis was used to assess the need for sediment grain size restrictions to resist erosion in subtidal areas. USACE guidance (Palermo et al. 1998, Figure 25) shows that for velocities below 20 cm/sec, fine-grained sediment is expected to be stable, even in shallow water. The measured current velocities were also considered with respect to the sediment transport diagram by Hjulstrom which compares particle size to water velocity required for erosion, transportation, and deposition (Krynine and Judd 1957). On this diagram, a velocity of

11 cm/sec is below the threshold for erosion for all particle sizes. The Hjulstrom diagram indicates that limited movement of fine-grained sediments might be expected; however, erosion is not expected.

This analysis indicates that even fine-grained cap material (silt and fine sand) will be adequate to resist erosion in the subtidal areas. With the exception of the areas subject to propeller wash (discussed below), no restrictions on cap material type in the areas below –19 feet MLLW are required to resist erosion.

A.3 NEARSHORE AREAS (RA1)

For the purposes of the erosion analysis, the nearshore areas of the site are defined as those areas outside the customary area of tug operation (as shown on Figure A-1) and at elevations between +14.8 feet MLLW (corresponding to extreme high water) and –19 feet MLLW. The selection of –19 feet MLLW was based on the wave-induced current analysis for nearshore waters, which is described in this section. This analysis indicated that for water depths of more than 15 feet the wind-generated, wave-induced bottom currents are below the threshold for initiation of motion for all particle sizes. At an extreme low tide (–4 feet MLLW), 15 feet of water depth corresponds to –19 MLLW, and thus –19 feet MLLW was selected as the lower bound of the nearshore area.

In the nearshore area, the primary erosion mechanisms are waves that are generated by wind and wakes of passing vessels. These waves, in turn, cause currents that are capable of eroding the seabed. The PSR site is subject to short-duration, wake-generated waves from vessel traffic within Elliott Bay. However, wake-generated waves are not expected to induce higher bottom currents than the wind-generated, wave-induced currents. The wake-generated waves do not exhibit a substantially larger height than the wind-generated waves and are of much shorter duration. Accordingly, wake-generated waves are not considered further in the erosion analysis.

Calculations of wind-generated wave characteristics were based on historical wind data and fetch available for generating waves that would affect the project site. Using these as input data, wave characteristics (height, period, and deep-water length) were calculated using ACES (Automated Coastal Engineering System, Version 1.07e). Limitations to fetch width (due to adjacent shoreline) were considered in accordance with ACES protocol.

A.3.1 Determination of Design Wind Speed

Only winds from northerly directions will generate waves of potential concern at the project site. Direct exposure of the PSR site to waves generated in Puget Sound is through a narrow

"window" that is defined by the angular sector from 315° to 330° true azimuth. A map of this window is included in Attachment A-1. This window extends from the PSR site to the eastern shoreline of Bainbridge Island, at distances that range from 7 to 22 statute miles (Table A-1). While the overall exposure is as described above, the window of exposure for any given location within the project site is somewhat less, ranging from only 5° on the west side to about 11° on the east side.

While this "window" defines the direct exposure of the PSR site, there is also the concern that waves generated by more northerly winds, such as those that damaged the Alki Avenue seawall in 1990, could be refracted around West Point toward the mouth of Elliott Bay. Accordingly, the analysis also included winds from 330° to 015°, through definition of three directional sectors, each spanning 15° and with distinctly different fetch lengths. This analysis is described in Section A.3.2.

A shorter fetch that is entirely within Elliott Bay and defined by the bay's northern shoreline was also evaluated. However, winds and waves generated at PSR from this shorter fetch were found to be of lesser magnitude than those generated by the longer fetches within Puget Sound. The following analysis focuses on winds and waves that may be generated within the longer fetches.

The analysis was conducted using data from the NOAA West Point wind monitoring station. These data consist of hourly observations during the 18-year period from 1984 through 2001. Analysis of the 18 years of record from West Point included determination of maximum wind speeds by year and cumulative frequency distributions of wind speed for each of the four sectors. Maximum wind speeds of record and selected statistics for each sector are listed in Table A-2.

The results of the analysis indicate that winds from the 315° to 330° direction are relatively infrequent, accounting for only 0.6% of all observations (911 of 144,820) and having speeds that were generally lower than those from the other three sectors. Moreover, the low frequency of observations from this sector is indicative also of the unsteadiness of winds from that direction, a fact that is reflected in the directional data. Accordingly, the wind speed selected for determination of the design wave was the 99th percentile value of all wind speeds from the 315° to 330° sector, which is 11.3 m/s (25.3 mph). Selection of the 99th percentile value means that winds of this speed and higher occurred 0.0063% of the time of record, or about 9 hours during the 16.5 years of record.

A.3.2 Determination of Design Wave

As noted above, the design wind speed was selected to be 11.3 m/s, or 25.3 mph. The geometry of the 315° to 330° fetch was defined by radials extending from the project site at 3-degree increments as listed in Table A-1. These data were provided to the ACES algorithm for computation of the significant wave height and period, according to the wave prediction equations for fetches of restricted width. Preliminary computations, using the same fetch-limited wave equations utilized by ACES, indicated that the wind would need to be steady along the longest fetch distance for nearly three hours to ensure that greatest wave energy would be developed (i.e. "fully-developed" seas). Notwithstanding the unlikelihood of such steady winds occurring, a three-hour duration was specified for the ACES computation to ensure fully-developed seas for the design wind conditions with the following results:

- Significant wave height = 2.86 ft
- Significant wave period = 3.49 s

To address the question of whether waves from the more northerly sectors (i.e., 330° to 015°) might be capable of entering Elliott Bay due to refraction around West Point, significant wave heights and periods corresponding to the maximum wind speed of record for each of the three 15° sectors were calculated with the wave prediction equations used by ACES for the maximum fetch available in each sector (Table A-3).

For waves to be susceptible to refraction, they must be long enough to be affected by the seabed. This occurs when waves enter water that is shallower than about one-quarter of their deep-water wave length. Using this practical criterion, even the longest waves of concern (from 345° to 360°) will not be susceptible to refraction until they enter water shallower than about 40 ft depth. A careful examination of the bathymetry around West Point shows that, for all northerly directions, water depths are greater than 40 feet within 200 feet of the point. This means that even the largest waves that might be generated by winds from those directions would "feel bottom" only within 100 to 200 feet of West Point and any refraction would be very localized with effects limited to the immediate area. Accordingly, refraction of waves from these directions into Elliott Bay was eliminated as a concern.

A.3.3 Estimation of Wave-Induced Seabed Currents

Linear wave theory[2] was utilized to calculate the seabed current speed induced by the design wave as it approaches the shoreline. The design wave has a deep-water wave length of 62 feet,

[2] See, for example, Lamb (1945), Ippen (1966), Milne-Thomson (1969), or Dean & Dalrymple (1984)

so it will begin to shoal (i.e. "feel bottom") as it enters water depths less than 20 feet. The shoaling process causes a steady reduction in wave length and an alteration of wave height that consists first of a decrease of about 10 percent, followed by a steady increase to breaking height. In general, waves will break when the height exceeds about 75 percent of the local water depth.

Table A-4 lists height, length and other parameters for the design wave as it approaches shore. Bottom current is also shown for depths from 50 feet to 3.5 feet, at which point the wave is presumed to break. From 3 feet depth into shallower water, the bottom current is estimated as the celerity of a solitary wave, which is a function only of water depth. The maximum bottom current speed, which occurs at a water depth of 3 feet, is 300 cm/s. At extreme low water conditions, a water depth of 3 feet corresponds to a seafloor elevation of -7 feet MLLW.

A.3.4 Aggregate Size to Resist Erosion in Nearshore Areas

The aggregate size required to resist any motion in nearshore areas was estimated using the procedure described in USACE engineering manual EM 1110-2-1601. Based on Plate 2-28, "Noncohesive Sediment Gradation and Permissible Velocity" (USACE 1994), for a maximum bottom current speed of 300 cm/s (9.8 ft/s), a grain size of about 7 inches (about 200 mm) is indicated to resist any motion.

The aggregate size required to resist motion was also estimated using the Shields parameter (Dean and Dalrymple 2002). For a maximum bottom current speed of 300 cm/s, an average grain size (D_{50}) of 1.9 inches (49 cm) is indicated. Derivation of the relationship between D_{50} and current speed and a table of D_{50} required to resist motion as a function of current speed are shown in Attachment A-1.

Before the wave breaks, the maximum bottom current speed is predicted to be 119 cm/s (4 ft/s). For this current speed, the estimated grain sizes required to resist motion are coarse sand (2 to 4.75 mm) and 7.5 mm using the USACE (1994, Table 2-5) and Dean and Dalrymple (2002) methods, respectively.

The estimated wave-induced bottom currents in the nearshore and very nearshore area imply that a fine-grained gravel material could be used to construct a relatively gently sloping cap in these areas, however, some motion of gravels will be induced from waves generated by relatively rare wind events at elevations above -7 feet MLLW. The fact that the gravel is subject to motion by waves indicates that a gravel cap in nearshore areas must be designed to specific slopes to approximate the natural profile of a beach. Such a beach will be subject to cross-shore sediment transport. A further evaluation of cross-shore sediment transport and allowable intertidal slopes (presented in Section A.6) also indicates that gravels will be required in the intertidal area.

As shown in Table A-4, seabed current speeds are less than 30 cm/sec for all cases in water depths of 15 feet (seabed elevations of -19 feet MLLW and lower) or more. For current speeds less than 30 cm/sec, material with a D_{50} of 1.0 mm (in the medium-grained sand range) should resist motion even in very shallow water. Even the relatively low current speeds of 30 cm/s at -19 feet MLLW would only occur as a result of an improbable combination of a very rare wave condition and extreme low water conditions.

The nearshore cap design east of Station 18+00 includes a slope break at -10 feet MLLW. Above -10 feet MLLW the slope is 1V:7H, and below -10 feet MLLW the slope is 1V:4H. At extreme low water, -10 feet MLLW would correspond to a water depth of 6 feet. At 6 feet water depth, the bottom current resulting from the design wave is 77 cm/s. For this current speed, the estimated grain sizes required to resist erosion are coarse sand (2 to 4.75 mm) and 3 mm using the USACE (1994, Table 2-5) and Dean and Dalrymple (2002) methods, respectively. Consequently, the gravels that comprise steeper slope below -10 feet MLLW will be stable against wave-induced motion, and are not subject to cross-shore sediment transport.

A.4 PROPELLER WASH ANALYSIS (RA2a, RA3)

The propeller wash analysis was conducted to evaluate cap material requirements to resist erosive forces associated with operations around the Crowley Marine Services pier. This analysis followed EPA and USACE guidance (USEPA 1998, Appendix A) for calculation of propeller jet velocities and resulting maximum bottom velocities. Calculations are included in Attachment A-1.

A.4.1 Vessel Characteristics and Calculated Velocities

In the area around the Crowley Marine pier, the most substantial erosive force is propeller wash from tugs operating around the pier. The areas of tug operations are shown in Figure A-1. Two classes of tugs were used as worst-case representative vessels for the propeller wash erosion analysis. Vessel characteristics used for the analysis were provided by Crowley Marine Services, who operate the largest tugs in the area. The vessel characteristics are summarized in Attachment A-1.

Crowley's Invader-class conventional line-haul tugs operate in deeper water near the pier, rarely approaching the pier head closer than 300 feet. Crowley's Robin-class conventional harbor tugs operate up to the pier head itself. For this analysis, tugs using conventional, rather than cycloidal, propulsion systems were used as a worst case. Similarly sized cycloidal tugs may be

used at the site, but typically generate water velocities higher in the water column, and thus produce lower bottom velocities and less erosion.

The worst-case scenarios considered for each of the two representative vessels assumed an extreme low tide, –4 feet MLLW, resulting in the shallowest water possible below the tug propeller and thus the greatest bottom velocity.

Assuming that the final grade of the cap approximates the existing bottom profile within the area of tug operation, the maximum bottom velocity at the pier head is estimated at 6 ft/sec (183 cm/sec). This bottom velocity would be produced by a harbor tug maneuvering at the pier head in 16 feet of water (the draft of these tugs is 16 feet). A line-haul tug maneuvering in 31 feet of water (the minimum depth in the area in which these tugs are customarily used near the pier—the draft of these tugs is 19 feet) would produce a maximum bottom velocity of approximately 3.5 ft/sec (107 cm/sec).

A.4.2 Approach for Determining Grain Size Requirements for Propeller Wash

Based on the calculated bottom velocities, USACE guidance was used to determine appropriate particle sizes for propeller wash erosion resistance. Because the maximum bottom velocities calculated were relatively low, riprap is not needed to resist propeller wash and the stone-sizing equation provided in the EPA guidance (USEPA 1998, Appendix A) does not appear to be applicable. The stone-sizing equation in this reference appears to be based on vessels maneuvering within channels, rather than within relatively open harbors, and anticipates a result of riprap-size stone. Use of this equation tended to result in D_{50} values for the armor material on the order of 0.8 to 2.25 feet, which is inconsistent with the existing substrate in the area. The logs of borings in the dredge area (USEPA 2002, Appendix C) indicate that the substrate in this area consists of soft silty sand, although it is acknowledged that this material may be periodically disturbed by propeller wash.

Riprap is required for slope stability in some areas, due to constructed grades. The analysis for sizing of riprap and filter material is described in Section A.5.

As an alternative to this equation, the maximum bottom velocities were compared to USACE engineering manual EM 1110-2-1601, Table 2-5, "Suggested Maximum Permissible Mean Channel Velocities" (USACE 1994). From to this table, a velocity of 6.0 ft/sec (183 cm/sec) is permissible for a bottom material consisting of fine gravel (typically defined as material with a grain size of 4.75 mm to 19 mm). Coarse sand (2.0 mm to 4.75 mm) is appropriate for areas with bottom velocities of 4.0 ft/sec (122 cm/sec) or less. Fine sand or sandy silt is appropriate for areas with bottom velocities less than 2.0 ft/sec (61 cm/sec). This latter criterion is consistent

with the USACE's observations of fine material movement in Puget Sound (USACE 1988), which defined a threshold speed of 50 cm/sec for resuspension of fine material.

As an additional check, calculations based on use of the Shields parameter (Dean and Dalrymple 2002) were made to estimate the D_{50} values required to resist motion at velocities greater than the threshold speed of 50 cm/sec. These calculations, shown in Attachment A-1 and summarized in Table A-4, give similar results to the above referenced table, although they tend to give a slightly larger D_{50} value for a given bottom velocity.

Materials specifications consider both of these procedures. It is recognized that materials with an appropriate grain size distribution will "self-armor" on the surface, as the smaller particles are removed by erosive forces and larger particles remain on the surface.

A.4.3 Results of Propeller Wash Analysis

To delineate the areas where different materials are required to resist propeller wash erosion, calculations were performed (Attachment A-1) to identify the depth at which the maximum bottom velocity equaled key permissible velocities in the USACE engineering manual EM 1110-2-1601. For the harbor tug scenario, the maximum bottom velocity drops to 4.0 ft/sec (122 cm/sec, the permissible velocity for coarse sand) when the tug is maneuvering in areas with a bottom elevation of –23 feet MLLW or deeper. For the line-haul tug, the maximum bottom velocity drops to 2.0 ft/sec (61 cm/sec, the permissible velocity for fine sand or sandy silt) when the tug is maneuvering in areas with a bottom depth of –49 feet MLLW or deeper.

The effects of propeller wash from maneuvering tugs extend beyond the area of actual operation of the tugs. The bottom velocities resulting from propeller wash are dependent on the distance from the operating tug and the depth of water. Calculations, included in Attachment A-1, were performed to evaluate the distances from operating tugs where bottom velocities dropped below key permissible velocities. The conservative scenario for this analysis is a tug operating near the eastern boundary of the tug operation area, with its propeller wash directed at the shoreline. For this scenario, bottom velocities were calculated for a 1-foot water depth (which equates to an elevation of –5 MLLW at extreme low tide). In addition to this scenario, selected combinations of water depth and distance were used in the calculations, based on the actual configuration of the harbor floor near the area of tug operations. The water velocities calculated for various water depths and distances from tug operation were then used to delimit the areas where different materials are required to resist propeller wash erosion beyond the area of actual operations.

The results of the propeller wash erosion analysis indicate that two different cap materials are required in zones near the pier head. Fine-grained gravel (4.75 mm to 19 mm) is required in

shallow areas within the zone of tug operation and within 150 feet of the zone of tug operation (to –25 feet MLLW within and very near tug operations, and to within –15 feet MLLW in shallow areas slightly further from operations). Coarse sand (4.75 mm to 2.0 mm) is required in the deeper zone of tug operation, from –25 feet MLLW to –50 feet MLLW, and at these depths within 300 feet of the tug operation area. In areas farther than 300 feet of tug operation, or with bottom elevations deeper than –50 feet MLLW, there are no restrictions on cap material type based on the propeller wash analysis.

The results of the propeller wash erosion analysis are summarized in Table A-4. The areas where different grain-size cap materials are required based on the erosion analysis as a whole are summarized in Table A-5 and shown in Figure A-2. It is noted that the gravels required for erosion resistance may have an effect on the types of benthic organisms that recolonize this area.

A.5 RIPRAP AND FILTER LAYER DESIGN

Riprap revetments were designed in general accordance with the U.S. Army Corps of Engineers, "Design of Coastal Revetments, Seawalls, and Bulkheads – Engineer Manual", 30 June 1995.

A.5.1 Riprap Design

Armor unit stability was addressed through calculation of the minimum weight that 50% of the stones must equal or exceed ($W_{50\,min}$). The $W_{50\,min}$ was calculated to be approximately 270 pounds, based on a design wave height of 2.9 feet. Approximate sizing limits were established based on the calculated $W_{50\,min}$, and in accordance with USACE guidelines. These limits, along with engineering judgement, were used as guidance for selection of an appropriate riprap specification.

Subject to the additional requirements listed following, the WSDOT 9-13.1(2) Light Loose Riprap specification was found to be suitable for this application.

- At least 50% of the stones shall have a weight greater than 300 lbs (i.e. $W_{50min} >$ 300 lbs);
- The riprap must be placed such that there is a well graded distribution of various stone sizes through the revetment;
- The maximum stone size shall be limited to 1,000 lbs (i.e. $W_{100max} = 1{,}000$ lbs);

The minimum riprap layer thickness was calculated, based on the design wave height and armor unit stability calculations, to be approximately 30 inches. Based on this calculation, the riprap layer thickness was designed at a minimum 24 inches plus an over-placement allowance of 12 inches. Assuming that, on average, half the over-placement allowance is placed, the net layer thickness will achieve the minimum requirement of the USACE guidance.

A.5.2 Filter Layer Design

The gradation recommendations of the USACE guidance are considered critical in areas where the riprap revetment will be within the tidal zone and potentially exposed to wave action. In these applications, the filter layer must be fine enough to prevent the underlying sand cap mix from being washed through the riprap and coarse enough to prevent the filter layer itself from being washed through the riprap. In applications where the riprap revetment will be installed below the tidal zone, use of a 2 ½ inch crushed rock is considered acceptable.

Gradation requirements for the filter layer that will underlay riprap revetments constructed within the tidal zone were calculated based on the sizing limits recommended by the USACE guidance. Stone weights were related to stone diameters by either: the USACE equation for armor thickness, assuming the number of units in the layer (n) was equal to 1; or, assuming the stone was a sphere. The filter layer minimum D_{85} was calculated to be between 0.26 feet and 0.33 feet.

The only commonly available product that has a D_{85} equal to or greater the range recommended by the USACE guidance is WSDOT 9-13.6 Quarry Spalls. However, while the quarry spalls would be coarse enough to prevent them from being washed through the riprap, they would not contain sufficient fines to prevent the egress of the sand cap mix. Construction of a second, thin filter layer, below the quarry spalls, that would prevent the escape of the underlying sand cap mix would be difficult to construct an the underwater environment and is considered impractical. Therefore, a compromise approach was adopted by specifying a blended material whose gradation would provide both particles that are large enough to prevent it from being washed through the riprap, but fine enough to contain the underlying sand cap mix.

The minimum thickness of the filter layer recommended by the USACE guidance is 3 times the median stone diameter. The minimum layer thickness was conservatively calculated, based on the D_{85} calculated above and not the median stone diameter, to be between 0.8 and 1.0 feet. Therefore the design filter layer thickness of 18 to 24 inches is adequate.

A.6 CROSS-SHORE SEDIMENT TRANSPORT AND ALLOWABLE INTERTIDAL SLOPES (RA1)

The *equilibrium profile* of a beach is the result of the long-term balance of forces acting on the beach. A wealth of empirical research on this topic has indicated that the equilibrium profile of a beach can be represented by a power law relationship such as

$$H(x) = A\,x^m$$

in which H(x) is local depth, as a function of distance x from shore. The coefficient A appears to depend mostly (although not entirely) on beach sediment grain size, while the exponent m varies between about 0.5 and 0.8, with a mean value of about 0.66 (Dean and Dalrymple 2002). Recommended values of A for sediment grain sizes from 0.1 to 1.1 mm were tabulated by Dean et al. (1994). USACE guidance adopts this approach and further defines correlations and empirical data for determination of A based on grain size (USACE 1995, 2002).

Setting m = 2/3 (i.e., the mean value of 0.66) in Equation (2), and then differentiating with respect to x, the following expression is obtained for seabed slope as a function of distance x from shore:

$$\text{Slope} = dH/dx = [(2/3)\,A\,x^{-1/3}\,]$$

Assuming various mean particle diameters, the above equations were used to compute the idealized seabed elevations and slopes at 10-foot intervals to a distance of 100 feet from the shoreline. To obtain a maximum slope specification for a given sediment grain size, the calculated net change in elevation over the first 50 feet from the shoreline was used. Attachment A-1 shows these calculations for the various cap material grain sizes.

As described in Section A.3, a fine-grained gravel (D_{50} of 4 to 20 mm) would resist erosion from wave-induced currents for all but the most severe events. Assuming a D_{50} in the middle of this range (12 mm), the calculated maximum permissible beach slope is 1V:7H. To add a factor of safety, a D_{50} of 18 mm should be used.

A.7 SUMMARY

The erosion analysis indicates certain restrictions on cap material types will be required in some RAs to resist erosion of the newly placed cap. These restrictions, summarized in Figure A-3, are expressed as D_{50} requirements and indicate the need for:

- Gravels in the intertidal zone (RA 1) where shallow slopes are used;
- Specific riprap and filter materials in RA1 for thick slope caps constructed to steep slopes;
- Coarse sand and gravels in subtidal areas affected by propeller wash (RA3 and portions of RA2a)

No restrictions on materials types are needed to resist erosion in RA4, RA5, or RA2b. Allowable slopes for material stability affect the final grades and materials specifications of the intertidal cap in RA1. Waves generated by rare storm events may result in some erosion (and associated maintenance requirements) of gravels used in the intertidal areas of RA1.

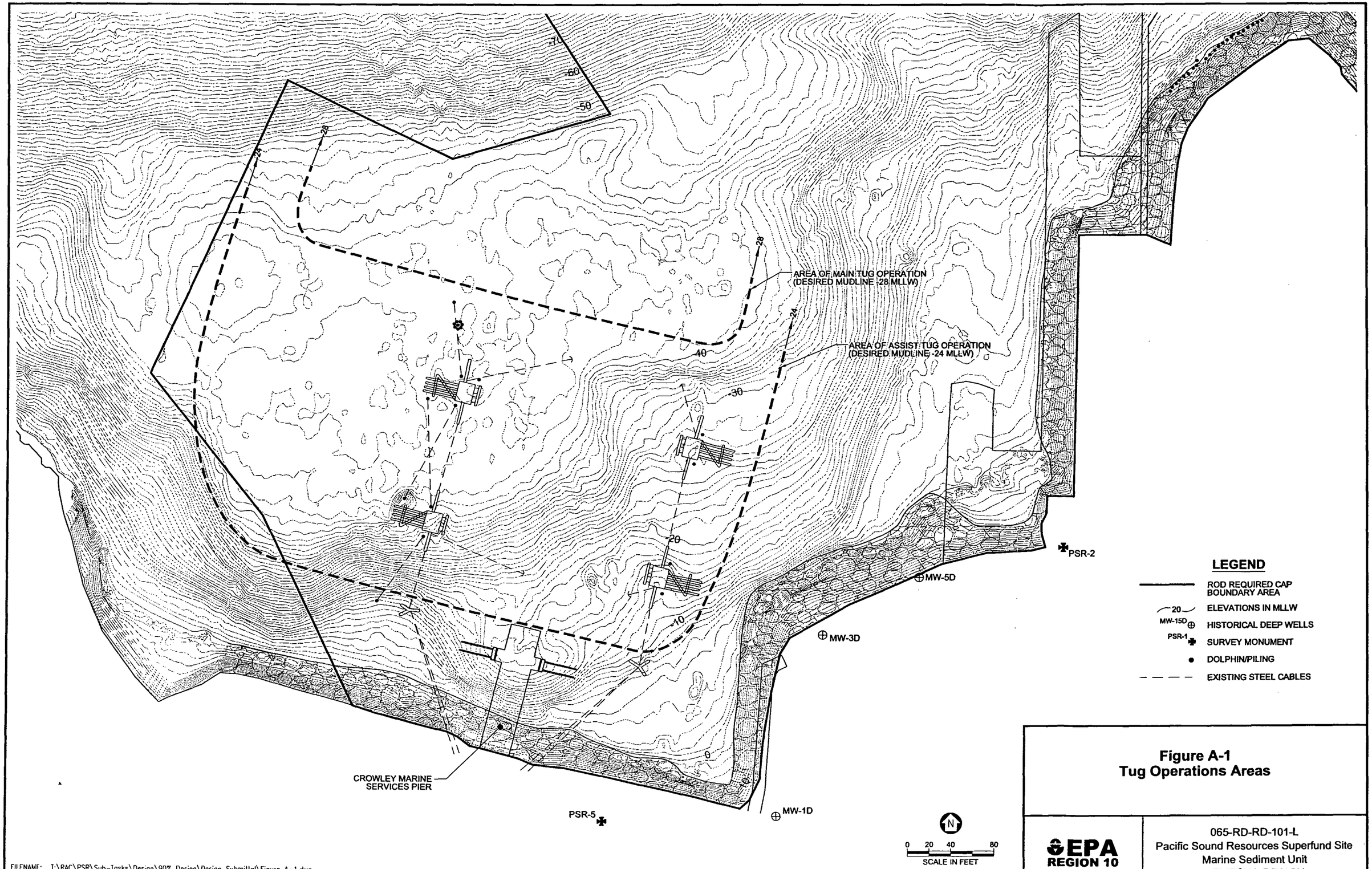

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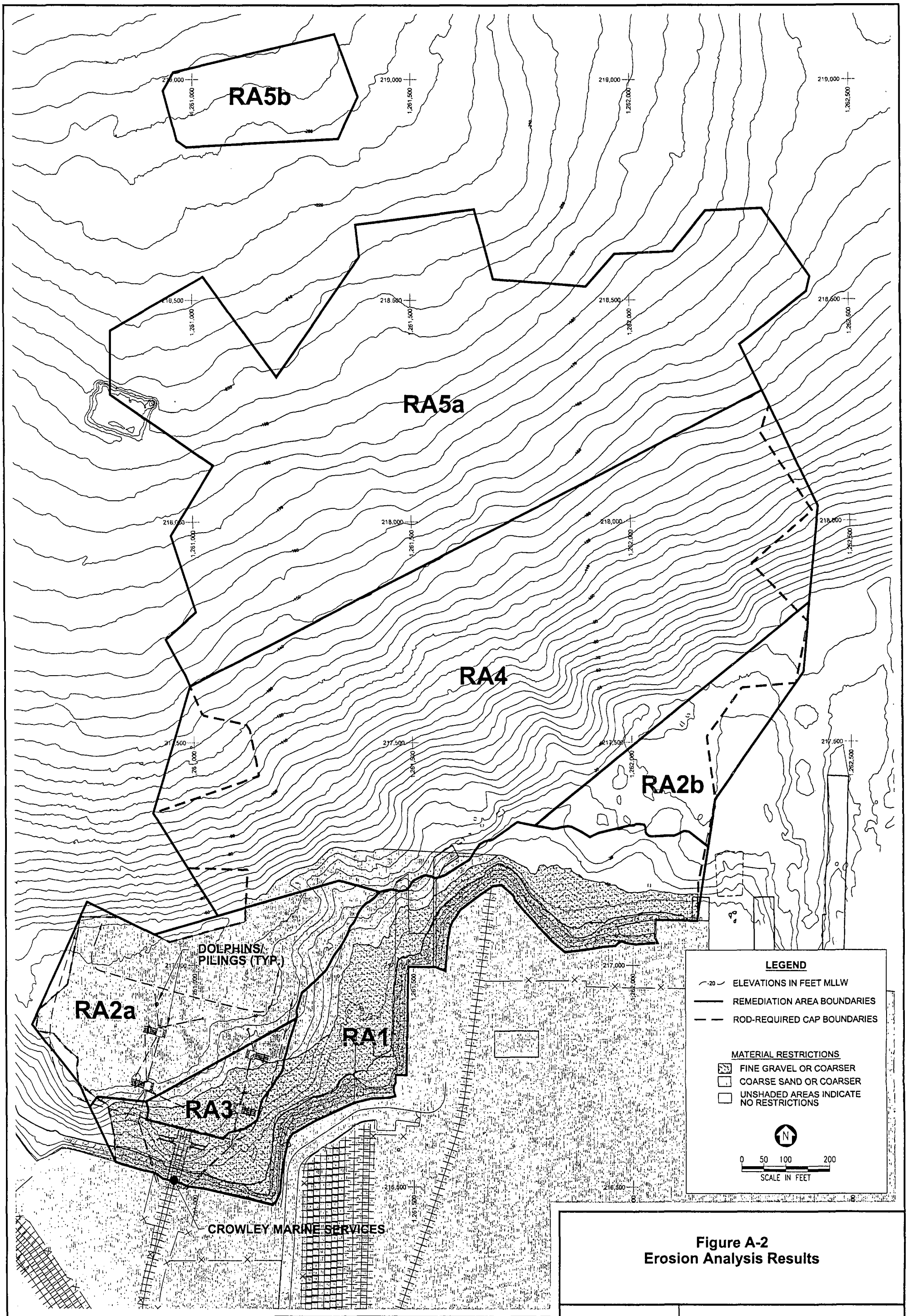
Figure A-1
Tug Operations Areas

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN



NOTE:
Material restrictions do not necessarily coincide with RA boundaries.

Figure A-2
Erosion Analysis Results

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

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Table A-1
Geometry of the "Long Fetch": Directions and Lengths of Fetches to PSR Site

Fetch Direction (Deg. True Az.)	Fetch Length (statute miles)	Fetch Limited By
315°	14.8	East shore – Bainbridge Island
318°	15.2	East shore – Bainbridge Island
321°	16.5	East shore – Bainbridge Island
324°	22.0	South shore – Kitsap Peninsula near Indianola
327°	20.7	South shore – Kitsap Peninsula near Indianola
330°	6.9	West Point

Table A-2
West Point Wind Data: Some Results of Statistical Analysis

Speed (m/s)	Directional Sector (degrees true azimuth)			
	315° - 330° [1]	330° - 345°	345° - 360°	360° - 015°
Maximum	14.2	14.3	18.8	16.7
99th-percentile	11.3	11.3	12.5	9.8
98th-percentile	7.9	10.4	11.4	9.0
95th-percentile	5.5	8.5	9.4	8.1
Percent of all observations from this sector	0.63	1.8	4.4	10.0

[1] 315° - 330° sector is the design sector
Note:
Observations of wind data from period of 1984-2001.

Table A-3
Significant Wave Properties for Fully-Developed Seas

	Design Sector	Other Sectors Examined[1]		
	315° - 330°	330° - 345°	345° - 360°	360° - 015°
Maximum fetch	22 mi.	7 mi.	22 mi.	19 mi.
Maximum wind speed	25.3 mph	32 mph	41 mph	37 mph
Significant wave height	2.86 ft	2.6 ft	5.9 ft	4.9 ft
Significant wave period	3.49 s	3.4 s	5.4 s	5.0 s
Deep-water wave length	62 ft	59 ft	149 ft	128 ft

[1] Fetches and wave characteristics evaluated at West Point, for consideration of refraction into Elliott Bay. However, such refraction was not found to be a significant concern.

Table A-4
Wave-Induced Bottom Currents

Wind	Design Wave		
(mph)	H (ft)	T (s)	L_0 (ft)
25.3	2.86	3.49	62.4

Depth, ft	Height, ft	Length, ft	Celerity, ft/s	n (=Cg/C)	k (=2pi/L)	H/D	Bottom Current, cm/s
>50	2.86	62.4	17.9	0.50	0.101	-	
50	2.86	62.4	17.9	0.50	0.101	0.06	1
45	2.86	62.4	17.9	0.50	0.101	0.06	2
40	2.85	62.4	17.9	0.50	0.101	0.07	3
35	2.84	62.3	17.9	0.51	0.101	0.08	5
30	2.82	62.3	17.8	0.51	0.101	0.09	8
25	2.78	62.0	17.8	0.53	0.101	0.11	12
20	2.71	61.3	17.6	0.57	0.102	0.14	19
15	2.60	59.4	17.0	0.63	0.106	0.17	31
10	2.53	54.6	15.6	0.73	0.115	0.25	49
9	2.53	52.9	15.2	0.76	0.119	0.28	54
8	2.53	51.0	14.6	0.78	0.123	0.32	60
7	2.55	48.6	13.9	0.80	0.129	0.36	68
6	2.59	45.8	13.1	0.83	0.137	0.43	77
5	2.65	42.5	12.2	0.86	0.148	0.53	90
4	2.74	38.6	11.1	0.88	0.163	0.68	108
3.5	2.80	36.3	10.4	0.90	0.173	0.80	119
3	*Note: Wave breaks when H/D = 0.75 (approx.)*						300
2	*Bottom current speed estimated as*						245
1	*celerity of solitary wave.*						173

Table A-5
Summary of Propeller Wash Analysis Results

Vessel (tug)	Distance from Edge of Tug Operation Area	Depth of Water[a] (feet)	Bottom Velocity Elevation (feet MLLW)	Maximum Bottom Velocity		Required Cap Grain Size (USACE 1994) (D_{50}, mm)	Required Cap Grain Size (Dean et al. 2002) (D_{50}, mm)
				(ft/sec)	(cm/sec)		
Harbor	Within[b]	16	-20	6.0	183	4.75 to 19	18
Line-haul	Within[b]	31	-35	3.5	107	2.0 to 4.75	6
Harbor	Within[b]	19	-23	4.0	122	2.0 to 4.75	8
Line-haul	Within[b]	45	-49	2.0	61	No restriction	2
Harbor	75 feet	1	-5	4.7	143	4.75 to 19	11
Harbor	150 feet	1	-5	2.3	72	2.0 to 4.75	3
Line-haul	120 feet	1	-5	5.2	158	4.75 to 19	13
Line-haul	150 feet	1	-5	4.2	127	2.0 to 4.75	8
Harbor	300 feet	1	-5	1.2	36	No restriction	0.7
Line-haul	300 feet	1	-5	2.1	63	No restriction	2

[a]At extreme low tide (-4 feet MLLW)
[b]"Within" means that the calculation is for areas within the area of tug operation, as identified by Crowley Marine Services

Notes:
cm - centimeters
D_{50} - the 50th percentile grain diameter
ft - feet
MLLW - mean lower low water
mm - millimeters
sec - seconds

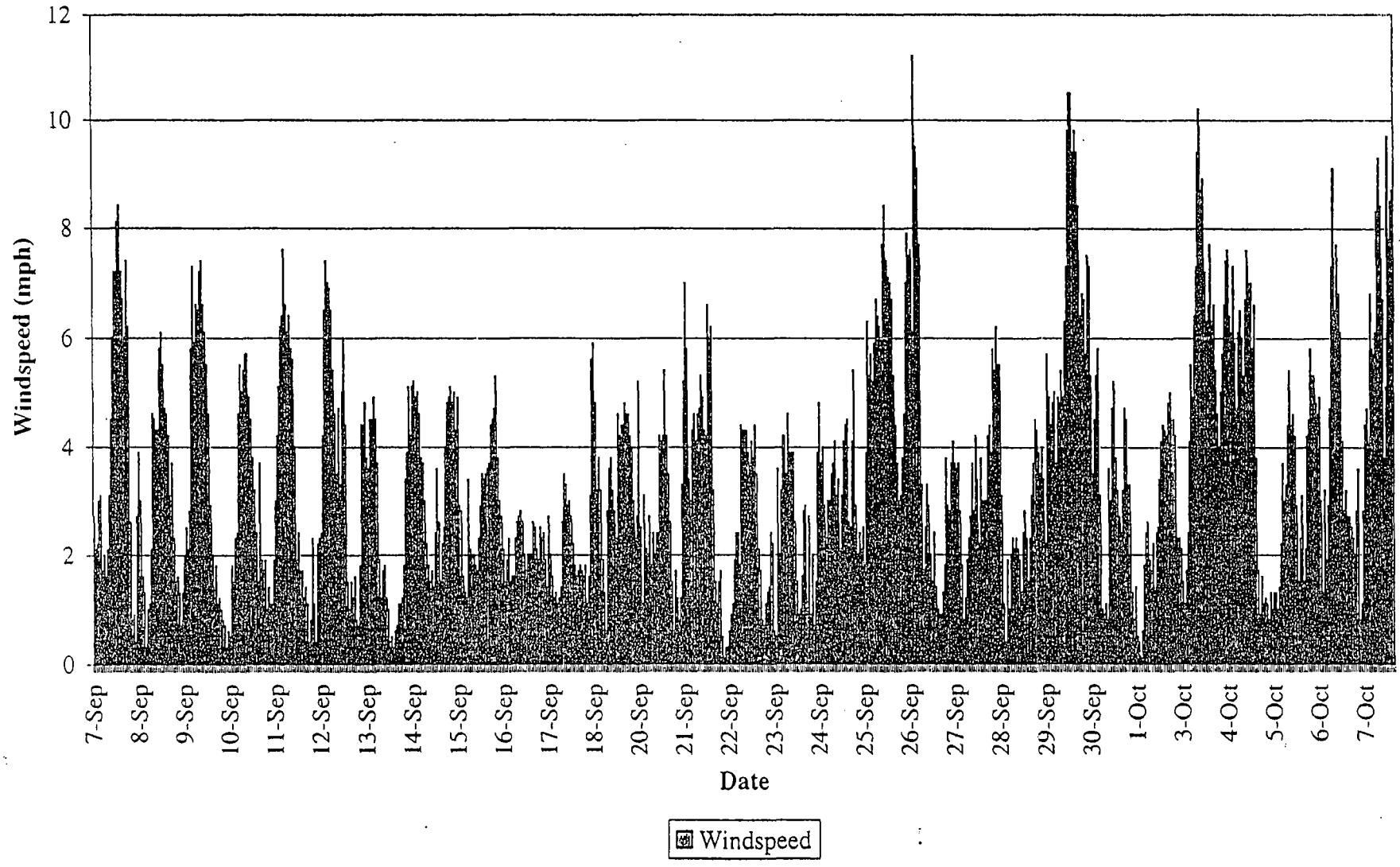
Table A-6
Overview of Erosion Analysis Results by Area

Remediation Areas Affected	Conditions	Area Definition	Controlling Mechanism	Max Bottom Velocity (cm/sec)	Required Cap Grain Size (USACE 1994) (D_{50}, mm)	Required Cap Grain Size (Dean et al. 2002) (D_{50}, mm)
RA2b, RA4, RA5	Subtidal	Below –19 ft MLLW, > 300 from tug operations	Ambient current	12	No restriction	0.08
RA1	Intertidal	+14 ft MLLW to –7 ft MLLW	Wave-induced currents	300	200	49
RA1, RA3	Shallow propwash, within ops	–7 ft MLLW to –25 ft MLLW, within area of tug ops	Harbor tug	183	4.75 to 19	18
RA2a	Deep propwash, within ops	–25 ft MLLW to –50 MLLW, within area of tug ops	Line-haul tug	107	2.0 to 4.75	6
RA1	Intertidal propwash, near ops	–7 ft MLLW to –15 ft MLLW, within 150 ft of tug ops	Both tug types	183	4.75 to 19	18
RA1	Intertidal propwash, farther from ops	–7 ft MLLW to –15 ft MLLW, within 150 to 300 ft of tug ops	Line-haul tug	122	2.0 to 4.75	8
RA2a	Deep propwash, near ops	–15 ft MLLW to –50 ft MLLW, within 300 ft of tug ops	Line-haul tug	106	2.0 to 4.75	6
RA2b, RA4, RA5	Beyond substantial propwash effect	Deeper than –50 MLLW or more than 300 ft from tug ops	Line-haul tug	Less than 61	No restriction	<1.9

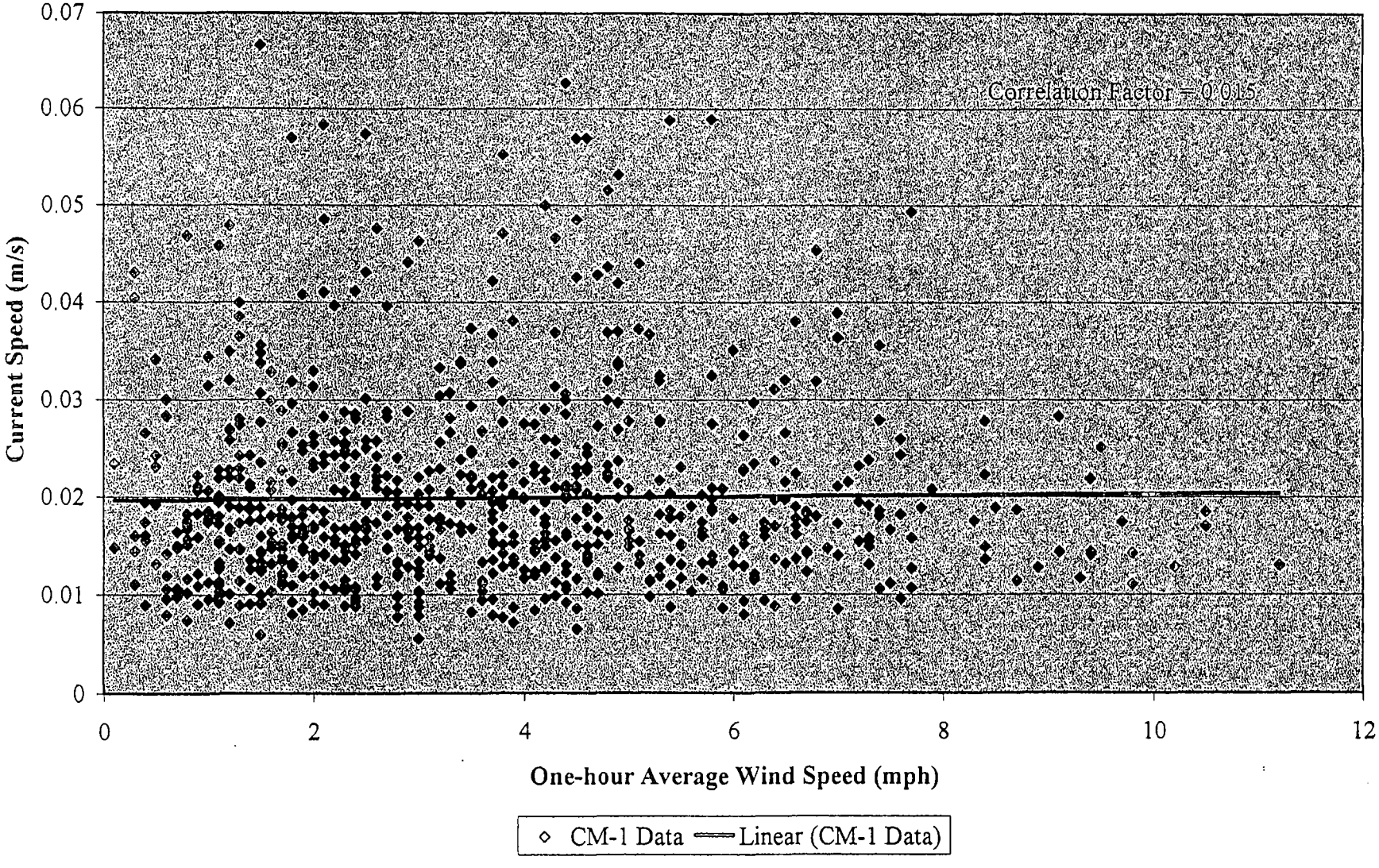
Notes:
cm - centimeters
D_{50} - The 50th percentile grain diameter
ft - feet
MLLW - mean lower low water
mm - millimeters
ops - operations
propwash - propeller wash
sec - seconds

ATTACHMENT A-1
EROSION ANALYSIS CALCULATIONS

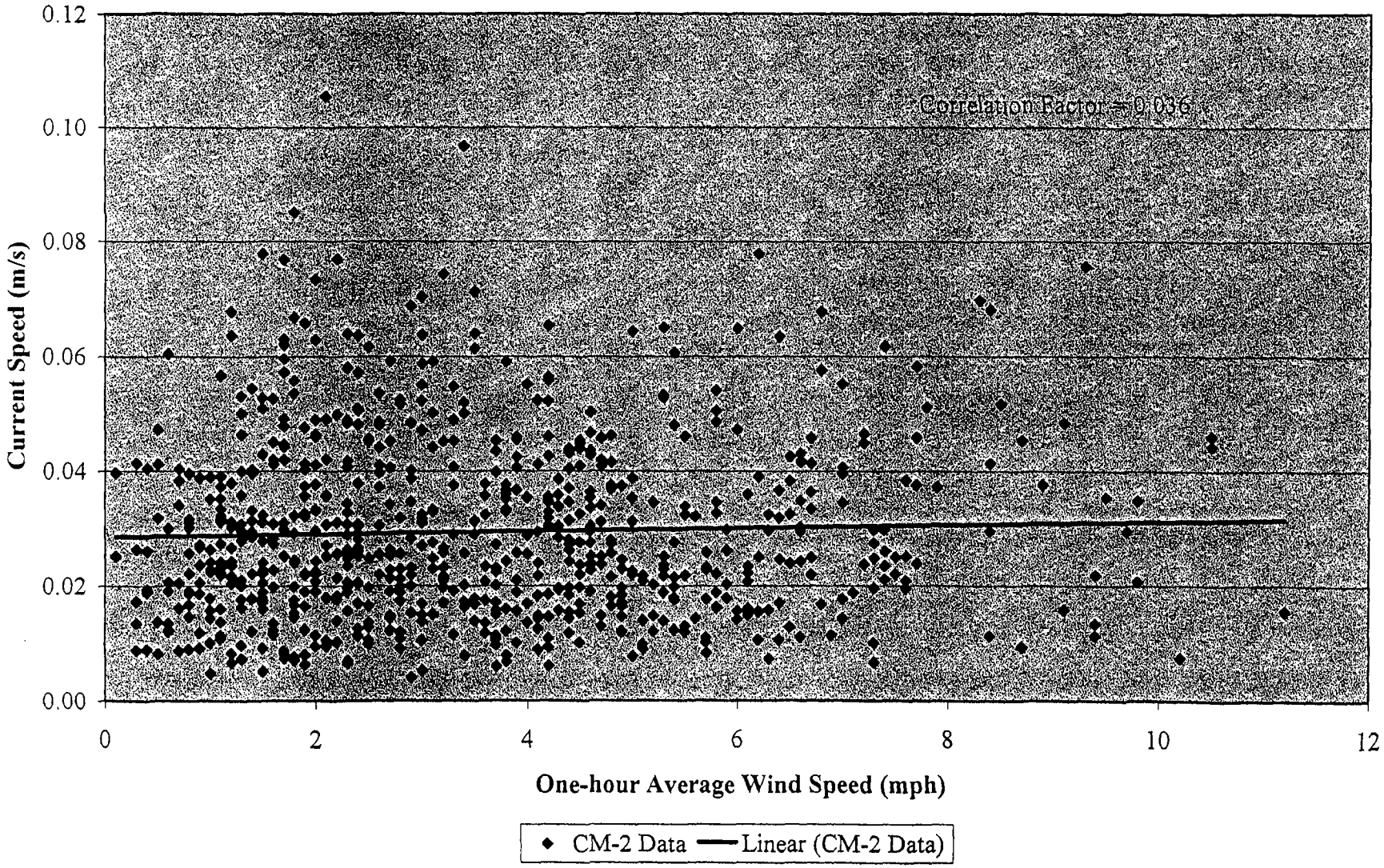
PSCAA Wind Data



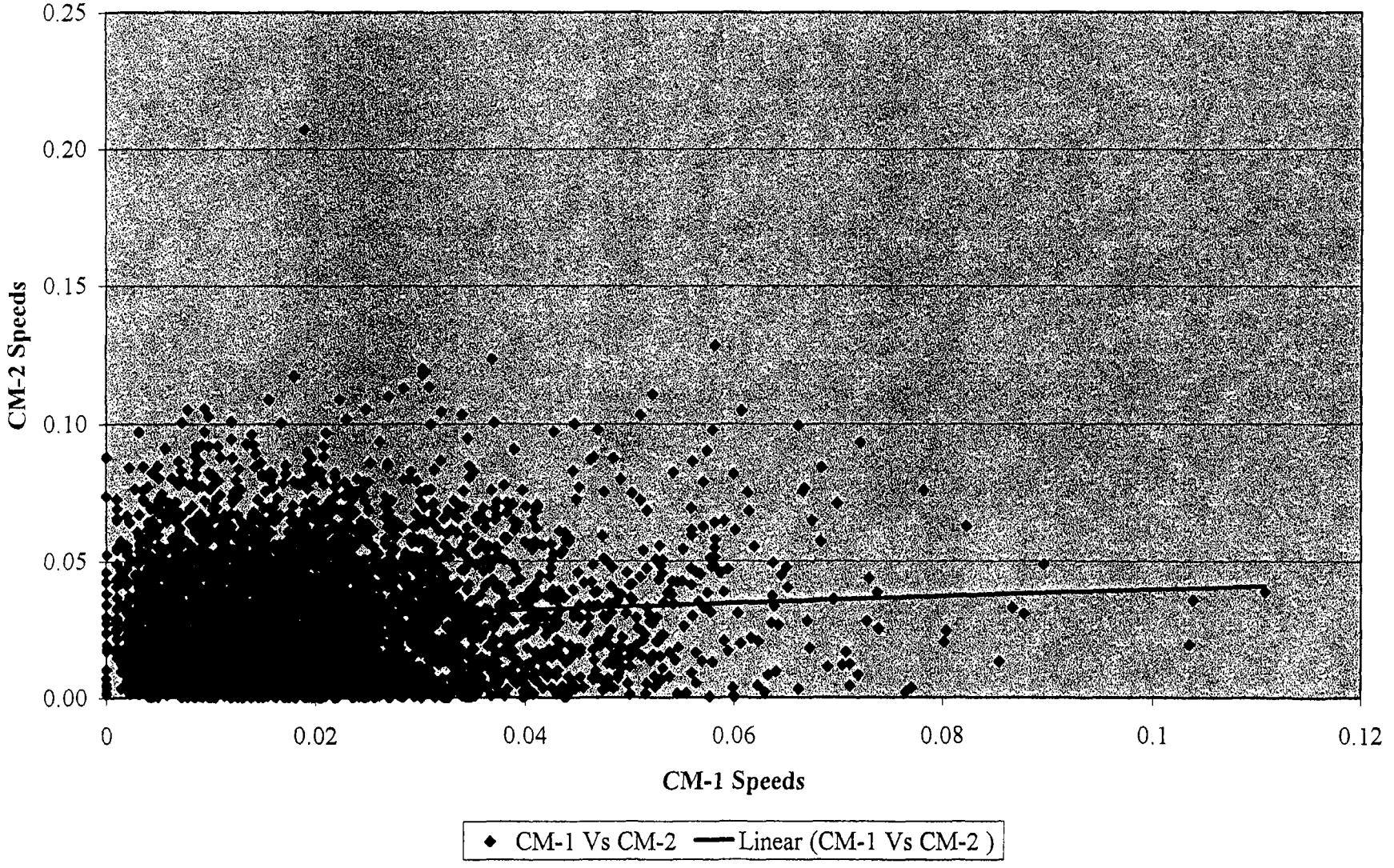
CM-1 Current Data Versus Wind Speed



CM-2 Current Data Versus Wind Speed

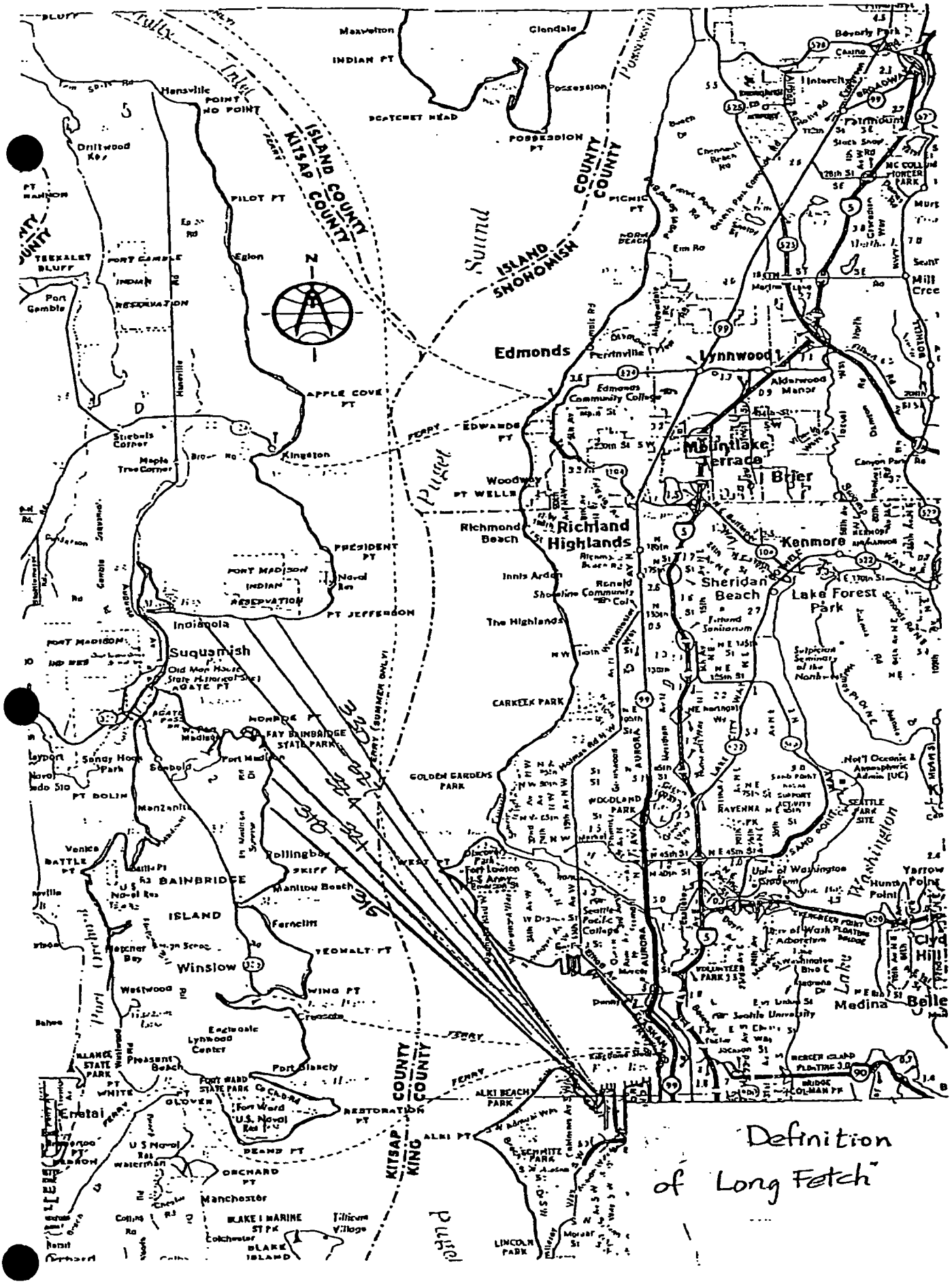


CM-1 Vs CM-2 Comparison



PSR Superfund Site
Time-lag Comparison of Bottom Current Data
CM-1 (shallow) to CM-2 (deep)

Scenario	Correlation Coefficient
Real time (no time lag between CM-1 and CM-2 data)	0.0772
CM-2 data shifted 30 minutes later in time relative to CM-1 data	0.0759
CM-2 data shifted 60 minutes later in time relative to CM-1 data	0.0710
CM-2 data shifted 90 minutes later in time relative to CM-1 data	0.0498
CM-2 data shifted 120 minutes later in time relative to CM-1 data	0.0454
CM-1 data shifted 30 minutes later in time relative to CM-2 data	0.0381
CM-1 data shifted 60 minutes later in time relative to CM-2 data	0.0067
CM-1 data shifted 90 minutes later in time relative to CM-2 data	-0.0154


Definition
of Long Fetch"

AUTOMATED COASTAL ENGINEERING SYSTEM (ACES)

Version 1.07

PURPOSE

This note discusses a microcomputer-based software package that contains reliable state-of-the-art solutions to various coastal engineering problems.

BACKGROUND

In 1986 the Coastal Engineering Research Center (CERC) recommended to the Office, Chief of Engineers that an Automated Coastal Engineering System (ACES) be developed to give Corps offices an interactive computer based design capability in the field of coastal engineering. The recommendation was in response to a charge by the Chief of Engineers, LTG E. R. Heiberg III, to the Coastal Engineering Research Board to provide improved design capabilities to Corps coastal specialists.

CERC formed an internal technical committee to develop recommendations for implementing an automated design System. This committee obtained input from Corps field offices regarding the form and development procedures preferred for the system. The information was obtained primarily from six regional workshops conducted in July 1986 and attended by more than one hundred coastal specialists.

Based on recommendations from the workshops, a Pilot Committee composed primarily of Corps District and Division coastal specialists was formed in September 1986 to guide development of the ACES. In addition an Automated Coastal Engineering Group was formed in February 1987 within CERC to implement its development.

INTRODUCTION

The ACES is a microcomputer-based design and analysis system in the field of coastal engineering. The contents range from simple algebraic expressions both theoretical and empirical in origin, to numerically intense algorithms spawned by the increasing power and affordability of computers. The methods in the ACES range from classical theory describing wave motion, to expressions resulting from tests with structures in wave flumes, and to recent numerical models describing the exchange of energy from the atmosphere to the sea surface.

ACES CONTENTS

The various methodologies included in ACES are called applications, and are organized into categories called functional areas differentiated according to general relevant physical processes and design or analysis activities. A summary of the applications currently resident in the ACES is given in Table 1.

TABLE 1
Current ACES Applications (Version 1.07)

Functional Area	Application Name
Wave Prediction	Windspeed Adjustment and Wave Growth
	Beta-Rayleigh distributions
	Extremal Significant Wave Height Analysis
	Constituent Tide Record Generation
Wave Theory	Linear Wave Theory
	Cnoidal Wave Theory
	Fourier Series Wave Theory

Wave Transformation	Linear Wave Theory with Snell's Law Irregular Wave Transformation (Goda's method) Combined Diffraction and Refraction by a Vertical Wedge
Structural Design	Breakwater Design Using Hudson and Related Equations Toe Protection Design Nonbreaking Wave Forces on Vertical Walls Rubble-Mound Revetment Design
Wave Runup, Transmission, and Overtopping	Irregular Wave Runup on Beaches Wave Runup and Overtopping on Impermeable Structures Wave Transmission on Impermeable Structures Wave Transmission Trough Permeable Structures
Littoral Processes	Longshore Sediment Transport Numerical Simulation of Time-Dependent Beach and Dune Erosion Calculation of Composite Grain-Size Distribution Beach Nourishment Overfill Ration and Volume
Inlet Processes	A Spatially Integrated Numerical Model for Inlet Hydraulics

DESCRIPTION OF ACES APPLICATIONS

The various applications within the functional areas represent a number of different methodologies of varying complexity. A brief description of each application follows.

WAVE PREDICTION FUNCTIONAL AREA

Windspeed Adjustment and Wave Growth

The methodologies represented in this ACES application provide quick and simple estimates for wave growth over open-water and restricted fetches in deep and shallow water. Also, improved methods (over those given in the Shore Protection Manual (SPM), 1984) are included for adjusting the observed winds to those required by wave growth formulas.

Beta-Rayleigh Distribution

This application provides a statistical representation for a shallow water wave height distribution. The Beta-Rayleigh distribution is expressed in familiar wave parameters: Hmo (energy based wave height), Tp (peak spectral wave period), and d(water depth). After constructing the distribution, other statistically based wave height estimates such as Hrms, Hmean, H1/10 can be easily computed. The Beta-Rayleigh distribution features a finite upper bound corresponding to the breaking wave height, and the expression collapses to the Rayleigh distribution in the deepwater limit. The methodology for this portion of the application is taken exclusively from Hughes and Borgman (1987).

Extremal Significant Wave Height Analysis

This application provides significant wave height estimates for various return periods. Confidence intervals are also provided. The approach developed by Goda (1988) is used to fit five candidate probability distributions to an input array of extreme significant wave heights. Candidate distribution functions are Fisher-Tippett Type I and Weibull with exponents ranging from 0.75 to 2.0. Goodness-of-fit information is provided for identifying the distributions which best match the input data.

Constituent Tide Record Generation

This application predicts a tide elevation record at a specific time and locale using known amplitudes and epochs for individual harmonic constituents.

WAVE THEORY FUNCTIONAL AREA

Linear Wave Theory

This application yields first-order approximations for various parameters of wave motion as predicted by the wave theory bearing the same name (also known as small amplitude, sinusoidal, or Airy theory). It provides estimates for engineering quantities such as water surface elevation, general wave properties, particle kinematics, and pressure as functions of wave height and period, water depth, and position in the waveform.

Cnoidal Wave Theory

This application yields various parameters of wave motion as predicted by first-order (Isobe, 1985) and second-order (Hardy and Kraus, 1987) approximations for cnoidal wave theory. It provides estimates for common items of interest such as water surface elevation, general wave properties, kinematics, and pressure as functions of wave height and period, water depth, and position in the waveform.

Fourier Series Wave Theory

This application yields various parameters for progressive waves of permanent form, as predicted by Fourier series approximation. It provides estimates for common engineering parameters such as water surface elevation, integral wave properties, and kinematics as functions of wave height, period, water depth, and position in the wave form which is assumed to exist on a uniform co-flowing current. Stokes first and second approximations for celerity (i.e., values of the mean Eulerian current or mean mass transport rate) may be specified. Fourier series of up to 25 terms may be selected to approximate the wave.

WAVE TRANSFORMATION FUNCTIONAL AREA

Linear Wave Theory with Snell's Law

This application provides a simple estimate for wave shoaling and refraction using Snell's law with wave properties predicted by linear wave theory. Given wave properties and a crest angle at a known depth, it predicts the values in deep water and at a subject location specified by a new water depth. An important assumption for this application is that all depth contours are assumed to be straight and parallel. The criteria of Singamsetti and Wind (1980) and Weggel (1972) are employed to provide an estimate for breaker parameters.

Irregular Wave Transformation (Goda's method)

This application yields cumulative probability distributions of wave heights as a field of irregular waves propagate from deep water through the surf zone. The application is based on two random-wave theories by Yoshimi Goda (1975 and 1984). The 1975 paper concerns transformation of random waves shoaling over a plane bottom with straight parallel contours. This analysis treated breaking and broken waves and resulted in cumulative probability distributions for wave heights given a water depth. It did not include refraction, however. The 1984 article details a refraction procedure for random waves propagating over a plane bottom with straight parallel contours assuming a particular incident spectrum. This ACES application combines the two approaches by treating directional random waves

propagating over a plane bottom with straight parallel contours. This application also uses the theory of Shuto (1974) for the shoaling calculation. The theories assume a Rayleigh distribution of wave heights in the nearshore zone and a Bretschneider-Mitsuyasu incident directional spectrum. The processes modeled include: Wave refraction, Wave shoaling, Wave breaking, Wave setup, and Surf beat.

Combined Diffraction and Reflection by a Vertical Wedge

This application estimates wave height modification due to combined diffraction and reflection near jettied harbor entrances, quay walls, and other such structures. Jetties and breakwaters are approximated as a single straight, semi-infinite breakwater by setting the wedge angle to zero. Corners of docks and quay walls may be represented by setting the wedge angle equal to 90 degrees. Additionally, such natural diffracting and reflecting obstacles as rocky headlands can be approximated by setting a particular value for the wedge angle.

STRUCTURAL DESIGN FUNCTIONAL AREA

Breakwater Design Using Hudson and Related Equations

A rubble structure is often composed of several layers of random-shaped or random-placed stones, protected with a cover layer of selected armor units of either quarrystone or specially shaped concrete units. This ACES application provides estimates for the armor weight, minimum crest width, armor thickness, and the number of armor units per unit area of a breakwater using Hudson's and related equations. The material presented herein can be found in Chapter 7 of the SPM (1984).

Toe Protection Design

Toe protection consists of armor for the beach or bottom material fronting a structure to prevent wave scour. This application determines armor stone size and width of a toe protection apron for vertical faced structures such as seawalls, bulkheads, quay walls, breakwaters, and groins. Apron width is determined by the geotechnical and hydraulic guidelines specified in Engineer Manual 1110-2-1614. Stone size is determined by a method (Tanimoto, Yagyu, and Goda, 1982) whereby a stability equation is applied to a single rubble unit placed at a position equal to the width of the toe apron and subjected to standing waves.

Nonbreaking Wave Forces on Vertical Walls

This application provides the pressure distribution and resultant force and moment loading on a vertical wall caused by normally-incident, nonbreaking, regular waves. The results can be used to design vertical structures in protected or fetch-limited regions when the water depth at the structure is greater than about 1.5 times the maximum expected wave height. The application provides the same results as found using the design curves given in Chapter 7 of the SPM (1984).

Rubble-Mound Revetment Design

Quarrystone is the most commonly used material for protecting earth embankments from wave attack because, where high-quality stone is available, it provides a stable and unusually durable revetment armor material at relatively low cost. This ACES application provides estimates for revetment armor and bedding layer stone sizes, thicknesses, and gradation characteristics. Also calculated are two values of runup on the revetment, an expected extreme, and a conservative runup value.

WAVE RUNUP, TRANSMISSION, AND OVERTOPPING FUNCTIONAL AREA

Irregular Wave Runup on Beaches

This application provides an approach to calculate runup statistical parameters for wave runup on smooth slope linear beaches. To account for permeable and rough slope natural beaches, the present approach needs to be modified by multiplying the results for the smooth slope linear beaches by a reduction factor. However, there is no guidance for such a reduction due to the sparsity of good field data on wave runup. The approach used in this ACES application is based on existing laboratory data on irregular wave runup (Mase and Iwagaki, 1984 and Mase, 1989).

Wave Runup and Overtopping on Impermeable Structures

This application provides estimates of wave runup and overtopping on rough and smooth slope structures that are assumed to be impermeable. Run-up heights and overtopping rates are estimated independently or jointly for monochromatic or irregular waves specified at the toe of the structure. The empirical equations suggested by Ahrens and McCartney (1975), Ahrens and Titus (1985), and Ahrens and Burke (1987) are used to predict runup, and Weggel (1976) to predict overtopping. Irregular waves are represented by a significant wave height and are assumed to conform to a Rayleigh distribution (Ahrens, 1977). The overtopping rate is estimated by summing the overtopping contributions from individual runups in the distribution.

Wave Transmission on Impermeable Structures

This application provides estimates of wave runup and transmission on rough and smooth slope structures. It also addresses wave transmission over impermeable vertical walls and composite structures. In all cases, monochromatic waves are specified at the toe of a structure that is assumed to be impermeable. For sloped structures, a method suggested by Ahrens and Titus (1985) and Ahrens and Burke (1987) is used to predict runup, while the method of Cross and Sollitt (1971) as modified by Seelig (1980) is used to predict overtopping. For vertical wall and composite structures, a method proposed by Goda, Takeda, and Moriya (1967) and Goda (1969) is used to predict wave transmission.

Wave Transmission Through Permeable Structures

Porous rubble-mound structures consisting of quarry stones of various sizes often offer an attractive solution to the problem of protecting a harbor against wave action. It is important to assess the effectiveness of a given breakwater design by predicting the amount of wave energy transmitted by the structure. This application determines wave transmission coefficients and transmitted wave heights for permeable breakwaters with crest elevations at or above the still-water level. This application can be used with breakwaters armored with stone or artificial armor units. The application uses a method developed for predicting wave transmission by overtopping coefficients using the ratio of breakwater freeboard to wave runup (suggested by Cross and Sollitt, 1971). The wave transmission by overtopping prediction method is then combined with the model of wave reflection and wave transmission through permeable structures of Madsen and White (1976). Seelig (1979,1980) had developed a similar version for mainframe processors.

LITTORAL PROCESSES FUNCTIONAL AREA

Longshore Sediment Transport

This application provides estimates of the potential longshore transport rate under the action of waves. The method used is based

on the empirical relationship between the Longshore component of wave energy flux entering the surf zone and the immersed weight of sand moved (Galvin, 1979). Two methods are available to the user depending on whether available input data are breaker wave height and direction or deepwater wave height and direction.

Numerical Simulation of Time-Dependent Beach and Dune Erosion

This application is a numerical beach and dune erosion model that predicts the evolution of an equilibrium beach profile from variations in water level and breaking wave height as occur during a storm. The model is one-dimensional (only onshore-offshore sediment transport is represented). It is based on the theory that an equilibrium profile results from uniform wave energy dissipation per unit volume of water in the surf zone. The general characteristics of the model are based on a model described by Kriebel (1982, 1984a, 1984b, 1986). Because of the complexity of this methodology and the input requirements, familiarization with the above references is strongly recommended.

Calculation of Composite Grain-Size Distributions

The major concern in the design of a sediment sampling plan for beach-fill purposes is determining the composite grain size characteristics of both the native beach and the potential borrow site. This application calculates a composite grain size distribution that reflects textural variability of the samples collected at the native beach or the potential borrow area.

Beach Nourishment Overfill Ratio and Volume

The methodologies represented in this ACES application provide two approaches to the planning and design of nourishment projects. The first approach is the calculation of the overfill ratio, which is defined as the volume of actual borrow material required to produce a unit volume of usable fill. The second approach is the calculation of a renourishment factor which is germane to the long-term maintenance of a project, and addresses the basic question of how often renourishment will be required if a particular borrow source is selected that is texturally different from the native beach sand.

INLET PROCESSES FUNCTIONAL AREA

A Spatially Integrated Numerical Model for Inlet Hydraulics

This application is a numerical model that estimates coastal inlet velocities, discharges, and bay levels as functions of time for a given time-dependent sea level fluctuation. Inlet hydraulics are predicted in this model by simultaneously solving the time-dependent momentum equation for flow in the inlet and the continuity equation relating the bay and sea levels to inlet discharge. The model is designed for cases where the bay water level fluctuates uniformly throughout the bay and the volume of water stored in the inlet between high and low water is negligible compared with the tidal prism of water that moves through the inlet and is stored in the bay. The model has been previously described by Seelig (1977) and Seelig, Harris, and Herchenroder (1977).

SYSTEM REQUIREMENTS

ACES is designed to run on IBM PC-AT (or compatible) machines with 640 Kb memory, a hard drive, and an 80287 math co-processor. The screen displays in ACES are designed in color. A color adaptor and monitor (EGA, PGA, or CGA) are preferable. Some monochrome display adaptors and monitors will also work. A printer is recommended, but not required. ACES is distributed on one high density diskette.

AVAILABILITY

Copies of version 1.07 are no longer available.

REFERENCES

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→ 11.3 m/s, restricted = 99th percentile wind speed

ACES | Mode: Single Case | Functional Area: Wave Prediction

Application: Wind Adjustment and Wave Growth

Item		Value	Units
El of Observed Wind	Zobs:	10.00	m
Observed Wind Speed	Uobs:	25.28	mph
Air Sea Temp. Diff.	ΔT:	0.00	deg C
Dur of Observed Wind	DurO:	3.00	hr
Dur of Final Wind	DurF:	3.00	hr
Lat. of Observation	LAT:	47.60	deg
Wind Fetch Length	F:	17.31	km
Wind Direction		322.50	deg
Eq Neutral Wind Spd	Ue:	25.23	mph
Adjusted Wind Speed	Ua:	30.96	mph
Mean Wave Direction		322.00	deg
Wave Height	Hmo:	2.86	ft
Wave Period	Tp:	3.49	sec

Wave Growth: Deep-water Fetch-limited

	Wind Obs Type
	Overwater (ship)
	Overwater
x	Shore (windward)
	Shore (leeward)
	Inland
	Geostrophic

	Wind Fetch Options		
	Open Water	x	Restricted

Options:
F1: New Case
F3: Print
F10: Exit Applic

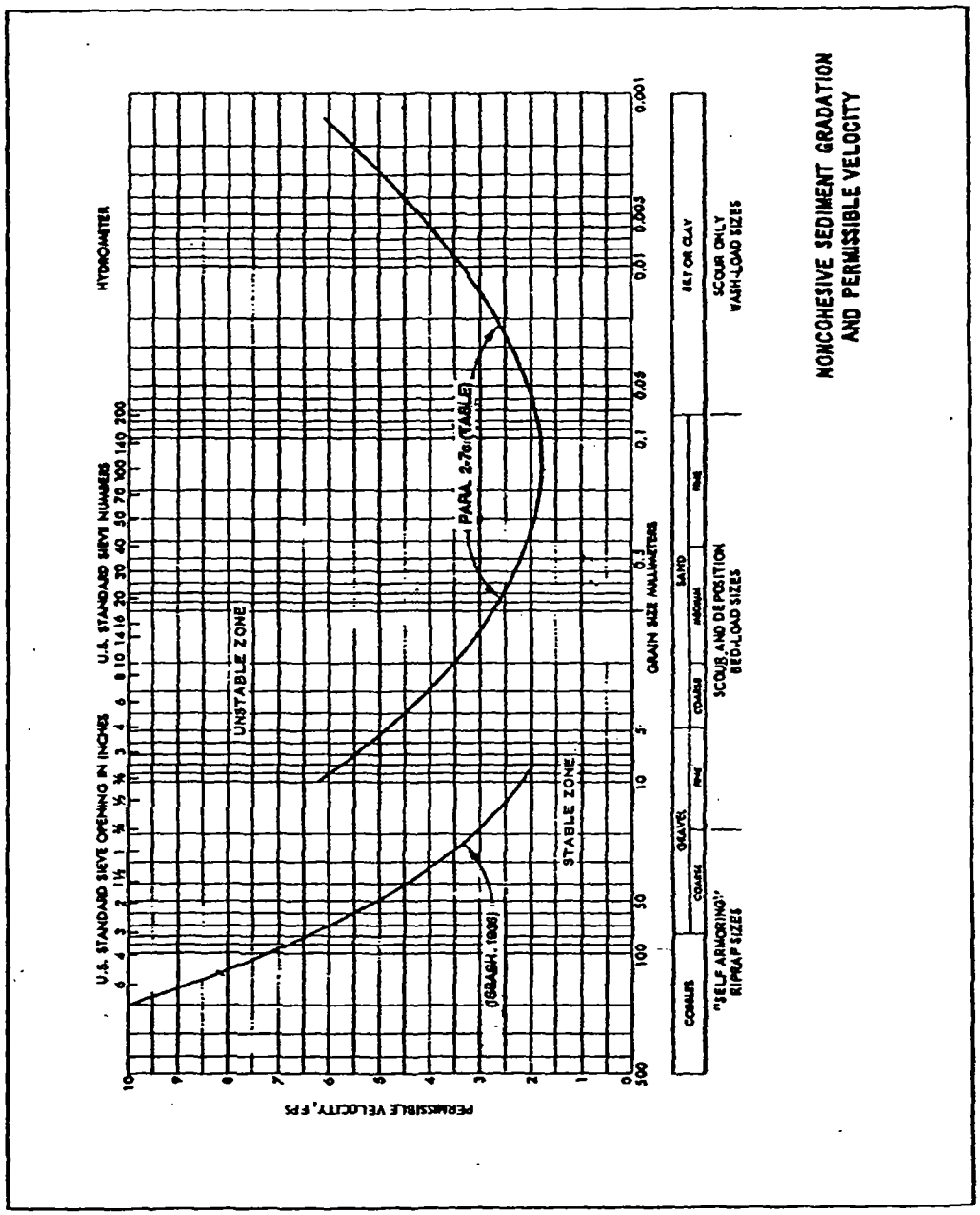

NONCOHESIVE SEDIMENT GRADATION
AND PERMISSIBLE VELOCITY
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
UNSTABLE ZONE
STABLE ZONE
PARA. 2-7a (TABLE)
(GRAGH, 1936)
PERMISSIBLE VELOCITY, FPS
GRAIN SIZE MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
"SELF ARMORING" RIPRAP SIZES
SCOUR AND DEPOSITION BED-LOAD SIZES
SCOUR ONLY WASH-LOAD SIZES

PLATE B-28

Determining Grain Size (D_{50}) to Resist Motion

There has been substantial research on the topic of minimum grain size necessary to resist motion under action of a fluid shear stress (e.g. Dean & Dalrymple 2002). There is nearly universal agreement that the best characterization of this process is given by the Shields parameter Ψ, which is defined as

$$\Psi = \tau_b / [(\rho_s - \rho)\, g\, d]$$

where τ_b = shear stress exerted on seabed by seawater motion

ρ_s = density of sediment (= 2.65 g/cm^3),

ρ = density of seawater (= 1.03 g/cm^3)

g = gravitational acceleration (= 981 cm/sec^2), and

d = sediment grain size diameter.

Setting d = median grain size diameter D_{50} , and solving,

$$D_{50} = \tau_b / [(\rho_s - \rho)\, g\, \Psi]$$

Bottom shear stress can be expressed as $\tau_b = \rho\, f\, U^2 / 8$, where f is the Darcy friction factor.

If the Shields parameter Ψ is less than 0.03, empirical evidence indicates that sediment motion does not occur. Inserting this value for Ψ, 0.02 for f, and the values shown above for the other variables, the following expression is obtained:

$$D_{50}\,(\text{mm}) = 0.000524\, [\, U\,(\text{cm/sec})\,]^{\,2} \qquad (1)$$

Equation (1) was used to compute minimum values of D_{50} to resist movement under fluid shear exerted on seabed by currents. The attached Excel spreadsheet summarizes these results.

D50 Required to Resist Erosion Versus Bottom Current Speed

D50 (mm) = 0.000524 [U (cm/s)]^2

U (cm/s)	D50 (mm)	U (ft/s)	D50 (in.)
0	0.00	0	0.00
10	0.05	0.33	0.00
20	0.21	0.65	0.01
30	0.47	0.98	0.02
40	0.84	1.31	0.03
50	1.31	1.64	0.05
60	1.89	1.96	0.07
70	2.57	2.29	0.10
80	3.35	2.62	0.13
90	4.24	2.95	0.17
100	5.24	3.27	0.21
110	6.34	3.60	0.25
120	7.55	3.93	0.30
130	8.86	4.26	0.35
140	10.27	4.58	0.40
150	11.79	4.91	0.46
160	13.41	5.24	0.53
170	15.14	5.57	0.60
180	16.98	5.89	0.67
190	18.92	6.22	0.74
200	20.96	6.55	0.83
200	20.96	6.55	0.8
250	32.75	8.19	1.3
300	47.16	9.82	1.9
350	64.19	11.46	2.5
380	75.67	12.44	3.0
400	83.84	13.10	3.3
500	131.00	16.37	5.2

Vessel Characteristics used in Propwash Erosion Analysis Tug Operations Pier PSR Sediment Cap Design

Parameters		Representative Vessels	
Vessel Characteristics	Units	Crowley Invader-class line-haul tug	Crowley Robin-class harbor tug
Maximum draft	Feet	19.0	16.0
Number of propellers	N/A	2	2
Number of rudders	N/A	3	2
Is propeller ducted, non-ducted, or tunnelled?	N/A	Non-ducted	Non-ducted
Vertical distance from water surface to center of propeller shaft	Feet	10.5	9.5
Propeller diameter	Feet	11.0	9.3
Vertical angle made by shaft and the horizontal	Degrees	4	2
Propeller pitch	Inches	89	68
Engine RPM during maneuvering	RPM	750	802
Gear reduction ratio	N/A	4.351	3.972
Propeller RPM during maneuvering	RPM	172	202
Horsepower per propeller during maneuvering	Hp	3,125	530

PSR PROPWASH VELOCITY CALCULATIONS - HARBOR TUG

Propwash bottom velocities at distance x from tug operation
Crowley heavy conventional tug, extreme low tide
From: Guidance for In-situ Subaqueous Capping of Contaminated Sediments: Appendix A: Armor Layer Design

Parameters - Harbor Tug

D_p	9.3	feet	Diameter of propeller
D_0	6.603	feet	For non-ducted propellers, $D_0 = 0.71*D_p$
U_0	19.2	ft/sec	Jet velocity exiting propeller, from previous calcs
x		feet	horizontal distance from propeller
z		feet	radial distance from propeller shaft
$V_{x,z}$		ft/sec	Velocity at coordinates x and z

Governing Equation:

$$V_x = U_o\{2.78(D_o/x)(\exp[-15.43(z/x)^2])\}$$

Calculations - Harbor Tug - Minimum water depth at distance

x (ft)	z (ft)	$2.78(D_0/x)$	$\exp[-15.43(z/x)^2]$	$V_{x,z}$ (ft/sec)	$V_{x,z}$ (cm/sec)
75	.1	0.244751	0.997260648	4.68635021	142.8399545
100	1	0.183563	0.99845819	3.5189833	107.2586109
125	1	0.146851	0.999012967	2.81675085	85.85456598
150	1	0.122376	0.999314457	2.34800076	71.5670632
175	1	0.104893	0.99949629	2.01293828	61.35435889
200	1	0.091782	0.999614324	1.761529	53.69140389
225	1	0.081584	0.999695256	1.56593033	47.72955637
250	1	0.073425	0.99975315	1.40941891	42.95908843
275	1	0.06675	0.999795988	1.28134482	39.05539012
300	1	0.061188	0.99982857	1.17460436	35.80194099

Calculations - Harbor Tug - Key water depths at key distances

x (ft)	z (ft)	$2.78(D_0/x)$	$\exp[-15.43(z/x)^2]$	$V_{x,z}$ (ft/sec)	$V_{x,z}$ (cm/sec)
50	16	0.367127	0.205968507	1.45183793	44.25202014
100	11	0.183563	0.829690118	2.92417419	89.12882925
100	1	0.183563	0.99845819	3.5189833	107.2586109
150	1	0.122376	0.999314457	2.34800076	71.5670632
175	1	0.104893	0.99949629	2.01293828	61.35435889

PSR PROPWASH VELOCITY CALCULATIONS - LINE HAUL TUG

Propwash bottom velocities at distance x from tug operation
Crowley heavy conventional tug, extreme low tide
From: Guidance for In-situ Subaqueous Capping of Contaminated Sediments: Appendix A: Armor Layer Design

Parameters - Line Haul Tug

D_p	11	feet	Diameter of propeller
D_0	7.81	feet	For non-ducted propellers, $D_0 = 0.71*D_p$
U_0	28.7	ft/sec	Jet velocity exiting propeller, from previous calcs
x		feet	horizontal distance from propeller
z		feet	radial distance from propeller shaft
$V_{x,z}$		ft/sec	Velocity at coordinates x and z

Governing Equation:
$V_x = U_o\{2.78(D_o/x)(\exp[-15.43(z/x)^2])\}$

Calculations - Line Haul Tug - minimum water depth at distance

x (ft)	z (ft)	$2.78(D_0/x)$	$\exp[-15.43(z/x)^2]$	$V_{x,z}$ (ft/sec)	$V_{x,z}$ (cm/sec)
120	1	0.180932	0.998929046	5.1871776	158.1051748
150	1	0.144745	0.999314457	4.1513432	126.5329405
175	1	0.124067	0.99949629	3.5589416	108.4765407
200	1	0.108559	0.999614324	3.1144417	94.92818217
225	1	0.096497	0.999695256	2.7686167	84.3874381
250	1	0.086847	0.99975315	2.4918994	75.95309261
275	1	0.078952	0.999795988	2.2654601	69.05122458
300	1	0.072373	0.99982857	2.0767395	63.29901866

Calculations - Line Haul Tug - Key water depths and distances

x (ft)	z (ft)	$2.78(D_0/x)$	$\exp[-15.43(z/x)^2]$	$V_{x,z}$ (ft/sec)	$V_{x,z}$ (cm/sec)
100	6	0.217118	0.945966616	5.8945891	179.6670758
80	11	0.271398	0.746975093	5.8182699	177.3408652
40	16	0.542795	0.084686422	1.3192634	40.21114882
40	21	0.542795	0.014223016	0.2215692	6.753430115
80	21	0.271398	0.34534083	2.6898971	81.98806378
100	21	0.217118	0.506382483	3.1554144	96.17703032
150	21	0.144745	0.739021696	3.0700373	93.57473773
175	21	0.124067	0.800761603	2.8513	86.90762485
200	21	0.108559	0.843567168	2.6282544	80.10919397
225	21	0.096497	0.874229419	2.421144	73.79647
250	21	0.086847	0.896843341	2.2353952	68.13484438
275	21	0.078952	0.913950763	2.0709415	63.12229713
300	21	0.072373	0.927180517	1.9258425	58.69967971
325	21	0.066806	0.937608746	1.797695	54.79374419
80	26	0.271398	0.195969989	1.5264315	46.52563079
100	26	0.217118	0.352371945	2.1957306	66.92586801
60	31	0.361863	0.016261535	0.1688838	5.147578475
80	31	0.271398	0.098577628	0.7678318	23.40351379
60	36	0.361863	0.003868842	0.0401798	1.224679507
80	46	0.271398	0.006087342	0.047415	1.445208151
150	16	0.144745	0.838987802	3.4853156	106.2324205

Find: Maximum bottom velocity resulting from propwash of maneuvering harbor tug

Reference: Corps Armor Layer Design

Given: Vessel characteristics provided by Crowley (attached)
Robin-Class Harbor Tug

Solution

Jet velocity exiting propeller

$$U_o = C_2 \left[\frac{P_d}{D_p^2} \right]^{1/3}$$

U_o = jet velocity exiting propeller in ft/sec

P_d = applied engine power/propeller in Hp

D_p = Propeller diameter in feet

$C_2 = 9.72$ for non-ducted propellers

$$U_o = 9.72 \left[\frac{530 \, H_p}{9.3^2} \right]^{1/3}$$

$$= 19.2 \text{ ft/sec}$$

Maximum bottom velocity

$$V_{b(max)} = C_1 U_o D_p / H_p$$

$V_{b(max)}$ = maximum bottom velocity

$C_1 = 0.22$ for non-ducted propeller

U_o = jet velocity exiting propeller

D_p = propeller diameter

H_p = distance from propeller shaft to channel bottom

$$V_{b(max)} = \frac{(0.22)(19.2 \text{ ft/sec.})(9.3 \text{ ft})}{6.5 \text{ ft}}$$

$$= 6.0 \text{ ft/sec}$$

Find: Depth at which bottom velocity produced by a maneuvering harbor tug drops to 4.0 ft/sec

Reference: Corps Armor Layer Design

Given: Previous calculated jet velocity exiting propeller, vessel characteristics

Solution

$$V_{b(max)} = C_1 U_o D_p / H_p$$

$V_{b(max)}$ = maximum bottom velocity

$C_1 = 0.22$ for non-ducted propellers
$U_o = 19.2$ ft/sec for harbor tug (jet velocity exiting propeller)
D_p = propeller diameter = 9.3 ft for harbor tug
H_p = Distance from propeller shaft to channel bottom

Re-arrange equation:

$$H_p = C_1 U_o D_p / V_{b(max)}$$

$$H_p = \frac{(0.22)(19.2 \text{ ft/sec})(9.3 \text{ ft})}{4.0 \text{ ft/sec}}$$

$$H_p = 9.82 \text{ ft}$$

Add distance from water surface to propeller shaft, 9.5 ft for harbor tug

Required water depth = 9.82 ft + 9.5 ft = 19.32 ft
At -4 MLLW,

19.32 ft + 4 ft = 23.32 ft MLLW

Find: Maximum bottom velocity resulting from propwash of maneuvering line-haul tug

Reference: Corps Armor Layer Design

Given: Vessel characteristics provided by Crowley (attached) for Invader-class line-haul tug

Solution

Jet velocity exiting propeller

$$U_o = C_2 \left[\frac{P_d}{D_p^2} \right]^{1/3}$$

U_o = jet velocity exiting propeller in ft/sec

P_d = applied engine power/propeller in Hp

D_p = propeller diameter in feet

$C_2 = 9.72$ for nonducted propellers

$$U_o = 9.72 \left[\frac{3{,}125 \, H_p}{11^2} \right]^{1/3}$$

$$= 28.7 \text{ ft/sec}$$

Maximum bottom velocity

$$V_{b(max)} = C_1 U_o D_p / H_p$$

$V_{b(max)}$ = maximum bottom velocity

C_1 = 0.22 for non-ducted propeller
U_o = jet velocity exiting propeller
D_p = propeller diameter
H_p = distance from propeller shaft to channel bottom

$$V_{b(max)} = \frac{(0.22)(28.7\ ft/sec)(11\ ft)}{20\ ft}$$

$$= 3.5\ ft/sec$$

Find: Depth at which bottom velocity produced by a maneuvering line-haul tug drops to 2.0 ft/sec

Reference: Corps Armor Layer Design

Given: Previous calculated jet velocity exiting propeller, vessel characteristics

Solution

$$V_{b(max)} = C_1 U_0 D_p / H_p$$

$V_{b(max)}$ = maximum bottom velocity

$C_1 = 0.22$ for non-ducted propellers
$U_0 = 28.7$ ft/sec for line-haul tug
D_p = propeller diameter = 11 ft
H_p = distance from propeller shaft to channel bottom

$$H_p = C_1 U_0 D_p / V_{b(max)}$$

$$H_p = \frac{(0.22)(28.7 \text{ ft/sec})(11)}{2.0 \text{ ft/sec}} = 34.7 \text{ ft}$$

Add distance from water surface to propeller shaft, 10.5 ft for line-haul tug, and correct for extreme low tide (-4 MLLW)

Required water depth = 34.7 ft + 10.5 ft + 4 ft

= 49.23 ft

CALCULATION OF ACCEPTABLE INTERTIDAL SLOPES

Equations and definitions

Equilibrium Profile = h(x) = Ax^(0.666) (1)
Slope = dh/dx = 0.666 Ax^(-0.333) (1)

A = 0.067 w^(0.44) (meters^1/3) (1), (3)
A' = Empirical values (4)
B=(ps-p)gD^3/(1000pu^2) = 11070*D^3 (2)
w = [(ps-p)gD/(9.1p)]^0.5 for B>10000 (2)
w = 14D^(1.1) cm/s for B<10000 (1)

Net Slope (50 feet) = x/h(50)

Notes:
u = kinematic viscosity = 0.0119 cm2/s
w = fall velocity (cm/s)
D = mean sediment diameter (mm)
h = depth (meters)
x = distance from shoreline (meters)

ps = particle density = 2.65 g/cm3
p = water density = 1.02 g/cm3
g = gravitational accel. = 981 cm/s2
A = Sediment Scale Parameter
B = grain buoyancy

D50 = 0.4 mm
B= 708
w = 5.11 cm/s
A = 0.137 m^1/3
A'= 0.13 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.288484	0.063105	15.846545
20	6.096	0.457729	0.050098	19.960783
30	9.144	0.589832	0.043771	22.846304
40	12.192	0.726283	0.038772	25.1432
50	15.24	0.842829	0.036924	27.082677
60	18.288	0.951417	0.034749	28.77789
70	21.336	1.054284	0.03301	30.293693
80	24.384	1.152338	0.031574	31.671129
90	27.432	1.246372	0.03036	32.938008
100	30.48	1.338971	0.029313	34.114152

Net Slope in first 50 feet 1: 18

D50 = 1 mm
B= 11070
w = 13.13 cm/s
A = 0.208 m^1/3
A'= 0.22 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.436914	0.095574	10.46311
20	6.096	0.693238	0.075875	13.17964
30	9.144	0.908153	0.065292	15.08489
40	12.192	1.099938	0.060236	16.60147
50	15.24	1.276175	0.055922	17.88206
60	18.288	1.440936	0.052628	19.00137
70	21.336	1.59873	0.049994	20.00222
80	24.384	1.745235	0.04782	20.91171
90	27.432	1.887651	0.045981	21.7482
100	30.48	2.024865	0.044396	22.52478

Net Slope in first 50 feet 1: 12

RATHER FAST Grain Size for Erosion Resistance

D50 = 5 mm
B= 474626
w = 24.56 cm/s
A = 0.274 m^1/3
A'= 0.30 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.575561	0.125902	7.942654
20	6.096	0.913223	0.099952	10.00481
30	9.144	1.186338	0.087328	11.4511
40	12.192	1.448982	0.07935	12.60235
50	15.24	1.681145	0.073668	13.57446
60	18.288	1.89819	0.069328	14.42414
70	21.336	2.103422	0.065859	15.1839
80	24.384	2.299053	0.062995	15.8743
90	27.432	2.486661	0.060572	16.50929
100	30.48	2.667418	0.058484	17.0988

Net Slope in first 50 feet 1: 9

D50 = 7 mm
B= 3787010
w = 34.73 cm/s
A = 0.319 m^1/3
A'= 0.35 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.670375	0.146643	6.819269
20	6.096	1.063662	0.116417	8.59078
30	9.144	1.393415	0.101714	9.831515
40	12.192	1.687678	0.092422	10.81994
50	15.24	1.958086	0.085803	11.65457
60	18.288	2.210686	0.080749	12.38407
70	21.336	2.449926	0.076708	13.03637
80	24.384	2.677784	0.073372	13.62913
90	27.432	2.896297	0.07055	14.17431
100	30.48	3.106631	0.068118	14.68044

Net Slope in first 50 feet 1: 8

D50 = 10 mm
B= 11070000
w = 41.51 cm/s
A = 0.345 m^1/3
A'= 0.41 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.725097	0.156613	6.384645
20	6.096	1.150488	0.12592	7.9415199
30	9.144	1.507158	0.110017	9.0895424
40	12.192	1.825442	0.099966	10.003377
50	15.24	2.117923	0.092807	10.775009
60	18.288	2.391359	0.08734	11.44846
70	21.336	2.648912	0.08297	12.052532
80	24.384	2.89637	0.079362	12.600553
90	27.432	3.13272	0.076309	13.104589
100	30.48	3.360439	0.073678	13.572525

Net Slope in first 50 feet 1: 7

VERY FAST Grain Size for Erosion Resistance

D50 = 20 mm
B= 64560240
w = 65.69 cm/s
A = 0.393 m^1/3
A'= 0.45 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.825194	0.180509	5.539884
20	6.096	1.309309	0.143303	6.978204
30	9.144	1.715216	0.125204	7.98687
40	12.192	2.077438	0.113766	8.789955
50	15.24	2.410294	0.105619	9.467888
60	18.288	2.721478	0.099397	10.06063
70	21.336	3.015722	0.094424	10.59055
80	24.384	3.296203	0.090317	11.07209
90	27.432	3.565181	0.086843	11.51499
100	30.48	3.824336	0.083849	11.92616

Net Slope in first 50 feet 1: 6

D50 = 25 mm
B= 172968750
w = 85.63 cm/s
A = 0.422 m^1/3
A'= 0.5 m^1/3

Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.887039	0.194038	5.153637
20	6.096	1.407437	0.154043	6.491676
30	9.144	1.843765	0.134588	7.43011
40	12.192	2.233134	0.122293	8.17711
50	15.24	2.590937	0.113535	8.807869
60	18.288	2.925443	0.106847	9.359189
70	21.336	3.24174	0.101501	9.852161
80	24.384	3.543242	0.097088	10.30013
90	27.432	3.832378	0.093352	10.71215
100	30.48	4.110956	0.090133	11.09466

Net Slope in first 50 feet 1: 8

D50 = 35 mm
B= 474626250
w = 77.65 cm/s
A = 0.455 m^1/3
A'= 0.53 m^1/3

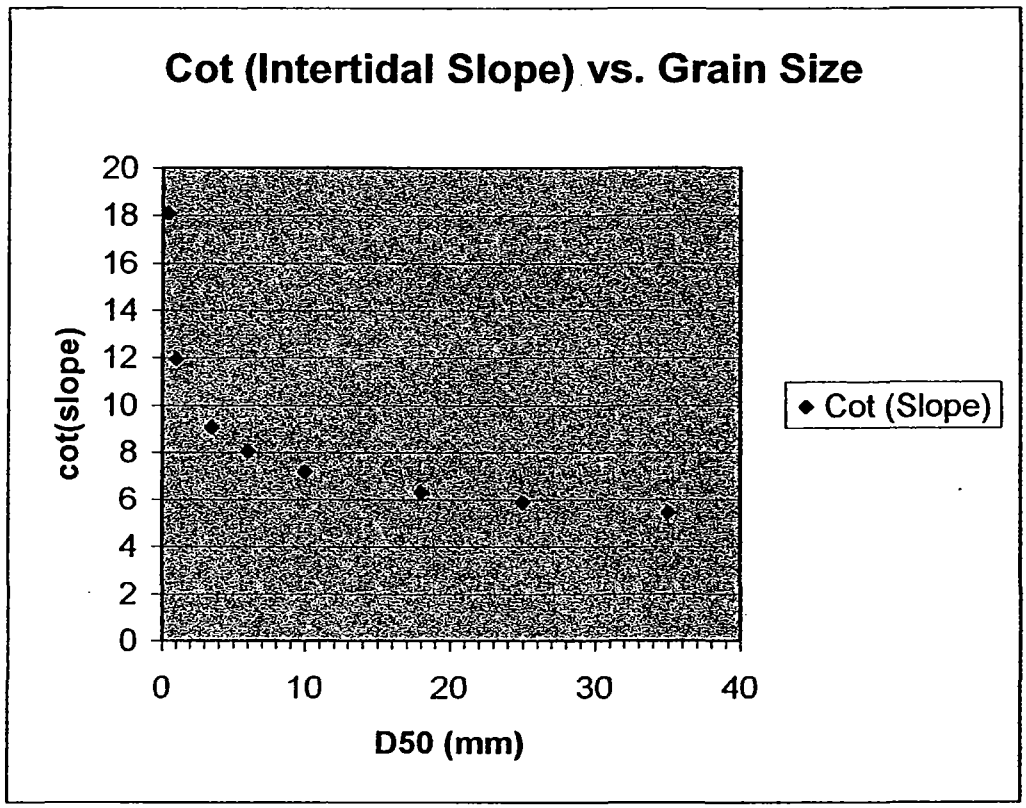
Distance from shore (ft)	Distance from shore (m)	h (m)	Local Slope	Slope = 1:___
10	3.048	0.655183	0.208946	4.785923
20	6.096	1.515574	0.165879	6.028492
30	9.144	1.985426	0.144929	6.899988
40	12.192	2.404712	0.131689	7.593669
50	15.24	2.790006	0.122256	8.179423
60	18.288	3.150212	0.115056	8.691408
70	21.336	3.490811	0.109299	9.149204
80	24.384	3.815478	0.104546	9.565213
90	27.432	4.12683	0.100524	9.947832
100	30.48	4.426812	0.097059	10.30305

Net Slope in first 50 feet 1: 5

Notes:
(1) Equations and definitions from USACE EM 1110-2-3301
(2) Equations and definitions from USACE CETN II-4
(3) A parameter calculated from correlation with fall speed after Dean 1987 (EM1110-2-11100, Figure III-3-17)
(4) A' parameter directly interpolated from empirical data after Moore 1982 (EM1110-2-11100, Figure III-3-17)

All slopes calculated based on the A parameter as described in Note (3). Use of the empirical A' as described in Note (4) would yield steeper allowable slopes.

CALCULATION OF ACCEPTABLE INTERTIDAL SLOPES



RIPRAP AND FILTER LAYER DESIGN FOR RA1

RIPRAP SIZING

PROBLEM STATEMENT AND CALCULATION OBJECTIVES

PROBLEM: Riprap revetments have been incorporated as part of the sediment cap design in the Marine Sediment Unit of the Puget Sound Resources site in Elliot Bay. Riprap revetments and underlying filter layers must be designed to resist movement from the design wave.

OBJECTIVE: Determine minimum stone size and gradation for riprap and filter layer in accordance with USACE design guidance. Confirm whether the material specifications assumed by the 30% design are consistent with the USACE design guidance,

DATA AVAILABLE

1. US Army Corps of Engineers, "Design of Coastal Revetments, Seawalls, and Bulkheads – Engineer Manual", 30 June 1995. Extracts included as Attachment E.

ASSUMPTIONS AND DESIGN DATA

2. Design Wave Height = 2.9 feet (From ACES, Section A.3);
3. Design Wave Height = Significant Wave Height = Monochromatic Wave Height;
4. Specific Weight of Rock = 160 lbs/ft^3;
5. Specific Weight of Seawater = 64 lbs/ft^3;
6. Riprap revetment slope = 26.6 degrees (1 (vertical) to 2 (horizontal) slope);
7. There will be no major overtopping of the riprap revetment structure; and
8. The toe of the riprap revetment is in deep water.

ANALYSIS AND RESULTS

Riprap Armor Unit Stability

1. Riprap armor unit stability was calculated from the equation developed by Hudson (1961), Equation 2-15 (USACE, 1995). For graded riprap, the armor unit stability is the minimum weight that 50% of the stones must equal or exceed ($W_{50\ min}$) to avoid damage at the design wave height.

2. Approximate sizing limits were established in accordance with the following guidelines (per USACE, 1995). These limits are intended by the USACE to serve as guidelines and engineering judgement should be used in relating them to economically available products.

   - $W_{100\ max} < 4 \times W_{50\ min}$ (or as economically available from quarry);
   - $W_{100\ min} > 2 \times W_{50\ min}$;
   - $W_{50\ max} \sim 1.5 \times W_{50\ min}$;
   - $W_{15\ min} \sim 0.4 \times W_{50\ min}$; and
   - $W_{15\ max} \sim W_{50\ min}$.

3. Refer to Attachment A for spreadsheet calculations and Attachment C for check calculations. The results of the calculations are summarized in Table 1 following. All weights are rounded up to the nearest 10 pounds.

Table 1 – Riprap Armor Sizing

Wave Height (feet)	Armor Unit Stability (lbs)	Sizing Limit Guidance (lbs)				
	$W_{50\ min}$	$W_{100\ max}$	$W_{100\ min}$	$W_{50\ max}$	$W_{15\ min}$	$W_{15\ max}$
2.9	270	1060	530	400	110	270

Minimum Riprap Layer Thickness

1. Minimum riprap layer thickness was calculated from the equation developed by Ahrens (1975), Equation 2-24 (USACE, 1995).

2. The calculation was based on the sizing limits calculated above. Average values were used where the guidance specified only maximum and minimum values. That is W_{100} was assumed to equal the average of $W_{100\ min}$ and $W_{100\ max}$.

3. Refer to Attachment A for spreadsheet calculations and Attachment C for check calculations. The result of the calculation is summarized following (rounded up to the nearest 0.5 foot):

   - Minimum Layer Thickness = 2.5 feet.

Riprap Revetment Toe Protection – Armor Unit Stability

1. Riprap armor unit stability for protection of the revetment toe was calculated from the Equation 2-25 (USACE, 1995). As above, the toe of the riprap revetment was assumed to be in deep water. Therefore, based on Figure 2-7 (USACE, 1995) the ratio of the depth to the top of the revetment toe protection to the total water depth was assumed to approach 1, and so the design stability number (N_s) was assumed to approach 300.

2. Refer to Attachment A for spreadsheet calculations and Attachment C for check calculations. The calculation demonstrated that it was not necessary to increase in the minimum stone weight (W_{50min}) in the toe protection structure from that determined for the riprap revetment.

Filter Layer Properties

1. Gradation requirements for the filter that will underlay the riprap revetment were calculated based on Equation 2-28 (USACE, 1995).

2. The calculation was based on the sizing limits calculated above. Average values were used where the guidance specified only maximum and minimum values. That is W_{15} was assumed to equal the average of $W_{15\ min}$ and $W_{15\ max}$.

3. Stone weights were related to stone diameters by either:

   - Equation 2-22 (USACE, 1995), assuming the number of stones in the layer (n) was equal to 1 and $k_\Delta = 1$; or
   - Assuming the stone was a sphere.

4. Refer to Attachment A for spreadsheet calculations and Attachment C for check calculations. The result of the calculation is summarized following:

   - Filter Layer d_{85} = 0.26 feet (from Equation 2-22, USACE, 1995); or
   - Filter Layer d_{85} = 0.33 feet (assuming stones are spheres).

5. Minimum filter layer thickness should be 3 times the median stone diameter. Conservatively, if the minimum layer thickness is calculated based on the d_{85} calculated above and not the median stone diameter, the minimum layer thickness should be:

   - Minimum Layer thickness = 0.8 to 1.0 feet.

CONCULSIONS

Riprap Specification

1. The 30% design was based on the assumption that riprap revetments would be constructed from material conforming to the WSDOT 9-13.1(2) Light Loose Riprap specification.

2. The WSDOT 9-13.1(2) Light Loose Riprap specification is suitable for this application with the following additional requirements:

   - At least 50% of the stones must have a weight greater than 300 lbs (i.e. $W_{50min} > 300$ lbs);
   - The riprap must be placed such that there is a well graded distribution of various stone sizes through the revetment;
   - The maximum stone size must be limited to 1,000 lbs (i.e. $W_{100max} = 1{,}000$ lbs);

   As shown in Attachment C, it is probable that material supplied in accordance with the WSDOT specification would satisfy these additional requirements. However, it is technically possible that a product could achieve the WSDOT specification, but fail to achieve the additional requirements. Therefore, it is recommended that the additional requirements be included as part of the specification for this project.

3. The 30% design was based on an assumed riprap revetment thickness of 18-inches, plus an over-placement allowance of 12 inches. The minimum riprap layer thickness recommended by the USACE guidance is 2.5 feet or 30 inches.

4. The riprap layer thickness should be increased to 24 inches, plus an over-placement allowance of 12 inches. Assuming that on average half the over-placement allowance is placed, the net layer thickness will achieve the minimum requirement of the USACE guidance.

Filter Layer Specification

1. The 30% design was based on the assumption that the filter layer would be comprised of a 2 ½ inch crushed rock meeting the Seattle No. 14 Specification.

2. The gradation recommendations of the USACE guidance are considered critical in areas where the riprap revetment will be within the tidal zone and potentially exposed to wave action. In these applications, the filter layer must be fine enough to prevent the underlying contaminated sediment from being washed through the riprap and coarse enough to prevent the filter layer itself from being washed through the riprap.

3. The minimum d_{85} recommended for the filter layer by the USACE guidance is between 0.26 and 0.33 feet. This recommendation is based on the gradation required to prevent the filter layer from being washed through the riprap. As shown in Attachment C, the d_{85} of the 2 ½ inch crushed rock product is between 0.1 and 0.2 feet and does not achieve the requirements of the USACE guidance.

4. The only commonly available product that has a d_{85} above the range recommended by the USACE guidance is WSDOT 9-13.6 Quarry Spalls (refer to Attachment D). As above, quarry spalls will be coarse enough to prevent them from being washed through the riprap, however they do not contain sufficient fines to prevent the egress of contaminated sediments. Addressing this in accordance with the USACE guidance would require placement of a second filter layer, installed below the quarry spalls, with a gradation that would prevent both its own escape through the quarry spalls and the escape of the underlying sediments. This approach would be difficult to

construct in the underwater environment in which these riprap revetments will be installed and is considered impractical.

5. A compromise approach is to provide a blended material whose gradation provide both particles that are large enough to prevent it from being washed through the riprap, but fine enough to contain the underlying sediments. Development of this gradation is described in Attachment D. The recommended material is a combination of roughly equal proportions of the 2 ½-inch crushed rock and quarry spalls, and is described in Table 2. The recommended gradation was developed in consultation with material suppliers to ensure it can be economically produced.

Table 2 – Filter Layer Gradation (for use in Tidal Zone)

Grain Size	% Passing
8-inches	100
3-inches	30 to 75
2-inches	20 to 60
¾-inch	15 to 40
40 sieve	0 to 5

6. It is recommended that Filter Layer Specifications be amended as follows:

   - For riprap revetments constructed within the tidal zone, gradation per Table 2 (Filter Layer 1); and

   - For riprap revetments constructed below the tidal zone, filter layer gradation per Settle No. 14, 2 ½ inch crushed rock (Filter Layer 2). Note that in addition to this gradation, Filter Layer 2 must contain a minimum TOC content of 0.5% (by weight).

7. The 30% design was based on an assumed filter layer thickness of 24 inches. This thickness was based on the minimum thickness required for containment of the underlying contaminated sediments. The minimum filter layer thickness recommended by the USACE guidance, based on the filter layer gradation, is conservatively calculated as 12 inches. Therefore the existing design is consistent with the USACE guidance.

ATTACHMENT A

6/29

RIP RAP SIZING CALCULATIONS

DESIGN CRITERIA

Design Wave Height	2.9	feet	From Jack Colonell
Armor Specific Weight	160	lb/ft3	
Waste Specific Weight	64	lb/ft3	
Riprap Slope (phi)	26.6	degrees	
	0.46425758	radians	
Cot (phi)	1.99695386		
Stability Coefficient	2.2	(from Table 2.3 USACE Guidance Manual for graded riprap)	
Toe Protection Stability No.	300	(from Figure 2-7 USACE Guidance Manual for deep water)	

Calculate Armor Unit Stability (Hudson 1961)

Wave Height (feet)	Stone Weight (W_{50}) (lbs)	"Gradation" Guidelines (lbs) W_{50min}	W_{100max}	W_{100min}	W_{50max}	W_{15min}	W_{15max}
4.65	1084.96	1084.96	4339.85	2169.92	1627.44	433.98	1084.96
4.07	727.51	727.51	2910.04	1455.02	1091.26	291.00	727.51
2.90	263.18	263.18	1052.71	526.36	394.77	105.27	263.18

Calculate Minimum Layer Thickness (Ahrens 1975)

Wave Height (feet)	W_{50} (lbs)	$W_{100\ (average)}$ (lbs)	Layer Thickness A	B	C	Minimum Layer Thickness (feet)
4.65	1084.96	3254.88	3.79	3.41	1.00	3.79
4.07	727.51	2182.53	3.31	2.99	1.00	3.31
2.90	263.18	789.53	2.36	2.13	1.00	2.36

Calculate Toe Protection

Wave Height (feet)	Stone Weight (W_{min}) (lbs)
4.65	1.77E-04
4.07	1.18E-04
2.90	4.28E-05

Calculate Filter Layer Properties

Wave Height (Feet)	Armor (based on a sphere) $W_{15(average)}$ (lbs)	V_{15} (ft^3)	$d_{15armor}$ (feet)	Armor (based on Eqn 2-22) $W_{15(average)}$ (lbs)	$d_{15armor}$ (feet)	Filter Size Range Minimum d_{85} (feet)	
4.65	759.47	4.75	2.09	759.47	1.68	0.52	0.42
4.07	509.26	3.18	1.83	509.26	1.47	0.46	0.37
2.90	184.22	1.15	1.30	184.22	1.05	0.33	0.26

URS

ATTACHMENT B

Job PSR | Project No. 33755206 | Sheet 1 of 11

Description Riprap Sizing | Computed by MAJ | Date 11/8/02

Checked by MJM | Date 11/18/02

Reference

DESIGN OF COASTAL REVETMENTS, SEAWALLS & BULKHEADS

USACE 30 June 1995

2-4 Design Conditions:

- minimum - with stand condition w/ 50% probability of being exceeded during project life.
- Project design criteria.

2-16 Armor Unit Stability. (Hudson) Per Schuchardt 11/8/02 Only use Hudson equation.

$$W = \frac{\gamma_r \cdot H^3}{K_D \left(\frac{\gamma_r}{\gamma_w} - 1 \right)^3 \cot\theta}$$

W = req'd W_{50} of armor.
γ_r = Specific weight of armor unit lb/ft³
H = monochromatic wave height. < 5 ft.
K_D = stability coefficient.
γ_w = specific weight of water (salt or fresh)
θ = structure slope (from horiz).

Store weight range from 0.75 → 1.25 of W.

Applicable to $H < 5$ ft
no major overtopping

For graded rip rap $n = 2$
$\cot\theta = 2.0 - 6.0$
$K_D = 2.2$
} from Table 2.4

Alternatively: $$N_s = \frac{H}{\left(\frac{W}{\gamma_r}\right)^{1/3} \cdot \left(\frac{\gamma_r}{\gamma_w} - 1\right)}$$

$$N_s = (K_D \cot\theta)^{1/3}$$

Note for irregular use correction of dumped riprap

$$N_{ss} = 1.14 \cot^{1/6}\theta$$

2.17 Layer Thickness - for Graded Riprap

$$r_{min} = \max\left[2.0\left(\frac{W_{50min}}{\gamma_r}\right)^{1/3} \text{ \& } 1.25\left(\frac{W_{100}}{\gamma_r}\right)^{1/3} \text{ \& } 1\right]$$

~~for~~ r_{min} = minimum layer thickness perpendicular to slope.
W_{50} = 50% of unit weight this or more.
W_{100} = maximum stone weight.

Gradation Req'ts: * W_{50min} from Armor and Stability

* $W_{100max} \leq 4 \times W_{50min}$ - AND = maximum economic supply.

* $W_{100min} > 2 \times W_{50min}$

$W_{50max} \approx 1.5 \times W_{50min}$

$W_{15min} \approx 0.4\ W_{50min}$

$W_{15max} \approx > W_{50min}$

2-19 Toe Protection

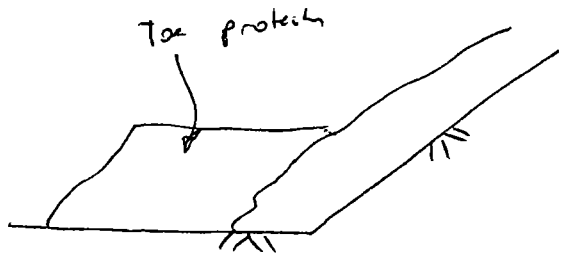
For submerged toes

$$W_{min} = \frac{\gamma_r H^3}{N_s^3 \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3}$$

N_s from figure 2-7.

For exposed toes - Use Armor Unit Stability equation.

Design



Undercut condition.

2-20 Filters

$$\frac{d_{15\,under}}{d_{85\,under}} < 4$$

↳ Riprap & Armor Stone Underlayers.

$$\frac{d_{15\,armor}}{d_{85\,filter}} < 4$$

relate stone diameter to weight by

$$r = n\, k_\Delta \left(\frac{W}{W_r}\right)^{1/3}$$

$\rho = m/V$

$\therefore V = m/\rho$

$V = \frac{4\pi r^3}{3}$

$\frac{4\pi r^3}{3} = \frac{m}{\rho}$

$r = \sqrt{\frac{3 \cdot m}{4 \cdot \pi \cdot \rho}}$

$n = 1$

k_Δ from table 2-4

W: weight

W_r - unit weight of stone.

→ Filter layer thickness should be > 3 d_{50} filter.

b. Consider multiple filter layers to retain natural material & prevent loss of fines

3-3 Design Procedure Checklist

1. Water level range
2. Wave height (monochromatic wave height / zero damage wave).
3. Select Armor
4. Size armor
5. Determine run up to set crest elevations
6. Determine overtopping expected
7. Design underdrainage features if required.
8. Provide surface drainage.
9. Design end conditions.
10. Design toe protection
11. Design Filter / underlayers

Appendix B B1 - Quarrystone & Crushed Riprap

- Riprap suitable for low energy conditions.
- Design recommendations
  - ↳ max slope 1 : 2 (h)
  - ↳ current need consideration.
- Design factors : * Zero damage wave height = f(stone weight)
  - * Wave runup potential ≈ 50% of smooth slope.
  - * Wave reflection is low

Required Info :

H = monochromatic wave height : Significant wave height.

γ_r = Specific weight of armor = 160 lb/ft³ (see ow)

γ_w = specific weight of water = 64.0 lb/ft³

Θ = structure slope = = 26.6°

W_r = armor density = ?

ATTACHMENT C

URS

Job PSR | Project No. 3375206 | Page 12 of 29
Description Rip Rap Sizing Calculation | Computed by MAS | Sheet 6 of 11
Checked by [illegible] | Date 11/11/02 | Date 11/8/02
Reference

Check calculation: for H = 2.9 ft.

Armor Unit Stability:

$$W = \frac{\gamma_r \cdot H^3}{K_D \left(\frac{\gamma_r}{\gamma_w} - 1 \right)^3 \cdot \cot\theta}$$

γ_r = 160 lb/ft³ (from Glacier data)

γ_w = 64 lb/ft³

K_D = 2.2 from Table 2.3

$\theta = \tan^{-1}(1/2) = 26.6°$

$$W = \frac{160 \times 2.9^3}{2.2 \times \left(\frac{160}{64} - 1 \right)^3 \times \cot(26.6)}$$

= 262.8 lbs (OK).

Minimum Layer Thickness:

$$r_{min} = \max \left[2.0 \left(\frac{W_{50min}}{\gamma_r} \right)^{1/3} \& 1.25 \left(\frac{W_{100}}{\gamma_r} \right)^{1/3} \& 1 \right]$$

W_{50min} = armor unit stability W = 262.8

W_{100} = $\frac{1}{2}(W_{100,max} + W_{100min})$ - assume.

= $\frac{1}{2} \cdot (4 \times W_{50min} + 2 \times W_{50min})$

= $3 \times W_{50min}$ = 788.4 lbs

$$r_{min} = \max\left[2 \times \left(\frac{262.8}{160}\right)^{1/3} \;\&\; 1.25\left(\frac{788.4}{160}\right)^{1/3} \;\&\; 1 \right]$$

$$= \max\left[2.4 \;\&\; 2.1 \;\&\; 1 \right]$$

$$= 2.4 \text{ feet.} \quad \text{(OK)}.$$

Toe Protection :

$$W_{min} = \frac{\gamma_r \cdot H^3}{N_s^3 \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3}$$

N_s : for deep water where the height of the toe is << height of water
$= 300$ (from Table 2.7)

$$W_{min} = \frac{160 \times 2.9^3}{300^3 \times \left(\frac{160}{64} - 1\right)^3}$$

$$= 4.3 \times 10^{-5} \text{ lbs} \quad \text{(OK)}.$$

Filter Layer

$$\frac{d_{15\,armor}}{d_{85\,filter}} < 4$$

$W_{15\,armor}$ = avge of $W_{15\,max}$ & $W_{15\,min}$

$$= \frac{1}{2} \times \left(0.4\, W_{50\,min} + W_{50\,min} \right)$$

$$= 0.7\, W_{50\,min} = 184.0 \text{ lbs}$$

Above the Stone is a sphere :

$$W_{15} = \gamma_r \times V_{15}$$

$$\therefore V_{15} = W_{15}/\gamma_r$$

$$V_{15} = \frac{4}{3}\pi r^3$$

$$\therefore r_{15} = \sqrt[3]{\frac{3\,V_{15}}{4\pi}}$$

$$d_{15} = 2 \times \left(\frac{3 \cdot V_{15}}{4\pi}\right)^{1/3}$$

$$= 2 \times \left(\frac{3 \cdot W_{15}}{4\pi\gamma_r}\right)^{1/3}$$

$$= 2 \times \left(\frac{3 \cdot 164}{4\pi \cdot 160}\right)^{1/3}$$

$$= 1.3 \text{ feet.}$$

$$d_{85\,filter} \geq \frac{d_{15\,armor}}{4}$$

$$> \frac{1.3}{4}$$

$$> 0.32 \text{ feet} \quad \text{(OK)}.$$

Alternately we $r = n \cdot k_\Delta \cdot \left(\frac{W}{\gamma_r}\right)^{1/3}$ if $n=1$ $r=d$, $k_\Delta = 1$ (sq)

$$d = \left(\frac{W}{\gamma_r}\right)^{1/3}$$

$$d_{15} = \left(\frac{164}{160}\right)^{1/3} = 1.0 \text{ feet.}$$

$$\therefore d_{85} > 0.26 \text{ feet.}$$

Check WSDOT Gradation for Light Loose Rip Rap 9-13.1(2)

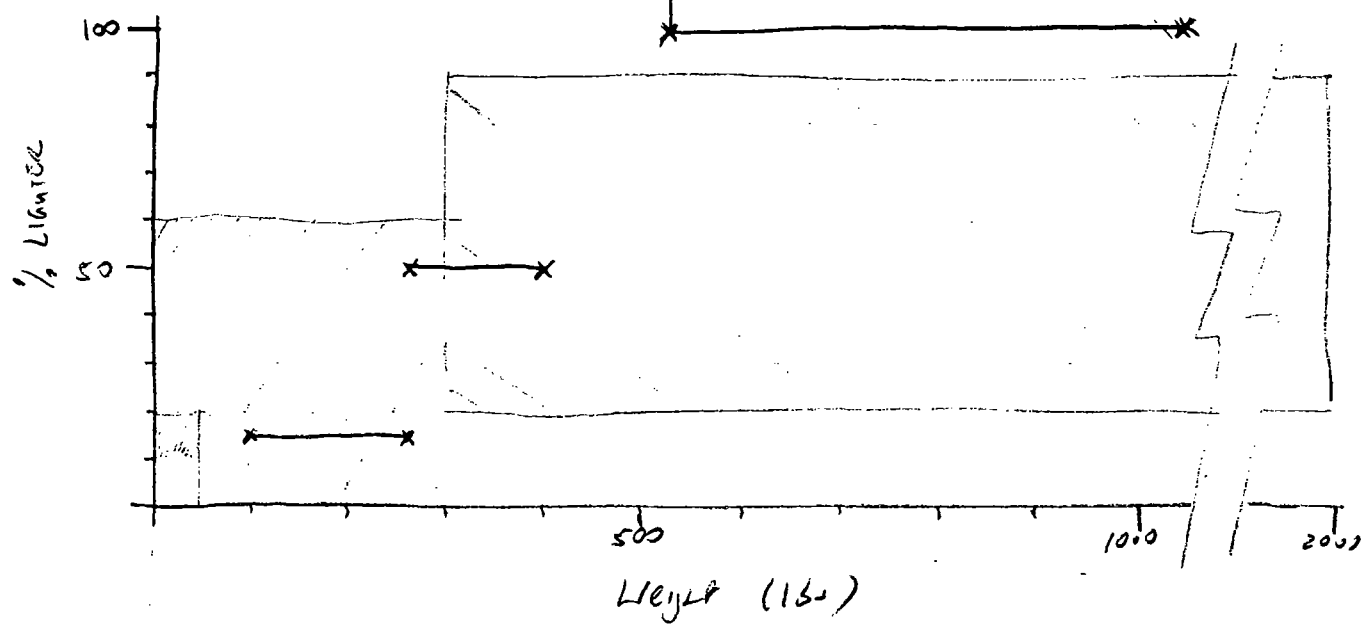
20%	→ 90%	300 lb to 2000 lb
15%	→ 80%	50 lb to 2000 lb
10%	→ 20%	< 50 lb.

↳ Approximate Weight "Gradation":

< 50 lb	10%	→ 20%
50 - 300 lb	0%	→ 60%
300 - 2000 lb	90%	→ 20%

↳ Recommended Gradation:

	min	max
W_{15}	105	263
W_{50}	263	395
W_{100}	526	1052



Conclusion: WSDOT Spec is broader than that recommended by USACE guidance.

WSDOT Spec is acceptable provided the product is well graded to avoid segregation and V_{SD} is > 300 lb.

↳ Note it is possible under the WSDOT spec to get a product that will not meet this. It is unlikely, but possible.

Chosen Filter layer Spec:

↳ Current Spec is Seattle No. 14 2½" crushed rock.

↳ Required from USACE Rip Rap design

$D_{85} > 0.32$ feet.

↳ From grading curve for 2½" crushed rock (see attached)

D_{85}: 28 mm → 60 mm

= 1.1 inch → 2.4"

= 0.09 → 0.2 feet

∴ Too small?

↳ From grading curve of Thea Foss (see attached)

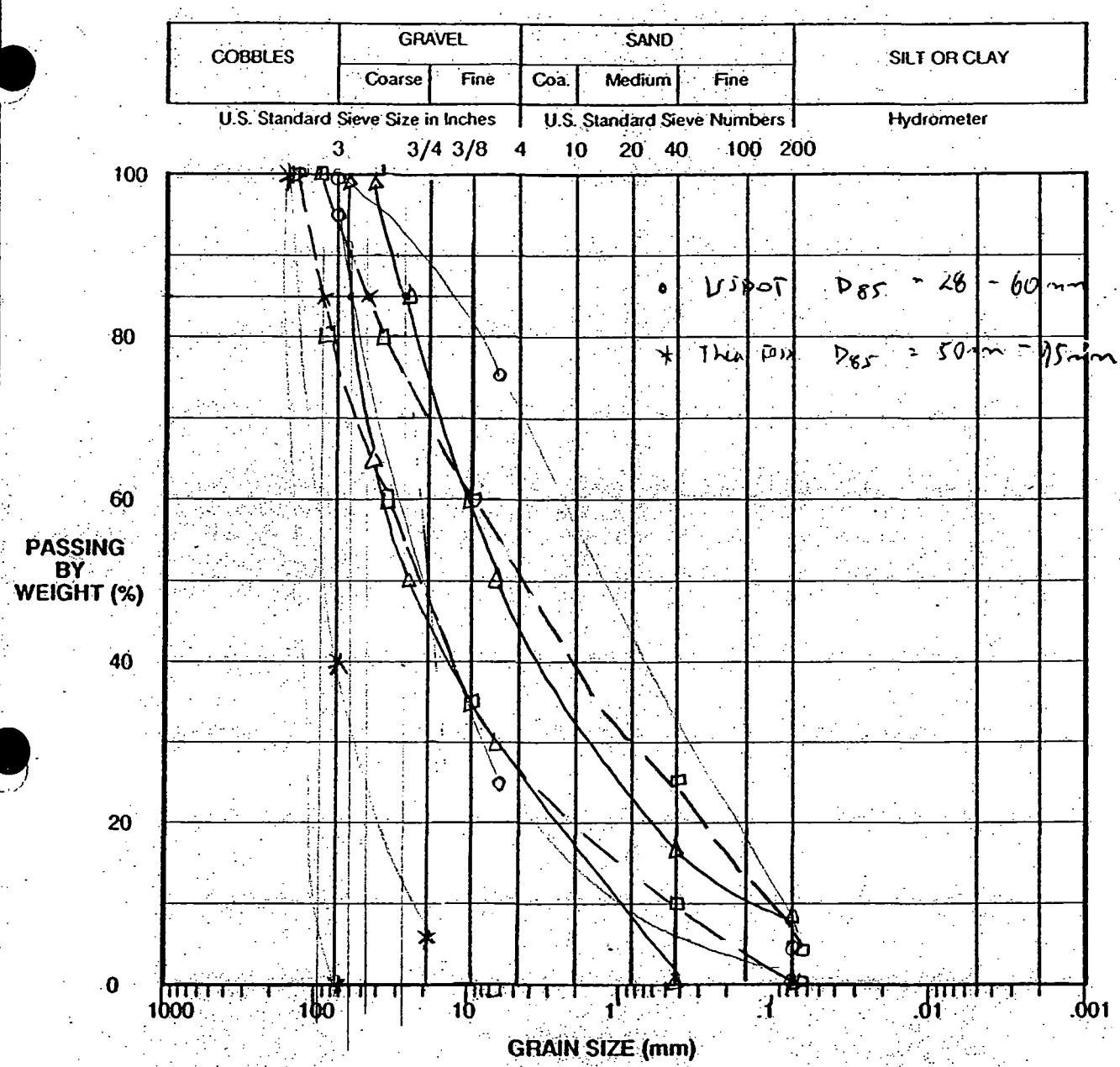
D_{85}: 50 – 95 mm

= 0.17 → 0.32 feet.

∴ Marginal - should be larger.

FILTER LAYER

17/29



GRAIN SIZE DISTRIBUTION

SYMBOL	BORING NO.	DEPTH (ft)	DESCRIPTION	% GRAVEL	% SAND	% FINES
△			WSDOT 9-03.9(1) Ballast Seattle No. 19 - 2½-inch crushed rock			
□			Thea Foss and Wheeler-Osgood Water Way Remediation - Slope Cap Filter Layer			
○			Seattle No 17 - Bank Run Gravel			

REMARKS:

† WSDOT 9-13.6 Quarry Spall

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FILTER LAYER SIZING CALCULATIONS

DESIGN CRITERIA

Wave Height (feet)	d_{50} (feet) From	To
2.90	0.33	0.26

Available Raw Materials:

	Grain Size (mm)	Quarry Spoils - % Passing Minimum	Maximum	Average	2-1/2" crushed rock - % passing Minimum	Maximum	Average
8-inches	200		100	100			100
3-inches	75	0	40	20			100
2.5-inches	62.5			5		100	100
2-inches	50			5	65	100	82.5
1-inch	25			5	50	85	67.5
3/4-inch	18.75	0	10	5			40
1/4-inch	6.25			0	30	50	40
40 sieve	0.42			0	0	16	8
200 sieve	0.075			0	0	9	4.5

Potential Mixtures:

	Grain Size (mm)	% Passing % Quarry Spalls 50 % 2-1/2 inch crushed rock 50	Grain Size (mm)	% Passing % Quarry Spalls 30 % 2-1/2 inch crushed rock 70	Grain Size (mm)	% Passing % Quarry Spalls 70 % 2-1/2 inch crushed rock 30
8-inches	200	100	200	100	200	100
3-inches	75	60	75	78	75	44
2.5-inches	62.5	52.5	62.5	71.5	62.5	33.5
2-inches	50	43.75	50	59.25	50	28.25
1-inch	25	36.25	25	48.75	25	23.75
3/4-inch	18.8	22.5	18.8	29.5	18.8	15.5
1/4-inch	6.3	20	6.3	28	6.3	12
40 sieve	0.42	4	0.42	5.6	0.42	2.4
200 sieve	0.075	2.25	0.075	3.15	0.075	1.35
	d_{85}	0.3 feet	d_{85}	0.25 feet	d_{85}	0.57 feet

Suggested Gradation:

Grain Size	% Passing Min	Max
8-inches	100	100
3-inches	44	76
2.5-inches	33.5	71.5
2-inches	28.25	59.25
1-inch	23.75	48.75
3/4-inch	15.5	29.5
1/4-inch	12	28
40 sieve	2.4	5.6
200 sieve	1.35	3.15

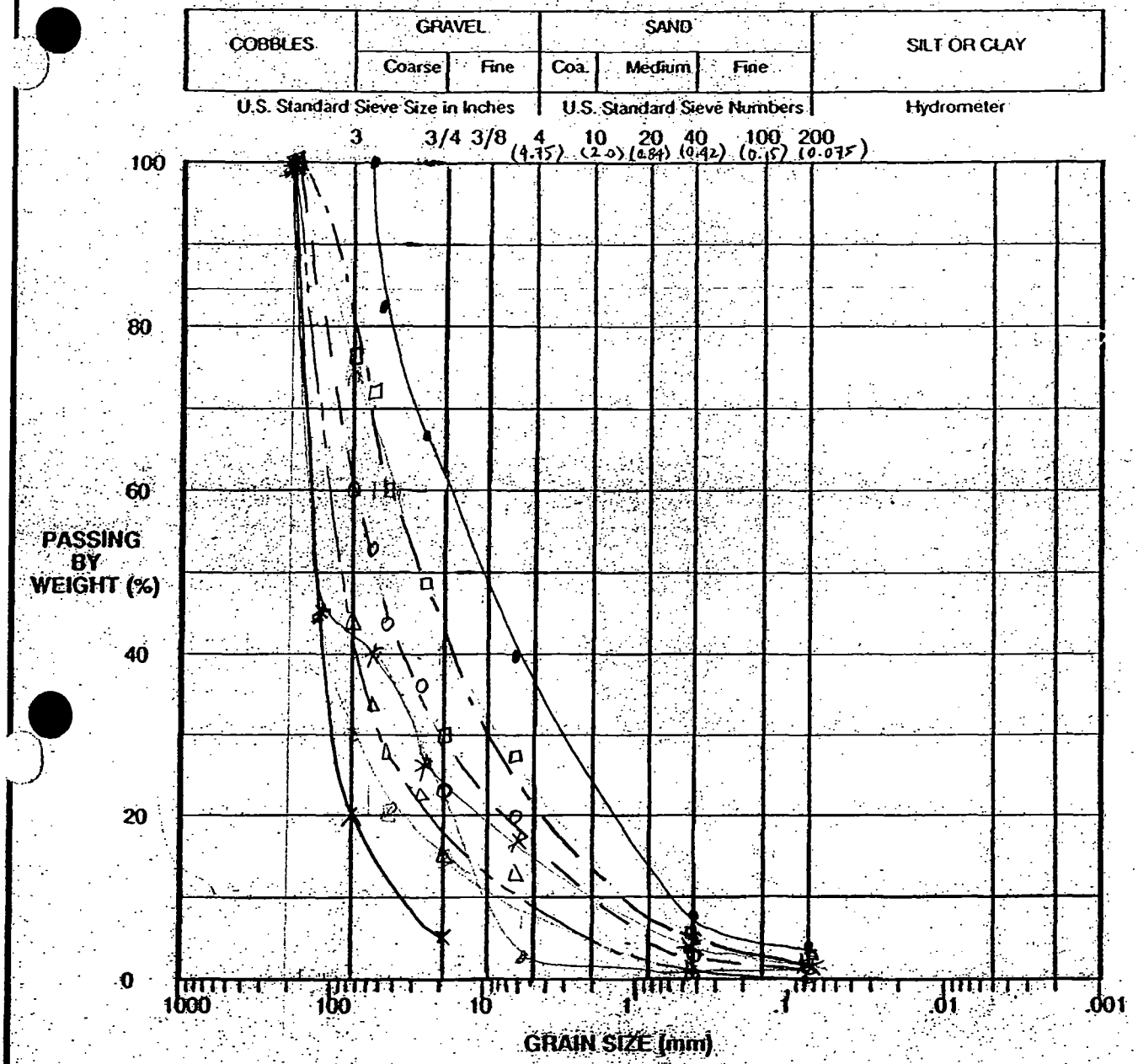
Simplified Gradation

Grain Size	% Passing Min	Max
8-inches		100
3-inches	40	75
2.5-inches		
2-inches	25	60
1-inch		
3/4-inch	15	30
1/4-inch		
40 sieve	0	5
200 sieve		

d_{85} 0.57 0.25

ATTACHMENT D

10/29



GRAIN SIZE DISTRIBUTION

SYMBOL	BORING NO.	DEPTH (ft)	DESCRIPTION	% GRAVEL	% SAND	% FINES

—×— Quarry Spalls WSDOT 9-13/6

—●— Ballast WSDOT 9-03.9(1) or 2½" crushed rock (Seattle No. 14)

—○— 50/50 mix ⇒ D_{85} = 100mm = 0.3 feet ∴ OK

—□— 30/70 mix ⇒ D_{85} = 75mm = 0.25 feet Borderline

—△— 70/30 mix ⇒ D_{85} = 170mm = 0.57 feet ∴ OK

REMARKS: * Glacier gradation of 50% Quarry Spalls & 50% 2½" mins

○ [illegible] 50% [illegible] 50% 2½ - 5/8

□ [illegible]

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ATTACHMENT E

20/29

EM 1110-2-1614
30 June 1995

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Design of Coastal Revetments, Seawalls, and Bulkheads

ENGINEER MANUAL

For other configurations of seawalls, Ward and Ahrens (1992) should be consulted, or physical model tests should be performed.

2-15. Stability and Flexibility

Structures can be built by using large monolithic masses that resist wave forces or by using aggregations of smaller units that are placed either in a random or in a well-ordered array. Examples of these are large reinforced concrete seawalls, quarrystone or riprap revetments, and geometric concrete block revetments. The massive monoliths and interlocking blocks often exhibit superior initial strength but, lacking flexibility, may not accommodate small amounts of differential settlement or toe scour that may lead to premature failure. Randomly placed rock or concrete armor units, on the other hand, experience settlement and readjustment under wave attack, and, up to a point, have reserve strength over design conditions. They typically do not fail catastrophically if minor damages are inflicted. The equations in this chapter are suitable for preliminary design for major structures. However, final design will usually require verification of stability and performance by hydraulic model studies. The design guidance herein may be used for final design for small structures where the consequences of failure are minor. For those cases, project funds are usually too limited to permit model studies.

2-16. Armor Unit Stability

a. The most widely used measure of armor unit stability is that developed by Hudson (1961) which is given in Equation 2-15:

$$W = \frac{\gamma_r H^3}{K_D \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3 \cot\theta} \qquad (2\text{-}15)$$

where

W = required individual armor unit weight, lb (or $W_{50_{min}}$ for graded riprap)

γ_r = specific weight of the armor unit, lb/ft^3

H = monochromatic wave height

K_D = stability coefficient given in Table 2-3

γ_w = specific weight of water at the site (salt or fresh)

θ = is structure slope (from the horizontal)

Stones within the cover layer can range from 0.75 to 1.25 W as long as 50 percent weigh at least W and the gradation is uniform across the structure's surface. Equation 2-15 can be used for preliminary and final design when H is less than 5 ft and there is no major overtopping of the structure. For larger wave heights, model tests are preferable to develop the optimum design. Armor weights determined with Equation 2-15 for monochromatic waves should be verified during model tests using spectral wave conditions.

b. Equation 2-15 is frequently presented as a stability formula with N_s as a stability number. Rewriting Equation 2-15 as

$$N_s = \frac{H}{\left(\frac{W}{\gamma_r}\right)^{1/3}\left(\frac{\gamma_r}{\gamma_w} - 1\right)} \qquad (2\text{-}16)$$

it is readily seen that

$$N_s = (K_D \cot\theta)^{1/3} \qquad (2\text{-}17)$$

By equating Equations 2-16 and 2-17, W is readily obtained.

c. For irregular wave conditions on revetments of dumped riprap, the recommended stability number is

$$N_{os} = 1.14 \cot^{1/6}\theta \qquad (2\text{-}18)$$

where N_{os} is the zero-damage stability number, and the value 1.14 is obtained from Ahrens (1981b), which recommended a value of 1.45 and using H_s with Equation 2-16, then modified based on Broderick (1983), which found using H_{10} (10 percent wave height, or average of highest 10-percent of the waves) in Equation 2-16 provided a better fit to the data. Assuming a Rayleigh wave height distribution, $H_{10} \approx 1.27\ H_s$. Because H_s is more readily available than H_{10}, the stability number in Equation 2-17 was adjusted (1.45/1.27 = 1.14) to allow H_s to be used in the stability equation while providing the more conservative effect of using H_{10} for the design.

d. Stability equations derived from an extensive series of laboratory tests in The Netherlands were presented in van der Meer and Pilarczyk (1987) and van der

Table 2-3
Suggested Values for Use In Determining Armor Weight (Breaking Wave Conditions)

Armor Unit	n[1]	Placement	Slope (cot θ)	K_D
Quarrystone				
Smooth rounded	2	Random	1.5 to 3.0	1.2
Smooth rounded	>3	Random	1.5 to 3.0	1.6
Rough angular	1	Random	1.5 to 3.0	Do Not Use
Rough angular	2	Random	1.5 to 3.0	2.0
Rough angular	>3	Random	1.5 to 3.0	2.2
Rough angular	2	Special[2]	1.5 to 3.0	7.0 to 20.0
Graded riprap[3]	2[4]	Random	2.0 to 6.0	2.2
Concrete Armor Units				
Tetrapod	2	Random	1.5 to 3.0	7.0
Tripod	2	Random	1.5 to 3.0	9.0
Tripod	1	Uniform	1.5 to 3.0	12.0
Dolos	2	Random	2.0 to 3.0[5]	15.0[6]

[1] n equals the number of equivalent spherical diameters corresponding to the median stone weight that would fit within the layer thickness.

[2] Special placement with long axes of stone placed perpendicular to the slope face. Model tests are described in Markle and Davidson (1979).

[3] Graded riprap is not recommended where wave heights exceed 5 ft.

[4] By definition, graded riprap thickness is two times the diameter of the minimum W_{50} size.

[5] Stability of dolosse on slope steeper than 1 on 2 should be verified by model tests.

[6] No damage design (3 to 5 percent of units move). If no rocking of armor (less than 2 percent) is desired, reduce K_D by approximately 50 percent.

Meer (1988a, 1988b). Two stability equations were presented. For plunging waves,

$$N_s = 6.2 P^{0.18} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \xi_z^{0.5} \tag{2-19}$$

and for surging or nonbreaking waves,

$$N_s = 1.0 P^{-0.13} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \sqrt{\cot\theta}\, \xi_z^{P} \tag{2-20}$$

where

P = permeability coefficient

S = damage level

N = number of waves

P varies from $P = 0.1$ for a riprap revetment over an impermeable slope to $P = 0.6$ for a mound of armor stone with no core. For the start of damage $S = 2$ for revetment slopes of 1:2 or 1:3, or $S = 3$ for revetment slopes of 1:4 to 1:6. The number of waves is difficult to estimate, but Equations 2-19 and 2-20 are valid for $N = 1{,}000$ to $N = 7{,}000$, so selecting 7,000 waves should provide a conservative estimate for stability. For structures other than riprap revetments, additional values of P and S are presented in van der Meer (1988a, 1988b).

e. Equations 2-19 and 2-20 were developed for deepwater wave conditions and do not include a wave-height truncation due to wave breaking. van der Meer therefore recommends a shallow water correction given as

$$\frac{N_{s\,(shallow\ water)}}{N_{s\,(deep\ water)}} = \frac{1.40\, H_s}{H_2} \tag{2-21}$$

where H_2 is the wave height exceeded by 2 percent of the waves. In deep water, $H_2 = 1.40\ H_s$, and there is no correction in Equation 2-21.

2-17. Layer Thickness

a. Armor units. As indicated in the SPM, the thickness of an armor layer can be determined by Equation 2-22:

$$r = n k_\Delta \left(\frac{W}{w_r} \right)^{1/3} \tag{2-22}$$

where r is the layer thickness in feet, n is the number of armor units that would fit within the layer thickness (typically n=2), and k_Δ is the layer coefficient given in Table 2-4. For estimating purposes, the number of armor units, N_r, for a given surface area in square feet, A, is

$$N_r = A n k_\Delta \left(1 - \frac{P}{100} \right) \left(\frac{w_r}{W} \right)^{2/3} \tag{2-23}$$

where P is the average porosity of the cover layer from Table 2-4.

b. Graded riprap. The layer thickness for graded riprap must be at least twice the nominal diameter of the W_{50} stone, where the nominal diameter is the cube root of the stone volume. In addition, r_{min} should be at least 25 percent greater than the nominal diameter of the largest stone and should always be greater than a minimum layer thickness of 1 ft (Ahrens 1975). Therefore,

$$r_{min} = \max \left[2.0 \left(\frac{W_{50\,min}}{\gamma_r} \right)^{1/3} ; \; 1.25 \left(\frac{W_{100}}{\gamma_r} \right)^{1/3} ; \; 1 \; ft \right] \tag{2-24}$$

where r_{min} is the minimum layer thickness perpendicular to the slope. Greater layer thicknesses will tend to increase the reserve strength of the revetment against waves greater than the design. Gradation (within broad limits) appears to have little effect on stability provided the W_{50} size is used to characterize the layer. The following are suggested guidelines for establishing gradation limits (from EM 1110-2-1601) (see also Ahrens 1981a):

(1) The lower limit of W_{50} stone, $W_{50\,min}$, should be selected based on stability requirements using Equation 2-15.

(2) The upper limit of the W_{100} stone, $W_{100\,max}$, should equal the maximum size that can be economically obtained from the quarry but not exceed 4 times $W_{50\,min}$.

(3) The lower limit of the W_{100} stone, $W_{100\,min}$, should not be less than twice $W_{50\,min}$.

(4) The upper limit of the W_{50} stone, $W_{50\,max}$, should be about 1.5 times $W_{50\,min}$.

(5) The lower limit of the W_{15} stone, $W_{15\,min}$, should be about 0.4 times $W_{50\,min}$.

(6) The upper limit of the W_{15} stone, $W_{15\,max}$, should be selected based on filter requirements specified in EM 1110-2-1901. It should slightly exceed $W_{50\,min}$.

(7) The bulk volume of stone lighter than $W_{15\,min}$ in a gradation should not exceed the volume of voids in the revetment without this lighter stone. In many cases, however, the actual quarry yield available will differ from the gradation limits specified above. In those cases the designer must exercise judgment as to the suitability of the supplied gradation. Primary consideration should be given to the $W_{50\,min}$ size under those circumstances. For instance, broader than recommended gradations may be suitable if the supplied W_{50} is somewhat heavier than the required $W_{50\,min}$. Segregation becomes a major problem, however, when the riprap is too broadly graded.

2-18. Reserve Stability

a. General. A well-known quality of randomly placed rubble structures is the ability to adjust and resettle under wave conditions that cause minor damages. This has been called reserve strength or reserve stability. Structures built of regular or uniformly placed units such as concrete blocks commonly have little or no reserve stability and may fail rapidly if submitted to greater than design conditions.

b. Armor units. Values for the stability coefficient, K_D, given in paragraph 2-16 allow up to 5 percent damages under design wave conditions. Table 2-5 contains values of wave heights producing increasing levels of damage. The wave heights are referenced to the zero-damage wave height ($H_{D=0}$) as used in Equation 2-15. Exposure of armor sized for $H_{D=0}$ to these larger wave heights should produce damages in the range given. If the armor stone available at a site is lighter than the stone size calculated using the wave height at the site, the zero-damage wave height for the available stone can be

Table 2-4
Layer Coefficients and Porosity for Various Armor Units

Armor Unit	n	Placement	K_Δ	P (%)
Quarrystone (smooth)	2	Random	1.00	38
Quarrystone (rough)	2	Random	1.00	37
Quarrystone (rough)	≥3	Random	1.00	40
Graded riprap	2*	Random	N/A	37
Tetrapod	2	Random	1.04	50
Tribar	2	Random	1.02	54
Tribar	1	Uniform	1.13	47
Dolos	2	Random	0.94	56

* By definition, riprap thickness equals two cubic lengths of W_{50} or 1.25 W_{100}.

Table 2-5
$H/H_{D=0}$ for Cover Layer Damage Levels for Various Armor Types ($H/H_{D=0}$ for Damage Level in Percent)

Unit	$0 \le \%_D < 5$	$5 \le \%_D < 10$	$10 \le \%_D < 15$	$15 \le \%_D < 20$	$20 \le \%_D \le 30$
Quarrystone (smooth)	1.00	1.08	1.14	1.20	1.29
Quarrystone (angular)	1.00	1.08	1.19	1.27	1.37
Tetrapods	1.00	1.09	1.17	1.24	1.32
Tribars	1.00	1.11	1.25	1.36	1.50
Dolos	1.00	1.10	1.14	1.17	1.20

calculated, and a ratio with the site's wave height can be used to estimate the damage that can be expected with the available stone. All values in the table are for randomly placed units, n=2, and minor overtopping. The values in Table 2-5 are adapted from Table 7-8 of the SPM. The SPM values are for breakwater design and nonbreaking wave conditions and include damage levels above 30 percent. Due to differences in the form of damage to breakwaters and revetments, revetments may fail before damages reach 30 percent. The values should be used with caution for damage levels from breaking and nonbreaking waves.

c. Graded riprap. Information on riprap reserve stability can be found in Ahrens (1981a). Reserve stability appears to be primarily related to the layer thickness although the median stone weight and structure slope are also important.

2-19. Toe Protection

a. General. Toe protection is supplemental armoring of the beach or bottom surface in front of a structure which prevents waves from scouring and undercutting it. Factors that affect the severity of toe scour include wave breaking (when near the toe), wave runup and backwash, wave reflection, and grain-size distribution of the beach or bottom materials. The revetment toe often requires special consideration because it is subjected to both hydraulic forces and the changing profiles of the beach fronting the revetment. Toe stability is essential because failure of the toe will generally lead to failure throughout the entire structure. Specific guidance for toe design based on either prototype or model results has not been developed. Some empirical suggested guidance is contained in Eckert (1983).

b. Revetments.

(1) Design procedure. Toe protection for revetments is generally governed by hydraulic criteria. Scour can be caused by waves, wave-induced currents, or tidal currents. For most revetments, waves and wave-induced currents will be most important. For submerged toe stone, weights can be predicted based on Equation 2-25:

$$W_{min} = \frac{\gamma_r H^3}{N_s^3 \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3} \quad (2\text{-}25)$$

where N_s is the design stability number for rubble toe protection in front of a vertical wall, as indicated in the SPM (see Figure 2-7). For toe structures exposed to wave action, the designer must select either Equation 2-15 which applies at or near the water surface or Equation 2-25 above. It should be recognized that Equation 2-25 yields a minimum weight and Equation 2-15 yields a median weight. Stone selection should be based on the weight gradations developed from each of the stone weights. The relative importance of these factors depends on the location of the structure and its elevation with respect to low water. When the toe protection is for scour caused by tidal or riverine currents alone, the designer is referred to EM 1110-2-1601. Virtually no data exist on currents acting on toe stone when they are a product of storm waves and tidal or riverine flow. It is assumed that the scour effects are partially additive. In the case of a revetment toe, some conservatism is provided by using the design stability number for toe protection in front of a vertical wall as suggested above.

Suggested toe configurations. Guidance contained in EM 1110-2-1601 which relates to toe design configurations for flood control channels is modified for coastal revetments and presented in Figure 2-4. This is offered solely to illustrate possible toe configurations. Other schemes known to be satisfactory by the designer are also acceptable. Designs I, II, IV, and V are for up to moderate toe scour conditions and construction in the dry. Designs III and VI can be used to reduce excavation when the stone in the toe trench is considered sacrificial and will be replaced after infrequent major events. A thickened toe similar to that in Design III can be used for underwater construction except that the toe stone is placed on the existing bottom rather than in an excavated trench.

c. Seawalls and bulkheads.

(1) General considerations. Design of toe protection for seawalls and bulkheads must consider geotechnical as well as hydraulic factors. Cantilevered, anchored, or gravity walls each depend on the soil in the toe area for their support. For cantilevered and anchored walls, this passive earth pressure zone must be maintained for stability against overturning. Gravity walls resist sliding through the frictional resistance developed between the soil and the base of the structure. Overturning is resisted by the moment of its own weight supported by the zone of bearing beneath the toe of the structure. Possible toe configurations are shown in Figure 2-5.

(2) Seepage forces. The hydraulic gradients of seepage flows beneath vertical walls can significantly increase toe scour. Steep exit gradients reduce the net effective weight of the soil, making sediment movement under waves and currents more likely. This seepage flow may originate from general groundwater conditions, water derived from wave overtopping of the structure, or from precipitation. A quantitative treatment of these factors is presented in Richart and Schmertmann (1958).

(3) Toe apron width. The toe apron width will depend on geotechnical and hydraulic factors. The passive earth pressure zone must be protected for a sheet-pile wall as shown in Figure 2-6. The minimum width, B, from a geotechnical perspective can be derived using the Rankine theory as described in Eckert (1983). In these cases the toe apron should be wider than the product of the effective embedment depth and the coefficient of passive earth pressure for the soil. Using hydraulic considerations, the toe apron should be at least twice the incident wave height for sheet-pile walls and equal to the incident wave height for gravity walls. In addition, the apron should be at least 40 percent of the depth at the structure, d_s. Greatest width predicted by these geotechnical and hydraulic factors should be used for design. In all cases, undercutting and unraveling of the edge of the apron must be minimized.

(4) Toe stone weight. Toe stone weight can be predicted based on Figure 2-7 (from Brebner and Donnelly 1962)). A design wave between H_1 and H_{10} is suggested. To apply the method assume a value of d_t the distance from the still water level to the top of the toe. If the resulting stone size and section geometry are not appropriate, a different d_t should be tried. Using the median stone weight determined by this method, the allowable gradation should be approximately 0.5 to 1.5 W.

2-20. Filters

A filter is a transitional layer of gravel, small stone, or fabric placed between the underlying soil and the structure. The filter prevents the migration of the fine soil particles through voids in the structure, distributes the weight of the armor units to provide more uniform settlement, and permits relief of hydrostatic pressures within the soils. For areas above the waterline, filters also

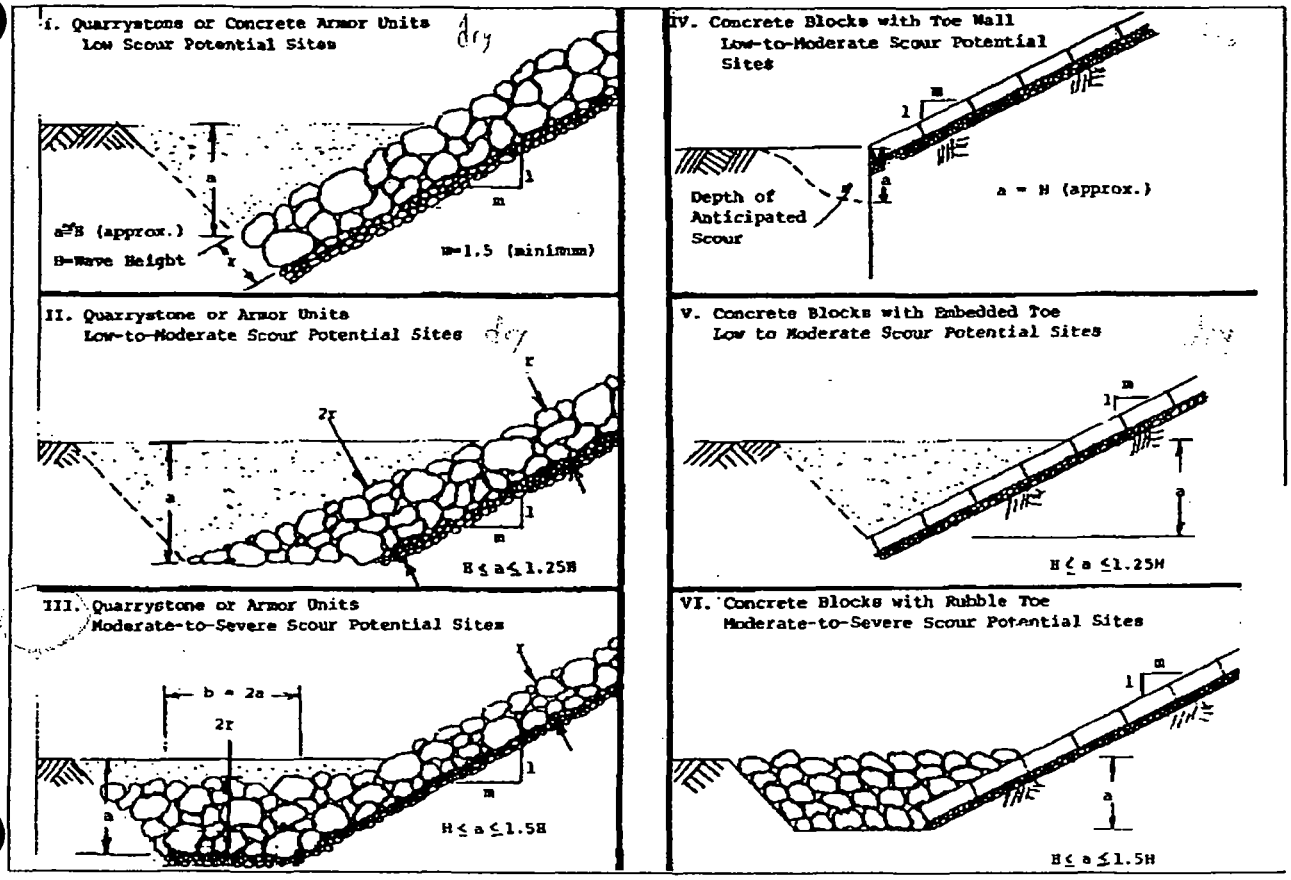

Figure 2-4. Revetment toe protection (Designs I through VI)

prevent surface water from causing erosion (gullies) beneath the riprap. In general form layers have the relation given in Equation 2-26:

$$\frac{d_{15\,upper}}{d_{85\,under}} < 4 \qquad (2\text{-}26)$$

Specific design guidance for gravel and stone filters is contained in EM 1110-2-1901 and EM 1110-2-2300 (see also Ahrens 1981a), and guidance for cloth filters is contained in CW 02215. The requirements contained in these will be briefly summarized in the following paragraphs.

a. Graded rock filters. The filter criteria can be stated as:

$$\frac{d_{15\,filter}}{d_{85\,soil}} < 4 \text{ to } 5 < \frac{d_{15\,filter}}{d_{15\,soil}} \qquad (2\text{-}27)$$

where the left side of Equation 2-27 is intended to prevent piping through the filter and the right side of Equation 2-27 provides for adequate permeability for structural bedding layers. This guidance also applies between successive layers of multilayered structures. Such designs are needed where a large disparity exists between the void size in the armor layer and the particle sizes in the underlying layer.

b. Riprap and armor stone underlayers. Underlayers for riprap revetments should be sized as in Equation 2-28,

$$\frac{d_{15\,armor}}{d_{85\,filter}} < 4 \qquad (2\text{-}28)$$

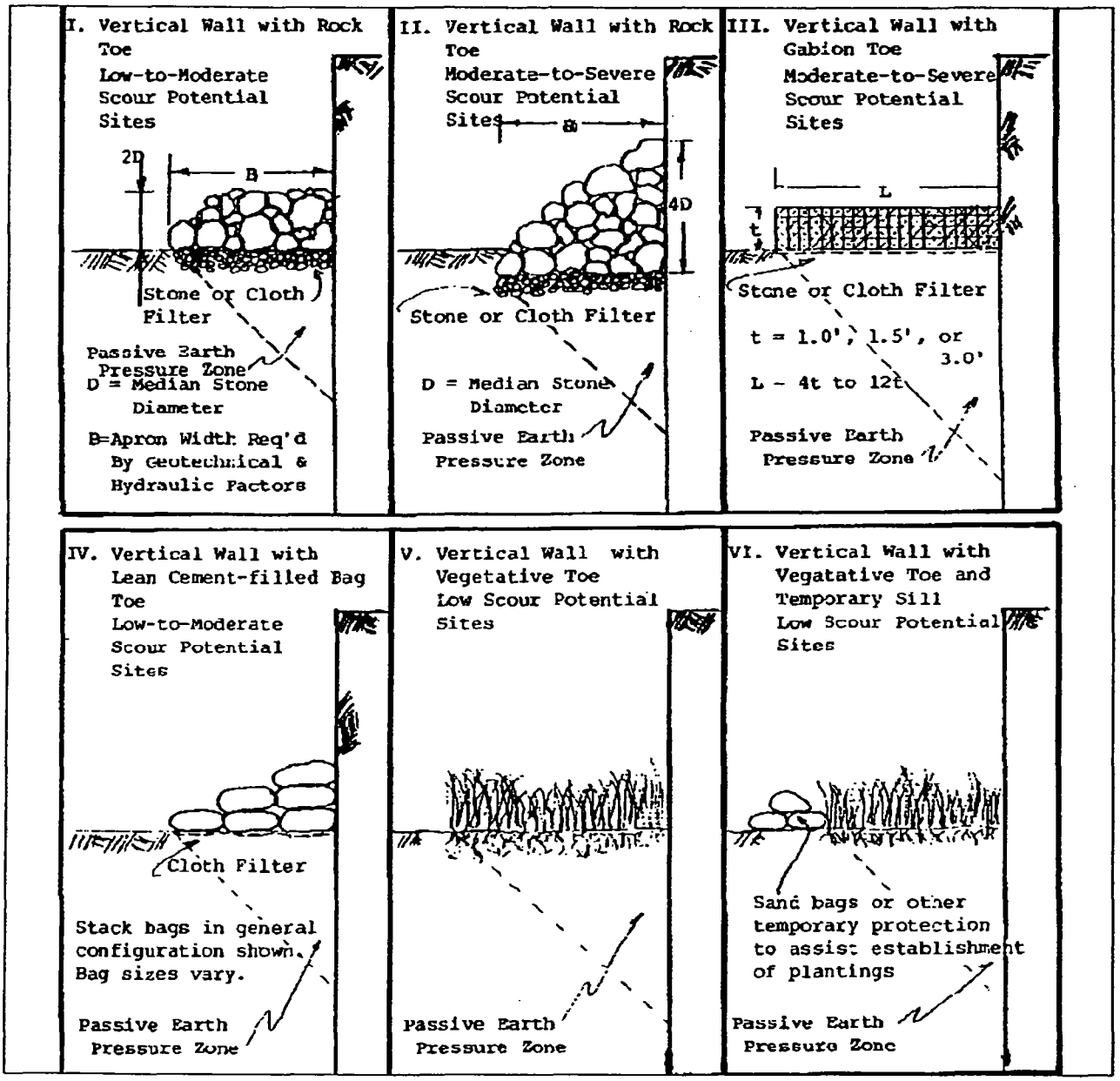

Figure 2-5. Seawall and bulkhead toe protection

where the stone diameter d can be related to the stone weight W through Equation 2-22 by setting n equal to 1.0. This is more restrictive than Equation 2-27 and provides an additional margin against variations in void sizes that may occur as the armor layer shifts under wave action. For large riprap sizes, each underlayer should meet the condition specified in Equation 2-28, and the layer thicknesses should be at least 3 median stone diameters. For armor and underlayers of uniform-sized quarrystone, the first underlayer should be at least 2 stone diameters thick, and the individual units should weigh about one-tenth the units in the armor layer. When concrete armor units with $K_D > 12$ are used, the underlayer should be quarrystone weighing about one-fifth of the overlying armor units.

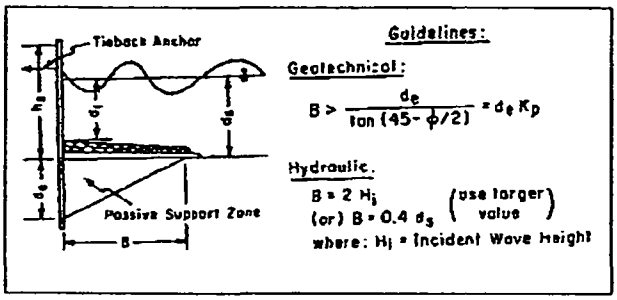

Figure 2-6. Toe aprons for sheet-pile bulkheads

c. Plastic filter fabric selection. Selection of filter cloth is based on the equivalent opening size (EOS), which is the number of the U.S. Standard Sieve having openings closest to the filter fabric openings. Material will first be retained on a sieve whose number is equal to the EOS. For granular soils with less than 50 percent fines (silts and clays) by weight (passing a No. 200 sieve), select the filter fabric by applying Equation 2-29:

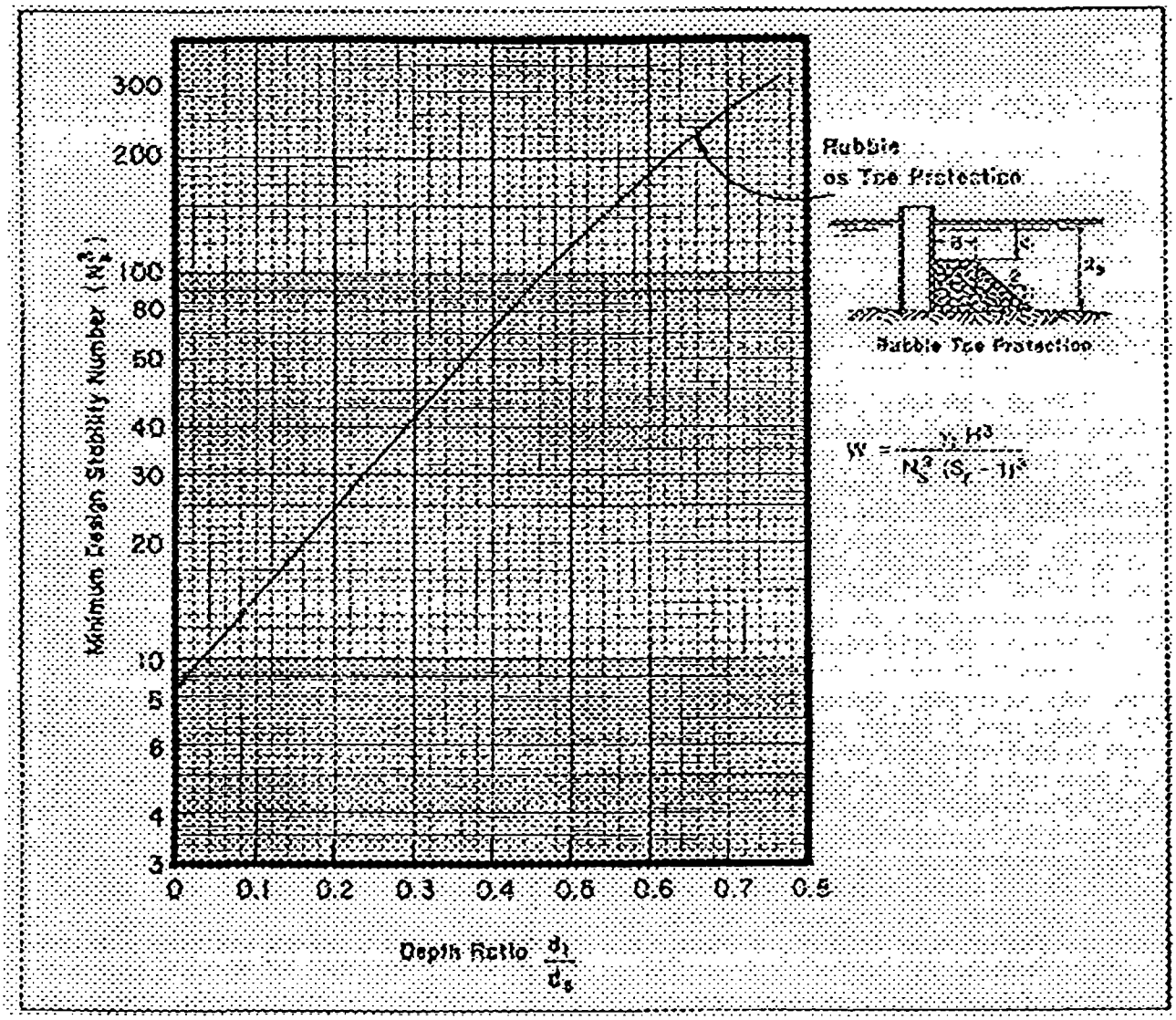

Figure 2-7. Value of N_s, toe protection design for vertical walls (from Brebner and Donnelly 1962)

$$\frac{EOS\ sieve}{d_{85\ soil}} \leq 1 \qquad (2\text{-}29)$$

For other soils, the EOS should be no larger than the openings in a No. 70 sieve. Furthermore, no fabric should be used whose EOS is greater than 100, and none should be used alone when the underlying soil contains more than 85 percent material passing a No. 200 sieve. In those cases, an intermediate sand layer may provide the necessary transition layer between the soil and the fabric. Finally, the gradient ratio of the filter fabric is limited to a maximum value of three. That is, based on a head permeability test, the hydraulic gradient through the fabric and the 1 in. of soil adjacent to the fabric (i_1) divided by the hydraulic gradient of the 2 in. of soil between 1 and 3 in. above the fabric (i_2) is:

$$Gradient\ ratio = \frac{i_1}{i_2} \leq 3 \qquad (2\text{-}30)$$

Studies such as those in Chen et al. (1981) suggest that these filter cloth selection requirements may be somewhat restrictive.

d. Filter fabric placement. Experience indicates that synthetic cloths can retain their strength even after long periods of exposure to both salt and fresh water. To provide good performance, however, a properly selected cloth should be installed with due regard for the following precautions. First, heavy armor units may stretch the cloth as they settle, eventually causing bursting of the fabric in tension. A stone bedding layer beneath armor units weighing more than 1 ton for above-water work (1.5 tons for underwater construction) is suggested (Dunham and Barrett 1974), and multiple underlayers may be needed under primary units weighing more than 10 tons. Filter guidance must be properly applied in these cases. Second, the filter cloth should not extend seaward of the armor layer; rather, it should terminate a few feet landward of the armor layers as shown in Figure 2-8. Third, adequate overlaps between sheets must be provided. For lightweight revetments this can be as little as 12 in. and may increase to 3 ft for larger underwater structures. Fourth, sufficient folds should be included to eliminate tension and stretching under settlement. Securing pins with washers is also advisable at 2-to 5-ft intervals along the midpoint of the overlaps. Last, proper stone placement requires beginning at the toe and proceeding up

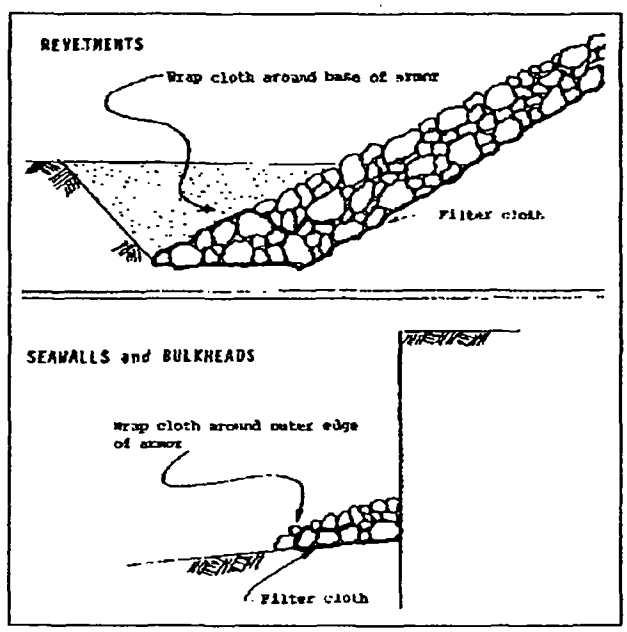

Figure 2-8. Use of filter cloth under revetment and toe protection stone

the slope. Dropping stone can rupture some fabrics even with free falls of only 1 ft, although Dunham and Barrett (1974) suggest that stones weighing up to 250 lb can safely be dropped from 3 ft. Greater drop heights are allowable under water where blocks up to 1 ton can be dropped through water columns of at least 5 ft.

2-21. Flank Protection

Flank protection is needed to limit vulnerability of a structure from the tendency for erosion to continue around its ends. Return sections are generally needed at both ends to prevent this. Sheet-pile structures can often be tied well into existing low banks, but the return sections of other devices such as rock revetments must usually be progressively lengthened as erosion continues. Extension of revetments past the point of active erosion should be considered but is often not feasible. In other cases, a thickened end section, similar to toe protection, can be used when the erosion rate is mild.

2-22. Corrosion

Corrosion is a primary problem with metals in brackish and salt water, particularly in the splash zone where materials are subjected to continuous wet-dry cycles. Mild carbon steel, for instance, will quickly corrode in such

Appendix B

APPENDIX B

CHEMICAL ISOLATION ANALYSIS

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B-1 Chemical Isolation Analysis Calculations

APPENDIX B

CHEMICAL ISOLATION ANALYSIS

B.1 INTRODUCTION

Chemical transport into the cap, and evaluation of the cap thickness and cap material requirements for chemical isolation, are discussed in this appendix. USACE and EPA have developed detailed guidance on the evaluation of these phenomena (USEPA 1998b; Palermo et al. 1998). Chemical transport mechanisms evaluated include:

- Long-term molecular diffusion
- Long-term advection of dissolved and colloidal-bound contaminants in porewater
- Short-term advection of contaminants in porewater resulting from consolidation of underlying sediments following cap placement

Evaluation of the long-term transport mechanisms is presented in Section B.2, and an evaluation of the short-term mechanisms is presented in Section B.3. The design criteria resulting from the chemical isolation analysis (i.e., required chemical isolation layer thickness and capping materials constraints) are presented in Section B.4. The detailed model outputs, along with the data used to estimate influent porewater concentrations and distribution coefficients, are documented in Attachment B-1 to this appendix.

To avoid unnecessary model runs for each detected chemical, a smaller subset of indicator chemicals was evaluated in the chemical isolation analysis. Representative low-molecular-weight polycyclic aromatic hydrocarbons (LPAHs), high-molecular-weight PAHs (HPAHs), and other semivolatile organic compounds (SVOCs) are selected based on the individual chemicals most likely to recontaminate capping material; the chemicals most likely to recontaminate the cap are those chemicals with the highest detected porewater concentrations and the lowest Sediment Quality Standard (SQS) values. Mercury was also evaluated as it was the only inorganic that frequently exceeded the SQS in the remedial investigation (RI) (USEPA 1998a). As discussed in the pre-design investigation data summary (USEPA 2002a), the indicator chemicals are:

- Naphthalene
- Acenaphthene

- Dibenz(a,h)anthracene
- Fluoranthene
- Dibenzofuran
- Mercury

Designing the cap for isolation of these chemicals addresses the most mobile chemicals and thus is protective for all of the chemicals of concern (COCs) identified in the Marine Sediment Unit (MSU).

The following sections are organized as follows:

- Section B.2 presents the baseline analysis of long-term chemical isolation. This analysis was used to determine the COC that exhibits the greatest recontamination potential (and thus "drives" the cap design) and to examine the sensitivity of the analysis to variability in input parameters.

- Section B.3 examines the potential for short-term recontamination of the cap resulting from consolidation of the underlying sediments and expression of porewater upward into the cap.

- Section B.4 presents the actual chemical isolation design analysis for each remediation area.

B.2 BASELINE LONG-TERM CHEMICAL ISOLATION

USACE guidance (Palermo et al. 1998, Appendix B) discusses the relative importance of advective/dispersive and diffusive transport (as quantified by the Peclet number) and presents the appropriate analytical solutions to the resulting transport equations. As calculated in the pre-design investigation data summary (USEPA 2002a), the Peclet number for this site is 0.56, indicating that both advective/dispersive and diffusive transport processes are important. Accordingly, the USACE advective-dispersive cap modeling procedure is used in the long-term chemical isolation analysis.

In the following analysis, two endpoints are used to quantify the long term transport of contaminants into the cap. These are:

- The time required for cap material to exceed the SQS for a given chemical, at the top of the chemical isolation layer

- The time required for porewater to exceed the state water quality criteria (WQC) (marine chronic) for a given chemical, at the top of the chemical isolation layer

The design life of the cap is taken as the time for either of these endpoints to be reached. This approach is inherently conservative. For example, compliance with the SQS is based on measured concentrations in the top 10 cm of sediments, which would imply that contamination of the chemical isolation layer, as well as the entire operational layer and a portion of the 15 cm bioturbation layer, would be permissible before the SQS is exceeded in the top 10 cm of the cap.

B.2.1 Analytical Solution to the Transport Equation

USACE guidance (Palermo et al. 1998, Appendix B) provides an analytical solution to the transport equation that does not include a loss term for biological degradation of chemicals within the cap. To allow for an evaluation of biological degradation during transport, a modified solution to the transport equation is used (Van Genuchten and Alves 1982):

$$C/C_o = 0.5 \exp[(v-m)x/2D] \operatorname{erfc}[(Rx-mt)/2(DRt)^{1/2}] + 0.5 \exp[(v+m)x/2D] \operatorname{erfc}[(Rx+mt)/2(DRt)^{1/2}] \quad (1)$$

in which the intermediate argument "m" is defined as:

$$m = v\,[1+4uD/v^2]^{1/2} \quad (2)$$

and where:

C = porewater concentration in cap
C_o = influent porewater concentration
v = porewater velocity (interstitial velocity)
x = distance from bottom of cap
D = dispersion coefficient
R = Retardation Factor = $1+K_{d,cap}*p/n_e$
t = time
$K_{d,cap}$ = distribution coefficient within the cap
p = bulk density
n_e = effective porosity
u = first-order decay constant

The dispersion coefficient is estimated as:

$$D = D_w n_e^{1/3} + dv \qquad (3)$$

where:

D_w = binary diffusivity of the chemical in water
d = longitudinal dispersivity

It is important to note that the equations above reduce to equation B32 in Palermo et al. (1998), for the case in which u = 0 (i.e., neglecting biodegradation). It is also noted that the term definitions above are based on porewater velocity, whereas the equations presented in Palermo et al. (1998) are based on the Darcy velocity. Thus, the terms v, D, and R must each be multiplied by a factor of porosity to be equivalent to the terms U, D_{disp}, and R_f (respectively) as defined in the USACE guidance.

B.2.2 Parameter Estimation

Table B-1 summarizes the chemical-specific input parameters to the advective-dispersive cap model. Table B-2 summarizes the physical input parameters. The "best estimate" values for these parameters are described below; the sensitivity of the model to variations in these parameters is discussed in a later subsection.

- **C_o.** Calculations of C_o are based on the measured porewater concentrations from the pre-design investigation, as reported in the pre-design investigation data summary (USEPA 2002a). The 95 percent upper confidence limit (UCL) on the mean is used as a conservative yet realistic estimate of porewater concentrations entering the cap. These calculations are shown in Attachment B-1.

- **$K_{d,cap}$.** The estimation of $K_{d,cap}$ values can be accomplished using either site-specific data from the porewater investigation or using a theoretical relationship. For organic chemicals, $K_{d,cap}$ is estimated based on the idealized relationship:

  $$K_{d,cap} = K_{oc} f_{oc,cap} \qquad (4)$$

  This relationship does not include a correction for dissolved organic carbon (DOC), as DOC data are not available and this correction is typically small for all but the most hydrophobic compounds such as HPAHs. Recently, investigators (Chen, Kan, and Tomson 2000; Chen et al. 2000) have found that a portion of

hydrophobic organic chemicals in sediment behave is if they are irreversibly sorbed, and these chemicals may exhibit higher desorption K_d values than adsorption K_d values. This effect suggests that there may be some uncertainty in using K_d values obtained from porewater investigations (which are desorption K_d values) to represent adsorption K_d values that apply to the cap material. While similar phenomena are well-known for metals (Myers et al. 1996) it has only recently been described for organics. Therefore, for organics, the theoretical relationship above was used instead of the site-specific partitioning behavior observed in the porewater investigation. For mercury, $K_{d,cap}$ was estimated based on recently reported literature values, which are from adsorption studies. The lowest of the recently reported literature values (2,500 L/kg) was used for mercury (Turner, Millward, and LeRoix 2001). The sensitivity analysis uses the ranges of observed values from the porewater study to evaluate the uncertainty in the value of $K_{d,cap}$.

- **D_w.** The binary diffusivity of the indicator chemicals in water is taken as 5×10^{-6} cm^2/sec (Palermo et al. 1998). As described in the guidance, binary diffusivity does not vary greatly among high-molecular weight compounds.

- **u.** The biodegradation rate is conservatively assumed to be zero for all compounds.

- **v.** The porewater velocity is based on the measured groundwater discharge rates, as reported in the pre-design investigation data summary (USEPA 2002a). The greatest absolute value of the measured groundwater velocity (0.0002 ft/day) is used as a conservative estimate.

- **d.** The value for longitudinal dispersivity cannot be directly measured, but is based on empirical observations of plumes in saturated flow conditions. Dispersivity is scale-dependent, and typically falls in the range of 0.01 to 1 times the scale of the system being modeled. Dispersivity may also be a function of the heterogeneity of the installed cap material, with greater variations in hydraulic conductivity resulting in higher dispersivity. Based on literature reviewed by USACE (Myers, Reible, and Easterly 2002), a dispersivity value of 0.01 times the effective cap thickness is used as the best estimate for caps less than 4 meters thick.

- **n_e.** The effective porosity of the emplaced cap is dependent on the specific cap material selected. The porosity may range from 0.25 to 0.5 for sand and 0.35 to

0.5 for silt (Freeze and Cherry 1979), and the effective porosity is typically slightly less than the porosity. Consistent with these ranges, a nominal value of 0.45 is assumed for both the effective porosity (n_e) and the porosity (n).

- **p.** The bulk density of the cap material is estimated from the particle mass density and the porosity, by the relationship :

$$p = (1-n)*g \qquad (5)$$

where g is the particle mass density. Assuming a nominal value of 2.65 g/cm^3 for g (Freeze and Cherry 1979), p is estimated at 1.46 g/cm^3.

- $\mathbf{f_{oc,cap}}$. The cap organic carbon fraction is nominally estimated at 0.02, based on analytical results of Duwamish River dredged material. The actual organic content of the cap material may vary by remedial area, depending on other required physical characteristics (such as particle size requirements) of the capping material. Actual design values for $f_{oc,\,cap}$ are presented in Section B.4.

B.2.3 Results

Table B-3 summarizes the results of the baseline long-term chemical isolation analysis. The results are quantified in two ways:

- The predicted time for an indicator chemical in sediment to exceed the SQS at the top of a 3-, 6-, and 12-inch chemical isolation layer
- The predicted time for an indicator chemical in porewater to exceed the WQC at the top of a 3-, 6-, and 12-inch chemical isolation layer

Naphthalene exhibits the earliest breakthrough of the indicator chemicals, requiring 9 years, 35 years, and 130 years to exceed the SQS at the top of a 3-, 6-, and 12-inch chemical isolation layer, respectively. Dibenzofuran exhibits breakthrough times almost identical to naphthalene. Model results for the 12-inch chemical isolation layer are shown in detail in Part II of Attachment B-1.

With the exception of fluoranthene, porewater concentrations were below WQC for all indicator chemicals at all times. Fluoranthene would require more than 10,000 years to exceed WQC in porewater for any of the assumed chemical isolation layer thicknesses.

The model output was checked against an independent solution to the transport equations, to ensure accuracy of the output. The parameters used in USACE guidance example calculations were input into the model, and the results were compared to the output of the example MathCad model formulated by Danny Reible (Palermo et al. 1998, Appendix B). Aside from slight rounding errors, the results were identical. These results are presented in Attachment B-1.

B.2.4 Sensitivity Analysis

To account for sample variability and other uncertainties in parameter estimation, the following sensitivity analysis examines the effect of varying key parameters on the model output. All sensitivity runs are based on the transport of naphthalene through the cap, as naphthalene (along with dibenzofuran) exhibits the fastest breakthrough of any of the indicator chemicals. Sensitivity is quantified as the predicted time for naphthalene to exceed the SQS at the top of a 12-inch chemical isolation layer. It is stressed that use of a 12-inch chemical isolation layer in the sensitivity analysis is purely for illustrative purposes. Actual design values for the chemical isolation layer thickness vary by remedial area and are discussed in Section B.4.2.

The following key parameters were examined:

- **C_o.** The value of C_o was varied from a lower bound based on the mean of the measured porewater concentrations to an upper bound based on the maximum measured porewater concentration. As seen in the worksheets in Attachment B-1, the maximum measured C_o generally compared favorably with the theoretical solubility of the indicator chemicals (as estimated by Raoult's Law). The HPAHs were exceptions, with maximum measured C_o values much greater than the theoretical solubility values. This is likely due to HPAH sorption to dissolved organic material. The fact that the maximum C_o approximated or exceeded the theoretical solubility suggests that higher porewater concentrations do not exist elsewhere within the MSU, even in localized areas that may have higher sediment concentrations.

- **$K_{d,cap}$.** The value of $K_{d,cap}$ was varied based on the range of site-specific partitioning observed in the porewater study. Site-specific distribution coefficients are calculated for the MSU fill ($K_{d,\,msuf}$) from the ratios of measured chemical concentrations in sediment to those in porewater. $K_{d,cap}$ values in the sensitivity analysis are based on the observed distribution coefficients in the marine sediment unit fill ($K_{d,msuf}$). The observed values of $K_{d,msuf}$ account for both dissolved and colloidally-sorbed contaminants, and are theoretically proportional to the organic carbon fraction of the sediment ($f_{oc,msuf}$) (Palermo et al. 1998,

equation B8). The estimated value of $K_{d,cap}$ must therefore be corrected to account for the anticipated organic carbon fraction of the cap ($f_{oc,cap}$). Further, this correction must be made on a sample-specific basis, due to the widely varying observed values of $f_{oc,msuf}$. Therefore, $K_{d,cap}$ is estimated for each sample result as:

$$K_{d,cap} = K_{d,msuf} (f_{oc,cap} / f_{oc,msuf}) \qquad (6)$$

Attachment B-1 presents the sample-specific calculations of $K_{d,cap}$, along with statistical estimates of $K_{d,cap}$. In the sensitivity analysis, the value of $K_{d,cap}$ was varied from a lower bound based on the minimum of the calculated sample-specific results, to an upper bound based on the mean of the calculated sample-specific results. For naphthalene, acenaphthene, and fluoranthene, the theoretically-derived $K_{d,cap}$ value falls within this range of empirically calculated $K_{d,cap}$ values (see Attachment B-1). For dibenz(a,h)anthracene, the theoretical $K_{d,cap}$ value is higher than the range of empirically calculated $K_{d,cap}$ values. For dibenzofuran, the theoretical $K_{d,cap}$ value is lower than the range of empirically calculated $K_{d,cap}$ values. For mercury, the range of empirically calculated $K_{d,cap}$ values is consistent with recently reported literature values (Turner, Millward, and LeRoix 2001).

- **u.** The biodegradation rate varies widely among the PAHs, and can be affected by site-specific factors such as temperature, PAH concentrations, presence of other contaminants, and dissolved oxygen concentrations. The PSR sediments are anaerobic, as evidenced by the low values of porewater dissolved oxygen (DO) and Eh measurements. Absent a site-specific study of naphthalene biological degradation at PSR, other sources of data were reviewed. Anaerobic biodegradation rates for phenanthrene were measured on Eagle Harbor sediments by the University of Washington Marine Bioremediation Group (Krieger-Brockett et al. 1999). The first-order decay rate for phenanthrene was measured at 0.0025 per day using the "injection core" method. An extrapolation of this degradation rate to naphthalene was made based on the compounds' solubilities; the calculated naphthalene degradation rate using this extrapolation is 0.226 per day (Hart Crowser 2002). There is some concern that the injection core method may over-estimate the rate of degradation. Other reported degradation rates for naphthalene are 0.0072 per day (for anaerobic groundwater) (Aronson and Howard 1997) and 0.041 per day in petroleum-contaminated sediments (Howard 1989). For the purpose of this analysis, the intermediate value of these biodegradation rates (0.041 per day) is assumed.

- **v.** The porewater velocity was varied by a factor of 2 for a lower bound estimate of 0.0001 ft/day to an upper bound estimate of 0.0004 ft/day. This variation accounts for potential inaccuracies in the groundwater discharge measurement methodology, potential changes in porewater velocity that may be caused by use of a capping material with an effective porosity different than the assumed value of 0.45, and potential decrease in hydraulic conductivity of existing sediments under the consolidation load of the cap.

- **d.** The value for longitudinal dispersivity typically falls in the range of 0.01 to 1 times the scale of the system being modeled. As previously discussed, the baseline estimate of dispersivity is at the lower end of this range. Dispersivity was varied upward for an upper bound estimate of 1 times the effective cap thickness.

- **$f_{oc,cap}$.** The cap organic carbon fraction was varied based on potential material types for various cap areas. The base case value of 0.02 represents Duwamish River dredged material. A lower bound estimate of 0.005 was used representing a relatively clean sand or gravel. An intermediate estimate of to 0.01 was used representing a silty sand or fine gravel with significant fines content. Adjusting $f_{oc,cap}$ to these lower values has two effects. First, $K_{d,cap}$ is adjusted downward [according to equation (4)], resulting in faster contaminant transport and lower equilibrium bulk sediment concentrations. Second, the adjusted $f_{oc,cap}$ is used in calculating the carbon-normalized sediment concentration. The net result is faster contaminant transport but an unchanged equilibrium carbon-normalized sediment concentration.

The sensitivity analysis is summarized in Table B-4. The predicted time for naphthalene to exceed the SQS at the top of a 12-inch chemical isolation layer varied from a low of 35 years to a high of more than 500 years under the varied parameters. Of the factors examined, the model is most sensitive to three parameters: $K_{d,cap}$, the biodegradation rate, and the cap organic carbon fraction.

- The range of values considered for $K_{d,cap}$ (17 to 728 L/kg) is based on the range of calculated site-specific values from the porewater study (presented in Attachment B-1). The baseline $K_{d,cap}$ estimate is based on the theoretical value of 40 L/kg, which is substantially lower than the 95 percent lower confidence level (LCL) of the calculated site-specific values, and so is considered conservative in itself (i.e., the baseline estimate is probably less than the true value of $K_{d,cap}$). The range of predicted performance (i.e., 90-year to 1,000-year recontamination of a 12-inch chemical isolation layer) using the range of calculated $K_{d,cap}$ values

suggests that the baseline estimate (130-year recontamination of a 12-inch chemical isolation layer) is conservative.

- The baseline analysis assumed no biodegradation, which is a highly conservative assumption particularly for the LPAHs. The sensitivity analysis results indicate that naphthalene will never recontaminate the cap above the SQS if biodegradation is accounted for.

- The cap organic carbon fraction is the only parameter that can be substantially controlled through specification of material type(s). However, cap materials specification is also constrained by other engineering factors such as the required erosion resistance of the material in various parts of the site, material placement methods, and the aggregate properties of readily available materials. Section B.4 presents the required cap organic carbon content and associated chemical isolation layer thicknesses for the various cap design areas in the MSU.

B.3 SHORT-TERM LOSSES FROM CONSOLIDATION

As a result of porewater expression during consolidation of the MSU sediments under the load of the cap, contaminants in porewater will migrate into the cap. This short-term effect, immediately following cap placement, is assessed in this section.

B.3.1 Analysis of Consolidation of Underlying Sediments

A one-dimensional consolidation model was used to evaluate the compression (consolidation) of the sediments during the cap placement process. The expected amount of compression was estimated for two typical subsurface profiles as described below:

- PROFILE A, consisting of an upper highly compressible 3.5-foot-thick organic silt layer overlying a thick layer of sandy silt to silty sand

- PROFILE B, consisting of sandy silt to silty sand without the upper highly compressible layer

Only these two relatively simple profiles were used due to the relatively consistent lithology across the site. PROFILE A was clearly identified at Boring B-5 and applies to most of the site. PROFILE B is most relevant to the offshore deep-water area, where CPT profiles P11, P15, and P19 suggest the absence of the upper highly compressible organic sediments. These profiles,

derived from the pre-design geotechnical investigations, are in good agreement with the results of the RI borings (USEPA 1998a).

Consolidation tests were performed in the laboratory on selected samples of the sediments, as reported in the pre-design investigation data summary (USEPA 2002). The highest compressibilities measured from the tests were used to represent the sediments in the analysis. Consequently, the results of the analyses are considered somewhat conservative, and likely overestimate the actual consolidation magnitudes expected at most locations.

To represent the upper 3.5 feet of sediments in PROFILE A, the compressibility measured from the consolidation test on the sample of organic silt labeled B5-1 (borehole 5 at a depth of 1 foot) was used. The compression ratio (Cc') for this sample was measured at 0.182 based on compression strain data, indicating the sediment is moderately to highly compressible. The compression ratio is the parameter most commonly used to represent soil compressibility as measured in the consolidation test.

To represent all the sediments below 3.5 feet in PROFILE A and all the sediments in PROFILE B, the compressibilities measured from the consolidation tests on the samples of sandy silt from B5-7 (borehole 5 at a depth of 16 feet) and B2-4 (borehole 2 at a depth of 8.5 feet) were used. The compression ratio for both samples B5-7 and B2-4 was approximately 0.095.

For the purpose of computing the time rate of settlement, relatively freely draining layers were assumed to exist within the poorly drained sandy silt deposits at vertical intervals of no more than about 10 feet apart. These freely draining layers represent irregularly distributed pockets/layers of sediments with more "granular" behavior that were observed in the borehole logs and cone penetration testing (CPT) profiles. The settlement time-rate computations were based on the coefficients of consolidation (Cv) measured in the laboratory consolidation tests, but modified to account for the typical observation that sediments consolidate more rapidly in the field than would be indicated by the laboratory values of Cv. The coefficient of consolidation used for the upper organic silt layer and for the lower silt/sand layer were equal to 1.35 ft^2/day and 10 ft^2/day, respectively.

The results of the settlement computations are presented in Table B-5 and in Figure B-1 as a plot of sediments settlement versus cap thickness. An example output of the CONSOL model results is presented in Attachment C-1 to Appendix C.

About 90 percent of the settlements are expected to occur within a few days of placement of the cap soil. Long-term secondary (creep) settlements will also take place within the sediments. The magnitude of this type of settlement will be proportional to the secondary compression ratio

measured in the laboratory consolidation tests. Secondary settlements were estimated to be on the order of 3 to 4 inches in the 10 years following cap placement, which is not of concern for cap stability but should be considered when evaluating bathymetric data from long-term monitoring.

The estimated settlement values listed in Table B-5 are idealized in that they are based on the presumption that the cap soil can be placed on the top of the sediments without mixing or stress-induced distortion at the interface between the two materials. In reality, the coarse particles from the cap material being placed will likely embed in and mix with the very soft upper sediments until a sufficient mass of cap material is placed. In addition to vertical consolidation of the sediments due to the pressure exerted by this mass of cap material, lateral deformation and upward bulging of the upper organic silt layer along the edge of the cap "lift" is expected to occur. This type of combined lateral and vertical deformation of the sediments, commonly referred to as a "mud wave," will result in additional vertical settlement of portions of the cap. If the cap pressure does not exceed the ultimate load-bearing limit of the sediments (i.e., the "bearing capacity"), the additional settlement from the phenomenon described above is estimated at less than roughly 30 percent of the consolidation settlement values.

B.3.2 Short-Term Contaminant Migration into Cap from Consolidation

The distance that the contaminant migrates into the cap during consolidation of the underlying sediment is given by Palermo et al. (1998, Appendix B):

$$T_{i,consol} = DL_{sed} / (n_e + pK_{d,cap}) \qquad (7)$$

where:

$T_{i,consol}$ = cap chemical isolation thickness lost due to short-term consolidation
DL_{sed} = sediment settlement distance

As previously described, the actual settlement distance will vary by location due to differing sediment compressibilities and differing cap thicknesses. As a screening-level check, the maximum settlement distance (17 inches, associated with a 5-foot thick cap) was evaluated for each of the indicator chemicals. The calculation of $T_{i,consol}$ is shown in the chemical isolation analysis worksheets in Attachment B-1 to this appendix. For all indicator chemicals, $T_{i,consol}$ was calculated at less than 1 inch. Therefore $T_{i,consol}$ is considered negligible with regard to the total cap thickness.

B.4 CHEMICAL ISOLATION LAYER DESIGN CRITERIA

B.4.1 Approach

The various remediation areas have substantially different requirements for materials types (associated with erosion and placement considerations), potentially widely varying materials costs, and potentially different acceptable design lives. One objective of the cap design process is to develop materials specifications that can be satisfied using available borrow sources or dredged material, while minimizing the need to manufacture material to meet the various specifications. With regard to chemical transport, the fraction of organic carbon in the capping material is a prime consideration in the cap materials specifications.

The approach for specifying the chemical isolation layer thicknesses (T_i) for each remediation area is as follows:

1. Preliminarily determine the general cap material type and source (based on the erosion analysis and placement considerations)

2. Specify a reasonable $f_{oc,cap}$ considering the properties of available sources of material

3. Consider overall cap thickness constraints and their impact on acceptable T_i

4. Specify a T_i value that yields an acceptable design life (at least 100 years) for each remediation area (the design life is defined as the predicted time for cap sediments to exceed the SQS at the top of the chemical isolation layer)

B.4.2 Results

For each remediation area, the chemical isolation model was run assuming the values $f_{oc,cap}$ and T_i from the process described above. These model runs used the best estimate values for all other parameters, and conservatively assumed no biodegradation. The resulting design life estimates are therefore considered conservative. The chemical isolation model runs for each remediation area are included in Attachment B-1.

Table B-6 summarizes this process and presents a preliminary specification of $f_{oc,cap}$ and T_i for the various remediation areas, along with a conservative estimate of the resulting cap design life. The cap design life estimate varies for the different remediation areas, as discussed below:

- **RA1.** A relatively thick T_i of 2 feet is specified, as this can be accomplished without additional cost given the 5-foot-thick cap requirement in RA1. Although relatively coarse materials will be required for the surface of RA1, a cap organic carbon content of 0.5 percent is assumed for the sandy material in the chemical isolation layer. This organic carbon content requirement will apply only to the bottom 2 feet of cap placed in RA1 (i.e., a separate materials specification will be developed for the bottom 2 feet of cap). A design life of 120 years is predicted based on these parameters.

- **RA2a and RA3.** A T_i of 2 feet is specified. Although relatively coarse materials will be required for the surface in these areas, a cap organic carbon content of 0.5 percent is assumed because a sandy material with significant fines content is specified for the chemical isolation layer. This organic carbon content requirement will apply only to the bottom 2 feet of cap placed in these areas (i.e., a separate materials specification will be developed for the bottom 2 feet of cap). A design life of 120 years is predicted based on these parameters.

- **RA2b.** A T_i of 2 feet is specified. Medium sand upland material will be used for cap material in this area, and a cap organic carbon content of 0.5 percent is specified. A design life of 120 years is predicted based on these parameters.

- **RA4.** A T_i of 2 feet is specified and a cap organic carbon content of 0.5 percent is specified for a medium sand upland material. These parameters yield a 120-year design life for RA4, which is consistent with the expected frequency of seismic events that may cause physical damage to this area (see Appendix C).

- **RA5.** A T_i of 1.5 feet is specified. A cap organic carbon content of 1 percent is specified consistent with dredged material properties from the Snohomish River. A design life of 140 years is predicted based on these parameters.

Because of the conservative assumptions in the chemical isolation modeling, the actual time required for cap sediments to exceed the SQS at the top of the chemical isolation layer is anticipated to be significantly longer than the design life estimates presented in this analysis.

B.5 SUMMARY

The long-term chemical isolation analysis indicates that naphthalene and dibenzofuran are the controlling chemicals for evaluating cap life. As modeled, cap life is limited by the time required for naphthalene to recontaminate cap sediments at the top of the chemical isolation layer. Biological degradation rates are considered uncertain, and were not accounted for in the base case analysis. Accounting for biological degradation, cap life would be likely limited by other chemicals with lower biodegradation rates, such as HPAHs, and substantially longer cap lives would be predicted. Thus, the base case analysis is considered conservative.

The settlement induced in the existing sediments due to the weight of the proposed cap was estimated using data primarily from laboratory tests. The initial settlement is expected to range from approximately 4 to 5 inches for the thinnest areas of the cap to approximately 17 inches where the cap thickness is 5 feet or greater in RA 1. An additional 2 to 4 inches of secondary (creep) settlement could occur over a 10-year period. The settlement is not expected to adversely affect the integrity of the cap. The estimated settlement distances (DL_{sed}) described in this section will be important when evaluating post-construction bathymetry for estimation of the actual cap thickness.

Short-term losses in cap chemical isolation thickness from consolidation are considered to be negligible and are not discussed further with regard to cap design.

Preliminary specification of $f_{oc,cap}$ and T_i have been developed, yielding estimated design lives (for chemical isolation) ranging from 120 to 140 years for the various remediation areas. The estimated design lives are considered conservative, and the actual cap lives will likely be much longer as contaminants biodegrade. The design life estimate of 120 years in RA4 is commensurate with the design level seismic event.

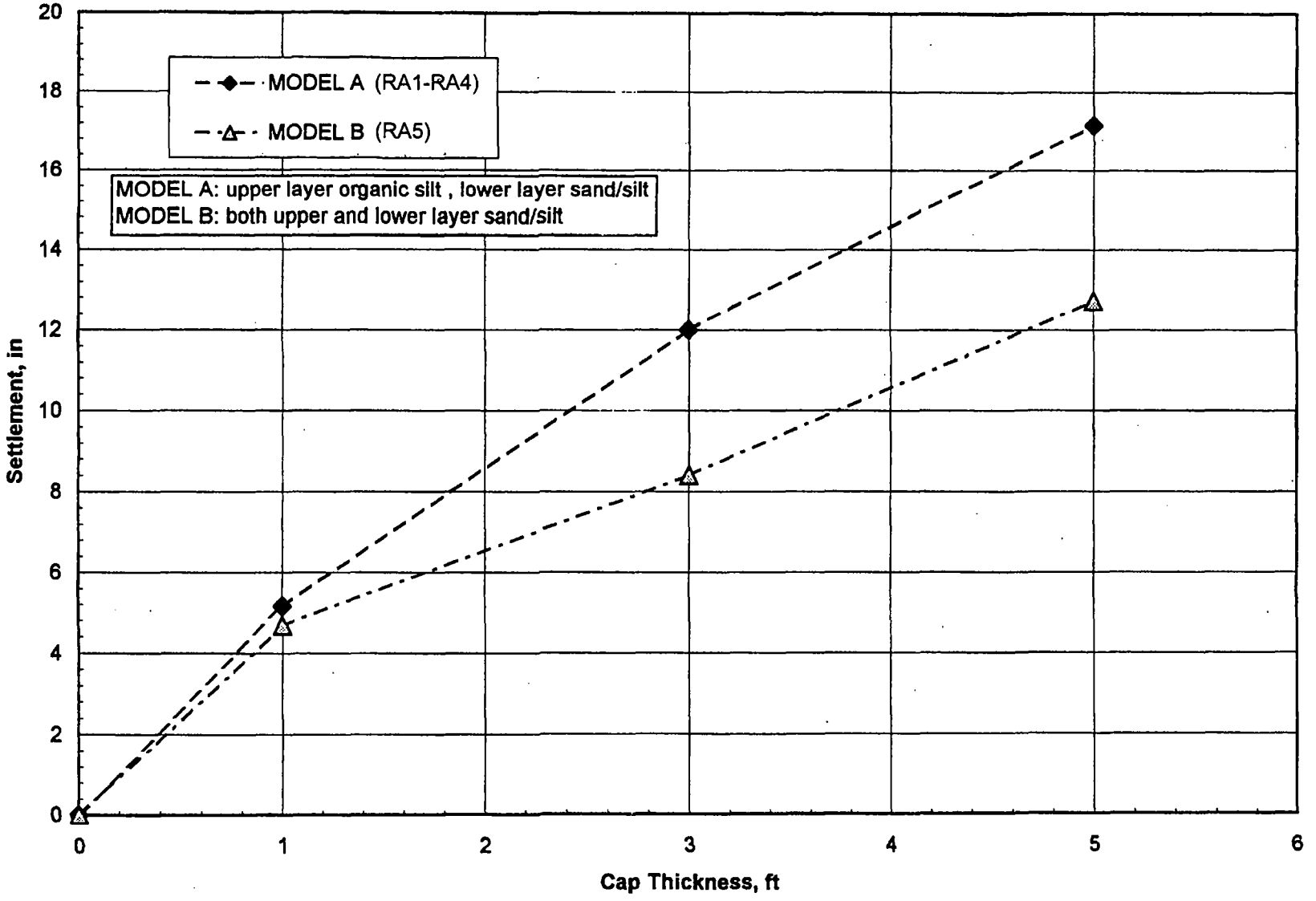


Figure B-1

Consolidation Settlement versus Cap Thickness

Job No. 53-F4006500.06

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

Table B-1
Chemical-Specific Cap Model Parameters

			Chemical					
Parameter	**Units**	**Basis**	**Naphthalene**	**Acenaphthene**	**Dibenz(a,h)anthracene**	**Fluoranthene**	**Dibenzofuran**	**Mercury**
Co - Influent porewater concentration	µg/L	95% UCL (1)	725	132	0.028	19.6	75.9	0.016
$K_{d,cap}$ - Distribution coefficient in cap	L/kg	Theoretical (2)	40	142	76000	2140	26	2500
Dw - Binary Diffusivity in water	cm^2/s	Palermo et al 1998	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06
u - Biodegradation rate	1/day	Assumed	0	0	0	0	0	0
SQS - Sediment Quality Standard	mg/kgOC	WAC 173-204-320	99	16	12	160	15	0.41 (3)
WQC - Water Quality Criterion	µg/L	WAC 173-201A	2350 (4)	970 (4)	(5)	16	(5)	0.025

Notes:
(1) 95% Upper Confidence Limit of measured porewater concentrations
(2) $K_{d,cap} = K_o f_{oc}$, assumes $f_{oc} = 0.02$
(3) Mercury SQS is mg/kg dry weight
(4) Lowest Observed Effect Level
(5) No criterion available

Table B-2
Baseline Physical Cap Model Parameters

Parameter	Symbol	Best Estimate Value
Porewater velocity	v	0.0002 ft/day
Longitudinal dispersivity	d	0.03 ft
Effective porosity	n_e	0.45
Bulk density	p	1.46 g/cm^3
Cap organic carbon fraction	$f_{oc,cap}$	0.02[a]

[a]Used for baseline analysis only. Material-specific f_{oc} used for RA-specific design criteria in Table B-6.

Table B-3
Summary of Baseline Chemical Isolation Model Inputs and Results

		Chemical					
Parameter	**Units**	**Naphthalene**	**Acenaphthene**	**Dibenz(a,h)-anthracene**	**Fluoranthene**	**Dibenzofuran**	**Mercury**
SQS	mg/kgOC	99	16	12	160	15	0.41 (4)
WQC	µg/L	2,350	970	(5)	16	(5)	0.025
Co (95% UCL)	µg/L	725	132	0.028	19.6	75.9	0.016
Sediment Concentration (95% UCL)	mg/kgOC	699	1,520	24.0	2,890	1,060	0.52 (4)
Sediment Exceedance Ratio (95% UCL)	–	7.1	95	2.0	18	70	1.3
Porewater Exceedance Ratio (95% UCL)	–	0.31	0.14	N/A	1.2	N/A	0.64
Calculated $K_{d,cap}$ (95% LCL)	L/kg	225	311	23,800	1,990	439	18,100
Theoretical $K_{d,cap}$	L/kg	40	142	76,000	2,140	26	2,500-750,000 (3)
Calculated Cap Life Estimates for Chemical Isolation Layer Thickness T_i = 0.25 feet							
Time to Exceed SQS (1)	Years	9	19	>10,000	500	9	>10,000
Time to Exceed WQC (2)	Years	N/A	N/A	N/A	>10,000	N/A	N/A

Table B-3 (Continued)
Summary of Baseline Chemical Isolation Model Inputs and Results

		Chemical					
Parameter	**Units**	**Naphthalene**	**Acenaphthene**	**Dibenz(a,h)-anthracene**	**Fluoranthene**	**Dibenzofuran**	**Mercury**
Calculated Cap Life Estimates for Chemical Isolation Layer Thickness T_i = 0.50 feet							
Time to Exceed SQS (1)	Years	35	74	>10,000	2,000	37	>10,000
Time to Exceed WQC (2)	Years	N/A	N/A	N/A	>10,000	N/A	N/A
Calculated Cap Life Estimates for Chemical Isolation Layer Thickness T_i = 1.00 feet							
Time to Exceed SQS (1)	Years	130	280	>10,000	7,400	130	>10,000
Time to Exceed WQC (2)	Years	N/A	N/A	N/A	>10,000	N/A	N/A

Notes:
(1) Time at which sediment will exceed the SQS at the top of the assumed chemical isolation layer. Overlying sediments would still be below SQS at this time
(2) Time at which porewater concentrations will exceed the WQC at the top of the assumed chemical isolation layer. Overlying porewater would still be below WQC at this time
(3) Turner, Millward, and LeRoix 2001- Lowest value used
(4) Mercury SQS and sediment concentrations in mg/kg dry
(5) No criterion available
N/A - Chemical concentration never exceeds the criterion or no criterion exists
All results based on f_{oc} = 0.02

Table B-4
Sensitivity Analysis of Long-Term Chemical Isolation Analysis

Parameter	Units	Estimate Range	Parameter Value	Time to Exceed SQS[a] (yr)
C_o - Influent porewater concentration	µg/L	Upper Bound	2400	85
		Lower Bound	364	190
$K_{d,cap}$ - Distribution coefficient in cap	L/kg	Upper Bound	728	1,000
		Lower Bound	17	90
u - Biodegradation rate	1/day	Upper Bound	0.041	Never
v - Porewater velocity	ft/day	Upper Bound	0.0004	115
		Lower Bound	0.0001	140
d - Longitudinal dispersivity	ft/day	Upper Bound	0.5	55
$f_{oc,cap}$ - Cap organic carbon fraction[b]	mg/mg	Intermediate	0.01[c]	65
		Lower Bound	0.005[d]	35
All parameters	--	Best Estimate	--	130

[a]All times are for exceedance of naphthalene SQS at top of chemical isolation layer, assumed T_i = 1.0 feet

[b]Adjusting $F_{oc,cap}$ also requires adjusting the best estimate $K_{d,cap}$.

[c]Theoretical $K_{d,cap}$ = 20 L/kg assuming foc,cap = 0.01

[d]Theoretical $K_{d,cap}$ = 10 L/kg assuming foc,cap = 0.005

Notes:
ft/day - feet per day
L/kg - liter per kilogram
µg/L - microgram per liter
mg/mg - milligram per milligram
SQS - Sediment Quality Standard

Table B-5
Estimated Primary Settlement of Sediments

Remediation Area	Assumed Cap Thickness (ft)	Subsurface PROFILE	Primary Settlement (inches)
RA1	5	A	17
RA2, RA3	3	A	12
RA4	1.5	A	5
RA5	5	B	13
RA5	3	B	8
RA5	1.5	B	4.5

Table B-6
Design Criteria for Chemical Isolation

Remediation Area	Assumed Material	Special Cap Thickness Constraints	Specification for $f_{oc,cap}$	Specification for T_1 (feet)	Design Life Estimate[a] (years)
RA1	Upland Sand and Gravel	Minimum T_{total} = 5 feet per ROD	0.005	2	120
RA2a and RA3	Upland Sand and Fine Gravel	Minimize T_{total} to reduce dredge requirements, reduce materials costs, and minimize load at top of slope	0.005	2	120
RA2b	Upland Medium Sand	Minimize T_{total} to reduce materials costs, and minimize load at top of slope	0.005	2	120
RA4	Upland Medium Sand	Minimize T_{total} to reduce materials costs, and produce design life commensurate with design seismic recurrence interval.	0.005	2	120
RA5	Dredged Material	None	0.01	1.5	140

[a] Conservative estimate assumes no biodegradation

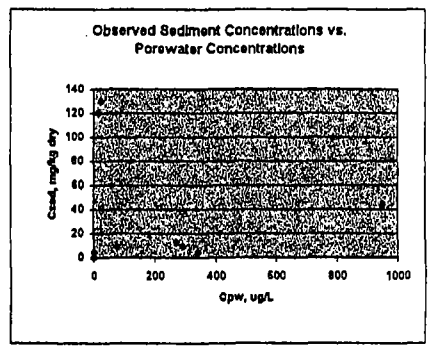
ATTACHMENT B-1
CHEMICAL ISOLATION ANALYSIS CALCULATIONS

Calculations of K_d and C_o

Table C-1
Design Distribution Coefficients and Porewater Concentrations: Naphthalene

Chemical [redacted]
Literature Koc [redacted] L/kg — SQS [redacted] mg/kgOC
Assumed Cap Foc [redacted] — WQC [redacted] ug/L

Location	Pore Water Naphthalene ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Naphthalene mg/kg RESULT	Qual.	CALC	Sediment Naphthalene mg/kgOC CALC	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	0.16		0.16	2.01		2.01	0.091		0.091	4.53	589	586
202-H	76	J	76	2.36		2.36	9.1	J	9.1	385.59	120	101
205-H	14		14	18.5		18.5	120	J	120	648.65	8571	927
204-H	950	J	950	2.47		2.47	44	J	44	1781.38	46	38
203-H	340	J	340	1.52		1.52	4.3	J	4.3	282.89	13	17
206-H	0.88		0.88	3.51		3.51	4.4	J	4.4	125.36	5000	2849
202-L	290	J	290	3.24		3.24	9.5	J	9.5	293.21	33	20
205-L	22	J	22	20.1		20.1	130	J	130	646.77	5909	588
201-L	0.3		0.3	2.06		2.06	0.27		0.27	13.11	900	874
203-L	270	J	270	1.53		1.53	13	J	13	849.67	48	63
206-L	0.84		0.84	5.58		5.58	4.6	J	4.6	82.44	5478	1983
204-L	2400	J	2400	1.65		1.65	2.4	J	2.4	145.45	n/c	n/c
	Count		12	Count		12	Count		12	12	Count 11	Count 11
	Mean		363.68	Mean		5.38	Mean		28.47	438.25	Mean 2425.92	Mean 727.72
	SD		697.68	SD		6.81	SD		46.63	503.45	SD 3159.01	SD 919.16
	95% CI		361.70	95% CI		3.43	95% CI		24.17	261.00	95% CI 1726.33	95% CI 502.30
	95% UCL		725.38	95% UCL		8.80	95% UCL		52.64	699.25	95% LCL 699.59	95% LCL 225.42
	Max		2400	Max		20.1	Max		130	1781.38	Minimum 13	Minimum 17



Summary of Co and Kd,cap Parameters: Naphthalene	Co (ug/L)	Basis	Kd,cap (L/kg)	Basis
Lower Bound	363.68	mean	17	min
Best Estimate	725.38	95%UCL	225	95% LCL
Upper Bound	2400	max	728	mean
Theoretical Value	4400	Raoult's Law	40.00	=Koc x foc,cap

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	7.08
WQC Exceedance Ratio (95% UCL)	0.31

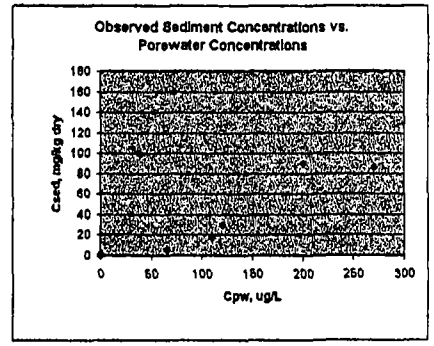
Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
Raoult's Law theoretical solubility as reported in PSR RI, Table 3-4

Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Table C-2
Design Distribution Coefficients and Porewater Concentrations: Acenaphthene

Chemical: [illegible]
Literature Koc: [illegible] L/kg — SQS: [illegible] mg/kgOC
Assumed Cap Foc: 0.02 — WQC: [illegible] ug/L

Location	Pore Water Acenaphthene ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Acenaphthene mg/kg RESULT	Qual.	CALC	Sediment Acenaphthene mg/kgOC CALC	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	0.012	J	0.012	2.01		2.01	0.067		0.067	3.33	5583	5558
202-H	200	J	200	2.36		2.36	90	J	90	3813.56	450	381
205-H	72	J	72	18.5		18.5	160	J	160	864.86	2222	240
204-H	120	J	120	2.47		2.47	30	J	30	1214.57	250	202
203-H	65	J	65	1.52		1.52	5.6	J	5.6	368.42	86	113
206-H	0.15		0.15	3.51		3.51	1.9	J	1.9	54.13	12667	7217
202-L	270	J	270	3.24		3.24	86	J	86	2654.32	319	197
205-L	38	J	38	20.1		20.1	100	J	100	497.51	2632	262
201-L	0.16		0.16	2.08		2.08	0.11		0.11	5.34	688	667
203-L	110	J	110	1.53		1.53	18	J	18	1176.47	164	214
206-L	0.16		0.16	5.58		5.58	1.7	J	1.7	30.47	10825	3808
204-L	160	J	160	1.65		1.65	1.5	J	1.5	90.91	n/c	n/c
	Count		12	Count		12	Count		12	12	Count 11	Count 11
	Mean		86.29	Mean		5.36	Mean		41.24	897.83	Mean 3244.06	Mean 1714.41
	SD		88.68	SD		8.61	SD		53.90	1202.96	SD 4488.68	SD 2568.72
	95% CI		45.97	95% CI		3.43	95% CI		27.94	623.65	95% CI 2452.96	95% CI 1403.75
	95% UCL		132.26	95% UCL		8.80	95% UCL		69.18	1521.47	95% LCL 791.09	95% LCL 310.68
	Max		270	Max		20.1	Max		160	3813.56	Minimum 86	Minimum 113



Summary of Co and Kd,cap Parameters:	Acenaphthene				
	Co (ug/L)	Basis		Kd,cap (L/kg)	Basis
Lower Bound	86.29	mean		113	min
Best Estimate	132.26	95%UCL		311	95% LCL
Upper Bound	270	max		1714	mean
Theoretical Value	150	Raoult's Law		141.80	=Koc x foc,cap

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	95.1
WQC Exceedance Ratio (95% UCL)	0.14

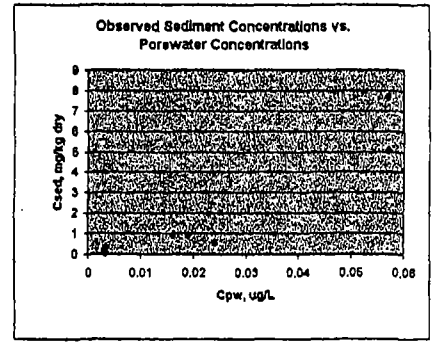
Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
Raoult's Law theoretical solubility as reported in PSR RI, Table 3-4

Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Table C-3
Design Distribution Coefficients and Porewater Concentrations:
Dibenz(a,h)anthracene

Chemical: [redacted]
LRerature Koc: [redacted] L/kg — SQS: [redacted] mg/kgOC
Assumed Cap Foc: [redacted] — WQC: [redacted] ug/L

Location	Pore Water Dibenz(a,h)anthracene ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Dibenz(a,h)anthracene mg/kg RESULT	Qual.	CALC	Sediment Dibenz(a,h)anthracene mg/kgOC CALC	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	0.0083	U	0.00315	2.01		2.01	0.086		0.086	4.28	27302	27166
202-H	0.038	U	0.019	2.36		2.36	0.87	J	0.87	36.86	45769	38805
205-H	0.057	J	0.057	18.5		18.5	7.7	J	7.7	41.62	135088	14604
204-H	0.024	J	0.024	2.47		2.47	0.56	J	0.56	22.67	23333	18893
203-H	0.0065	U	0.00325	1.52		1.52	0.07	J	0.07	4.61	21538	28340
206-H	0.0063	U	0.00315	3.51		3.51	0.25	J	0.25	7.12	79385	45222
202-L	0.032	U	0.016	3.24		3.24	0.94	J	0.94	29.01	58750	36265
205-L	0.057		0.057	20.1		20.1	5.1	J	5.1	25.37	89474	8903
201-L	0.0063	U	0.00315	2.08		2.06	0.11		0.11	5.34	34921	33904
203-L	0.0064	U	0.0032	1.53		1.53	0.15	J	0.15	9.80	46875	81275
206-L	0.0067	U	0.00335	5.56		5.56	0.34	J	0.34	6.09	101493	36377
204-L	0.021	J	0.021	1.65		1.65	0.19	J	0.19	11.52	n/c	n/c
	Count		12	Count		12	Count		12	12	Count 11	Count 11
	Mean		0.02	Mean		5.38	Mean		1.36	17.03	Mean 60357.05	Mean 31795.80
	SD		0.02	SD		6.61	SD		2.43	13.47	SD 36742.02	SD 14708.13
	95% CI		0.01	95% CI		3.43	95% CI		1.26	8.99	95% CI 20078.69	95% CI 8037.67
	95% UCL		0.03	95% UCL		8.80	95% UCL		2.63	24.01	95% LCL 40278.35	95% LCL 23758.13
	Max		0.057	Max		20.1	Max		7.7	41.62	Minimum 21538	Minimum 8903



Summary of Co and Kd,cap Parameters:	Dibenz(a,h)anthracene			
	Co (ug/L)	Basis	Kd,cap (L/kg)	Basis
Lower Bound	0.02	mean	8903	min
Best Estimate	0.03	95%UCL	23758	95% LCL
Upper Bound	0.057	max	31798	mean
Theoretical Value	0.0001	Raoult's Law	76000	=Koc x foc,cap

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	2.0
WQC Exceedance Ratio (95% UCL)	N/A

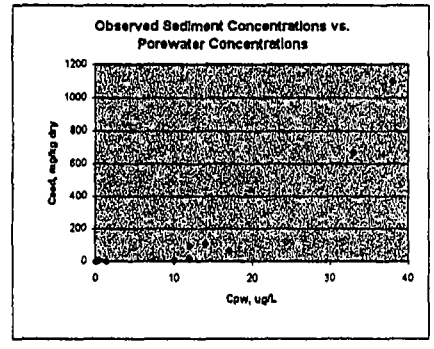
Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
Raoult's Law theoretical solubility as reported in PSR RI, Table 3-4

Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Table C-4
Design Distribution Coefficients and Porewater Concentrations:
Fluoranthene

Chemical [redacted]
Literature Koc [redacted] L/kg SQS [redacted] mg/kgOC
Assumed Cap Foc [redacted] WQC [redacted] ug/L

Location	Pore Water Fluoranthene ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Fluoranthene mg/kg RESULT	Qual.	CALC	Sediment Fluoranthene mg/kgOC CALC	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	0.042	J	0.042	2.01		2.01	1.4		1.4	69.65	33333	33167
202-H	12	J	12	2.38		2.38	99	J	99	4194.92	8250	6992
205-H	38	J	38	18.5		18.5	1100	J	1100	5945.95	28947	3129
204-H	17	J	17	2.47		2.47	66	J	66	2672.06	3882	3144
203-H	10	J	10	1.52		1.52	8.2	J	8.2	539.47	820	1079
206-H	0.2	J	0.2	3.51		3.51	4.3	J	4.3	122.51	21500	12251
202-L	14	J	14	3.24		3.24	110	J	110	3395.06	7857	4850
205-L	33	J	33	20.1		20.1	670	J	670	3333.33	20303	2020
201-L	1.4	J	1.4	2.08		2.08	1.7	J	1.7	82.52	1214	1179
203-L	12	J	12	1.53		1.53	17	J	17	1111.11	1417	1852
206-L	0.41	J	0.41	5.58		5.58	9.4	J	9.4	168.46	22927	8218
204-L	19	J	19	1.65		1.65	13	J	13	787.88	n/c	n/c
	Count		12	Count		12	Count		12	12	Count 11	Count 11
	Mean		13.09	Mean		5.38	Mean		175.00	1868.58	Mean 13677.36	Mean 7080.03
	SD		12.46	SD		6.61	SD		346.19	1977.87	SD 12001.73	SD 9319.02
	95% CI		6.47	95% CI		3.43	95% CI		179.47	1025.38	95% CI 6558.68	95% CI 5092.83
	95% UCL		19.56	95% UCL		8.80	95% UCL		354.47	2893.96	95% LCL 7118.69	95% LCL 1987.39
	Max		38	Max		20.1	Max		1100	5945.95	Minimum 820	Minimum 1079



Summary of Co and Kd,cap Parameters:	Fluoranthene			
	Co (ug/L)	Basis	Kd,cap (L/kg)	Basis
Lower Bound	13.09	mean	1079	min
Best Estimate	19.56	95%UCL	1987	95% LCL
Upper Bound	38	max	7080	mean
Theoretical Value	6.0	Raoult's Law	2140	=Koc x foc,cap

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	18.1
WQC Exceedance Ratio (95% UCL)	1.22

Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
Raoult's Law theoretical solubility as reported in PSR RI, Table 3-4

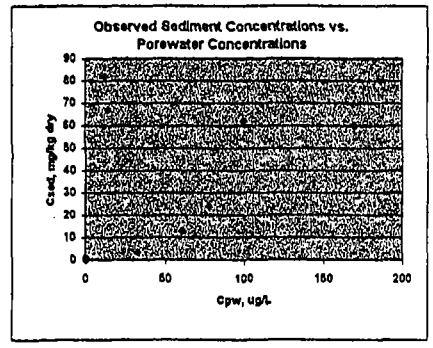
Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Table C-5
Design Distribution Coefficients and Porewater Concentrations:
Dibenzofuran

Chemical [redacted]
Literature Koc [redacted] L/kg SQS [redacted] mg/kgOC
Assumed Cap Foc [redacted] WQC [redacted] ug/L

Location	Pore Water Dibenzofuran ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Dibenzofuran mg/kg RESULT	Qual.	CALC	Sediment Dibenzofuran mg/kgOC CALC
201-H	0.028	U	0.014	2.01		2.01	0.072		0.072	3.58
202-H	100	J	100	2.36		2.36	62	J	62	2627.12
205-H	12		12	18.5		18.5	82	J	82	443.24
204-H	78	J	78	2.47		2.47	24	J	24	971.66
203-H	33	J	33	1.52		1.52	3.4	J	3.4	223.68
208-H	0.074		0.074	3.51		3.51	1.3	J	1.3	37.04
202-L	170	J	170	3.24		3.24	60	J	60	1851.85
205-L	14		14	20.1		20.1	67	J	67	333.33
201-L	0.074		0.074	2.06		2.06	0.1		0.1	4.85
203-L	61	J	61	1.53		1.53	13	J	13	849.67
206-L	0.081		0.081	5.58		5.58	1.1	J	1.1	19.71
204-L	100	J	100	1.65		1.65	1.3	J	1.3	78.79
	Count		12	Count		12	Count		12	12
	Mean		47.35	Mean		5.38	Mean		26.27	620.38
	SD		54.98	SD		6.61	SD		31.62	839.07
	95% CI		28.49	95% CI		3.43	95% CI		18.49	434.99
	95% UCL		75.85	95% UCL		8.80	95% UCL		42.77	1055.37
	Max		170	Max		20.1	Max		82	2627.12

Location	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	5143	5117
202-H	620	525
205-H	6833	739
204-H	308	249
203-H	103	138
208-H	17568	10010
202-L	353	218
205-L	4786	476
201-L	1351	1312
203-L	213	279
206-L	13580	4887
	n/c	n/c
Count	11	Count 11
Mean	4623.44	Mean 2175.30
SD	5970.23	SD 3178.10
95% CI	3282.60	95% CI 1738.78
95% LCL	1360.84	95% LCL 436.53
Minimum	103	Minimum 138



Summary of Co and Kd,cap Parameters:	Dibenzofuran			
	Co (ug/L)	Basis	Kd,cap (L/kg)	Basis
Lower Bound	47.35	mean	138	min
Best Estimate	75.85	95%UCL	439	95% LCL
Upper Bound	170	max	2175	mean
Theoretical Value	260	Raoult's Law	26	=Koc x foc,cap

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	70.4
WQC Exceedance Ratio (95% UCL)	N/A

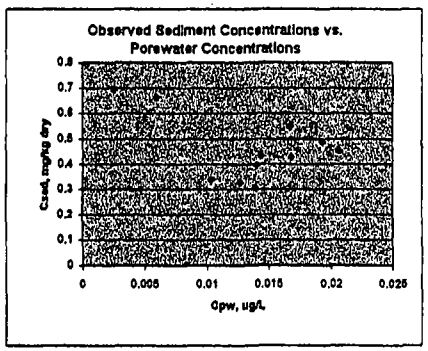
Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
Raoult's Law theoretical solubility as reported in PSR RI, Table 3-4

Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Table C-6
Design Distribution Coefficients and Porewater Concentrations:
Mercury

Chemical [redacted]
Literature Koc [redacted] L/kg
Assumed Cap Foc [redacted]
SQS [redacted] mg/kg (dry)
WQC [redacted] ug/L

Location	Pore Water Mercury ug/l RESULT	Qual.	CALC	Sediment Total Organic Carbon % RESULT	Qual.	CALC	Sediment Mercury mg/kg RESULT	Qual.	CALC	Observed Kd,sed L/kg	Predicted Kd,cap L/kg
201-H	0.014		0.014	2.01		2.01	0.398	J	0.398	28429	28267
202-H	0.0143		0.0143	2.38		2.38	0.433	J	0.433	30280	25681
205-H	0.0059		0.0059	18.5		18.5	0.665	J	0.665	112712	12185
204-H	0.0139		0.0139	2.47		2.47	0.308	J	0.308	22156	17942
203-H	0.0127		0.0127	1.52		1.52	0.329	J	0.329	25906	34088
206-H	0.0103		0.0103	3.51		3.51	0.338	J	0.338	32816	18898
202-L	0.0206		0.0206	3.24		3.24	0.453	J	0.453	21990	13574
205-L	0.005	U	0.0025	20.1		20.1	0.696	J	0.696	278400	27701
201-L	0.0168		0.0168	2.08		2.08	0.427	J	0.427	25417	24676
203-L	0.0193		0.0193	1.53		1.53	0.486	J	0.486	25181	32917
206-L	0.0167		0.0167	5.58		5.58	0.548	J	0.548	32814	11761
204-L	0.0129		0.0129	1.65		1.65	0.138	J	0.138	n/c	n/c
	Count		12	Count		12	Count		12	Count 11	Count 11
	Mean		0.013	Mean		5.36	Mean		0.43	Mean 57827.47	Mean 22499.07
	SD		0.005	SD		6.61	SD		0.15	SD 77606.50	SD 8090.98
	95% CI		0.003	95% CI		3.43	95% CI		0.08	95% CI 42411.32	95% CI 4421.53
	95% UCL		0.016	95% UCL		6.80	95% UCL		0.52	95% LCL 15418.15	95% LCL 18077.54
	Max		0.0206	Max		20.1	Max		0.696	Minimum 21990	Minimum 11761



Summary of Co and Kd,cap Parameters: Mercury	Co (ug/L)	Basis	Kd,cap (L/kg)	Basis
Lower Bound	0.013	mean	11761	min
Best Estimate	0.016	95%UCL	18078	95% LCL
Upper Bound	0.0206	max	22499	mean
Theoretical Value	-	-	2,500 - 750,000 (1)	

Sediment and Porewater Exceedance Ratios	
SQS Exceedance Ratio (95% UCL)	1.3
WQC Exceedance Ratio (95% UCL)	0.84

Notes:
CALC - calculated result assumes 1/2 detection limit for U-qualified data
Co - porewater concentration entering cap
CI - confidence interval
foc - fraction organic carbon
H - High Tide
L - Low Tide
Kd,cap - predicted distribution coefficient in cap
Kd,sed - observed sediment distribution coefficient
n/c - Porewater results from 204-L are believed to result from a sheen and are not used to calculate partitioning coefficients
95% UCL - 95% Upper confidence limit, assumes normal distribution
95% LCL - 95% Lower confidence limit, assumes normal distribution
(1) - Turner et al, 2001

Formulae:
Based on the observed Kd,sed values, Kd,cap values are calculated as: Kd,cap = Kd,sed x foc,cap/foc,sed
The theoretical Kd,cap value is calculated as: Kd,ideal = Koc x foc,cap
The observed sediment distribution coefficients are calculated as: Kd,sed = Csed/Cpw

Baseline Chemical Isolation Analysis for All Indicator Chemicals

Chemical Isolation Analysis for Naphth
PSR Superfund Site

Advec **...sitive Transport Formulae:**

Kd=foc'...	Walton 1991, p.185
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))		Van Genuchten and Alves (1982)
W =	((v-m)*x)/(2*D)		
X =	(R*x-m*t)/(SQRT(4*D*R*t))		
Y =	((v+m)*x)/(2*D)		
Z =	(R*x+m*t)/(SQRT(4*D*R*t))		
m=	v*(SQRT(1+((4*u*D)/v^2))		
ERFC()=	1-ERF()		

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

...SHADED CELLS...

		Hydraulic Calculations		Transport Calculations		Chemical Data			
Data:	Kh	[illegible]	ft/d	Koc	[illegible]	ml/g	[illegible]		
	n	[illegible]		foc	[illegible]		Kd (theoretica	40	L/kg
	ne	[illegible]		R	130.56		Kd, cap	[illegible]	L/kg
	g	2.66	gm/cm3	u	[illegible]	/d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible]	ft	d	[illegible]	ft	WQC	[illegible]	ug/L (LOEL)
	L	[illegible]	ft	Co	[illegible]	ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4576	gm/cm3	d	0.9144	cm			
	i		ft/ft	u	0	/s			
	v	[illegible]	ft/d	Kd,cap	40	ml/g			
	v	7.06E-06	cm/s	D	3.9E-06	cm2/sec			
				m	7.05E-06	cm/sec	(m=v for u=0)		

...es:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.00E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOL... ...ON

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap)	USEPA 1998	

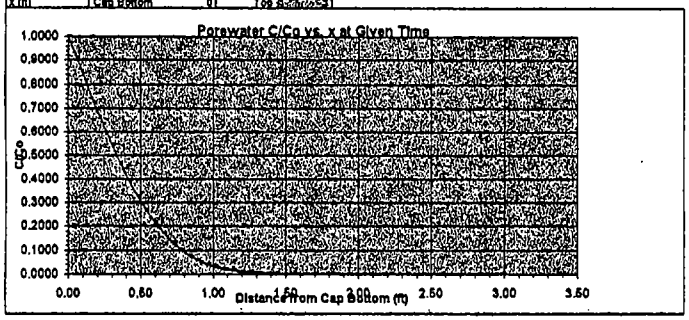
Cap thickness lost due to expression of porewater during consolidation (ft)

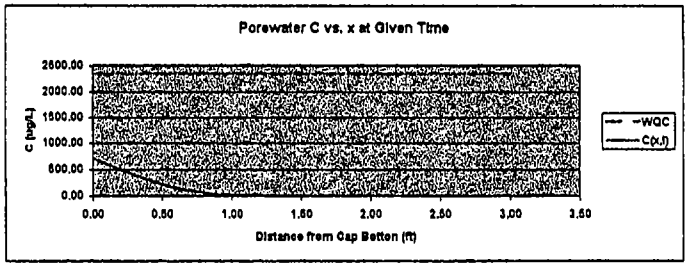
Tl,consol =	0.024	feet	(typically negligible)

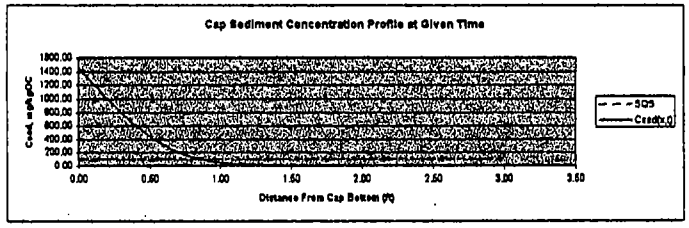
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	[illegible]	
x (ft)	Cap Bottom	0	Top o...	[illegible]	



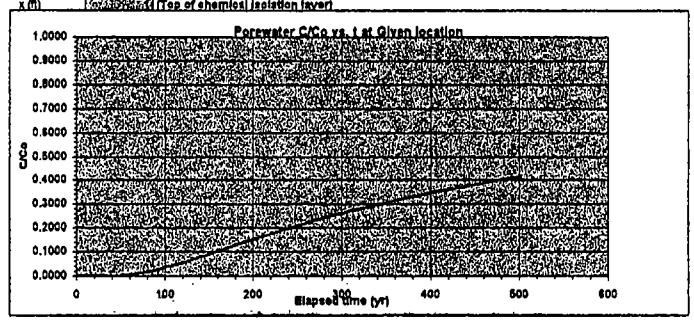


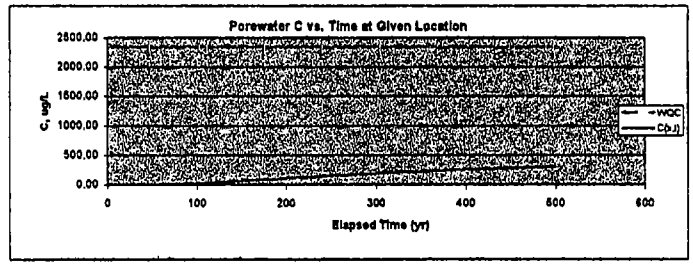


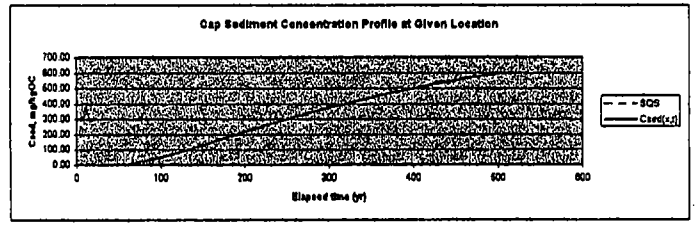
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	500	
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)		







Chemical Isolation Analysis for Naphthalene
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-8.78E-02	1.098	0.000E+00	0.000	0.901	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.520E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.16E+09	0.06	1.8	0.000	9.42E-03	0.989	3.312E-02	0.182	0.797	0.9982	2350.00	658.43	99.00	1316.86	10.0	3.15E+08	1.0	30.5	0.000	4.94E+00	0.000	5.520E-01	4.996	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.01E-01	0.887	6.624E-02	0.276	0.696	0.9162	2350.00	591.01	99.00	1182.02	20.0	6.31E+08	1.0	30.5	0.000	3.47E+00	0.000	5.520E-01	3.552	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.16E+09	0.18	5.5	0.000	1.95E-01	0.783	9.936E-02	0.371	0.600	0.7228	2350.00	524.06	99.00	1048.12	30.0	9.46E+08	1.0	30.5	0.000	2.82E+00	0.000	5.520E-01	2.916	0.000	0.0001	2350.00	0.05	99.00	0.10
36500	3.15E+09	0.24	7.3	0.000	2.89E-01	0.683	1.325E-01	0.465	0.511	0.5328	2350.00	458.87	99.00	917.73	40.0	1.26E+09	1.0	30.5	0.000	2.43E+00	0.001	5.520E-01	2.539	0.000	0.0006	2350.00	0.42	99.00	0.85
36500	3.16E+09	0.30	9.1	0.000	3.83E-01	0.599	1.656E-01	0.559	0.429	0.5470	2350.00	396.58	99.00	793.16	50.0	1.58E+09	1.0	30.5	0.000	2.16E+00	0.002	5.520E-01	2.264	0.001	0.0022	2350.00	1.60	99.00	3.20
36500	3.16E+09	0.36	11.0	0.000	4.76E-01	0.499	1.987E-01	0.653	0.365	0.4665	2350.00	338.19	99.00	676.38	60.0	1.89E+09	1.0	30.5	0.000	1.96E+00	0.006	5.520E-01	2.096	0.003	0.0054	2350.00	3.93	99.00	7.86
36500	3.16E+09	0.42	12.8	0.000	5.72E-01	0.419	2.318E-01	0.748	0.290	0.3924	2350.00	284.46	99.00	568.92	70.0	2.21E+09	1.0	30.5	0.000	1.80E+00	0.011	5.520E-01	1.951	0.006	0.0104	2350.00	7.54	99.00	15.07
36500	3.15E+09	0.48	14.6	0.000	6.66E-01	0.346	2.649E-01	0.842	0.234	0.3254	2350.00	235.93	99.00	471.86	80.0	2.52E+09	1.0	30.5	0.000	1.66E+00	0.018	5.520E-01	1.838	0.009	0.0170	2350.00	12.36	99.00	24.71
36500	3.15E+09	0.54	16.5	0.000	7.60E-01	0.282	2.981E-01	0.936	0.196	0.2651	2350.00	192.89	99.00	385.79	90.0	2.84E+09	1.0	30.5	0.000	1.57E+00	0.026	5.520E-01	1.739	0.014	0.0252	2350.00	18.23	99.00	36.47
36500	3.15E+09	0.60	18.3	0.000	8.55E-01	0.227	3.312E-01	1.030	0.145	0.2144	2350.00	155.43	99.00	310.85	100.0	3.16E+09	1.0	30.5	0.000	1.48E+00	0.036	5.520E-01	1.659	0.018	0.0345	2350.00	24.98	99.00	49.97
36500	3.16E+09	0.66	20.1	0.000	9.49E-01	0.180	3.643E-01	1.125	0.112	0.1702	2350.00	123.39	99.00	246.79	110.0	3.47E+09	1.0	30.5	0.000	1.41E+00	0.047	5.520E-01	1.590	0.025	0.0447	2350.00	32.42	99.00	64.84
36500	3.16E+09	0.72	21.9	0.000	1.04E+00	0.140	3.974E-01	1.219	0.085	0.1331	2350.00	96.50	99.00	193.00	120.0	3.78E+09	1.0	30.5	0.000	1.34E+00	0.058	5.520E-01	1.530	0.030	0.0557	2350.00	40.37	99.00	80.75
36500	3.16E+09	0.78	23.8	0.000	1.14E+00	0.108	4.305E-01	1.313	0.063	0.1025	2350.00	74.33	99.00	148.66	130.0	4.10E+09	1.0	30.5	0.000	1.28E+00	0.071	5.520E-01	1.478	0.037	0.0672	2350.00	48.70	99.00	97.40
36500	3.15E+09	0.84	25.6	0.000	1.23E+00	0.082	4.636E-01	1.407	0.047	0.0778	2350.00	56.37	99.00	112.76	140.0	4.42E+09	1.0	30.5	0.000	1.22E+00	0.084	5.520E-01	1.432	0.043	0.0790	2350.00	57.26	99.00	114.57
36500	3.15E+09	0.90	27.4	0.000	1.33E+00	0.061	4.968E-01	1.502	0.034	0.0581	2350.00	42.10	99.00	84.19	150.0	4.73E+09	1.0	30.5	0.000	1.16E+00	0.097	5.520E-01	1.390	0.049	0.0911	2350.00	66.03	99.00	132.05
36500	3.15E+09	0.96	29.3	0.000	1.42E+00	0.046	5.299E-01	1.596	0.024	0.0427	2350.00	30.96	99.00	61.89	160.0	5.05E+09	1.0	30.5	0.000	1.13E+00	0.110	5.520E-01	1.363	0.056	0.1032	2350.00	74.85	99.00	149.69
36500	3.15E+09	1.02	31.1	0.000	1.51E+00	0.032	5.630E-01	1.690	0.017	0.0309	2350.00	22.39	99.00	44.78	170.0	5.35E+09	1.0	30.5	0.000	1.09E+00	0.123	5.520E-01	1.319	0.062	0.1154	2350.00	83.69	99.00	167.37
36500	3.15E+09	1.08	32.9	0.000	1.61E+00	0.023	5.961E-01	1.784	0.012	0.0220	2350.00	15.94	99.00	31.89	180.0	5.68E+09	1.0	30.5	0.000	1.05E+00	0.136	5.520E-01	1.269	0.068	0.1276	2350.00	92.49	99.00	184.98
36500	3.15E+09	1.14	34.7	0.000	1.70E+00	0.016	6.292E-01	1.879	0.008	0.0154	2350.00	11.17	99.00	22.34	190.0	5.99E+09	1.0	30.5	0.000	1.02E+00	0.150	5.520E-01	1.261	0.075	0.1398	2350.00	101.23	99.00	202.46
36500	3.15E+09	1.20	36.6	0.000	1.80E+00	0.011	6.624E-01	1.973	0.005	0.0106	2350.00	7.70	99.00	15.40	200.0	6.31E+09	1.0	30.5	0.000	9.87E-01	0.163	5.520E-01	1.236	0.081	0.1516	2350.00	109.87	99.00	219.74
36500	3.16E+09	1.26	38.4	0.000	1.89E+00	0.007	6.956E-01	2.067	0.003	0.0072	2350.00	5.22	99.00	10.45	210.0	6.62E+09	1.0	30.5	0.000	9.57E-01	0.176	5.520E-01	1.211	0.087	0.1633	2350.00	118.39	99.00	236.79
36500	3.15E+09	1.32	40.2	0.000	1.99E+00	0.005	7.286E-01	2.161	0.002	0.0048	2350.00	3.49	99.00	6.97	220.0	6.94E+09	1.0	30.5	0.000	9.29E-01	0.189	5.520E-01	1.189	0.093	0.1749	2350.00	126.77	99.00	253.54
36500	3.15E+09	1.38	42.1	0.000	2.08E+00	0.003	7.617E-01	2.256	0.001	0.0032	2350.00	2.29	99.00	4.58	230.0	7.25E+09	1.0	30.5	0.000	9.03E-01	0.202	5.520E-01	1.169	0.098	0.1862	2350.00	135.01	99.00	270.01
36500	3.15E+09	1.44	43.9	0.000	2.17E+00	0.002	7.948E-01	2.350	0.001	0.0020	2350.00	1.48	99.00	2.95	240.0	7.57E+09	1.0	30.5	0.000	8.76E-01	0.214	5.520E-01	1.150	0.104	0.1974	2350.00	143.08	99.00	286.17
36500	3.15E+09	1.50	45.7	0.000	2.27E+00	0.001	8.278E-01	2.444	0.001	0.0013	2350.00	0.94	99.00	1.88	250.0	7.88E+09	1.0	30.5	0.000	8.50E-01	0.227	5.520E-01	1.132	0.109	0.2083	2350.00	151.00	99.00	301.99
36500	3.16E+09	1.56	47.5	0.000	2.36E+00	0.001	8.611E-01	2.539	0.000	0.0008	2350.00	0.59	99.00	1.17	260.0	8.20E+09	1.0	30.5	0.000	8.23E-01	0.239	5.520E-01	1.116	0.115	0.2190	2350.00	158.74	99.00	317.48
36500	3.15E+09	1.62	49.4	0.000	2.46E+00	0.001	8.942E-01	2.633	0.000	0.0005	2350.00	0.36	99.00	0.72	270.0	8.51E+09	1.0	30.5	0.000	8.12E-01	0.251	5.520E-01	1.100	0.120	0.2294	2350.00	166.32	99.00	332.64
36500	3.15E+09	1.68	51.2	0.000	2.55E+00	0.000	9.273E-01	2.727	0.000	0.0003	2350.00	0.22	99.00	0.43	280.0	8.83E+09	1.0	30.5	0.000	7.92E-01	0.263	5.520E-01	1.086	0.126	0.2396	2350.00	173.73	99.00	347.46
36500	3.15E+09	1.74	53.0	0.000	2.65E+00	0.000	9.604E-01	2.821	0.000	0.0002	2350.00	0.13	99.00	0.26	290.0	9.15E+09	1.0	30.5	0.000	7.73E-01	0.274	5.520E-01	1.072	0.129	0.2498	2350.00	180.97	99.00	361.95
36500	3.15E+09	1.80	54.9	0.000	2.74E+00	0.000	9.935E-01	2.916	0.000	0.0001	2350.00	0.08	99.00	0.16	300.0	9.46E+09	1.0	30.5	0.000	7.55E-01	0.286	5.520E-01	1.059	0.134	0.2594	2350.00	188.05	99.00	376.10
36500	3.15E+09	1.86	56.7	0.000	2.83E+00	0.000	1.027E+00	3.010	0.000	0.0001	2350.00	0.04	99.00	0.09	310.0	9.78E+09	1.0	30.5	0.000	7.38E-01	0.297	5.520E-01	1.047	0.139	0.2689	2350.00	194.96	99.00	389.93
36500	3.15E+09	1.92	58.5	0.000	2.93E+00	0.000	1.060E+00	3.104	0.000	0.0000	2350.00	0.02	99.00	0.05	320.0	1.01E+10	1.0	30.5	0.000	7.21E-01	0.308	5.520E-01	1.035	0.143	0.2782	2350.00	201.72	99.00	403.44
36500	3.15E+09	1.98	60.4	0.000	3.02E+00	0.000	1.093E+00	3.199	0.000	0.0000	2350.00	0.01	99.00	0.03	330.0	1.04E+10	1.0	30.5	0.000	7.05E-01	0.319	5.520E-01	1.024	0.147	0.2873	2350.00	208.31	99.00	416.63
36500	3.15E+09	2.04	62.2	0.000	3.12E+00	0.000	1.126E+00	3.293	0.000	0.0000	2350.00	0.01	99.00	0.01	340.0	1.07E+10	1.0	30.5	0.000	6.90E-01	0.329	5.520E-01	1.014	0.152	0.2962	2350.00	214.76	99.00	429.51
36500	3.15E+09	2.10	64.0	0.000	3.21E+00	0.000	1.159E+00	3.387	0.000	0.0000	2350.00	0.00	99.00	0.01	350.0	1.10E+10	1.0	30.5	0.000	6.76E-01	0.340	5.520E-01	1.004	0.156	0.3049	2350.00	221.05	99.00	442.10
36500	3.15E+09	2.16	65.8	0.000	3.31E+00	0.000	1.192E+00	3.481	0.000	0.0000	2350.00	0.00	99.00	0.00	360.0	1.14E+10	1.0	30.5	0.000	6.61E-01	0.350	5.520E-01	0.995	0.160	0.3134	2350.00	227.20	99.00	454.39
36500	3.15E+09	2.22	67.7	0.000	3.40E+00	0.000	1.226E+00	3.575	0.000	0.0000	2350.00	0.00	99.00	0.00	370.0	1.17E+10	1.0	30.5	0.000	6.46E-01	0.360	5.520E-01	0.986	0.163	0.3217	2350.00	233.20	99.00	466.40
36500	3.15E+09	2.28	69.5	0.000	3.49E+00	0.000	1.258E+00	3.670	0.000	0.0000	2350.00	0.00	99.00	0.00	380.0	1.20E+10	1.0	30.5	0.000	6.32E-01	0.369	5.520E-01	0.977	0.167	0.3297	2350.00	239.07	99.00	478.14
36500	3.15E+09	2.34	71.3	0.000	3.59E+00	0.000	1.292E+00	3.764	0.000	0.0000	2350.00	0.00	99.00	0.00	390.0	1.23E+10	1.0	30.5	0.000	6.22E-01	0.379	5.520E-01	0.969	0.171	0.3377	2350.00	244.80	99.00	489.60
36500	3.15E+09	2.40	73.2	0.000	3.68E+00	0.000	1.325E+00	3.858	0.000	0.0000	2350.00	0.00	99.00	0.00	400.0	1.26E+10	1.0	30.5	0.000	6.10E-01	0.388	5.520E-01	0.961	0.174	0.3454	2350.00	250.40	99.00	500.80
36500	3.16E+09	2.46	75.0	0.000	3.78E+00	0.000	1.358E+00	3.952	0.000	0.0000	2350.00	0.00	99.00	0.00	410.0	1.29E+10	1.0	30.5	0.000	5.98E-01	0.398	5.520E-01	0.954	0.177	0.3529	2350.00	255.88	99.00	511.75
36500	3.15E+09	2.52	76.8	0.000	3.87E+00	0.000	1.391E+00	4.047	0.000	0.0000	2350.00	0.00	99.00	0.00	420.0	1.32E+10	1.0	30.5	0.000	5.87E-01	0.407	5.520E-01	0.947	0.181	0.3603	2350.00	261.23	99.00	522.46
36500	3.15E+09	2.58	78.6	0.000	3.97E+00	0.000	1.424E+00	4.141	0.000	0.0000	2350.00	0.00	99.00	0.00	430.0	1.36E+10	1.0	30.5	0.000	5.76E-01	0.416	5.520E-01	0.940	0.184	0.3675	2350.00	266.46	99.00	532.93
36500	3.15E+09	2.64	80.5	0.000	4.06E+00	0.000	1.457E+00	4.235	0.000	0.0000	2350.00	0.00	99.00	0.00	440.0	1.39E+10	1.0	30.5	0.000	5.65E-01	0.426	5.520E-01	0.933	0.187	0.3746	2350.00	271.58	99.00	543.16
36500	3.15E+09	2.70	82.3	0.000	4.15E+00	0.000	1.490E+00	4.329	0.000	0.0000	2350.00	0.00	99.00	0.00	450.0	1.42E+10	1.0	30.5	0.000	5.54E-01	0.433	5.520E-01	0.927	0.190	0.3816	2350.00	276.59	99.00	553.17
36500	3.15E+09	2.76	84.1	0.000	4.25E+00	0.000	1.523E+00	4.424	0.000	0.0000	2350.00	0.00	99.00	0.00	460.0	1.45E+10	1.0	30.5	0.000	5.44E-01	0.442	5.520E-01	0.921	0.193	0.3883	2350.00	281.49	99.00	562.97
36500	3.15E+09	2.82	86.0	0.000	4.34E+00	0.000	1.557E+00	4.518	0.000	0.0000	2350.00	0.00	99.00	0.00	470.0	1.48E+10	1.0	30.5	0.000	5.34E-01	0.450	5.520E-01	0.916	0.196	0.3949	2350.00	286.28	99.00	572.55
36500	3.15E+09	2.88	87.8	0.000	4.44E+00	0.000	1.590E+00	4.612	0.000	0.0000	2350.00	0.00	99.00	0.00	480.0	1.51E+10	1.0	30.5	0.000	5.25E-01	0.458	5.520E-01	0.909	0.199	0.4013	2350.00	290.97	99.00	581.93
36500	3.15E+09	2.94	89.6	0.000	4.53E+00	0.000	1.623E+00	4.706	0.000	0.0000	2350.00	0.00	99.00	0.00	490.0	1.55E+10	1.0	30.5	0.000	5.16E-01	0.466	5.520E-01	0.904	0.201	0.4077	2350.00	295.56	99.00	591.12
36500	3.15E+09	3.00	91.4	0.000	4.62E+00	0.000	1.656E+00	4.801	0.000	0.0000	2350.00	0.00	99.00	0.00	500.0	1.58E+10	1.0	30.5	0.000	5.06E-01	0.474	5.520E-01	0.899	0.204	0.4139	2350.00	300.05	99.00	600.11

Note 1: Adapted from Equation B-29, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Acenaphthene
PSR Superfund Site

Advect. / Dsp Transport Formulae:

Kd=foc*Koc	Watson 1991, p.186
R=1+(Kd.cap*p)/ne	Watson 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.136
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*x-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2))
ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	42 ft/d	Koc	7780.3 ml/g			
	n	0.45	foc	0.02	Kd (theoretical	141.6 L/kg	
	ne	0.45	R	459.63	Kd, cap	142 L/kg	
	g	2.16 gm/cm3	u	1.14E-08 /d	SQS	16 mg/kgOC	
	DL,sed	0.17 ft	d	0.03 ft	WQC	570 ug/L	(LOEL)
	L	1.0664 ft	Co	1.9 ug/L	Dw	1.1E-05 cm2/sec	
Results:	p	1.4675 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	0.0002 ft/d	Kd,cap	142 ml/g			
	v	7.056E-09 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-09 cm/sec	(m=v for u=0)		

Conversions:

C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOL.

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DL,sed / (n+p*Kd,cap) — USEPA 1999

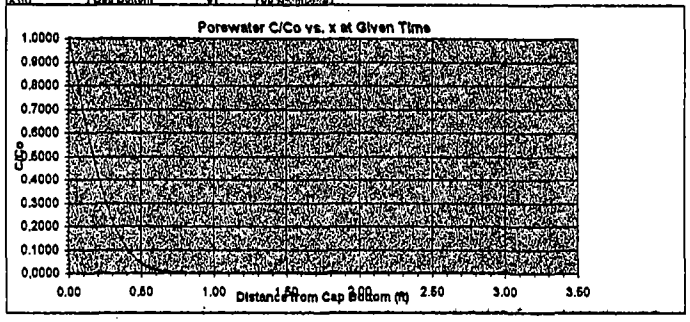
Cap thickness lost due to expression of porewater during consolidation (ft)

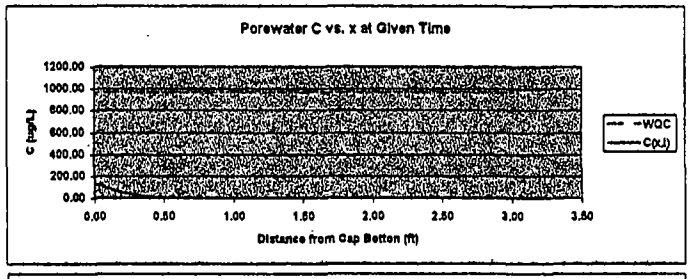
Tl,consol = 0.007 feet (typically negligible)

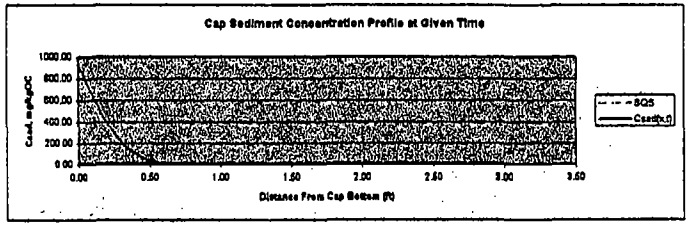
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	100 yrs
x (ft)	Cap Bottom	0	Top 3.5 ft



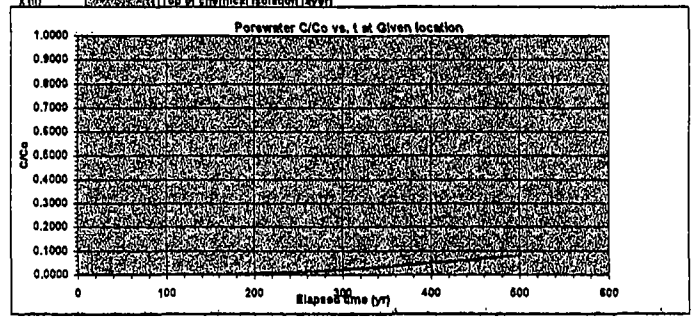


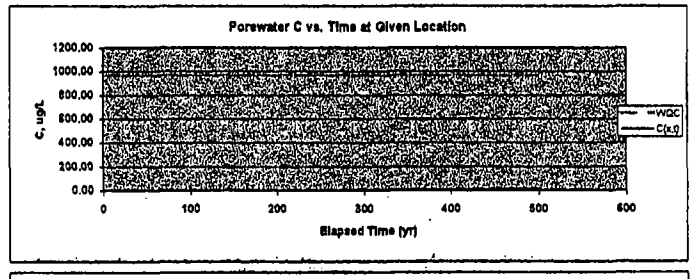


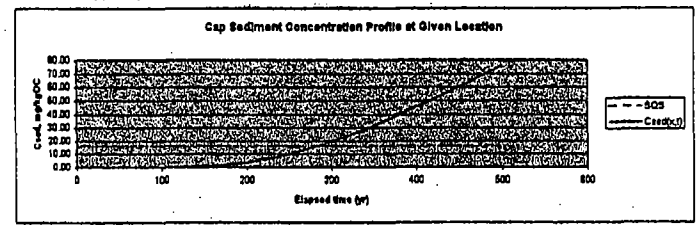
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	500
x (ft)	Top of Cap	3.5	(Top of chemical isolation layer)	







Chemical Isolation Analysis for Acenaphthene
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Cseq(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-4.68E-02	1.053	0.000E+00	0.047	0.947	1.0000	970.00	132.00	16.00	934.56
36500	3.15E+09	0.08	1.8	0.000	1.30E-01	0.854	3.312E-02	0.224	0.792	0.8156	970.00	107.56	16.00	762.21
36500	3.15E+09	0.12	3.7	0.000	3.07E-01	0.664	6.624E-02	0.401	0.571	0.6372	970.00	84.12	16.00	595.54
36500	3.15E+09	0.18	5.5	0.000	4.84E-01	0.494	9.935E-02	0.577	0.414	0.4757	970.00	62.79	16.00	444.55
36500	3.15E+09	0.24	7.3	0.000	6.61E-01	0.350	1.325E-01	0.754	0.286	0.3384	970.00	44.67	16.00	316.28
36500	3.15E+09	0.30	9.1	0.000	8.37E-01	0.236	1.656E-01	0.931	0.186	0.2290	970.00	30.23	16.00	214.03
36500	3.15E+09	0.36	11.0	0.000	1.01E+00	0.161	1.987E-01	1.109	0.117	0.1472	970.00	19.43	16.00	137.64
36500	3.15E+09	0.42	12.8	0.000	1.19E+00	0.092	2.319E-01	1.285	0.069	0.0897	970.00	11.84	16.00	83.81
36500	3.15E+09	0.48	14.6	0.000	1.37E+00	0.053	2.649E-01	1.462	0.039	0.0518	970.00	6.83	16.00	48.36
36500	3.15E+09	0.54	16.5	0.000	1.54E+00	0.028	2.981E-01	1.639	0.020	0.0283	970.00	3.73	16.00	26.41
36500	3.15E+09	0.60	18.3	0.000	1.72E+00	0.015	3.312E-01	1.816	0.010	0.0146	970.00	1.93	16.00	13.63
36500	3.15E+09	0.66	20.1	0.000	1.90E+00	0.007	3.643E-01	1.992	0.005	0.0071	970.00	0.94	16.00	6.65
36500	3.15E+09	0.72	21.9	0.000	2.08E+00	0.003	3.974E-01	2.169	0.002	0.0033	970.00	0.43	16.00	3.06
36500	3.15E+09	0.78	23.8	0.000	2.25E+00	0.001	4.305E-01	2.346	0.001	0.0014	970.00	0.19	16.00	1.33
36500	3.15E+09	0.84	25.6	0.000	2.43E+00	0.001	4.636E-01	2.523	0.000	0.0006	970.00	0.08	16.00	0.54
36500	3.15E+09	0.90	27.4	0.000	2.61E+00	0.000	4.966E-01	2.700	0.000	0.0002	970.00	0.03	16.00	0.21
36500	3.15E+09	0.96	29.3	0.000	2.78E+00	0.000	5.299E-01	2.876	0.000	0.0001	970.00	0.01	16.00	0.08
36500	3.15E+09	1.02	31.1	0.000	2.96E+00	0.000	5.630E-01	3.053	0.000	0.0000	970.00	0.00	16.00	0.03
36500	3.15E+09	1.08	32.9	0.000	3.14E+00	0.000	5.961E-01	3.230	0.000	0.0000	970.00	0.00	16.00	0.01
36500	3.15E+09	1.14	34.7	0.000	3.31E+00	0.000	6.292E-01	3.407	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.20	36.6	0.000	3.49E+00	0.000	6.624E-01	3.584	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.26	38.4	0.000	3.67E+00	0.000	6.955E-01	3.761	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.32	40.2	0.000	3.84E+00	0.000	7.286E-01	3.938	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.38	42.1	0.000	4.02E+00	0.000	7.617E-01	4.114	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.44	43.9	0.000	4.20E+00	0.000	7.948E-01	4.291	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.50	45.7	0.000	4.37E+00	0.000	8.279E-01	4.468	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.56	47.6	0.000	4.55E+00	0.000	8.611E-01	4.645	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.62	49.4	0.000	4.73E+00	0.000	8.942E-01	4.822	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.68	51.2	0.000	4.91E+00	0.000	9.273E-01	4.999	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.74	53.0	0.000	5.08E+00	0.000	9.604E-01	5.176	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.80	54.9	0.000	5.26E+00	0.000	9.935E-01	5.352	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.86	56.7	0.000	5.44E+00	0.000	1.027E+00	5.529	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.92	58.5	0.000	5.61E+00	0.000	1.060E+00	5.706	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	1.98	60.4	0.000	5.79E+00	0.000	1.093E+00	5.883	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.04	62.2	0.000	5.97E+00	0.000	1.126E+00	6.060	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.10	64.0	0.000	6.14E+00	0.000	1.159E+00	6.237	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.16	65.8	0.000	6.32E+00	0.000	1.192E+00	6.414	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.22	67.7	0.000	6.50E+00	0.000	1.225E+00	6.590	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.28	69.5	0.000	6.67E+00	0.000	1.258E+00	6.767	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.34	71.3	0.000	6.85E+00	0.000	1.292E+00	6.944	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.40	73.2	0.000	7.03E+00	0.000	1.325E+00	7.121	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.46	75.0	0.000	7.20E+00	0.000	1.358E+00	7.298	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.52	76.8	0.000	7.38E+00	0.000	1.391E+00	7.475	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.58	78.6	0.000	7.56E+00	0.000	1.424E+00	7.652	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.64	80.5	0.000	7.73E+00	0.000	1.457E+00	7.829	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.70	82.3	0.000	7.91E+00	0.000	1.490E+00	8.005	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.76	84.1	0.000	8.09E+00	0.000	1.523E+00	8.182	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.82	86.0	0.000	8.27E+00	0.000	1.557E+00	8.359	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.88	87.8	0.000	8.44E+00	0.000	1.590E+00	8.536	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	2.94	89.6	0.000	8.62E+00	0.000	1.623E+00	8.713	0.000	0.0000	970.00	0.00	16.00	0.00
36500	3.15E+09	3.00	91.4	0.000	8.80E+00	0.000	1.656E+00	8.890	0.000	0.0000	970.00	0.00	16.00	0.00

INPUT				CALCULATIONS						OUTPUT				
t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Cseq(x,t) (mg/kgOC)
0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.620E-01	#DIV/0!	#DIV/0!	#DIV/0!	970.00	#DIV/0!	16.00	#DIV/0!
10.0	3.15E+08	1.0	30.5	0.000	9.31E+00	0.000	5.620E-01	9.336	0.000	0.0000	970.00	0.00	16.00	0.00
20.0	6.31E+08	1.0	30.5	0.000	6.57E+00	0.000	5.620E-01	6.612	0.000	0.0000	970.00	0.00	16.00	0.00
30.0	9.46E+08	1.0	30.5	0.000	5.36E+00	0.000	5.620E-01	5.407	0.000	0.0000	970.00	0.00	16.00	0.00
40.0	1.26E+09	1.0	30.5	0.000	4.63E+00	0.000	5.620E-01	4.690	0.000	0.0000	970.00	0.00	16.00	0.00
50.0	1.58E+09	1.0	30.5	0.000	4.14E+00	0.000	5.620E-01	4.202	0.000	0.0000	970.00	0.00	16.00	0.00
60.0	1.89E+09	1.0	30.5	0.000	3.77E+00	0.000	5.620E-01	3.842	0.000	0.0000	970.00	0.00	16.00	0.00
70.0	2.21E+09	1.0	30.5	0.000	3.48E+00	0.000	5.620E-01	3.562	0.000	0.0000	970.00	0.00	16.00	0.00
80.0	2.52E+09	1.0	30.5	0.000	3.25E+00	0.000	5.620E-01	3.337	0.000	0.0000	970.00	0.00	16.00	0.00
90.0	2.84E+09	1.0	30.5	0.000	3.06E+00	0.000	5.620E-01	3.151	0.000	0.0000	970.00	0.00	16.00	0.01
100.0	3.15E+09	1.0	30.5	0.000	2.90E+00	0.000	5.620E-01	2.994	0.000	0.0000	970.00	0.01	16.00	0.04
110.0	3.47E+09	1.0	30.5	0.000	2.76E+00	0.000	5.620E-01	2.860	0.000	0.0001	970.00	0.01	16.00	0.09
120.0	3.78E+09	1.0	30.5	0.000	2.64E+00	0.000	5.620E-01	2.742	0.000	0.0002	970.00	0.02	16.00	0.17
130.0	4.10E+09	1.0	30.5	0.000	2.53E+00	0.000	5.620E-01	2.639	0.000	0.0003	970.00	0.04	16.00	0.31
140.0	4.42E+09	1.0	30.5	0.000	2.44E+00	0.001	5.620E-01	2.547	0.000	0.0005	970.00	0.07	16.00	0.52
150.0	4.73E+09	1.0	30.5	0.000	2.35E+00	0.001	5.620E-01	2.464	0.000	0.0009	970.00	0.12	16.00	0.82
160.0	5.05E+09	1.0	30.5	0.000	2.27E+00	0.001	5.620E-01	2.388	0.001	0.0013	970.00	0.17	16.00	1.21
170.0	5.36E+09	1.0	30.5	0.000	2.20E+00	0.002	5.620E-01	2.322	0.001	0.0018	970.00	0.24	16.00	1.70
180.0	5.68E+09	1.0	30.5	0.000	2.13E+00	0.003	5.620E-01	2.260	0.001	0.0025	970.00	0.33	16.00	2.32
190.0	5.99E+09	1.0	30.5	0.000	2.07E+00	0.003	5.620E-01	2.203	0.002	0.0033	970.00	0.43	16.00	3.08
200.0	6.31E+09	1.0	30.5	0.000	2.02E+00	0.004	5.620E-01	2.150	0.002	0.0042	970.00	0.56	16.00	3.93
210.0	6.62E+09	1.0	30.5	0.000	1.97E+00	0.005	5.620E-01	2.102	0.003	0.0053	970.00	0.70	16.00	4.93
220.0	6.94E+09	1.0	30.5	0.000	1.92E+00	0.007	5.620E-01	2.057	0.004	0.0065	970.00	0.86	16.00	6.07
230.0	7.25E+09	1.0	30.5	0.000	1.87E+00	0.008	5.620E-01	2.015	0.004	0.0079	970.00	1.04	16.00	7.34
240.0	7.57E+09	1.0	30.5	0.000	1.83E+00	0.010	5.620E-01	1.976	0.005	0.0094	970.00	1.23	16.00	8.74
250.0	7.88E+09	1.0	30.5	0.000	1.79E+00	0.011	5.620E-01	1.938	0.006	0.0110	970.00	1.48	16.00	10.27
260.0	8.20E+09	1.0	30.5	0.000	1.75E+00	0.013	5.620E-01	1.903	0.007	0.0128	970.00	1.69	16.00	11.93
270.0	8.51E+09	1.0	30.5	0.000	1.72E+00	0.015	5.620E-01	1.871	0.008	0.0147	970.00	1.94	16.00	13.71
280.0	8.83E+09	1.0	30.5	0.000	1.68E+00	0.017	5.620E-01	1.840	0.009	0.0167	970.00	2.20	16.00	15.60
290.0	9.15E+09	1.0	30.5	0.000	1.65E+00	0.020	5.620E-01	1.811	0.010	0.0188	970.00	2.49	16.00	17.61
300.0	9.46E+09	1.0	30.5	0.000	1.62E+00	0.022	5.620E-01	1.783	0.012	0.0211	970.00	2.79	16.00	19.72
310.0	9.78E+09	1.0	30.5	0.000	1.59E+00	0.024	5.620E-01	1.757	0.013	0.0235	970.00	3.10	16.00	21.93
320.0	1.01E+10	1.0	30.5	0.000	1.56E+00	0.027	5.620E-01	1.731	0.014	0.0259	970.00	3.42	16.00	24.24
330.0	1.04E+10	1.0	30.5	0.000	1.54E+00	0.030	5.620E-01	1.708	0.016	0.0285	970.00	3.76	16.00	26.64
340.0	1.07E+10	1.0	30.5	0.000	1.51E+00	0.032	5.620E-01	1.686	0.017	0.0312	970.00	4.11	16.00	29.12
350.0	1.10E+10	1.0	30.5	0.000	1.49E+00	0.035	5.620E-01	1.663	0.019	0.0339	970.00	4.47	16.00	31.67
360.0	1.14E+10	1.0	30.5	0.000	1.46E+00	0.039	5.620E-01	1.642	0.020	0.0367	970.00	4.84	16.00	34.30
370.0	1.17E+10	1.0	30.5	0.000	1.44E+00	0.041	5.620E-01	1.622	0.022	0.0396	970.00	5.23	16.00	37.00
380.0	1.20E+10	1.0	30.5	0.000	1.42E+00	0.045	5.620E-01	1.603	0.023	0.0425	970.00	5.61	16.00	39.75
390.0	1.23E+10	1.0	30.5	0.000	1.40E+00	0.048	5.620E-01	1.585	0.026	0.0455	970.00	6.01	16.00	42.57
400.0	1.26E+10	1.0	30.5	0.000	1.38E+00	0.051	5.620E-01	1.567	0.027	0.0486	970.00	6.42	16.00	45.43
410.0	1.29E+10	1.0	30.5	0.000	1.36E+00	0.054	5.620E-01	1.550	0.028	0.0517	970.00	6.83	16.00	48.35
420.0	1.32E+10	1.0	30.5	0.000	1.34E+00	0.058	5.620E-01	1.534	0.030	0.0549	970.00	7.25	16.00	51.31
430.0	1.36E+10	1.0	30.5	0.000	1.32E+00	0.061	5.620E-01	1.519	0.032	0.0581	970.00	7.67	16.00	54.31
440.0	1.39E+10	1.0	30.5	0.000	1.31E+00	0.065	5.620E-01	1.503	0.033	0.0614	970.00	8.10	16.00	57.34
450.0	1.42E+10	1.0	30.5	0.000	1.29E+00	0.068	5.620E-01	1.489	0.035	0.0646	970.00	8.53	16.00	60.41
460.0	1.45E+10	1.0	30.5	0.000	1.27E+00	0.072	5.620E-01	1.475	0.037	0.0679	970.00	8.97	16.00	63.50
470.0	1.48E+10	1.0	30.5	0.000	1.26E+00	0.075	5.620E-01	1.461	0.039	0.0713	970.00	9.41	16.00	66.62
480.0	1.51E+10	1.0	30.5	0.000	1.24E+00	0.079	5.620E-01	1.448	0.041	0.0747	970.00	9.85	16.00	69.77
490.0	1.55E+10	1.0	30.5	0.000	1.23E+00	0.082	5.620E-01	1.435	0.042	0.0780	970.00	10.30	16.00	72.93
500.0	1.58E+10	1.0	30.5	0.000	1.21E+00	0.086	5.620E-01	1.423	0.044	0.0814	970.00	10.75	16.00	76.11

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Cseq(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Dibenz(r[redacted]cene
PSR Superfund Site

Advection-Dispersion Transport Formulae:

Kd=foc*Koc	Watson 1991, p.186
R=1+(Kd,cap*p)/ne	Watson 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.139
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)

X = (R*x-m*t)/(SQRT(4*D*R*t))

Y = ((v+m)*x)/(2*D)

Z = (R*x+m*t)/(SQRT(4*D*R*t))

m= v*(SQRT(1+((4*u*D)/v^2))

ERFC0= 1-ERF0

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g	Dibenz(a,h)anthracene		
	n	[redacted]	foc	[redacted]	Kd (theoretica	76000	L/kg
	ne	[redacted]	R	246156.58	Kd, cap	[redacted]	L/kg
	g	[redacted] gm/cm3	u	[redacted] /a	SQS	[redacted]	mg/kgOC
	DL,sed	[redacted] ft	d	[redacted] ft	WQC	[redacted]	ug/L (none)
	L	[redacted] ft	Co	[redacted] ug/L	Dw	[redacted]	cm2/sec
Results:	p	1.4678 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /a			
	v	[redacted] ft/d	Kd,cap	76000 ml/g			
	v	7.056E-08 cm/s	D	3.9E-08 cm2/sec			
			m	7.056E-08 cm/sec	(m=v for u=0)		

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/a)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap) — USEPA 1998

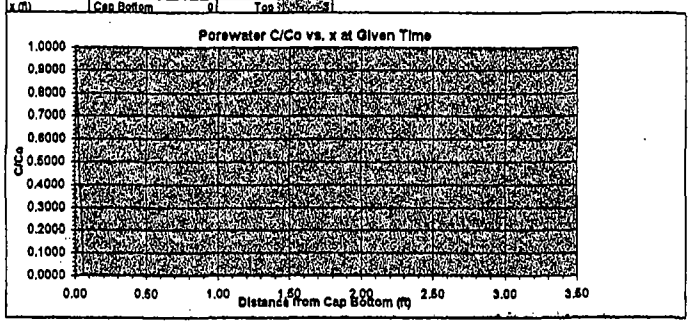
Cap thickness lost due to expression of porewater during consolidation (ft)

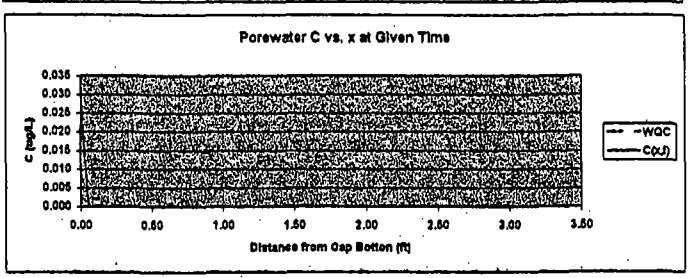
Tl,consol = 0.000 feet (typically negligible)

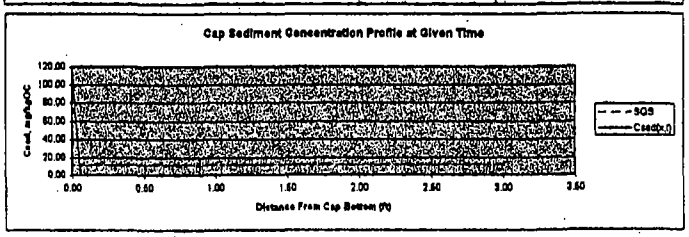
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500 days =	[redacted]	
x (ft)	Cap Bottom	0	Top [redacted]



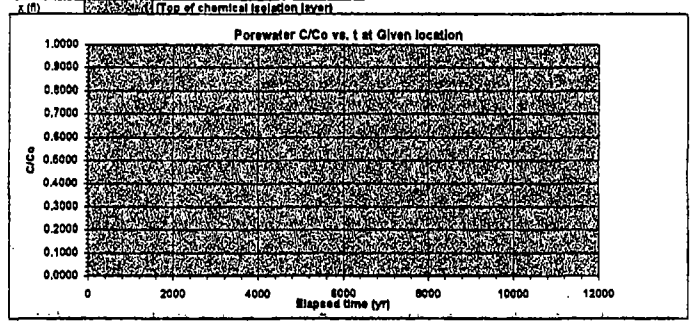


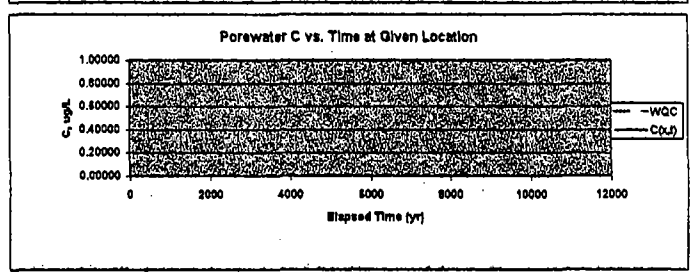


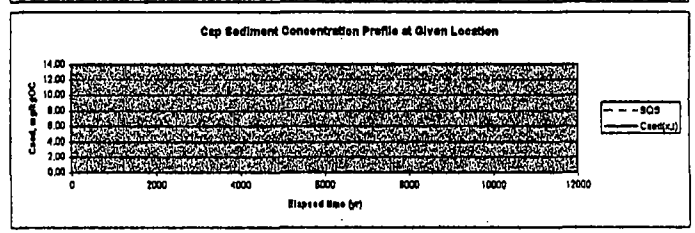
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	10000	
x (ft)	[redacted]	(Top of chemical isolation layer)			







Chemical Isolation Analysis for Dibenz(a,h)a[redacted]ene
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT				
										B(x,t)	WQC	C(x,t)	SQS	Csed(x,t)										B(x,t)	WQC	C(x,t)	SQS	Csed(x,t)
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)		(ug/L)	(ug/L)	(mg/kgOC)	(mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)		(ug/L)	(ug/L)	(mg/kgOC)	(mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-2.02E-03	1.002	0.000E+00	0.002	0.998	1.0000	0.000	0.030	12.00	114.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	6.520E-01	#DIV/0!	#DIV/0!	#DIV/0!	0.00000	#DIV/0!	12.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	4.09E+00	0.000	3.312E-02	4.095	0.000	0.0000	0.000	0.000	12.00	0.00	200.0	6.31E+09	1.0	30.5	0.000	4.82E+01	#NUM!	6.520E-01	48.237	#NUM!	#NUM!	0.00000	#NUM!	12.00	#NUM!
36500	3.15E+09	0.12	3.7	0.000	8.16E+00	0.000	6.624E-02	8.189	0.000	0.0000	0.000	0.000	12.00	0.00	400.0	1.26E+10	1.0	30.5	0.000	3.41E+01	#NUM!	6.520E-01	34.111	#NUM!	#NUM!	0.00000	#NUM!	12.00	#NUM!
36500	3.15E+09	0.18	5.5	0.000	1.23E+01	0.000	9.935E-02	12.280	0.000	0.0000	0.000	0.000	12.00	0.00	600.0	1.89E+10	1.0	30.5	0.000	2.78E+01	#NUM!	6.520E-01	27.853	#NUM!	#NUM!	0.00000	#NUM!	12.00	#NUM!
36500	3.15E+09	0.24	7.3	0.000	1.64E+01	0.000	1.325E-01	16.373	0.000	0.0000	0.000	0.000	12.00	0.00	800.0	2.52E+10	1.0	30.5	0.000	2.41E+01	0.000	6.520E-01	24.123	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.30	9.1	0.000	2.05E+01	0.000	1.656E-01	20.466	0.000	0.0000	0.000	0.000	12.00	0.00	1000.0	3.15E+10	1.0	30.5	0.000	2.16E+01	0.000	6.520E-01	21.577	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.36	11.0	0.000	2.46E+01	0.000	1.987E-01	24.559	0.000	0.0000	0.000	0.000	12.00	0.00	1200.0	3.78E+10	1.0	30.5	0.000	1.97E+01	0.000	6.520E-01	19.698	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.42	12.8	0.000	2.86E+01	#NUM!	2.318E-01	28.652	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	1400.0	4.42E+10	1.0	30.5	0.000	1.82E+01	0.000	6.520E-01	18.238	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.48	14.6	0.000	3.27E+01	#NUM!	2.649E-01	32.744	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	1600.0	5.05E+10	1.0	30.5	0.000	1.70E+01	0.000	6.520E-01	17.061	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.54	16.5	0.000	3.68E+01	#NUM!	2.981E-01	36.837	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	1800.0	5.68E+10	1.0	30.5	0.000	1.61E+01	0.000	6.520E-01	16.087	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.60	18.3	0.000	4.09E+01	#NUM!	3.312E-01	40.930	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	2000.0	6.31E+10	1.0	30.5	0.000	1.52E+01	0.000	6.520E-01	15.252	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.66	20.1	0.000	4.50E+01	#NUM!	3.643E-01	45.023	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	2200.0	6.94E+10	1.0	30.5	0.000	1.45E+01	0.000	6.520E-01	14.563	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.72	21.9	0.000	4.91E+01	#NUM!	3.974E-01	49.116	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	2400.0	7.57E+10	1.0	30.5	0.000	1.39E+01	0.000	6.520E-01	13.934	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.78	23.8	0.000	5.32E+01	#NUM!	4.305E-01	53.208	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	2600.0	8.20E+10	1.0	30.5	0.000	1.34E+01	0.000	6.520E-01	13.388	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.84	25.6	0.000	5.73E+01	#NUM!	4.636E-01	57.301	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	2800.0	8.83E+10	1.0	30.5	0.000	1.29E+01	0.000	6.520E-01	12.902	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.90	27.4	0.000	6.14E+01	#NUM!	4.966E-01	61.394	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	3000.0	9.46E+10	1.0	30.5	0.000	1.24E+01	0.000	6.520E-01	12.466	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	0.96	29.3	0.000	6.55E+01	#NUM!	5.298E-01	65.487	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	3200.0	1.01E+11	1.0	30.5	0.000	1.20E+01	0.000	6.520E-01	12.070	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.02	31.1	0.000	6.96E+01	#NUM!	5.630E-01	69.580	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	3400.0	1.07E+11	1.0	30.5	0.000	1.17E+01	0.000	6.520E-01	11.710	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.08	32.9	0.000	7.37E+01	#NUM!	5.961E-01	73.672	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	3600.0	1.14E+11	1.0	30.5	0.000	1.14E+01	0.000	6.520E-01	11.381	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.14	34.7	0.000	7.78E+01	#NUM!	6.292E-01	77.765	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	3800.0	1.20E+11	1.0	30.5	0.000	1.11E+01	0.000	6.520E-01	11.078	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.20	36.5	0.000	8.19E+01	#NUM!	6.624E-01	81.858	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	4000.0	1.26E+11	1.0	30.5	0.000	1.08E+01	0.000	6.520E-01	10.798	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.26	38.4	0.000	8.59E+01	#NUM!	6.955E-01	85.951	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	4200.0	1.32E+11	1.0	30.5	0.000	1.05E+01	0.000	6.520E-01	10.539	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.32	40.2	0.000	9.00E+01	#NUM!	7.286E-01	90.044	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	4400.0	1.39E+11	1.0	30.5	0.000	1.03E+01	0.000	6.520E-01	10.297	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.38	42.1	0.000	9.41E+01	#NUM!	7.617E-01	94.136	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	4600.0	1.45E+11	1.0	30.5	0.000	1.00E+01	0.000	6.520E-01	10.071	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.44	43.9	0.000	9.82E+01	#NUM!	7.949E-01	98.229	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	4800.0	1.51E+11	1.0	30.5	0.000	9.83E+00	0.000	6.520E-01	9.850	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.50	45.7	0.000	1.02E+02	#NUM!	8.279E-01	102.322	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	5000.0	1.58E+11	1.0	30.5	0.000	9.63E+00	0.000	6.520E-01	9.651	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.56	47.5	0.000	1.06E+02	#NUM!	8.611E-01	106.415	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	5200.0	1.64E+11	1.0	30.5	0.000	9.44E+00	0.000	6.520E-01	9.474	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.62	49.4	0.000	1.11E+02	#NUM!	8.942E-01	110.507	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	5400.0	1.70E+11	1.0	30.5	0.000	9.27E+00	0.000	6.520E-01	9.298	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.68	51.2	0.000	1.15E+02	#NUM!	9.273E-01	114.600	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	5600.0	1.77E+11	1.0	30.5	0.000	9.10E+00	0.000	6.520E-01	9.131	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.74	53.0	0.000	1.19E+02	#NUM!	9.604E-01	118.693	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	5800.0	1.83E+11	1.0	30.5	0.000	8.94E+00	0.000	6.520E-01	8.972	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.80	54.9	0.000	1.23E+02	#NUM!	9.935E-01	122.786	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	6000.0	1.89E+11	1.0	30.5	0.000	8.79E+00	0.000	6.520E-01	8.822	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.86	56.7	0.000	1.27E+02	#NUM!	1.027E+00	126.879	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	6200.0	1.96E+11	1.0	30.5	0.000	8.65E+00	0.000	6.520E-01	8.679	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.92	58.5	0.000	1.31E+02	#NUM!	1.060E+00	130.971	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	6400.0	2.02E+11	1.0	30.5	0.000	8.51E+00	0.000	6.520E-01	8.543	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	1.98	60.4	0.000	1.35E+02	#NUM!	1.093E+00	135.064	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	6600.0	2.08E+11	1.0	30.5	0.000	9.38E+00	0.000	6.520E-01	8.413	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.04	62.2	0.000	1.39E+02	#NUM!	1.126E+00	139.157	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	6800.0	2.14E+11	1.0	30.5	0.000	9.26E+00	0.000	6.520E-01	8.289	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.10	64.0	0.000	1.43E+02	#NUM!	1.159E+00	143.250	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	7000.0	2.21E+11	1.0	30.5	0.000	9.14E+00	0.000	6.520E-01	9.170	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.16	65.8	0.000	1.47E+02	#NUM!	1.192E+00	147.343	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	7200.0	2.27E+11	1.0	30.5	0.000	8.02E+00	0.000	6.520E-01	8.056	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.22	67.7	0.000	1.51E+02	#NUM!	1.225E+00	151.435	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	7400.0	2.33E+11	1.0	30.5	0.000	7.91E+00	0.000	6.520E-01	7.947	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.28	69.5	0.000	1.55E+02	#NUM!	1.258E+00	155.528	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	7600.0	2.40E+11	1.0	30.5	0.000	7.81E+00	0.000	6.520E-01	7.842	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.34	71.3	0.000	1.60E+02	#NUM!	1.292E+00	159.621	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	7800.0	2.46E+11	1.0	30.5	0.000	7.71E+00	0.000	6.520E-01	7.741	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.40	73.2	0.000	1.64E+02	#NUM!	1.325E+00	163.714	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	8000.0	2.52E+11	1.0	30.5	0.000	7.61E+00	0.000	6.520E-01	7.640	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.46	75.0	0.000	1.68E+02	#NUM!	1.358E+00	167.807	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	8200.0	2.59E+11	1.0	30.5	0.000	7.51E+00	0.000	6.520E-01	7.551	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.52	76.8	0.000	1.72E+02	#NUM!	1.391E+00	171.899	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	8400.0	2.65E+11	1.0	30.5	0.000	7.42E+00	0.000	6.520E-01	7.461	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.58	78.6	0.000	1.76E+02	#NUM!	1.424E+00	175.992	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	8600.0	2.71E+11	1.0	30.5	0.000	7.34E+00	0.000	6.520E-01	7.374	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.64	80.5	0.000	1.80E+02	#NUM!	1.457E+00	180.085	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	8800.0	2.78E+11	1.0	30.5	0.000	7.26E+00	0.000	6.520E-01	7.291	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.70	82.3	0.000	1.84E+02	#NUM!	1.490E+00	184.178	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	9000.0	2.84E+11	1.0	30.5	0.000	7.17E+00	0.000	6.520E-01	7.209	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.76	84.1	0.000	1.88E+02	#NUM!	1.523E+00	188.271	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	9200.0	2.90E+11	1.0	30.5	0.000	7.09E+00	0.000	6.520E-01	7.131	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.82	86.0	0.000	1.92E+02	#NUM!	1.557E+00	192.363	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	9400.0	2.96E+11	1.0	30.5	0.000	7.02E+00	0.000	6.520E-01	7.055	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.88	87.8	0.000	1.96E+02	#NUM!	1.590E+00	196.456	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	9600.0	3.02E+11	1.0	30.5	0.000	6.94E+00	0.000	6.520E-01	6.982	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	2.94	89.6	0.000	2.01E+02	#NUM!	1.623E+00	200.549	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	9800.0	3.09E+11	1.0	30.5	0.000	6.87E+00	0.000	6.520E-01	6.911	0.000	0.0000	0.00000	0.00000	12.00	0.00
36500	3.15E+09	3.00	91.4	0.000	2.05E+02	#NUM!	1.656E+00	204.642	#NUM!	#NUM!	0.000	#NUM!	12.00	#NUM!	10000.0	3.15E+11	1.0	30.5	0.000	6.80E+00	0.000	6.520E-01	6.842	0.000	0.0000	0.00000	0.00000	12.00	0.00

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Flouran
PSR Superfund Site

Advecti... ...sive Transport Formulae:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + av	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v+m)*x)/(2*D)
X = (R*x-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2))
ERFC0= 1-ERF()

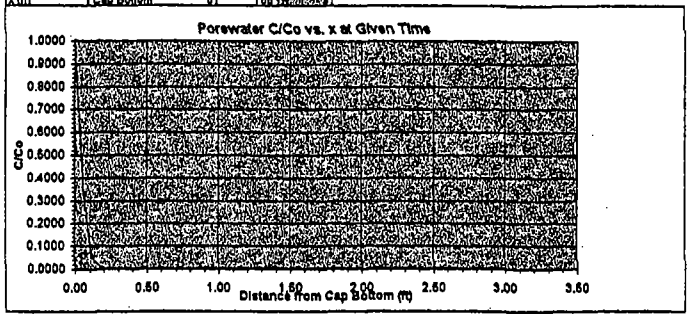
1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

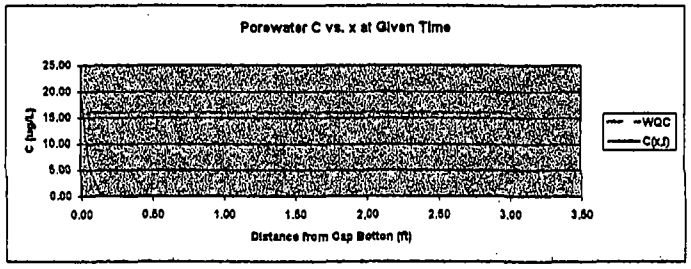
	Hydraulic Calculations		Transport Calculations		Chemical Data	
Data:	Kh	[illegible] ft/s	Koc	[illegible] ml/g	[illegible]	
	n	[illegible]	foc	[illegible]	Kd (theoretica	2200 L/kg
	ne	[illegible]	R	7128.56	Kd, cap	[illegible] L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible] mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible] ug/L
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible] cm2/sec
Results:	p	1.4575 gm/cm3	d	0.9144 cm		
	i	ft/ft	u	0 /s		
	v	[illegible] ft/d	Kd,cap	2200 ml/g		
	v	7.056E-08 cm/s	D	3.9E-06 cm2/sec		
			m	7.056E-08 cm/sec	(m=v for u=0)	

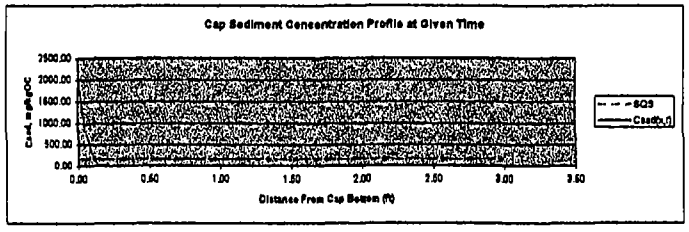
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	yrs
x (ft)	Cap Bottom	0	Top [illegible]	[illegible]







		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLI... ...ON

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DL,sed / (n+p*Kd,cap) — USEPA 1999

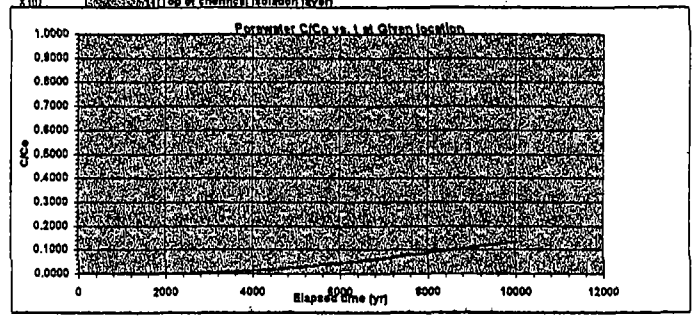
Cap thickness lost due to expression of porewater during consolidation (ft)

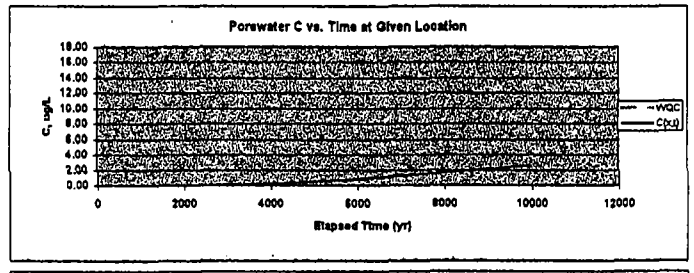
Tl,consol = 0.000 feet (typically negligible)

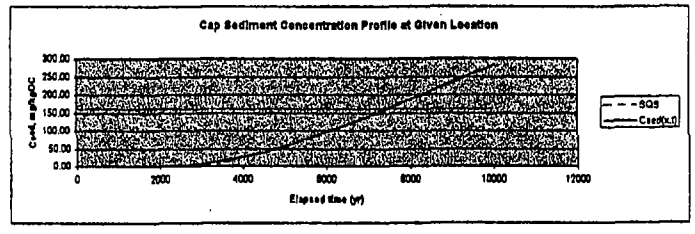
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	10950
x (ft)	[illegible]	ft (Top of chemical isolation layer)		







Chemical Isolation Analysis for Flouranthe
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.19E-02	1.013	0.000E+00	0.012	0.987	1.0000	16.00	19.84	160.00	2161.60	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.520E-01	#DIV/0!	#DIV/0!	#DIV/0!	16.00	#DIV/0!	160.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	6.85E-01	0.333	3.312E-02	0.708	0.317	0.3301	16.00	6.48	160.00	710.23	200.0	6.31E+09	1.0	30.5	0.000	6.19E+00	0.000	5.520E-01	8.224	0.000	0.0000	16.00	0.00	160.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.38E+00	0.051	6.624E-02	1.405	0.047	0.0505	16.00	0.99	160.00	108.69	400.0	1.26E+10	1.0	30.5	0.000	5.76E+00	0.000	5.520E-01	8.027	0.000	0.0000	16.00	0.00	160.00	0.00
36500	3.15E+09	0.18	5.5	0.000	2.08E+00	0.003	9.935E-02	2.101	0.003	0.0033	16.00	0.06	160.00	7.08	600.0	1.89E+10	1.0	30.5	0.000	4.71E+00	0.000	5.520E-01	4.767	0.000	0.0000	16.00	0.00	160.00	0.00
36500	3.15E+09	0.24	7.3	0.000	2.77E+00	0.000	1.325E-01	2.797	0.000	0.0001	16.00	0.00	160.00	0.19	800.0	2.52E+10	1.0	30.5	0.000	4.07E+00	0.000	5.520E-01	4.137	0.000	0.0000	16.00	0.00	160.00	0.00
36500	3.15E+09	0.30	9.1	0.000	3.47E+00	0.000	1.656E-01	3.494	0.000	0.0000	16.00	0.00	160.00	0.00	1000.0	3.15E+10	1.0	30.5	0.000	3.63E+00	0.000	5.520E-01	3.708	0.000	0.0000	16.00	0.00	160.00	0.00
36500	3.15E+09	0.36	11.0	0.000	4.17E+00	0.000	1.987E-01	4.190	0.000	0.0000	16.00	0.00	160.00	0.00	1200.0	3.78E+10	1.0	30.5	0.000	3.31E+00	0.000	5.520E-01	3.392	0.000	0.0000	16.00	0.00	160.00	0.01
36500	3.15E+09	0.42	12.8	0.000	4.86E+00	0.000	2.318E-01	4.887	0.000	0.0000	16.00	0.00	160.00	0.00	1400.0	4.42E+10	1.0	30.5	0.000	3.06E+00	0.000	5.520E-01	3.146	0.000	0.0000	16.00	0.00	160.00	0.03
36500	3.15E+09	0.48	14.6	0.000	5.56E+00	0.000	2.649E-01	5.583	0.000	0.0000	16.00	0.00	160.00	0.00	1600.0	5.05E+10	1.0	30.5	0.000	2.86E+00	0.000	5.520E-01	2.949	0.000	0.0001	16.00	0.00	160.00	0.12
36500	3.15E+09	0.54	16.5	0.000	6.26E+00	0.000	2.981E-01	6.279	0.000	0.0000	16.00	0.00	160.00	0.00	1800.0	5.68E+10	1.0	30.5	0.000	2.69E+00	0.000	5.520E-01	2.786	0.000	0.0001	16.00	0.00	160.00	0.31
36500	3.15E+09	0.60	18.3	0.000	6.95E+00	0.000	3.312E-01	6.976	0.000	0.0000	16.00	0.00	160.00	0.00	2000.0	6.31E+10	1.0	30.5	0.000	2.54E+00	0.000	5.520E-01	2.648	0.000	0.0003	16.00	0.01	160.00	0.69
36500	3.15E+09	0.66	20.1	0.000	7.65E+00	0.000	3.643E-01	7.672	0.000	0.0000	16.00	0.00	160.00	0.00	2200.0	6.94E+10	1.0	30.5	0.000	2.42E+00	0.001	5.520E-01	2.530	0.000	0.0006	16.00	0.01	160.00	1.32
36500	3.15E+09	0.72	21.9	0.000	8.34E+00	0.000	3.974E-01	8.369	0.000	0.0000	16.00	0.00	160.00	0.00	2400.0	7.57E+10	1.0	30.5	0.000	2.31E+00	0.001	5.520E-01	2.427	0.001	0.0011	16.00	0.02	160.00	2.28
36500	3.15E+09	0.78	23.8	0.000	9.04E+00	0.000	4.305E-01	9.065	0.000	0.0000	16.00	0.00	160.00	0.00	2600.0	8.20E+10	1.0	30.5	0.000	2.22E+00	0.002	5.520E-01	2.337	0.001	0.0017	16.00	0.03	160.00	3.63
36500	3.15E+09	0.84	25.6	0.000	9.74E+00	0.000	4.636E-01	9.761	0.000	0.0000	16.00	0.00	160.00	0.00	2800.0	8.83E+10	1.0	30.5	0.000	2.13E+00	0.003	5.520E-01	2.256	0.001	0.0025	16.00	0.05	160.00	5.43
36500	3.15E+09	0.90	27.4	0.000	1.04E+01	0.000	4.968E-01	10.458	0.000	0.0000	16.00	0.00	160.00	0.00	3000.0	9.46E+10	1.0	30.5	0.000	2.05E+00	0.004	5.520E-01	2.184	0.002	0.0036	16.00	0.07	160.00	7.71
36500	3.15E+09	0.96	29.3	0.000	1.11E+01	0.000	5.299E-01	11.154	0.000	0.0000	16.00	0.00	160.00	0.00	3200.0	1.01E+11	1.0	30.5	0.000	1.96E+00	0.005	5.520E-01	2.119	0.003	0.0049	16.00	0.10	160.00	10.49
36500	3.15E+09	1.02	31.1	0.000	1.18E+01	0.000	5.630E-01	11.851	0.000	0.0000	16.00	0.00	160.00	0.00	3400.0	1.07E+11	1.0	30.5	0.000	1.92E+00	0.007	5.520E-01	2.060	0.004	0.0064	16.00	0.13	160.00	13.78
36500	3.15E+09	1.08	32.9	0.000	1.25E+01	0.000	5.961E-01	12.547	0.000	0.0000	16.00	0.00	160.00	0.00	3600.0	1.14E+11	1.0	30.5	0.000	1.86E+00	0.008	5.520E-01	2.006	0.005	0.0082	16.00	0.16	160.00	17.58
36500	3.15E+09	1.14	34.7	0.000	1.32E+01	0.000	6.292E-01	13.243	0.000	0.0000	16.00	0.00	160.00	0.00	3800.0	1.20E+11	1.0	30.5	0.000	1.81E+00	0.010	5.520E-01	1.956	0.006	0.0102	16.00	0.20	160.00	21.88
36500	3.15E+09	1.20	36.6	0.000	1.39E+01	0.000	6.624E-01	13.940	0.000	0.0000	16.00	0.00	160.00	0.00	4000.0	1.26E+11	1.0	30.5	0.000	1.76E+00	0.013	5.520E-01	1.910	0.007	0.0124	16.00	0.24	160.00	26.67
36500	3.15E+09	1.26	38.4	0.000	1.45E+01	0.000	6.955E-01	14.636	0.000	0.0000	16.00	0.00	160.00	0.00	4200.0	1.32E+11	1.0	30.5	0.000	1.71E+00	0.015	5.520E-01	1.866	0.008	0.0148	16.00	0.29	160.00	31.93
36500	3.15E+09	1.32	40.2	0.000	1.53E+01	0.000	7.286E-01	15.333	0.000	0.0000	16.00	0.00	160.00	0.00	4400.0	1.39E+11	1.0	30.5	0.000	1.67E+00	0.018	5.520E-01	1.825	0.010	0.0176	16.00	0.34	160.00	37.64
36500	3.15E+09	1.38	42.1	0.000	1.60E+01	0.000	7.617E-01	16.029	0.000	0.0000	16.00	0.00	160.00	0.00	4600.0	1.45E+11	1.0	30.5	0.000	1.63E+00	0.021	5.520E-01	1.792	0.011	0.0203	16.00	0.40	160.00	43.76
36500	3.15E+09	1.44	43.9	0.000	1.67E+01	0.000	7.948E-01	16.725	0.000	0.0000	16.00	0.00	160.00	0.00	4800.0	1.51E+11	1.0	30.5	0.000	1.59E+00	0.024	5.520E-01	1.758	0.013	0.0234	16.00	0.46	160.00	50.26
36500	3.15E+09	1.50	45.7	0.000	1.74E+01	0.000	8.279E-01	17.422	0.000	0.0000	16.00	0.00	160.00	0.00	5000.0	1.58E+11	1.0	30.5	0.000	1.56E+00	0.028	5.520E-01	1.725	0.016	0.0266	16.00	0.52	160.00	57.16
36500	3.15E+09	1.56	47.5	0.000	1.81E+01	0.000	8.611E-01	18.118	0.000	0.0000	16.00	0.00	160.00	0.00	5200.0	1.64E+11	1.0	30.5	0.000	1.52E+00	0.031	5.520E-01	1.695	0.017	0.0299	16.00	0.59	160.00	64.37
36500	3.15E+09	1.62	49.4	0.000	1.88E+01	0.000	8.942E-01	18.814	0.000	0.0000	16.00	0.00	160.00	0.00	5400.0	1.70E+11	1.0	30.5	0.000	1.49E+00	0.035	5.520E-01	1.667	0.019	0.0334	16.00	0.65	160.00	71.89
36500	3.15E+09	1.68	51.2	0.000	1.95E+01	0.000	9.273E-01	19.511	0.000	0.0000	16.00	0.00	160.00	0.00	5600.0	1.77E+11	1.0	30.5	0.000	1.46E+00	0.039	5.520E-01	1.640	0.020	0.0370	16.00	0.72	160.00	79.69
36500	3.15E+09	1.74	53.0	0.000	2.02E+01	0.000	9.604E-01	20.207	0.000	0.0000	16.00	0.00	160.00	0.00	5800.0	1.83E+11	1.0	30.5	0.000	1.43E+00	0.043	5.520E-01	1.616	0.022	0.0408	16.00	0.80	160.00	87.74
36500	3.15E+09	1.80	54.9	0.000	2.09E+01	0.000	9.935E-01	20.904	0.000	0.0000	16.00	0.00	160.00	0.00	6000.0	1.89E+11	1.0	30.5	0.000	1.41E+00	0.047	5.520E-01	1.590	0.024	0.0446	16.00	0.87	160.00	96.02
36500	3.15E+09	1.86	56.7	0.000	2.16E+01	0.000	1.027E+00	21.600	0.000	0.0000	16.00	0.00	160.00	0.00	6200.0	1.96E+11	1.0	30.5	0.000	1.38E+00	0.051	5.520E-01	1.569	0.027	0.0486	16.00	0.96	160.00	104.51
36500	3.15E+09	1.92	58.5	0.000	2.23E+01	0.000	1.060E+00	22.296	0.000	0.0000	16.00	0.00	160.00	0.00	6400.0	2.02E+11	1.0	30.5	0.000	1.36E+00	0.055	5.520E-01	1.548	0.029	0.0526	16.00	1.03	160.00	113.19
36500	3.15E+09	1.98	60.4	0.000	2.30E+01	0.000	1.093E+00	22.993	0.000	0.0000	16.00	0.00	160.00	0.00	6600.0	2.08E+11	1.0	30.5	0.000	1.33E+00	0.060	5.520E-01	1.525	0.031	0.0567	16.00	1.11	160.00	122.03
36500	3.15E+09	2.04	62.2	0.000	2.37E+01	0.000	1.126E+00	23.689	0.000	0.0000	16.00	0.00	160.00	0.00	6800.0	2.14E+11	1.0	30.5	0.000	1.31E+00	0.064	5.520E-01	1.506	0.033	0.0609	16.00	1.19	160.00	131.01
36500	3.15E+09	2.10	64.0	0.000	2.44E+01	0.000	1.159E+00	24.386	0.000	0.0000	16.00	0.00	160.00	0.00	7000.0	2.21E+11	1.0	30.5	0.000	1.29E+00	0.069	5.520E-01	1.487	0.036	0.0651	16.00	1.27	160.00	140.11
36500	3.15E+09	2.16	65.8	0.000	2.51E+01	0.000	1.192E+00	25.082	0.000	0.0000	16.00	0.00	160.00	0.00	7200.0	2.27E+11	1.0	30.5	0.000	1.27E+00	0.073	5.520E-01	1.469	0.038	0.0694	16.00	1.36	160.00	149.33
36500	3.15E+09	2.22	67.7	0.000	2.58E+01	0.000	1.226E+00	25.779	0.000	0.0000	16.00	0.00	160.00	0.00	7400.0	2.33E+11	1.0	30.5	0.000	1.25E+00	0.078	5.520E-01	1.452	0.040	0.0737	16.00	1.44	160.00	158.64
36500	3.15E+09	2.28	69.5	0.000	2.65E+01	0.000	1.258E+00	26.476	0.000	0.0000	16.00	0.00	160.00	0.00	7600.0	2.40E+11	1.0	30.5	0.000	1.23E+00	0.083	5.520E-01	1.436	0.042	0.0781	16.00	1.53	160.00	168.02
36500	3.15E+09	2.34	71.3	0.000	2.71E+01	0.000	1.292E+00	27.171	0.000	0.0000	16.00	0.00	160.00	0.00	7800.0	2.46E+11	1.0	30.5	0.000	1.21E+00	0.087	5.520E-01	1.419	0.045	0.0825	16.00	1.61	160.00	177.47
36500	3.15E+09	2.40	73.2	0.000	2.78E+01	#NUM!	1.325E+00	27.868	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	8000.0	2.52E+11	1.0	30.5	0.000	1.19E+00	0.092	5.520E-01	1.404	0.047	0.0869	16.00	1.70	160.00	186.96
36500	3.15E+09	2.46	75.0	0.000	2.85E+01	#NUM!	1.358E+00	28.564	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	8200.0	2.59E+11	1.0	30.5	0.000	1.17E+00	0.097	5.520E-01	1.389	0.049	0.0913	16.00	1.79	160.00	196.52
36500	3.15E+09	2.52	76.8	0.000	2.92E+01	#NUM!	1.391E+00	29.260	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	8400.0	2.65E+11	1.0	30.5	0.000	1.16E+00	0.102	5.520E-01	1.376	0.052	0.0958	16.00	1.87	160.00	206.10
36500	3.15E+09	2.58	78.6	0.000	2.99E+01	#NUM!	1.424E+00	29.957	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	8600.0	2.71E+11	1.0	30.5	0.000	1.14E+00	0.107	5.520E-01	1.362	0.054	0.1002	16.00	1.96	160.00	215.69
36500	3.15E+09	2.64	80.5	0.000	3.06E+01	#NUM!	1.457E+00	30.653	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	8800.0	2.78E+11	1.0	30.5	0.000	1.13E+00	0.111	5.520E-01	1.349	0.056	0.1047	16.00	2.05	160.00	225.30
36500	3.15E+09	2.70	82.3	0.000	3.13E+01	#NUM!	1.490E+00	31.350	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	9000.0	2.84E+11	1.0	30.5	0.000	1.11E+00	0.116	5.520E-01	1.336	0.059	0.1092	16.00	2.14	160.00	234.92
36500	3.15E+09	2.76	84.1	0.000	3.20E+01	#NUM!	1.523E+00	32.048	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	9200.0	2.90E+11	1.0	30.5	0.000	1.10E+00	0.121	5.520E-01	1.324	0.061	0.1136	16.00	2.22	160.00	244.53
36500	3.15E+09	2.82	86.0	0.000	3.27E+01	#NUM!	1.557E+00	32.742	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	9400.0	2.96E+11	1.0	30.5	0.000	1.08E+00	0.126	5.520E-01	1.312	0.063	0.1181	16.00	2.31	160.00	254.13
36500	3.15E+09	2.88	87.8	0.000	3.34E+01	#NUM!	1.590E+00	33.439	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	9600.0	3.03E+11	1.0	30.5	0.000	1.07E+00	0.131	5.520E-01	1.301	0.065	0.1226	16.00	2.40	160.00	263.71
36500	3.15E+09	2.94	89.6	0.000	3.41E+01	#NUM!	1.623E+00	34.135	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	9800.0	3.09E+11	1.0	30.5	0.000	1.05E+00	0.136	5.520E-01	1.290	0.068	0.1270	16.00	2.48	160.00	273.27
36500	3.15E+09	3.00	91.4	0.000	3.48E+01	#NUM!	1.655E+00	34.832	#NUM!	#NUM!	16.00	#NUM!	160.00	#NUM!	10000.0	3.15E+11	1.0	30.5	0.000	1.04E+00	0.141	5.520E-01	1.280	0.070	0.1314	16.00	2.57	160.00	282.80

Note 1: *Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms*
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Dibenzo
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.136
v=K*i/ne	Linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W =	((v-m)*x)/(2*D)	
X =	(R*x-m*t)/(SQRT(4*D*R*t))	
Y =	((v+m)*x)/(2*D)	
Z =	(R*x+m*t)/(SQRT(4*D*R*t))	
m=	v*(SQRT(1+((4*u*D)/v^2))	
ERFC0=	1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g	[redacted]		
	n	[redacted]	foc	[redacted]	Kd (theoretica	26	L/kg
	ne	0.434	R	65.21	Kd, cap	[redacted]	L/kg
	g	[redacted] gm/cm3	u	[redacted] /d	SQS	0	mg/kgOC
	DL,sed	[redacted] ft	d	[redacted] ft	WQC		ug/L (none)
	L	[redacted] ft	Co	[redacted] ug/L	Dw	[redacted]	cm2/sec
Results:	p	1.4575 gm/cm3	d	0.8144 cm			
	i	ft/ft	u	0 /s			
	v	[redacted] ft/d	Kd,cap	26 ml/g			
	v	7.056E-08 cm/s	D	3.1E-06 cm2/sec			
			m	7.056E-08 cm/sec	(m=v for u=0)		

C(x,t)	Porewater concentration in cap (ug/L)	Conversions:	
Co	influent porewater concentration (ug/L)	1 µg =	1.000E-06 gm
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.0 1g/100ml
d	dispersivity (cm)	1 % wt =	1.00E+04 mg/L
D	dispersion coefficient (cm2/s)	1 mg/L =	1000 ug/l
Dw	binary diffusivity of chemical in water (cm2/s)	1 day =	86400 sec
DL,sed	consolidation depth of sediment (ft)		
foc	cap material organic carbon fraction (/)	1 foot =	30.48 cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278 cm/sec
HL	half life (d)		
i	head gradient (not used)		
Kd	theoretical distribution coefficient (L/kg)		
Kd,cap	cap distribution coefficient (L/kg)		
Koc	soil-water partition coefficient (g/g)		
L	thickness of cap (ft)		
n	porosity (/)		
ne	effective porosity (/)		
p	bulk density (gm/cm3)		
R	retardation factor (/)		
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)		
t	time (s)		
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)		
u	first order decay constant (1/s)		
v	average linear groundwater velocity (cm/s) (measured)		
x	distance from cap bottom (cm)		
WQC	State Water Quality Criterion (ug/L)		

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap)	USEPA 1998	

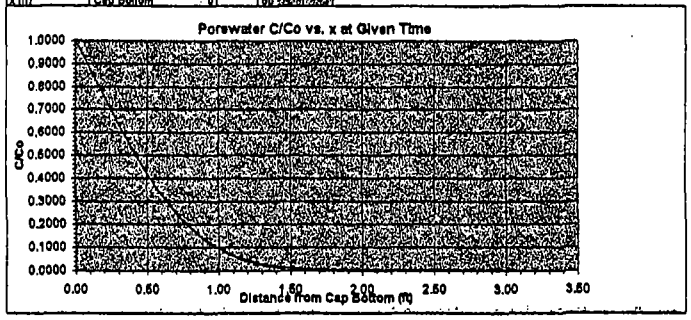
Cap thickness lost due to expression of porewater during consolidation (ft)

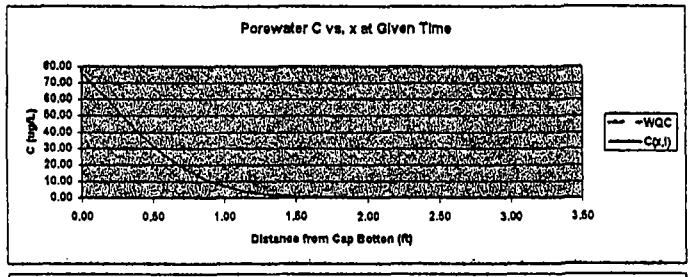
Tl,consol =	0.037 feet	(typically negligible)

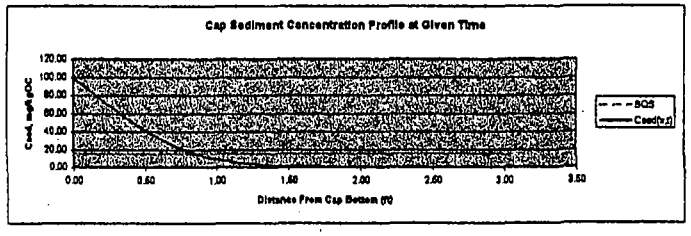
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[redacted]	[redacted]
x (ft)	Cap Bottom	0	Top	[redacted]



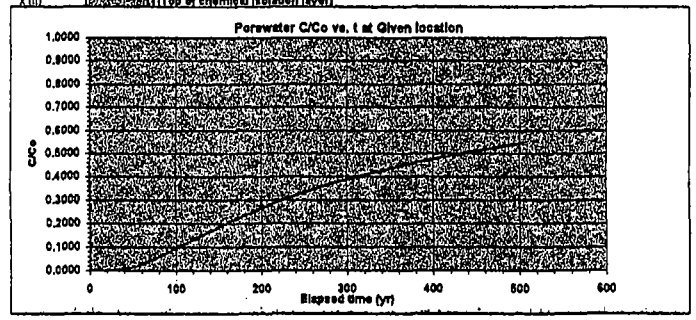


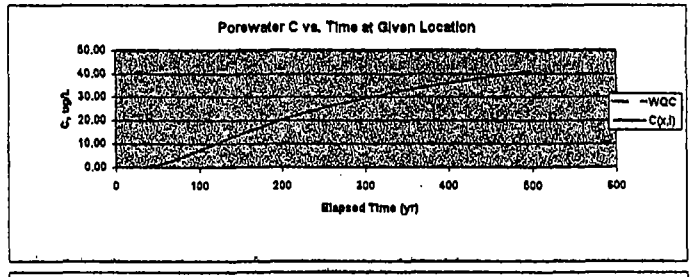


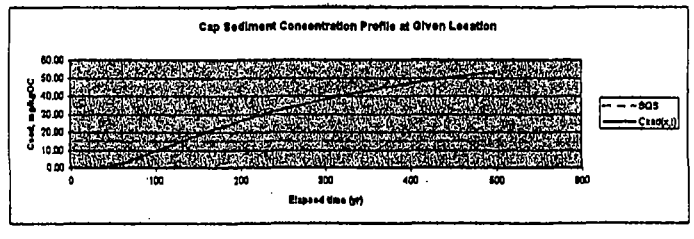
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	999
x (ft)	[redacted]	[redacted]	(Top of chemical isolation layer)	







Chemical Isolation Analysis for Dibenzofuran
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.09E-01	1.122	0.000E+00	0.169	0.878	1.0000	0.00	75.85	15.00	56.61
36500	3.15E+09	0.06	1.8	0.000	-3.26E-02	1.037	3.312E-02	0.185	0.794	0.9288	0.00	70.43	15.00	51.57
36500	3.15E+09	0.12	3.7	0.000	4.35E-02	0.951	6.624E-02	0.201	0.712	0.8556	0.00	64.91	15.00	46.39
36500	3.15E+09	0.18	5.5	0.000	1.20E-01	0.866	9.935E-02	0.337	0.633	0.7826	0.00	59.36	15.00	77.17
36500	3.15E+09	0.24	7.3	0.000	1.96E-01	0.782	1.325E-01	0.413	0.559	0.7099	0.00	53.86	15.00	70.00
36500	3.15E+09	0.30	9.1	0.000	2.72E-01	0.700	1.656E-01	0.489	0.489	0.6385	0.00	48.44	15.00	62.97
36500	3.15E+09	0.36	11.0	0.000	3.48E-01	0.622	1.987E-01	0.566	0.424	0.5697	0.00	43.21	15.00	56.17
36500	3.15E+09	0.42	12.8	0.000	4.24E-01	0.548	2.318E-01	0.642	0.364	0.5038	0.00	38.21	15.00	49.67
36500	3.15E+09	0.48	14.6	0.000	5.00E-01	0.479	2.649E-01	0.719	0.310	0.4416	0.00	33.49	15.00	43.64
36500	3.15E+09	0.54	16.5	0.000	5.77E-01	0.415	2.981E-01	0.794	0.261	0.3838	0.00	29.09	15.00	37.82
36500	3.15E+09	0.60	18.3	0.000	6.53E-01	0.356	3.312E-01	0.870	0.218	0.3301	0.00	25.04	15.00	32.55
36500	3.15E+09	0.66	20.1	0.000	7.29E-01	0.303	3.643E-01	0.946	0.181	0.2814	0.00	21.35	15.00	27.75
36500	3.15E+09	0.72	21.9	0.000	8.06E-01	0.256	3.974E-01	1.023	0.148	0.2377	0.00	18.03	15.00	23.44
36500	3.15E+09	0.78	23.8	0.000	8.81E-01	0.213	4.305E-01	1.099	0.120	0.1988	0.00	15.08	15.00	19.60
36500	3.15E+09	0.84	25.6	0.000	9.57E-01	0.176	4.636E-01	1.175	0.097	0.1647	0.00	12.49	15.00	16.24
36500	3.15E+09	0.90	27.4	0.000	1.03E+00	0.144	4.968E-01	1.251	0.077	0.1351	0.00	10.25	15.00	13.32
36500	3.15E+09	0.96	29.3	0.000	1.11E+00	0.117	5.299E-01	1.327	0.061	0.1097	0.00	8.32	15.00	10.82
36500	3.15E+09	1.02	31.1	0.000	1.19E+00	0.094	5.630E-01	1.403	0.047	0.0882	0.00	6.69	15.00	8.70
36500	3.15E+09	1.08	32.9	0.000	1.26E+00	0.074	5.961E-01	1.479	0.036	0.0702	0.00	5.33	15.00	6.92
36500	3.15E+09	1.14	34.7	0.000	1.34E+00	0.058	6.292E-01	1.556	0.028	0.0553	0.00	4.20	15.00	5.45
36500	3.15E+09	1.20	36.6	0.000	1.41E+00	0.045	6.624E-01	1.632	0.021	0.0431	0.00	3.27	15.00	4.25
36500	3.15E+09	1.26	38.4	0.000	1.49E+00	0.035	6.955E-01	1.708	0.016	0.0333	0.00	2.52	15.00	3.28
36500	3.15E+09	1.32	40.2	0.000	1.57E+00	0.027	7.286E-01	1.784	0.012	0.0254	0.00	1.93	15.00	2.51
36500	3.15E+09	1.38	42.1	0.000	1.64E+00	0.020	7.617E-01	1.860	0.009	0.0192	0.00	1.46	15.00	1.89
36500	3.15E+09	1.44	43.9	0.000	1.72E+00	0.015	7.948E-01	1.936	0.006	0.0144	0.00	1.09	15.00	1.42
36500	3.15E+09	1.50	45.7	0.000	1.79E+00	0.011	8.279E-01	2.012	0.004	0.0106	0.00	0.81	15.00	1.05
36500	3.15E+09	1.56	47.6	0.000	1.87E+00	0.008	8.611E-01	2.089	0.003	0.0078	0.00	0.59	15.00	0.77
36500	3.15E+09	1.62	49.4	0.000	1.95E+00	0.006	8.942E-01	2.165	0.002	0.0056	0.00	0.43	15.00	0.56
36500	3.15E+09	1.68	51.2	0.000	2.02E+00	0.004	9.273E-01	2.241	0.002	0.0040	0.00	0.31	15.00	0.40
36500	3.15E+09	1.74	53.0	0.000	2.10E+00	0.003	9.604E-01	2.317	0.001	0.0029	0.00	0.22	15.00	0.28
36500	3.15E+09	1.80	54.9	0.000	2.18E+00	0.002	9.936E-01	2.393	0.001	0.0020	0.00	0.15	15.00	0.20
36500	3.15E+09	1.86	56.7	0.000	2.25E+00	0.001	1.027E+00	2.469	0.000	0.0014	0.00	0.11	15.00	0.14
36500	3.15E+09	1.92	58.5	0.000	2.33E+00	0.001	1.060E+00	2.545	0.000	0.0010	0.00	0.07	15.00	0.09
36500	3.15E+09	1.98	60.4	0.000	2.40E+00	0.001	1.093E+00	2.622	0.000	0.0006	0.00	0.05	15.00	0.06
36500	3.15E+09	2.04	62.2	0.000	2.48E+00	0.000	1.126E+00	2.698	0.000	0.0004	0.00	0.03	15.00	0.04
36500	3.15E+09	2.10	64.0	0.000	2.56E+00	0.000	1.159E+00	2.774	0.000	0.0003	0.00	0.02	15.00	0.03
36500	3.15E+09	2.16	65.9	0.000	2.63E+00	0.000	1.192E+00	2.850	0.000	0.0002	0.00	0.01	15.00	0.02
36500	3.15E+09	2.22	67.7	0.000	2.71E+00	0.000	1.225E+00	2.926	0.000	0.0001	0.00	0.01	15.00	0.01
36500	3.15E+09	2.28	69.5	0.000	2.78E+00	0.000	1.258E+00	3.002	0.000	0.0001	0.00	0.01	15.00	0.01
36500	3.15E+09	2.34	71.3	0.000	2.86E+00	0.000	1.292E+00	3.079	0.000	0.0001	0.00	0.00	15.00	0.00
36500	3.15E+09	2.40	73.2	0.000	2.94E+00	0.000	1.325E+00	3.155	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.46	75.0	0.000	3.01E+00	0.000	1.358E+00	3.231	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.52	76.8	0.000	3.09E+00	0.000	1.391E+00	3.307	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.58	78.6	0.000	3.17E+00	0.000	1.424E+00	3.383	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.64	80.5	0.000	3.24E+00	0.000	1.457E+00	3.459	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.70	82.3	0.000	3.32E+00	0.000	1.490E+00	3.535	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.76	84.1	0.000	3.39E+00	0.000	1.523E+00	3.612	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.82	86.0	0.000	3.47E+00	0.000	1.557E+00	3.688	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.88	87.8	0.000	3.55E+00	0.000	1.590E+00	3.764	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	2.94	89.6	0.000	3.62E+00	0.000	1.623E+00	3.840	0.000	0.0000	0.00	0.00	15.00	0.00
36500	3.15E+09	3.00	91.4	0.000	3.70E+00	0.000	1.656E+00	3.916	0.000	0.0000	0.00	0.00	15.00	0.00

INPUT				CALCULATIONS						OUTPUT				
t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.820E-01	#DIV/0!	#DIV/0!	#DIV/0!	0.00	#DIV/0!	15.00	#DIV/0!
10.0	3.15E+08	1.0	30.5	0.000	3.96E+00	0.000	5.820E-01	4.048	0.000	0.0000	0.00	0.00	15.00	0.00
20.0	6.31E+08	1.0	30.5	0.000	2.78E+00	0.000	5.820E-01	2.887	0.000	0.0001	0.00	0.01	15.00	0.01
30.0	9.46E+08	1.0	30.5	0.000	2.26E+00	0.001	5.820E-01	2.377	0.001	0.0014	0.00	0.10	15.00	0.14
40.0	1.26E+09	1.0	30.5	0.000	1.94E+00	0.008	5.820E-01	2.075	0.003	0.0060	0.00	0.45	15.00	0.59
50.0	1.58E+09	1.0	30.5	0.000	1.72E+00	0.015	5.820E-01	1.872	0.008	0.0146	0.00	1.11	15.00	1.44
60.0	1.89E+09	1.0	30.5	0.000	1.56E+00	0.029	5.820E-01	1.723	0.015	0.0269	0.00	2.04	15.00	2.66
70.0	2.21E+09	1.0	30.5	0.000	1.43E+00	0.044	5.820E-01	1.609	0.023	0.0418	0.00	3.17	15.00	4.12
80.0	2.52E+09	1.0	30.5	0.000	1.32E+00	0.062	5.820E-01	1.516	0.032	0.0588	0.00	4.44	15.00	5.76
90.0	2.84E+09	1.0	30.5	0.000	1.23E+00	0.081	5.820E-01	1.441	0.042	0.0766	0.00	5.80	15.00	7.54
100.0	3.15E+09	1.0	30.5	0.000	1.16E+00	0.101	5.820E-01	1.378	0.051	0.0950	0.00	7.20	15.00	9.36
110.0	3.47E+09	1.0	30.5	0.000	1.10E+00	0.121	5.820E-01	1.324	0.061	0.1136	0.00	8.62	15.00	11.21
120.0	3.78E+09	1.0	30.5	0.000	1.04E+00	0.142	5.820E-01	1.276	0.071	0.1322	0.00	10.03	15.00	13.04
130.0	4.10E+09	1.0	30.5	0.000	9.89E-01	0.162	5.820E-01	1.237	0.080	0.1506	0.00	11.42	15.00	14.85
140.0	4.42E+09	1.0	30.5	0.000	9.44E-01	0.182	5.820E-01	1.201	0.089	0.1686	0.00	12.78	15.00	16.62
150.0	4.73E+09	1.0	30.5	0.000	9.03E-01	0.202	5.820E-01	1.169	0.098	0.1860	0.00	14.11	15.00	18.34
160.0	5.05E+09	1.0	30.5	0.000	8.66E-01	0.221	5.820E-01	1.141	0.107	0.2030	0.00	15.40	15.00	20.02
170.0	5.36E+09	1.0	30.5	0.000	8.32E-01	0.240	5.820E-01	1.115	0.116	0.2194	0.00	16.64	15.00	21.64
180.0	5.68E+09	1.0	30.5	0.000	8.00E-01	0.259	5.820E-01	1.092	0.123	0.2354	0.00	17.85	15.00	23.21
190.0	5.99E+09	1.0	30.5	0.000	7.71E-01	0.276	5.820E-01	1.071	0.130	0.2507	0.00	19.02	15.00	24.72
200.0	6.31E+09	1.0	30.5	0.000	7.44E-01	0.293	5.820E-01	1.051	0.137	0.2656	0.00	20.14	15.00	26.18
210.0	6.62E+08	1.0	30.5	0.000	7.19E-01	0.310	5.820E-01	1.033	0.144	0.2799	0.00	21.23	15.00	27.59
220.0	6.94E+08	1.0	30.5	0.000	6.94E-01	0.326	5.820E-01	1.017	0.150	0.2936	0.00	22.27	15.00	28.95
230.0	7.25E+08	1.0	30.5	0.000	6.72E-01	0.342	5.820E-01	1.002	0.157	0.3069	0.00	23.28	15.00	30.27
240.0	7.57E+08	1.0	30.5	0.000	6.51E-01	0.357	5.820E-01	0.988	0.162	0.3198	0.00	24.26	15.00	31.53
250.0	7.88E+08	1.0	30.5	0.000	6.31E-01	0.372	5.820E-01	0.975	0.168	0.3322	0.00	25.19	15.00	32.75
260.0	8.20E+08	1.0	30.5	0.000	6.12E-01	0.387	5.820E-01	0.962	0.173	0.3441	0.00	26.10	15.00	33.93
270.0	8.51E+08	1.0	30.5	0.000	5.94E-01	0.401	5.820E-01	0.951	0.178	0.3557	0.00	26.98	15.00	35.07
280.0	8.83E+08	1.0	30.5	0.000	5.77E-01	0.416	5.820E-01	0.940	0.184	0.3668	0.00	27.82	15.00	36.17
290.0	9.15E+08	1.0	30.5	0.000	5.60E-01	0.429	5.820E-01	0.930	0.188	0.3776	0.00	28.64	15.00	37.23
300.0	9.46E+08	1.0	30.5	0.000	5.44E-01	0.441	5.820E-01	0.921	0.193	0.3880	0.00	29.43	15.00	38.26
310.0	9.78E+08	1.0	30.5	0.000	5.29E-01	0.454	5.820E-01	0.912	0.197	0.3981	0.00	30.20	15.00	39.25
320.0	1.01E+10	1.0	30.5	0.000	5.15E-01	0.466	5.820E-01	0.904	0.201	0.4078	0.00	30.94	15.00	40.22
330.0	1.04E+10	1.0	30.5	0.000	5.01E-01	0.479	5.820E-01	0.896	0.205	0.4173	0.00	31.65	15.00	41.16
340.0	1.07E+10	1.0	30.5	0.000	4.88E-01	0.490	5.820E-01	0.889	0.209	0.4264	0.00	32.34	15.00	42.08
350.0	1.10E+10	1.0	30.5	0.000	4.75E-01	0.502	5.820E-01	0.882	0.212	0.4353	0.00	33.02	15.00	42.92
360.0	1.14E+10	1.0	30.5	0.000	4.63E-01	0.513	5.820E-01	0.875	0.216	0.4439	0.00	33.67	15.00	43.77
370.0	1.17E+10	1.0	30.5	0.000	4.51E-01	0.524	5.820E-01	0.869	0.219	0.4522	0.00	34.30	15.00	44.59
380.0	1.20E+10	1.0	30.5	0.000	4.39E-01	0.535	5.820E-01	0.863	0.222	0.4603	0.00	34.92	15.00	45.39
390.0	1.23E+10	1.0	30.5	0.000	4.28E-01	0.546	5.820E-01	0.857	0.225	0.4682	0.00	35.51	15.00	46.16
400.0	1.26E+10	1.0	30.5	0.000	4.17E-01	0.555	5.820E-01	0.852	0.228	0.4758	0.00	36.09	15.00	46.92
410.0	1.29E+10	1.0	30.5	0.000	4.07E-01	0.565	5.820E-01	0.847	0.231	0.4832	0.00	36.65	15.00	47.65
420.0	1.32E+10	1.0	30.5	0.000	3.96E-01	0.576	5.820E-01	0.842	0.234	0.4904	0.00	37.20	15.00	48.36
430.0	1.36E+10	1.0	30.5	0.000	3.87E-01	0.586	5.820E-01	0.837	0.236	0.4974	0.00	37.73	15.00	49.05
440.0	1.39E+10	1.0	30.5	0.000	3.77E-01	0.594	5.820E-01	0.833	0.239	0.5043	0.00	38.25	15.00	49.72
450.0	1.42E+10	1.0	30.5	0.000	3.68E-01	0.603	5.820E-01	0.829	0.241	0.5109	0.00	38.76	15.00	50.39
460.0	1.45E+10	1.0	30.5	0.000	3.59E-01	0.612	5.820E-01	0.825	0.243	0.5174	0.00	39.24	15.00	51.02
470.0	1.48E+10	1.0	30.5	0.000	3.50E-01	0.621	5.820E-01	0.821	0.246	0.5237	0.00	39.72	15.00	51.64
480.0	1.51E+10	1.0	30.5	0.000	3.41E-01	0.630	5.820E-01	0.817	0.248	0.5298	0.00	40.19	15.00	52.24
490.0	1.55E+10	1.0	30.5	0.000	3.33E-01	0.638	5.820E-01	0.814	0.250	0.5358	0.00	40.64	15.00	52.83
500.0	1.58E+10	1.0	30.5	0.000	3.24E-01	0.646	5.820E-01	0.811	0.252	0.5416	0.00	41.08	15.00	53.41

Note 1: Adapted from Equation B-26, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Mercury
PSR Superfund Site

Advective-Dispersive Transport Formulae:

Kd=foc*Koc		Watson 1991, p.186
R=1+(Kd,cap*p)/ne		Watson 1991, p.184
p=g(1-n)		Krynine and Judd,1957, p.138
v=K*i/ne		linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap		Partitioning definition
D = Dw(n^1/3) + dv		[see note 1)
d = 0.01*L		T. Meyers 2002 (USACE)
C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W =	((v+m)*x)/(2*D)	
X =	(R*x-m*t)/(SQRT(4*D*R*t))	
Y =	((v-m)*x)/(2*D)	
Z =	(R*x+m*t)/(SQRT(4*D*R*t))	
m=	v*(SQRT(1+((4*v*D)/v^2))	
ERFC()=	1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00036278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DL,sed / (n+p*Kd,cap)	USEPA 1998

Cap thickness lost due to expression of porewater during consolidation (ft)

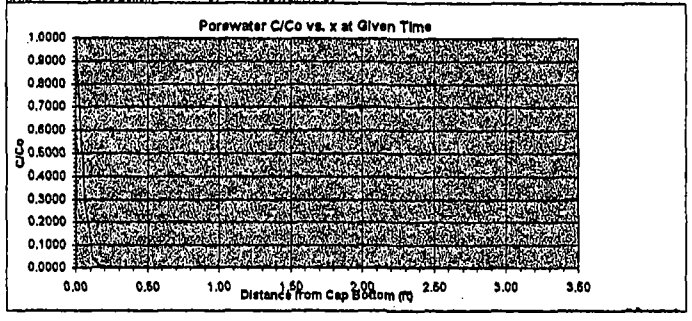
Tl,consol =	0.000 feet	(typically negligible)

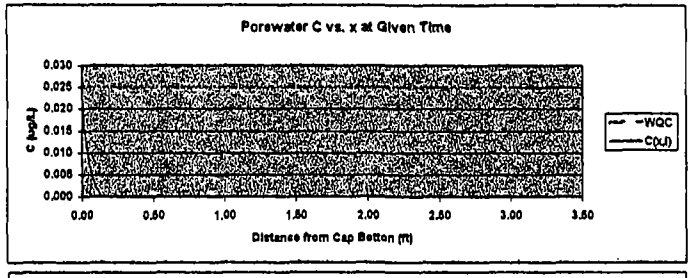
		Hydraulic Calculations		Transport Calculations		Chemical Data	
Data:	Kh	[illegible]	ft/d	Koc	[illegible] ml/g	[illegible]	
	n	[illegible]		foc	[illegible]	Kd (theoretical2500 - 750, L/kg	
	ne	[illegible]		R	8098.22	Kd, cap	[illegible] L/kg
	g	[illegible]	gm/cm3	u	[illegible] /d	SQS	[illegible] mg/kg
	DL,sed	[illegible]	ft	d	[illegible] ft	WQC	[illegible] ug/L
	L	[illegible]	ft	Co	[illegible] ug/L	Dw	[illegible] cm2/sec
Results:	p	1.4576	gm/cm3	d	0.9144	cm	
	i		ft/ft	u	0	/s	
	v	[illegible]	ft/d	Kd,cap	2500	ml/g	
	v	7.056E-06	cm/s	D	3.9E-06	cm2/sec	
				m	7.056E-06	cm/sec	(m=v for u=0)

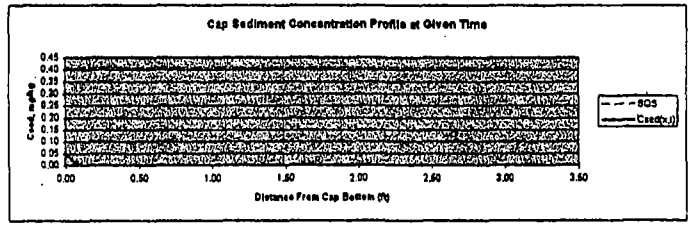
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	[illegible]	
x (ft)	Cap Bottom	0	Top of Cap	[illegible]	



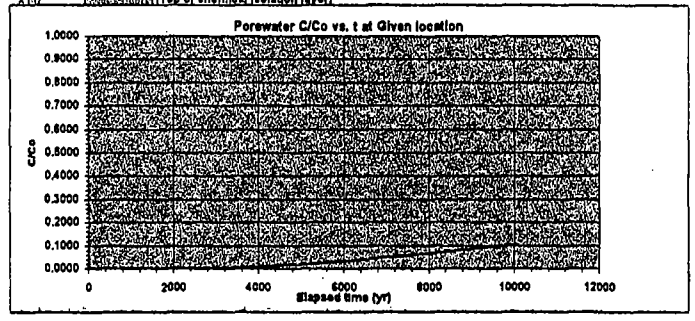


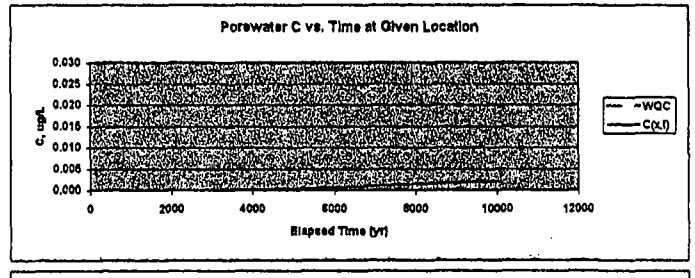


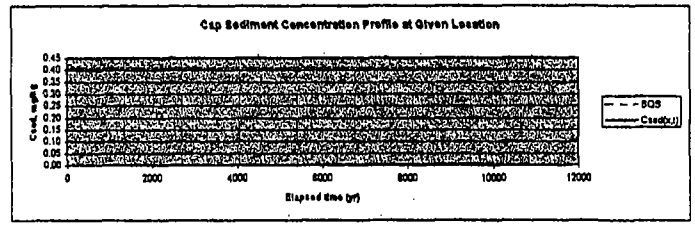
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	10000	
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)		







Chemical Isolation Analysis for Mercury
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kg)	Csed(x,t) (mg/kg)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kg)	Csed(x,t) (mg/kg)
36500	3.15E+09	0.00	0.0	0.000	-1.12E-02	1.013	0.000E+00	0.011	0.987	1.0000	0.025	0.02	0.41	0.05	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	6.52OE-01	#DIV/0!	#DIV/0!	#DIV/0!	0.025	#DIV/0!	0.41	#DIV/0!
36500	3.15E+09	0.08	1.8	0.000	7.31E-01	0.301	3.312E-02	0.754	0.247	0.2867	0.025	0.01	0.41	0.01	200.0	6.31E+09	1.0	30.5	0.000	8.73E+00	0.000	6.520E-01	8.764	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.12	3.7	0.000	1.47E+00	0.037	6.624E-02	1.498	0.034	0.0370	0.025	0.00	0.41	0.00	400.0	1.26E+10	1.0	30.5	0.000	6.18E+00	0.000	6.520E-01	6.209	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.16	5.5	0.000	2.22E+00	0.002	9.936E-02	2.238	0.002	0.0017	0.025	0.00	0.41	0.00	600.0	1.89E+10	1.0	30.5	0.000	5.02E+00	0.000	6.520E-01	5.078	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.24	7.3	0.000	2.96E+00	0.000	1.325E-01	2.981	0.000	0.0000	0.025	0.00	0.41	0.00	800.0	2.52E+10	1.0	30.5	0.000	4.34E+00	0.000	6.520E-01	4.406	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.30	9.1	0.000	3.70E+00	0.000	1.656E-01	3.723	0.000	0.0000	0.025	0.00	0.41	0.00	1000.0	3.16E+10	1.0	30.5	0.000	3.88E+00	0.000	6.520E-01	3.948	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.36	11.0	0.000	4.44E+00	0.000	1.987E-01	4.465	0.000	0.0000	0.025	0.00	0.41	0.00	1200.0	3.78E+10	1.0	30.5	0.000	3.53E+00	0.000	6.520E-01	3.610	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.42	12.8	0.000	5.19E+00	0.000	2.318E-01	5.208	0.000	0.0000	0.025	0.00	0.41	0.00	1400.0	4.42E+10	1.0	30.5	0.000	3.28E+00	0.000	6.520E-01	3.346	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.48	14.6	0.000	5.93E+00	0.000	2.649E-01	5.950	0.000	0.0000	0.025	0.00	0.41	0.00	1600.0	5.05E+10	1.0	30.5	0.000	3.06E+00	0.000	6.520E-01	3.138	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.54	16.5	0.000	6.67E+00	0.000	2.991E-01	6.692	0.000	0.0000	0.025	0.00	0.41	0.00	1800.0	5.68E+10	1.0	30.5	0.000	2.87E+00	0.000	6.520E-01	2.964	0.000	0.0000	0.025	0.00	0.41	0.00
36500	3.15E+09	0.60	18.3	0.000	7.41E+00	0.000	3.312E-01	7.435	0.000	0.0000	0.025	0.00	0.41	0.00	2000.0	6.31E+10	1.0	30.5	0.000	2.72E+00	0.000	6.520E-01	2.816	0.000	0.0001	0.025	0.00	0.41	0.00
36500	3.15E+09	0.66	20.1	0.000	8.15E+00	0.000	3.643E-01	8.177	0.000	0.0000	0.025	0.00	0.41	0.00	2200.0	6.94E+10	1.0	30.5	0.000	2.59E+00	0.000	6.520E-01	2.690	0.000	0.0003	0.025	0.00	0.41	0.00
36500	3.15E+09	0.72	21.9	0.000	8.90E+00	0.000	3.974E-01	8.919	0.000	0.0000	0.025	0.00	0.41	0.00	2400.0	7.57E+10	1.0	30.5	0.000	2.47E+00	0.000	6.520E-01	2.580	0.000	0.0005	0.025	0.00	0.41	0.00
36500	3.15E+09	0.78	23.8	0.000	9.64E+00	0.000	4.305E-01	9.662	0.000	0.0000	0.025	0.00	0.41	0.00	2600.0	8.20E+10	1.0	30.5	0.000	2.37E+00	0.001	6.520E-01	2.483	0.000	0.0008	0.025	0.00	0.41	0.00
36500	3.15E+09	0.84	25.6	0.000	1.04E+01	0.000	4.636E-01	10.404	0.000	0.0000	0.025	0.00	0.41	0.00	2800.0	8.83E+10	1.0	30.5	0.000	2.29E+00	0.001	6.520E-01	2.397	0.001	0.0012	0.025	0.00	0.41	0.00
36500	3.15E+09	0.90	27.4	0.000	1.11E+01	0.000	4.966E-01	11.146	0.000	0.0000	0.025	0.00	0.41	0.00	3000.0	9.46E+10	1.0	30.5	0.000	2.20E+00	0.002	6.520E-01	2.320	0.001	0.0018	0.025	0.00	0.41	0.00
36500	3.15E+09	0.96	29.3	0.000	1.19E+01	0.000	5.299E-01	11.889	0.000	0.0000	0.025	0.00	0.41	0.00	3200.0	1.01E+11	1.0	30.5	0.000	2.12E+00	0.003	6.520E-01	2.250	0.001	0.0026	0.025	0.00	0.41	0.00
36500	3.15E+09	1.02	31.1	0.000	1.26E+01	0.000	5.630E-01	12.631	0.000	0.0000	0.025	0.00	0.41	0.00	3400.0	1.07E+11	1.0	30.5	0.000	2.06E+00	0.004	6.520E-01	2.187	0.002	0.0038	0.025	0.00	0.41	0.00
36500	3.15E+09	1.08	32.9	0.000	1.34E+01	0.000	5.961E-01	13.373	0.000	0.0000	0.025	0.00	0.41	0.00	3600.0	1.14E+11	1.0	30.5	0.000	2.00E+00	0.005	6.520E-01	2.129	0.003	0.0047	0.025	0.00	0.41	0.00
36500	3.15E+09	1.14	34.7	0.000	1.41E+01	0.000	6.292E-01	14.116	0.000	0.0000	0.025	0.00	0.41	0.00	3800.0	1.20E+11	1.0	30.5	0.000	1.94E+00	0.006	6.520E-01	2.076	0.003	0.0060	0.025	0.00	0.41	0.00
36500	3.15E+09	1.20	36.5	0.000	1.48E+01	0.000	6.624E-01	14.858	0.000	0.0000	0.025	0.00	0.41	0.00	4000.0	1.26E+11	1.0	30.5	0.000	1.89E+00	0.009	6.520E-01	2.027	0.004	0.0074	0.025	0.00	0.41	0.00
36500	3.15E+09	1.26	38.4	0.000	1.55E+01	0.000	6.955E-01	15.601	0.000	0.0000	0.025	0.00	0.41	0.00	4200.0	1.32E+11	1.0	30.5	0.000	1.84E+00	0.009	6.520E-01	1.981	0.005	0.0091	0.025	0.00	0.41	0.00
36500	3.15E+09	1.32	40.2	0.000	1.63E+01	0.000	7.286E-01	16.343	0.000	0.0000	0.025	0.00	0.41	0.00	4400.0	1.39E+11	1.0	30.5	0.000	1.79E+00	0.011	6.520E-01	1.939	0.006	0.0109	0.025	0.00	0.41	0.00
36500	3.15E+09	1.38	42.1	0.000	1.71E+01	0.000	7.617E-01	17.085	0.000	0.0000	0.025	0.00	0.41	0.00	4600.0	1.45E+11	1.0	30.5	0.000	1.75E+00	0.013	6.520E-01	1.900	0.007	0.0130	0.025	0.00	0.41	0.00
36500	3.15E+09	1.44	43.9	0.000	1.78E+01	0.000	7.948E-01	17.828	0.000	0.0000	0.025	0.00	0.41	0.00	4800.0	1.51E+11	1.0	30.5	0.000	1.71E+00	0.016	6.520E-01	1.863	0.008	0.0152	0.025	0.00	0.41	0.00
36500	3.15E+09	1.50	45.7	0.000	1.85E+01	0.000	8.279E-01	18.570	0.000	0.0000	0.025	0.00	0.41	0.00	5000.0	1.58E+11	1.0	30.5	0.000	1.67E+00	0.018	6.520E-01	1.829	0.010	0.0176	0.025	0.00	0.41	0.00
36500	3.15E+09	1.56	47.5	0.000	1.93E+01	0.000	8.611E-01	19.312	0.000	0.0000	0.025	0.00	0.41	0.00	5200.0	1.64E+11	1.0	30.5	0.000	1.64E+00	0.021	6.520E-01	1.796	0.011	0.0200	0.025	0.00	0.41	0.00
36500	3.15E+09	1.62	49.4	0.000	2.00E+01	0.000	8.942E-01	20.056	0.000	0.0000	0.025	0.00	0.41	0.00	5400.0	1.70E+11	1.0	30.5	0.000	1.60E+00	0.024	6.520E-01	1.766	0.013	0.0226	0.025	0.00	0.41	0.00
36500	3.15E+09	1.68	51.2	0.000	2.08E+01	0.000	9.273E-01	20.797	0.000	0.0000	0.025	0.00	0.41	0.00	5600.0	1.77E+11	1.0	30.5	0.000	1.57E+00	0.026	6.520E-01	1.737	0.014	0.0254	0.025	0.00	0.41	0.00
36500	3.15E+09	1.74	53.0	0.000	2.15E+01	0.000	9.604E-01	21.539	0.000	0.0000	0.025	0.00	0.41	0.00	5800.0	1.83E+11	1.0	30.5	0.000	1.54E+00	0.029	6.520E-01	1.710	0.016	0.0283	0.025	0.00	0.41	0.00
36500	3.15E+09	1.80	54.8	0.000	2.23E+01	0.000	9.935E-01	22.282	0.000	0.0000	0.025	0.00	0.41	0.00	6000.0	1.89E+11	1.0	30.5	0.000	1.51E+00	0.033	6.520E-01	1.684	0.017	0.0313	0.025	0.00	0.41	0.00
36500	3.15E+09	1.86	56.7	0.000	2.30E+01	0.000	1.027E+00	23.024	0.000	0.0000	0.025	0.00	0.41	0.00	6200.0	1.96E+11	1.0	30.5	0.000	1.48E+00	0.036	6.520E-01	1.659	0.019	0.0344	0.025	0.00	0.41	0.00
36500	3.15E+09	1.92	58.5	0.000	2.37E+01	0.000	1.060E+00	23.768	0.000	0.0000	0.025	0.00	0.41	0.00	6400.0	2.02E+11	1.0	30.5	0.000	1.46E+00	0.039	6.520E-01	1.636	0.021	0.0376	0.025	0.00	0.41	0.00
36500	3.15E+09	1.98	60.4	0.000	2.45E+01	0.000	1.093E+00	24.509	0.000	0.0000	0.025	0.00	0.41	0.00	6600.0	2.08E+11	1.0	30.5	0.000	1.43E+00	0.043	6.520E-01	1.614	0.022	0.0409	0.025	0.00	0.41	0.00
36500	3.15E+09	2.04	62.2	0.000	2.52E+01	0.000	1.126E+00	25.251	0.000	0.0000	0.025	0.00	0.41	0.00	6800.0	2.14E+11	1.0	30.5	0.000	1.41E+00	0.048	6.520E-01	1.592	0.024	0.0443	0.025	0.00	0.41	0.00
36500	3.15E+09	2.10	64.0	0.000	2.60E+01	0.000	1.159E+00	25.993	0.000	0.0000	0.025	0.00	0.41	0.00	7000.0	2.21E+11	1.0	30.5	0.000	1.39E+00	0.050	6.520E-01	1.572	0.026	0.0478	0.025	0.00	0.41	0.00
36500	3.15E+09	2.16	65.8	0.000	2.67E+01	0.000	1.192E+00	26.736	0.000	0.0000	0.025	0.00	0.41	0.00	7200.0	2.27E+11	1.0	30.5	0.000	1.36E+00	0.054	6.520E-01	1.553	0.028	0.0513	0.025	0.00	0.41	0.00
36500	3.15E+09	2.22	67.7	0.000	2.75E+01	#NUM!	1.225E+00	27.478	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	7400.0	2.33E+11	1.0	30.5	0.000	1.34E+00	0.056	6.520E-01	1.534	0.030	0.0549	0.025	0.00	0.41	0.00
36500	3.15E+09	2.28	69.5	0.000	2.82E+01	#NUM!	1.258E+00	28.220	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	7600.0	2.40E+11	1.0	30.5	0.000	1.32E+00	0.062	6.520E-01	1.516	0.032	0.0585	0.025	0.00	0.41	0.00
36500	3.15E+09	2.34	71.3	0.000	2.89E+01	#NUM!	1.292E+00	28.963	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	7800.0	2.46E+11	1.0	30.5	0.000	1.30E+00	0.065	6.520E-01	1.499	0.034	0.0622	0.025	0.00	0.41	0.00
36500	3.15E+09	2.40	73.2	0.000	2.97E+01	#NUM!	1.325E+00	29.705	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	8000.0	2.52E+11	1.0	30.5	0.000	1.28E+00	0.069	6.520E-01	1.483	0.036	0.0660	0.025	0.00	0.41	0.00
36500	3.15E+09	2.46	75.0	0.000	3.04E+01	#NUM!	1.358E+00	30.448	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	8200.0	2.59E+11	1.0	30.5	0.000	1.27E+00	0.074	6.520E-01	1.467	0.038	0.0698	0.025	0.00	0.41	0.00
36500	3.15E+09	2.52	76.8	0.000	3.12E+01	#NUM!	1.391E+00	31.190	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	8400.0	2.65E+11	1.0	30.5	0.000	1.25E+00	0.078	6.520E-01	1.452	0.040	0.0736	0.025	0.00	0.41	0.00
36500	3.15E+09	2.58	78.6	0.000	3.19E+01	#NUM!	1.424E+00	31.932	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	8600.0	2.71E+11	1.0	30.5	0.000	1.23E+00	0.082	6.520E-01	1.438	0.042	0.0774	0.025	0.00	0.41	0.00
36500	3.15E+09	2.64	80.5	0.000	3.27E+01	#NUM!	1.457E+00	32.675	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	8800.0	2.78E+11	1.0	30.5	0.000	1.21E+00	0.086	6.520E-01	1.424	0.044	0.0813	0.025	0.00	0.41	0.00
36500	3.15E+09	2.70	82.3	0.000	3.34E+01	#NUM!	1.490E+00	33.417	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	9000.0	2.84E+11	1.0	30.5	0.000	1.20E+00	0.090	6.520E-01	1.410	0.046	0.0851	0.025	0.00	0.41	0.00
36500	3.15E+09	2.76	84.1	0.000	3.41E+01	#NUM!	1.523E+00	34.159	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	9200.0	2.90E+11	1.0	30.5	0.000	1.18E+00	0.094	6.520E-01	1.397	0.048	0.0890	0.025	0.00	0.41	0.00
36500	3.15E+09	2.82	86.0	0.000	3.49E+01	#NUM!	1.557E+00	34.902	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	9400.0	2.96E+11	1.0	30.5	0.000	1.17E+00	0.099	6.520E-01	1.384	0.050	0.0929	0.025	0.00	0.41	0.00
36500	3.15E+09	2.88	87.8	0.000	3.56E+01	#NUM!	1.590E+00	35.644	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	9600.0	3.03E+11	1.0	30.5	0.000	1.15E+00	0.103	6.520E-01	1.372	0.052	0.0969	0.025	0.00	0.41	0.00
36500	3.15E+09	2.94	89.6	0.000	3.64E+01	#NUM!	1.623E+00	36.386	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	9800.0	3.09E+11	1.0	30.5	0.000	1.14E+00	0.107	6.520E-01	1.360	0.054	0.1008	0.025	0.00	0.41	0.01
36500	3.15E+09	3.00	91.4	0.000	3.71E+01	#NUM!	1.655E+00	37.129	#NUM!	#NUM!	0.025	#NUM!	0.41	#NUM!	10000.0	3.15E+11	1.0	30.5	0.000	1.13E+00	0.111	6.520E-01	1.349	0.056	0.1047	0.025	0.00	0.41	0.01

Note 1: Adapted from Equation B-26, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

TEST OF PSR CHEMICAL ISOLATION SPRE[redacted]T AGAINST CORPS GUIDANCE OUTPUT

Formul.		
K=foc*Kd		Walton 1991, p.186
R=1+(Kd,cap*p)/ne		Walton 1991, p.184
p=g(1-n)		Krynine and Judd,1957, p.138
v=K*i/ne		linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap		Partitioning definition (see note 3)
D = Dw(n^1/3) + dv		(See Note 1)
d = 0.01*L		T. Meyers 2002 (USACE)
i = dh/L		gradient calculation
C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(Z))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W =	((v-m)*x)/(2*D)	
X =	(R*x+m*t)/(SQRT(4*D*R*t))	
Y =	((v+m)*x)/(2*D)	
Z =	(R*x+m*t)/(SQRT(4*D*R*t))	
m=	v*(SQRT(1+((4*u*D)/v^2))	
ERFC()=	1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by
M. Easterly, USACE

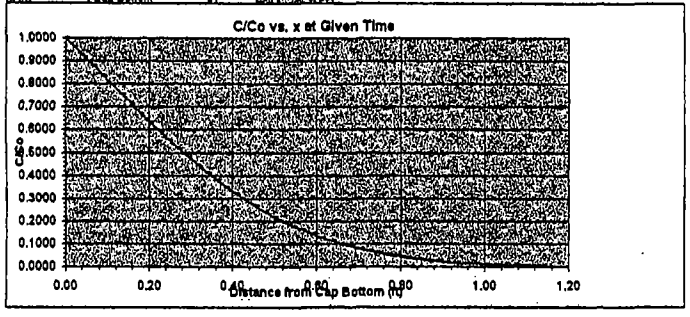
		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	Influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water			
dh	head differential over distance L			
foc	soil organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient			
Kd	theoretical distribution coefficient (ml/g)			
Kd,cap	cap distribution coefficient			
Koc	soil-water partition coefficient (g/g)			
L	thickness of chemical isolation layer (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard			
t	time			
u	first order decay constant			
v	average linear groundwater velocity (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion			

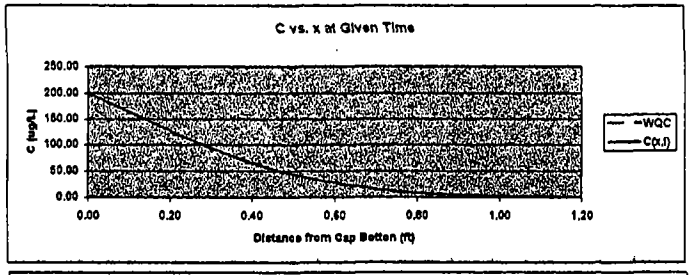
	Hydraulic Calculations		Transport Calculations		Chemical Data	
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g	[redacted]	
	n	[redacted]	foc	[redacted]	Kd (theoretical	1000
	ne	[redacted]	R	1251.00	Kd, cap	[redacted]
	g	[redacted] gm/cm3	u	[redacted] /d	SQS	[redacted] mg/kgOC
	dh	[redacted] ft	d	[redacted] ft	WQC	[redacted] ug/L
	L	[redacted] ft	Co	[redacted] ug/L	Dw	[redacted] cm2/sec
Results:	p	1.28 gm/cm3	d	34.7472 cm		
	i	0.000 ft/ft	u	0 /s		
	v	[redacted] ft/d	Kd,cap	600 ml/g		
	v	8.343E-07 cm/s	D	2.6E-06 cm2/sec		
			m	8.343E-07 cm/sec	(m=v for u=0)	

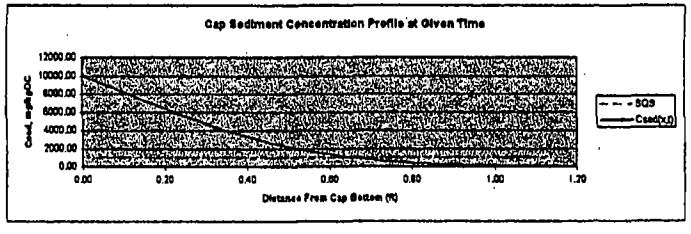
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t (day)	[redacted]	=	100 yr
x (ft)	Cap Bottom	0	Exit [redacted]



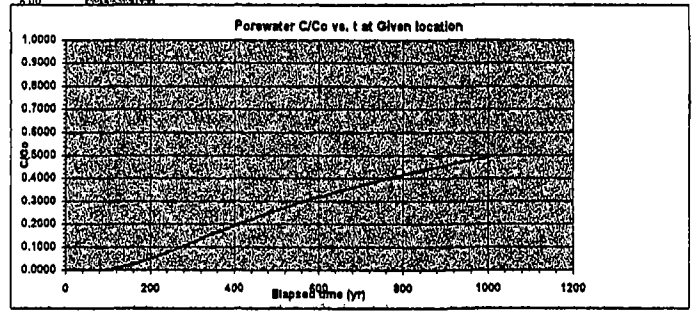


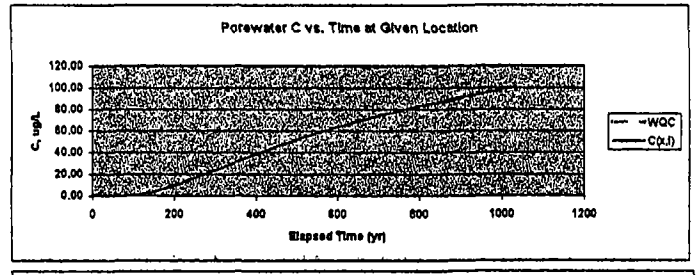


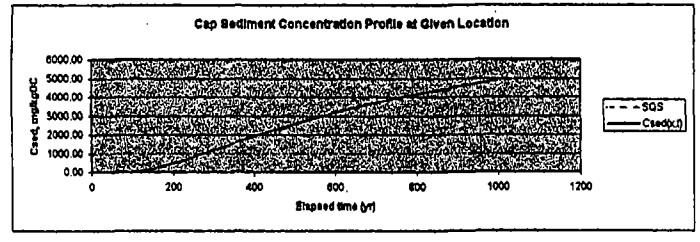
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	1000	
x (ft)	[redacted]				







TEST OF PSR CHEMICAL ISOLATION SPREADSH[redacted]GAINST CORPS GUIDANCE OUTPUT

[redacted]T				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-9.97E-02	1.111	0.000E+00	0.089	0.889	1.0000	0.00	200.00	1000.00	10000.00	0	0.00E+00	1.1	34.7	0.000	#DIV/0!	#DIV/0!	8.474E-01	#DIV/0!	#DIV/0!	#DIV/0!	0.00	#DIV/0!	1000.00	#DIV/0!
36500	3.15E+09	0.02	0.7	0.000	-5.56E-02	1.063	1.695E-02	0.142	0.841	0.9593	0.00	191.85	1000.00	9592.68	20.0	6.31E+08	1.1	34.7	0.000	4.75E+00	0.000	8.474E-01	4.842	0.000	0.0000	0.00	0.00	1000.00	0.00
36500	3.15E+09	0.05	1.4	0.000	-1.29E-02	1.015	3.390E-02	0.185	0.794	0.9180	0.00	183.60	1000.00	9180.15	40.0	1.26E+09	1.1	34.7	0.000	3.33E+00	0.000	8.474E-01	3.455	0.000	0.0000	0.00	0.00	1000.00	0.02
36500	3.15E+09	0.07	2.1	0.000	3.00E-02	0.966	5.084E-02	0.227	0.748	0.8764	0.00	175.28	1000.00	8764.16	60.0	1.89E+09	1.1	34.7	0.000	2.69E+00	0.000	8.474E-01	2.846	0.000	0.0001	0.00	0.03	1000.00	1.36
36500	3.15E+09	0.09	2.8	0.000	7.28E-02	0.918	6.779E-02	0.270	0.702	0.8346	0.00	166.93	1000.00	8346.49	80.0	2.52E+09	1.1	34.7	0.000	2.31E+00	0.001	8.474E-01	2.467	0.000	0.0011	0.00	0.21	1000.00	10.51
36500	3.15E+09	0.11	3.5	0.000	1.16E-01	0.870	8.474E-02	0.313	0.658	0.7929	0.00	158.58	1000.00	7929.81	100.0	3.15E+09	1.1	34.7	0.000	2.05E+00	0.004	8.474E-01	2.244	0.002	0.0037	0.00	0.73	1000.00	36.81
36500	3.15E+09	0.14	4.2	0.000	1.69E-01	0.822	1.017E-01	0.356	0.614	0.7513	0.00	150.26	1000.00	7512.65	120.0	3.78E+09	1.1	34.7	0.000	1.85E+00	0.009	8.474E-01	2.067	0.003	0.0085	0.00	1.70	1000.00	84.80
36500	3.15E+09	0.16	4.9	0.000	2.02E-01	0.776	1.186E-01	0.399	0.572	0.7100	0.00	142.01	1000.00	7100.30	140.0	4.42E+09	1.1	34.7	0.000	1.70E+00	0.016	8.474E-01	1.930	0.006	0.0156	0.00	3.12	1000.00	156.09
36500	3.15E+09	0.18	5.6	0.000	2.45E-01	0.729	1.356E-01	0.442	0.532	0.6693	0.00	133.86	1000.00	6692.78	160.0	5.05E+09	1.1	34.7	0.000	1.57E+00	0.028	8.474E-01	1.821	0.010	0.0248	0.00	4.98	1000.00	248.11
36500	3.15E+09	0.21	6.3	0.000	2.87E-01	0.684	1.525E-01	0.485	0.493	0.6292	0.00	125.84	1000.00	6291.83	180.0	5.68E+09	1.1	34.7	0.000	1.47E+00	0.038	8.474E-01	1.732	0.014	0.0357	0.00	7.15	1000.00	357.35
36500	3.15E+09	0.23	6.9	0.000	3.30E-01	0.640	1.695E-01	0.528	0.455	0.5899	0.00	117.98	1000.00	5898.91	200.0	6.31E+09	1.1	34.7	0.000	1.38E+00	0.051	8.474E-01	1.657	0.019	0.0480	0.00	9.60	1000.00	480.11
36500	3.15E+09	0.25	7.6	0.000	3.73E-01	0.598	1.864E-01	0.571	0.420	0.5516	0.00	110.31	1000.00	5515.40	220.0	6.94E+09	1.1	34.7	0.000	1.30E+00	0.068	8.474E-01	1.593	0.024	0.0613	0.00	12.26	1000.00	612.94
36500	3.15E+09	0.27	8.3	0.000	4.16E-01	0.556	2.034E-01	0.614	0.385	0.5143	0.00	102.85	1000.00	5142.53	240.0	7.57E+09	1.1	34.7	0.000	1.23E+00	0.091	8.474E-01	1.538	0.030	0.0763	0.00	15.08	1000.00	762.93
36500	3.15E+09	0.30	9.0	0.000	4.59E-01	0.518	2.203E-01	0.657	0.353	0.4781	0.00	95.63	1000.00	4781.42	260.0	8.20E+09	1.1	34.7	0.000	1.17E+00	0.098	8.474E-01	1.490	0.035	0.0896	0.00	17.95	1000.00	897.65
36500	3.15E+09	0.32	9.7	0.000	5.02E-01	0.479	2.373E-01	0.700	0.323	0.4433	0.00	88.66	1000.00	4433.06	280.0	8.83E+09	1.1	34.7	0.000	1.12E+00	0.114	8.474E-01	1.447	0.041	0.1045	0.00	20.90	1000.00	1045.17
36500	3.15E+09	0.34	10.4	0.000	5.45E-01	0.441	2.542E-01	0.742	0.294	0.4098	0.00	81.97	1000.00	4098.30	300.0	9.46E+09	1.1	34.7	0.000	1.07E+00	0.131	8.474E-01	1.410	0.046	0.1194	0.00	23.88	1000.00	1193.95
36500	3.15E+09	0.36	11.1	0.000	5.88E-01	0.406	2.712E-01	0.785	0.267	0.3778	0.00	75.56	1000.00	3777.86	320.0	1.01E+10	1.1	34.7	0.000	1.02E+00	0.149	8.474E-01	1.376	0.052	0.1343	0.00	26.86	1000.00	1342.81
36500	3.15E+09	0.39	11.8	0.000	6.31E-01	0.372	2.881E-01	0.828	0.241	0.3472	0.00	69.45	1000.00	3472.29	340.0	1.07E+10	1.1	34.7	0.000	9.82E-01	0.165	8.474E-01	1.346	0.057	0.1491	0.00	29.82	1000.00	1490.83
36500	3.15E+09	0.41	12.5	0.000	6.74E-01	0.341	3.051E-01	0.871	0.218	0.3182	0.00	63.64	1000.00	3182.03	360.0	1.14E+10	1.1	34.7	0.000	9.44E-01	0.183	8.474E-01	1.318	0.062	0.1637	0.00	32.75	1000.00	1637.32
36500	3.15E+09	0.43	13.2	0.000	7.17E-01	0.311	3.220E-01	0.914	0.198	0.2907	0.00	58.15	1000.00	2907.35	380.0	1.20E+10	1.1	34.7	0.000	9.08E-01	0.199	8.474E-01	1.293	0.067	0.1782	0.00	35.63	1000.00	1781.74
36500	3.15E+09	0.46	13.9	0.000	7.60E-01	0.283	3.390E-01	0.957	0.178	0.2648	0.00	52.97	1000.00	2648.42	400.0	1.26E+10	1.1	34.7	0.000	8.75E-01	0.216	8.474E-01	1.270	0.072	0.1924	0.00	38.47	1000.00	1923.71
36500	3.15E+09	0.48	14.6	0.000	8.02E-01	0.256	3.559E-01	1.000	0.157	0.2405	0.00	48.11	1000.00	2405.26	420.0	1.32E+10	1.1	34.7	0.000	8.45E-01	0.232	8.474E-01	1.249	0.077	0.2063	0.00	41.26	1000.00	2062.97
36500	3.15E+09	0.50	15.3	0.000	8.45E-01	0.232	3.729E-01	1.043	0.140	0.2178	0.00	43.56	1000.00	2177.77	440.0	1.39E+10	1.1	34.7	0.000	8.16E-01	0.249	8.474E-01	1.230	0.082	0.2199	0.00	43.99	1000.00	2199.31
36500	3.15E+09	0.52	16.0	0.000	8.88E-01	0.209	3.898E-01	1.086	0.125	0.1968	0.00	39.32	1000.00	1965.76	460.0	1.45E+10	1.1	34.7	0.000	7.89E-01	0.266	8.474E-01	1.212	0.088	0.2333	0.00	46.65	1000.00	2332.61
36500	3.15E+09	0.55	16.7	0.000	9.31E-01	0.188	4.068E-01	1.129	0.110	0.1749	0.00	35.36	1000.00	1748.90	480.0	1.51E+10	1.1	34.7	0.000	7.63E-01	0.281	8.474E-01	1.195	0.091	0.2463	0.00	49.26	1000.00	2462.80
36500	3.15E+09	0.57	17.4	0.000	9.74E-01	0.168	4.237E-01	1.172	0.098	0.1587	0.00	31.74	1000.00	1586.81	500.0	1.58E+10	1.1	34.7	0.000	7.39E-01	0.296	8.474E-01	1.180	0.095	0.2589	0.00	51.80	1000.00	2589.84
36500	3.15E+09	0.59	18.1	0.000	1.02E+00	0.150	4.407E-01	1.214	0.086	0.1419	0.00	28.38	1000.00	1418.02	520.0	1.64E+10	1.1	34.7	0.000	7.16E-01	0.311	8.474E-01	1.166	0.099	0.2714	0.00	54.27	1000.00	2713.73
36500	3.15E+09	0.62	18.8	0.000	1.06E+00	0.134	4.576E-01	1.257	0.075	0.1265	0.00	25.30	1000.00	1264.87	540.0	1.70E+10	1.1	34.7	0.000	6.94E-01	0.326	8.474E-01	1.153	0.103	0.2834	0.00	56.69	1000.00	2834.48
36500	3.15E+09	0.64	19.5	0.000	1.10E+00	0.119	4.746E-01	1.300	0.066	0.1124	0.00	22.48	1000.00	1124.09	560.0	1.77E+10	1.1	34.7	0.000	6.73E-01	0.341	8.474E-01	1.140	0.107	0.2952	0.00	59.04	1000.00	2952.17
36500	3.15E+09	0.66	20.2	0.000	1.15E+00	0.105	4.915E-01	1.343	0.057	0.0998	0.00	19.91	1000.00	995.72	580.0	1.83E+10	1.1	34.7	0.000	6.53E-01	0.356	8.474E-01	1.129	0.110	0.3067	0.00	61.34	1000.00	3066.80
36500	3.15E+09	0.68	20.9	0.000	1.19E+00	0.093	5.084E-01	1.388	0.050	0.0879	0.00	17.58	1000.00	879.19	600.0	1.89E+10	1.1	34.7	0.000	6.34E-01	0.370	8.474E-01	1.118	0.114	0.3178	0.00	63.57	1000.00	3178.46
36500	3.15E+09	0.71	21.5	0.000	1.23E+00	0.082	5.254E-01	1.429	0.043	0.0774	0.00	15.48	1000.00	773.81	620.0	1.96E+10	1.1	34.7	0.000	6.16E-01	0.384	8.474E-01	1.108	0.117	0.3287	0.00	65.74	1000.00	3287.22
36500	3.15E+09	0.73	22.2	0.000	1.27E+00	0.071	5.423E-01	1.472	0.037	0.0679	0.00	13.58	1000.00	678.86	640.0	2.02E+10	1.1	34.7	0.000	5.98E-01	0.397	8.474E-01	1.098	0.120	0.3393	0.00	67.86	1000.00	3393.14
36500	3.15E+09	0.75	22.9	0.000	1.32E+00	0.062	5.593E-01	1.515	0.032	0.0594	0.00	11.87	1000.00	593.53	660.0	2.08E+10	1.1	34.7	0.000	5.82E-01	0.411	8.474E-01	1.089	0.124	0.3496	0.00	69.93	1000.00	3496.31
36500	3.15E+09	0.78	23.6	0.000	1.36E+00	0.054	5.762E-01	1.558	0.028	0.0517	0.00	10.35	1000.00	517.41	680.0	2.14E+10	1.1	34.7	0.000	5.65E-01	0.424	8.474E-01	1.080	0.127	0.3597	0.00	71.94	1000.00	3596.80
36500	3.15E+09	0.80	24.3	0.000	1.40E+00	0.047	5.932E-01	1.601	0.024	0.0460	0.00	9.19	1000.00	449.61	700.0	2.21E+10	1.1	34.7	0.000	5.50E-01	0.437	8.474E-01	1.072	0.129	0.3695	0.00	73.89	1000.00	3694.70
36500	3.15E+09	0.82	25.0	0.000	1.45E+00	0.041	6.101E-01	1.644	0.020	0.0389	0.00	7.78	1000.00	389.24	720.0	2.27E+10	1.1	34.7	0.000	5.35E-01	0.450	8.474E-01	1.065	0.132	0.3790	0.00	75.80	1000.00	3790.09
36500	3.15E+09	0.84	25.7	0.000	1.49E+00	0.035	6.271E-01	1.687	0.017	0.0336	0.00	6.72	1000.00	335.94	740.0	2.33E+10	1.1	34.7	0.000	5.20E-01	0.462	8.474E-01	1.057	0.136	0.3883	0.00	77.66	1000.00	3883.04
36500	3.15E+09	0.87	26.4	0.000	1.53E+00	0.030	6.440E-01	1.729	0.014	0.0289	0.00	5.78	1000.00	288.99	760.0	2.40E+10	1.1	34.7	0.000	5.06E-01	0.474	8.474E-01	1.051	0.137	0.3974	0.00	79.47	1000.00	3973.64
36500	3.15E+09	0.89	27.1	0.000	1.57E+00	0.026	6.610E-01	1.772	0.012	0.0249	0.00	4.96	1000.00	247.78	780.0	2.46E+10	1.1	34.7	0.000	4.93E-01	0.486	8.474E-01	1.044	0.140	0.4062	0.00	81.24	1000.00	4061.96
36500	3.15E+09	0.91	27.8	0.000	1.62E+00	0.022	6.779E-01	1.815	0.010	0.0212	0.00	4.23	1000.00	211.71	800.0	2.52E+10	1.1	34.7	0.000	4.78E-01	0.498	8.474E-01	1.038	0.142	0.4148	0.00	82.96	1000.00	4149.07
36500	3.15E+09	0.93	28.5	0.000	1.66E+00	0.019	6.949E-01	1.858	0.009	0.0180	0.00	3.61	1000.00	180.31	820.0	2.59E+10	1.1	34.7	0.000	4.67E-01	0.509	8.474E-01	1.032	0.144	0.4232	0.00	84.64	1000.00	4232.05
36500	3.15E+09	0.96	29.2	0.000	1.70E+00	0.016	7.118E-01	1.901	0.007	0.0153	0.00	3.05	1000.00	153.05	840.0	2.65E+10	1.1	34.7	0.000	4.54E-01	0.521	8.474E-01	1.026	0.147	0.4314	0.00	86.28	1000.00	4313.97
36500	3.15E+09	0.98	29.9	0.000	1.75E+00	0.014	7.288E-01	1.944	0.006	0.0129	0.00	2.59	1000.00	129.47	860.0	2.71E+10	1.1	34.7	0.000	4.42E-01	0.532	8.474E-01	1.021	0.149	0.4394	0.00	87.88	1000.00	4393.90
36500	3.15E+09	1.00	30.6	0.000	1.79E+00	0.011	7.457E-01	1.987	0.005	0.0109	0.00	2.18	1000.00	109.15	880.0	2.78E+10	1.1	34.7	0.000	4.30E-01	0.543	8.474E-01	1.016	0.151	0.4472	0.00	89.44	1000.00	4471.80
36500	3.15E+09	1.03	31.3	0.000	1.83E+00	0.010	7.627E-01	2.030	0.004	0.0092	0.00	1.83	1000.00	91.72	900.0	2.84E+10	1.1	34.7	0.000	4.19E-01	0.553	8.474E-01	1.011	0.153	0.4546	0.00	90.96	1000.00	4545.04
36500	3.15E+09	1.05	32.0	0.000	1.88E+00	0.008	7.796E-01	2.073	0.003	0.0077	0.00	1.54	1000.00	76.91	920.0	2.90E+10	1.1	34.7	0.000	4.09E-01	0.564	8.474E-01	1.007	0.154	0.4622	0.00	92.45	1000.00	4622.38
36500	3.15E+09	1.07	32.7	0.000	1.92E+00	0.007	7.966E-01	2.116	0.003	0.0064	0.00	1.28	1000.00	64.11	940.0	2.96E+10	1.1	34.7	0.000	3.97E-01	0.574	8.474E-01	1.003	0.156	0.4695	0.00	93.90	1000.00	4694.89
36500	3.15E+09	1.09	33.4	0.000	1.96E+00	0.006	8.135E-01	2.159	0.002	0.0053	0.00	1.07	1000.00	53.32	960.0	3.03E+10	1.1	34.7	0.000	3.87E-01	0.585	8.474E-01	0.998	0.158	0.4766	0.00	95.32	1000.00	4765.91
36500	3.15E+09	1.12	34.1	0.000	2.00E+00	0.005	8.305E-01	2.201	0.002	0.0044	0.00	0.88	1000.00	44.20	980.0	3.09E+10	1.1	34.7	0.000	3.76E-01	0.595	8.474E-01	0.994	0.160	0.4836	0.00	96.70	1000.00	4836.20
36500	3.15E+09	1.14	34.7	0.000	2.05E+00	0.004	8.474E-01	2.244	0.002	0.0037	0.00	0.73	1000.00	36.51	1000.0	3.15E+10	1.1	34.7	0.000	3.66E-01	0.604	8.474E-01	0.991	0.161	0.4903	0.00	98.06	1000.00	4902.92

Note 1: Adapted from Equation B-26, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Input parameters are taken from example Mathcad spreadsheet in Appendix B of Corps guidance
Input velocity, calculated retardation factor, and calculated dispersion coefficient differ from example by a factor of porosity due to term definition
Output is compared to example Mathcad spreadsheet in Appendix B of Corps Guidance as shown below:

Time (years)	OUTPUT C(x,t) (ug/L)	Mathcad Example C(x,t) (ug/L)
100	0.7302779	0.701
500	51.796819	51.306
1000	98.058391	97.544

Note 3: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis of Chemical Isolation Analysis

Sensitivity Analysis for Chemical Isolation Analysis - Varying Co - U
PSR Superfund Site

Advec... Transport Formulae:

Kd=foc*Koc	Watton 1991, p.185
R=1+(Kd,cap*p)/ne	Watton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))		Van Genuchten and Alves (1982)
	W =	((v-m)*x)/(2*D)	
	X =	(R*x-m*t)/(SQRT(4*D*R*t))	
	Y =	((v+m)*x)/(2*D)	
	Z =	(R*x+m*t)/(SQRT(4*D*R*t))	
	m=	v*(SQRT(1+((4*u*D)/v^2))	
	ERFC()=	1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by
M. Easterly, USACE

Conversions!

C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06 gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0 g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04 mg/L
d	dispersivity (cm)	1 mg/L =	1000 ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400 sec
Dw	binary diffusivity of chemical in water (cm2/s)		
DL,sed	consolidation depth of sediment (ft)		
foc	cap material organic carbon fraction (-)	1 foot =	30.48 cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278 cm/sec
HL	half life (d)		
i	head gradient (not used)		
Kd	theoretical distribution coefficient (L/kg)		
Kd,cap	cap distribution coefficient (L/kg)		
Koc	soil-water partition coefficient (g/g)		
L	thickness of cap (ft)		
n	porosity (-)		
ne	effective porosity (-)		
p	bulk density (gm/cm3)		
R	*retardation factor (-)*		
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)		
t	time (s)		
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)		
u	first order decay constant (1/s)		
v	average linear groundwater velocity (cm/s) (measured)		
x	distance from cap bottom (cm)		
WQC	State Water Quality Criterion (ug/L)		

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap)	USEPA 1996

Cap thickness lost due to expression of porewater during consolidation (ft)

Tl,consol =	0.024 feet	(typically negligible)

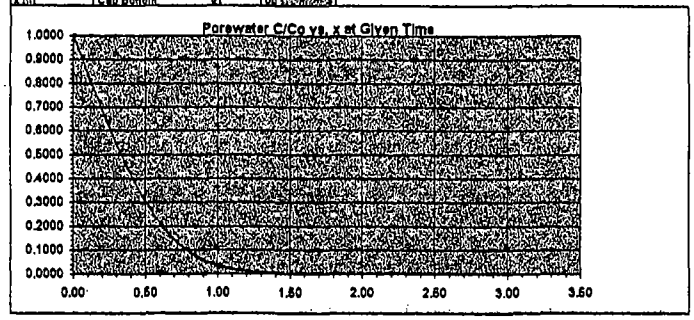
[illegible]

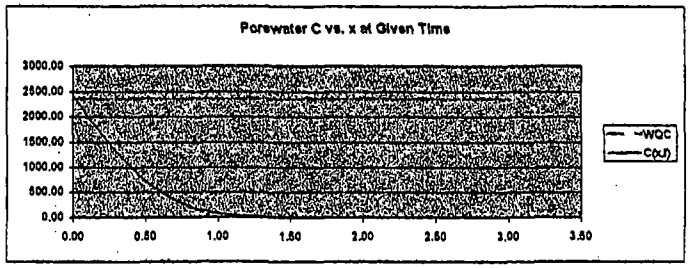
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	40 L/kg	
	ne	[illegible]	R	130.56	Kd, cap	[illegible] L/kg	
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible] mg/kgOC	
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible] ug/L	(LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible] cm2/sec	
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	40 ml/g			
	v	7.056E-08 cm/s	D	3.9E-06 cm2/sec			
			n	7.056E-08 cm/sec	(n=v for u=0)		

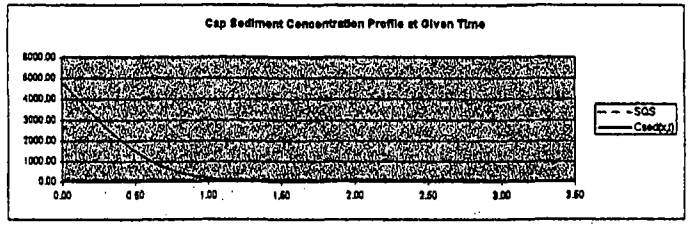
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	[illegible]	
x (ft)	Cap Bottom	0	Top	[illegible]	



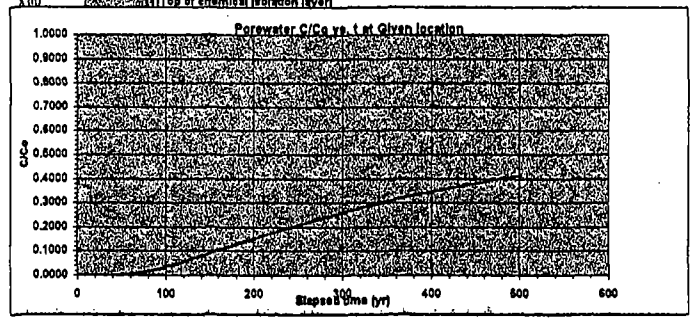


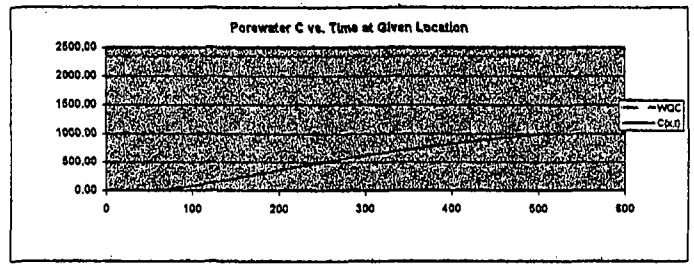


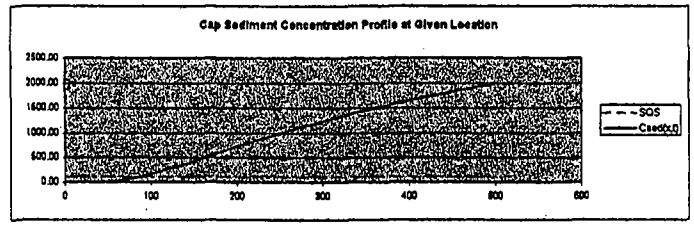
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600	
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)		







Sensitivity Analysis for Chemical Isolation Analysis - Varying Co - Upper Bo
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT				CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-8.76E-02	1.099	0.000E+00	0.000	0.501	1.0000	2350.00	2400.00	99.00	4800.00	0	0.00E+00		1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.620E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	5.42E-03	0.993	3.312E-02	0.182	0.797	0.9082	2350.00	2179.64	99.00	4359.27	10.0	3.15E+08		1.0	30.5	0.000	4.94E+00	0.000	5.620E-01	4.998	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.01E-01	0.887	6.624E-02	0.276	0.696	0.8152	2350.00	1956.44	99.00	3912.89	20.0	6.31E+08		1.0	30.5	0.000	3.47E+00	0.000	5.620E-01	3.862	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	1.95E-01	0.783	9.936E-02	0.371	0.600	0.7228	2350.00	1734.83	99.00	3469.65	30.0	9.46E+08		1.0	30.5	0.000	2.92E+00	0.000	5.620E-01	2.915	0.000	0.0001	2350.00	0.18	99.00	0.31
36500	3.15E+09	0.24	7.3	0.000	2.89E-01	0.683	1.325E-01	0.465	0.511	0.6329	2350.00	1519.01	99.00	3038.01	40.0	1.26E+09		1.0	30.5	0.000	2.43E+00	0.001	5.620E-01	2.539	0.000	0.0008	2350.00	1.40	99.00	2.80
36500	3.15E+09	0.30	9.1	0.000	3.83E-01	0.589	1.656E-01	0.559	0.429	0.5470	2350.00	1312.82	99.00	2625.64	50.0	1.58E+09		1.0	30.5	0.000	2.16E+00	0.002	5.620E-01	2.264	0.001	0.0022	2350.00	5.29	99.00	10.58
36500	3.15E+09	0.36	11.0	0.000	4.76E-01	0.499	1.987E-01	0.653	0.355	0.4665	2350.00	1119.62	99.00	2239.04	60.0	1.89E+09		1.0	30.5	0.000	1.96E+00	0.006	5.620E-01	2.096	0.003	0.0054	2350.00	13.01	99.00	26.02
36500	3.15E+09	0.42	12.8	0.000	5.72E-01	0.419	2.318E-01	0.748	0.290	0.3924	2350.00	941.66	99.00	1883.31	70.0	2.21E+09		1.0	30.5	0.000	1.80E+00	0.011	5.620E-01	1.961	0.008	0.0104	2350.00	24.94	99.00	49.89
36500	3.15E+09	0.48	14.6	0.000	6.66E-01	0.348	2.649E-01	0.842	0.234	0.3264	2350.00	781.00	99.00	1562.01	80.0	2.52E+09		1.0	30.5	0.000	1.66E+00	0.018	5.620E-01	1.835	0.009	0.0170	2350.00	40.90	99.00	81.80
36500	3.15E+09	0.54	16.5	0.000	7.60E-01	0.282	2.981E-01	0.936	0.186	0.2661	2350.00	638.55	99.00	1277.09	90.0	2.84E+09		1.0	30.5	0.000	1.57E+00	0.026	5.620E-01	1.739	0.014	0.0252	2350.00	60.36	99.00	120.72
36500	3.15E+09	0.60	18.3	0.000	8.55E-01	0.227	3.312E-01	1.030	0.148	0.2144	2350.00	514.51	99.00	1029.03	100.0	3.15E+09		1.0	30.5	0.000	1.48E+00	0.036	5.620E-01	1.659	0.019	0.0345	2350.00	82.71	99.00	165.41
36500	3.15E+09	0.66	20.1	0.000	9.49E-01	0.180	3.643E-01	1.125	0.112	0.1702	2350.00	408.47	99.00	816.95	110.0	3.47E+09		1.0	30.5	0.000	1.41E+00	0.047	5.620E-01	1.590	0.025	0.0447	2350.00	107.32	99.00	214.64
36500	3.15E+09	0.72	21.9	0.000	1.04E+00	0.140	3.974E-01	1.219	0.086	0.1331	2350.00	319.45	99.00	638.90	120.0	3.78E+09		1.0	30.5	0.000	1.34E+00	0.058	5.620E-01	1.530	0.030	0.0557	2350.00	133.65	99.00	267.30
36500	3.15E+09	0.78	23.8	0.000	1.14E+00	0.108	4.305E-01	1.313	0.063	0.1025	2350.00	246.05	99.00	492.10	130.0	4.10E+09		1.0	30.5	0.000	1.28E+00	0.071	5.620E-01	1.478	0.037	0.0672	2350.00	161.22	99.00	322.44
36500	3.15E+09	0.84	25.6	0.000	1.23E+00	0.082	4.636E-01	1.407	0.047	0.0778	2350.00	186.82	99.00	373.24	140.0	4.42E+09		1.0	30.5	0.000	1.22E+00	0.084	5.620E-01	1.432	0.043	0.0790	2350.00	189.83	99.00	379.27
36500	3.15E+09	0.90	27.4	0.000	1.33E+00	0.061	4.968E-01	1.502	0.034	0.0581	2350.00	139.36	99.00	278.71	150.0	4.73E+09		1.0	30.5	0.000	1.19E+00	0.097	5.620E-01	1.390	0.049	0.0911	2350.00	218.67	99.00	437.14
36500	3.15E+09	0.96	29.3	0.000	1.42E+00	0.045	5.299E-01	1.596	0.024	0.0427	2350.00	102.44	99.00	204.68	160.0	5.05E+09		1.0	30.5	0.000	1.13E+00	0.110	5.620E-01	1.353	0.056	0.1032	2350.00	247.77	99.00	495.53
36500	3.15E+09	1.02	31.1	0.000	1.51E+00	0.032	5.630E-01	1.690	0.017	0.0309	2350.00	74.12	99.00	148.24	170.0	5.36E+09		1.0	30.5	0.000	1.09E+00	0.123	5.620E-01	1.318	0.062	0.1164	2350.00	277.02	99.00	554.05
36500	3.15E+09	1.08	32.9	0.000	1.61E+00	0.023	5.961E-01	1.784	0.012	0.0220	2350.00	52.78	99.00	105.55	180.0	5.68E+09		1.0	30.5	0.000	1.05E+00	0.136	5.620E-01	1.288	0.068	0.1276	2350.00	306.18	99.00	612.36
36500	3.15E+09	1.14	34.7	0.000	1.70E+00	0.016	6.292E-01	1.879	0.008	0.0154	2350.00	36.98	99.00	73.96	190.0	5.99E+09		1.0	30.5	0.000	1.02E+00	0.150	5.620E-01	1.261	0.075	0.1396	2350.00	335.11	99.00	670.21
36500	3.15E+09	1.20	36.6	0.000	1.80E+00	0.011	6.624E-01	1.973	0.006	0.0106	2350.00	25.49	99.00	50.99	200.0	6.31E+09		1.0	30.5	0.000	9.87E-01	0.163	5.620E-01	1.235	0.081	0.1515	2350.00	363.71	99.00	727.41
36500	3.15E+09	1.26	38.4	0.000	1.89E+00	0.007	6.955E-01	2.067	0.003	0.0072	2350.00	17.29	99.00	34.58	210.0	6.62E+09		1.0	30.5	0.000	9.67E-01	0.176	5.620E-01	1.211	0.087	0.1633	2350.00	391.91	99.00	783.82
36500	3.15E+09	1.32	40.2	0.000	1.99E+00	0.005	7.286E-01	2.161	0.002	0.0048	2350.00	11.54	99.00	23.08	220.0	6.94E+09		1.0	30.5	0.000	9.28E-01	0.189	5.620E-01	1.169	0.093	0.1748	2350.00	419.66	99.00	839.32
36500	3.15E+09	1.38	42.1	0.000	2.08E+00	0.003	7.617E-01	2.256	0.001	0.0032	2350.00	7.57	99.00	15.15	230.0	7.25E+09		1.0	30.5	0.000	9.03E-01	0.202	5.620E-01	1.169	0.098	0.1862	2350.00	446.92	99.00	893.83
36500	3.15E+09	1.44	43.9	0.000	2.17E+00	0.002	7.948E-01	2.350	0.001	0.0020	2350.00	4.89	99.00	9.78	240.0	7.57E+09		1.0	30.5	0.000	8.78E-01	0.214	5.620E-01	1.150	0.104	0.1974	2350.00	473.65	99.00	947.31
36500	3.15E+09	1.50	45.7	0.000	2.27E+00	0.001	8.279E-01	2.444	0.001	0.0013	2350.00	3.10	99.00	6.21	250.0	7.88E+09		1.0	30.5	0.000	8.55E-01	0.227	5.620E-01	1.132	0.109	0.2083	2350.00	499.95	99.00	999.70
36500	3.15E+09	1.56	47.5	0.000	2.36E+00	0.001	8.611E-01	2.539	0.000	0.0008	2350.00	1.94	99.00	3.88	260.0	8.20E+09		1.0	30.5	0.000	8.33E-01	0.239	5.620E-01	1.116	0.115	0.2190	2350.00	525.49	99.00	1050.98
36500	3.15E+09	1.62	49.4	0.000	2.46E+00	0.001	8.942E-01	2.633	0.000	0.0005	2350.00	1.19	99.00	2.38	270.0	8.51E+09		1.0	30.5	0.000	8.12E-01	0.251	5.620E-01	1.100	0.120	0.2294	2350.00	550.58	99.00	1101.16
36500	3.15E+09	1.68	51.2	0.000	2.55E+00	0.000	9.273E-01	2.727	0.000	0.0003	2350.00	0.72	99.00	1.44	280.0	8.83E+09		1.0	30.5	0.000	7.92E-01	0.263	5.620E-01	1.086	0.125	0.2398	2350.00	576.11	99.00	1152.22
36500	3.15E+09	1.74	53.0	0.000	2.65E+00	0.000	9.604E-01	2.821	0.000	0.0002	2350.00	0.43	99.00	0.85	290.0	9.16E+09		1.0	30.5	0.000	7.73E-01	0.274	5.620E-01	1.072	0.129	0.2498	2350.00	599.09	99.00	1198.17
36500	3.15E+09	1.80	54.9	0.000	2.74E+00	0.000	9.935E-01	2.916	0.000	0.0001	2350.00	0.25	99.00	0.50	300.0	9.46E+09		1.0	30.5	0.000	7.55E-01	0.286	5.620E-01	1.059	0.134	0.2594	2350.00	622.51	99.00	1245.03
36500	3.15E+09	1.86	56.7	0.000	2.83E+00	0.000	1.027E+00	3.010	0.000	0.0001	2350.00	0.14	99.00	0.29	310.0	9.78E+09		1.0	30.5	0.000	7.38E-01	0.297	5.620E-01	1.047	0.139	0.2689	2350.00	645.40	99.00	1290.80
36500	3.15E+09	1.92	58.6	0.000	2.93E+00	0.000	1.060E+00	3.104	0.000	0.0000	2350.00	0.08	99.00	0.16	320.0	1.01E+10		1.0	30.5	0.000	7.21E-01	0.309	5.620E-01	1.035	0.143	0.2782	2350.00	667.76	99.00	1335.51
36500	3.15E+09	1.98	60.4	0.000	3.02E+00	0.000	1.093E+00	3.198	0.000	0.0000	2350.00	0.04	99.00	0.09	330.0	1.04E+10		1.0	30.5	0.000	7.05E-01	0.319	5.620E-01	1.024	0.147	0.2873	2350.00	689.69	99.00	1379.19
36500	3.15E+09	2.04	62.2	0.000	3.12E+00	0.000	1.126E+00	3.293	0.000	0.0000	2350.00	0.02	99.00	0.05	340.0	1.07E+10		1.0	30.5	0.000	6.90E-01	0.329	5.620E-01	1.014	0.152	0.2962	2350.00	710.92	99.00	1421.84
36500	3.15E+09	2.10	64.0	0.000	3.21E+00	0.000	1.159E+00	3.387	0.000	0.0000	2350.00	0.01	99.00	0.03	350.0	1.10E+10		1.0	30.5	0.000	6.75E-01	0.340	5.620E-01	1.004	0.156	0.3049	2350.00	731.75	99.00	1463.50
36500	3.15E+09	2.16	65.8	0.000	3.31E+00	0.000	1.192E+00	3.481	0.000	0.0000	2350.00	0.01	99.00	0.01	360.0	1.14E+10		1.0	30.5	0.000	6.61E-01	0.350	5.620E-01	0.995	0.160	0.3134	2350.00	752.10	99.00	1504.20
36500	3.15E+09	2.22	67.7	0.000	3.40E+00	0.000	1.225E+00	3.575	0.000	0.0000	2350.00	0.00	99.00	0.01	370.0	1.17E+10		1.0	30.5	0.000	6.46E-01	0.360	5.620E-01	0.986	0.163	0.3217	2350.00	771.98	99.00	1543.95
36500	3.15E+09	2.28	69.5	0.000	3.49E+00	0.000	1.258E+00	3.670	0.000	0.0000	2350.00	0.00	99.00	0.00	380.0	1.20E+10		1.0	30.5	0.000	6.35E-01	0.369	5.620E-01	0.977	0.167	0.3297	2350.00	791.40	99.00	1582.79
36500	3.15E+09	2.34	71.3	0.000	3.59E+00	0.000	1.292E+00	3.764	0.000	0.0000	2350.00	0.00	99.00	0.00	390.0	1.23E+10		1.0	30.5	0.000	6.22E-01	0.379	5.620E-01	0.969	0.171	0.3377	2350.00	810.37	99.00	1620.74
36500	3.15E+09	2.40	73.2	0.000	3.68E+00	0.000	1.325E+00	3.858	0.000	0.0000	2350.00	0.00	99.00	0.00	400.0	1.26E+10		1.0	30.5	0.000	6.10E-01	0.389	5.620E-01	0.961	0.174	0.3454	2350.00	828.92	99.00	1657.83
36500	3.15E+09	2.46	75.0	0.000	3.78E+00	0.000	1.358E+00	3.952	0.000	0.0000	2350.00	0.00	99.00	0.00	410.0	1.29E+10		1.0	30.5	0.000	5.98E-01	0.398	5.620E-01	0.954	0.177	0.3529	2350.00	847.04	99.00	1694.08
36500	3.15E+09	2.52	76.8	0.000	3.87E+00	0.000	1.391E+00	4.047	0.000	0.0000	2350.00	0.00	99.00	0.00	420.0	1.32E+10		1.0	30.5	0.000	5.87E-01	0.407	5.620E-01	0.947	0.181	0.3603	2350.00	864.78	99.00	1729.52
36500	3.15E+09	2.58	78.6	0.000	3.97E+00	0.000	1.424E+00	4.141	0.000	0.0000	2350.00	0.00	99.00	0.00	430.0	1.36E+10		1.0	30.5	0.000	5.75E-01	0.416	5.620E-01	0.940	0.184	0.3676	2350.00	882.08	99.00	1764.17
36500	3.15E+09	2.64	80.5	0.000	4.06E+00	0.000	1.457E+00	4.235	0.000	0.0000	2350.00	0.00	99.00	0.00	440.0	1.39E+10		1.0	30.5	0.000	5.65E-01	0.426	5.620E-01	0.933	0.187	0.3748	2350.00	899.03	99.00	1798.06
36500	3.15E+09	2.70	82.3	0.000	4.15E+00	0.000	1.490E+00	4.329	0.000	0.0000	2350.00	0.00	99.00	0.00	450.0	1.42E+10		1.0	30.5	0.000	5.54E-01	0.433	5.620E-01	0.927	0.190	0.3815	2350.00	915.60	99.00	1831.19
36500	3.15E+09	2.76	84.1	0.000	4.25E+00	0.000	1.523E+00	4.424	0.000	0.0000	2350.00	0.00	99.00	0.00	460.0	1.45E+10		1.0	30.5	0.000	5.44E-01	0.442	5.620E-01	0.921	0.193	0.3883	2350.00	931.81	99.00	1863.62
36500	3.15E+09	2.82	86.0	0.000	4.34E+00	0.000	1.557E+00	4.518	0.000	0.0000	2350.00	0.00	99.00	0.00	470.0	1.48E+10		1.0	30.5	0.000	5.34E-01	0.450	5.620E-01	0.916	0.196	0.3949	2350.00	947.67	99.00	1895.35
36500	3.15E+09	2.88	87.8	0.000	4.44E+00	0.000	1.590E+00	4.612	0.000	0.0000	2350.00	0.00	99.00	0.00	480.0	1.51E+10		1.0	30.5	0.000	5.25E-01	0.459	5.620E-01	0.909	0.198	0.4013	2350.00	963.20	99.00	1926.40
36500	3.15E+09	2.94	89.6	0.000	4.53E+00	0.000	1.623E+00	4.706	0.000	0.0000	2350.00	0.00	99.00	0.00	490.0	1.55E+10		1.0	30.5	0.000	5.15E-01	0.466	5.620E-01	0.904	0.201	0.4077	2350.00	978.40	99.00	1956.80
36500	3.15E+09	3.00	91.4	0.000	4.62E+00	0.000	1.656E+00	4.801	0.000	0.0000	2350.00	0.00	99.00	0.00	500.0	1.58E+10		1.0	30.5	0.000	5.06E-01	0.474	5.620E-01	0.899	0.204	0.4139	2350.00	993.26	99.00	1986.56

Note 1: Adapted from Equation B-26, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying Co - Lo
PSR Superfund Site

Advecti... ...erative Transport Formulae:

Kd=foc*Koc	Walton 1991, p.166
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition (see note 2)
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Y))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*x+v*t)/(SQRT(4*D*R*t))
Y = ((v-m)*x)/(2*D)
Z = (R*x-m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2)))
ERFC0= 1-ERF0

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	40	L/kg
	ne	[illegible]	R	130.56	Kd, cap	[illegible]	L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L (LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	40 ml/g			
	v	7.056E-09 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-09 cm/sec	(m=v for u=0)		

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap) — USEPA 1998

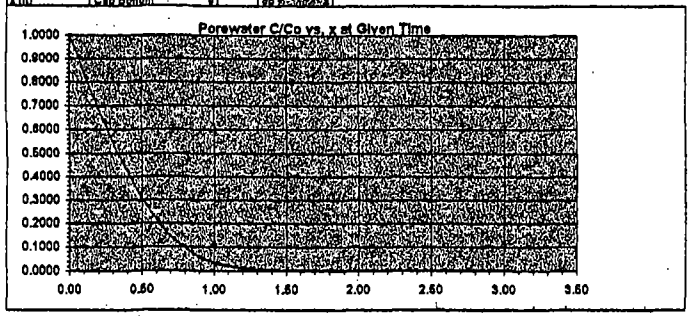
Cap thickness lost due to expression of porewater during consolidation (ft)

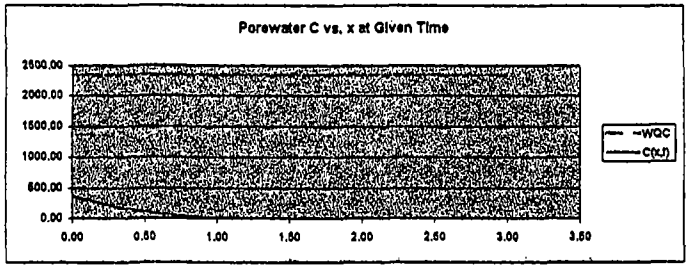
Tl,consol = 0.024 feet (typically negligible)

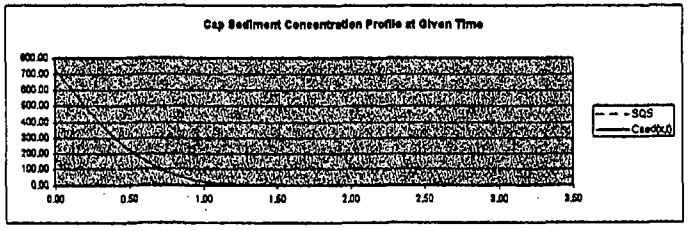
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500 days =	[illegible]	
x (ft)	Cap Bottom	0	Top S...



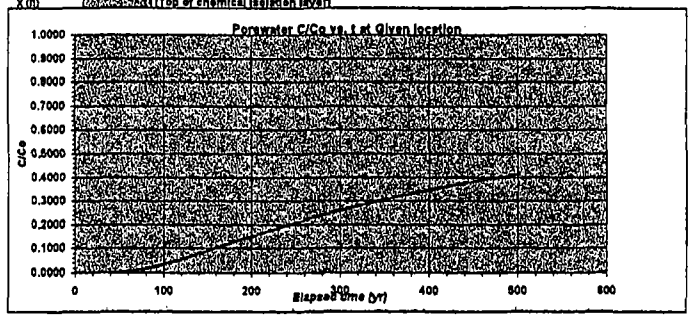


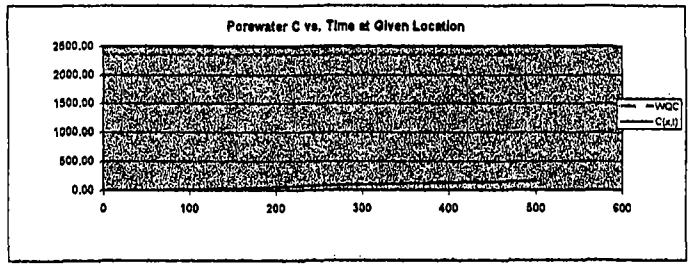


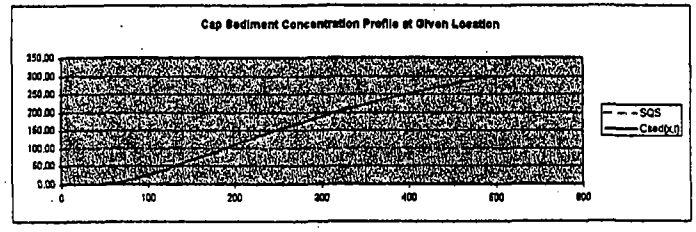
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	549
x (ft)	[illegible] ((Top of chemical isolation layer)			







Sensitivity Analysis for Chemical Isolation Analysis - Varying Co - Lower Bo
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-8.76E-02	1.099	0.000E+00	0.000	0.901	1.0000	2350.00	364.00	99.00	720.00
36500	3.15E+09	0.08	1.9	0.000	6.42E-03	0.993	3.312E-02	0.102	0.797	0.9062	2350.00	330.68	99.00	661.16
36500	3.15E+09	0.12	3.7	0.000	1.01E-01	0.887	5.624E-02	0.276	0.696	0.8152	2350.00	296.73	99.00	593.46
36500	3.15E+09	0.16	5.5	0.000	1.95E-01	0.783	9.935E-02	0.371	0.600	0.7228	2350.00	263.12	99.00	526.23
36500	3.15E+09	0.24	7.3	0.000	2.89E-01	0.683	1.326E-01	0.466	0.511	0.6329	2350.00	230.38	99.00	460.77
36500	3.15E+09	0.30	9.1	0.000	3.83E-01	0.588	1.656E-01	0.559	0.429	0.5470	2350.00	199.11	99.00	398.22
36500	3.15E+09	0.36	11.0	0.000	4.78E-01	0.499	1.987E-01	0.653	0.355	0.4685	2350.00	169.79	99.00	339.59
36500	3.15E+09	0.42	12.8	0.000	5.72E-01	0.418	2.319E-01	0.748	0.290	0.3924	2350.00	142.82	99.00	285.64
36500	3.15E+09	0.48	14.6	0.000	6.66E-01	0.346	2.649E-01	0.842	0.234	0.3254	2350.00	118.45	99.00	236.90
36500	3.15E+09	0.54	16.5	0.000	7.60E-01	0.282	2.981E-01	0.936	0.186	0.2681	2350.00	96.85	99.00	193.69
36500	3.15E+09	0.60	18.3	0.000	8.55E-01	0.227	3.312E-01	1.030	0.145	0.2144	2350.00	78.03	99.00	156.07
36500	3.15E+09	0.66	20.1	0.000	9.49E-01	0.180	3.643E-01	1.125	0.112	0.1702	2350.00	61.95	99.00	123.90
36500	3.15E+09	0.72	21.9	0.000	1.04E+00	0.140	3.974E-01	1.219	0.085	0.1331	2350.00	48.46	99.00	96.90
36500	3.15E+09	0.78	23.8	0.000	1.14E+00	0.108	4.305E-01	1.313	0.063	0.1026	2350.00	37.32	99.00	74.64
36500	3.15E+09	0.84	25.6	0.000	1.23E+00	0.082	4.636E-01	1.407	0.047	0.0778	2350.00	28.30	99.00	56.61
36500	3.15E+09	0.90	27.4	0.000	1.33E+00	0.061	4.966E-01	1.502	0.034	0.0581	2350.00	21.14	99.00	42.27
36500	3.15E+09	0.96	29.3	0.000	1.42E+00	0.045	5.297E-01	1.596	0.024	0.0427	2350.00	15.54	99.00	31.07
36500	3.15E+09	1.02	31.1	0.000	1.51E+00	0.032	5.630E-01	1.690	0.017	0.0309	2350.00	11.24	99.00	22.48
36500	3.15E+09	1.08	32.9	0.000	1.61E+00	0.023	5.961E-01	1.784	0.012	0.0220	2350.00	8.00	99.00	16.01
36500	3.15E+09	1.14	34.7	0.000	1.70E+00	0.016	6.292E-01	1.879	0.008	0.0154	2350.00	5.61	99.00	11.22
36500	3.15E+09	1.20	36.6	0.000	1.80E+00	0.011	6.624E-01	1.973	0.005	0.0106	2350.00	3.87	99.00	7.73
36500	3.15E+09	1.26	38.4	0.000	1.89E+00	0.007	6.955E-01	2.067	0.003	0.0072	2350.00	2.62	99.00	5.25
36500	3.15E+09	1.32	40.2	0.000	1.99E+00	0.005	7.286E-01	2.161	0.002	0.0049	2350.00	1.75	99.00	3.50
36500	3.15E+09	1.38	42.1	0.000	2.08E+00	0.003	7.617E-01	2.256	0.001	0.0032	2350.00	1.15	99.00	2.30
36500	3.15E+09	1.44	43.9	0.000	2.17E+00	0.002	7.948E-01	2.350	0.001	0.0020	2350.00	0.74	99.00	1.48
36500	3.15E+09	1.50	45.7	0.000	2.27E+00	0.001	8.279E-01	2.444	0.001	0.0013	2350.00	0.47	99.00	0.94
36500	3.15E+09	1.56	47.5	0.000	2.36E+00	0.001	8.611E-01	2.539	0.000	0.0008	2350.00	0.29	99.00	0.59
36500	3.15E+09	1.62	49.4	0.000	2.46E+00	0.001	8.942E-01	2.633	0.000	0.0005	2350.00	0.18	99.00	0.36
36500	3.15E+09	1.68	51.2	0.000	2.55E+00	0.000	9.273E-01	2.727	0.000	0.0003	2350.00	0.11	99.00	0.22
36500	3.15E+09	1.74	53.0	0.000	2.65E+00	0.000	9.604E-01	2.821	0.000	0.0002	2350.00	0.06	99.00	0.13
36500	3.15E+09	1.80	54.9	0.000	2.74E+00	0.000	9.936E-01	2.916	0.000	0.0001	2350.00	0.04	99.00	0.08
36500	3.15E+09	1.86	56.7	0.000	2.83E+00	0.000	1.027E+00	3.010	0.000	0.0001	2350.00	0.02	99.00	0.04
36500	3.15E+09	1.92	58.5	0.000	2.93E+00	0.000	1.060E+00	3.104	0.000	0.0000	2350.00	0.01	99.00	0.02
36500	3.15E+09	1.98	60.4	0.000	3.02E+00	0.000	1.093E+00	3.198	0.000	0.0000	2350.00	0.01	99.00	0.01
36500	3.15E+09	2.04	62.2	0.000	3.12E+00	0.000	1.126E+00	3.293	0.000	0.0000	2350.00	0.00	99.00	0.01
36500	3.15E+09	2.10	64.0	0.000	3.21E+00	0.000	1.159E+00	3.387	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.16	65.8	0.000	3.31E+00	0.000	1.192E+00	3.481	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.22	67.7	0.000	3.40E+00	0.000	1.225E+00	3.576	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.28	69.5	0.000	3.49E+00	0.000	1.258E+00	3.670	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.34	71.3	0.000	3.59E+00	0.000	1.292E+00	3.764	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.40	73.2	0.000	3.68E+00	0.000	1.325E+00	3.858	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.46	75.0	0.000	3.78E+00	0.000	1.358E+00	3.952	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.52	76.8	0.000	3.87E+00	0.000	1.391E+00	4.047	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.58	78.6	0.000	3.97E+00	0.000	1.424E+00	4.141	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.64	80.5	0.000	4.06E+00	0.000	1.457E+00	4.235	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.70	82.3	0.000	4.16E+00	0.000	1.490E+00	4.329	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.76	84.1	0.000	4.25E+00	0.000	1.523E+00	4.424	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.82	86.0	0.000	4.34E+00	0.000	1.557E+00	4.518	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.88	87.8	0.000	4.44E+00	0.000	1.590E+00	4.612	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	2.94	89.6	0.000	4.53E+00	0.000	1.623E+00	4.706	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	3.00	91.4	0.000	4.62E+00	0.000	1.656E+00	4.801	0.000	0.0000	2350.00	0.00	99.00	0.00

INPUT				CALCULATIONS						OUTPUT				
t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.620E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
10.0	3.15E+08	1.0	30.5	0.000	4.94E+00	0.000	5.620E-01	4.998	0.000	0.0000	2350.00	0.00	99.00	0.00
20.0	6.31E+08	1.0	30.5	0.000	3.47E+00	0.000	5.620E-01	3.562	0.000	0.0000	2350.00	0.00	99.00	0.00
30.0	9.46E+08	1.0	30.5	0.000	2.82E+00	0.000	5.620E-01	2.918	0.000	0.0001	2350.00	0.02	99.00	0.05
40.0	1.26E+09	1.0	30.5	0.000	2.43E+00	0.001	5.620E-01	2.539	0.000	0.0006	2350.00	0.21	99.00	0.42
50.0	1.58E+09	1.0	30.5	0.000	2.18E+00	0.002	5.620E-01	2.284	0.001	0.0022	2350.00	0.80	99.00	1.61
60.0	1.89E+09	1.0	30.5	0.000	1.98E+00	0.006	5.620E-01	2.096	0.003	0.0054	2350.00	1.97	99.00	3.95
70.0	2.21E+09	1.0	30.5	0.000	1.83E+00	0.011	5.620E-01	1.951	0.006	0.0104	2350.00	3.78	99.00	7.57
80.0	2.52E+09	1.0	30.5	0.000	1.69E+00	0.019	5.620E-01	1.835	0.009	0.0170	2350.00	6.20	99.00	12.41
90.0	2.84E+09	1.0	30.5	0.000	1.57E+00	0.028	5.620E-01	1.739	0.014	0.0252	2350.00	9.15	99.00	18.31
100.0	3.15E+09	1.0	30.5	0.000	1.48E+00	0.036	5.620E-01	1.659	0.019	0.0345	2350.00	12.64	99.00	25.09
110.0	3.47E+09	1.0	30.5	0.000	1.41E+00	0.047	5.620E-01	1.590	0.025	0.0447	2350.00	16.28	99.00	32.55
120.0	3.78E+09	1.0	30.5	0.000	1.34E+00	0.058	5.620E-01	1.530	0.030	0.0557	2350.00	20.27	99.00	40.54
130.0	4.10E+09	1.0	30.5	0.000	1.28E+00	0.071	5.620E-01	1.478	0.037	0.0672	2350.00	24.45	99.00	48.90
140.0	4.42E+09	1.0	30.5	0.000	1.22E+00	0.084	5.620E-01	1.432	0.043	0.0790	2350.00	28.76	99.00	57.52
150.0	4.73E+09	1.0	30.5	0.000	1.18E+00	0.097	5.620E-01	1.390	0.049	0.0911	2350.00	33.15	99.00	66.30
160.0	5.05E+09	1.0	30.5	0.000	1.13E+00	0.110	5.620E-01	1.353	0.056	0.1032	2350.00	37.58	99.00	75.16
170.0	5.36E+09	1.0	30.5	0.000	1.09E+00	0.123	5.620E-01	1.319	0.062	0.1154	2350.00	42.02	99.00	84.03
180.0	5.68E+09	1.0	30.5	0.000	1.05E+00	0.136	5.620E-01	1.289	0.068	0.1276	2350.00	46.44	99.00	92.87
190.0	5.99E+09	1.0	30.5	0.000	1.02E+00	0.150	5.620E-01	1.261	0.075	0.1396	2350.00	50.82	99.00	101.65
200.0	6.31E+09	1.0	30.5	0.000	9.87E-01	0.163	5.620E-01	1.236	0.081	0.1515	2350.00	55.16	99.00	110.32
210.0	6.62E+09	1.0	30.5	0.000	9.57E-01	0.176	5.620E-01	1.211	0.087	0.1633	2350.00	59.44	99.00	118.88
220.0	6.94E+09	1.0	30.5	0.000	9.29E-01	0.189	5.620E-01	1.189	0.093	0.1748	2350.00	63.65	99.00	127.30
230.0	7.25E+09	1.0	30.5	0.000	9.03E-01	0.202	5.620E-01	1.169	0.099	0.1862	2350.00	67.78	99.00	135.56
240.0	7.57E+09	1.0	30.5	0.000	8.78E-01	0.214	5.620E-01	1.150	0.104	0.1974	2350.00	71.84	99.00	143.67
250.0	7.88E+09	1.0	30.5	0.000	8.55E-01	0.227	5.620E-01	1.132	0.109	0.2083	2350.00	75.81	99.00	151.62
260.0	8.20E+09	1.0	30.5	0.000	8.33E-01	0.239	5.620E-01	1.116	0.115	0.2190	2350.00	79.70	99.00	159.40
270.0	8.51E+09	1.0	30.5	0.000	8.12E-01	0.251	5.620E-01	1.100	0.120	0.2294	2350.00	83.50	99.00	167.01
280.0	8.83E+09	1.0	30.5	0.000	7.92E-01	0.263	5.620E-01	1.086	0.125	0.2396	2350.00	87.23	99.00	174.46
290.0	9.15E+09	1.0	30.5	0.000	7.73E-01	0.274	5.620E-01	1.072	0.129	0.2496	2350.00	90.88	99.00	181.72
300.0	9.46E+09	1.0	30.5	0.000	7.55E-01	0.286	5.620E-01	1.059	0.134	0.2594	2350.00	94.41	99.00	188.83
310.0	9.78E+09	1.0	30.5	0.000	7.38E-01	0.297	5.620E-01	1.047	0.139	0.2689	2350.00	97.89	99.00	195.77
320.0	1.01E+10	1.0	30.5	0.000	7.21E-01	0.308	5.620E-01	1.035	0.143	0.2782	2350.00	101.28	99.00	202.55
330.0	1.04E+10	1.0	30.5	0.000	7.05E-01	0.319	5.620E-01	1.024	0.147	0.2873	2350.00	104.59	99.00	209.19
340.0	1.07E+10	1.0	30.5	0.000	6.90E-01	0.329	5.620E-01	1.014	0.152	0.2962	2350.00	107.82	99.00	215.65
350.0	1.10E+10	1.0	30.5	0.000	6.75E-01	0.340	5.620E-01	1.004	0.156	0.3049	2350.00	110.96	99.00	221.96
360.0	1.14E+10	1.0	30.5	0.000	6.61E-01	0.350	5.620E-01	0.995	0.160	0.3134	2350.00	114.07	99.00	228.14
370.0	1.17E+10	1.0	30.5	0.000	6.46E-01	0.360	5.620E-01	0.986	0.163	0.3217	2350.00	117.08	99.00	234.17
380.0	1.20E+10	1.0	30.5	0.000	6.35E-01	0.369	5.620E-01	0.977	0.167	0.3297	2350.00	120.03	99.00	240.06
390.0	1.23E+10	1.0	30.5	0.000	6.22E-01	0.379	5.620E-01	0.969	0.171	0.3377	2350.00	122.91	99.00	245.81
400.0	1.26E+10	1.0	30.5	0.000	6.10E-01	0.388	5.620E-01	0.961	0.174	0.3454	2350.00	125.72	99.00	251.44
410.0	1.29E+10	1.0	30.5	0.000	5.98E-01	0.398	5.620E-01	0.954	0.177	0.3529	2350.00	128.47	99.00	256.94
420.0	1.32E+10	1.0	30.5	0.000	5.87E-01	0.407	5.620E-01	0.947	0.181	0.3603	2350.00	131.15	99.00	262.31
430.0	1.36E+10	1.0	30.5	0.000	5.75E-01	0.416	5.620E-01	0.940	0.184	0.3675	2350.00	133.78	99.00	267.57
440.0	1.39E+10	1.0	30.5	0.000	5.65E-01	0.425	5.620E-01	0.933	0.187	0.3746	2350.00	136.35	99.00	272.70
450.0	1.42E+10	1.0	30.5	0.000	5.54E-01	0.433	5.620E-01	0.927	0.190	0.3815	2350.00	138.87	99.00	277.73
460.0	1.45E+10	1.0	30.5	0.000	5.44E-01	0.442	5.620E-01	0.921	0.193	0.3883	2350.00	141.32	99.00	282.65
470.0	1.48E+10	1.0	30.5	0.000	5.34E-01	0.450	5.620E-01	0.915	0.196	0.3949	2350.00	143.73	99.00	287.46
480.0	1.51E+10	1.0	30.5	0.000	5.25E-01	0.458	5.620E-01	0.909	0.199	0.4013	2350.00	146.09	99.00	292.17
490.0	1.55E+10	1.0	30.5	0.000	5.15E-01	0.466	5.620E-01	0.904	0.201	0.4077	2350.00	148.39	99.00	296.78
500.0	1.58E+10	1.0	30.5	0.000	5.06E-01	0.474	5.620E-01	0.899	0.204	0.4139	2350.00	150.65	99.00	301.30

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying Kd - Upper
PSR Superfund Site

Advect **Active Transport Formulae:**

Kd=foc*Koc	Watson 1991, p.188
R=1+(Kd,cap*p)/ne	Watson 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.136
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Z))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*x-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2))
ERFC0= 1-ERF()

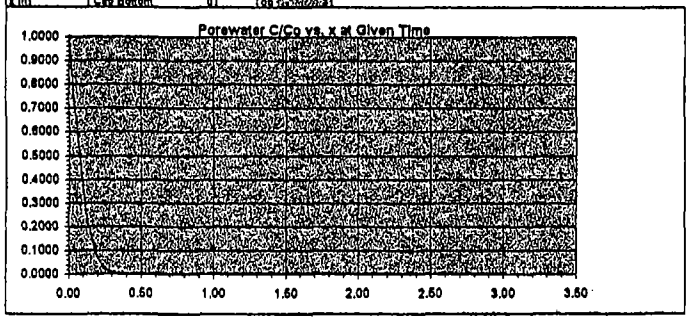
1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

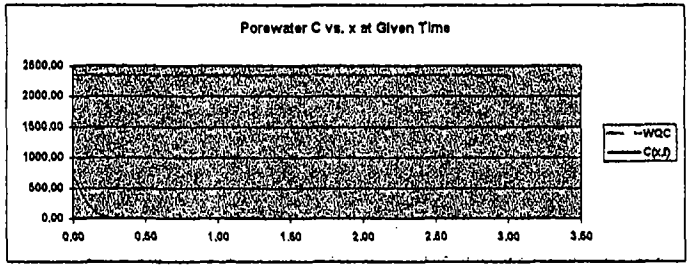
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	40	L/kg
	ne	[illegible]	R	2358.91	Kd, cap	[illegible]	L/kg
	g	2.65 gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L (LOEL)
	i	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4675 gm/cm3	d	0.0144 cm			
	I	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	726 ml/g			
	v	7.05E-08 cm/s	D	3.9E-06 cm2/sec			
			m	7.05E-08 cm/sec	(m=v for u=0)		

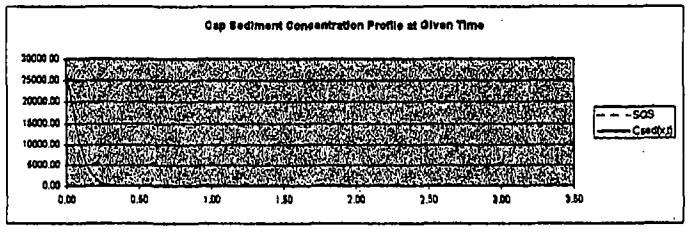
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36510	days =	[illegible]	[illegible]	[illegible]
x (ft)	Cap Bottom	0	Top	[illegible]	[illegible]







C(x,t)	Porewater concentration in cap (ug/L)	Conversions: 1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	lb/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DL,sed / (n+p*Kd,cap) — USEPA 1998

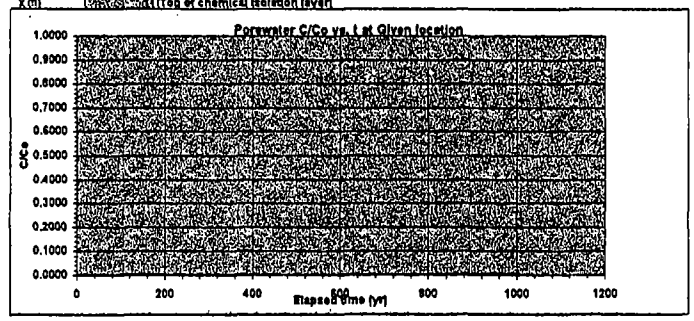
Cap thickness lost due to expression of porewater during consolidation (ft)

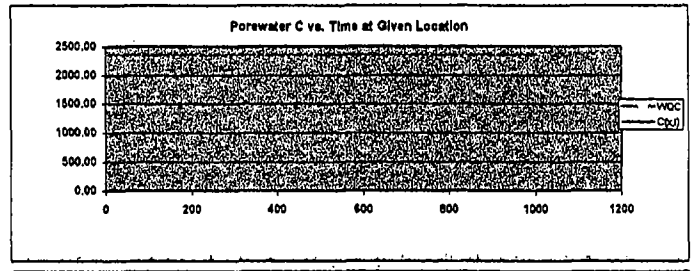
TI,consol = 0.001 feet (typically negligible)

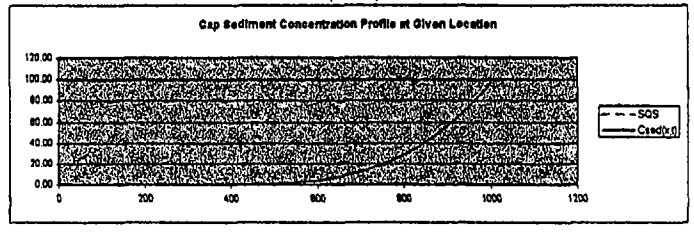
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	1000	
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)		







Sensitivity Analysis for Chemical Isolation Analysis - Varying Kd - Upper Bo
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT				CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-2.07E-03	1.023	0.000E+00	0.021	0.977	1.0000	2350.00	725.00	99.00	26390.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	6.620E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	3.80E-01	0.591	3.312E-02	0.421	0.581	0.5804	2350.00	420.81	99.00	15317.40	20.0	6.31E+08	1.0	30.5	0.000	1.48E+01	0.000	6.620E-01	14.841	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	7.61E-01	0.370	6.624E-02	0.822	0.248	0.2857	2350.00	182.64	99.00	7012.21	40.0	1.26E+09	1.0	30.5	0.000	1.05E+01	0.000	6.620E-01	10.571	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	1.18E+00	0.096	9.935E-02	1.223	0.084	0.0937	2350.00	67.91	99.00	2472.10	60.0	1.89E+09	1.0	30.5	0.000	8.60E+00	0.000	6.620E-01	8.637	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.24	7.3	0.000	1.58E+00	0.025	1.325E-01	1.623	0.022	0.0250	2350.00	18.14	99.00	660.28	80.0	2.52E+09	1.0	30.5	0.000	7.45E+00	0.000	6.620E-01	7.484	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.30	9.1	0.000	1.96E+00	0.005	1.656E-01	2.024	0.004	0.0050	2350.00	3.63	99.00	132.13	100.0	3.15E+09	1.0	30.5	0.000	6.66E+00	0.000	6.620E-01	6.689	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.36	11.0	0.000	2.36E+00	0.001	1.987E-01	2.425	0.001	0.0007	2350.00	0.54	99.00	19.66	120.0	3.78E+09	1.0	30.5	0.000	6.07E+00	0.000	6.620E-01	6.118	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.42	12.8	0.000	2.76E+00	0.000	2.319E-01	2.825	0.000	0.0001	2350.00	0.06	99.00	2.16	140.0	4.42E+09	1.0	30.5	0.000	5.62E+00	0.000	6.620E-01	5.668	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.48	14.6	0.000	3.16E+00	0.000	2.649E-01	3.226	0.000	0.0000	2350.00	0.00	99.00	0.18	160.0	5.05E+09	1.0	30.5	0.000	5.26E+00	0.000	6.620E-01	5.306	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.54	16.5	0.000	3.56E+00	0.000	2.981E-01	3.627	0.000	0.0000	2350.00	0.00	99.00	0.01	180.0	5.68E+09	1.0	30.5	0.000	4.95E+00	0.000	6.620E-01	5.005	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.60	18.3	0.000	3.95E+00	0.000	3.312E-01	4.027	0.000	0.0000	2350.00	0.00	99.00	0.00	200.0	6.31E+09	1.0	30.5	0.000	4.69E+00	0.000	6.620E-01	4.751	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.66	20.1	0.000	4.35E+00	0.000	3.643E-01	4.428	0.000	0.0000	2350.00	0.00	99.00	0.00	220.0	6.94E+09	1.0	30.5	0.000	4.47E+00	0.000	6.620E-01	4.533	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.72	21.9	0.000	4.79E+00	0.000	3.974E-01	4.829	0.000	0.0000	2350.00	0.00	99.00	0.00	240.0	7.57E+09	1.0	30.5	0.000	4.29E+00	0.000	6.620E-01	4.342	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.78	23.8	0.000	5.19E+00	0.000	4.305E-01	5.229	0.000	0.0000	2350.00	0.00	99.00	0.00	260.0	8.20E+09	1.0	30.5	0.000	4.11E+00	0.000	6.620E-01	4.176	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.84	25.6	0.000	5.59E+00	0.000	4.636E-01	5.630	0.000	0.0000	2350.00	0.00	99.00	0.00	280.0	8.83E+09	1.0	30.5	0.000	3.95E+00	0.000	6.620E-01	4.026	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.90	27.4	0.000	5.99E+00	0.000	4.968E-01	6.030	0.000	0.0000	2350.00	0.00	99.00	0.00	300.0	9.46E+09	1.0	30.5	0.000	3.92E+00	0.000	6.620E-01	3.891	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.96	29.3	0.000	6.38E+00	0.000	5.299E-01	6.431	0.000	0.0000	2350.00	0.00	99.00	0.00	320.0	1.01E+10	1.0	30.5	0.000	3.70E+00	0.000	6.620E-01	3.770	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	1.02	31.1	0.000	6.79E+00	0.000	5.630E-01	6.832	0.000	0.0000	2350.00	0.00	99.00	0.00	340.0	1.07E+10	1.0	30.5	0.000	3.58E+00	0.000	6.620E-01	3.660	0.000	0.0000	2350.00	0.00	99.00	0.01
36500	3.15E+09	1.08	32.9	0.000	7.19E+00	0.000	5.961E-01	7.232	0.000	0.0000	2350.00	0.00	99.00	0.00	360.0	1.14E+10	1.0	30.5	0.000	3.48E+00	0.000	6.620E-01	3.559	0.000	0.0000	2350.00	0.00	99.00	0.02
36500	3.15E+09	1.14	34.7	0.000	7.59E+00	0.000	6.292E-01	7.633	0.000	0.0000	2350.00	0.00	99.00	0.00	380.0	1.20E+10	1.0	30.5	0.000	3.39E+00	0.000	6.620E-01	3.466	0.000	0.0000	2350.00	0.00	99.00	0.04
36500	3.15E+09	1.20	36.6	0.000	7.99E+00	0.000	6.624E-01	8.034	0.000	0.0000	2350.00	0.00	99.00	0.00	400.0	1.26E+10	1.0	30.5	0.000	3.30E+00	0.000	6.620E-01	3.380	0.000	0.0000	2350.00	0.00	99.00	0.08
36500	3.15E+09	1.26	38.4	0.000	8.39E+00	0.000	6.955E-01	8.434	0.000	0.0000	2350.00	0.00	99.00	0.00	420.0	1.32E+10	1.0	30.5	0.000	3.22E+00	0.000	6.620E-01	3.301	0.000	0.0000	2350.00	0.00	99.00	0.14
36500	3.15E+09	1.32	40.2	0.000	8.79E+00	0.000	7.286E-01	8.835	0.000	0.0000	2350.00	0.00	99.00	0.00	440.0	1.39E+10	1.0	30.5	0.000	3.14E+00	0.000	6.620E-01	3.227	0.000	0.0000	2350.00	0.01	99.00	0.23
36500	3.15E+09	1.38	42.1	0.000	9.19E+00	0.000	7.617E-01	9.238	0.000	0.0000	2350.00	0.00	99.00	0.00	460.0	1.45E+10	1.0	30.5	0.000	3.07E+00	0.000	6.620E-01	3.158	0.000	0.0000	2350.00	0.01	99.00	0.37
36500	3.15E+09	1.44	43.9	0.000	9.60E+00	0.000	7.948E-01	9.638	0.000	0.0000	2350.00	0.00	99.00	0.00	480.0	1.51E+10	1.0	30.5	0.000	3.00E+00	0.000	6.620E-01	3.093	0.000	0.0000	2350.00	0.02	99.00	0.57
36500	3.15E+09	1.50	45.7	0.000	1.00E+01	0.000	8.279E-01	10.037	0.000	0.0000	2350.00	0.00	99.00	0.00	500.0	1.58E+10	1.0	30.5	0.000	2.94E+00	0.000	6.620E-01	3.033	0.000	0.0000	2350.00	0.02	99.00	0.84
36500	3.15E+09	1.56	47.5	0.000	1.04E+01	0.000	8.611E-01	10.439	0.000	0.0000	2350.00	0.00	99.00	0.00	520.0	1.64E+10	1.0	30.5	0.000	2.88E+00	0.000	6.620E-01	2.976	0.000	0.0000	2350.00	0.03	99.00	1.20
36500	3.15E+09	1.62	49.4	0.000	1.08E+01	0.000	8.942E-01	10.838	0.000	0.0000	2350.00	0.00	99.00	0.00	540.0	1.70E+10	1.0	30.5	0.000	2.83E+00	0.000	6.620E-01	2.922	0.000	0.0001	2350.00	0.05	99.00	1.68
36500	3.15E+09	1.68	51.2	0.000	1.12E+01	0.000	9.273E-01	11.239	0.000	0.0000	2350.00	0.00	99.00	0.00	560.0	1.77E+10	1.0	30.5	0.000	2.77E+00	0.000	6.620E-01	2.871	0.000	0.0001	2350.00	0.08	99.00	2.29
36500	3.15E+09	1.74	53.0	0.000	1.16E+01	0.000	9.604E-01	11.640	0.000	0.0000	2350.00	0.00	99.00	0.00	580.0	1.83E+10	1.0	30.5	0.000	2.72E+00	0.000	6.620E-01	2.822	0.000	0.0001	2350.00	0.08	99.00	3.06
36500	3.15E+09	1.80	54.9	0.000	1.20E+01	0.000	9.935E-01	12.040	0.000	0.0000	2350.00	0.00	99.00	0.00	600.0	1.89E+10	1.0	30.5	0.000	2.68E+00	0.000	6.620E-01	2.777	0.000	0.0002	2350.00	0.11	99.00	4.01
36500	3.15E+09	1.86	56.7	0.000	1.24E+01	0.000	1.027E+00	12.441	0.000	0.0000	2350.00	0.00	99.00	0.00	620.0	1.96E+10	1.0	30.5	0.000	2.63E+00	0.000	6.620E-01	2.733	0.000	0.0002	2350.00	0.14	99.00	5.17
36500	3.15E+09	1.92	58.5	0.000	1.28E+01	0.000	1.060E+00	12.842	0.000	0.0000	2350.00	0.00	99.00	0.00	640.0	2.02E+10	1.0	30.5	0.000	2.59E+00	0.000	6.620E-01	2.692	0.000	0.0002	2350.00	0.18	99.00	6.57
36500	3.15E+09	1.98	60.4	0.000	1.32E+01	0.000	1.093E+00	13.242	0.000	0.0000	2350.00	0.00	99.00	0.00	660.0	2.08E+10	1.0	30.5	0.000	2.55E+00	0.000	6.620E-01	2.652	0.000	0.0003	2350.00	0.23	99.00	8.22
36500	3.15E+09	2.04	62.2	0.000	1.36E+01	0.000	1.126E+00	13.643	0.000	0.0000	2350.00	0.00	99.00	0.00	680.0	2.14E+10	1.0	30.5	0.000	2.51E+00	0.000	6.620E-01	2.615	0.000	0.0004	2350.00	0.28	99.00	10.16
36500	3.15E+09	2.10	64.0	0.000	1.40E+01	0.000	1.159E+00	14.044	0.000	0.0000	2350.00	0.00	99.00	0.00	700.0	2.21E+10	1.0	30.5	0.000	2.47E+00	0.000	6.620E-01	2.579	0.000	0.0005	2350.00	0.34	99.00	12.41
36500	3.15E+09	2.16	65.8	0.000	1.44E+01	0.000	1.192E+00	14.444	0.000	0.0000	2350.00	0.00	99.00	0.00	720.0	2.27E+10	1.0	30.5	0.000	2.43E+00	0.001	6.620E-01	2.544	0.000	0.0006	2350.00	0.41	99.00	15.00
36500	3.15E+09	2.22	67.7	0.000	1.48E+01	0.000	1.226E+00	14.845	0.000	0.0000	2350.00	0.00	99.00	0.00	740.0	2.33E+10	1.0	30.5	0.000	2.40E+00	0.001	6.620E-01	2.511	0.000	0.0007	2350.00	0.49	99.00	17.85
36500	3.15E+09	2.28	69.5	0.000	1.52E+01	0.000	1.258E+00	15.245	0.000	0.0000	2350.00	0.00	99.00	0.00	760.0	2.40E+10	1.0	30.5	0.000	2.37E+00	0.001	6.620E-01	2.479	0.000	0.0008	2350.00	0.58	99.00	21.28
36500	3.15E+09	2.34	71.3	0.000	1.56E+01	0.000	1.292E+00	15.646	0.000	0.0000	2350.00	0.00	99.00	0.00	780.0	2.46E+10	1.0	30.5	0.000	2.33E+00	0.001	6.620E-01	2.448	0.001	0.0009	2350.00	0.69	99.00	25.01
36500	3.15E+09	2.40	73.2	0.000	1.60E+01	0.000	1.325E+00	16.047	0.000	0.0000	2350.00	0.00	99.00	0.00	800.0	2.52E+10	1.0	30.5	0.000	2.30E+00	0.001	6.620E-01	2.419	0.001	0.0011	2350.00	0.80	99.00	28.18
36500	3.15E+09	2.46	75.0	0.000	1.64E+01	0.000	1.358E+00	16.447	0.000	0.0000	2350.00	0.00	99.00	0.00	820.0	2.59E+10	1.0	30.5	0.000	2.27E+00	0.001	6.620E-01	2.391	0.001	0.0013	2350.00	0.93	99.00	33.78
36500	3.15E+09	2.52	76.8	0.000	1.68E+01	0.000	1.391E+00	16.848	0.000	0.0000	2350.00	0.00	99.00	0.00	840.0	2.65E+10	1.0	30.5	0.000	2.24E+00	0.002	6.620E-01	2.364	0.001	0.0015	2350.00	1.07	99.00	38.86
36500	3.15E+09	2.58	78.6	0.000	1.72E+01	0.000	1.424E+00	17.249	0.000	0.0000	2350.00	0.00	99.00	0.00	860.0	2.71E+10	1.0	30.5	0.000	2.22E+00	0.002	6.620E-01	2.336	0.001	0.0017	2350.00	1.22	99.00	44.41
36500	3.15E+09	2.64	80.5	0.000	1.76E+01	0.000	1.457E+00	17.649	0.000	0.0000	2350.00	0.00	99.00	0.00	880.0	2.78E+10	1.0	30.5	0.000	2.19E+00	0.002	6.620E-01	2.312	0.001	0.0019	2350.00	1.39	99.00	50.46
36500	3.15E+09	2.70	82.3	0.000	1.80E+01	0.000	1.490E+00	18.050	0.000	0.0000	2350.00	0.00	99.00	0.00	900.0	2.84E+10	1.0	30.5	0.000	2.16E+00	0.002	6.620E-01	2.288	0.001	0.0022	2350.00	1.57	99.00	57.01
36500	3.15E+09	2.76	84.1	0.000	1.84E+01	0.000	1.523E+00	18.451	0.000	0.0000	2350.00	0.00	99.00	0.00	920.0	2.90E+10	1.0	30.5	0.000	2.14E+00	0.002	6.620E-01	2.264	0.001	0.0024	2350.00	1.76	99.00	64.10
36500	3.15E+09	2.82	86.0	0.000	1.88E+01	0.000	1.557E+00	18.851	0.000	0.0000	2350.00	0.00	99.00	0.00	940.0	2.96E+10	1.0	30.5	0.000	2.11E+00	0.003	6.620E-01	2.241	0.002	0.0027	2350.00	1.97	99.00	71.71
36500	3.15E+09	2.88	87.8	0.000	1.92E+01	0.000	1.590E+00	19.252	0.000	0.0000	2350.00	0.00	99.00	0.00	960.0	3.03E+10	1.0	30.5	0.000	2.09E+00	0.003	6.620E-01	2.219	0.002	0.0030	2350.00	2.19	99.00	79.87
36500	3.15E+09	2.94	89.6	0.000	1.96E+01	0.000	1.623E+00	19.653	0.000	0.0000	2350.00	0.00	99.00	0.00	980.0	3.09E+10	1.0	30.5	0.000	2.07E+00	0.003	6.620E-01	2.198	0.002	0.0034	2350.00	2.43	99.00	88.68
36500	3.15E+09	3.00	91.4	0.000	2.00E+01	0.000	1.656E+00	20.053	0.000	0.0000	2350.00	0.00	99.00	0.00	1000.0	3.15E+10	1.0	30.5	0.000	2.05E+00	0.004	6.620E-01	2.177	0.002	0.0037	2350.00	2.69	99.00	97.86

Note 1: *Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms*

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying Kd - Lov
PSR Superfund Site

Advecti... ...rative Transport Formulae:

Kd=foc*Koc	Walton 1991, p.166
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.136
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*x+m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2)))
ERFC0= 1-ERF0

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

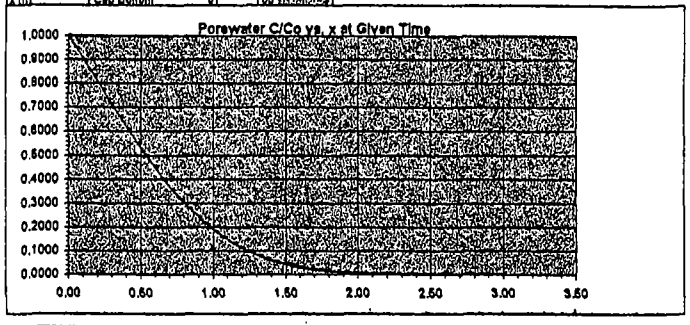
...ENSITIVITY ANALYSIS

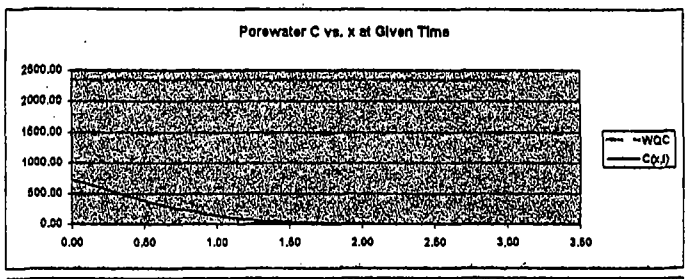
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	40	L/kg
	ne	[illegible]	R	68.06	Kd, cap	[illegible]	L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L (LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	17 ml/g			
	v	7.05E-08 cm/s	D	3.9E-06 cm2/sec			
			m	7.05E-08 cm/sec	(m=v for u=0)		

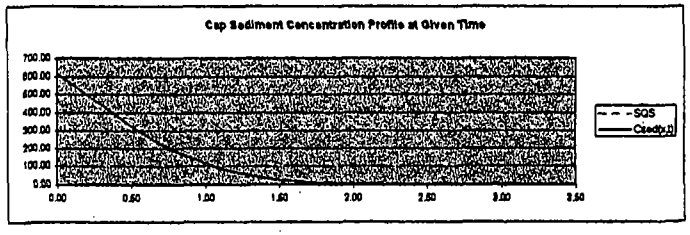
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	[illegible]
x (ft)	Cap Bottom	0	Top [illegible]	[illegible]







C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (p/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLI... ...ON

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap)	USEPA 1996

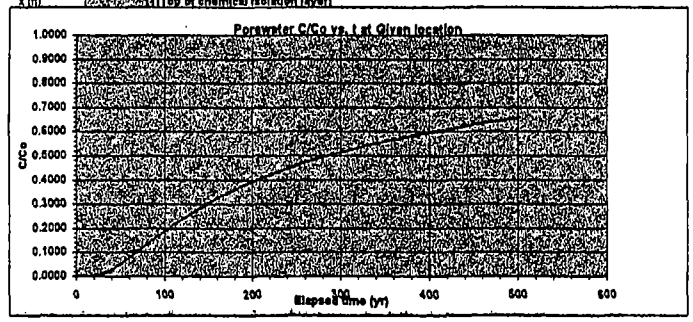
Cap thickness lost due to expression of porewater during consolidation (ft)

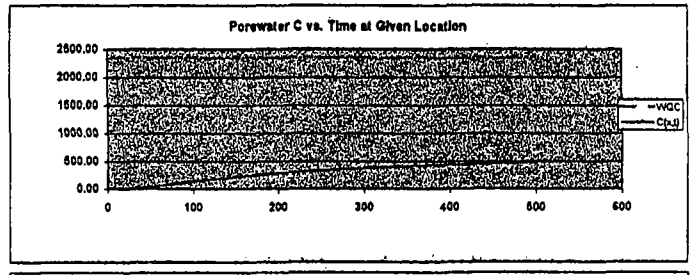
Tl,consol =	0.858 feet	(typically negligible)

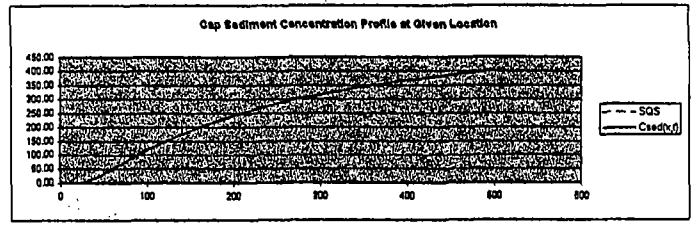
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)	







Sensitivity Analysis for Chemical Isolation Analysis - Varying Kd - Lower Bo
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.34E-01	1.150	0.000E+00	0.134	0.850	1.0000	2350.00	725.00	99.00	616.25	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.520E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-7.23E-02	1.081	3.312E-02	0.196	0.782	0.9448	2350.00	684.98	99.00	582.23	10.0	3.15E+08	1.0	30.5	0.000	3.31E+00	0.000	5.520E-01	3.299	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	-1.05E-02	1.012	6.624E-02	0.256	0.715	0.8965	2350.00	643.98	99.00	547.38	20.0	6.31E+08	1.0	30.5	0.000	2.34E+00	0.002	5.520E-01	2.362	0.001	0.0016	2350.00	1.08	99.00	0.92
36500	3.15E+09	0.18	5.5	0.000	5.12E-02	0.942	9.936E-02	0.319	0.662	0.8309	2350.00	602.41	99.00	512.05	30.0	9.46E+08	1.0	30.5	0.000	1.81E+00	0.011	5.520E-01	1.953	0.006	0.0103	2350.00	7.48	99.00	6.36
36500	3.15E+09	0.24	7.3	0.000	1.13E-01	0.873	1.325E-01	0.381	0.590	0.7732	2350.00	560.50	99.00	476.61	40.0	1.26E+09	1.0	30.5	0.000	1.54E+00	0.029	5.520E-01	1.712	0.015	0.0280	2350.00	20.29	99.00	17.24
36500	3.15E+09	0.30	9.1	0.000	1.75E-01	0.806	1.656E-01	0.443	0.531	0.7188	2350.00	518.93	99.00	441.09	50.0	1.58E+09	1.0	30.5	0.000	1.36E+00	0.054	5.520E-01	1.561	0.029	0.0517	2350.00	37.49	99.00	31.87
36500	3.15E+09	0.36	11.0	0.000	2.37E-01	0.738	1.987E-01	0.505	0.476	0.6590	2350.00	477.76	99.00	406.09	60.0	1.89E+09	1.0	30.5	0.000	1.23E+00	0.093	5.520E-01	1.433	0.043	0.0787	2350.00	57.05	99.00	48.49
36500	3.15E+09	0.42	12.8	0.000	2.98E-01	0.673	2.318E-01	0.566	0.423	0.6033	2350.00	437.40	99.00	371.79	70.0	2.21E+09	1.0	30.5	0.000	1.12E+00	0.114	5.520E-01	1.343	0.056	0.1069	2350.00	77.51	99.00	65.89
36500	3.15E+09	0.48	14.6	0.000	3.60E-01	0.611	2.649E-01	0.628	0.374	0.5492	2350.00	398.21	99.00	338.47	80.0	2.52E+09	1.0	30.5	0.000	1.03E+00	0.145	5.520E-01	1.271	0.072	0.1352	2350.00	98.01	99.00	83.31
36500	3.15E+09	0.54	16.5	0.000	4.22E-01	0.561	2.981E-01	0.690	0.329	0.4972	2350.00	360.44	99.00	306.37	90.0	2.84E+09	1.0	30.5	0.000	9.56E-01	0.178	5.520E-01	1.212	0.088	0.1628	2350.00	118.05	99.00	100.34
36500	3.15E+09	0.60	18.3	0.000	4.84E-01	0.494	3.312E-01	0.752	0.288	0.4474	2350.00	324.35	99.00	275.69	100.0	3.15E+09	1.0	30.5	0.000	8.96E-01	0.206	5.520E-01	1.163	0.100	0.1894	2350.00	137.35	99.00	116.75
36500	3.15E+09	0.66	20.1	0.000	5.45E-01	0.441	3.643E-01	0.813	0.250	0.4002	2350.00	290.14	99.00	246.62	110.0	3.47E+09	1.0	30.5	0.000	8.41E-01	0.234	5.520E-01	1.122	0.113	0.2149	2350.00	155.79	99.00	132.43
36500	3.15E+09	0.72	21.9	0.000	6.07E-01	0.391	3.974E-01	0.875	0.216	0.3568	2350.00	257.98	99.00	219.28	120.0	3.78E+09	1.0	30.5	0.000	7.93E-01	0.262	5.520E-01	1.087	0.124	0.2381	2350.00	173.33	99.00	147.33
36500	3.15E+09	0.78	23.8	0.000	6.69E-01	0.344	4.305E-01	0.937	0.185	0.3146	2350.00	227.98	99.00	193.78	130.0	4.10E+09	1.0	30.5	0.000	7.50E-01	0.289	5.520E-01	1.056	0.135	0.2620	2350.00	189.97	99.00	161.47
36500	3.15E+09	0.84	25.6	0.000	7.31E-01	0.301	4.636E-01	0.999	0.158	0.2762	2350.00	200.23	99.00	170.19	140.0	4.42E+09	1.0	30.5	0.000	7.11E-01	0.314	5.520E-01	1.029	0.146	0.2837	2350.00	205.72	99.00	174.86
36500	3.15E+09	0.90	27.4	0.000	7.92E-01	0.262	4.966E-01	1.061	0.134	0.2410	2350.00	174.76	99.00	148.54	150.0	4.73E+09	1.0	30.5	0.000	6.76E-01	0.339	5.520E-01	1.006	0.155	0.3043	2350.00	220.63	99.00	187.53
36500	3.15E+09	0.96	29.3	0.000	8.54E-01	0.227	5.289E-01	1.122	0.112	0.2091	2350.00	151.56	99.00	128.83	160.0	5.05E+09	1.0	30.5	0.000	6.44E-01	0.362	5.520E-01	0.983	0.164	0.3239	2350.00	234.75	99.00	199.53
36500	3.15E+09	1.02	31.1	0.000	9.15E-01	0.195	5.630E-01	1.184	0.094	0.1802	2350.00	130.61	99.00	111.02	170.0	5.36E+09	1.0	30.5	0.000	6.15E-01	0.385	5.520E-01	0.964	0.173	0.3422	2350.00	248.12	99.00	210.90
36500	3.15E+09	1.08	32.9	0.000	9.76E-01	0.167	5.961E-01	1.248	0.078	0.1542	2350.00	111.83	99.00	95.05	180.0	5.68E+09	1.0	30.5	0.000	5.87E-01	0.406	5.520E-01	0.947	0.180	0.3597	2350.00	260.80	99.00	221.68
36500	3.15E+09	1.14	34.7	0.000	1.04E+00	0.142	6.292E-01	1.308	0.064	0.1312	2350.00	95.13	99.00	80.86	190.0	5.99E+09	1.0	30.5	0.000	5.62E-01	0.427	5.520E-01	0.932	0.188	0.3763	2350.00	272.83	99.00	231.90
36500	3.15E+09	1.20	36.6	0.000	1.10E+00	0.119	6.624E-01	1.368	0.053	0.1109	2350.00	80.39	99.00	68.33	200.0	6.31E+09	1.0	30.5	0.000	5.38E-01	0.448	5.520E-01	0.917	0.194	0.3921	2350.00	284.26	99.00	241.62
36500	3.15E+09	1.26	38.4	0.000	1.16E+00	0.100	6.955E-01	1.431	0.043	0.0931	2350.00	67.49	99.00	57.37	210.0	6.62E+09	1.0	30.5	0.000	5.16E-01	0.468	5.520E-01	0.905	0.201	0.4071	2350.00	295.13	99.00	250.86
36500	3.15E+09	1.32	40.2	0.000	1.22E+00	0.083	7.286E-01	1.493	0.035	0.0778	2350.00	56.28	99.00	47.84	220.0	6.94E+09	1.0	30.5	0.000	4.95E-01	0.484	5.520E-01	0.893	0.207	0.4213	2350.00	305.47	99.00	259.66
36500	3.15E+09	1.38	42.1	0.000	1.29E+00	0.069	7.617E-01	1.555	0.028	0.0643	2350.00	46.62	99.00	39.63	230.0	7.25E+09	1.0	30.5	0.000	4.76E-01	0.501	5.520E-01	0.882	0.212	0.4348	2350.00	315.33	99.00	268.03
36500	3.15E+09	1.44	43.9	0.000	1.35E+00	0.057	7.948E-01	1.616	0.022	0.0529	2350.00	38.36	99.00	32.61	240.0	7.57E+09	1.0	30.5	0.000	4.57E-01	0.519	5.520E-01	0.872	0.217	0.4479	2350.00	324.74	99.00	276.03
36500	3.15E+09	1.50	45.7	0.000	1.41E+00	0.046	8.279E-01	1.678	0.018	0.0432	2350.00	31.35	99.00	26.65	250.0	7.88E+09	1.0	30.5	0.000	4.39E-01	0.535	5.520E-01	0.863	0.222	0.4603	2350.00	333.73	99.00	283.67
36500	3.15E+09	1.56	47.5	0.000	1.47E+00	0.037	8.611E-01	1.740	0.014	0.0351	2350.00	25.45	99.00	21.63	260.0	8.20E+09	1.0	30.5	0.000	4.22E-01	0.550	5.520E-01	0.855	0.227	0.4722	2350.00	342.32	99.00	290.97
36500	3.15E+09	1.62	49.4	0.000	1.53E+00	0.030	8.942E-01	1.802	0.011	0.0283	2350.00	20.51	99.00	17.44	270.0	8.51E+09	1.0	30.5	0.000	4.06E-01	0.565	5.520E-01	0.847	0.231	0.4835	2350.00	350.64	99.00	297.96
36500	3.15E+09	1.68	51.2	0.000	1.60E+00	0.024	9.273E-01	1.863	0.008	0.0227	2350.00	16.42	99.00	13.96	280.0	8.83E+09	1.0	30.5	0.000	3.91E-01	0.580	5.520E-01	0.840	0.235	0.4944	2350.00	358.42	99.00	304.66
36500	3.15E+09	1.74	53.0	0.000	1.66E+00	0.019	9.604E-01	1.925	0.006	0.0180	2350.00	13.06	99.00	11.10	290.0	9.16E+09	1.0	30.5	0.000	3.76E-01	0.595	5.520E-01	0.833	0.239	0.5049	2350.00	365.96	99.00	311.08
36500	3.15E+09	1.80	54.9	0.000	1.72E+00	0.015	9.935E-01	1.987	0.005	0.0142	2350.00	10.31	99.00	8.76	300.0	9.46E+09	1.0	30.5	0.000	3.62E-01	0.609	5.520E-01	0.827	0.242	0.5149	2350.00	373.23	99.00	317.24
36500	3.15E+09	1.86	56.7	0.000	1.78E+00	0.012	1.027E+00	2.049	0.004	0.0111	2350.00	8.06	99.00	6.87	310.0	9.78E+09	1.0	30.5	0.000	3.49E-01	0.622	5.520E-01	0.821	0.246	0.5244	2350.00	380.20	99.00	323.17
36500	3.15E+09	1.92	58.5	0.000	1.84E+00	0.009	1.060E+00	2.111	0.003	0.0087	2350.00	6.29	99.00	5.35	320.0	1.01E+10	1.0	30.5	0.000	3.36E-01	0.635	5.520E-01	0.815	0.249	0.5337	2350.00	386.90	99.00	328.86
36500	3.15E+09	1.98	60.4	0.000	1.90E+00	0.007	1.093E+00	2.172	0.002	0.0067	2350.00	4.87	99.00	4.14	330.0	1.04E+10	1.0	30.5	0.000	3.23E-01	0.648	5.520E-01	0.810	0.252	0.5425	2350.00	393.35	99.00	334.34
36500	3.15E+09	2.04	62.2	0.000	1.97E+00	0.005	1.126E+00	2.234	0.002	0.0052	2350.00	3.74	99.00	3.18	340.0	1.07E+10	1.0	30.5	0.000	3.11E-01	0.660	5.520E-01	0.805	0.255	0.5511	2350.00	399.56	99.00	339.62
36500	3.15E+09	2.10	64.0	0.000	2.03E+00	0.004	1.159E+00	2.296	0.001	0.0039	2350.00	2.85	99.00	2.42	350.0	1.10E+10	1.0	30.5	0.000	2.99E-01	0.672	5.520E-01	0.801	0.257	0.5594	2350.00	405.54	99.00	344.71
36500	3.15E+09	2.16	65.8	0.000	2.09E+00	0.003	1.192E+00	2.358	0.001	0.0030	2350.00	2.16	99.00	1.83	360.0	1.14E+10	1.0	30.5	0.000	2.88E-01	0.684	5.520E-01	0.797	0.260	0.5673	2350.00	411.32	99.00	349.62
36500	3.15E+09	2.22	67.7	0.000	2.15E+00	0.002	1.225E+00	2.419	0.001	0.0022	2350.00	1.62	99.00	1.38	370.0	1.17E+10	1.0	30.5	0.000	2.77E-01	0.695	5.520E-01	0.793	0.262	0.5750	2350.00	416.89	99.00	354.36
36500	3.15E+09	2.28	69.5	0.000	2.21E+00	0.002	1.258E+00	2.481	0.000	0.0017	2350.00	1.21	99.00	1.03	380.0	1.20E+10	1.0	30.5	0.000	2.67E-01	0.706	5.520E-01	0.789	0.264	0.5826	2350.00	422.26	99.00	358.94
36500	3.15E+09	2.34	71.3	0.000	2.27E+00	0.001	1.292E+00	2.543	0.000	0.0012	2350.00	0.90	99.00	0.76	390.0	1.23E+10	1.0	30.5	0.000	2.57E-01	0.717	5.520E-01	0.786	0.266	0.5898	2350.00	427.48	99.00	363.36
36500	3.15E+09	2.40	73.2	0.000	2.34E+00	0.001	1.325E+00	2.605	0.000	0.0009	2350.00	0.68	99.00	0.58	400.0	1.26E+10	1.0	30.5	0.000	2.47E-01	0.727	5.520E-01	0.783	0.268	0.5966	2350.00	432.52	99.00	367.64
36500	3.15E+09	2.46	75.0	0.000	2.40E+00	0.001	1.358E+00	2.666	0.000	0.0007	2350.00	0.48	99.00	0.41	410.0	1.29E+10	1.0	30.5	0.000	2.37E-01	0.738	5.520E-01	0.780	0.270	0.6033	2350.00	437.39	99.00	371.78
36500	3.15E+09	2.52	76.8	0.000	2.46E+00	0.001	1.391E+00	2.728	0.000	0.0005	2350.00	0.35	99.00	0.30	420.0	1.32E+10	1.0	30.5	0.000	2.28E-01	0.748	5.520E-01	0.777	0.272	0.6098	2350.00	442.11	99.00	375.80
36500	3.15E+09	2.58	78.6	0.000	2.52E+00	0.000	1.424E+00	2.790	0.000	0.0003	2350.00	0.25	99.00	0.21	430.0	1.36E+10	1.0	30.5	0.000	2.18E-01	0.757	5.520E-01	0.774	0.273	0.6161	2350.00	446.68	99.00	379.68
36500	3.15E+09	2.64	80.5	0.000	2.58E+00	0.000	1.457E+00	2.852	0.000	0.0002	2350.00	0.18	99.00	0.15	440.0	1.39E+10	1.0	30.5	0.000	2.10E-01	0.767	5.520E-01	0.772	0.275	0.6222	2350.00	451.12	99.00	383.45
36500	3.15E+09	2.70	82.3	0.000	2.65E+00	0.000	1.490E+00	2.913	0.000	0.0002	2350.00	0.13	99.00	0.11	450.0	1.42E+10	1.0	30.5	0.000	2.01E-01	0.776	5.520E-01	0.770	0.276	0.6282	2350.00	455.42	99.00	387.11
36500	3.15E+09	2.76	84.1	0.000	2.71E+00	0.000	1.523E+00	2.975	0.000	0.0001	2350.00	0.09	99.00	0.08	460.0	1.45E+10	1.0	30.5	0.000	1.92E-01	0.785	5.520E-01	0.767	0.278	0.6339	2350.00	459.69	99.00	390.65
36500	3.15E+09	2.82	86.0	0.000	2.77E+00	0.000	1.557E+00	3.037	0.000	0.0001	2350.00	0.06	99.00	0.05	470.0	1.48E+10	1.0	30.5	0.000	1.84E-01	0.794	5.520E-01	0.765	0.279	0.6396	2350.00	463.65	99.00	394.10
36500	3.15E+09	2.88	87.8	0.000	2.83E+00	0.000	1.590E+00	3.099	0.000	0.0001	2350.00	0.04	99.00	0.04	480.0	1.51E+10	1.0	30.5	0.000	1.76E-01	0.803	5.520E-01	0.764	0.280	0.6449	2350.00	467.58	99.00	397.45
36500	3.15E+09	2.94	89.6	0.000	2.89E+00	0.000	1.623E+00	3.161	0.000	0.0000	2350.00	0.03	99.00	0.03	490.0	1.55E+10	1.0	30.5	0.000	1.68E-01	0.812	5.520E-01	0.762	0.281	0.6502	2350.00	471.41	99.00	400.70
36500	3.15E+09	3.00	91.4	0.000	2.95E+00	0.000	1.656E+00	3.222	0.000	0.0000	2350.00	0.02	99.00	0.02	500.0	1.58E+10	1.0	30.5	0.000	1.61E-01	0.820	5.520E-01	0.760	0.282	0.6554	2350.00	475.13	99.00	403.86

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying Biodeg[redacted]per Bound
PSR Superfund Site

Advective-Dispersive Transport Formulas

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + av	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)
C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W = ((v-m)*x)/(2*D)	
X = (R*v-m*t)/(SQRT(4*D*R*t))	
Y = ((v+m)*x)/(2*D)	
Z = (R*v+m*t)/(SQRT(4*D*R*t))	
m= v*(SQRT(1+((4*u*D)/v^2))	
ERFC()= 1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by
M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations			Chemical Data		
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g		[redacted]		
	n	[redacted]	foc	[redacted]		Kd (theoretica	40	L/kg
	ne	[redacted]	R	130.56		Kd, cap	[redacted]	L/kg
	g	[redacted] gm/cm3	u	[redacted] /d		SQS	[redacted]	mg/kgOC
	DL,sed	[redacted] ft	d	[redacted] ft		WQC	[redacted]	ug/L (LOEL)
	L	[redacted] ft	Ce	[redacted] ug/L		Dw	[redacted]	cm2/sec
Results:	p	1.4578 gm/cm3	d	0.9144 cm				
	i	ft/ft	u	4.745E-07 /s				
	v	[redacted] ft/d	Kd,cap	40 ml/g				
	v	7.058E-08 cm/s	D	3.9E-06 cm2/sec				
			m	2.72E-06 cm/sec				

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DL,sed / (n+p*Kd,cap)	USEPA 1999	

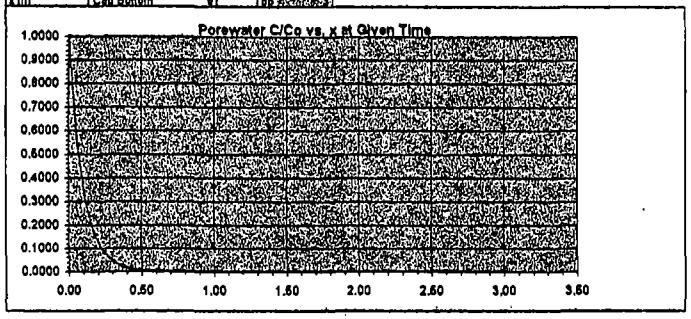
Cap thickness lost due to expression of porewater during consolidation (ft)

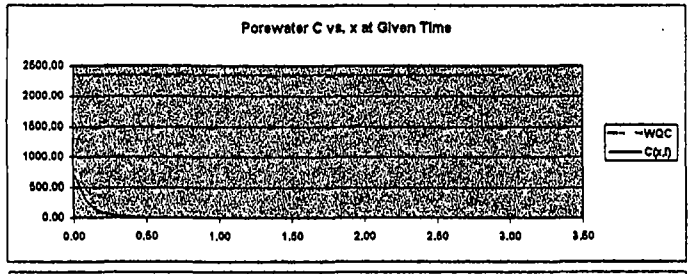
Tl,consol =	0.024 feet	(typically negligible)

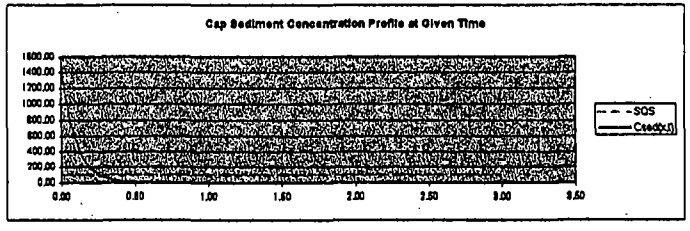
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[redacted]
x (ft)	Cap Bottom	0	Top [redacted]



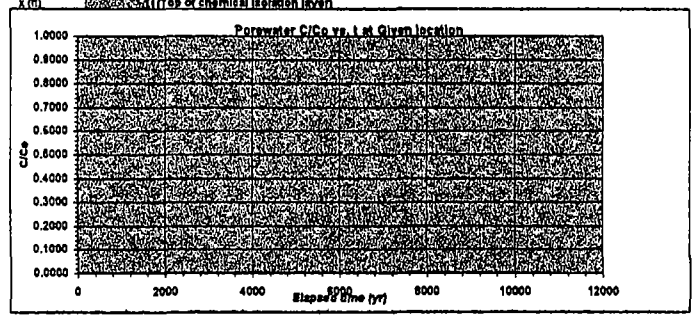


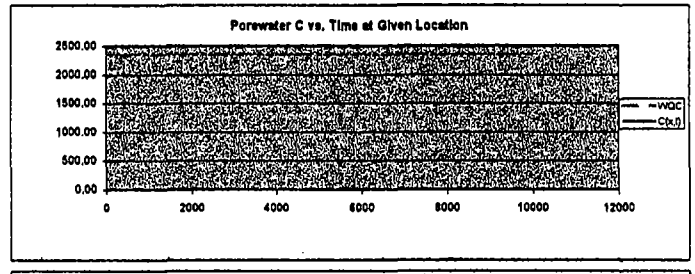


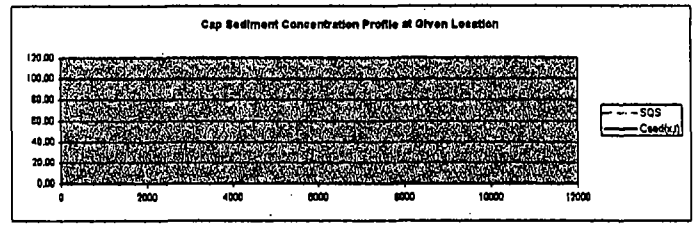
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	10000	
x (ft)	[redacted]		(Top of chemical isolation layer)		







Sensitivity Analysis for Chemical Isolation Analysis - Varying Biodegradat[illegible]per Bound
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-3.39E+00	2.000	0.000E+00	3.387	0.000	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	1.0	30.5	-10.365	#DIV/0!	#DIV/0!	1.092E+01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	-0.622	-3.29E+00	2.000	6.660E-01	3.481	0.000	0.5369	2350.00	389.27	99.00	778.54	200.0	6.31E+09	1.0	30.5	-10.365	-3.69E+00	2.000	1.092E+01	6.900	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.12	3.7	-1.244	-3.20E+00	2.000	1.310E+00	3.575	0.000	0.2883	2350.00	209.01	99.00	418.02	400.0	1.26E+10	1.0	30.5	-10.365	-6.99E+00	2.000	1.092E+01	7.589	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.18	5.5	-1.866	-3.10E+00	2.000	1.965E+00	3.670	0.000	0.1548	2350.00	112.22	99.00	224.45	600.0	1.89E+10	1.0	30.5	-10.365	-7.65E+00	2.000	1.092E+01	8.937	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.24	7.3	-2.488	-3.01E+00	2.000	2.620E+00	3.764	0.000	0.0831	2350.00	60.26	99.00	120.51	800.0	2.52E+10	1.0	30.5	-10.365	-9.02E+00	2.000	1.092E+01	10.135	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.30	9.1	-3.109	-2.92E+00	2.000	3.275E+00	3.858	0.000	0.0446	2350.00	32.35	99.00	64.71	1000.0	3.15E+10	1.0	30.5	-10.365	-1.03E+01	2.000	1.092E+01	11.207	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.36	11.0	-3.731	-2.82E+00	2.000	3.930E+00	3.952	0.000	0.0240	2350.00	17.37	99.00	34.74	1200.0	3.78E+10	1.0	30.5	-10.365	-1.13E+01	2.000	1.092E+01	12.186	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.42	12.8	-4.353	-2.73E+00	2.000	4.585E+00	4.047	0.000	0.0129	2350.00	9.33	99.00	18.65	1400.0	4.42E+10	1.0	30.5	-10.365	-1.23E+01	2.000	1.092E+01	13.092	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.48	14.6	-4.975	-2.63E+00	2.000	5.240E+00	4.141	0.000	0.0068	2350.00	5.01	99.00	10.02	1600.0	5.05E+10	1.0	30.5	-10.365	-1.32E+01	2.000	1.092E+01	13.940	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.54	16.5	-5.597	-2.54E+00	2.000	5.895E+00	4.235	0.000	0.0037	2350.00	2.69	99.00	5.38	1800.0	5.68E+10	1.0	30.5	-10.365	-1.40E+01	2.000	1.092E+01	14.738	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.60	18.3	-6.219	-2.44E+00	1.999	6.550E+00	4.329	0.000	0.0020	2350.00	1.44	99.00	2.88	2000.0	6.31E+10	1.0	30.5	-10.365	-1.48E+01	2.000	1.092E+01	15.497	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.66	20.1	-6.841	-2.35E+00	1.999	7.205E+00	4.424	0.000	0.0011	2350.00	0.78	99.00	1.56	2200.0	6.94E+10	1.0	30.5	-10.365	-1.56E+01	2.000	1.092E+01	16.220	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.72	21.9	-7.463	-2.26E+00	1.999	7.860E+00	4.518	0.000	0.0006	2350.00	0.42	99.00	0.83	2400.0	7.57E+10	1.0	30.5	-10.365	-1.63E+01	2.000	1.092E+01	16.912	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.78	23.8	-8.085	-2.16E+00	1.998	8.515E+00	4.612	0.000	0.0003	2350.00	0.22	99.00	0.45	2600.0	8.20E+10	1.0	30.5	-10.365	-1.70E+01	2.000	1.092E+01	17.577	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.84	25.6	-8.707	-2.07E+00	1.997	9.170E+00	4.706	0.000	0.0002	2350.00	0.12	99.00	0.24	2800.0	8.83E+10	1.0	30.5	-10.365	-1.76E+01	2.000	1.092E+01	18.218	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.90	27.4	-9.328	-1.97E+00	1.996	9.825E+00	4.801	0.000	0.0001	2350.00	0.06	99.00	0.13	3000.0	9.46E+10	1.0	30.5	-10.365	-1.83E+01	2.000	1.092E+01	18.837	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	0.96	29.3	-9.950	-1.88E+00	1.992	1.048E+01	4.895	0.000	0.0000	2350.00	0.03	99.00	0.07	3200.0	1.01E+11	1.0	30.5	-10.365	-1.89E+01	2.000	1.092E+01	19.436	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.02	31.1	-10.572	-1.78E+00	1.988	1.114E+01	4.989	0.000	0.0000	2350.00	0.02	99.00	0.04	3400.0	1.07E+11	1.0	30.5	-10.365	-1.95E+01	2.000	1.092E+01	20.018	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.08	32.9	-11.194	-1.69E+00	1.983	1.179E+01	5.083	0.000	0.0000	2350.00	0.01	99.00	0.02	3600.0	1.14E+11	1.0	30.5	-10.365	-2.01E+01	2.000	1.092E+01	20.582	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.14	34.7	-11.816	-1.60E+00	1.976	1.245E+01	5.176	0.000	0.0000	2350.00	0.01	99.00	0.01	3800.0	1.20E+11	1.0	30.5	-10.365	-2.06E+01	2.000	1.092E+01	21.132	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.20	36.6	-12.438	-1.50E+00	1.966	1.310E+01	5.272	0.000	0.0000	2350.00	0.00	99.00	0.01	4000.0	1.26E+11	1.0	30.5	-10.365	-2.12E+01	2.000	1.092E+01	21.668	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.26	38.4	-13.060	-1.41E+00	1.953	1.376E+01	5.366	0.000	0.0000	2350.00	0.00	99.00	0.00	4200.0	1.32E+11	1.0	30.5	-10.365	-2.17E+01	2.000	1.092E+01	22.191	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.32	40.2	-13.682	-1.31E+00	1.937	1.441E+01	5.460	0.000	0.0000	2350.00	0.00	99.00	0.00	4400.0	1.39E+11	1.0	30.5	-10.365	-2.22E+01	2.000	1.092E+01	22.702	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.38	42.1	-14.304	-1.22E+00	1.918	1.507E+01	5.555	0.000	0.0000	2350.00	0.00	99.00	0.00	4600.0	1.45E+11	1.0	30.5	-10.365	-2.27E+01	2.000	1.092E+01	23.202	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.44	43.9	-14.926	-1.12E+00	1.898	1.572E+01	5.649	0.000	0.0000	2350.00	0.00	99.00	0.00	4800.0	1.51E+11	1.0	30.5	-10.365	-2.32E+01	2.000	1.092E+01	23.691	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.50	45.7	-15.547	-1.03E+00	1.875	1.638E+01	5.743	0.000	0.0000	2350.00	0.00	99.00	0.00	5000.0	1.58E+11	1.0	30.5	-10.365	-2.37E+01	2.000	1.092E+01	24.170	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.56	47.5	-16.169	-9.36E-01	1.851	1.703E+01	5.837	0.000	0.0000	2350.00	0.00	99.00	0.00	5200.0	1.64E+11	1.0	30.5	-10.365	-2.42E+01	2.000	1.092E+01	24.640	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.62	49.4	-16.791	-8.42E-01	1.766	1.769E+01	5.932	0.000	0.0000	2350.00	0.00	99.00	0.00	5400.0	1.70E+11	1.0	30.5	-10.365	-2.47E+01	2.000	1.092E+01	25.101	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.68	51.2	-17.413	-7.48E-01	1.710	1.834E+01	6.026	0.000	0.0000	2350.00	0.00	99.00	0.00	5600.0	1.77E+11	1.0	30.5	-10.365	-2.51E+01	2.000	1.092E+01	25.554	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.74	53.0	-18.036	-6.53E-01	1.644	1.900E+01	6.120	0.000	0.0000	2350.00	0.00	99.00	0.00	5800.0	1.83E+11	1.0	30.5	-10.365	-2.56E+01	2.000	1.092E+01	25.999	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.80	54.9	-18.657	-5.59E-01	1.571	1.965E+01	6.214	0.000	0.0000	2350.00	0.00	99.00	0.00	6000.0	1.89E+11	1.0	30.5	-10.365	-2.60E+01	2.000	1.092E+01	26.437	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.86	56.7	-19.279	-4.65E-01	1.489	2.031E+01	6.309	0.000	0.0000	2350.00	0.00	99.00	0.00	6200.0	1.96E+11	1.0	30.5	-10.365	-2.65E+01	2.000	1.092E+01	26.867	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.92	58.5	-19.901	-3.71E-01	1.400	2.096E+01	6.403	0.000	0.0000	2350.00	0.00	99.00	0.00	6400.0	2.02E+11	1.0	30.5	-10.365	-2.69E+01	2.000	1.092E+01	27.291	0.000	0.0000	2350.00	0.02	99.00	0.05
36500	3.15E+09	1.98	60.4	-20.522	-2.76E-01	1.304	2.162E+01	6.497	0.000	0.0000	2350.00	0.00	99.00	0.00	6600.0	2.08E+11	1.0	30.5	-10.365	-2.73E+01	2.000	1.092E+01	27.708	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.04	62.2	-21.144	-1.82E-01	1.203	2.227E+01	6.592	0.000	0.0000	2350.00	0.00	99.00	0.00	6800.0	2.14E+11	1.0	30.5	-10.365	-2.77E+01	#NUM!	1.092E+01	28.119	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.10	64.0	-21.766	-8.78E-02	1.099	2.293E+01	6.686	0.000	0.0000	2350.00	0.00	99.00	0.00	7000.0	2.21E+11	1.0	30.5	-10.365	-2.81E+01	#NUM!	1.092E+01	28.524	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.16	65.8	-22.388	6.46E-03	0.993	2.358E+01	6.780	0.000	0.0000	2350.00	0.00	99.00	0.00	7200.0	2.27E+11	1.0	30.5	-10.365	-2.86E+01	#NUM!	1.092E+01	28.923	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.22	67.7	-23.010	1.01E-01	0.887	2.424E+01	6.874	0.000	0.0000	2350.00	0.00	99.00	0.00	7400.0	2.33E+11	1.0	30.5	-10.365	-2.90E+01	#NUM!	1.092E+01	29.317	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.28	69.5	-23.632	1.95E-01	0.783	2.489E+01	6.969	0.000	0.0000	2350.00	0.00	99.00	0.00	7600.0	2.40E+11	1.0	30.5	-10.365	-2.93E+01	#NUM!	1.092E+01	29.705	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.34	71.3	-24.254	2.89E-01	0.683	2.555E+01	7.063	0.000	0.0000	2350.00	0.00	99.00	0.00	7800.0	2.46E+11	1.0	30.5	-10.365	-2.97E+01	#NUM!	1.092E+01	30.089	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.40	73.2	-24.876	3.83E-01	0.588	2.620E+01	7.157	0.000	0.0000	2350.00	0.00	99.00	0.00	8000.0	2.52E+11	1.0	30.5	-10.365	-3.01E+01	#NUM!	1.092E+01	30.468	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.46	75.0	-25.498	4.76E-01	0.499	2.686E+01	7.251	0.000	0.0000	2350.00	0.00	99.00	0.00	8200.0	2.59E+11	1.0	30.5	-10.365	-3.05E+01	#NUM!	1.092E+01	30.842	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.52	76.8	-26.120	5.72E-01	0.419	2.751E+01	7.346	0.000	0.0000	2350.00	0.00	99.00	0.00	8400.0	2.65E+11	1.0	30.5	-10.365	-3.09E+01	#NUM!	1.092E+01	31.212	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.58	78.6	-26.741	6.66E-01	0.346	2.817E+01	7.440	0.000	0.0000	2350.00	0.00	99.00	0.00	8600.0	2.71E+11	1.0	30.5	-10.365	-3.12E+01	#NUM!	1.092E+01	31.577	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.64	80.5	-27.363	7.61E-01	0.282	2.882E+01	7.534	0.000	0.0000	2350.00	0.00	99.00	0.00	8800.0	2.78E+11	1.0	30.5	-10.365	-3.16E+01	#NUM!	1.092E+01	31.938	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.70	82.3	-27.985	8.55E-01	0.227	2.946E+01	7.628	0.000	0.0000	2350.00	0.00	99.00	0.00	9000.0	2.84E+11	1.0	30.5	-10.365	-3.20E+01	#NUM!	1.092E+01	32.295	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.76	84.1	-28.607	9.49E-01	0.180	3.012E+01	7.723	0.000	0.0000	2350.00	0.00	99.00	0.00	9200.0	2.90E+11	1.0	30.5	-10.365	-3.23E+01	#NUM!	1.092E+01	32.649	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.82	86.0	-29.229	1.04E+00	0.140	3.079E+01	7.817	0.000	0.0000	2350.00	0.00	99.00	0.00	9400.0	2.96E+11	1.0	30.5	-10.365	-3.27E+01	#NUM!	1.092E+01	32.999	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.88	87.8	-29.851	1.14E+00	0.108	3.144E+01	7.911	0.000	0.0000	2350.00	0.00	99.00	0.00	9600.0	3.03E+11	1.0	30.5	-10.365	-3.30E+01	#NUM!	1.092E+01	33.344	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	2.94	89.6	-30.473	1.23E+00	0.082	3.210E+01	8.005	0.000	0.0000	2350.00	0.00	99.00	0.00	9800.0	3.09E+11	1.0	30.5	-10.365	-3.34E+01	#NUM!	1.092E+01	33.686	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!
36500	3.15E+09	3.00	91.4	-31.095	1.33E+00	0.061	3.275E+01	8.100	0.000	0.0000	2350.00	0.00	99.00	0.00	10000.0	3.15E+11	1.0	30.5	-10.365	-3.37E+01	#NUM!	1.092E+01	34.025	#NUM!	#NUM!	2350.00	#NUM!	99.00	#NUM!

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying v - Lowr
PSR Superfund Site

Advect... Diffusion Equation Formulae:

Kd=foc*Koc	Walton 1991, p.166
R=1+(Kd,cap*p)/ne	Walton 1991, p.164
p=g(1-n)	Krynine and Judd,1957, p.139
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) =	(0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z))		Van Genuchten and Alves (1982)
	W =	((v-m)*x)/(2*D)	
	X =	(R*x-m*t)/(SQRT(4*D*R*t))	
	Y =	((v+m)*x)/(2*D)	
	Z =	(R*x+m*t)/(SQRT(4*D*R*t))	
	m=	v*(SQRT(1+((4*u*D)/v^2))	
	ERFC()=	1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	disperion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Ti,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Ti,consol = DLsed / (n+p*Kd,cap)	USEPA 1998	

Cap thickness lost due to expression of porewater during consolidation (ft)

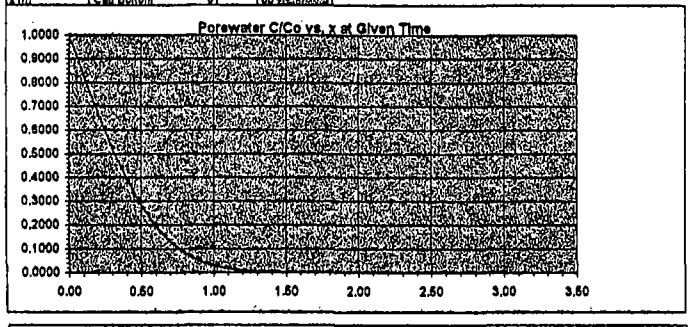
Ti,consol =	0.024 feet	(typically negligible)

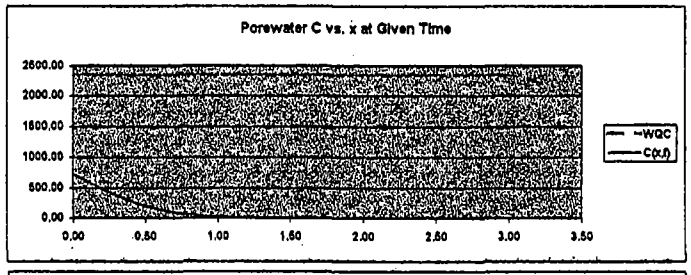
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	1.42 ft/d	Koc	1950.2 ml/g			
	n	0.45	foc	0.077	Kd (theoretica	40 L/kg	
	ne	0.45	R	130.56	Kd, cap	240 L/kg	
	g	2.66 gm/cm3	u	1.42E-08 /d	SQS	1E+06 mg/kgOC	
	DL,sed	0.1 ft	d	0.0144 ft	WQC	0.150 ug/L	(LOEL)
	L	2.1666 ft	Co	1.0000 ug/L	Dw	8.43E-06 cm2/sec	
Results:	p	1.4575 gm/cm3	d	0.0144 cm			
	i	n/a ft/ft	u	0 /s			
	v	0.0000476 ft/d	Kd,cap	40 ml/g			
	v	3.629E-08 cm/s	D	3.9E-08 cm2/sec			
	m	3.629E-08 cm/sec	m	3.629E-08 cm/sec			(m=v for u=0)

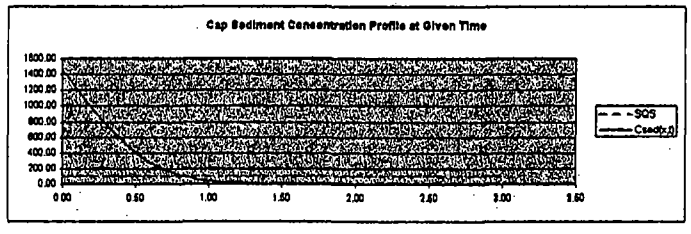
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	100 yrs
x (ft)	Cap Bottom	0	Top of Cap 2.1666



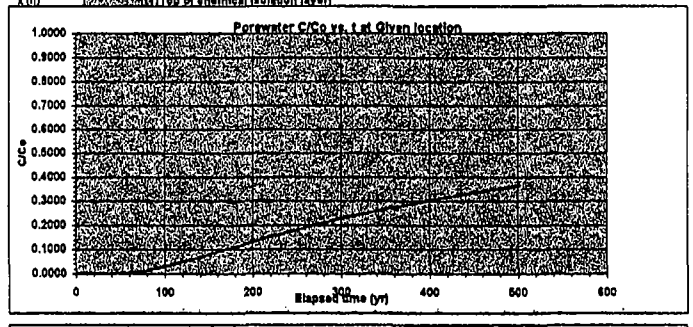


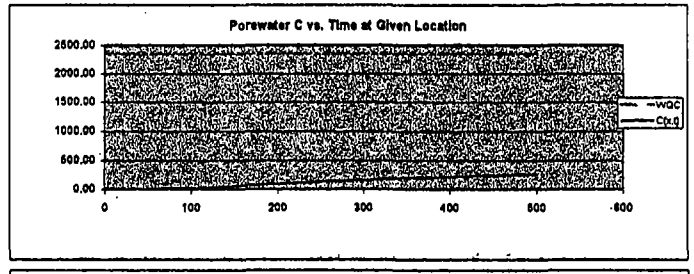


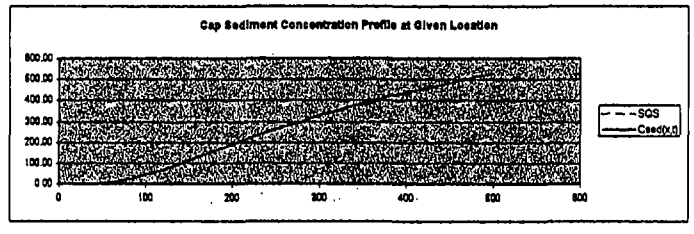
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600
x (ft)	2.1666	(Top of chemical isolation layer)		







Sensitivity Analysis for Chemical Isolation Analysis - Varying v - Lower Bou
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Cseq(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Cseq(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-4.41E-02	1.050	0.000E+00	0.044	0.950	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	2.783E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	6.06E-02	0.943	1.670E-02	0.139	0.844	0.9008	2350.00	653.10	99.00	1306.21	10.0	3.15E+08	1.0	30.5	0.000	4.97E+00	0.000	2.783E-01	6.002	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.45E-01	0.837	3.339E-02	0.233	0.741	0.8019	2350.00	581.39	99.00	1162.77	20.0	6.31E+08	1.0	30.5	0.000	3.51E+00	0.000	2.783E-01	3.647	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	2.40E-01	0.734	5.009E-02	0.328	0.643	0.7051	2350.00	511.19	99.00	1022.38	30.0	9.46E+08	1.0	30.5	0.000	2.86E+00	0.000	2.783E-01	2.904	0.000	0.0001	2350.00	0.04	99.00	0.09
36500	3.15E+09	0.24	7.3	0.000	3.34E-01	0.636	6.678E-02	0.423	0.550	0.6121	2350.00	443.76	99.00	887.51	40.0	1.26E+09	1.0	30.5	0.000	2.47E+00	0.000	2.783E-01	2.522	0.000	0.0005	2350.00	0.35	99.00	0.70
36500	3.15E+09	0.30	9.1	0.000	4.29E-01	0.544	8.348E-02	0.517	0.464	0.5244	2350.00	380.17	99.00	760.33	50.0	1.58E+09	1.0	30.5	0.000	2.20E+00	0.002	2.783E-01	2.262	0.001	0.0018	2350.00	1.34	99.00	2.67
36500	3.15E+09	0.36	11.0	0.000	5.24E-01	0.459	1.002E-01	0.612	0.387	0.4432	2350.00	321.31	99.00	642.61	60.0	1.89E+09	1.0	30.5	0.000	2.00E+00	0.005	2.783E-01	2.071	0.003	0.0046	2350.00	3.31	99.00	6.62
36500	3.15E+09	0.42	12.8	0.000	6.18E-01	0.382	1.169E-01	0.707	0.318	0.3694	2350.00	267.91	99.00	535.82	70.0	2.21E+09	1.0	30.5	0.000	1.85E+00	0.009	2.783E-01	1.922	0.007	0.0088	2350.00	6.38	99.00	12.76
36500	3.15E+09	0.48	14.6	0.000	7.13E-01	0.313	1.336E-01	0.801	0.257	0.3038	2350.00	220.08	99.00	440.15	80.0	2.52E+09	1.0	30.5	0.000	1.72E+00	0.016	2.783E-01	1.803	0.011	0.0145	2350.00	10.50	99.00	21.01
36500	3.15E+09	0.54	16.5	0.000	8.08E-01	0.253	1.503E-01	0.896	0.206	0.2459	2350.00	178.25	99.00	356.50	90.0	2.84E+09	1.0	30.5	0.000	1.62E+00	0.022	2.783E-01	1.705	0.016	0.0215	2350.00	15.55	99.00	31.11
36500	3.15E+09	0.60	18.3	0.000	9.02E-01	0.202	1.670E-01	0.991	0.161	0.1962	2350.00	142.26	99.00	284.52	100.0	3.15E+09	1.0	30.5	0.000	1.53E+00	0.030	2.783E-01	1.622	0.022	0.0296	2350.00	21.37	99.00	42.74
36500	3.15E+09	0.66	20.1	0.000	9.97E-01	0.159	1.837E-01	1.085	0.125	0.1543	2350.00	111.85	99.00	223.69	110.0	3.47E+09	1.0	30.5	0.000	1.45E+00	0.039	2.783E-01	1.550	0.028	0.0383	2350.00	27.80	99.00	55.59
36500	3.15E+09	0.72	21.9	0.000	1.09E+00	0.123	2.004E-01	1.180	0.095	0.1196	2350.00	86.81	99.00	173.62	120.0	3.78E+09	1.0	30.5	0.000	1.39E+00	0.049	2.783E-01	1.488	0.035	0.0478	2350.00	34.68	99.00	69.37
36500	3.15E+09	0.78	23.8	0.000	1.19E+00	0.093	2.171E-01	1.276	0.071	0.0911	2350.00	66.05	99.00	132.09	130.0	4.10E+09	1.0	30.5	0.000	1.33E+00	0.059	2.783E-01	1.434	0.043	0.0578	2350.00	41.91	99.00	83.82
36500	3.15E+09	0.84	25.6	0.000	1.28E+00	0.070	2.339E-01	1.369	0.053	0.0684	2350.00	49.59	99.00	99.17	140.0	4.42E+09	1.0	30.5	0.000	1.28E+00	0.070	2.783E-01	1.385	0.050	0.0681	2350.00	49.37	99.00	98.74
36500	3.15E+09	0.90	27.4	0.000	1.38E+00	0.052	2.505E-01	1.464	0.038	0.0506	2350.00	36.66	99.00	73.29	150.0	4.73E+09	1.0	30.5	0.000	1.23E+00	0.091	2.783E-01	1.342	0.058	0.0786	2350.00	56.98	99.00	113.96
36500	3.15E+09	0.96	29.3	0.000	1.47E+00	0.038	2.672E-01	1.558	0.028	0.0368	2350.00	26.66	99.00	53.32	160.0	5.05E+09	1.0	30.5	0.000	1.19E+00	0.092	2.783E-01	1.303	0.065	0.0892	2350.00	64.67	99.00	129.34
36500	3.15E+09	1.02	31.1	0.000	1.56E+00	0.027	2.839E-01	1.653	0.019	0.0263	2350.00	19.08	99.00	38.17	170.0	5.36E+09	1.0	30.5	0.000	1.18E+00	0.103	2.783E-01	1.267	0.073	0.0998	2350.00	72.29	99.00	144.77
36500	3.15E+09	1.08	32.9	0.000	1.65E+00	0.019	3.005E-01	1.748	0.013	0.0185	2350.00	13.44	99.00	26.89	180.0	5.68E+09	1.0	30.5	0.000	1.12E+00	0.114	2.783E-01	1.236	0.081	0.1105	2350.00	80.09	99.00	160.17
36500	3.15E+09	1.14	34.7	0.000	1.75E+00	0.013	3.172E-01	1.842	0.009	0.0129	2350.00	9.32	99.00	18.63	190.0	5.99E+09	1.0	30.5	0.000	1.08E+00	0.125	2.783E-01	1.205	0.088	0.1210	2350.00	87.74	99.00	175.47
36500	3.15E+09	1.20	36.6	0.000	1.85E+00	0.009	3.339E-01	1.937	0.006	0.0089	2350.00	6.35	99.00	12.71	200.0	6.31E+09	1.0	30.5	0.000	1.05E+00	0.136	2.783E-01	1.176	0.096	0.1315	2350.00	95.31	99.00	190.62
36500	3.15E+09	1.26	38.4	0.000	1.94E+00	0.006	3.506E-01	2.032	0.004	0.0059	2350.00	4.26	99.00	8.52	210.0	6.62E+09	1.0	30.5	0.000	1.02E+00	0.147	2.783E-01	1.152	0.103	0.1418	2350.00	102.78	99.00	205.56
36500	3.15E+09	1.32	40.2	0.000	2.04E+00	0.004	3.673E-01	2.126	0.003	0.0039	2350.00	2.81	99.00	5.62	220.0	6.94E+09	1.0	30.5	0.000	9.88E-01	0.158	2.783E-01	1.129	0.110	0.1519	2350.00	110.14	99.00	220.29
36500	3.15E+09	1.38	42.1	0.000	2.13E+00	0.003	3.840E-01	2.221	0.002	0.0025	2350.00	1.82	99.00	3.65	230.0	7.25E+09	1.0	30.5	0.000	9.73E-01	0.169	2.783E-01	1.107	0.117	0.1619	2350.00	117.38	99.00	234.77
36500	3.15E+09	1.44	43.9	0.000	2.23E+00	0.002	4.007E-01	2.316	0.001	0.0016	2350.00	1.16	99.00	2.33	240.0	7.57E+09	1.0	30.5	0.000	9.60E-01	0.179	2.783E-01	1.087	0.124	0.1717	2350.00	124.49	99.00	249.00
36500	3.15E+09	1.50	45.7	0.000	2.32E+00	0.001	4.174E-01	2.410	0.001	0.0010	2350.00	0.73	99.00	1.46	250.0	7.88E+09	1.0	30.5	0.000	9.26E-01	0.189	2.783E-01	1.067	0.131	0.1813	2350.00	131.46	99.00	262.92
36500	3.15E+09	1.56	47.5	0.000	2.42E+00	0.001	4.341E-01	2.506	0.000	0.0006	2350.00	0.45	99.00	0.90	260.0	8.20E+09	1.0	30.5	0.000	9.07E-01	0.199	2.783E-01	1.049	0.138	0.1907	2350.00	138.29	99.00	276.58
36500	3.15E+09	1.62	49.4	0.000	2.51E+00	0.000	4.508E-01	2.600	0.000	0.0004	2350.00	0.27	99.00	0.55	270.0	8.51E+09	1.0	30.5	0.000	8.89E-01	0.208	2.783E-01	1.032	0.144	0.2000	2350.00	144.96	99.00	289.96
36500	3.15E+09	1.68	51.2	0.000	2.61E+00	0.000	4.675E-01	2.694	0.000	0.0002	2350.00	0.16	99.00	0.33	280.0	8.83E+09	1.0	30.5	0.000	8.69E-01	0.219	2.783E-01	1.017	0.151	0.2090	2350.00	151.52	99.00	303.04
36500	3.15E+09	1.74	53.0	0.000	2.70E+00	0.000	4.842E-01	2.789	0.000	0.0001	2350.00	0.10	99.00	0.19	290.0	9.15E+09	1.0	30.5	0.000	8.51E-01	0.229	2.783E-01	1.001	0.157	0.2178	2350.00	157.92	99.00	315.84
36500	3.15E+09	1.80	54.9	0.000	2.80E+00	0.000	5.009E-01	2.884	0.000	0.0001	2350.00	0.06	99.00	0.11	300.0	9.46E+09	1.0	30.5	0.000	8.34E-01	0.238	2.783E-01	0.987	0.163	0.2265	2350.00	164.18	99.00	328.36
36500	3.15E+09	1.86	56.7	0.000	2.89E+00	0.000	5.176E-01	2.978	0.000	0.0000	2350.00	0.03	99.00	0.06	310.0	9.78E+09	1.0	30.5	0.000	8.18E-01	0.247	2.783E-01	0.974	0.169	0.2349	2350.00	170.30	99.00	340.60
36500	3.15E+09	1.92	58.5	0.000	2.98E+00	0.000	5.343E-01	3.073	0.000	0.0000	2350.00	0.02	99.00	0.03	320.0	1.01E+10	1.0	30.5	0.000	8.03E-01	0.256	2.783E-01	0.961	0.174	0.2432	2350.00	176.29	99.00	352.57
36500	3.15E+09	1.98	60.4	0.000	3.08E+00	0.000	5.510E-01	3.168	0.000	0.0000	2350.00	0.01	99.00	0.02	330.0	1.04E+10	1.0	30.5	0.000	7.88E-01	0.265	2.783E-01	0.948	0.180	0.2512	2350.00	182.13	99.00	364.27
36500	3.15E+09	2.04	62.2	0.000	3.17E+00	0.000	5.677E-01	3.262	0.000	0.0000	2350.00	0.01	99.00	0.01	340.0	1.07E+10	1.0	30.5	0.000	7.74E-01	0.274	2.783E-01	0.937	0.186	0.2591	2350.00	187.85	99.00	375.70
36500	3.15E+09	2.10	64.0	0.000	3.27E+00	0.000	5.844E-01	3.357	0.000	0.0000	2350.00	0.00	99.00	0.01	350.0	1.10E+10	1.0	30.5	0.000	7.61E-01	0.282	2.783E-01	0.926	0.190	0.2666	2350.00	193.44	99.00	386.88
36500	3.15E+09	2.16	65.8	0.000	3.36E+00	0.000	6.011E-01	3.451	0.000	0.0000	2350.00	0.00	99.00	0.00	360.0	1.14E+10	1.0	30.5	0.000	7.48E-01	0.290	2.783E-01	0.916	0.196	0.2743	2350.00	198.80	99.00	397.60
36500	3.15E+09	2.22	67.7	0.000	3.46E+00	0.000	6.178E-01	3.546	0.000	0.0000	2350.00	0.00	99.00	0.00	370.0	1.17E+10	1.0	30.5	0.000	7.36E-01	0.298	2.783E-01	0.906	0.201	0.2817	2350.00	204.24	99.00	408.48
36500	3.15E+09	2.28	69.5	0.000	3.55E+00	0.000	6.345E-01	3.641	0.000	0.0000	2350.00	0.00	99.00	0.00	380.0	1.20E+10	1.0	30.5	0.000	7.23E-01	0.306	2.783E-01	0.895	0.206	0.2889	2350.00	209.46	99.00	418.93
36500	3.15E+09	2.34	71.3	0.000	3.65E+00	0.000	6.512E-01	3.735	0.000	0.0000	2350.00	0.00	99.00	0.00	390.0	1.23E+10	1.0	30.5	0.000	7.12E-01	0.314	2.783E-01	0.886	0.210	0.2960	2350.00	214.57	99.00	429.14
36500	3.15E+09	2.40	73.2	0.000	3.74E+00	0.000	6.679E-01	3.830	0.000	0.0000	2350.00	0.00	99.00	0.00	400.0	1.26E+10	1.0	30.5	0.000	7.01E-01	0.322	2.783E-01	0.877	0.215	0.3028	2350.00	219.56	99.00	439.12
36500	3.15E+09	2.46	75.0	0.000	3.84E+00	0.000	6.846E-01	3.925	0.000	0.0000	2350.00	0.00	99.00	0.00	410.0	1.29E+10	1.0	30.5	0.000	6.90E-01	0.328	2.783E-01	0.868	0.219	0.3096	2350.00	224.44	99.00	448.89
36500	3.15E+09	2.52	76.8	0.000	3.93E+00	0.000	7.013E-01	4.019	0.000	0.0000	2350.00	0.00	99.00	0.00	420.0	1.32E+10	1.0	30.5	0.000	6.79E-01	0.337	2.783E-01	0.860	0.224	0.3162	2350.00	229.22	99.00	458.44
36500	3.15E+09	2.58	78.6	0.000	4.03E+00	0.000	7.180E-01	4.114	0.000	0.0000	2350.00	0.00	99.00	0.00	430.0	1.36E+10	1.0	30.5	0.000	6.69E-01	0.344	2.783E-01	0.852	0.228	0.3226	2350.00	233.90	99.00	467.79
36500	3.15E+09	2.64	80.5	0.000	4.12E+00	0.000	7.347E-01	4.209	0.000	0.0000	2350.00	0.00	99.00	0.00	440.0	1.39E+10	1.0	30.5	0.000	6.60E-01	0.351	2.783E-01	0.845	0.232	0.3289	2350.00	238.47	99.00	476.94
36500	3.15E+09	2.70	82.3	0.000	4.22E+00	0.000	7.514E-01	4.303	0.000	0.0000	2350.00	0.00	99.00	0.00	450.0	1.42E+10	1.0	30.5	0.000	6.50E-01	0.359	2.783E-01	0.837	0.236	0.3351	2350.00	242.96	99.00	485.89
36500	3.15E+09	2.76	84.1	0.000	4.31E+00	0.000	7.681E-01	4.398	0.000	0.0000	2350.00	0.00	99.00	0.00	460.0	1.45E+10	1.0	30.5	0.000	6.41E-01	0.365	2.783E-01	0.830	0.240	0.3411	2350.00	247.33	99.00	494.66
36500	3.15E+09	2.82	86.0	0.000	4.40E+00	0.000	7.848E-01	4.493	0.000	0.0000	2350.00	0.00	99.00	0.00	470.0	1.48E+10	1.0	30.5	0.000	6.32E-01	0.371	2.783E-01	0.823	0.244	0.3471	2350.00	251.62	99.00	503.24
36500	3.15E+09	2.88	87.8	0.000	4.50E+00	0.000	8.015E-01	4.587	0.000	0.0000	2350.00	0.00	99.00	0.00	480.0	1.51E+10	1.0	30.5	0.000	6.23E-01	0.378	2.783E-01	0.817	0.248	0.3529	2350.00	255.83	99.00	511.65
36500	3.15E+09	2.94	89.6	0.000	4.59E+00	0.000	8.182E-01	4.682	0.000	0.0000	2350.00	0.00	99.00	0.00	490.0	1.55E+10	1.0	30.5	0.000	6.15E-01	0.384	2.783E-01	0.810	0.252	0.3585	2350.00	259.94	99.00	519.89
36500	3.15E+09	3.00	91.4	0.000	4.68E+00	0.000	8.349E-01	4.777	0.000	0.0000	2350.00	0.00	99.00	0.00	500.0	1.58E+10	1.0	30.5	0.000	6.07E-01	0.391	2.783E-01	0.804	0.256	0.3641	2350.00	263.98	99.00	527.95

Note 1: Adapted from Equation B-29, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Cseq(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying v - Upper
PSR Superfund Site

Advective-Dispersive Transport Formulae:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.139
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*x-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2))
ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data			
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]			
	n	[illegible]	foc	[illegible]	Kd (theoretical	40	L/kg	
	ne	[illegible]	R	130.56	Kd, cap	[illegible]	L/kg	
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC	
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L	(LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec	
Results:	p	1.4676 gm/cm3	d	0.9144 cm				
	i	ft/ft	u	0 /s				
	v	[illegible] ft/d	Kd,cap	40 ml/g				
	v	1.411E-07 cm/s	D	4.0E-06 cm2/sec				
			m	1.411E-07 cm/sec	(m=v for u=0)			

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap) — USEPA 1999

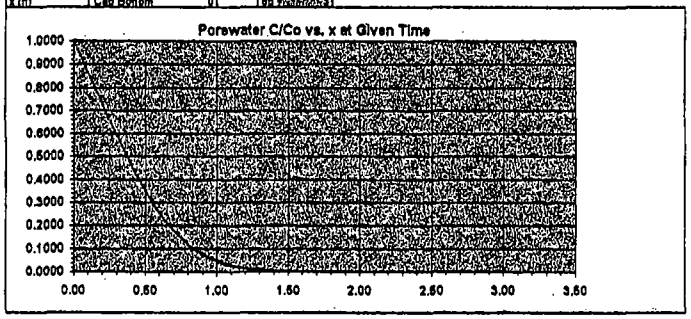
Cap thickness lost due to expression of porewater during consolidation (ft)

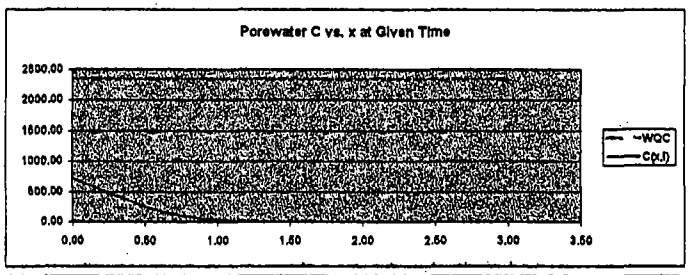
TI,consol = 0.024 feet (typically negligible)

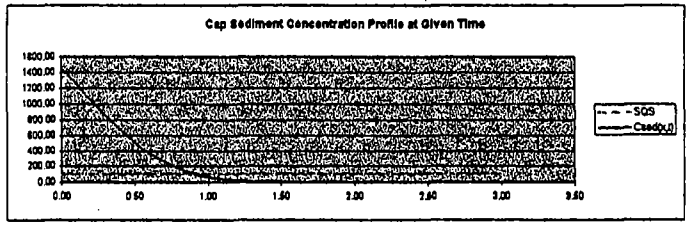
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]
x (ft)	Cap Bottom	0	Top [illegible]



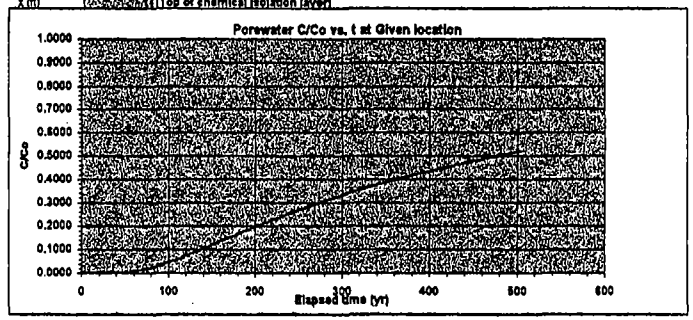


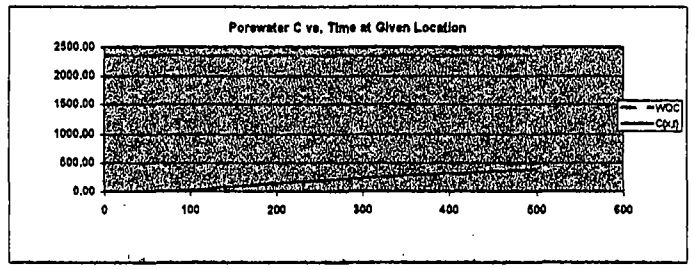


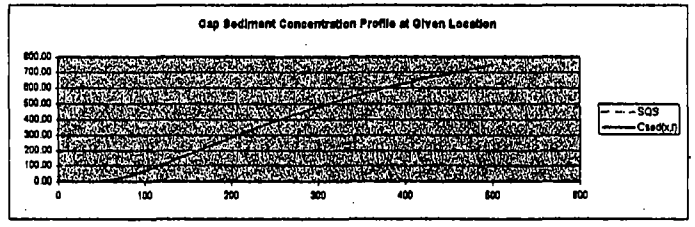
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600	
x (ft)	[illegible]	(Top of chemical isolation layer)			







Sensitivity Analysis for Chemical Isolation Analysis - Varying v - Upper Bou
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT				CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (m)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.195	0.000E+00	0.174	0.805	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	1.086E+00	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-9.06E-02	1.091	6.618E-02	0.269	0.706	0.9217	2350.00	668.22	99.00	1336.43	10.0	3.15E+08	1.0	30.5	0.000	4.87E+00	0.000	1.086E+00	4.962	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.27E-02	0.986	1.303E-01	0.381	0.609	0.8400	2350.00	608.98	99.00	1217.95	20.0	6.31E+08	1.0	30.5	0.000	3.41E+00	0.000	1.086E+00	3.582	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	1.06E-01	0.881	1.955E-01	0.455	0.529	0.7585	2350.00	548.50	99.00	1096.99	30.0	9.46E+08	1.0	30.5	0.000	2.75E+00	0.000	1.086E+00	2.940	0.000	0.0001	2350.00	0.07	99.00	0.14
36500	3.15E+09	0.24	7.3	0.000	2.00E-01	0.778	2.606E-01	0.549	0.438	0.6731	2350.00	488.03	99.00	976.05	40.0	1.26E+09	1.0	30.5	0.000	2.35E+00	0.001	1.086E+00	2.574	0.000	0.0008	2350.00	0.61	99.00	1.22
36500	3.15E+09	0.30	9.1	0.000	2.93E-01	0.678	3.258E-01	0.642	0.364	0.5914	2350.00	428.77	99.00	857.55	50.0	1.58E+09	1.0	30.5	0.000	2.09E+00	0.003	1.086E+00	2.327	0.001	0.0031	2350.00	2.26	99.00	4.51
36500	3.15E+09	0.36	11.0	0.000	3.87E-01	0.584	3.909E-01	0.735	0.298	0.5129	2350.00	371.84	99.00	743.69	60.0	1.89E+09	1.0	30.5	0.000	1.88E+00	0.008	1.086E+00	2.146	0.002	0.0075	2350.00	5.46	99.00	10.93
36500	3.15E+09	0.42	12.8	0.000	4.80E-01	0.497	4.561E-01	0.829	0.241	0.4389	2350.00	318.19	99.00	636.38	70.0	2.21E+09	1.0	30.5	0.000	1.72E+00	0.016	1.086E+00	2.008	0.005	0.0143	2350.00	10.36	99.00	20.72
36500	3.15E+09	0.48	14.6	0.000	5.74E-01	0.417	5.213E-01	0.922	0.192	0.3706	2350.00	268.56	99.00	537.16	80.0	2.52E+09	1.0	30.5	0.000	1.59E+00	0.025	1.086E+00	1.898	0.007	0.0232	2350.00	16.83	99.00	33.67
36500	3.15E+09	0.54	16.5	0.000	6.67E-01	0.346	5.864E-01	1.016	0.151	0.3084	2350.00	223.56	99.00	447.12	90.0	2.84E+09	1.0	30.5	0.000	1.48E+00	0.037	1.086E+00	1.809	0.011	0.0340	2350.00	24.67	99.00	49.33
36500	3.15E+09	0.60	18.3	0.000	7.61E-01	0.282	6.515E-01	1.109	0.117	0.2530	2350.00	183.46	99.00	366.91	100.0	3.15E+09	1.0	30.5	0.000	1.38E+00	0.050	1.086E+00	1.732	0.014	0.0463	2350.00	33.59	99.00	67.19
36500	3.15E+09	0.66	20.1	0.000	8.54E-01	0.227	7.167E-01	1.203	0.089	0.2047	2350.00	148.39	99.00	296.77	110.0	3.47E+09	1.0	30.5	0.000	1.30E+00	0.065	1.086E+00	1.668	0.018	0.0598	2350.00	43.37	99.00	86.73
36500	3.15E+09	0.72	21.9	0.000	9.48E-01	0.180	7.818E-01	1.296	0.067	0.1631	2350.00	118.28	99.00	236.53	120.0	3.78E+09	1.0	30.5	0.000	1.23E+00	0.082	1.086E+00	1.613	0.023	0.0742	2350.00	53.76	99.00	107.52
36500	3.15E+09	0.78	23.8	0.000	1.04E+00	0.141	8.470E-01	1.390	0.049	0.1281	2350.00	92.86	99.00	185.73	130.0	4.10E+09	1.0	30.5	0.000	1.17E+00	0.099	1.086E+00	1.565	0.027	0.0891	2350.00	64.59	99.00	129.18
36500	3.15E+09	0.84	25.6	0.000	1.13E+00	0.109	9.122E-01	1.483	0.036	0.0991	2350.00	71.83	99.00	143.65	140.0	4.42E+09	1.0	30.5	0.000	1.11E+00	0.118	1.086E+00	1.523	0.031	0.1044	2350.00	75.70	99.00	151.40
36500	3.15E+09	0.90	27.4	0.000	1.23E+00	0.092	9.773E-01	1.577	0.026	0.0766	2350.00	54.71	99.00	109.43	150.0	4.73E+09	1.0	30.5	0.000	1.06E+00	0.134	1.086E+00	1.486	0.035	0.1199	2350.00	86.96	99.00	173.93
36500	3.15E+09	0.96	29.3	0.000	1.32E+00	0.062	1.043E+00	1.670	0.018	0.0565	2350.00	41.04	99.00	82.09	160.0	5.05E+09	1.0	30.5	0.000	1.01E+00	0.153	1.086E+00	1.452	0.040	0.1356	2350.00	98.29	99.00	196.57
36500	3.15E+09	1.02	31.1	0.000	1.42E+00	0.046	1.108E+00	1.764	0.013	0.0418	2350.00	30.31	99.00	60.62	170.0	5.36E+09	1.0	30.5	0.000	9.68E-01	0.171	1.086E+00	1.422	0.044	0.1512	2350.00	109.59	99.00	219.17
36500	3.15E+09	1.08	32.9	0.000	1.51E+00	0.033	1.173E+00	1.857	0.009	0.0304	2350.00	22.04	99.00	44.08	180.0	5.68E+09	1.0	30.5	0.000	9.26E-01	0.190	1.086E+00	1.396	0.048	0.1666	2350.00	120.81	99.00	241.61
36500	3.15E+09	1.14	34.7	0.000	1.60E+00	0.023	1.238E+00	1.950	0.006	0.0218	2350.00	15.77	99.00	31.55	190.0	5.99E+09	1.0	30.5	0.000	8.90E-01	0.208	1.086E+00	1.371	0.053	0.1819	2350.00	131.90	99.00	263.80
36500	3.15E+09	1.20	36.6	0.000	1.70E+00	0.016	1.303E+00	2.044	0.004	0.0153	2350.00	11.11	99.00	22.22	200.0	6.31E+09	1.0	30.5	0.000	8.56E-01	0.226	1.086E+00	1.346	0.057	0.1970	2350.00	142.93	99.00	285.86
36500	3.15E+09	1.26	38.4	0.000	1.79E+00	0.011	1.368E+00	2.137	0.003	0.0106	2350.00	7.70	99.00	15.40	210.0	6.62E+09	1.0	30.5	0.000	8.23E-01	0.245	1.086E+00	1.320	0.060	0.2119	2350.00	153.67	99.00	307.16
36500	3.15E+09	1.32	40.2	0.000	1.88E+00	0.008	1.433E+00	2.231	0.002	0.0072	2350.00	5.25	99.00	10.51	220.0	6.94E+09	1.0	30.5	0.000	7.92E-01	0.263	1.086E+00	1.309	0.064	0.2264	2350.00	164.11	99.00	328.23
36500	3.15E+09	1.38	42.1	0.000	1.98E+00	0.005	1.499E+00	2.324	0.001	0.0049	2350.00	3.53	99.00	7.05	230.0	7.25E+09	1.0	30.5	0.000	7.63E-01	0.280	1.086E+00	1.292	0.069	0.2408	2350.00	174.43	99.00	348.86
36500	3.15E+09	1.44	43.9	0.000	2.07E+00	0.003	1.564E+00	2.418	0.001	0.0032	2350.00	2.33	99.00	4.66	240.0	7.57E+09	1.0	30.5	0.000	7.36E-01	0.298	1.086E+00	1.276	0.071	0.2546	2350.00	184.62	99.00	369.24
36500	3.15E+09	1.50	45.7	0.000	2.16E+00	0.002	1.629E+00	2.511	0.000	0.0021	2350.00	1.51	99.00	3.03	250.0	7.88E+09	1.0	30.5	0.000	7.10E-01	0.315	1.086E+00	1.261	0.075	0.2681	2350.00	194.38	99.00	388.76
36500	3.15E+09	1.56	47.5	0.000	2.26E+00	0.001	1.694E+00	2.605	0.000	0.0013	2350.00	0.97	99.00	1.93	260.0	8.20E+09	1.0	30.5	0.000	6.85E-01	0.332	1.086E+00	1.247	0.078	0.2814	2350.00	204.00	99.00	408.00
36500	3.15E+09	1.62	49.4	0.000	2.36E+00	0.001	1.759E+00	2.698	0.000	0.0008	2350.00	0.61	99.00	1.22	270.0	8.51E+09	1.0	30.5	0.000	6.62E-01	0.349	1.086E+00	1.236	0.081	0.2943	2350.00	213.39	99.00	426.78
36500	3.15E+09	1.68	51.2	0.000	2.44E+00	0.001	1.824E+00	2.792	0.000	0.0005	2350.00	0.38	99.00	0.75	280.0	8.83E+09	1.0	30.5	0.000	6.40E-01	0.366	1.086E+00	1.223	0.084	0.3070	2350.00	222.64	99.00	445.28
36500	3.15E+09	1.74	53.0	0.000	2.54E+00	0.000	1.890E+00	2.885	0.000	0.0003	2350.00	0.23	99.00	0.46	290.0	9.15E+09	1.0	30.5	0.000	6.18E-01	0.382	1.086E+00	1.212	0.087	0.3193	2350.00	231.46	99.00	462.92
36500	3.15E+09	1.80	54.9	0.000	2.63E+00	0.000	1.955E+00	2.979	0.000	0.0002	2350.00	0.14	99.00	0.27	300.0	9.46E+09	1.0	30.5	0.000	5.98E-01	0.399	1.086E+00	1.201	0.089	0.3312	2350.00	240.15	99.00	480.31
36500	3.15E+09	1.86	56.7	0.000	2.72E+00	0.000	2.020E+00	3.072	0.000	0.0001	2350.00	0.08	99.00	0.16	310.0	9.78E+09	1.0	30.5	0.000	5.78E-01	0.414	1.086E+00	1.192	0.092	0.3429	2350.00	248.62	99.00	497.26
36500	3.15E+09	1.92	58.5	0.000	2.82E+00	0.000	2.085E+00	3.166	0.000	0.0001	2350.00	0.05	99.00	0.09	320.0	1.01E+10	1.0	30.5	0.000	5.59E-01	0.428	1.086E+00	1.183	0.094	0.3543	2350.00	256.87	99.00	513.75
36500	3.15E+09	1.98	60.4	0.000	2.91E+00	0.000	2.150E+00	3.259	0.000	0.0000	2350.00	0.03	99.00	0.05	330.0	1.04E+10	1.0	30.5	0.000	5.41E-01	0.444	1.086E+00	1.174	0.097	0.3654	2350.00	264.91	99.00	529.82
36500	3.15E+09	2.04	62.2	0.000	3.00E+00	0.000	2.215E+00	3.353	0.000	0.0000	2350.00	0.01	99.00	0.03	340.0	1.07E+10	1.0	30.5	0.000	5.24E-01	0.459	1.086E+00	1.166	0.099	0.3762	2350.00	272.74	99.00	545.48
36500	3.15E+09	2.10	64.0	0.000	3.10E+00	0.000	2.280E+00	3.446	0.000	0.0000	2350.00	0.01	99.00	0.02	350.0	1.10E+10	1.0	30.5	0.000	5.07E-01	0.473	1.086E+00	1.159	0.101	0.3867	2350.00	280.37	99.00	560.73
36500	3.15E+09	2.16	65.8	0.000	3.19E+00	0.000	2.345E+00	3.540	0.000	0.0000	2350.00	0.00	99.00	0.01	360.0	1.14E+10	1.0	30.5	0.000	4.91E-01	0.488	1.086E+00	1.152	0.103	0.3970	2350.00	287.80	99.00	575.59
36500	3.15E+09	2.22	67.7	0.000	3.28E+00	0.000	2.411E+00	3.633	0.000	0.0000	2350.00	0.00	99.00	0.00	370.0	1.17E+10	1.0	30.5	0.000	4.75E-01	0.502	1.086E+00	1.146	0.105	0.4069	2350.00	295.04	99.00	590.08
36500	3.15E+09	2.28	69.5	0.000	3.38E+00	0.000	2.476E+00	3.727	0.000	0.0000	2350.00	0.00	99.00	0.00	380.0	1.20E+10	1.0	30.5	0.000	4.60E-01	0.516	1.086E+00	1.139	0.107	0.4167	2350.00	302.09	99.00	604.19
36500	3.15E+09	2.34	71.3	0.000	3.47E+00	0.000	2.541E+00	3.820	0.000	0.0000	2350.00	0.00	99.00	0.00	390.0	1.23E+10	1.0	30.5	0.000	4.45E-01	0.529	1.086E+00	1.133	0.109	0.4262	2350.00	308.97	99.00	617.94
36500	3.15E+09	2.40	73.2	0.000	3.57E+00	0.000	2.606E+00	3.914	0.000	0.0000	2350.00	0.00	99.00	0.00	400.0	1.26E+10	1.0	30.5	0.000	4.31E-01	0.543	1.086E+00	1.128	0.111	0.4354	2350.00	315.67	99.00	631.35
36500	3.15E+09	2.46	75.0	0.000	3.66E+00	0.000	2.671E+00	4.007	0.000	0.0000	2350.00	0.00	99.00	0.00	410.0	1.29E+10	1.0	30.5	0.000	4.17E-01	0.556	1.086E+00	1.122	0.112	0.4444	2350.00	322.21	99.00	644.42
36500	3.15E+09	2.52	76.8	0.000	3.76E+00	0.000	2.737E+00	4.101	0.000	0.0000	2350.00	0.00	99.00	0.00	420.0	1.32E+10	1.0	30.5	0.000	4.03E-01	0.569	1.086E+00	1.117	0.114	0.4532	2350.00	328.59	99.00	657.18
36500	3.15E+09	2.59	78.6	0.000	3.85E+00	0.000	2.802E+00	4.194	0.000	0.0000	2350.00	0.00	99.00	0.00	430.0	1.36E+10	1.0	30.5	0.000	3.90E-01	0.581	1.086E+00	1.113	0.116	0.4619	2350.00	334.80	99.00	669.59
36500	3.15E+09	2.64	80.5	0.000	3.94E+00	0.000	2.867E+00	4.288	0.000	0.0000	2350.00	0.00	99.00	0.00	440.0	1.39E+10	1.0	30.5	0.000	3.77E-01	0.594	1.086E+00	1.109	0.117	0.4702	2350.00	340.86	99.00	681.72
36500	3.15E+09	2.70	82.3	0.000	4.03E+00	0.000	2.932E+00	4.381	0.000	0.0000	2350.00	0.00	99.00	0.00	450.0	1.42E+10	1.0	30.5	0.000	3.65E-01	0.606	1.086E+00	1.104	0.119	0.4783	2350.00	346.79	99.00	693.55
36500	3.15E+09	2.76	84.1	0.000	4.13E+00	0.000	2.997E+00	4.475	0.000	0.0000	2350.00	0.00	99.00	0.00	460.0	1.45E+10	1.0	30.5	0.000	3.53E-01	0.618	1.086E+00	1.100	0.120	0.4863	2350.00	352.56	99.00	705.10
36500	3.15E+09	2.82	86.0	0.000	4.22E+00	0.000	3.061E+00	4.568	0.000	0.0000	2350.00	0.00	99.00	0.00	470.0	1.48E+10	1.0	30.5	0.000	3.41E-01	0.630	1.086E+00	1.096	0.121	0.4941	2350.00	358.19	99.00	716.37
36500	3.15E+09	2.89	87.8	0.000	4.31E+00	0.000	3.126E+00	4.662	0.000	0.0000	2350.00	0.00	99.00	0.00	480.0	1.51E+10	1.0	30.5	0.000	3.29E-01	0.641	1.086E+00	1.093	0.122	0.5018	2350.00	363.69	99.00	727.38
36500	3.15E+09	2.94	89.6	0.000	4.41E+00	0.000	3.192E+00	4.755	0.000	0.0000	2350.00	0.00	99.00	0.00	490.0	1.55E+10	1.0	30.5	0.000	3.18E-01	0.653	1.086E+00	1.090	0.123	0.5091	2350.00	369.06	99.00	738.12
36500	3.15E+09	3.00	91.4	0.000	4.50E+00	0.000	3.258E+00	4.849	0.000	0.0000	2350.00	0.00	99.00	0.00	500.0	1.58E+10	1.0	30.5	0.000	3.07E-01	0.664	1.086E+00	1.086	0.124	0.5163	2350.00	374.31	99.00	748.62

Note 1: Adapted from Equation B-29, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying d - Upp
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Weber 1991, p.185
R=1+(Kd,cap*p)/ne	Weber 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)

X = (R*x-m*t)/(SQRT(4*D*R*t))

Y = ((v+m)*x)/(2*D)

Z = (R*x+m*t)/(SQRT(4*D*R*t))

m= v*(SQRT(1+((4*u*D)/v^2))

ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap) — USEPA 1998

Cap thickness lost due to expression of porewater during consolidation (ft)

TI,consol = 0.024 feet (typically negligible)

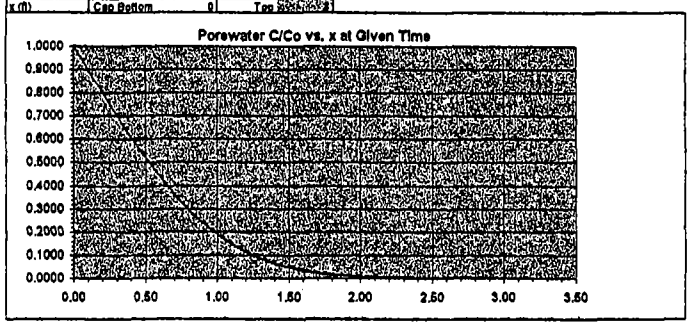
Hydraulic and Transport Calculations

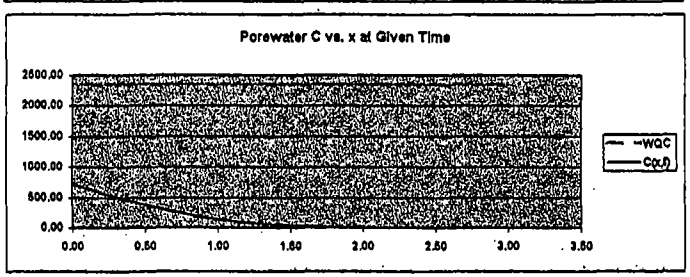
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretical	40	L/kg
	ne	[illegible]	R	130.56	Kd, cap	[illegible]	L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L (LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4875 gm/cm3	d	91.44 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	40 ml/g			
	v	7.056E-06 cm/s	D	1.0E-05 cm2/sec			
			m	7.056E-06 cm/sec	(m=v for u=0)		

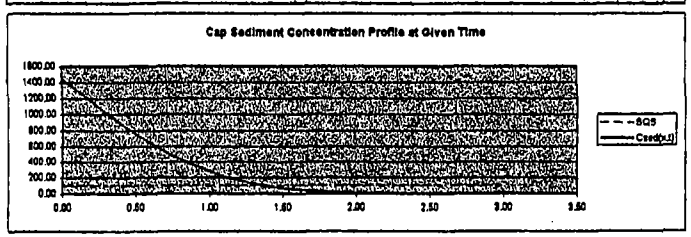
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]
x (ft)	Cap Bottom	0	Top [illegible]



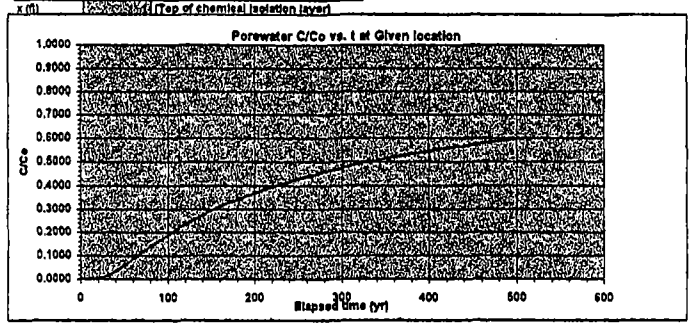


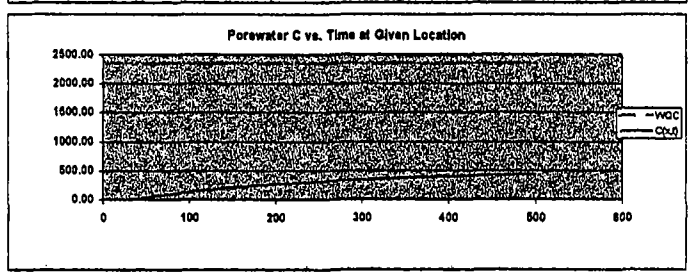


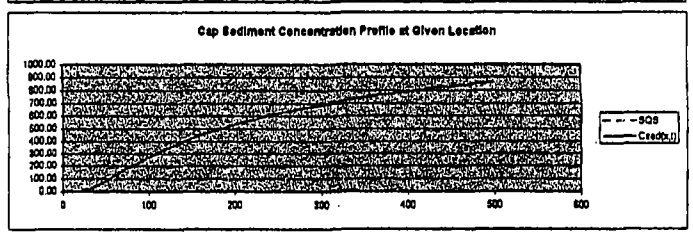
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	599	
x (ft)	[illegible] (Top of chemical isolation layer)				







Sensitivity Analysis for Chemical Isolation Analysis - Varying d - Upper Bou
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-5.41E-02	1.061	0.000E+00	0.054	0.935	1.0000	2350.00	726.00	99.00	1450.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	2.091E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	3.95E-03	0.996	1.265E-02	0.112	0.874	0.9403	2350.00	681.73	99.00	1363.46	10.0	3.15E+08	1.0	30.5	0.000	3.04E+00	0.000	2.091E-01	3.076	0.000	0.0000	2350.00	0.01	99.00	0.02
36500	3.15E+09	0.12	3.7	0.000	5.20E-02	0.930	2.510E-02	0.170	0.810	0.8803	2350.00	639.23	99.00	1278.46	20.0	6.31E+08	1.0	30.5	0.000	2.14E+00	0.002	2.091E-01	2.166	0.002	0.0028	2350.00	1.79	99.00	3.59
36500	3.15E+09	0.18	5.5	0.000	1.20E-01	0.866	3.764E-02	0.228	0.747	0.8204	2350.00	594.83	99.00	1189.65	30.0	9.46E+08	1.0	30.5	0.000	1.74E+00	0.014	2.091E-01	1.795	0.011	0.0139	2350.00	10.09	99.00	20.17
36500	3.15E+09	0.24	7.3	0.000	1.76E-01	0.801	5.019E-02	0.286	0.686	0.7611	2350.00	551.82	99.00	1103.64	40.0	1.26E+09	1.0	30.5	0.000	1.48E+00	0.035	2.091E-01	1.563	0.027	0.0339	2350.00	24.61	99.00	49.22
36500	3.15E+09	0.30	9.1	0.000	2.34E-01	0.738	6.274E-02	0.344	0.626	0.7028	2350.00	509.52	99.00	1019.03	50.0	1.58E+09	1.0	30.5	0.000	1.33E+00	0.060	2.091E-01	1.406	0.047	0.0589	2350.00	42.71	99.00	85.42
36500	3.15E+09	0.36	11.0	0.000	2.94E-01	0.678	7.529E-02	0.402	0.570	0.6456	2350.00	468.20	99.00	936.39	60.0	1.89E+09	1.0	30.5	0.000	1.21E+00	0.089	2.091E-01	1.290	0.068	0.0869	2350.00	62.29	99.00	124.59
36500	3.15E+09	0.42	12.8	0.000	3.52E-01	0.619	8.783E-02	0.460	0.518	0.5905	2350.00	428.12	99.00	856.24	70.0	2.21E+09	1.0	30.5	0.000	1.11E+00	0.118	2.091E-01	1.201	0.099	0.1133	2350.00	82.11	99.00	164.23
36500	3.15E+09	0.48	14.6	0.000	4.10E-01	0.562	1.004E-01	0.518	0.464	0.5373	2350.00	389.63	99.00	779.05	80.0	2.52E+09	1.0	30.5	0.000	1.03E+00	0.144	2.091E-01	1.129	0.110	0.1400	2350.00	101.49	99.00	202.98
36500	3.15E+09	0.54	16.5	0.000	4.69E-01	0.509	1.129E-01	0.576	0.416	0.4864	2350.00	352.61	99.00	705.23	90.0	2.84E+09	1.0	30.5	0.000	9.68E-01	0.171	2.091E-01	1.071	0.130	0.1656	2350.00	120.09	99.00	240.18
36500	3.15E+09	0.60	18.3	0.000	5.26E-01	0.457	1.255E-01	0.634	0.370	0.4380	2350.00	317.56	99.00	635.11	100.0	3.15E+09	1.0	30.5	0.000	9.13E-01	0.197	2.091E-01	1.021	0.149	0.1900	2350.00	137.76	99.00	275.53
36500	3.15E+09	0.66	20.1	0.000	5.84E-01	0.409	1.380E-01	0.692	0.328	0.3924	2350.00	284.49	99.00	568.98	110.0	3.47E+09	1.0	30.5	0.000	8.65E-01	0.221	2.091E-01	0.979	0.166	0.2131	2350.00	154.46	99.00	308.93
36500	3.15E+09	0.72	21.9	0.000	6.42E-01	0.364	1.506E-01	0.750	0.289	0.3497	2350.00	253.52	99.00	507.04	120.0	3.78E+09	1.0	30.5	0.000	8.23E-01	0.244	2.091E-01	0.942	0.183	0.2349	2350.00	170.20	99.00	340.41
36500	3.15E+09	0.78	23.8	0.000	7.00E-01	0.322	1.631E-01	0.808	0.253	0.3099	2350.00	224.71	99.00	449.42	130.0	4.10E+09	1.0	30.5	0.000	7.86E-01	0.268	2.091E-01	0.910	0.198	0.2552	2350.00	185.02	99.00	370.05
36500	3.15E+09	0.84	25.6	0.000	7.58E-01	0.284	1.757E-01	0.866	0.221	0.2732	2350.00	198.10	99.00	396.19	140.0	4.42E+09	1.0	30.5	0.000	7.53E-01	0.287	2.091E-01	0.881	0.213	0.2745	2350.00	198.99	99.00	397.98
36500	3.15E+09	0.90	27.4	0.000	8.16E-01	0.248	1.882E-01	0.924	0.191	0.2398	2350.00	173.87	99.00	347.35	150.0	4.73E+09	1.0	30.5	0.000	7.23E-01	0.306	2.091E-01	0.856	0.228	0.2926	2350.00	212.12	99.00	424.24
36500	3.15E+09	0.96	29.3	0.000	8.74E-01	0.216	2.008E-01	0.982	0.166	0.2089	2350.00	151.42	99.00	302.84	160.0	5.05E+09	1.0	30.5	0.000	6.95E-01	0.325	2.091E-01	0.833	0.239	0.3097	2350.00	224.61	99.00	449.03
36500	3.15E+09	1.02	31.1	0.000	9.32E-01	0.187	2.133E-01	1.040	0.141	0.1811	2350.00	131.28	99.00	262.56	170.0	5.36E+09	1.0	30.5	0.000	6.71E-01	0.343	2.091E-01	0.812	0.251	0.3258	2350.00	236.22	99.00	472.43
36500	3.15E+09	1.08	32.9	0.000	9.90E-01	0.161	2.258E-01	1.098	0.120	0.1561	2350.00	113.18	99.00	226.36	180.0	5.68E+09	1.0	30.5	0.000	6.48E-01	0.359	2.091E-01	0.793	0.262	0.3411	2350.00	247.28	99.00	494.56
36500	3.15E+09	1.14	34.7	0.000	1.05E+00	0.138	2.384E-01	1.156	0.102	0.1338	2350.00	97.01	99.00	194.03	190.0	5.99E+09	1.0	30.5	0.000	6.27E-01	0.376	2.091E-01	0.776	0.272	0.3555	2350.00	257.75	99.00	515.50
36500	3.15E+09	1.20	36.6	0.000	1.11E+00	0.118	2.510E-01	1.214	0.086	0.1140	2350.00	82.59	99.00	165.36	200.0	6.31E+09	1.0	30.5	0.000	6.07E-01	0.390	2.091E-01	0.760	0.282	0.3692	2350.00	267.69	99.00	535.38
36500	3.15E+09	1.26	38.4	0.000	1.16E+00	0.100	2.635E-01	1.272	0.072	0.0968	2350.00	70.06	99.00	140.12	210.0	6.62E+09	1.0	30.5	0.000	5.89E-01	0.405	2.091E-01	0.746	0.292	0.3822	2350.00	277.11	99.00	554.21
36500	3.15E+09	1.32	40.2	0.000	1.22E+00	0.084	2.761E-01	1.330	0.060	0.0814	2350.00	59.02	99.00	118.04	220.0	6.94E+09	1.0	30.5	0.000	5.72E-01	0.419	2.091E-01	0.732	0.300	0.3946	2350.00	286.07	99.00	572.14
36500	3.15E+09	1.38	42.1	0.000	1.28E+00	0.070	2.886E-01	1.388	0.050	0.0682	2350.00	49.43	99.00	98.85	230.0	7.25E+09	1.0	30.5	0.000	5.54E-01	0.432	2.091E-01	0.720	0.309	0.4063	2350.00	294.60	99.00	589.20
36500	3.15E+09	1.44	43.9	0.000	1.34E+00	0.058	3.011E-01	1.447	0.041	0.0569	2350.00	41.15	99.00	82.30	240.0	7.57E+09	1.0	30.5	0.000	5.40E-01	0.446	2.091E-01	0.708	0.317	0.4176	2350.00	302.73	99.00	605.47
36500	3.15E+09	1.50	45.7	0.000	1.40E+00	0.048	3.137E-01	1.506	0.033	0.0470	2350.00	34.05	99.00	68.11	250.0	7.88E+09	1.0	30.5	0.000	5.26E-01	0.457	2.091E-01	0.697	0.324	0.4283	2350.00	310.50	99.00	620.99
36500	3.15E+09	1.56	47.5	0.000	1.46E+00	0.040	3.262E-01	1.563	0.027	0.0386	2350.00	28.02	99.00	56.03	260.0	8.20E+09	1.0	30.5	0.000	5.13E-01	0.469	2.091E-01	0.687	0.331	0.4385	2350.00	317.92	99.00	635.83
36500	3.15E+09	1.62	49.4	0.000	1.51E+00	0.032	3.388E-01	1.621	0.022	0.0316	2350.00	22.91	99.00	45.82	270.0	8.51E+09	1.0	30.5	0.000	5.00E-01	0.480	2.091E-01	0.677	0.338	0.4483	2350.00	325.01	99.00	650.03
36500	3.15E+09	1.68	51.2	0.000	1.57E+00	0.026	3.513E-01	1.679	0.018	0.0257	2350.00	18.62	99.00	37.24	280.0	8.83E+09	1.0	30.5	0.000	4.87E-01	0.491	2.091E-01	0.668	0.345	0.4577	2350.00	331.91	99.00	663.83
36500	3.15E+09	1.74	53.0	0.000	1.63E+00	0.021	3.639E-01	1.737	0.014	0.0207	2350.00	15.04	99.00	30.09	290.0	9.15E+09	1.0	30.5	0.000	4.76E-01	0.501	2.091E-01	0.660	0.351	0.4667	2350.00	338.33	99.00	676.67
36500	3.15E+09	1.80	54.9	0.000	1.69E+00	0.017	3.764E-01	1.795	0.011	0.0167	2350.00	12.08	99.00	24.16	300.0	9.46E+09	1.0	30.5	0.000	4.65E-01	0.511	2.091E-01	0.652	0.357	0.4753	2350.00	344.59	99.00	689.19
36500	3.15E+09	1.86	56.7	0.000	1.74E+00	0.014	3.890E-01	1.853	0.009	0.0133	2350.00	9.64	99.00	19.28	310.0	9.78E+09	1.0	30.5	0.000	4.54E-01	0.521	2.091E-01	0.644	0.362	0.4838	2350.00	350.61	99.00	701.21
36500	3.15E+09	1.92	58.5	0.000	1.80E+00	0.011	4.015E-01	1.911	0.007	0.0105	2350.00	7.65	99.00	15.29	320.0	1.01E+10	1.0	30.5	0.000	4.44E-01	0.530	2.091E-01	0.637	0.367	0.4916	2350.00	356.39	99.00	712.78
36500	3.15E+09	1.98	60.4	0.000	1.86E+00	0.009	4.141E-01	1.969	0.005	0.0083	2350.00	6.03	99.00	12.06	330.0	1.04E+10	1.0	30.5	0.000	4.34E-01	0.539	2.091E-01	0.631	0.373	0.4993	2350.00	361.96	99.00	723.92
36500	3.15E+09	2.04	62.2	0.000	1.92E+00	0.007	4.266E-01	2.027	0.004	0.0065	2350.00	4.72	99.00	9.45	340.0	1.07E+10	1.0	30.5	0.000	4.25E-01	0.548	2.091E-01	0.624	0.377	0.5067	2350.00	367.33	99.00	734.65
36500	3.15E+09	2.10	64.0	0.000	1.98E+00	0.005	4.392E-01	2.085	0.003	0.0051	2350.00	3.69	99.00	7.38	350.0	1.10E+10	1.0	30.5	0.000	4.16E-01	0.557	2.091E-01	0.618	0.382	0.5138	2350.00	372.60	99.00	745.20
36500	3.15E+09	2.16	65.8	0.000	2.03E+00	0.004	4.517E-01	2.143	0.002	0.0039	2350.00	2.85	99.00	5.69	360.0	1.14E+10	1.0	30.5	0.000	4.07E-01	0.565	2.091E-01	0.612	0.387	0.5207	2350.00	377.49	99.00	754.98
36500	3.15E+09	2.22	67.7	0.000	2.09E+00	0.003	4.643E-01	2.201	0.002	0.0030	2350.00	2.18	99.00	4.36	370.0	1.17E+10	1.0	30.5	0.000	3.99E-01	0.573	2.091E-01	0.607	0.391	0.5273	2350.00	382.32	99.00	764.63
36500	3.15E+09	2.28	69.5	0.000	2.15E+00	0.002	4.768E-01	2.259	0.001	0.0023	2350.00	1.67	99.00	3.34	380.0	1.20E+10	1.0	30.5	0.000	3.91E-01	0.581	2.091E-01	0.601	0.395	0.5338	2350.00	386.88	99.00	773.75
36500	3.15E+09	2.34	71.3	0.000	2.21E+00	0.002	4.894E-01	2.317	0.001	0.0018	2350.00	1.27	99.00	2.54	390.0	1.23E+10	1.0	30.5	0.000	3.83E-01	0.588	2.091E-01	0.596	0.399	0.5400	2350.00	391.49	99.00	782.97
36500	3.15E+09	2.40	73.2	0.000	2.27E+00	0.001	5.019E-01	2.375	0.001	0.0013	2350.00	0.96	99.00	1.92	400.0	1.26E+10	1.0	30.5	0.000	3.75E-01	0.596	2.091E-01	0.592	0.403	0.5460	2350.00	395.85	99.00	791.70
36500	3.15E+09	2.46	75.0	0.000	2.32E+00	0.001	5.145E-01	2.433	0.001	0.0010	2350.00	0.72	99.00	1.44	410.0	1.29E+10	1.0	30.5	0.000	3.68E-01	0.603	2.091E-01	0.587	0.406	0.5516	2350.00	400.06	99.00	800.15
36500	3.15E+09	2.52	76.8	0.000	2.38E+00	0.001	5.270E-01	2.491	0.000	0.0007	2350.00	0.54	99.00	1.07	420.0	1.32E+10	1.0	30.5	0.000	3.61E-01	0.610	2.091E-01	0.583	0.410	0.5575	2350.00	404.17	99.00	808.35
36500	3.15E+09	2.58	78.6	0.000	2.44E+00	0.001	5.396E-01	2.549	0.000	0.0005	2350.00	0.40	99.00	0.79	430.0	1.36E+10	1.0	30.5	0.000	3.54E-01	0.616	2.091E-01	0.578	0.413	0.5630	2350.00	408.15	99.00	816.29
36500	3.15E+09	2.64	80.5	0.000	2.50E+00	0.000	5.521E-01	2.607	0.000	0.0004	2350.00	0.29	99.00	0.58	440.0	1.39E+10	1.0	30.5	0.000	3.48E-01	0.623	2.091E-01	0.574	0.417	0.5683	2350.00	412.00	99.00	824.00
36500	3.15E+09	2.70	82.3	0.000	2.56E+00	0.000	5.647E-01	2.665	0.000	0.0003	2350.00	0.21	99.00	0.43	450.0	1.42E+10	1.0	30.5	0.000	3.41E-01	0.629	2.091E-01	0.571	0.420	0.5734	2350.00	415.74	99.00	831.49
36500	3.15E+09	2.76	84.1	0.000	2.61E+00	0.000	5.772E-01	2.723	0.000	0.0002	2350.00	0.15	99.00	0.31	460.0	1.45E+10	1.0	30.5	0.000	3.35E-01	0.636	2.091E-01	0.567	0.423	0.5785	2350.00	419.38	99.00	838.76
36500	3.15E+09	2.82	86.0	0.000	2.67E+00	0.000	5.897E-01	2.781	0.000	0.0002	2350.00	0.11	99.00	0.22	470.0	1.48E+10	1.0	30.5	0.000	3.29E-01	0.642	2.091E-01	0.563	0.426	0.5833	2350.00	422.91	99.00	845.82
36500	3.15E+09	2.88	87.8	0.000	2.73E+00	0.000	6.023E-01	2.839	0.000	0.0001	2350.00	0.08	99.00	0.16	480.0	1.51E+10	1.0	30.5	0.000	3.23E-01	0.648	2.091E-01	0.560	0.429	0.5881	2350.00	426.35	99.00	852.70
36500	3.15E+09	2.94	89.6	0.000	2.79E+00	0.000	6.148E-01	2.897	0.000	0.0001	2350.00	0.06	99.00	0.11	490.0	1.55E+10	1.0	30.5	0.000	3.17E-01	0.654	2.091E-01	0.557	0.431	0.5927	2350.00	429.69	99.00	859.38
36500	3.15E+09	3.00	91.4	0.000	2.85E+00	0.000	6.274E-01	2.955	0.000	0.0001	2350.00	0.04	99.00	0.08	500.0	1.58E+10	1.0	30.5	0.000	3.12E-01	0.660	2.091E-01	0.553	0.434	0.5972	2350.00	432.94	99.00	865.88

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying foc - Int[illegible]alue
PSR Superfund Site

Adve[illegible]ersive Transport Formulae:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)

X = (R*x-m*t)/(SQRT(4*D*R*t))

Y = ((v+m)*x)/(2*D)

Z = (R*x+m*t)/(SQRT(4*D*R*t))

m= v*(SQRT(1+((4*u*D)/v^2))

ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

[illegible]

		Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]			
	n	[illegible]	foc	[illegible]	Kd (theoretica	20	L/kg	
	ne	[illegible]	R	66.76	Kd, cap	[illegible]	L/kg	
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC	
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L	(LOEL)
	i	[illegible] ft	Ce	[illegible] ug/L	Dw	[illegible]	cm2/sec	
Results:	p	1.4576 gm/cm3	d	0.9144 cm				
	I	ft/ft	u	0 /s				
	v	[illegible] ft/d	Kd,cap	20 ml/g				
	v	7.05E-06 cm/s	D	3.9E-06 cm2/sec				
			m	7.05E-06 cm/sec	(m=v for u=0)			

Conversions:

C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	Influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap)	USEPA 1998

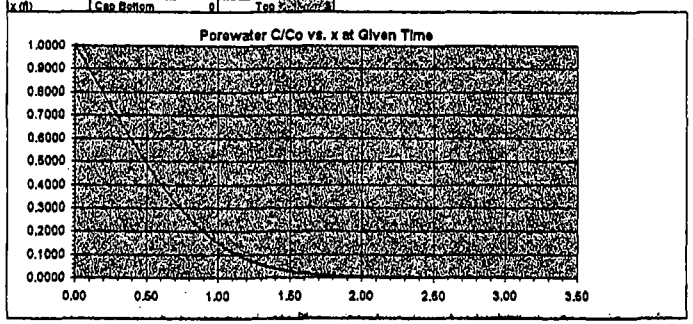
Cap thickness lost due to expression of porewater during consolidation (ft)

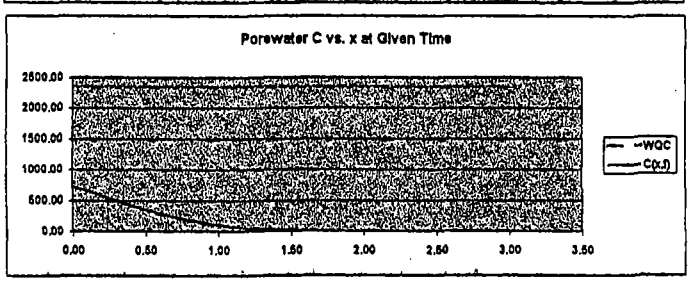
TI,consol = 0.048 feet (typically negligible)

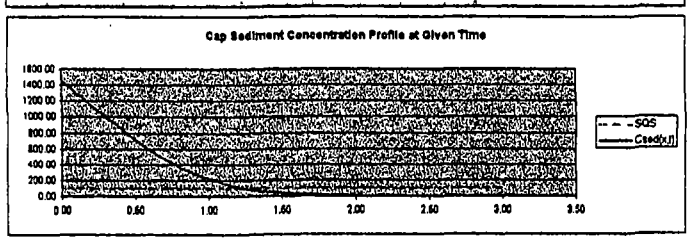
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	years
x (ft)	Cap Bottom	0	Top	[illegible]



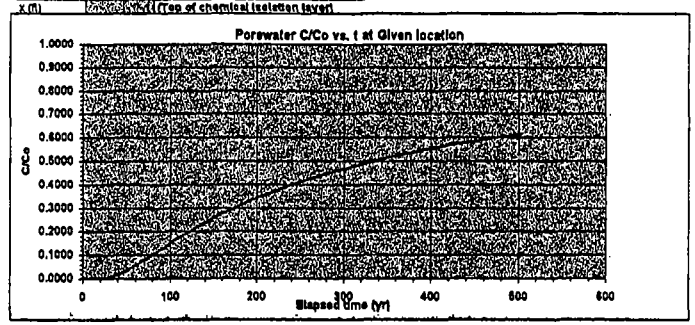


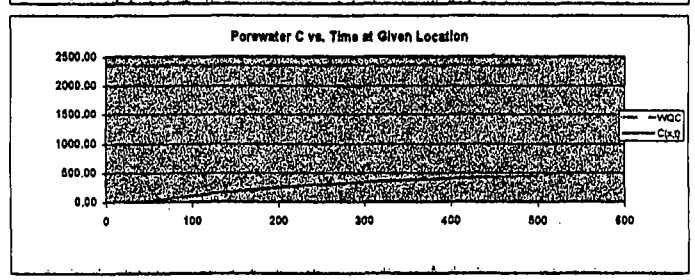


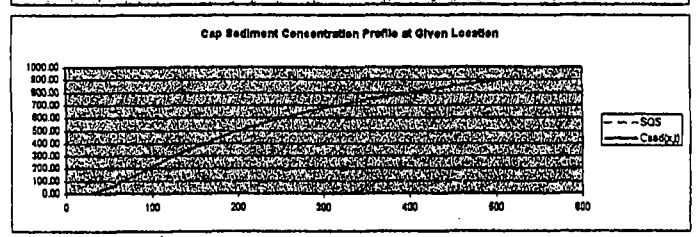
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600
x (ft)	[illegible]	(Top of chemical isolation layer)		







Sensitivity Analysis for Chemical Isolation Analysis - Varying foc - Intermed[redacted]lue
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
I (dpy)	I (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	I (yr)	I (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.24E-01	1.139	0.000E+00	0.124	0.881	1.0000	2350.00	725.00	99.00	1460.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.520E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-8.66E-02	1.064	3.312E-02	0.191	0.767	0.9390	2350.00	680.79	99.00	1361.58	10.0	3.15E+08	1.0	30.5	0.000	3.49E+00	0.000	5.520E-01	3.565	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.01E-02	0.989	6.624E-02	0.256	0.716	0.8767	2350.00	635.58	99.00	1271.17	20.0	6.31E+08	1.0	30.5	0.000	2.44E+00	0.001	5.520E-01	2.649	0.000	0.0006	2350.00	0.40	99.00	0.80
36500	3.15E+09	0.18	5.5	0.000	7.70E-02	0.913	9.936E-02	0.324	0.646	0.8138	2350.00	589.86	99.00	1179.70	30.0	9.46E+08	1.0	30.5	0.000	1.97E+00	0.005	5.520E-01	2.104	0.003	0.0052	2350.00	3.80	99.00	7.59
36500	3.15E+09	0.24	7.3	0.000	1.44E-01	0.839	1.325E-01	0.391	0.580	0.7504	2350.00	544.06	99.00	1088.12	40.0	1.26E+09	1.0	30.5	0.000	1.60E+00	0.017	5.520E-01	1.841	0.009	0.0186	2350.00	12.03	99.00	24.06
36500	3.15E+09	0.30	9.1	0.000	2.11E-01	0.768	1.656E-01	0.458	0.517	0.6876	2350.00	498.68	99.00	997.35	50.0	1.58E+09	1.0	30.5	0.000	1.43E+00	0.035	5.520E-01	1.664	0.019	0.0337	2350.00	24.44	99.00	48.89
36500	3.15E+09	0.36	11.0	0.000	2.76E-01	0.695	1.987E-01	0.525	0.459	0.6264	2350.00	454.14	99.00	908.29	60.0	1.89E+09	1.0	30.5	0.000	1.30E+00	0.057	5.520E-01	1.535	0.030	0.0547	2350.00	39.63	99.00	79.26
36500	3.15E+09	0.42	12.9	0.000	3.46E-01	0.626	2.318E-01	0.592	0.402	0.5667	2350.00	410.97	99.00	821.74	70.0	2.21E+09	1.0	30.5	0.000	1.23E+00	0.082	5.520E-01	1.438	0.042	0.0777	2350.00	56.38	99.00	112.72
36500	3.15E+09	0.48	14.6	0.000	4.11E-01	0.561	2.649E-01	0.659	0.351	0.5093	2350.00	369.23	99.00	738.46	80.0	2.52E+09	1.0	30.5	0.000	1.14E+00	0.106	5.520E-01	1.357	0.055	0.1018	2350.00	73.77	99.00	147.54
36500	3.15E+09	0.54	16.5	0.000	4.78E-01	0.499	2.981E-01	0.726	0.305	0.4546	2350.00	329.65	99.00	659.30	90.0	2.84E+09	1.0	30.5	0.000	1.06E+00	0.135	5.520E-01	1.293	0.069	0.1269	2350.00	91.29	99.00	182.58
36500	3.15E+09	0.60	18.3	0.000	5.46E-01	0.441	3.312E-01	0.793	0.262	0.4029	2350.00	292.09	99.00	584.18	100.0	3.15E+09	1.0	30.5	0.000	9.91E-01	0.161	5.520E-01	1.239	0.080	0.1497	2350.00	108.56	99.00	217.13
36500	3.15E+09	0.66	20.1	0.000	6.12E-01	0.387	3.643E-01	0.860	0.224	0.3546	2350.00	257.07	99.00	514.13	110.0	3.47E+09	1.0	30.5	0.000	9.33E-01	0.197	5.520E-01	1.193	0.092	0.1729	2350.00	125.38	99.00	250.76
36500	3.15E+09	0.72	21.9	0.000	6.79E-01	0.337	3.974E-01	0.927	0.190	0.3098	2350.00	224.63	99.00	449.25	120.0	3.78E+09	1.0	30.5	0.000	8.82E-01	0.212	5.520E-01	1.163	0.103	0.1953	2350.00	141.62	99.00	283.24
36500	3.15E+09	0.78	23.8	0.000	7.46E-01	0.291	4.305E-01	0.994	0.160	0.2688	2350.00	194.86	99.00	389.71	130.0	4.10E+09	1.0	30.5	0.000	8.37E-01	0.237	5.520E-01	1.119	0.114	0.2169	2350.00	157.22	99.00	314.45
36500	3.15E+09	0.84	25.6	0.000	8.13E-01	0.250	4.636E-01	1.060	0.134	0.2314	2350.00	167.79	99.00	335.58	140.0	4.42E+09	1.0	30.5	0.000	7.96E-01	0.260	5.520E-01	1.089	0.124	0.2376	2350.00	172.17	99.00	344.34
36500	3.15E+09	0.90	27.4	0.000	8.80E-01	0.213	4.966E-01	1.127	0.111	0.1978	2350.00	143.41	99.00	286.83	150.0	4.73E+09	1.0	30.5	0.000	7.59E-01	0.283	5.520E-01	1.062	0.133	0.2572	2350.00	186.46	99.00	372.90
36500	3.15E+09	0.96	29.3	0.000	9.47E-01	0.181	5.299E-01	1.194	0.091	0.1678	2350.00	121.66	99.00	243.32	160.0	5.05E+09	1.0	30.5	0.000	7.25E-01	0.305	5.520E-01	1.038	0.142	0.2760	2360.00	200.09	99.00	400.18
36500	3.15E+09	1.02	31.1	0.000	1.01E+00	0.152	5.630E-01	1.261	0.075	0.1413	2350.00	102.42	99.00	204.85	170.0	5.36E+09	1.0	30.5	0.000	6.94E-01	0.326	5.520E-01	1.017	0.151	0.2939	2360.00	213.11	99.00	426.21
36500	3.15E+09	1.08	32.9	0.000	1.08E+00	0.126	5.961E-01	1.329	0.060	0.1180	2350.00	85.57	99.00	171.14	180.0	5.68E+09	1.0	30.5	0.000	6.65E-01	0.347	5.520E-01	0.997	0.159	0.3111	2350.00	225.53	99.00	451.06
36500	3.15E+09	1.14	34.7	0.000	1.15E+00	0.105	6.292E-01	1.396	0.049	0.0978	2350.00	70.94	99.00	141.88	190.0	5.99E+09	1.0	30.5	0.000	6.38E-01	0.367	5.520E-01	0.980	0.168	0.3274	2350.00	237.39	99.00	474.77
36500	3.15E+09	1.20	36.6	0.000	1.21E+00	0.088	6.624E-01	1.462	0.039	0.0805	2350.00	58.38	99.00	116.71	200.0	6.31E+09	1.0	30.5	0.000	6.13E-01	0.386	5.520E-01	0.963	0.173	0.3431	2350.00	248.71	99.00	497.42
36500	3.15E+09	1.26	38.4	0.000	1.26E+00	0.070	6.955E-01	1.529	0.031	0.0657	2350.00	47.62	99.00	95.25	210.0	6.62E+09	1.0	30.5	0.000	5.90E-01	0.404	5.520E-01	0.949	0.180	0.3580	2350.00	259.53	99.00	519.07
36500	3.15E+09	1.32	40.2	0.000	1.32E+00	0.057	7.286E-01	1.596	0.024	0.0532	2350.00	38.56	99.00	77.13	220.0	6.94E+09	1.0	30.5	0.000	5.68E-01	0.422	5.520E-01	0.935	0.186	0.3723	2350.00	269.86	99.00	539.76
36500	3.15E+09	1.38	42.1	0.000	1.42E+00	0.045	7.617E-01	1.663	0.019	0.0427	2350.00	30.98	99.00	61.95	230.0	7.25E+09	1.0	30.5	0.000	5.48E-01	0.439	5.520E-01	0.923	0.192	0.3859	2350.00	279.78	99.00	559.57
36500	3.15E+09	1.44	43.9	0.000	1.48E+00	0.036	7.948E-01	1.729	0.014	0.0340	2350.00	24.69	99.00	49.37	240.0	7.57E+09	1.0	30.5	0.000	5.28E-01	0.455	5.520E-01	0.911	0.197	0.3990	2350.00	289.27	99.00	578.53
36500	3.15E+09	1.50	45.7	0.000	1.55E+00	0.026	8.279E-01	1.796	0.011	0.0269	2350.00	19.51	99.00	39.03	250.0	7.88E+09	1.0	30.5	0.000	5.10E-01	0.471	5.520E-01	0.901	0.203	0.4116	2350.00	298.36	99.00	596.71
36500	3.15E+09	1.56	47.5	0.000	1.62E+00	0.022	8.611E-01	1.863	0.008	0.0211	2350.00	15.30	99.00	30.60	260.0	8.20E+09	1.0	30.5	0.000	4.92E-01	0.487	5.520E-01	0.891	0.208	0.4236	2360.00	307.07	99.00	614.15
36500	3.15E+09	1.62	49.4	0.000	1.68E+00	0.017	8.942E-01	1.930	0.006	0.0164	2350.00	11.90	99.00	23.80	270.0	8.51E+09	1.0	30.5	0.000	4.75E-01	0.502	5.520E-01	0.882	0.212	0.4351	2350.00	316.44	99.00	630.89
36500	3.15E+09	1.68	51.2	0.000	1.75E+00	0.013	9.273E-01	1.997	0.005	0.0127	2350.00	9.18	99.00	18.36	280.0	8.83E+09	1.0	30.5	0.000	4.59E-01	0.516	5.520E-01	0.873	0.217	0.4462	2360.00	323.48	99.00	646.97
36500	3.15E+09	1.74	53.0	0.000	1.82E+00	0.010	9.604E-01	2.064	0.004	0.0097	2350.00	7.03	99.00	14.05	290.0	9.15E+09	1.0	30.5	0.000	4.44E-01	0.530	5.520E-01	0.866	0.221	0.4569	2350.00	331.22	99.00	662.43
36500	3.15E+09	1.80	54.9	0.000	1.88E+00	0.008	9.935E-01	2.131	0.003	0.0074	2360.00	5.33	99.00	10.66	300.0	9.46E+09	1.0	30.5	0.000	4.29E-01	0.544	5.520E-01	0.858	0.225	0.4671	2350.00	338.66	99.00	677.31
36500	3.15E+09	1.86	56.7	0.000	1.95E+00	0.006	1.027E+00	2.198	0.002	0.0055	2360.00	4.01	99.00	8.03	310.0	9.78E+09	1.0	30.5	0.000	4.15E-01	0.557	5.520E-01	0.851	0.229	0.4770	2350.00	346.02	99.00	691.64
36500	3.15E+09	1.92	58.5	0.000	2.02E+00	0.004	1.060E+00	2.265	0.001	0.0041	2350.00	3.00	99.00	5.99	320.0	1.01E+10	1.0	30.5	0.000	4.02E-01	0.570	5.520E-01	0.845	0.232	0.4865	2350.00	352.73	99.00	705.45
36500	3.15E+09	1.98	60.4	0.000	2.08E+00	0.003	1.093E+00	2.332	0.001	0.0031	2350.00	2.22	99.00	4.43	330.0	1.04E+10	1.0	30.5	0.000	3.89E-01	0.582	5.520E-01	0.839	0.236	0.4957	2350.00	359.38	99.00	718.77
36500	3.15E+09	2.04	62.2	0.000	2.15E+00	0.002	1.126E+00	2.399	0.001	0.0022	2350.00	1.63	99.00	3.26	340.0	1.07E+10	1.0	30.5	0.000	3.77E-01	0.594	5.520E-01	0.833	0.239	0.5046	2350.00	365.91	99.00	731.82
36500	3.15E+09	2.10	64.0	0.000	2.22E+00	0.002	1.159E+00	2.465	0.000	0.0016	2350.00	1.19	99.00	2.37	350.0	1.10E+10	1.0	30.5	0.000	3.65E-01	0.606	5.520E-01	0.828	0.242	0.5131	2350.00	372.01	99.00	744.03
36500	3.15E+09	2.16	65.8	0.000	2.28E+00	0.001	1.192E+00	2.532	0.000	0.0012	2350.00	0.86	99.00	1.71	360.0	1.14E+10	1.0	30.5	0.000	3.53E-01	0.618	5.520E-01	0.822	0.245	0.5214	2350.00	378.01	99.00	756.02
36500	3.15E+09	2.22	67.7	0.000	2.35E+00	0.001	1.225E+00	2.599	0.000	0.0008	2350.00	0.61	99.00	1.22	370.0	1.17E+10	1.0	30.5	0.000	3.42E-01	0.629	5.520E-01	0.818	0.247	0.5294	2350.00	383.81	99.00	767.62
36500	3.15E+09	2.28	69.5	0.000	2.42E+00	0.001	1.258E+00	2.666	0.000	0.0006	2350.00	0.43	99.00	0.87	380.0	1.20E+10	1.0	30.5	0.000	3.31E-01	0.640	5.520E-01	0.813	0.250	0.5371	2350.00	389.42	99.00	778.84
36500	3.15E+09	2.34	71.3	0.000	2.49E+00	0.000	1.292E+00	2.733	0.000	0.0004	2350.00	0.31	99.00	0.61	390.0	1.23E+10	1.0	30.5	0.000	3.20E-01	0.651	5.520E-01	0.809	0.253	0.5446	2350.00	394.85	99.00	789.70
36500	3.15E+09	2.40	73.2	0.000	2.55E+00	0.000	1.325E+00	2.800	0.000	0.0003	2350.00	0.21	99.00	0.43	400.0	1.26E+10	1.0	30.5	0.000	3.10E-01	0.661	5.520E-01	0.805	0.255	0.5519	2350.00	400.11	99.00	800.22
36500	3.15E+09	2.46	75.0	0.000	2.62E+00	0.000	1.358E+00	2.867	0.000	0.0002	2350.00	0.15	99.00	0.30	410.0	1.29E+10	1.0	30.5	0.000	3.00E-01	0.671	5.520E-01	0.801	0.257	0.5589	2350.00	405.21	99.00	810.42
36500	3.15E+09	2.52	76.8	0.000	2.69E+00	0.000	1.391E+00	2.934	0.000	0.0001	2350.00	0.10	99.00	0.20	420.0	1.32E+10	1.0	30.5	0.000	2.90E-01	0.681	5.520E-01	0.798	0.259	0.5657	2350.00	410.16	99.00	820.31
36500	3.15E+09	2.58	78.6	0.000	2.75E+00	0.000	1.424E+00	3.001	0.000	0.0001	2350.00	0.07	99.00	0.14	430.0	1.36E+10	1.0	30.5	0.000	2.81E-01	0.691	5.520E-01	0.794	0.261	0.5723	2350.00	414.86	99.00	829.71
36500	3.15E+09	2.64	80.5	0.000	2.82E+00	0.000	1.457E+00	3.068	0.000	0.0001	2350.00	0.05	99.00	0.09	440.0	1.39E+10	1.0	30.5	0.000	2.72E-01	0.700	5.520E-01	0.791	0.263	0.5788	2350.00	419.81	99.00	839.62
36500	3.15E+09	2.70	82.3	0.000	2.89E+00	0.000	1.490E+00	3.134	0.000	0.0000	2350.00	0.03	99.00	0.06	450.0	1.42E+10	1.0	30.5	0.000	2.63E-01	0.710	5.520E-01	0.788	0.266	0.5850	2350.00	424.13	99.00	848.27
36500	3.15E+09	2.76	84.1	0.000	2.95E+00	0.000	1.523E+00	3.201	0.000	0.0000	2350.00	0.02	99.00	0.04	460.0	1.45E+10	1.0	30.5	0.000	2.54E-01	0.719	5.520E-01	0.785	0.267	0.5911	2350.00	428.53	99.00	857.06
36500	3.15E+09	2.82	86.0	0.000	3.02E+00	0.000	1.557E+00	3.268	0.000	0.0000	2350.00	0.01	99.00	0.03	470.0	1.48E+10	1.0	30.5	0.000	2.46E-01	0.728	5.520E-01	0.783	0.268	0.5970	2350.00	432.80	99.00	865.60
36500	3.15E+09	2.88	87.8	0.000	3.09E+00	0.000	1.590E+00	3.335	0.000	0.0000	2350.00	0.01	99.00	0.02	480.0	1.51E+10	1.0	30.5	0.000	2.38E-01	0.737	5.520E-01	0.780	0.270	0.6027	2350.00	436.98	99.00	873.92
36500	3.15E+09	2.94	89.6	0.000	3.15E+00	0.000	1.623E+00	3.402	0.000	0.0000	2350.00	0.01	99.00	0.01	490.0	1.55E+10	1.0	30.5	0.000	2.30E-01	0.745	5.520E-01	0.778	0.271	0.6083	2350.00	441.00	99.00	882.00
36500	3.15E+09	3.00	91.4	0.000	3.22E+00	0.000	1.656E+00	3.469	0.000	0.0000	2350.00	0.00	99.00	0.01	500.0	1.58E+10	1.0	30.5	0.000	2.22E-01	0.754	5.520E-01	0.776	0.273	0.6137	2350.00	444.94	99.00	889.87

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Sensitivity Analysis for Chemical Isolation Analysis - Varying foc - L
PSR Superfund Site

Advective-Dispersive Transport Formulae:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.136
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)
C/Co= B(x,t) = (0.5*EXP(W)*ERFC(Q))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W = ((v-m)*x)/(2*D)	
X = (R*x-m*t)/(SQRT(4*D*R*t))	
Y = ((v+m)*x)/(2*D)	
Z = (R*x+m*t)/(SQRT(4*D*R*t))	
m= v*(SQRT(1+((4*u*D)/v^2))	
ERFC()= 1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DL,sed / (n+p*Kd,cap)	USEPA 1998

Cap thickness lost due to expression of porewater during consolidation (ft)

Tl,consol =	0.894 feet	(typically negligible)

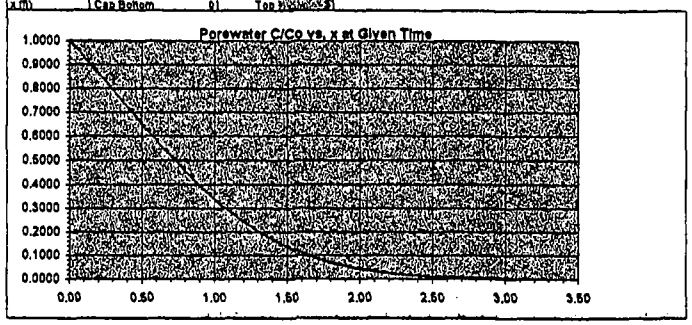
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g	[redacted]		
	n	[redacted]	foc	[redacted]	Kd (theoretical	10	L/kg
	ne	[redacted]	R	33.39	Kd, cap	[redacted]	L/kg
	g	2.65 gm/cm3	u	[redacted] /d	SQS	[redacted]	mg/kgOC
	DL,sed	[redacted] ft	d	[redacted] ft	WQC	[redacted]	ug/L
	L	[redacted] ft	Co	[redacted] ug/L	Dw	[redacted]	cm2/sec
Results:	p	1.4675 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[redacted] ft/s	Kd,cap	10 ml/g			
	v	7.056E-08 cm/s	D	3.9E-08 cm2/sec			
			m	7.056E-08 cm/sec	(m=v for u=0)		

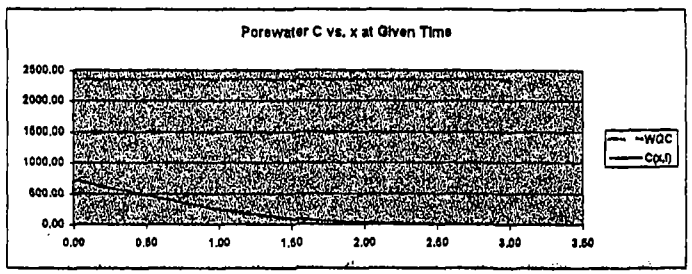
(LOEL)

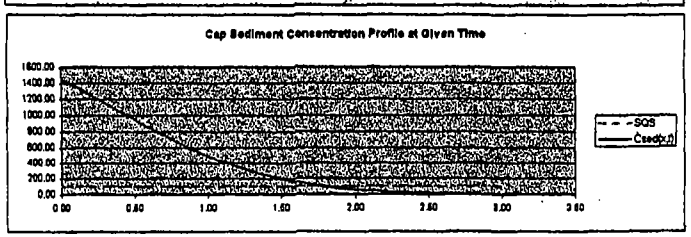
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[redacted]	
x (ft)	Cap Bottom	0	Top	[redacted]



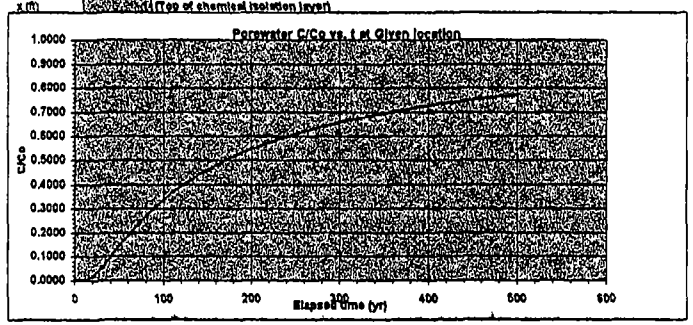


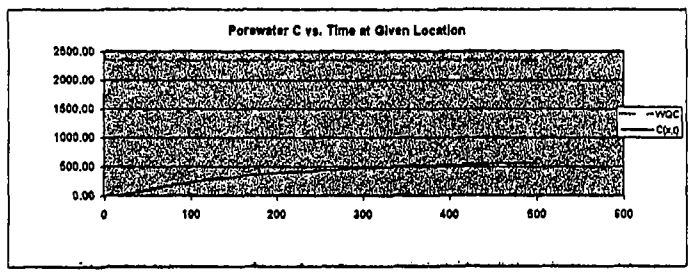


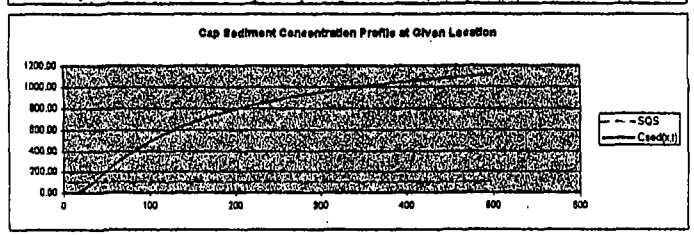
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	500
x (ft)	[redacted] (Top of chemical isolation layer)			







Sensitivity Analysis for Chemical Isolation Analysis - Varying foc - Lowerer
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT				
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQG (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQG (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.194	0.000E+00	0.174	0.826	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	1.0	30.5	0.000	#DIV/0!	#DIV/0!	5.620E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-1.26E-01	1.141	3.312E-02	0.221	0.764	0.9606	2350.00	698.40	99.00	1392.79	10.0	3.15E+08	1.0	30.5	0.000	2.46E+00	0.001	5.620E-01	2.667	0.000	0.0005	2350.00	0.38	99.00	0.73
36500	3.15E+09	0.12	3.7	0.000	-7.94E-02	1.089	8.624E-02	0.269	0.704	0.9200	2350.00	667.01	99.00	1334.02	20.0	6.31E+08	1.0	30.5	0.000	1.70E+00	0.016	5.620E-01	1.854	0.009	0.0157	2350.00	11.41	99.00	22.81
36500	3.15E+09	0.18	5.5	0.000	-3.07E-02	1.035	9.935E-02	0.317	0.654	0.8796	2350.00	636.99	99.00	1273.99	30.0	9.46E+08	1.0	30.5	0.000	1.36E+00	0.065	5.620E-01	1.546	0.029	0.0527	2350.00	38.19	99.00	76.37
36500	3.15E+09	0.24	7.3	0.000	1.70E-02	0.991	1.325E-01	0.364	0.606	0.8386	2350.00	608.50	99.00	1212.99	40.0	1.26E+09	1.0	30.5	0.000	1.15E+00	0.106	5.620E-01	1.388	0.053	0.0989	2350.00	71.67	99.00	143.34
36500	3.15E+09	0.30	9.1	0.000	6.46E-02	0.927	1.656E-01	0.412	0.550	0.7941	2350.00	575.70	99.00	1151.39	50.0	1.58E+09	1.0	30.5	0.000	1.00E+00	0.157	5.620E-01	1.246	0.078	0.1462	2350.00	106.00	99.00	212.00
36500	3.15E+09	0.36	11.0	0.000	1.12E-01	0.874	1.987E-01	0.460	0.516	0.7514	2350.00	544.78	99.00	1089.51	60.0	1.89E+09	1.0	30.5	0.000	8.81E-01	0.208	5.620E-01	1.160	0.101	0.1914	2350.00	138.75	99.00	277.50
36500	3.15E+09	0.42	12.8	0.000	1.60E-01	0.821	2.318E-01	0.507	0.473	0.7087	2350.00	513.84	99.00	1027.69	70.0	2.21E+09	1.0	30.5	0.000	8.04E-01	0.256	5.620E-01	1.085	0.122	0.2332	2350.00	169.09	99.00	338.19
36500	3.15E+09	0.48	14.6	0.000	2.08E-01	0.769	2.649E-01	0.556	0.432	0.6664	2350.00	483.11	99.00	966.22	80.0	2.52E+09	1.0	30.5	0.000	7.33E-01	0.300	5.620E-01	1.044	0.140	0.2716	2350.00	196.99	99.00	393.76
36500	3.15E+09	0.54	16.5	0.000	2.55E-01	0.718	2.981E-01	0.603	0.394	0.6245	2350.00	452.73	99.00	905.46	90.0	2.84E+09	1.0	30.5	0.000	6.71E-01	0.341	5.620E-01	1.002	0.158	0.3085	2350.00	222.24	99.00	444.47
36500	3.15E+09	0.60	18.3	0.000	3.03E-01	0.668	3.312E-01	0.650	0.350	0.5832	2350.00	422.64	99.00	845.28	100.0	3.15E+09	1.0	30.5	0.000	6.21E-01	0.380	5.620E-01	0.968	0.171	0.3384	2350.00	245.37	99.00	490.76
36500	3.15E+09	0.66	20.1	0.000	3.51E-01	0.620	3.643E-01	0.699	0.324	0.5429	2350.00	393.58	99.00	787.17	110.0	3.47E+09	1.0	30.5	0.000	5.76E-01	0.416	5.620E-01	0.940	0.184	0.3676	2350.00	266.62	99.00	533.26
36500	3.15E+09	0.72	21.9	0.000	3.98E-01	0.573	3.974E-01	0.746	0.292	0.5036	2350.00	365.10	99.00	730.19	120.0	3.78E+09	1.0	30.5	0.000	5.36E-01	0.449	5.620E-01	0.915	0.195	0.3944	2350.00	285.91	99.00	571.81
36500	3.15E+09	0.78	23.8	0.000	4.46E-01	0.529	4.305E-01	0.793	0.262	0.4666	2350.00	337.49	99.00	674.98	130.0	4.10E+09	1.0	30.5	0.000	4.99E-01	0.481	5.620E-01	0.896	0.206	0.4189	2350.00	303.72	99.00	607.44
36500	3.15E+09	0.84	25.6	0.000	4.94E-01	0.486	4.634E-01	0.841	0.234	0.4288	2350.00	310.88	99.00	621.75	140.0	4.42E+09	1.0	30.5	0.000	4.66E-01	0.510	5.620E-01	0.877	0.216	0.4416	2350.00	320.15	99.00	640.30
36500	3.15E+09	0.90	27.4	0.000	5.41E-01	0.444	4.955E-01	0.889	0.209	0.3938	2350.00	285.34	99.00	570.68	150.0	4.73E+09	1.0	30.5	0.000	4.36E-01	0.539	5.620E-01	0.861	0.223	0.4628	2350.00	335.35	99.00	670.70
36500	3.15E+09	0.96	29.3	0.000	5.89E-01	0.405	5.299E-01	0.936	0.165	0.3599	2350.00	260.96	99.00	521.91	160.0	5.05E+09	1.0	30.5	0.000	4.09E-01	0.564	5.620E-01	0.846	0.231	0.4820	2350.00	349.45	99.00	698.90
36500	3.15E+09	1.02	31.1	0.000	6.37E-01	0.368	5.630E-01	0.984	0.164	0.3280	2350.00	237.79	99.00	475.58	170.0	5.36E+09	1.0	30.5	0.000	3.83E-01	0.589	5.620E-01	0.836	0.237	0.5001	2350.00	362.57	99.00	725.13
36500	3.15E+09	1.08	32.9	0.000	6.84E-01	0.333	5.961E-01	1.032	0.145	0.2978	2350.00	215.88	99.00	431.77	180.0	5.68E+09	1.0	30.5	0.000	3.59E-01	0.612	5.620E-01	0.825	0.243	0.5170	2350.00	374.80	99.00	749.61
36500	3.15E+09	1.14	34.7	0.000	7.32E-01	0.301	6.292E-01	1.079	0.127	0.2693	2350.00	195.27	99.00	390.54	190.0	5.99E+09	1.0	30.5	0.000	3.37E-01	0.634	5.620E-01	0.815	0.249	0.5329	2350.00	386.25	99.00	772.50
36500	3.15E+09	1.20	36.6	0.000	7.80E-01	0.270	6.624E-01	1.127	0.111	0.2427	2350.00	176.98	99.00	353.93	200.0	6.31E+09	1.0	30.5	0.000	3.16E-01	0.655	5.620E-01	0.807	0.254	0.5476	2350.00	396.99	99.00	793.96
36500	3.15E+09	1.26	38.4	0.000	8.27E-01	0.242	6.955E-01	1.176	0.097	0.2179	2350.00	157.97	99.00	315.94	210.0	6.62E+09	1.0	30.5	0.000	2.97E-01	0.675	5.620E-01	0.800	0.258	0.5615	2350.00	407.08	99.00	814.13
36500	3.15E+09	1.32	40.2	0.000	8.76E-01	0.216	7.286E-01	1.222	0.084	0.1949	2350.00	141.27	99.00	282.56	220.0	6.94E+09	1.0	30.5	0.000	2.78E-01	0.694	5.620E-01	0.793	0.262	0.5746	2350.00	416.58	99.00	833.11
36500	3.15E+09	1.38	42.1	0.000	9.23E-01	0.192	7.617E-01	1.270	0.072	0.1736	2350.00	125.86	99.00	251.72	230.0	7.25E+09	1.0	30.5	0.000	2.60E-01	0.713	5.620E-01	0.787	0.266	0.5869	2350.00	425.52	99.00	851.03
36500	3.15E+09	1.44	43.9	0.000	9.70E-01	0.170	7.948E-01	1.318	0.062	0.1541	2350.00	111.70	99.00	223.40	240.0	7.57E+09	1.0	30.5	0.000	2.44E-01	0.730	5.620E-01	0.782	0.269	0.5986	2350.00	433.98	99.00	867.96
36500	3.15E+09	1.50	45.7	0.000	1.02E+00	0.150	8.279E-01	1.365	0.053	0.1362	2350.00	98.74	99.00	197.49	250.0	7.88E+09	1.0	30.5	0.000	2.28E-01	0.747	5.620E-01	0.777	0.272	0.6097	2350.00	442.00	99.00	884.00
36500	3.15E+09	1.56	47.5	0.000	1.07E+00	0.132	8.611E-01	1.413	0.046	0.1199	2350.00	86.95	99.00	173.90	260.0	8.20E+09	1.0	30.5	0.000	2.13E-01	0.764	5.620E-01	0.773	0.274	0.6201	2350.00	449.60	99.00	899.21
36500	3.15E+09	1.62	49.4	0.000	1.11E+00	0.116	8.942E-01	1.461	0.039	0.1052	2350.00	76.27	99.00	152.53	270.0	8.51E+09	1.0	30.5	0.000	1.99E-01	0.778	5.620E-01	0.769	0.277	0.6301	2350.00	456.93	99.00	913.85
36500	3.15E+09	1.68	51.2	0.000	1.16E+00	0.101	9.273E-01	1.508	0.033	0.0919	2350.00	66.63	99.00	133.26	280.0	8.83E+09	1.0	30.5	0.000	1.84E-01	0.795	5.620E-01	0.765	0.279	0.6396	2350.00	463.70	99.00	927.40
36500	3.15E+09	1.74	53.0	0.000	1.21E+00	0.087	9.604E-01	1.556	0.028	0.0800	2350.00	57.99	99.00	116.06	290.0	9.15E+09	1.0	30.5	0.000	1.71E-01	0.809	5.620E-01	0.762	0.281	0.6486	2350.00	470.24	99.00	940.49
36500	3.15E+09	1.80	54.9	0.000	1.26E+00	0.076	9.935E-01	1.604	0.023	0.0693	2350.00	50.25	99.00	100.51	300.0	9.46E+09	1.0	30.5	0.000	1.58E-01	0.823	5.620E-01	0.760	0.283	0.6572	2350.00	476.49	99.00	952.98
36500	3.15E+09	1.86	56.7	0.000	1.30E+00	0.065	1.027E+00	1.651	0.020	0.0599	2350.00	43.38	99.00	86.76	310.0	9.78E+09	1.0	30.5	0.000	1.46E-01	0.837	5.620E-01	0.757	0.284	0.6654	2350.00	482.45	99.00	964.90
36500	3.15E+09	1.92	58.5	0.000	1.35E+00	0.056	1.060E+00	1.699	0.016	0.0514	2350.00	37.30	99.00	74.60	320.0	1.01E+10	1.0	30.5	0.000	1.33E-01	0.850	5.620E-01	0.755	0.286	0.6733	2350.00	488.16	99.00	976.30
36500	3.15E+09	1.98	60.4	0.000	1.40E+00	0.048	1.093E+00	1.747	0.014	0.0441	2350.00	31.94	99.00	63.88	330.0	1.04E+10	1.0	30.5	0.000	1.22E-01	0.863	5.620E-01	0.753	0.287	0.6808	2350.00	493.61	99.00	987.22
36500	3.15E+09	2.04	62.2	0.000	1.45E+00	0.041	1.126E+00	1.794	0.011	0.0378	2350.00	27.24	99.00	54.47	340.0	1.07E+10	1.0	30.5	0.000	1.11E-01	0.875	5.620E-01	0.751	0.288	0.6881	2350.00	498.84	99.00	997.68
36500	3.15E+09	2.10	64.0	0.000	1.49E+00	0.036	1.159E+00	1.842	0.009	0.0319	2350.00	23.13	99.00	46.27	350.0	1.10E+10	1.0	30.5	0.000	9.97E-02	0.888	5.620E-01	0.750	0.289	0.6950	2350.00	503.86	99.00	1007.71
36500	3.15E+09	2.16	65.8	0.000	1.54E+00	0.029	1.192E+00	1.890	0.008	0.0270	2350.00	19.57	99.00	39.14	360.0	1.14E+10	1.0	30.5	0.000	8.91E-02	0.900	5.620E-01	0.748	0.290	0.7016	2350.00	508.67	99.00	1017.34
36500	3.15E+09	2.22	67.7	0.000	1.59E+00	0.026	1.226E+00	1.937	0.006	0.0227	2350.00	16.48	99.00	32.97	370.0	1.17E+10	1.0	30.5	0.000	7.89E-02	0.911	5.620E-01	0.747	0.291	0.7080	2350.00	513.30	99.00	1026.60
36500	3.15E+09	2.28	69.5	0.000	1.64E+00	0.021	1.259E+00	1.985	0.005	0.0191	2350.00	13.83	99.00	27.66	380.0	1.20E+10	1.0	30.5	0.000	6.89E-02	0.922	5.620E-01	0.746	0.291	0.7141	2350.00	517.75	99.00	1035.50
36500	3.15E+09	2.34	71.3	0.000	1.69E+00	0.017	1.292E+00	2.033	0.004	0.0159	2350.00	11.55	99.00	23.11	390.0	1.23E+10	1.0	30.5	0.000	5.93E-02	0.933	5.620E-01	0.745	0.292	0.7200	2350.00	522.03	99.00	1044.07
36500	3.15E+09	2.40	73.2	0.000	1.73E+00	0.014	1.325E+00	2.080	0.003	0.0133	2350.00	9.61	99.00	19.22	400.0	1.26E+10	1.0	30.5	0.000	4.99E-02	0.944	5.620E-01	0.745	0.292	0.7257	2350.00	526.16	99.00	1052.32
36500	3.15E+09	2.46	75.0	0.000	1.78E+00	0.012	1.358E+00	2.128	0.003	0.0110	2350.00	7.96	99.00	15.93	410.0	1.29E+10	1.0	30.5	0.000	4.06E-02	0.954	5.620E-01	0.744	0.293	0.7312	2350.00	530.14	99.00	1060.28
36500	3.15E+09	2.52	76.8	0.000	1.83E+00	0.010	1.391E+00	2.176	0.002	0.0091	2350.00	6.57	99.00	13.14	420.0	1.32E+10	1.0	30.5	0.000	3.17E-02	0.964	5.620E-01	0.744	0.293	0.7365	2350.00	533.98	99.00	1067.96
36500	3.15E+09	2.58	78.8	0.000	1.88E+00	0.008	1.424E+00	2.223	0.002	0.0074	2350.00	5.40	99.00	10.80	430.0	1.35E+10	1.0	30.5	0.000	2.29E-02	0.974	5.620E-01	0.743	0.293	0.7416	2350.00	537.69	99.00	1075.37
36500	3.15E+09	2.64	80.5	0.000	1.92E+00	0.007	1.457E+00	2.271	0.001	0.0061	2350.00	4.42	99.00	8.83	440.0	1.39E+10	1.0	30.5	0.000	1.44E-02	0.984	5.620E-01	0.743	0.293	0.7466	2350.00	541.27	99.00	1082.53
36500	3.15E+09	2.70	82.3	0.000	1.97E+00	0.005	1.490E+00	2.319	0.001	0.0050	2350.00	3.60	99.00	7.20	450.0	1.42E+10	1.0	30.5	0.000	6.04E-03	0.993	5.620E-01	0.743	0.293	0.7513	2350.00	544.73	99.00	1089.46
36500	3.15E+09	2.76	84.1	0.000	2.02E+00	0.004	1.523E+00	2.368	0.001	0.0040	2350.00	2.92	99.00	5.84	460.0	1.45E+10	1.0	30.5	0.000	-2.12E-03	1.002	5.620E-01	0.743	0.293	0.7560	2350.00	548.08	99.00	1096.15
36500	3.15E+09	2.82	86.0	0.000	2.07E+00	0.003	1.557E+00	2.416	0.001	0.0033	2350.00	2.36	99.00	4.72	470.0	1.48E+10	1.0	30.5	0.000	-1.01E-02	1.011	5.620E-01	0.743	0.293	0.7604	2350.00	551.32	99.00	1102.64
36500	3.15E+09	2.88	87.8	0.000	2.11E+00	0.003	1.590E+00	2.462	0.000	0.0026	2350.00	1.90	99.00	3.79	480.0	1.51E+10	1.0	30.5	0.000	-1.79E-02	1.020	5.620E-01	0.743	0.293	0.7646	2350.00	554.46	99.00	1108.91
36500	3.15E+09	2.94	89.6	0.000	2.16E+00	0.002	1.623E+00	2.509	0.000	0.0021	2350.00	1.52	99.00	3.04	490.0	1.55E+10	1.0	30.5	0.000	-2.56E-02	1.029	5.620E-01	0.743	0.293	0.7690	2350.00	557.50	99.00	1114.99
36500	3.15E+09	3.00	91.4	0.000	2.21E+00	0.002	1.656E+00	2.557	0.000	0.0017	2350.00	1.21	99.00	2.42	500.0	1.58E+10	1.0	30.5	0.000	-3.31E-02	1.037	5.620E-01	0.744	0.293	0.7730	2350.00	560.45	99.00	1120.89

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for Specific Remediation Areas

Chemical Isolation Analysis for RA1
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Wallon 1991, p.186
R=1+(Kd,cap*p)/ne	Wallon 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)

X = (R*x-m*t)/(SQRT(4*D*R*t))

Y = ((v+m)*x)/(2*D)

Z = (R*x+m*t)/(SQRT(4*D*R*t))

m= v*(SQRT(1+((4*v*D)/v^2)))

ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

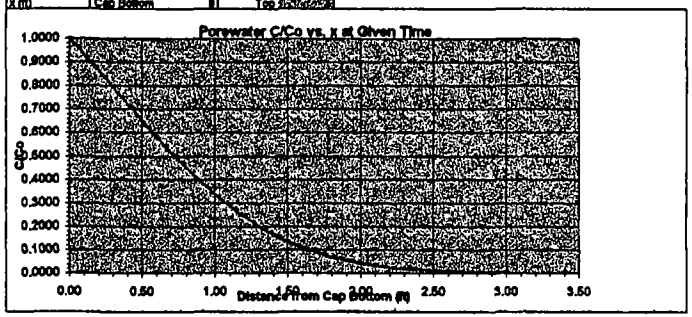
[redacted]

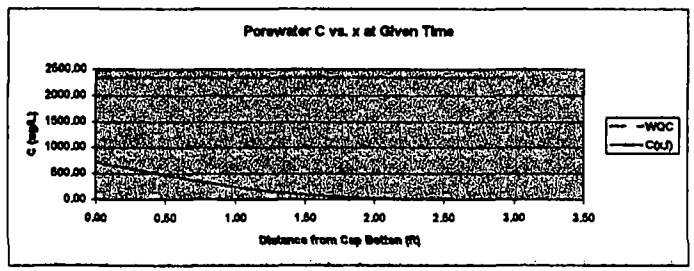
	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[redacted] ft/d	Koc	[redacted] ml/g	[redacted]		
	n	[redacted]	foc	[redacted]	Kd (theoretica	10 L/kg	
	ne	[redacted]	R	23.39	Kd, cap	[redacted] L/kg	
	g	[redacted] gm/cm3	u	[redacted] ft	SQS	[redacted] mg/kgOC	
	DL_sed	[redacted] ft	d	[redacted] ft	WQC	[redacted] ug/L	(LOEL)
	L	[redacted] ft	Co	[redacted] ug/L	Dw	[redacted] cm2/sec	
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[redacted] ft/d	Kd,cap	10 ml/g			
	v	7.056E-08 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-08 cm/sec	(m=v for u=0)		

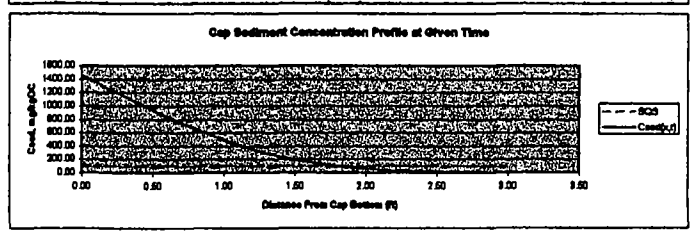
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	28549	days =	[redacted]
x (ft)	Cap Bottom	0	Top [redacted]







Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	Influent porewater concentration (ug/L)	1 % wt =	1.0	lg/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL_sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (/)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (/)			
ne	effective porosity (/)			
p	bulk density (gm/cm3)			
R	retardation factor (/)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap)	USEPA 1996

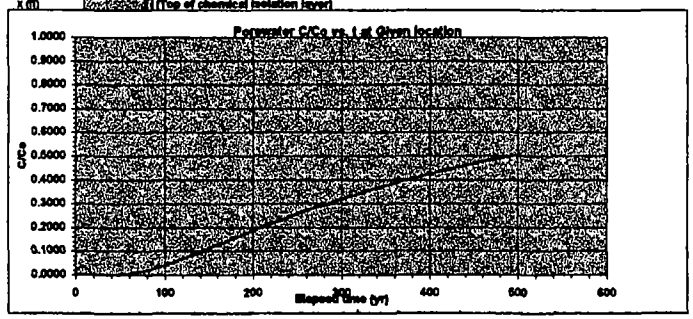
Cap thickness lost due to expression of porewater during consolidation (ft)

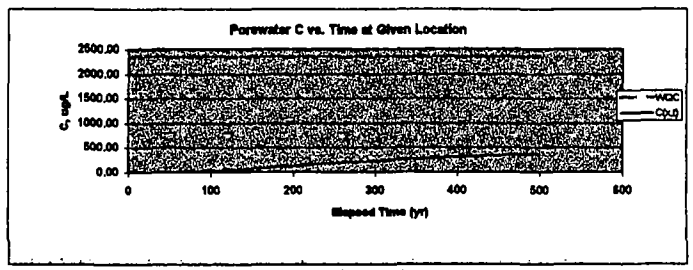
TI,consol =	0.894 feet	(typically negligible)

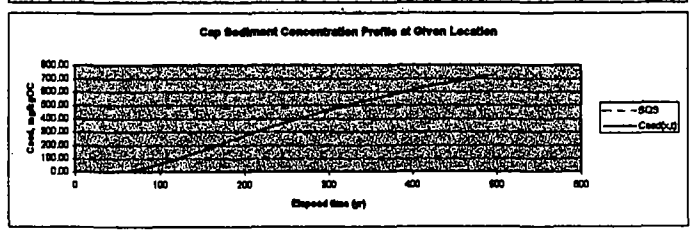
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish 549
x (ft)	[redacted]	(Top of chemical isolation layer)	







Chemical Isolation Analysis for RA1
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	Si(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	Si(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.194	0.000E+00	0.174	0.806	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	2.0	61.0	0.000	#DIV/0!	#DIV/0!	1.104E+00	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-1.26E-01	1.141	3.312E-02	0.221	0.764	0.9805	2350.00	696.40	99.00	1392.79	10.0	3.15E+08	2.0	61.0	0.000	4.97E+00	0.000	1.104E+00	5.079	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	-7.84E-02	1.088	5.634E-02	0.269	0.704	0.9200	2350.00	667.01	99.00	1334.02	20.0	6.31E+08	2.0	61.0	0.000	3.48E+00	0.000	1.104E+00	3.531	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	-3.07E-02	1.035	9.935E-02	0.317	0.654	0.8786	2350.00	636.99	99.00	1273.98	30.0	9.46E+08	2.0	61.0	0.000	2.81E+00	0.000	1.104E+00	2.896	0.000	0.0001	2350.00	0.05	99.00	0.10
36500	3.15E+09	0.24	7.3	0.000	1.70E-02	0.981	1.325E-01	0.364	0.606	0.8365	2350.00	606.50	99.00	1212.99	40.0	1.26E+09	2.0	61.0	0.000	2.40E+00	0.001	1.104E+00	2.622	0.000	0.0007	2350.00	0.47	99.00	0.95
36500	3.15E+09	0.30	9.1	0.000	6.44E-02	0.927	1.656E-01	0.412	0.560	0.7941	2350.00	575.70	99.00	1151.39	50.0	1.58E+09	2.0	61.0	0.000	2.12E+00	0.003	1.104E+00	2.379	0.001	0.0025	2350.00	1.84	99.00	3.69
36500	3.15E+09	0.36	11.0	0.000	1.12E-01	0.874	1.987E-01	0.460	0.516	0.7514	2350.00	544.78	99.00	1089.51	60.0	1.89E+09	2.0	61.0	0.000	1.92E+00	0.007	1.104E+00	2.166	0.002	0.0064	2350.00	4.61	99.00	9.23
36500	3.15E+09	0.42	12.8	0.000	1.60E-01	0.821	2.318E-01	0.507	0.473	0.7067	2350.00	513.84	99.00	1027.69	70.0	2.21E+09	2.0	61.0	0.000	1.75E+00	0.013	1.104E+00	2.044	0.004	0.0124	2350.00	8.96	99.00	17.91
36500	3.15E+09	0.48	14.6	0.000	2.06E-01	0.769	2.649E-01	0.555	0.432	0.6664	2350.00	483.11	99.00	966.22	80.0	2.52E+09	2.0	61.0	0.000	1.62E+00	0.022	1.104E+00	1.932	0.006	0.0204	2350.00	14.81	99.00	29.62
36500	3.15E+09	0.54	16.5	0.000	2.55E-01	0.719	2.981E-01	0.603	0.394	0.6246	2350.00	452.73	99.00	905.46	90.0	2.84E+09	2.0	61.0	0.000	1.51E+00	0.033	1.104E+00	1.840	0.009	0.0304	2350.00	22.00	99.00	44.01
36500	3.15E+09	0.60	18.3	0.000	3.03E-01	0.669	3.312E-01	0.650	0.358	0.5832	2350.00	422.84	99.00	845.68	100.0	3.15E+09	2.0	61.0	0.000	1.42E+00	0.045	1.104E+00	1.763	0.013	0.0418	2350.00	30.30	99.00	60.60
36500	3.15E+09	0.66	20.1	0.000	3.51E-01	0.620	3.643E-01	0.696	0.324	0.5429	2350.00	393.68	99.00	787.17	110.0	3.47E+09	2.0	61.0	0.000	1.33E+00	0.059	1.104E+00	1.697	0.016	0.0544	2350.00	39.47	99.00	78.94
36500	3.15E+09	0.72	21.9	0.000	3.98E-01	0.573	3.974E-01	0.746	0.292	0.5036	2350.00	365.10	99.00	730.19	120.0	3.78E+09	2.0	61.0	0.000	1.26E+00	0.075	1.104E+00	1.641	0.020	0.0690	2350.00	49.31	99.00	98.61
36500	3.15E+09	0.79	23.8	0.000	4.46E-01	0.529	4.306E-01	0.793	0.263	0.4656	2350.00	337.49	99.00	674.98	130.0	4.10E+09	2.0	61.0	0.000	1.20E+00	0.091	1.104E+00	1.592	0.024	0.0822	2350.00	59.82	99.00	119.64
36500	3.15E+09	0.84	25.6	0.000	4.94E-01	0.485	4.636E-01	0.841	0.234	0.4298	2350.00	310.88	99.00	621.76	140.0	4.42E+09	2.0	61.0	0.000	1.14E+00	0.108	1.104E+00	1.548	0.029	0.0968	2350.00	70.26	99.00	140.52
36500	3.15E+09	0.90	27.4	0.000	5.41E-01	0.444	4.968E-01	0.889	0.209	0.3936	2350.00	285.34	99.00	570.68	150.0	4.73E+09	2.0	61.0	0.000	1.09E+00	0.125	1.104E+00	1.510	0.033	0.1119	2350.00	81.11	99.00	162.21
36500	3.15E+09	0.96	29.3	0.000	5.89E-01	0.405	5.299E-01	0.936	0.185	0.3589	2350.00	260.96	99.00	521.91	160.0	5.05E+09	2.0	61.0	0.000	1.04E+00	0.143	1.104E+00	1.478	0.037	0.1270	2350.00	92.05	99.00	184.11
36500	3.15E+09	1.02	31.1	0.000	6.37E-01	0.369	5.630E-01	0.984	0.164	0.3280	2350.00	237.79	99.00	475.58	170.0	5.36E+09	2.0	61.0	0.000	9.92E-01	0.161	1.104E+00	1.445	0.041	0.1421	2350.00	103.02	99.00	206.04
36500	3.15E+09	1.08	32.9	0.000	6.84E-01	0.333	5.961E-01	1.032	0.145	0.2978	2350.00	215.88	99.00	431.77	180.0	5.68E+09	2.0	61.0	0.000	9.51E-01	0.179	1.104E+00	1.417	0.046	0.1572	2350.00	113.96	99.00	227.89
36500	3.15E+09	1.14	34.7	0.000	7.32E-01	0.301	6.292E-01	1.079	0.127	0.2693	2350.00	195.27	99.00	390.54	190.0	5.99E+09	2.0	61.0	0.000	9.13E-01	0.197	1.104E+00	1.392	0.049	0.1721	2350.00	124.76	99.00	249.57
36500	3.15E+09	1.20	36.6	0.000	7.80E-01	0.270	6.624E-01	1.127	0.111	0.2427	2350.00	175.96	99.00	351.93	200.0	6.31E+09	2.0	61.0	0.000	8.78E-01	0.214	1.104E+00	1.369	0.053	0.1869	2350.00	135.49	99.00	270.99
36500	3.15E+09	1.26	38.4	0.000	8.27E-01	0.242	6.955E-01	1.176	0.097	0.2179	2350.00	157.97	99.00	315.94	210.0	6.62E+09	2.0	61.0	0.000	8.45E-01	0.232	1.104E+00	1.348	0.057	0.2014	2350.00	146.04	99.00	292.08
36500	3.15E+09	1.32	40.2	0.000	8.75E-01	0.216	7.286E-01	1.222	0.084	0.1949	2350.00	141.27	99.00	282.55	220.0	6.94E+09	2.0	61.0	0.000	8.14E-01	0.250	1.104E+00	1.329	0.060	0.2157	2350.00	156.41	99.00	312.82
36500	3.15E+09	1.38	42.1	0.000	9.23E-01	0.192	7.617E-01	1.270	0.072	0.1736	2350.00	125.86	99.00	251.72	230.0	7.25E+09	2.0	61.0	0.000	7.84E-01	0.267	1.104E+00	1.311	0.064	0.2296	2350.00	166.58	99.00	333.17
36500	3.15E+09	1.44	43.9	0.000	9.70E-01	0.170	7.948E-01	1.318	0.062	0.1541	2350.00	111.70	99.00	223.40	240.0	7.57E+09	2.0	61.0	0.000	7.57E-01	0.285	1.104E+00	1.295	0.067	0.2435	2350.00	176.65	99.00	353.10
36500	3.15E+09	1.50	45.7	0.000	1.02E+00	0.150	8.279E-01	1.365	0.053	0.1362	2350.00	98.74	99.00	197.49	250.0	7.88E+09	2.0	61.0	0.000	7.30E-01	0.302	1.104E+00	1.280	0.070	0.2570	2350.00	186.31	99.00	372.61
36500	3.15E+09	1.56	47.5	0.000	1.07E+00	0.132	8.611E-01	1.413	0.046	0.1199	2350.00	86.95	99.00	173.90	260.0	8.20E+09	2.0	61.0	0.000	7.05E-01	0.319	1.104E+00	1.265	0.074	0.2701	2350.00	195.84	99.00	391.68
36500	3.15E+09	1.62	49.4	0.000	1.11E+00	0.115	8.942E-01	1.461	0.039	0.1052	2350.00	76.27	99.00	152.53	270.0	8.51E+09	2.0	61.0	0.000	6.82E-01	0.335	1.104E+00	1.252	0.077	0.2830	2350.00	205.18	99.00	410.33
36500	3.15E+09	1.68	51.2	0.000	1.16E+00	0.101	9.273E-01	1.508	0.033	0.0919	2350.00	66.63	99.00	133.26	280.0	8.83E+09	2.0	61.0	0.000	6.59E-01	0.351	1.104E+00	1.240	0.079	0.2956	2350.00	214.25	99.00	428.51
36500	3.15E+09	1.74	53.0	0.000	1.21E+00	0.087	9.604E-01	1.556	0.028	0.0800	2350.00	57.98	99.00	116.96	290.0	9.15E+09	2.0	61.0	0.000	6.37E-01	0.367	1.104E+00	1.229	0.082	0.3078	2350.00	223.13	99.00	446.26
36500	3.15E+09	1.80	54.9	0.000	1.26E+00	0.076	9.935E-01	1.604	0.023	0.0693	2350.00	50.25	99.00	100.51	300.0	9.46E+09	2.0	61.0	0.000	6.16E-01	0.383	1.104E+00	1.218	0.085	0.3197	2350.00	231.79	99.00	463.58
36500	3.15E+09	1.86	56.7	0.000	1.30E+00	0.065	1.027E+00	1.651	0.020	0.0599	2350.00	43.38	99.00	86.76	310.0	9.78E+09	2.0	61.0	0.000	5.97E-01	0.399	1.104E+00	1.208	0.088	0.3314	2350.00	240.24	99.00	480.47
36500	3.15E+09	1.92	58.5	0.000	1.35E+00	0.056	1.060E+00	1.699	0.016	0.0514	2350.00	37.30	99.00	74.60	320.0	1.01E+10	2.0	61.0	0.000	5.78E-01	0.414	1.104E+00	1.199	0.090	0.3427	2350.00	248.47	99.00	496.95
36500	3.15E+09	1.98	60.4	0.000	1.40E+00	0.048	1.093E+00	1.747	0.014	0.0441	2350.00	31.94	99.00	63.88	330.0	1.04E+10	2.0	61.0	0.000	5.59E-01	0.429	1.104E+00	1.190	0.092	0.3538	2350.00	256.51	99.00	513.01
36500	3.15E+09	2.04	62.2	0.000	1.45E+00	0.041	1.126E+00	1.794	0.011	0.0378	2350.00	27.34	99.00	54.67	340.0	1.07E+10	2.0	61.0	0.000	5.41E-01	0.444	1.104E+00	1.182	0.095	0.3648	2350.00	264.34	99.00	528.68
36500	3.15E+09	2.10	64.0	0.000	1.49E+00	0.035	1.159E+00	1.842	0.009	0.0319	2350.00	23.13	99.00	46.27	350.0	1.10E+10	2.0	61.0	0.000	5.24E-01	0.458	1.104E+00	1.174	0.097	0.3751	2350.00	271.87	99.00	543.75
36500	3.15E+09	2.16	65.9	0.000	1.54E+00	0.029	1.192E+00	1.890	0.008	0.0270	2350.00	19.57	99.00	39.14	360.0	1.14E+10	2.0	61.0	0.000	5.06E-01	0.473	1.104E+00	1.167	0.099	0.3864	2350.00	279.42	99.00	558.84
36500	3.15E+09	2.22	67.7	0.000	1.59E+00	0.025	1.226E+00	1.937	0.006	0.0227	2350.00	16.48	99.00	32.97	370.0	1.17E+10	2.0	61.0	0.000	4.92E-01	0.487	1.104E+00	1.160	0.101	0.3954	2350.00	286.68	99.00	573.36
36500	3.15E+09	2.28	69.5	0.000	1.64E+00	0.021	1.259E+00	1.985	0.005	0.0191	2350.00	13.83	99.00	27.66	380.0	1.20E+10	2.0	61.0	0.000	4.76E-01	0.500	1.104E+00	1.154	0.103	0.4052	2350.00	293.76	99.00	587.52
36500	3.15E+09	2.34	71.3	0.000	1.69E+00	0.017	1.292E+00	2.033	0.004	0.0160	2350.00	11.56	99.00	23.11	390.0	1.23E+10	2.0	61.0	0.000	4.62E-01	0.514	1.104E+00	1.148	0.105	0.4147	2350.00	300.68	99.00	601.33
36500	3.15E+09	2.40	73.2	0.000	1.73E+00	0.014	1.325E+00	2.080	0.003	0.0133	2350.00	9.61	99.00	19.22	400.0	1.26E+10	2.0	61.0	0.000	4.47E-01	0.527	1.104E+00	1.142	0.108	0.4240	2350.00	307.40	99.00	614.80
36500	3.15E+09	2.46	75.0	0.000	1.78E+00	0.012	1.358E+00	2.128	0.003	0.0110	2350.00	7.96	99.00	15.93	410.0	1.29E+10	2.0	61.0	0.000	4.33E-01	0.540	1.104E+00	1.138	0.108	0.4331	2350.00	313.97	99.00	627.94
36500	3.15E+09	2.52	76.8	0.000	1.83E+00	0.010	1.391E+00	2.176	0.002	0.0091	2350.00	6.57	99.00	13.14	420.0	1.32E+10	2.0	61.0	0.000	4.19E-01	0.553	1.104E+00	1.131	0.110	0.4419	2350.00	320.38	99.00	640.76
36500	3.15E+09	2.58	78.6	0.000	1.88E+00	0.008	1.424E+00	2.223	0.002	0.0074	2350.00	5.40	99.00	10.80	430.0	1.36E+10	2.0	61.0	0.000	4.06E-01	0.566	1.104E+00	1.126	0.111	0.4505	2350.00	326.64	99.00	653.28
36500	3.15E+09	2.64	80.5	0.000	1.92E+00	0.007	1.457E+00	2.271	0.001	0.0061	2350.00	4.42	99.00	8.83	440.0	1.39E+10	2.0	61.0	0.000	3.93E-01	0.578	1.104E+00	1.122	0.113	0.4590	2350.00	332.74	99.00	665.48
36500	3.15E+09	2.70	82.3	0.000	1.97E+00	0.005	1.490E+00	2.319	0.001	0.0050	2350.00	3.60	99.00	7.20	450.0	1.42E+10	2.0	61.0	0.000	3.81E-01	0.590	1.104E+00	1.117	0.114	0.4672	2350.00	338.71	99.00	677.41
36500	3.15E+09	2.76	84.1	0.000	2.02E+00	0.004	1.523E+00	2.368	0.001	0.0040	2350.00	2.92	99.00	5.84	460.0	1.45E+10	2.0	61.0	0.000	3.69E-01	0.602	1.104E+00	1.113	0.116	0.4752	2350.00	344.53	99.00	689.06
36500	3.15E+09	2.82	86.0	0.000	2.07E+00	0.003	1.557E+00	2.414	0.001	0.0033	2350.00	2.36	99.00	4.72	470.0	1.48E+10	2.0	61.0	0.000	3.56E-01	0.614	1.104E+00	1.109	0.117	0.4830	2350.00	350.21	99.00	700.42
36500	3.15E+09	2.88	87.8	0.000	2.11E+00	0.003	1.590E+00	2.462	0.000	0.0026	2350.00	1.90	99.00	3.79	480.0	1.51E+10	2.0	61.0	0.000	3.45E-01	0.626	1.104E+00	1.106	0.118	0.4907	2350.00	355.76	99.00	711.53
36500	3.15E+09	2.94	89.6	0.000	2.16E+00	0.002	1.623E+00	2.509	0.000	0.0021	2350.00	1.52	99.00	3.04	490.0	1.55E+10	2.0	61.0	0.000	3.33E-01	0.637	1.104E+00	1.102	0.119	0.4982	2350.00	361.19	99.00	722.38
36500	3.15E+09	3.00	91.4	0.000	2.21E+00	0.002	1.656E+00	2.557	0.000	0.0017	2350.00	1.21	99.00	2.42	500.0	1.58E+10	2.0	61.0	0.000	3.22E-01	0.649	1.104E+00	1.099	0.120	0.5055	2350.00	366.49	99.00	732.98

Note 1: Adapted from Equation B-29, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for RA2a and RA3
PSR Superfund Site

Advective-Dispersive Transport Formulae:

Kd=foc*Koc	Walton 1991, p.196
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=Cp(t)*Kd,cap	Partitioning definition [see note 2]
D = Dse(t)*I/D) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)
C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W = ((v-m)*x)/(2*D)	
X = (R*x-m*t)/(SQRT(4*D*R*t))	
Y = ((v+m)*x)/(2*D)	
Z = (R*x+m*t)/(SQRT(4*D*R*t))	
m= v*(SQRT(1+((4*u*D)/v^2)))	
ERFC()= 1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

Variables:

Cp(t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
C_sed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/hr)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL_sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
I	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TLconsol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TLconsol = DLsed / (n+p*Kd,cap)	USEPA 1998	

Cap thickness lost due to expression of porewater during consolidation (ft)

TLconsol =	0.004 feet	(typically negligible)

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	10	L/kg
	ne	[illegible]	R	33.39	Kd, cap	[illegible]	L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	NE	mg/kgOC
	DL_sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	I	#/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	10 ml/g			
	v	7.056E-08 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-08 cm/sec			

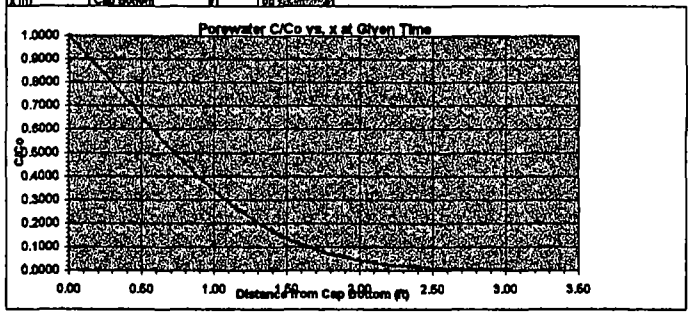
(LOEL)

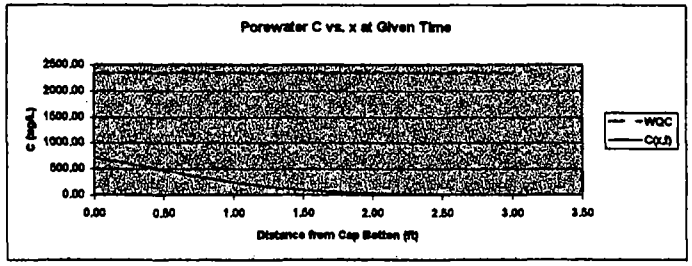
(m=v for u=0)

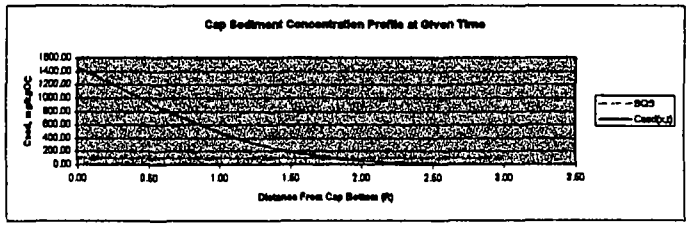
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	24569	days =	[illegible] yrs
x (ft)	Cap Bottom	0	Top [illegible] 3.5



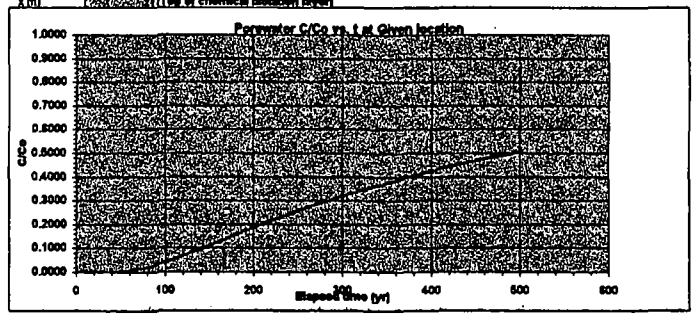


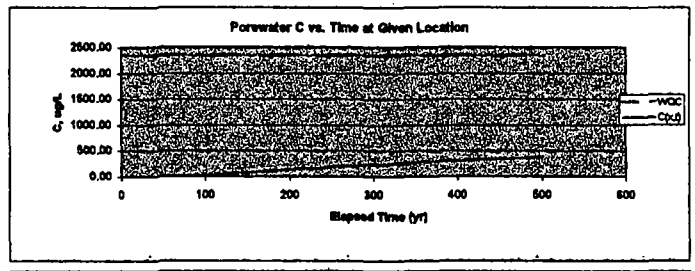


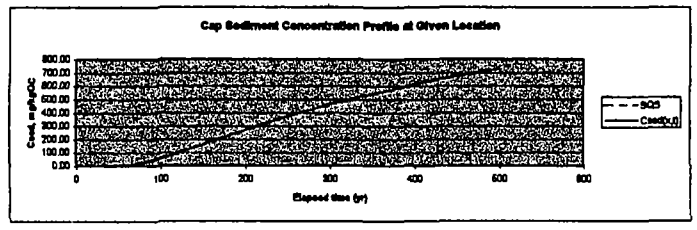
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	500	
x (ft)	[illegible] ft	(Top of chemical isolation layer)			







Chemical Isolation Analysis for RA2a and RA3
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS					OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.194	0.000E+00	0.174	0.806	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00		2.0	61.0	0.000	#DIV/0!	#DIV/0!	1.104E+00	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-1.26E-01	1.141	3.312E-02	0.221	0.764	0.9605	2350.00	696.40	99.00	1392.79	10.0	3.16E+08		2.0	61.0	0.000	4.97E+00	0.000	1.104E+00	5.079	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	-7.84E-02	1.088	6.624E-02	0.269	0.704	0.9200	2350.00	667.01	99.00	1334.02	20.0	6.31E+08		2.0	61.0	0.000	3.48E+00	0.000	1.104E+00	3.631	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	-3.07E-02	1.035	9.935E-02	0.317	0.654	0.8796	2350.00	638.99	99.00	1273.98	30.0	9.46E+08		2.0	61.0	0.000	2.81E+00	0.000	1.104E+00	2.996	0.000	0.0001	2350.00	0.05	99.00	0.10
36500	3.15E+09	0.24	7.3	0.000	1.70E-02	0.981	1.325E-01	0.364	0.608	0.8365	2350.00	606.50	99.00	1212.99	40.0	1.26E+09		2.0	61.0	0.000	2.40E+00	0.001	1.104E+00	2.622	0.000	0.0007	2350.00	0.47	99.00	0.95
36500	3.15E+09	0.30	9.1	0.000	6.46E-02	0.927	1.656E-01	0.412	0.560	0.7941	2350.00	575.70	99.00	1151.39	50.0	1.58E+09		2.0	61.0	0.000	2.12E+00	0.003	1.104E+00	2.370	0.001	0.0025	2350.00	1.84	99.00	3.69
36500	3.15E+09	0.36	11.0	0.000	1.12E-01	0.874	1.987E-01	0.460	0.518	0.7514	2350.00	544.75	99.00	1089.51	60.0	1.89E+09		2.0	61.0	0.000	1.92E+00	0.007	1.104E+00	2.186	0.002	0.0064	2350.00	4.61	99.00	9.23
36500	3.15E+09	0.42	12.9	0.000	1.60E-01	0.821	2.318E-01	0.507	0.473	0.7067	2350.00	513.04	99.00	1027.68	70.0	2.21E+09		2.0	61.0	0.000	1.75E+00	0.013	1.104E+00	2.044	0.004	0.0124	2350.00	8.96	99.00	17.91
36500	3.15E+09	0.48	14.6	0.000	2.09E-01	0.769	2.649E-01	0.555	0.432	0.6664	2350.00	483.11	99.00	966.22	80.0	2.52E+09		2.0	61.0	0.000	1.62E+00	0.022	1.104E+00	1.932	0.006	0.0204	2350.00	14.81	99.00	29.62
36500	3.15E+09	0.54	16.5	0.000	2.56E-01	0.718	2.981E-01	0.603	0.394	0.6345	2350.00	452.73	99.00	905.46	90.0	2.84E+09		2.0	61.0	0.000	1.51E+00	0.033	1.104E+00	1.840	0.009	0.0304	2350.00	22.00	99.00	44.01
36500	3.15E+09	0.60	18.3	0.000	3.03E-01	0.668	3.312E-01	0.650	0.358	0.5932	2350.00	422.84	99.00	845.68	100.0	3.16E+09		2.0	61.0	0.000	1.42E+00	0.046	1.104E+00	1.763	0.013	0.0418	2350.00	30.30	99.00	60.60
36500	3.15E+09	0.66	20.1	0.000	3.51E-01	0.620	3.643E-01	0.696	0.324	0.5429	2350.00	393.58	99.00	787.17	110.0	3.47E+09		2.0	61.0	0.000	1.33E+00	0.059	1.104E+00	1.697	0.016	0.0544	2350.00	39.47	99.00	78.94
36500	3.15E+09	0.72	21.9	0.000	3.99E-01	0.573	3.974E-01	0.744	0.292	0.5036	2350.00	365.10	99.00	730.19	120.0	3.79E+09		2.0	61.0	0.000	1.25E+00	0.075	1.104E+00	1.641	0.020	0.0690	2350.00	49.91	99.00	99.81
36500	3.15E+09	0.78	23.8	0.000	4.46E-01	0.528	4.305E-01	0.793	0.262	0.4655	2350.00	337.49	99.00	674.98	130.0	4.10E+09		2.0	61.0	0.000	1.20E+00	0.091	1.104E+00	1.592	0.024	0.0822	2350.00	59.52	99.00	119.04
36500	3.15E+09	0.84	25.6	0.000	4.94E-01	0.486	4.636E-01	0.841	0.234	0.4288	2350.00	310.88	99.00	621.76	140.0	4.42E+09		2.0	61.0	0.000	1.14E+00	0.108	1.104E+00	1.548	0.029	0.0969	2350.00	70.26	99.00	140.52
36500	3.15E+09	0.90	27.4	0.000	5.41E-01	0.444	4.968E-01	0.888	0.209	0.3936	2350.00	285.34	99.00	570.68	150.0	4.73E+09		2.0	61.0	0.000	1.09E+00	0.125	1.104E+00	1.510	0.033	0.1119	2350.00	81.11	99.00	162.21
36500	3.15E+09	0.96	29.3	0.000	5.89E-01	0.405	5.299E-01	0.938	0.185	0.3599	2350.00	260.96	99.00	521.91	160.0	5.05E+09		2.0	61.0	0.000	1.04E+00	0.143	1.104E+00	1.476	0.037	0.1270	2350.00	92.06	99.00	184.11
36500	3.15E+09	1.02	31.1	0.000	6.37E-01	0.369	5.630E-01	0.984	0.164	0.3280	2350.00	237.79	99.00	475.58	170.0	5.36E+09		2.0	61.0	0.000	9.92E-01	0.161	1.104E+00	1.445	0.041	0.1421	2350.00	103.02	99.00	206.04
36500	3.15E+09	1.08	32.9	0.000	6.84E-01	0.333	5.961E-01	1.032	0.145	0.2978	2350.00	215.88	99.00	431.77	180.0	5.68E+09		2.0	61.0	0.000	9.51E-01	0.179	1.104E+00	1.417	0.045	0.1572	2350.00	113.95	99.00	227.89
36500	3.15E+09	1.14	34.7	0.000	7.32E-01	0.301	6.292E-01	1.079	0.127	0.2693	2350.00	195.27	99.00	390.54	190.0	5.99E+09		2.0	61.0	0.000	9.13E-01	0.197	1.104E+00	1.392	0.049	0.1721	2350.00	124.78	99.00	249.57
36500	3.15E+09	1.20	36.6	0.000	7.80E-01	0.270	6.624E-01	1.127	0.111	0.2427	2350.00	175.96	99.00	351.93	200.0	6.31E+09		2.0	61.0	0.000	8.76E-01	0.214	1.104E+00	1.369	0.053	0.1869	2350.00	135.49	99.00	270.99
36500	3.15E+09	1.26	38.4	0.000	8.27E-01	0.242	6.955E-01	1.176	0.097	0.2179	2350.00	157.97	99.00	315.94	210.0	6.62E+09		2.0	61.0	0.000	8.45E-01	0.232	1.104E+00	1.348	0.057	0.2014	2350.00	146.04	99.00	292.08
36500	3.15E+09	1.32	40.2	0.000	8.75E-01	0.216	7.286E-01	1.222	0.084	0.1949	2350.00	141.27	99.00	282.56	220.0	6.94E+09		2.0	61.0	0.000	8.14E-01	0.250	1.104E+00	1.329	0.060	0.2157	2350.00	156.41	99.00	312.82
36500	3.15E+09	1.38	42.1	0.000	9.23E-01	0.192	7.617E-01	1.270	0.072	0.1736	2350.00	125.86	99.00	251.72	230.0	7.25E+09		2.0	61.0	0.000	7.84E-01	0.267	1.104E+00	1.311	0.064	0.2298	2350.00	166.68	99.00	333.17
36500	3.15E+09	1.44	43.9	0.000	9.70E-01	0.170	7.948E-01	1.318	0.062	0.1541	2350.00	111.70	99.00	223.40	240.0	7.57E+09		2.0	61.0	0.000	7.57E-01	0.285	1.104E+00	1.296	0.067	0.2435	2350.00	176.55	99.00	353.10
36500	3.15E+09	1.50	45.7	0.000	1.02E+00	0.150	8.279E-01	1.365	0.053	0.1362	2350.00	98.74	99.00	197.49	250.0	7.89E+09		2.0	61.0	0.000	7.30E-01	0.302	1.104E+00	1.280	0.070	0.2570	2350.00	186.31	99.00	372.61
36500	3.15E+09	1.56	47.5	0.000	1.07E+00	0.132	8.611E-01	1.413	0.046	0.1199	2350.00	86.95	99.00	173.90	260.0	8.20E+09		2.0	61.0	0.000	7.05E-01	0.319	1.104E+00	1.265	0.074	0.2701	2350.00	195.84	99.00	391.68
36500	3.15E+09	1.62	49.4	0.000	1.11E+00	0.115	8.942E-01	1.461	0.039	0.1052	2350.00	76.27	99.00	152.53	270.0	8.51E+09		2.0	61.0	0.000	6.82E-01	0.336	1.104E+00	1.252	0.077	0.2830	2350.00	205.16	99.00	410.32
36500	3.15E+09	1.68	51.2	0.000	1.16E+00	0.101	9.273E-01	1.508	0.033	0.0919	2350.00	66.63	99.00	133.26	280.0	8.83E+09		2.0	61.0	0.000	6.59E-01	0.351	1.104E+00	1.240	0.079	0.2956	2350.00	214.28	99.00	428.51
36500	3.15E+09	1.74	53.0	0.000	1.21E+00	0.087	9.604E-01	1.556	0.028	0.0800	2350.00	57.99	99.00	115.96	290.0	9.15E+09		2.0	61.0	0.000	6.37E-01	0.367	1.104E+00	1.229	0.082	0.3076	2360.00	223.13	99.00	446.26
36500	3.15E+09	1.80	54.9	0.000	1.26E+00	0.076	9.935E-01	1.604	0.023	0.0693	2350.00	50.25	99.00	100.51	300.0	9.46E+09		2.0	61.0	0.000	6.16E-01	0.383	1.104E+00	1.218	0.085	0.3197	2350.00	231.79	99.00	463.58
36500	3.15E+09	1.86	56.7	0.000	1.30E+00	0.066	1.027E+00	1.651	0.020	0.0598	2350.00	43.38	99.00	86.76	310.0	9.78E+09		2.0	61.0	0.000	5.97E-01	0.399	1.104E+00	1.208	0.089	0.3314	2350.00	240.24	99.00	480.47
36500	3.15E+09	1.92	58.5	0.000	1.35E+00	0.058	1.060E+00	1.699	0.018	0.0514	2350.00	37.30	99.00	74.60	320.0	1.01E+10		2.0	61.0	0.000	5.78E-01	0.414	1.104E+00	1.199	0.093	0.3427	2350.00	248.47	99.00	496.95
36500	3.15E+09	1.98	60.4	0.000	1.40E+00	0.048	1.093E+00	1.747	0.014	0.0441	2350.00	31.84	99.00	63.68	330.0	1.04E+10		2.0	61.0	0.000	5.59E-01	0.429	1.104E+00	1.190	0.097	0.3538	2350.00	256.51	99.00	513.01
36500	3.15E+09	2.04	62.2	0.000	1.45E+00	0.041	1.126E+00	1.794	0.011	0.0378	2350.00	27.24	99.00	54.47	340.0	1.07E+10		2.0	61.0	0.000	5.41E-01	0.444	1.104E+00	1.182	0.099	0.3646	2350.00	264.34	99.00	528.68
36500	3.15E+09	2.10	64.0	0.000	1.49E+00	0.035	1.159E+00	1.842	0.009	0.0319	2350.00	23.13	99.00	46.27	350.0	1.10E+10		2.0	61.0	0.000	5.24E-01	0.458	1.104E+00	1.174	0.097	0.3751	2350.00	271.97	99.00	543.95
36500	3.15E+09	2.16	65.8	0.000	1.54E+00	0.029	1.192E+00	1.890	0.006	0.0270	2350.00	19.57	99.00	39.14	360.0	1.14E+10		2.0	61.0	0.000	5.08E-01	0.473	1.104E+00	1.167	0.099	0.3854	2350.00	279.42	99.00	558.84
36500	3.15E+09	2.22	67.7	0.000	1.59E+00	0.025	1.226E+00	1.937	0.006	0.0227	2350.00	16.48	99.00	32.97	370.0	1.17E+10		2.0	61.0	0.000	4.92E-01	0.487	1.104E+00	1.160	0.101	0.3954	2350.00	286.68	99.00	573.36
36500	3.15E+09	2.28	69.5	0.000	1.64E+00	0.021	1.258E+00	1.985	0.005	0.0191	2350.00	13.83	99.00	27.66	380.0	1.20E+10		2.0	61.0	0.000	4.76E-01	0.500	1.104E+00	1.154	0.103	0.4052	2350.00	293.78	99.00	587.52
36500	3.15E+09	2.34	71.3	0.000	1.69E+00	0.017	1.292E+00	2.033	0.004	0.0159	2350.00	11.55	99.00	23.11	390.0	1.23E+10		2.0	61.0	0.000	4.62E-01	0.514	1.104E+00	1.148	0.105	0.4147	2350.00	300.68	99.00	601.33
36500	3.15E+09	2.40	73.2	0.000	1.73E+00	0.014	1.325E+00	2.080	0.003	0.0133	2350.00	9.61	99.00	19.22	400.0	1.26E+10		2.0	61.0	0.000	4.47E-01	0.527	1.104E+00	1.142	0.106	0.4240	2350.00	307.40	99.00	614.80
36500	3.15E+09	2.46	75.0	0.000	1.78E+00	0.012	1.358E+00	2.128	0.003	0.0110	2350.00	7.96	99.00	15.93	410.0	1.29E+10		2.0	61.0	0.000	4.33E-01	0.540	1.104E+00	1.136	0.108	0.4331	2350.00	313.97	99.00	627.94
36500	3.15E+09	2.52	76.8	0.000	1.83E+00	0.010	1.391E+00	2.176	0.002	0.0091	2350.00	6.57	99.00	13.14	420.0	1.32E+10		2.0	61.0	0.000	4.19E-01	0.553	1.104E+00	1.131	0.110	0.4419	2350.00	320.38	99.00	640.76
36500	3.15E+09	2.58	78.6	0.000	1.88E+00	0.008	1.424E+00	2.223	0.002	0.0074	2350.00	5.40	99.00	10.80	430.0	1.36E+10		2.0	61.0	0.000	4.06E-01	0.566	1.104E+00	1.126	0.111	0.4505	2350.00	326.64	99.00	653.28
36500	3.15E+09	2.64	80.5	0.000	1.92E+00	0.007	1.457E+00	2.271	0.001	0.0061	2350.00	4.42	99.00	8.83	440.0	1.39E+10		2.0	61.0	0.000	3.93E-01	0.578	1.104E+00	1.122	0.113	0.4590	2350.00	332.74	99.00	665.49
36500	3.15E+09	2.70	82.3	0.000	1.97E+00	0.005	1.490E+00	2.319	0.001	0.0050	2350.00	3.60	99.00	7.20	450.0	1.42E+10		2.0	61.0	0.000	3.81E-01	0.590	1.104E+00	1.117	0.114	0.4672	2350.00	338.71	99.00	677.41
36500	3.15E+09	2.76	84.1	0.000	2.02E+00	0.004	1.523E+00	2.368	0.001	0.0040	2350.00	2.92	99.00	5.84	460.0	1.45E+10		2.0	61.0	0.000	3.69E-01	0.602	1.104E+00	1.113	0.115	0.4752	2350.00	344.53	99.00	689.05
36500	3.15E+09	2.82	86.0	0.000	2.07E+00	0.003	1.557E+00	2.416	0.001	0.0033	2350.00	2.36	99.00	4.72	470.0	1.48E+10		2.0	61.0	0.000	3.56E-01	0.614	1.104E+00	1.109	0.117	0.4830	2350.00	350.21	99.00	700.42
36500	3.15E+09	2.88	87.8	0.000	2.11E+00	0.003	1.590E+00	2.462	0.000	0.0026	2350.00	1.90	99.00	3.79	480.0	1.51E+10		2.0	61.0	0.000	3.45E-01	0.626	1.104E+00	1.106	0.118	0.4907	2350.00	355.76	99.00	711.53
36500	3.15E+09	2.94	89.6	0.000	2.16E+00	0.002	1.623E+00	2.509	0.000	0.0021	2350.00	1.52	99.00	3.04	490.0	1.55E+10		2.0	61.0	0.000	3.33E-01	0.637	1.104E+00	1.102	0.119	0.4982	2350.00	361.19	99.00	722.38
36500	3.15E+09	3.00	91.4	0.000	2.21E+00	0.002	1.656E+00	2.557	0.000	0.0017	2350.00	1.21	99.00	2.42	500.0	1.58E+10		2.0	61.0	0.000	3.22E-01	0.649	1.104E+00	1.099	0.120	0.5056	2350.00	366.49	99.00	732.98

Note 1: Adapted from Equation B-26, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms

Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for RA2b
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Walton 1991, p.186
R=1+(rb*Kd,cap*p)/ne	Walton 1991, p.194
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*t)/(2*D)
X = (R*x-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*t)/(2*D)
Z = (R*x+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2)))
ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	10	L/kg
	ne	[illegible]	R	33.39	Kd, cap	[illegible]	L/kg
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible]	mg/kgOC
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible]	ug/L (LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible]	cm2/sec
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	10 ml/g			
	v	7.056E-06 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-06 cm/sec	(m=v for u=0)		

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 ug =	1.000E-06	gm
Co	Influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap) — USEPA 1998

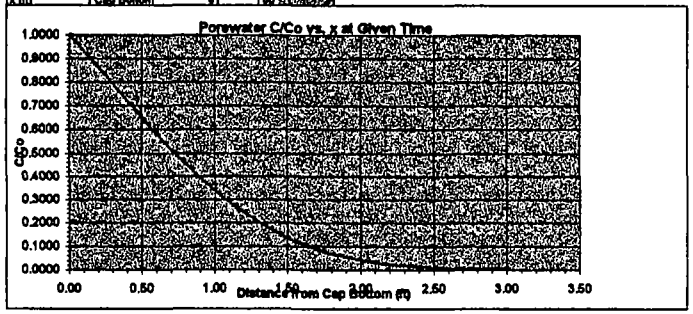
Cap thickness lost due to expression of porewater during consolidation (ft)

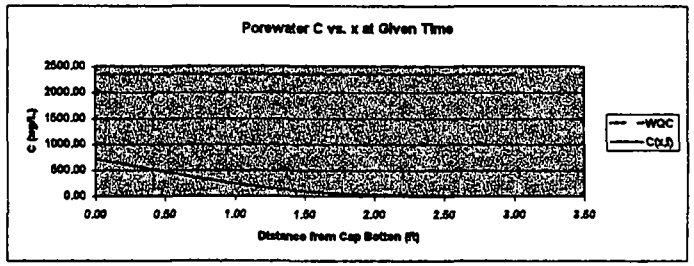
TI,consol = 0.094 feet (typically negligible)

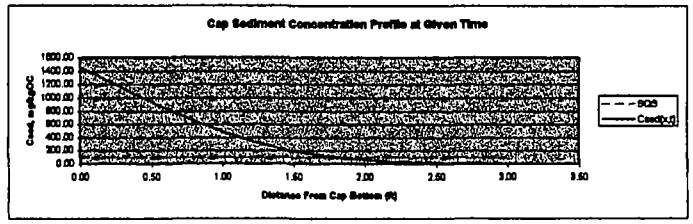
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	26100	days =	[illegible]
x (ft)	Cap Bottom	0	Top [illegible]



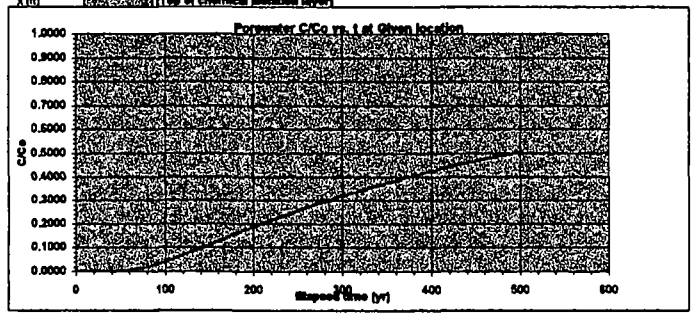


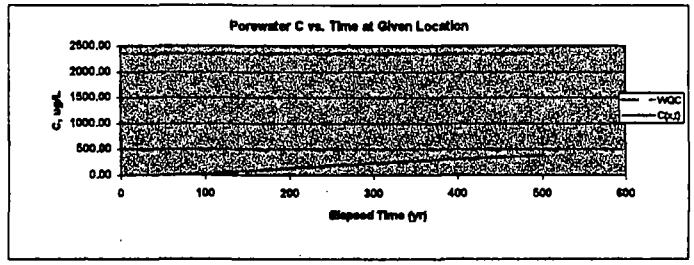


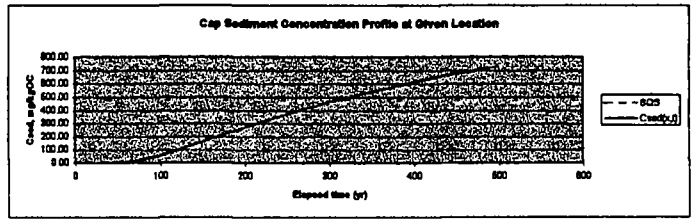
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600
x (ft)	[illegible]	[illegible]	(Top of chemical isolation layer)	







Chemical Isolation Analysis for RA2b
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT			
										B(x,t)	WQC	C(x,t)	SQS	Csed(x,t)										B(x,t)	WQC	C(x,t)	SQS	Csed(x,t)
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)		(ug/L)	(ug/L)	(mg/kgOC)	(mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)		(ug/L)	(ug/L)	(mg/kgOC)	(mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.194	0.000E+00	0.174	0.806	1.0000	2350.00	725.00	99.00	1460.00	0	0.00E+00	2.0	61.0	0.000	#DIV/0!	#DIV/0!	1.104E+00	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-1.26E-01	1.141	3.31E-02	0.221	0.784	0.9605	2350.00	696.40	99.00	1392.79	10.0	3.15E+08	2.0	61.0	0.000	4.97E+00	0.000	1.104E+00	5.079	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	-7.94E-02	1.088	6.62E-02	0.269	0.704	0.9200	2350.00	667.01	99.00	1334.02	20.0	6.31E+08	2.0	61.0	0.000	3.48E+00	0.000	1.104E+00	3.631	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	-3.07E-02	1.035	9.93E-02	0.317	0.654	0.8796	2350.00	638.99	99.00	1273.98	30.0	9.46E+08	2.0	61.0	0.000	2.81E+00	0.000	1.104E+00	2.996	0.000	0.0001	2350.00	0.05	99.00	0.10
36500	3.15E+09	0.24	7.3	0.000	1.70E-02	0.981	1.32E-01	0.364	0.606	0.8365	2350.00	606.50	99.00	1212.99	40.0	1.26E+09	2.0	61.0	0.000	2.40E+00	0.001	1.104E+00	2.622	0.000	0.0007	2350.00	0.47	99.00	0.95
36500	3.15E+09	0.30	9.1	0.000	6.46E-02	0.927	1.65E-01	0.412	0.560	0.7941	2350.00	578.70	99.00	1151.38	50.0	1.58E+09	2.0	61.0	0.000	2.12E+00	0.003	1.104E+00	2.370	0.001	0.0025	2350.00	1.84	99.00	3.69
36500	3.15E+09	0.36	11.0	0.000	1.12E-01	0.874	1.98E-01	0.460	0.516	0.7514	2350.00	544.76	99.00	1089.51	60.0	1.89E+09	2.0	61.0	0.000	1.92E+00	0.007	1.104E+00	2.196	0.002	0.0064	2350.00	4.61	99.00	9.23
36500	3.15E+09	0.42	12.8	0.000	1.60E-01	0.821	2.31E-01	0.507	0.473	0.7067	2350.00	513.84	99.00	1027.69	70.0	2.21E+09	2.0	61.0	0.000	1.75E+00	0.013	1.104E+00	2.044	0.004	0.0124	2350.00	8.96	99.00	17.91
36500	3.15E+09	0.48	14.6	0.000	2.06E-01	0.769	2.64E-01	0.556	0.432	0.6664	2350.00	483.11	99.00	966.22	80.0	2.52E+09	2.0	61.0	0.000	1.62E+00	0.022	1.104E+00	1.932	0.006	0.0204	2350.00	14.81	99.00	29.62
36500	3.15E+09	0.54	16.5	0.000	2.55E-01	0.718	2.96E-01	0.603	0.394	0.6245	2350.00	452.73	99.00	905.46	90.0	2.84E+09	2.0	61.0	0.000	1.51E+00	0.033	1.104E+00	1.840	0.009	0.0304	2350.00	22.00	99.00	44.01
36500	3.15E+09	0.60	18.3	0.000	3.03E-01	0.668	3.31E-01	0.650	0.358	0.5832	2350.00	422.94	99.00	845.88	100.0	3.15E+09	2.0	61.0	0.000	1.42E+00	0.045	1.104E+00	1.763	0.013	0.0418	2350.00	30.30	99.00	60.60
36500	3.15E+09	0.66	20.1	0.000	3.51E-01	0.620	3.64E-01	0.696	0.324	0.5429	2350.00	393.58	99.00	787.17	110.0	3.47E+09	2.0	61.0	0.000	1.33E+00	0.059	1.104E+00	1.697	0.016	0.0544	2350.00	39.47	99.00	78.94
36500	3.15E+09	0.72	21.9	0.000	3.99E-01	0.573	3.97E-01	0.746	0.292	0.5036	2350.00	365.10	99.00	730.19	120.0	3.78E+09	2.0	61.0	0.000	1.26E+00	0.076	1.104E+00	1.641	0.020	0.0680	2350.00	49.31	99.00	98.61
36500	3.15E+09	0.78	23.8	0.000	4.46E-01	0.529	4.30E-01	0.793	0.262	0.4655	2350.00	337.49	99.00	674.98	130.0	4.10E+09	2.0	61.0	0.000	1.20E+00	0.091	1.104E+00	1.592	0.024	0.0822	2350.00	59.62	99.00	119.24
36500	3.15E+09	0.84	25.6	0.000	4.94E-01	0.486	4.63E-01	0.841	0.234	0.4288	2350.00	310.88	99.00	621.75	140.0	4.42E+09	2.0	61.0	0.000	1.14E+00	0.108	1.104E+00	1.548	0.029	0.0969	2350.00	70.26	99.00	140.52
36500	3.15E+09	0.90	27.4	0.000	5.41E-01	0.444	4.96E-01	0.889	0.209	0.3936	2350.00	285.34	99.00	570.68	150.0	4.73E+09	2.0	61.0	0.000	1.08E+00	0.125	1.104E+00	1.510	0.033	0.1119	2350.00	81.11	99.00	162.21
36500	3.15E+09	0.96	29.3	0.000	5.89E-01	0.405	5.29E-01	0.936	0.185	0.3599	2350.00	260.96	99.00	521.91	160.0	5.05E+09	2.0	61.0	0.000	1.04E+00	0.143	1.104E+00	1.476	0.037	0.1270	2350.00	92.05	99.00	184.11
36500	3.15E+09	1.02	31.1	0.000	6.37E-01	0.368	5.63E-01	0.984	0.164	0.3280	2350.00	237.79	99.00	475.58	170.0	5.36E+09	2.0	61.0	0.000	9.82E-01	0.161	1.104E+00	1.446	0.041	0.1421	2350.00	103.02	99.00	206.04
36500	3.15E+09	1.08	32.9	0.000	6.84E-01	0.333	5.96E-01	1.032	0.148	0.2978	2350.00	215.88	99.00	431.77	180.0	5.68E+09	2.0	61.0	0.000	9.31E-01	0.179	1.104E+00	1.417	0.045	0.1572	2350.00	113.95	99.00	227.89
36500	3.15E+09	1.14	34.7	0.000	7.32E-01	0.301	6.29ZE-01	1.079	0.127	0.2693	2350.00	195.27	99.00	390.54	190.0	5.99E+09	2.0	61.0	0.000	9.13E-01	0.197	1.104E+00	1.392	0.049	0.1721	2350.00	124.78	99.00	249.57
36500	3.15E+09	1.20	36.6	0.000	7.80E-01	0.270	6.62ZE-01	1.127	0.111	0.2427	2350.00	175.96	99.00	351.93	200.0	6.31E+09	2.0	61.0	0.000	8.78E-01	0.214	1.104E+00	1.369	0.053	0.1869	2350.00	135.49	99.00	270.98
36500	3.15E+09	1.26	38.4	0.000	8.27E-01	0.242	6.955E-01	1.175	0.097	0.2179	2350.00	157.97	99.00	315.94	210.0	6.62E+09	2.0	61.0	0.000	8.45E-01	0.232	1.104E+00	1.348	0.057	0.2014	2350.00	146.04	99.00	292.08
36500	3.15E+09	1.32	40.2	0.000	8.76E-01	0.216	7.29ZE-01	1.222	0.084	0.1949	2350.00	141.27	99.00	282.56	220.0	6.94E+09	2.0	61.0	0.000	8.14E-01	0.250	1.104E+00	1.329	0.060	0.2167	2350.00	156.41	99.00	312.82
36500	3.15E+09	1.38	42.1	0.000	9.23E-01	0.192	7.617E-01	1.270	0.072	0.1738	2350.00	125.88	99.00	251.72	230.0	7.25E+09	2.0	61.0	0.000	7.84E-01	0.267	1.104E+00	1.311	0.064	0.2298	2350.00	166.58	99.00	333.17
36500	3.15E+09	1.44	43.9	0.000	9.70E-01	0.170	7.94ZE-01	1.318	0.062	0.1541	2350.00	111.70	99.00	223.40	240.0	7.57E+09	2.0	61.0	0.000	7.57E-01	0.285	1.104E+00	1.295	0.067	0.2435	2350.00	176.56	99.00	353.10
36500	3.15E+09	1.50	45.7	0.000	1.02E+00	0.150	8.27ZE-01	1.365	0.053	0.1362	2350.00	98.74	99.00	197.49	250.0	7.88E+09	2.0	61.0	0.000	7.30E-01	0.302	1.104E+00	1.280	0.070	0.2570	2350.00	186.31	99.00	372.61
36500	3.15E+09	1.56	47.5	0.000	1.07E+00	0.132	8.611E-01	1.413	0.046	0.1199	2350.00	86.95	99.00	173.90	260.0	8.20E+09	2.0	61.0	0.000	7.05E-01	0.319	1.104E+00	1.265	0.074	0.2701	2350.00	195.84	99.00	391.68
36500	3.15E+09	1.62	49.4	0.000	1.11E+00	0.115	8.94ZE-01	1.461	0.039	0.1062	2350.00	76.27	99.00	152.53	270.0	8.51E+09	2.0	61.0	0.000	6.82E-01	0.335	1.104E+00	1.252	0.077	0.2830	2350.00	205.16	99.00	410.32
36500	3.15E+09	1.68	51.2	0.000	1.16E+00	0.101	9.273E-01	1.508	0.033	0.0918	2350.00	66.63	99.00	133.26	280.0	8.83E+09	2.0	61.0	0.000	6.59E-01	0.351	1.104E+00	1.240	0.079	0.2955	2350.00	214.25	99.00	428.51
36500	3.15E+09	1.74	53.0	0.000	1.21E+00	0.087	9.604E-01	1.556	0.028	0.0800	2350.00	57.98	99.00	115.96	290.0	9.15E+09	2.0	61.0	0.000	6.37E-01	0.367	1.104E+00	1.229	0.082	0.3078	2350.00	223.13	99.00	446.26
36500	3.15E+09	1.80	54.8	0.000	1.26E+00	0.076	9.935E-01	1.604	0.023	0.0693	2350.00	50.25	99.00	100.51	300.0	9.46E+09	2.0	61.0	0.000	6.16E-01	0.383	1.104E+00	1.218	0.085	0.3197	2350.00	231.79	99.00	463.58
36500	3.15E+09	1.86	56.7	0.000	1.30E+00	0.065	1.027E+00	1.651	0.020	0.0598	2350.00	43.38	99.00	86.76	310.0	9.78E+09	2.0	61.0	0.000	5.97E-01	0.399	1.104E+00	1.208	0.088	0.3314	2350.00	240.24	99.00	480.47
36500	3.15E+09	1.92	58.5	0.000	1.35E+00	0.055	1.060E+00	1.699	0.016	0.0514	2350.00	37.30	99.00	74.60	320.0	1.01E+10	2.0	61.0	0.000	5.78E-01	0.414	1.104E+00	1.199	0.090	0.3427	2350.00	248.47	99.00	496.95
36500	3.15E+09	1.98	60.4	0.000	1.40E+00	0.046	1.093E+00	1.747	0.014	0.0441	2350.00	31.94	99.00	63.88	330.0	1.04E+10	2.0	61.0	0.000	5.59E-01	0.429	1.104E+00	1.190	0.092	0.3538	2350.00	256.51	99.00	513.01
36500	3.15E+09	2.04	62.2	0.000	1.45E+00	0.041	1.126E+00	1.794	0.011	0.0376	2350.00	27.24	99.00	54.47	340.0	1.07E+10	2.0	61.0	0.000	5.41E-01	0.444	1.104E+00	1.182	0.095	0.3648	2350.00	264.34	99.00	528.68
36500	3.15E+09	2.10	64.0	0.000	1.49E+00	0.035	1.159E+00	1.842	0.009	0.0319	2350.00	23.13	99.00	46.27	350.0	1.10E+10	2.0	61.0	0.000	5.24E-01	0.458	1.104E+00	1.174	0.097	0.3751	2350.00	271.97	99.00	543.95
36500	3.15E+09	2.16	65.8	0.000	1.54E+00	0.029	1.192E+00	1.890	0.008	0.0270	2350.00	19.57	99.00	39.14	360.0	1.14E+10	2.0	61.0	0.000	5.08E-01	0.473	1.104E+00	1.167	0.099	0.3854	2350.00	279.42	99.00	558.84
36500	3.15E+09	2.22	67.7	0.000	1.59E+00	0.025	1.226E+00	1.937	0.006	0.0227	2350.00	16.48	99.00	32.97	370.0	1.17E+10	2.0	61.0	0.000	4.92E-01	0.487	1.104E+00	1.160	0.101	0.3954	2350.00	286.68	99.00	573.36
36500	3.15E+09	2.28	69.5	0.000	1.64E+00	0.021	1.258E+00	1.985	0.005	0.0191	2350.00	13.83	99.00	27.66	380.0	1.20E+10	2.0	61.0	0.000	4.76E-01	0.500	1.104E+00	1.154	0.103	0.4052	2350.00	293.76	99.00	587.52
36500	3.15E+09	2.34	71.3	0.000	1.69E+00	0.017	1.292E+00	2.033	0.004	0.0160	2350.00	11.65	99.00	23.31	390.0	1.23E+10	2.0	61.0	0.000	4.62E-01	0.514	1.104E+00	1.148	0.105	0.4147	2350.00	300.66	99.00	601.33
36500	3.15E+09	2.40	73.2	0.000	1.73E+00	0.014	1.325E+00	2.080	0.003	0.0133	2350.00	9.81	99.00	19.62	400.0	1.26E+10	2.0	61.0	0.000	4.47E-01	0.527	1.104E+00	1.142	0.108	0.4240	2350.00	307.40	99.00	614.80
36500	3.15E+09	2.46	75.0	0.000	1.78E+00	0.012	1.358E+00	2.128	0.003	0.0110	2350.00	7.96	99.00	15.93	410.0	1.29E+10	2.0	61.0	0.000	4.33E-01	0.540	1.104E+00	1.136	0.109	0.4331	2350.00	313.97	99.00	627.94
36500	3.15E+09	2.52	76.8	0.000	1.83E+00	0.010	1.391E+00	2.176	0.002	0.0091	2350.00	6.57	99.00	13.14	420.0	1.32E+10	2.0	61.0	0.000	4.19E-01	0.553	1.104E+00	1.131	0.110	0.4419	2350.00	320.38	99.00	640.76
36500	3.15E+09	2.58	78.6	0.000	1.88E+00	0.008	1.424E+00	2.223	0.002	0.0074	2350.00	5.40	99.00	10.80	430.0	1.36E+10	2.0	61.0	0.000	4.06E-01	0.566	1.104E+00	1.126	0.111	0.4505	2350.00	326.64	99.00	653.28
36500	3.15E+09	2.64	80.5	0.000	1.92E+00	0.007	1.457E+00	2.271	0.001	0.0061	2350.00	4.42	99.00	8.83	440.0	1.39E+10	2.0	61.0	0.000	3.93E-01	0.578	1.104E+00	1.122	0.113	0.4590	2350.00	332.74	99.00	665.49
36500	3.15E+09	2.70	82.3	0.000	1.97E+00	0.005	1.490E+00	2.319	0.001	0.0050	2350.00	3.60	99.00	7.20	450.0	1.42E+10	2.0	61.0	0.000	3.81E-01	0.590	1.104E+00	1.117	0.114	0.4672	2350.00	338.71	99.00	677.41
36500	3.15E+09	2.76	84.1	0.000	2.02E+00	0.004	1.523E+00	2.368	0.001	0.0040	2350.00	2.92	99.00	5.84	460.0	1.46E+10	2.0	61.0	0.000	3.69E-01	0.602	1.104E+00	1.113	0.115	0.4752	2350.00	344.53	99.00	689.06
36500	3.15E+09	2.82	86.0	0.000	2.07E+00	0.003	1.557E+00	2.414	0.001	0.0033	2350.00	2.38	99.00	4.72	470.0	1.48E+10	2.0	61.0	0.000	3.56E-01	0.614	1.104E+00	1.109	0.117	0.4830	2350.00	350.21	99.00	700.42
36500	3.15E+09	2.88	87.8	0.000	2.11E+00	0.003	1.590E+00	2.462	0.000	0.0026	2350.00	1.90	99.00	3.79	480.0	1.51E+10	2.0	61.0	0.000	3.45E-01	0.626	1.104E+00	1.106	0.118	0.4907	2350.00	355.76	99.00	711.53
36500	3.15E+09	2.94	89.6	0.000	2.16E+00	0.002	1.623E+00	2.509	0.000	0.0021	2350.00	1.52	99.00	3.04	490.0	1.55E+10	2.0	61.0	0.000	3.33E-01	0.637	1.104E+00	1.102	0.119	0.4982	2350.00	361.19	99.00	722.38
36500	3.15E+09	3.00	91.4	0.000	2.21E+00	0.002	1.656E+00	2.557	0.000	0.0017	2350.00	1.21	99.00	2.42	500.0	1.58E+10	2.0	61.0	0.000	3.22E-01	0.649	1.104E+00	1.099	0.120	0.5056	2350.00	366.49	99.00	732.98

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for RA4
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Wallon 1991, p.186
R=1+(Kd,cap*p)/ne	Wallon 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.138
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	[see note 1]
d = 0.01*L	T. Meyers 2002 (USACE)

C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z)) — Van Genuchten and Alves (1982)

W = ((v-m)*x)/(2*D)
X = (R*t-m*t)/(SQRT(4*D*R*t))
Y = ((v+m)*x)/(2*D)
Z = (R*t+m*t)/(SQRT(4*D*R*t))
m= v*(SQRT(1+((4*u*D)/v^2))
ERFC()= 1-ERF()

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	[illegible] ft/d	Koc	[illegible] ml/g	[illegible]		
	n	[illegible]	foc	[illegible]	Kd (theoretica	10 L/kg	
	ne	[illegible]	R	33.39	Kd, cap	[illegible] L/kg	
	g	[illegible] gm/cm3	u	[illegible] /d	SQS	[illegible] mg/kgOC	
	DL,sed	[illegible] ft	d	[illegible] ft	WQC	[illegible] ug/L	(LOEL)
	L	[illegible] ft	Co	[illegible] ug/L	Dw	[illegible] cm2/sec	
Results:	p	1.4575 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 /s			
	v	[illegible] ft/d	Kd,cap	10 ml/g			
	v	7.056E-08 cm/s	D	3.9E-06 cm2/sec			
			m	7.056E-08 cm/sec	(m=v for u=0)		

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	Influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or mg/kgOC)			
t	time (s)			
Tl,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

Tl,consol = DLsed / (n+p*Kd,cap)	USEPA 1998

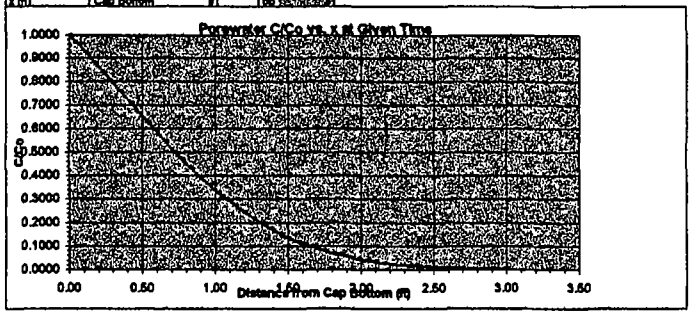
Cap thickness lost due to expression of porewater during consolidation (ft)

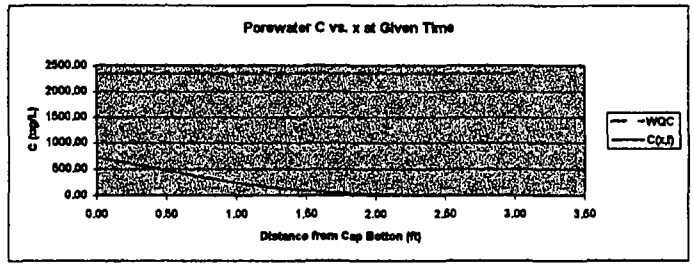
Tl,consol =	0.004 feet	(typically negligible)

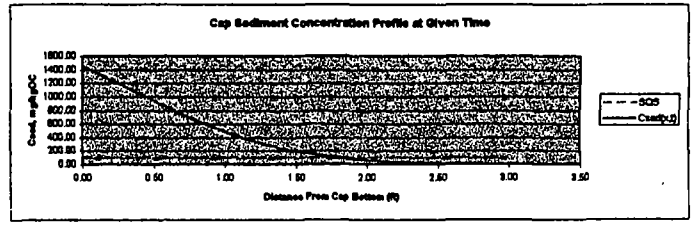
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	[illegible]	[illegible]
x (ft)	Cap Bottom	0	Top [illegible]	[illegible]



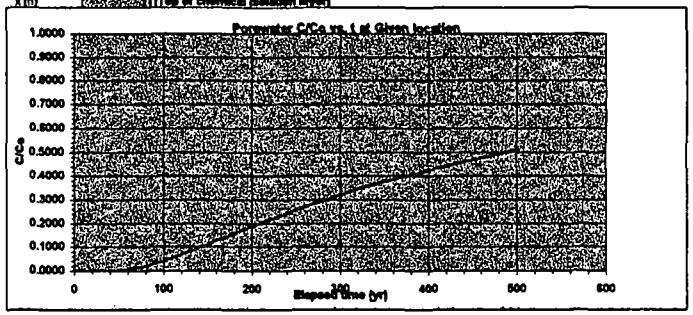


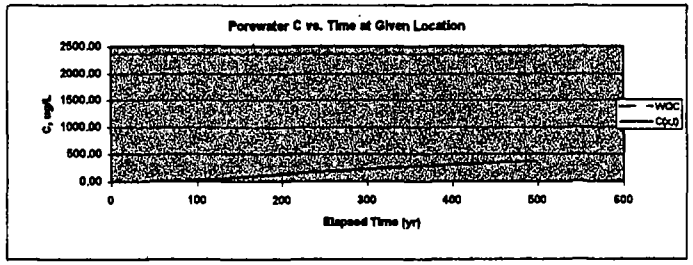


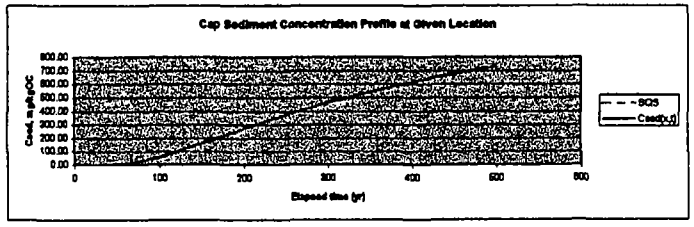
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	500
x (ft)	[illegible]	0	Top of chemical isolation layer	







Chemical Isolation Analysis for RA4
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT				INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.74E-01	1.194	0.000E+00	0.174	0.806	1.0000	2350.00	725.00	99.00	1450.00	0	0.00E+00	2.0	61.0	0.000	#DIV/0!	#DIV/0!	1.104E+00	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.06	1.8	0.000	-1.26E-01	1.141	3.312E-02	0.221	0.754	0.9805	2350.00	696.40	99.00	1392.79	10.0	3.15E+08	2.0	61.0	0.000	4.97E+00	0.000	1.104E+00	5.079	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	-7.84E-02	1.088	6.624E-02	0.269	0.704	0.9200	2350.00	667.01	99.00	1334.02	20.0	6.31E+08	2.0	61.0	0.000	3.46E+00	0.000	1.104E+00	3.531	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.18	5.5	0.000	-3.07E-02	1.035	9.935E-02	0.317	0.654	0.8788	2350.00	636.99	99.00	1273.98	30.0	9.46E+08	2.0	61.0	0.000	2.81E+00	0.000	1.104E+00	2.866	0.000	0.0001	2350.00	0.05	99.00	0.10
36500	3.15E+09	0.24	7.3	0.000	1.70E-02	0.981	1.325E-01	0.364	0.606	0.8365	2350.00	606.50	99.00	1212.99	40.0	1.26E+09	2.0	61.0	0.000	2.40E+00	0.001	1.104E+00	2.622	0.000	0.0007	2350.00	0.47	99.00	0.95
36500	3.15E+09	0.30	9.1	0.000	6.46E-02	0.927	1.656E-01	0.412	0.560	0.7941	2350.00	575.70	99.00	1151.39	50.0	1.58E+09	2.0	61.0	0.000	2.12E+00	0.003	1.104E+00	2.370	0.001	0.0025	2350.00	1.84	99.00	3.69
36500	3.15E+09	0.36	11.0	0.000	1.12E-01	0.874	1.987E-01	0.460	0.516	0.7514	2350.00	544.76	99.00	1089.51	60.0	1.89E+09	2.0	61.0	0.000	1.93E+00	0.007	1.104E+00	2.196	0.002	0.0064	2350.00	4.61	99.00	9.23
36500	3.15E+09	0.42	12.8	0.000	1.60E-01	0.821	2.318E-01	0.507	0.473	0.7087	2350.00	513.84	99.00	1027.68	70.0	2.21E+09	2.0	61.0	0.000	1.75E+00	0.013	1.104E+00	2.044	0.004	0.0124	2350.00	8.98	99.00	17.91
36500	3.15E+09	0.48	14.6	0.000	2.09E-01	0.769	2.649E-01	0.555	0.432	0.6664	2350.00	483.11	99.00	966.22	80.0	2.52E+09	2.0	61.0	0.000	1.62E+00	0.022	1.104E+00	1.932	0.006	0.0204	2350.00	14.81	99.00	29.62
36500	3.15E+09	0.54	16.5	0.000	2.55E-01	0.718	2.981E-01	0.603	0.394	0.6245	2350.00	452.73	99.00	905.46	90.0	2.84E+09	2.0	61.0	0.000	1.51E+00	0.033	1.104E+00	1.840	0.009	0.0304	2350.00	22.00	99.00	44.01
36500	3.15E+09	0.60	18.3	0.000	3.03E-01	0.668	3.312E-01	0.650	0.356	0.5832	2350.00	422.84	99.00	845.68	100.0	3.15E+09	2.0	61.0	0.000	1.42E+00	0.045	1.104E+00	1.763	0.013	0.0418	2350.00	30.30	99.00	60.60
36500	3.15E+09	0.66	20.1	0.000	3.51E-01	0.620	3.643E-01	0.698	0.324	0.5429	2350.00	393.58	99.00	787.17	110.0	3.47E+09	2.0	61.0	0.000	1.33E+00	0.059	1.104E+00	1.697	0.016	0.0544	2350.00	39.47	99.00	78.94
36500	3.15E+09	0.72	21.9	0.000	3.99E-01	0.573	3.974E-01	0.746	0.292	0.5036	2350.00	365.10	99.00	730.19	120.0	3.79E+09	2.0	61.0	0.000	1.26E+00	0.075	1.104E+00	1.641	0.020	0.0690	2350.00	49.31	99.00	98.61
36500	3.15E+09	0.78	23.8	0.000	4.48E-01	0.528	4.305E-01	0.793	0.262	0.4655	2350.00	337.49	99.00	674.98	130.0	4.10E+09	2.0	61.0	0.000	1.20E+00	0.091	1.104E+00	1.592	0.024	0.0822	2350.00	58.82	99.00	118.24
36500	3.15E+09	0.84	25.6	0.000	4.94E-01	0.485	4.634E-01	0.841	0.234	0.4288	2350.00	310.88	99.00	621.76	140.0	4.42E+09	2.0	61.0	0.000	1.14E+00	0.108	1.104E+00	1.548	0.029	0.0969	2350.00	70.26	99.00	140.52
36500	3.15E+09	0.90	27.4	0.000	5.41E-01	0.444	4.966E-01	0.889	0.209	0.3936	2350.00	285.34	99.00	570.68	150.0	4.73E+09	2.0	61.0	0.000	1.08E+00	0.126	1.104E+00	1.510	0.033	0.1119	2350.00	81.11	99.00	162.21
36500	3.15E+09	0.96	29.3	0.000	5.89E-01	0.405	5.298E-01	0.938	0.185	0.3599	2350.00	260.96	99.00	521.91	160.0	5.05E+09	2.0	61.0	0.000	1.04E+00	0.143	1.104E+00	1.476	0.037	0.1270	2350.00	92.05	99.00	184.11
36500	3.15E+09	1.02	31.1	0.000	6.37E-01	0.368	5.630E-01	0.984	0.164	0.3290	2350.00	237.79	99.00	475.58	170.0	5.36E+09	2.0	61.0	0.000	9.92E-01	0.161	1.104E+00	1.445	0.041	0.1421	2350.00	103.02	99.00	206.04
36500	3.15E+09	1.08	32.9	0.000	6.84E-01	0.333	5.961E-01	1.032	0.146	0.2976	2350.00	215.88	99.00	431.77	180.0	5.68E+09	2.0	61.0	0.000	9.51E-01	0.179	1.104E+00	1.417	0.045	0.1572	2350.00	113.95	99.00	227.89
36500	3.15E+09	1.14	34.7	0.000	7.32E-01	0.301	6.292E-01	1.079	0.127	0.2693	2350.00	195.27	99.00	390.54	190.0	5.99E+09	2.0	61.0	0.000	9.13E-01	0.197	1.104E+00	1.392	0.049	0.1721	2350.00	124.78	99.00	249.57
36500	3.15E+09	1.20	36.6	0.000	7.80E-01	0.270	6.624E-01	1.127	0.111	0.2427	2350.00	175.96	99.00	351.93	200.0	6.31E+09	2.0	61.0	0.000	8.76E-01	0.214	1.104E+00	1.369	0.053	0.1869	2350.00	135.49	99.00	270.98
36500	3.15E+09	1.26	38.4	0.000	8.27E-01	0.242	6.956E-01	1.175	0.097	0.2179	2350.00	157.97	99.00	315.94	210.0	6.62E+09	2.0	61.0	0.000	8.45E-01	0.232	1.104E+00	1.348	0.057	0.2014	2350.00	146.04	99.00	292.08
36500	3.15E+09	1.32	40.2	0.000	8.75E-01	0.216	7.286E-01	1.222	0.084	0.1949	2350.00	141.27	99.00	282.55	220.0	6.94E+09	2.0	61.0	0.000	8.14E-01	0.250	1.104E+00	1.329	0.060	0.2157	2350.00	156.41	99.00	312.82
36500	3.15E+09	1.38	42.1	0.000	9.23E-01	0.192	7.617E-01	1.270	0.072	0.1736	2350.00	125.86	99.00	251.72	230.0	7.25E+09	2.0	61.0	0.000	7.84E-01	0.267	1.104E+00	1.311	0.064	0.2299	2350.00	166.58	99.00	333.17
36500	3.15E+09	1.44	43.9	0.000	9.70E-01	0.170	7.949E-01	1.318	0.062	0.1541	2350.00	111.70	99.00	223.40	240.0	7.57E+09	2.0	61.0	0.000	7.57E-01	0.285	1.104E+00	1.295	0.067	0.2435	2350.00	176.55	99.00	353.10
36500	3.15E+09	1.50	45.7	0.000	1.02E+00	0.150	8.279E-01	1.365	0.053	0.1362	2350.00	98.74	99.00	197.49	250.0	7.89E+09	2.0	61.0	0.000	7.30E-01	0.302	1.104E+00	1.280	0.070	0.2570	2350.00	186.31	99.00	372.61
36500	3.15E+09	1.56	47.5	0.000	1.07E+00	0.132	8.611E-01	1.413	0.046	0.1199	2350.00	86.95	99.00	173.90	260.0	8.20E+09	2.0	61.0	0.000	7.05E-01	0.319	1.104E+00	1.265	0.074	0.2701	2350.00	195.84	99.00	391.68
36500	3.15E+09	1.62	49.4	0.000	1.11E+00	0.116	8.942E-01	1.461	0.039	0.1052	2350.00	76.27	99.00	152.53	270.0	8.51E+09	2.0	61.0	0.000	6.82E-01	0.335	1.104E+00	1.252	0.077	0.2830	2350.00	205.16	99.00	410.32
36500	3.15E+09	1.68	51.2	0.000	1.16E+00	0.101	9.273E-01	1.508	0.033	0.0919	2350.00	66.63	99.00	133.26	280.0	8.83E+09	2.0	61.0	0.000	6.59E-01	0.351	1.104E+00	1.240	0.079	0.2955	2350.00	214.25	99.00	428.51
36500	3.15E+09	1.74	53.0	0.000	1.21E+00	0.087	9.604E-01	1.556	0.029	0.0800	2350.00	57.98	99.00	115.96	290.0	9.15E+09	2.0	61.0	0.000	6.37E-01	0.367	1.104E+00	1.229	0.082	0.3078	2350.00	223.13	99.00	446.26
36500	3.15E+09	1.80	54.9	0.000	1.26E+00	0.076	9.935E-01	1.604	0.023	0.0693	2350.00	50.25	99.00	100.51	300.0	9.46E+09	2.0	61.0	0.000	6.16E-01	0.383	1.104E+00	1.218	0.085	0.3197	2350.00	231.78	99.00	463.56
36500	3.15E+09	1.86	56.7	0.000	1.30E+00	0.065	1.027E+00	1.651	0.020	0.0598	2350.00	43.38	99.00	86.76	310.0	9.78E+09	2.0	61.0	0.000	5.97E-01	0.399	1.104E+00	1.208	0.088	0.3314	2350.00	240.24	99.00	480.47
36500	3.15E+09	1.92	58.5	0.000	1.35E+00	0.056	1.060E+00	1.699	0.016	0.0514	2350.00	37.30	99.00	74.60	320.0	1.01E+10	2.0	61.0	0.000	5.78E-01	0.414	1.104E+00	1.199	0.090	0.3427	2350.00	248.47	99.00	496.95
36500	3.15E+09	1.98	60.4	0.000	1.40E+00	0.048	1.093E+00	1.747	0.014	0.0441	2350.00	31.94	99.00	63.88	330.0	1.04E+10	2.0	61.0	0.000	5.59E-01	0.429	1.104E+00	1.190	0.092	0.3538	2350.00	256.51	99.00	513.01
36500	3.15E+09	2.04	62.2	0.000	1.45E+00	0.041	1.126E+00	1.794	0.011	0.0376	2350.00	27.24	99.00	54.47	340.0	1.07E+10	2.0	61.0	0.000	5.41E-01	0.444	1.104E+00	1.182	0.095	0.3648	2350.00	264.34	99.00	528.68
36500	3.15E+09	2.10	64.0	0.000	1.49E+00	0.035	1.159E+00	1.842	0.009	0.0319	2350.00	23.13	99.00	46.27	350.0	1.10E+10	2.0	61.0	0.000	5.24E-01	0.458	1.104E+00	1.174	0.097	0.3751	2350.00	271.97	99.00	543.96
36500	3.15E+09	2.16	65.8	0.000	1.54E+00	0.029	1.192E+00	1.890	0.008	0.0270	2350.00	19.57	99.00	39.14	360.0	1.14E+10	2.0	61.0	0.000	5.08E-01	0.473	1.104E+00	1.167	0.099	0.3854	2350.00	279.42	99.00	558.84
36500	3.15E+09	2.22	67.7	0.000	1.59E+00	0.025	1.225E+00	1.937	0.006	0.0227	2350.00	16.48	99.00	32.97	370.0	1.17E+10	2.0	61.0	0.000	4.92E-01	0.487	1.104E+00	1.160	0.101	0.3954	2350.00	286.68	99.00	573.36
36500	3.15E+09	2.28	69.5	0.000	1.64E+00	0.021	1.258E+00	1.985	0.005	0.0191	2350.00	13.83	99.00	27.66	380.0	1.20E+10	2.0	61.0	0.000	4.76E-01	0.500	1.104E+00	1.154	0.103	0.4052	2350.00	293.76	99.00	587.52
36500	3.15E+09	2.34	71.3	0.000	1.69E+00	0.017	1.292E+00	2.033	0.004	0.0159	2350.00	11.55	99.00	23.11	390.0	1.23E+10	2.0	61.0	0.000	4.62E-01	0.514	1.104E+00	1.148	0.105	0.4147	2350.00	300.66	99.00	601.33
36500	3.15E+09	2.40	73.2	0.000	1.73E+00	0.014	1.325E+00	2.080	0.003	0.0133	2350.00	9.61	99.00	19.22	400.0	1.26E+10	2.0	61.0	0.000	4.47E-01	0.527	1.104E+00	1.142	0.108	0.4240	2350.00	307.40	99.00	614.80
36500	3.15E+09	2.46	75.0	0.000	1.78E+00	0.012	1.358E+00	2.128	0.003	0.0110	2350.00	7.96	99.00	15.93	410.0	1.29E+10	2.0	61.0	0.000	4.33E-01	0.540	1.104E+00	1.136	0.108	0.4331	2350.00	313.97	99.00	627.94
36500	3.15E+09	2.52	76.8	0.000	1.83E+00	0.010	1.391E+00	2.176	0.002	0.0091	2350.00	6.57	99.00	13.14	420.0	1.32E+10	2.0	61.0	0.000	4.19E-01	0.553	1.104E+00	1.131	0.110	0.4419	2350.00	320.38	99.00	640.76
36500	3.15E+09	2.58	78.6	0.000	1.88E+00	0.008	1.424E+00	2.223	0.002	0.0074	2350.00	5.40	99.00	10.80	430.0	1.36E+10	2.0	61.0	0.000	4.06E-01	0.566	1.104E+00	1.126	0.111	0.4505	2350.00	326.64	99.00	653.29
36500	3.15E+09	2.64	80.5	0.000	1.92E+00	0.007	1.457E+00	2.271	0.001	0.0061	2350.00	4.42	99.00	8.83	440.0	1.39E+10	2.0	61.0	0.000	3.93E-01	0.578	1.104E+00	1.122	0.113	0.4590	2350.00	332.74	99.00	665.49
36500	3.15E+09	2.70	82.3	0.000	1.97E+00	0.005	1.490E+00	2.319	0.001	0.0050	2350.00	3.60	99.00	7.20	450.0	1.42E+10	2.0	61.0	0.000	3.81E-01	0.590	1.104E+00	1.117	0.114	0.4672	2350.00	338.71	99.00	677.41
36500	3.15E+09	2.76	84.1	0.000	2.02E+00	0.004	1.523E+00	2.368	0.001	0.0040	2350.00	2.92	99.00	5.84	460.0	1.45E+10	2.0	61.0	0.000	3.69E-01	0.602	1.104E+00	1.113	0.116	0.4752	2350.00	344.53	99.00	689.06
36500	3.15E+09	2.82	86.0	0.000	2.07E+00	0.003	1.557E+00	2.416	0.001	0.0033	2350.00	2.36	99.00	4.72	470.0	1.48E+10	2.0	61.0	0.000	3.56E-01	0.614	1.104E+00	1.109	0.117	0.4830	2350.00	350.21	99.00	700.42
36500	3.15E+09	2.88	87.8	0.000	2.11E+00	0.003	1.590E+00	2.462	0.000	0.0026	2350.00	1.90	99.00	3.79	480.0	1.51E+10	2.0	61.0	0.000	3.46E-01	0.626	1.104E+00	1.106	0.118	0.4907	2350.00	355.76	99.00	711.53
36500	3.15E+09	2.94	89.6	0.000	2.16E+00	0.002	1.623E+00	2.509	0.000	0.0021	2350.00	1.52	99.00	3.04	490.0	1.55E+10	2.0	61.0	0.000	3.33E-01	0.637	1.104E+00	1.102	0.119	0.4982	2350.00	361.19	99.00	722.38
36500	3.15E+09	3.00	91.4	0.000	2.21E+00	0.002	1.656E+00	2.557	0.000	0.0017	2350.00	1.21	99.00	2.42	500.0	1.58E+10	2.0	61.0	0.000	3.22E-01	0.649	1.104E+00	1.099	0.120	0.5055	2350.00	366.49	99.00	732.98

Note 1: Adapted from Equation B-28, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Chemical Isolation Analysis for RA5
PSR Superfund Site

Advective-Dispersive Transport Formulas:

Kd=foc*Koc	Walton 1991, p.186
R=1+(Kd,cap*p)/ne	Walton 1991, p.184
p=g(1-n)	Krynine and Judd,1957, p.128
v=K*i/ne	linear velocity calculation
Csed(x,t)=C(x,t)*Kd,cap	Partitioning definition [see note 2]
D = Dw(n^1/3) + dv	(see note 1)
d = 0.01*L	T. Meyers 2002 (USACE)
C/Co= B(x,t) = (0.5*EXP(W)*ERFC(X))+(0.5*EXP(Y)*ERFC(Z))	Van Genuchten and Alves (1982)
W = ((v-w)*x)/(2*D)	
X = (R*x-v*t)/(SQRT(4*D*R*t))	
Y = ((v+w)*x)/(2*D)	
Z = (R*x+v*t)/(SQRT(4*D*R*t))	
w= v*(SQRT(1+((4*u*D)/v^2))	
ERFC()= 1-ERF()	

1D TRANSPORT SOLUTION
Adapted from spreadsheet provided by M. Easterly, USACE

	Hydraulic Calculations		Transport Calculations		Chemical Data		
Data:	Kh	ft/d	Koc	ml/g			
	n		foc		Kd (theoretical	20	L/kg
	ne		R	88.78	Kd, cap		L/kg
	g	gm/cm3	u	ft/	SQS		mg/kgOC
	DL,sed	ft	d	ft	WQC		ug/L (LOEL)
	L	ft	Co	ug/L	Dw		cm2/sec
Results:	p	1.4578 gm/cm3	d	0.9144 cm			
	i	ft/ft	u	0 ft/s			
	v	ft/d	Kd,cap	20 ml/g			
	v	7.066E-06 cm/s	D	3.9E-06 cm2/sec			
			m	7.066E-06 cm/sec	(m=v for u=0)		

Variables:

		Conversions:		
C(x,t)	Porewater concentration in cap (ug/L)	1 µg =	1.000E-06	gm
Co	influent porewater concentration (ug/L)	1 % wt =	1.0	1g/100ml
Csed(x,t)	cap sediment concentration (mg/kgOC)	1 % wt =	1.00E+04	mg/L
d	dispersivity (cm)	1 mg/L =	1000	ug/l
D	dispersion coefficient (cm2/s)	1 day =	86400	sec
Dw	binary diffusivity of chemical in water (cm2/s)			
DL,sed	consolidation depth of sediment (ft)			
foc	cap material organic carbon fraction (-)	1 foot =	30.48	cm
g	mass particle density (gm/cm3)	1 ft/day =	0.00035278	cm/sec
HL	half life (d)			
i	head gradient (not used)			
Kd	theoretical distribution coefficient (L/kg)			
Kd,cap	cap distribution coefficient (L/kg)			
Koc	soil-water partition coefficient (g/g)			
L	thickness of cap (ft)			
n	porosity (-)			
ne	effective porosity (-)			
p	bulk density (gm/cm3)			
R	retardation factor (-)			
SQS	State Sediment Quality Standard (mg/kg or ug/kgOC)			
t	time (s)			
TI,consol	Cap thickness lost due to expression of porewater during consolidation (ft)			
u	first order decay constant (1/s)			
v	average linear groundwater velocity (cm/s) (measured)			
x	distance from cap bottom (cm)			
WQC	State Water Quality Criterion (ug/L)			

ANALYSIS OF CAP LOSSES DURING CONSOLIDATION

Formula for Short-Term Contaminant Migration Due to Consolidation

TI,consol = DLsed / (n+p*Kd,cap)	USEPA 1996

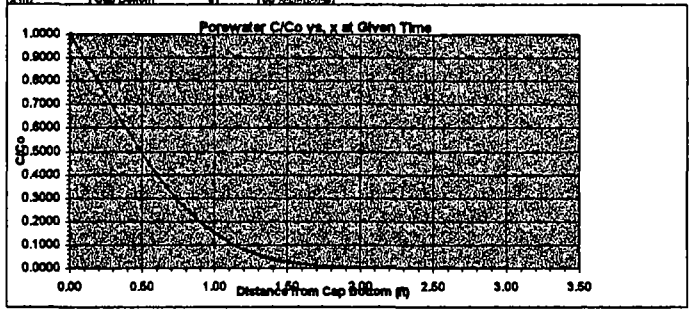
Cap thickness lost due to expression of porewater during consolidation (ft)

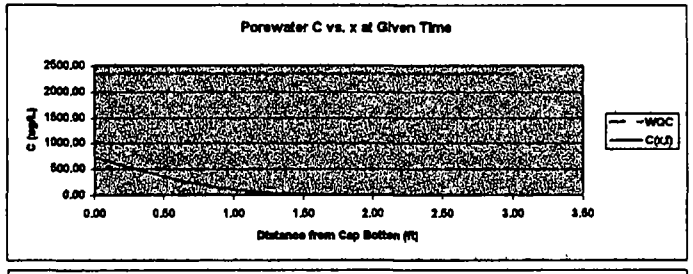
TI,consol =	8.948 feet	(typically negligible)

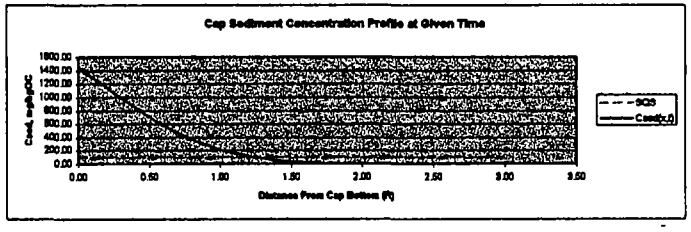
CONCENTRATION PROFILES THROUGH CAP AT GIVEN TIME

Concentration vs. distance output specifications

t	36500	days =	100 yrs
x (ft)	Cap Bottom	0	Top [illegible]



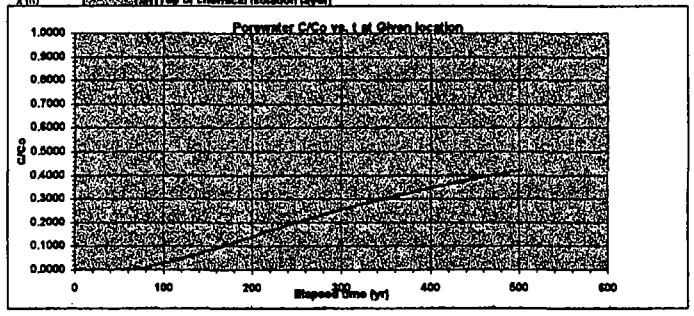


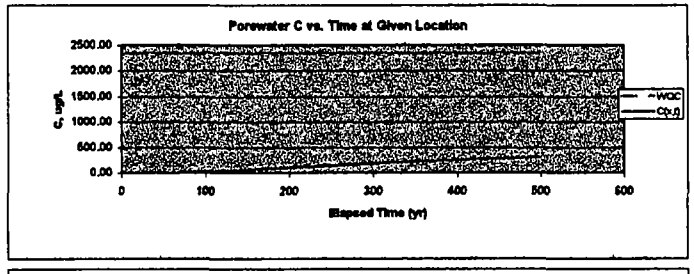


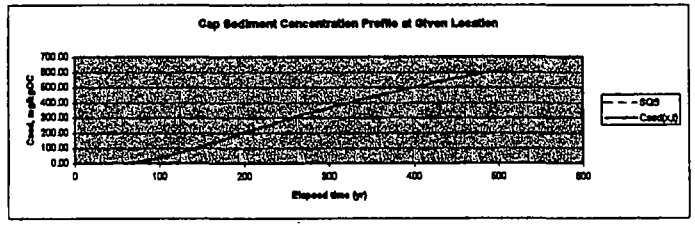
CONCENTRATION PROFILES AT TOP OF CHEMICAL ISOLATION LAYER

Concentration vs. time output specifications

t (yr)	Start	0	Finish	600
x (ft)	[illegible] (Top of chemical isolation layer)			







Chemical Isolation Analysis for RA5
PSR Superfund Site

INPUT				CALCULATIONS						OUTPUT					INPUT			CALCULATIONS						OUTPUT			
t (day)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)	t (yr)	t (sec)	x (ft)	x (cm)	W	X	1-ERF(X)	Y	Z	1-ERF(Z)	B(x,t)	WQC (ug/L)	C(x,t) (ug/L)	SQS (mg/kgOC)	Csed(x,t) (mg/kgOC)
36500	3.15E+09	0.00	0.0	0.000	-1.34E-01	1.139	0.000E+00	0.134	0.851	1.0000	2350.00	726.00	99.00	1450.00	0	0.00E+00	1.5	45.7	0.000	#DIV/0!	#DIV/0!	0.279E-01	#DIV/0!	#DIV/0!	#DIV/0!	2350.00	#DIV/0!	99.00	#DIV/0!
36500	3.15E+09	0.08	1.9	0.000	-6.68E-02	1.064	3.312E-02	0.191	0.787	0.9390	2350.00	680.79	99.00	1361.58	10.0	3.15E+08	1.5	45.7	0.000	5.26E+00	0.000	0.279E-01	5.328	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.12	3.7	0.000	1.01E-02	0.989	5.024E-02	0.256	0.716	0.8787	2350.00	635.58	99.00	1271.17	20.0	6.31E+08	1.5	45.7	0.000	3.68E+00	0.000	0.279E-01	3.795	0.000	0.0000	2350.00	0.00	99.00	0.00
36500	3.15E+09	0.16	5.5	0.000	7.70E-02	0.913	9.935E-02	0.334	0.646	0.8138	2350.00	589.86	99.00	1179.70	30.0	9.46E+08	1.5	45.7	0.000	2.99E+00	0.000	0.279E-01	3.122	0.000	0.0000	2350.00	0.02	99.00	0.03
36500	3.15E+09	0.24	7.3	0.000	1.44E-01	0.839	1.226E-01	0.391	0.560	0.7504	2350.00	544.06	99.00	1088.12	40.0	1.26E+09	1.5	45.7	0.000	2.57E+00	0.000	0.279E-01	2.723	0.000	0.0003	2350.00	0.20	99.00	0.40
36500	3.15E+09	0.30	9.1	0.000	2.11E-01	0.766	1.656E-01	0.466	0.517	0.6879	2350.00	498.69	99.00	997.35	50.0	1.58E+09	1.5	45.7	0.000	2.29E+00	0.001	0.279E-01	2.453	0.001	0.0012	2350.00	0.90	99.00	1.79
36500	3.15E+09	0.36	11.0	0.000	2.78E-01	0.695	1.967E-01	0.525	0.469	0.6264	2350.00	454.14	99.00	908.29	60.0	1.89E+09	1.5	45.7	0.000	2.06E+00	0.004	0.279E-01	2.256	0.001	0.0034	2350.00	2.48	99.00	4.92
36500	3.15E+09	0.42	12.8	0.000	3.45E-01	0.626	2.218E-01	0.582	0.422	0.5667	2350.00	410.87	99.00	821.74	70.0	2.21E+09	1.5	45.7	0.000	1.90E+00	0.007	0.279E-01	2.103	0.003	0.0070	2350.00	5.10	99.00	10.21
36500	3.15E+09	0.48	14.6	0.000	4.11E-01	0.561	2.449E-01	0.639	0.381	0.5093	2350.00	369.23	99.00	738.46	80.0	2.52E+09	1.5	45.7	0.000	1.76E+00	0.013	0.279E-01	1.961	0.005	0.0122	2350.00	8.86	99.00	17.76
36500	3.15E+09	0.54	16.5	0.000	4.78E-01	0.499	2.661E-01	0.726	0.305	0.4546	2350.00	329.55	99.00	659.10	90.0	2.84E+09	1.5	45.7	0.000	1.65E+00	0.020	0.279E-01	1.880	0.008	0.0199	2350.00	13.72	99.00	27.45
36500	3.15E+09	0.60	18.3	0.000	5.45E-01	0.441	3.312E-01	0.793	0.262	0.4029	2350.00	292.09	99.00	584.18	100.0	3.15E+09	1.5	45.7	0.000	1.55E+00	0.029	0.279E-01	1.796	0.011	0.0269	2350.00	19.51	99.00	39.03
36500	3.15E+09	0.66	20.1	0.000	6.12E-01	0.387	3.643E-01	0.860	0.224	0.3546	2350.00	257.07	99.00	514.13	110.0	3.47E+09	1.5	45.7	0.000	1.46E+00	0.038	0.279E-01	1.725	0.015	0.0360	2350.00	26.10	99.00	52.20
36500	3.15E+09	0.72	21.9	0.000	6.79E-01	0.337	3.974E-01	0.927	0.190	0.3096	2350.00	224.53	99.00	449.25	120.0	3.78E+09	1.5	45.7	0.000	1.39E+00	0.049	0.279E-01	1.662	0.019	0.0460	2350.00	33.33	99.00	66.67
36500	3.15E+09	0.78	23.8	0.000	7.46E-01	0.291	4.305E-01	0.994	0.160	0.2688	2350.00	194.86	99.00	389.71	130.0	4.10E+09	1.5	45.7	0.000	1.33E+00	0.061	0.279E-01	1.606	0.023	0.0567	2350.00	41.08	99.00	82.16
36500	3.15E+09	0.84	25.6	0.000	8.13E-01	0.250	4.636E-01	1.060	0.134	0.2314	2350.00	167.78	99.00	335.56	140.0	4.42E+09	1.5	45.7	0.000	1.27E+00	0.073	0.279E-01	1.560	0.027	0.0679	2350.00	49.21	99.00	98.42
36500	3.15E+09	0.90	27.4	0.000	8.80E-01	0.213	4.968E-01	1.127	0.111	0.1978	2350.00	143.41	99.00	286.83	150.0	4.73E+09	1.5	45.7	0.000	1.21E+00	0.086	0.279E-01	1.517	0.032	0.0795	2350.00	57.63	99.00	115.26
36500	3.15E+09	0.96	29.3	0.000	9.47E-01	0.181	5.299E-01	1.194	0.091	0.1678	2350.00	121.66	99.00	243.32	160.0	5.05E+09	1.5	45.7	0.000	1.17E+00	0.099	0.279E-01	1.479	0.036	0.0914	2350.00	66.24	99.00	132.48
36500	3.15E+09	1.02	31.1	0.000	1.01E+00	0.152	5.630E-01	1.261	0.075	0.1413	2350.00	102.42	99.00	204.85	170.0	5.36E+09	1.5	45.7	0.000	1.12E+00	0.113	0.279E-01	1.444	0.041	0.1034	2350.00	74.89	99.00	149.85
36500	3.15E+09	1.08	32.9	0.000	1.08E+00	0.126	5.961E-01	1.328	0.060	0.1180	2350.00	85.57	99.00	171.14	180.0	5.68E+09	1.5	45.7	0.000	1.08E+00	0.126	0.279E-01	1.413	0.046	0.1155	2350.00	83.77	99.00	167.55
36500	3.15E+09	1.14	34.7	0.000	1.15E+00	0.105	6.292E-01	1.395	0.049	0.0978	2350.00	70.94	99.00	141.88	190.0	5.99E+09	1.5	45.7	0.000	1.04E+00	0.140	0.279E-01	1.384	0.050	0.1277	2350.00	92.56	99.00	185.17
36500	3.15E+09	1.20	36.6	0.000	1.21E+00	0.086	6.624E-01	1.462	0.039	0.0805	2350.00	58.35	99.00	116.71	200.0	6.31E+09	1.5	45.7	0.000	1.01E+00	0.154	0.279E-01	1.358	0.055	0.1398	2350.00	101.37	99.00	202.74
36500	3.15E+09	1.26	38.4	0.000	1.26E+00	0.070	6.955E-01	1.529	0.031	0.0657	2350.00	47.62	99.00	95.25	210.0	6.62E+09	1.5	45.7	0.000	9.75E-01	0.169	0.279E-01	1.334	0.059	0.1519	2350.00	110.10	99.00	220.20
36500	3.15E+09	1.32	40.2	0.000	1.35E+00	0.057	7.286E-01	1.596	0.024	0.0532	2350.00	38.56	99.00	77.13	220.0	6.94E+09	1.5	45.7	0.000	9.44E-01	0.182	0.279E-01	1.311	0.064	0.1638	2350.00	118.78	99.00	237.49
36500	3.15E+09	1.38	42.1	0.000	1.42E+00	0.045	7.617E-01	1.663	0.019	0.0427	2350.00	30.96	99.00	61.95	230.0	7.26E+09	1.5	45.7	0.000	9.15E-01	0.196	0.279E-01	1.291	0.068	0.1756	2350.00	127.29	99.00	254.58
36500	3.15E+09	1.44	43.9	0.000	1.48E+00	0.036	7.948E-01	1.729	0.014	0.0340	2350.00	24.69	99.00	49.37	240.0	7.57E+09	1.5	45.7	0.000	8.88E-01	0.209	0.279E-01	1.271	0.072	0.1872	2350.00	135.72	99.00	271.43
36500	3.15E+09	1.50	45.7	0.000	1.55E+00	0.029	8.279E-01	1.796	0.011	0.0269	2350.00	19.51	99.00	39.03	250.0	7.88E+09	1.5	45.7	0.000	8.62E-01	0.223	0.279E-01	1.254	0.076	0.1986	2350.00	144.02	99.00	288.03
36500	3.15E+09	1.56	47.5	0.000	1.62E+00	0.022	8.611E-01	1.863	0.008	0.0211	2350.00	15.30	99.00	30.60	260.0	8.20E+09	1.5	45.7	0.000	8.38E-01	0.236	0.279E-01	1.237	0.080	0.2099	2350.00	152.18	99.00	304.35
36500	3.15E+09	1.62	49.4	0.000	1.68E+00	0.017	8.942E-01	1.930	0.006	0.0164	2350.00	11.90	99.00	23.80	270.0	8.51E+09	1.5	45.7	0.000	8.16E-01	0.249	0.279E-01	1.221	0.084	0.2210	2350.00	160.19	99.00	320.38
36500	3.15E+09	1.68	51.2	0.000	1.75E+00	0.013	9.273E-01	1.997	0.005	0.0127	2350.00	9.16	99.00	18.34	280.0	8.83E+09	1.5	45.7	0.000	7.92E-01	0.262	0.279E-01	1.207	0.088	0.2318	2350.00	168.06	99.00	336.12
36500	3.15E+09	1.74	53.0	0.000	1.82E+00	0.010	9.604E-01	2.064	0.004	0.0097	2350.00	7.03	99.00	14.06	290.0	9.15E+09	1.5	45.7	0.000	7.71E-01	0.275	0.279E-01	1.193	0.092	0.2424	2350.00	175.77	99.00	351.55
36500	3.15E+09	1.80	54.9	0.000	1.88E+00	0.008	9.935E-01	2.131	0.003	0.0074	2350.00	5.33	99.00	10.66	300.0	9.46E+09	1.5	45.7	0.000	7.51E-01	0.288	0.279E-01	1.180	0.096	0.2529	2350.00	183.34	99.00	366.68
36500	3.15E+09	1.86	56.7	0.000	1.95E+00	0.006	1.027E+00	2.198	0.002	0.0055	2350.00	4.01	99.00	8.03	310.0	9.78E+09	1.5	45.7	0.000	7.32E-01	0.301	0.279E-01	1.168	0.099	0.2631	2350.00	190.76	99.00	381.50
36500	3.15E+09	1.92	58.5	0.000	2.02E+00	0.004	1.060E+00	2.265	0.001	0.0041	2350.00	3.00	99.00	5.99	320.0	1.01E+10	1.5	45.7	0.000	7.14E-01	0.313	0.279E-01	1.158	0.102	0.2731	2350.00	198.01	99.00	396.01
36500	3.15E+09	1.98	60.4	0.000	2.08E+00	0.003	1.093E+00	2.332	0.001	0.0031	2350.00	2.22	99.00	4.43	330.0	1.04E+10	1.5	45.7	0.000	6.96E-01	0.325	0.279E-01	1.148	0.106	0.2829	2350.00	205.11	99.00	410.23
36500	3.15E+09	2.04	62.2	0.000	2.15E+00	0.002	1.126E+00	2.399	0.001	0.0022	2350.00	1.63	99.00	3.26	340.0	1.07E+10	1.5	45.7	0.000	6.79E-01	0.337	0.279E-01	1.135	0.109	0.2925	2350.00	212.07	99.00	424.14
36500	3.15E+09	2.10	64.0	0.000	2.22E+00	0.002	1.159E+00	2.465	0.000	0.0016	2350.00	1.18	99.00	2.37	350.0	1.10E+10	1.5	45.7	0.000	6.63E-01	0.349	0.279E-01	1.126	0.111	0.3019	2350.00	218.89	99.00	437.78
36500	3.15E+09	2.16	65.8	0.000	2.28E+00	0.001	1.192E+00	2.532	0.000	0.0012	2350.00	0.86	99.00	1.71	360.0	1.14E+10	1.5	45.7	0.000	6.47E-01	0.360	0.279E-01	1.116	0.114	0.3111	2350.00	225.54	99.00	451.09
36500	3.15E+09	2.22	67.7	0.000	2.35E+00	0.001	1.225E+00	2.599	0.000	0.0008	2350.00	0.61	99.00	1.22	370.0	1.17E+10	1.5	45.7	0.000	6.32E-01	0.372	0.279E-01	1.106	0.117	0.3201	2350.00	232.07	99.00	464.13
36500	3.15E+09	2.28	69.5	0.000	2.42E+00	0.001	1.258E+00	2.666	0.000	0.0006	2350.00	0.43	99.00	0.87	380.0	1.20E+10	1.5	45.7	0.000	6.17E-01	0.383	0.279E-01	1.099	0.120	0.3289	2350.00	238.45	99.00	476.90
36500	3.15E+09	2.34	71.3	0.000	2.49E+00	0.000	1.292E+00	2.733	0.000	0.0004	2350.00	0.31	99.00	0.61	390.0	1.23E+10	1.5	45.7	0.000	6.03E-01	0.394	0.279E-01	1.091	0.123	0.3375	2350.00	244.49	99.00	489.39
36500	3.15E+09	2.40	73.2	0.000	2.55E+00	0.000	1.325E+00	2.800	0.000	0.0003	2350.00	0.21	99.00	0.43	400.0	1.26E+10	1.5	45.7	0.000	5.89E-01	0.405	0.279E-01	1.084	0.125	0.3459	2350.00	250.91	99.00	501.81
36500	3.15E+09	2.46	75.0	0.000	2.62E+00	0.000	1.358E+00	2.867	0.000	0.0002	2350.00	0.15	99.00	0.30	410.0	1.29E+10	1.5	45.7	0.000	5.75E-01	0.416	0.279E-01	1.077	0.128	0.3542	2350.00	256.79	99.00	513.57
36500	3.15E+09	2.52	76.8	0.000	2.69E+00	0.000	1.391E+00	2.934	0.000	0.0001	2350.00	0.10	99.00	0.20	420.0	1.32E+10	1.5	45.7	0.000	5.63E-01	0.426	0.279E-01	1.070	0.130	0.3623	2350.00	262.64	99.00	525.28
36500	3.15E+09	2.58	78.6	0.000	2.76E+00	0.000	1.424E+00	3.001	0.000	0.0001	2350.00	0.07	99.00	0.14	430.0	1.36E+10	1.5	45.7	0.000	5.50E-01	0.437	0.279E-01	1.063	0.133	0.3702	2350.00	268.37	99.00	536.75
36500	3.15E+09	2.64	80.5	0.000	2.82E+00	0.000	1.457E+00	3.068	0.000	0.0001	2350.00	0.05	99.00	0.09	440.0	1.39E+10	1.5	45.7	0.000	5.38E-01	0.447	0.279E-01	1.057	0.136	0.3779	2350.00	273.96	99.00	547.97
36500	3.15E+09	2.70	82.3	0.000	2.89E+00	0.000	1.490E+00	3.134	0.000	0.0000	2350.00	0.03	99.00	0.06	450.0	1.42E+10	1.5	45.7	0.000	5.26E-01	0.457	0.279E-01	1.051	0.137	0.3856	2350.00	279.48	99.00	558.96
36500	3.15E+09	2.76	84.1	0.000	2.95E+00	0.000	1.523E+00	3.201	0.000	0.0000	2350.00	0.02	99.00	0.04	460.0	1.45E+10	1.5	45.7	0.000	5.14E-01	0.467	0.279E-01	1.045	0.139	0.3929	2350.00	284.85	99.00	569.71
36500	3.15E+09	2.82	86.0	0.000	3.02E+00	0.000	1.557E+00	3.268	0.000	0.0000	2350.00	0.01	99.00	0.03	470.0	1.48E+10	1.5	45.7	0.000	5.03E-01	0.477	0.279E-01	1.040	0.141	0.4002	2350.00	290.12	99.00	580.24
36500	3.15E+09	2.88	87.8	0.000	3.09E+00	0.000	1.590E+00	3.335	0.000	0.0000	2350.00	0.01	99.00	0.02	480.0	1.51E+10	1.5	45.7	0.000	4.92E-01	0.486	0.279E-01	1.035	0.143	0.4073	2350.00	295.29	99.00	590.58
36500	3.15E+09	2.94	89.6	0.000	3.15E+00	0.000	1.623E+00	3.402	0.000	0.0000	2350.00	0.01	99.00	0.01	490.0	1.55E+10	1.5	45.7	0.000	4.82E-01	0.496	0.279E-01	1.030	0.145	0.4143	2350.00	300.33	99.00	600.67
36500	3.15E+09	3.00	91.4	0.000	3.22E+00	0.000	1.656E+00	3.469	0.000	0.0000	2350.00	0.00	99.00	0.01	500.0	1.58E+10	1.5	45.7	0.000	4.71E-01	0.505	0.279E-01	1.025	0.147	0.4211	2350.00	305.29	99.00	610.57

Note 1: Adapted from Equation B-20, Guidance for Subaqueous Dredged Material Capping. Equation differs by a factor of porosity due to definition of terms
Note 2: Calculated Csed(x,t) is divided by foc to obtain carbon-normalized concentrations

Appendix C

APPENDIX C

SLOPE STABILITY EVALUATION

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APPENDIX C

SLOPE STABILITY EVALUATION

C.1 EXISTING SUBMARINE LANDSLIDES

High-resolution bathymetry following the February 2001 Nisqually earthquake identified geomorphologic features within the Duwamish River delta that can be interpreted as scars from past landslides. At least five of these past slides can be identified at the site, as shown in Figure C-1. The apparent slide features were examined to provide insight as to potential future landslide failure modes and extent.

The features appear to have an elongated tongue-like shape, some with a bottleneck opening that is up to 400 feet long from crest to toe, 100 to 150 feet wide, and 10 to 15 feet deep. Beyond the toe of the slide, a deposition zone, typically in the form of a bulge or a lobe, resulting from the flow of the sediments is observed. The elongated geometry of the landslides resembles that of many submarine landslides reported in the literature (Andresen and Bjerrum 1966; Sladen et al. 1985; Kraft, Gavin, and Burtom 1992; and Gardner et al. 2001). Slide debris run-out distances of several hundred to 1,000 feet have been observed at PSR. As discussed in the pre-design investigation data summary (USEPA 2002a), the comparison of pre- and post-Nisqually earthquake bathymetry data suggests that these landslides occurred some time prior to the Nisqually earthquake. The cause of these landslides is not known. One or more mechanisms might have contributed to trigger the slides, including liquefaction due to earthquake motions, construction activities in the area such as fill placement and dredging, and seepage pressures during falling tides.

Regardless of the actual cause of the previous landslides, any future instability of these slopes is expected to occur in a like manner with similar slide geometries, plan dimensions, and depths.

C.2 SUBSURFACE CONDITIONS

Subsurface conditions at the site consist of fill composed of soils of various origins overlying a thick deposit of native sediments. Generally the subsurface consists of mixtures of sand and silts with fines content typically between 30 percent and 80 percent. An upper layer, 2 to 3.5 feet thick and composed of very soft silt with organic matter at some locations, was observed throughout most of the site. Below this surficial silt, identification of specific strata was not possible as the changes in sediment character tended to be gradational and seemingly random

within and between borings and probes. However, the presence of randomly distributed zones of sediments with more pronounced granular behavior was observed in most of the cone profiles and borehole logs. These granular zones are typically 5 to 10 feet thick and are usually located within the upper 30 feet of sediments.

Borehole and cone penetration testing (CPT) logs were used to develop a vertical sequence of soil "layers" that is roughly representative of conditions across the site. That sequence is described below, in order of increasing depth:

2.5 feet of sensitive fine-grained sediments (Upper Silt)
10 feet of sandy silt (Intermediate Silt)
10 feet of silty sand (Upper Sand)
30 feet of sandy silt (Lower Silt)
Silty sand down to bedrock (Lower Sand)
Bedrock at an assumed depth of 400 feet below mudline

In addition, for the post-capping conditions, the subsurface profile included a cap with an assumed thickness as described in the consolidation analysis (Table C-1).

Two critical sections within the site area were selected for slope stability analysis:

- **SECTION 1:** This represents a full slope section through RA2, RA4, and RA5 in the direction of the maximum slope gradient, the failure of which would involve a large area of the sediments within the Marine Sediment Unit (MSU). The section of slope includes a relatively steep portion with an average inclination of about 20 percent (12 degrees) and is shown in Figure C-1. Within this steep portion, a maximum slope inclination of about 29 percent (16 degrees) was measured near the crest of the slope. The steep portion extends for a length of about 300 feet in the direction of the maximum slope gradient and then flattens to an average inclination of about 12 percent (7 degrees). This section was the easternmost one passing through the CPT probes P16, P17, P18, and P19, and boreholes B5 and B6.

- **SECTION 2:** This represents a local steepened section in RA4 along the margin of an existing landslide feature, where small localized failures could occur repeatedly (retrogressive) and eventually involve a more significant portion of the slope. Local steepened zones with inclinations up to 50 percent (27 degrees) were observed in SECTION 2 near the margin of the landslide feature identified as

slide 3 in Figure C-1. SECTION 2 was selected because the slopes along the margins of slide 3 appear to be approximately the steepest at the site.

C.3 COMPUTATION METHOD

The limit equilibrium approach was adopted for the slope stability analyses of the sediments. The commercially available UTEXAS 4.0 software (Shinoak Software, Austin, Texas) and Spencer's method of analysis were utilized.

The UTEXAS 4.0 software was used to conduct an automatic search for the most critical circular failure surface, i.e., the surface with minimum factor of safety, for each of the two critical sections. In addition, an analysis was carried out for the full section (SECTION 1) by imposing a predetermined shallow failure surface resembling the existing landslide features at the site.

C.4 STATIC STABILITY

C.4.1 Strength Parameters

Strength parameters for static slope stability analyses were assigned based on an interpretation of the result of the field standard penetration tests (SPTs), CPTs, and field vane shear tests (VSTs). A summary of the strength parameters is presented in Table C-2.

The undrained shear strengths (s_u) of the Upper Silt measured in VSTs and CPTs ranged from 10 pounds per square foot (psf) to more than 100 psf. The selected value of 35 psf was obtained by back-analysis of the steepened SECTION 2 to find the shear strength that would produce a safety factor of at least 1.0. The strength of the Intermediate Silt was modeled as linearly increasing with depth based on average CPT s_u values. A friction angle for the Upper Sand layer was selected based on correlations between friction angle and CPT and SPT data and on the physical observation of the coarser nature of this material. The CPT and SPT correlations suggested magnitudes of friction angles for the Upper Sand between 37 degrees and 39 degrees and 28 degrees and 30 degrees, respectively. An intermediate angle of friction of 32 degrees was therefore selected for the Upper Sand layer. The Lower Silt layer was modeled with a uniform undrained shear strength of 1,000 psf based on average CPT s_u values. A friction angle of 35 degrees was estimated for the Lower Sand using published values for medium dense sand.

The placement of the cap was assumed to induce an increase in strength in the Upper Silt only, where most of the sediment compression is expected to occur. A uniform increase in undrained

shear strength of 30 psf was assigned to the Upper Silt layer. This increase in strength was computed assuming the increase in shear strength to be proportional to the compression of the sediments (Skempton 1944) estimated upon placement of a 1.5-foot-thick cap.

C.4.2 Results of Static Slope Stability Analyses

The results of the slope stability analyses for the temporary condition preceding the capping and for the permanent condition after the capping of the sediments are summarized in Table C-3. An example output of UTEXAS 4.0 runs is presented in Attachment C-1 to this appendix.

Note that the increase in factors of safety that occur in the post-capping scenario compared with the pre-capping scenario are the result of the strength gain anticipated for the Upper Silt as a consequence of compression under the slowly increasing cap load.

Factors of safety greater than 3.0 were computed for failures of significant size at SECTION 1 during static loading, indicating a stable slope under static conditions. These factors of safety are well above the minimum value of 1.5 typically considered appropriate for permanent slopes. Results of the analyses are graphically illustrated for the post-capping case in Figures C-2 and C-3.

Lower but still adequate factors of safety (as low as 1.73) were estimated for the steepened area at SECTION 2 along the fringe of the previous landslide zone, indicating a stable slope under static conditions. Automatic search routines by the UTEXAS 4.0 software did not appear to properly reflect the lowest factors of safety for these shallow and limited-extent failures, so specific failure surface searches were used. The results are graphically illustrated for the post-capping case in Figure C-4.

C.5 SEISMIC STABILITY

C.5.1 Approach

In accordance with the industry standard, the approach to the analysis of stability for the seismic case proceeded first with an evaluation of the potential for liquefaction, then progressed to the analysis of slope stability. The slope stability analysis uses soil strength parameters which depend on whether liquefaction is expected during the design level earthquake.

The evaluation of future liquefaction potential and seismic slope stability was guided by the interpreted site response to the M = 6.8 Nisqually earthquake of February 28, 2001. In particular,

the apparent absence of significant liquefaction or large-scale instability of the submarine slopes after the earthquake, as indicated by a comparison of pre- and post-earthquake bathymetric maps of the site, was used to provide "ground truth" for the standard analysis methodologies.

The industry standard approach to the evaluation of liquefaction potential is described in Youd et al. (2001), and involves an empirical analysis based on measured sampler penetration resistance (N-values) or CPT cone tip resistance values. Using this approach, the acceleration level of 0.22g that was measured at Harbor Island at a ground surface location approximately 1 mile south of the site should have liquefied the sediments to depths of at least 30 feet. This result is inconsistent with the observed lack of significant liquefaction.

One of the possible interpretations of this prediction-versus-observation inconsistency is that the actual acceleration level at the site was lower than at the Harbor Island surface measurement location, possibly due to the effect of the deep water. However, it should be noted that another important contributing factor might have been the high fraction of fines measured in the laboratory grain size analysis tests on the samples of sediments. Soils with a high fines content are not as susceptible to liquefaction as sands with low fines contents.

Given the uncertainty in the liquification potential, it was conservatively assumed that the sediments are in fact liquefiable, but that the actual ground acceleration level within the sediment slopes was less than the measured acceleration at the Harbor Island surface monitoring location. Further discussion of the analysis is presented below.

C.5.2 Liquefaction Analysis

A preliminary evaluation of the liquefaction potential of the sediments was performed using the qualitative Chinese criteria (Seed and Idriss 1982) and Tsuchida (1970) criteria. The Chinese criteria are based on clay fraction, plasticity properties, and moisture content. The clay content (particles smaller than 5 micrometers [μm]) of all the sediment samples tested in the pre-design investigation was less than 15 percent; all samples tested for this investigation had liquid limits less than 35 percent and moisture content values greater than 0.9 times the liquid limit. According to the Chinese criteria, these observations indicate that the sediments at this site can be considered to be potentially liquefiable.

The Tsuchida criterion is illustrated in Figure C-5, which shows the gradation curves obtained for the sediment samples from this study and the remedial investigation/feasibility study (RI/FS) (USEPA 1998). The gradation curves lie mostly within the outer boundary curves, which identify potentially liquefiable soils. However, the tails of some gradation curves cut across the

Tsuchida boundary curves. Therefore, according to the Tsuchida criterion, the sediments with highest fines content may not be liquefiable.

Liquefaction analyses based on SPT and CPT data were performed using LiquefyPro software (CivilTech Software) and using the magnitude of the Nisqually earthquake and the acceleration measured at Harbor Island. The standard SPT method and Seed's CPT method of analysis (Seed and De Alba 1986) were used. Corrections factors for fines content were computed using the Idriss and Seed (1997) and Stark and Olson (1995) methods for the SPT and the CPT analyses, respectively.

For the SPT analysis, the fines content was assigned to each soil type encountered along the profile. For the CPT analysis, values of fines content and D_{50} were assigned to each soil type classified based on the typical values measured in the laboratory tests on the same type of soils. The fines contents ranged from 20 to 88 percent, while the D_{50} values ranged from 0.075 to 0.10 mm.

The results of the SPT and CPT liquefaction analyses are presented in Figures C-6 through C-9 for representative borings and cone probes. Example LiquefyPro outputs are presented in Attachment C-2. Both CPT and SPT liquefaction analyses yielded factors of safety less than 1.0, indicating liquefaction for large regions of the subsurface materials. This extensive liquefaction would have caused large-scale slope failures at the site, which conflicts with the lack of evidence of liquefaction and large-scale slope instability at the site following the Nisqually earthquake. Given the limited precision of the pre-Nisqually bathymetry, the occurrence of small local zones of liquefaction, settlement, and sloughing due to the Nisqually earthquake cannot be ruled out.

For a more realistic yet conservative analysis, the assumption was made that the Nisqually earthquake brought the sediments to just below the trigger point of liquefaction, i.e., the factor of safety of liquefaction was approximately 1.0. The LiquefyPro software was then used to back-calculate the ground acceleration that would result in a safety factor against liquefaction of 1.0. This back-calculated ground acceleration value was then used for further evaluation of slope stability.

When SPT N-values from the borings were used for the back-calculation process, the ground acceleration value that would first trigger liquefaction ranged from approximately 0.07g in borings B2, B3, B4 and B6 to approximately 0.11g in boring B1. When CPT data were used for the back-calculation process, the ground acceleration value that would first trigger liquefaction was approximately 0.13g to 0.14g. As the CPT data is viewed as being somewhat more reliable than N-values from the borings in these conditions, the back-calculated ground acceleration value from the CPT analysis was considered the most appropriate value to use in this study.

C.5.3 Seismic Design Parameters

The return period associated with the Nisqually event was estimated to be 30 to 50 years (Crosson 2002). Designing a cap for such an event appears to be reasonable given the absence of any direct human health risks from a slope failure, and the typical range of design events used in the United States (return period of 2,500 years for high-hazard dams, 475 years for buildings and bridges, and 100 years for landfills). Slope failures from seismic events would cause short-term disruption of the benthic community and potentially pose short-term ecological risks if contaminated sediments are re-exposed. However, such disruptions will be repaired as part of the long-term maintenance of the cap. Thus, it is important to stress that a slope failure does not constitute a failure of the remedy. The anticipated slope failure mode and extent are discussed further in Section C.6.

An earthquake magnitude of 6.8 and a peak ground acceleration (PGA) corresponding to the liquefaction-triggering value of 0.13g computed from CPT back-analysis were therefore considered to be the seismic design parameters for this project.

C.5.4 Shear Strength Parameters and Pseudo-Static Slope Stability Analysis

The stability of the sediment slopes during a seismic event was evaluated for the permanent condition after capping. The seismic slope stability analysis was performed on the same two critical profiles (SECTIONS 1 and 2) previously identified. In accordance with the industry standard approach for slopes without life-threatening consequences of failure, the pseudo-static approach to slope stability analysis was applied using the UTEXAS 4.0 software. A seismic coefficient equal to 0.5 of the design PGA was adopted. This seismic coefficient is consistent with the value of 0.5 recommended by EPA's RCRA Subtitle D Seismic Design Guidance for Municipal Solid Waste Landfill Facilities.

The undrained shear strengths of the sediments were reduced from the static values to account for strength degradation induced by seismic loading. Because of the uncertainties associated with the exact magnitude of the post-cyclic undrained shear strength of the sediments, a parametric study was carried out using shear strength reductions of 20 and 30 percent. Shaking-induced shear strength losses in nonliquefied fine grained soils are typically assumed to be less than 20 percent (Martin 1992). However, cyclic undrained strength reductions of 30 percent or more have been recorded for clays (Pradhan et al. 1999), and even more substantial strength losses could be expected for granular soils approaching liquefaction. Considering the soft nature of sediments at this site, an upper limit of strength loss of 30 percent was used in the absence of liquefaction.

C.5.5 Results of Seismic Slope Stability Analyses

The results of the seismic slope stability analysis for the permanent condition after capping are summarized in Table C-4. An example output of UTEXAS 4.0 is presented in Attachment C-1.

Seismic factors of safety greater than 1.3 were computed for the full slope at SECTION 1 for both the shallow and deep failure modes. Seismic factors of safety less than 1.0 were computed for the local steepened slope at SECTION 2 along the margin of an existing landslide feature, indicating that local failures may be expected in steepened zones of the sediments.

Figures C-10 and C-11 show the slip surfaces with minimum factor of safety for the full slope SECTION 1 and the local steepened SECTION 2, respectively. The extent of the predicted failure for the local steepened zones is relatively small and involves mainly the upper cap material and few feet of the Upper Silt layer for a distance of about 100 feet in the direction of the maximum slope gradient. The position of the critical circles for the full slope section is very close to that observed for the static loading case.

Additional analyses were performed to estimate the seismic coefficient that would result in a safety factor of 1.0, i.e., the onset of failure of the slope. The results are shown in Table C-5. For the SECTION 1 slope configuration, the seismic coefficients resulting in failure indicate that an event with a seismic coefficient of at least 0.11 (i.e., PGA of at least 0.22g) at the submarine slope location (hence approximately 0.37g at the Harbor Island seismometer station) is needed to induce failure. For the steep SECTION 2 slope configuration, a seismic coefficient of only 0.01 (i.e., a PGA of 0.02g) at the submarine slope location is needed to theoretically produce a failure.

C.6 ESTIMATED FAILURE MODE AND EXTENT

The results of the slope stability analyses indicate that the submarine slopes at this site are stable under static conditions. The design event consisting of a magnitude 6.8 seismic event with a dry ground surface PGA 0.22g and an actual submarine slope PGA of 0.13g (i.e., 60 percent of the dry ground PGA) is not expected to cause large-scale slope instability, but may trigger local shallow failures in the steeper zones near the margins of existing landslides.

Local submarine failures in steepened areas have been reported to develop into large-scale retrogressive failures. These are tongue-shaped with a bottleneck opening at the location of the initial slide (Andresen and Bjerrum 1971), similar to the existing slides observed at the site. Such slope failures may occur in the future as discussed below.

Although seismic events are believed to be a significant cause of large scale submarine landslides, a number of case histories document other types of mechanisms that can trigger such failures. A submarine landslide occurred at Alki point in the Puget Sound in 1986 (Kraft, Gavin, and Burtom 1992) during dredging for construction of an offshore pipeline. The cause of the landslide was attributed to a collapse mechanism in the soil that caused liquefaction as a result of dredging in low tidal conditions. The slide involved approximately the upper 10 feet of sediments that consisted of medium dense sands, and extended about 1,000 feet from crest to toe of the slide. Five liquefaction slides occurred in 1983 during construction of a hydraulically placed submarine sand berm at Nerlerk in the Canadian Beaufort Sea (Sladen et al. 1985). These slides were attributed to loading arising from the placement of the fill itself in local oversteepened zones. The berm slopes were generally smaller than 10 percent (6 degrees). However the local oversteepening caused by placement of the fill with a single point technique, produced slopes up to 32 percent (18 degrees). The slides were described as bowl-shaped with lengths in the direction of the maximum slope gradient between 600 and 1,200 feet and depths not exceeding 30 feet.

Based on the above case histories and on the observations discussed in Section C.1, it is hypothesized that, if a submarine slope failure is triggered at the site by either an earthquake or other mechanisms, the slide will probably involve the upper 10 to 20 feet of sediments for a length of several hundred feet in the direction of the maximum slope gradient. The width of the slide will probably not exceed 100 feet. Several of these failures could conceivably develop during a large earthquake with a magnitude in excess of 7. The zone of sediment accumulation, which begins at the toe of the slide zone, will probably extend for several hundred feet or more in the direction of the maximum slope gradient. The fine fraction of the sediments will become suspended and, depending on currents and other factors, may be re-deposited at the sea bottom after days or weeks.

A pertinent question for the long-term maintenance of the cap is how often will earthquakes large enough to cause large scale liquefaction and landsliding occur at the site. The return frequency for seismically induced ground acceleration values high enough to initiate the liquefaction and landsliding was examined using data developed and published by the United States Geologic Survey (USGS) (2000). The USGS has considered all sources of potential earthquakes to produce "hazard curves" that provide estimates of ground acceleration versus the frequency at which these acceleration values are expected to be exceeded. The hazard curves are developed assuming that subsurface conditions are midway between "rock" and a "very dense soil to soft rock," i.e., midway between the Uniform Building Codes Soil Profile Types S_B and S_C. A modified hazard curve for Harbor Island is shown on Figure C-12, showing the return period for various PGA values for the rock/dense soil condition. Also shown are estimates of the return period for a "soft" soil profile (Soil Profile Type S_E) that is representative of the site and that

would predict dry ground PGA values on Harbor Island. Assuming that the submarine slopes will see only about 60 percent of the PGA measured at the ground surface seismograph station and that a submarine slope PGA of at least 0.18g would be needed to generate significant liquefaction (30 percent above the liquefaction-triggering PGA level of 0.13), this figure suggests that shaking strong enough to cause significant landsliding could be expected every 100 years or more.

C.7 SLOPE STABILITY ANALYSES OF RA1 CAP

Attachment C-3 presents geotechnical evaluations of the RA1 cap, including the following:

- An evaluation of static and seismic slope stability for two cap transects representative of the steepest cases where a 2H:1V revetment is placed above existing slopes that are inclined at more than 10 degrees;
- An evaluation of statice slope stability for a temporary dredge cutback slope, where the cutback extends to the toe of an existing revetment; and
- An analysis of downdrag forces on the Viewing Pier and likely effects of cap placement around this structure.

The results are presented in Attachment C-3 and summarized in Section 4 of the Basis of Design.

C.8 SUMMARY

The existing slopes at the site are stable and appear to have remained stable during recent magnitude 6.8 Nisqually earthquake. Slope stability analyses indicated that proper placement of the cap will not result in unstable slopes for static loading conditions.

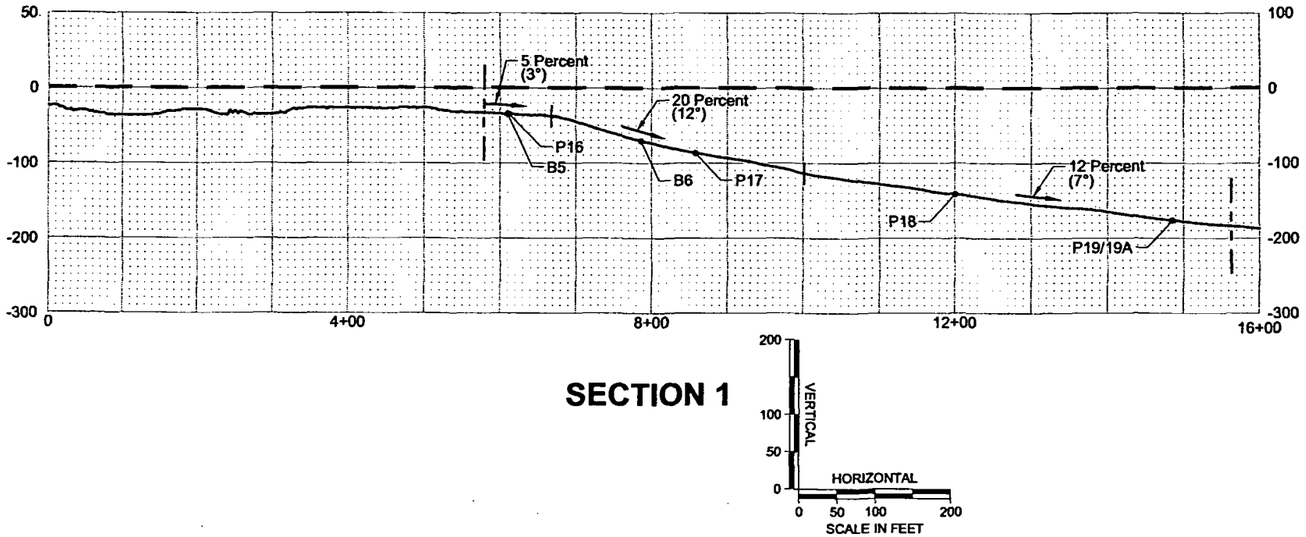
Bathymetric data suggest the presence of at least five features that are interpreted as past landslides, most likely the result of historic earthquakes. Analyses indicate that moderate size earthquakes like the Nisqually event will not cause large-scale landslides, but could cause instability at localized oversteepened areas that can be found at the edges of some of the old landslide features. Such moderate size seismic events would typically occur at 30- to 50-year intervals, and potentially cause minor cap damage.

Larger earthquakes with return periods of roughly 100 years or more (with an associated submarine PGA of at least 0.18g) will likely cause substantial liquefaction that will result in large scale landslides of size and shape similar to the historic slides suggested by the bathymetric data. Such slides would typically involve individual slide masses approximately 20 feet deep, 100 feet wide and several hundred feet long, which would run out to distances of at least several hundred feet beyond the toe of the slide zone.

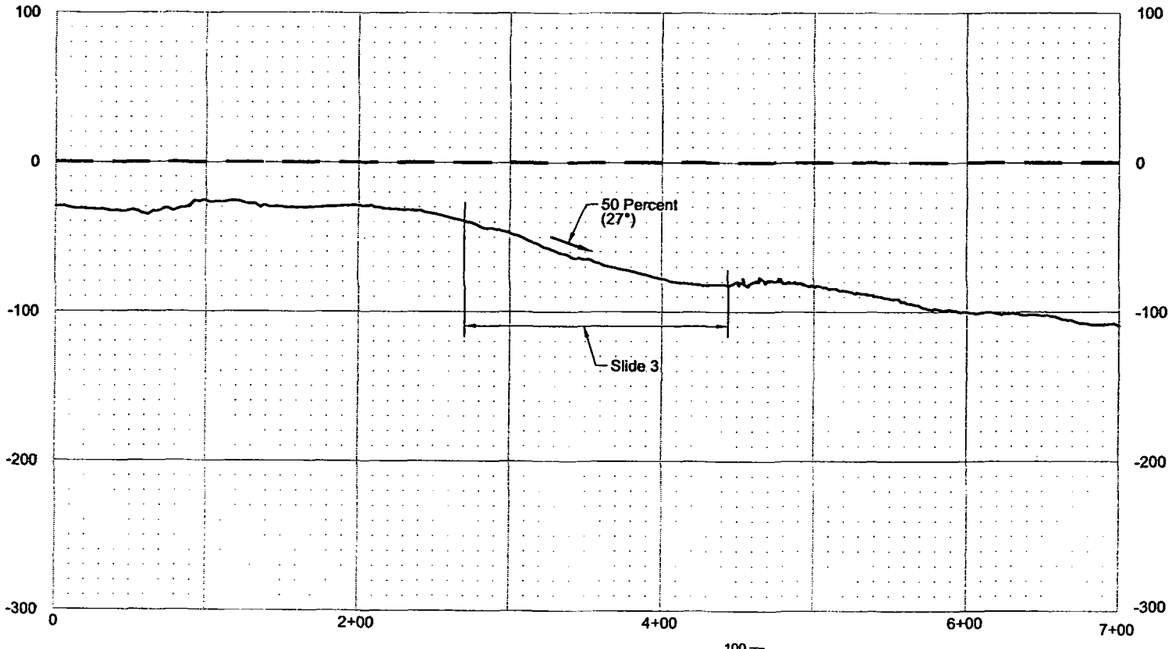
The slope failures that may result from these seismic events do not pose human health risks but will cause short-term disruption to the benthic community in the affected slide zone. Such cap damage will be repaired as part of the long-term operation and maintenance of the remedy.

Placement of too much cap soil at one time could result in a bearing capacity failure along the edges of the cap placement area, where excessive deformation and cap disturbance and mixing would occur. In RA4 and near the top of the slope in RA2, careful placement is considered essential to minimize any bearing capacity failures that may trigger larger slides. In RA1 through RA4, where the upper existing sediments are softest, the thickness of cap placed at one time should be limited to relatively thin lifts. Subsequent lifts can be thicker. In RA5, where the upper sediments are more competent, lift thickness in excess of 3 feet could theoretically be placed at one time.

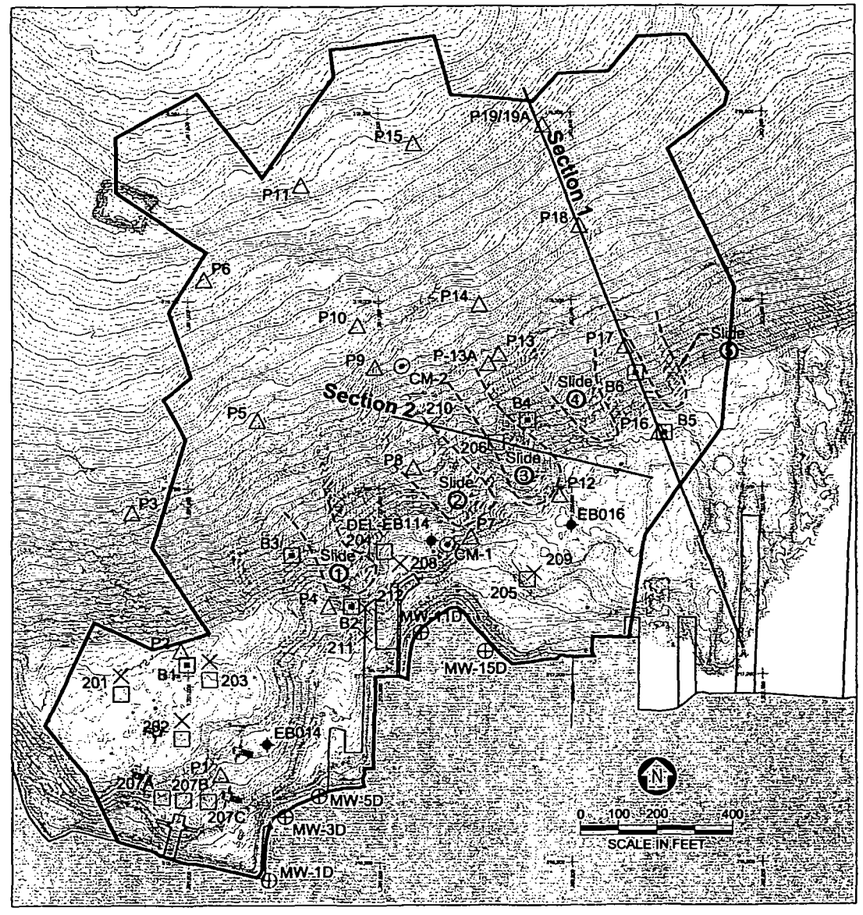
Slope stability analyses of the RA1 cap have led to specific design modifications, as summarized in Section 4 of the Basis of Design. As designed, the RA1 cap has acceptable static and seismic stability.



SECTION 1



SECTION 2



LEGEND

- MLLW
- CAP Design Limits
- Slope Boundaries
- MW-15D — Historical Deep Wells
- EB016 — Historical Deep Sediment Borings
- 201 — Vibracore Borings for Chemical Analysis
- B-1 — Geotechnical Boring
- P-1 — Cone Penetration Test
- CM-1 — Current Meter Deployment
- 211 — Groundwater Discharge Measurements

Figure C-1
Cross Sections for
Slope Stability Analyses

EPA REGION 10

065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

FILENAME: T:\RAC\PSR\Sub-Tasks\Design\90% Design\Design Submittal\Figure C-1.dwg
EDIT DATE: 11/19/02 AT: 14:43

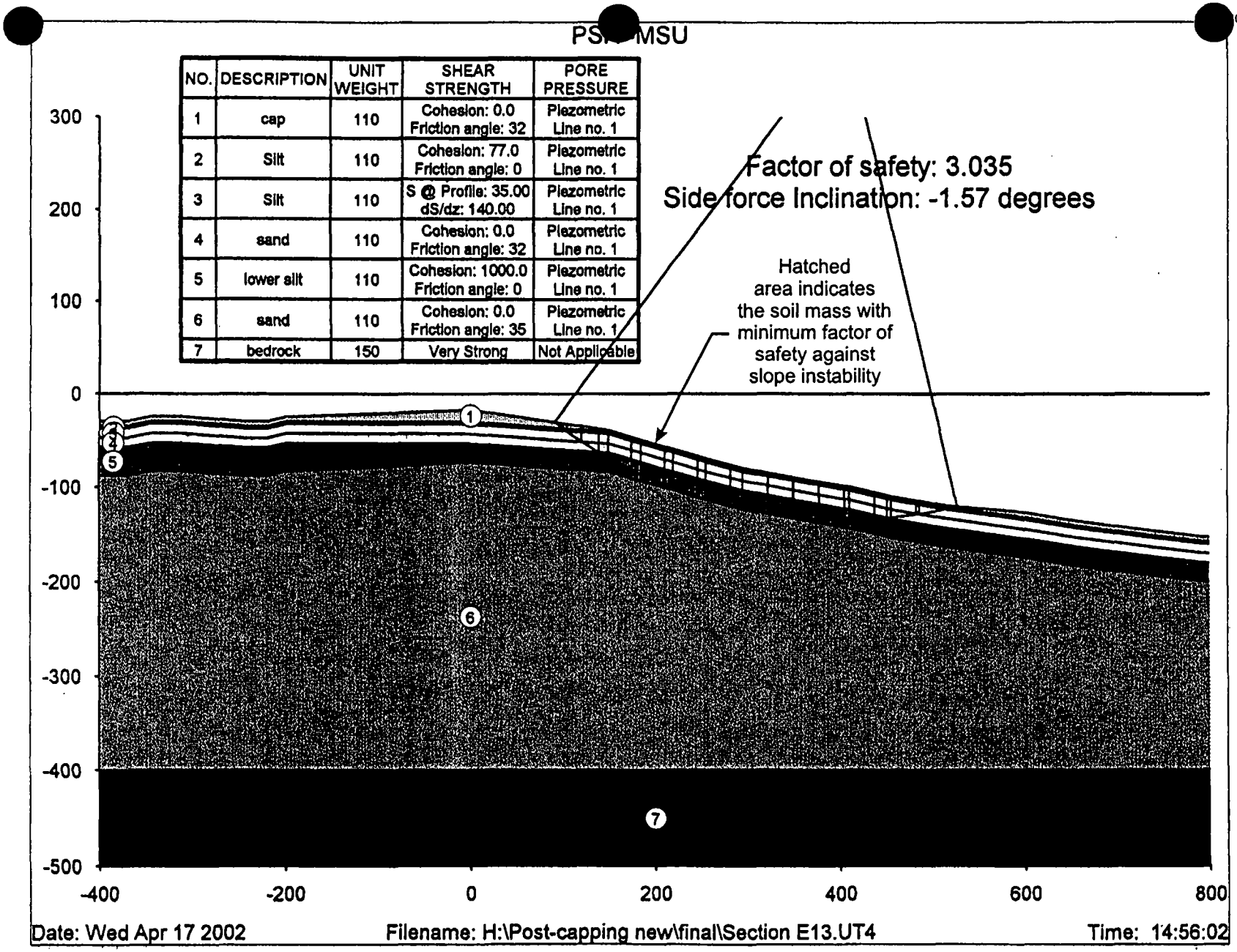


Figure C-2

Graphical Results of Post-Capping Static Slope Stability Analysis at SECTION 1

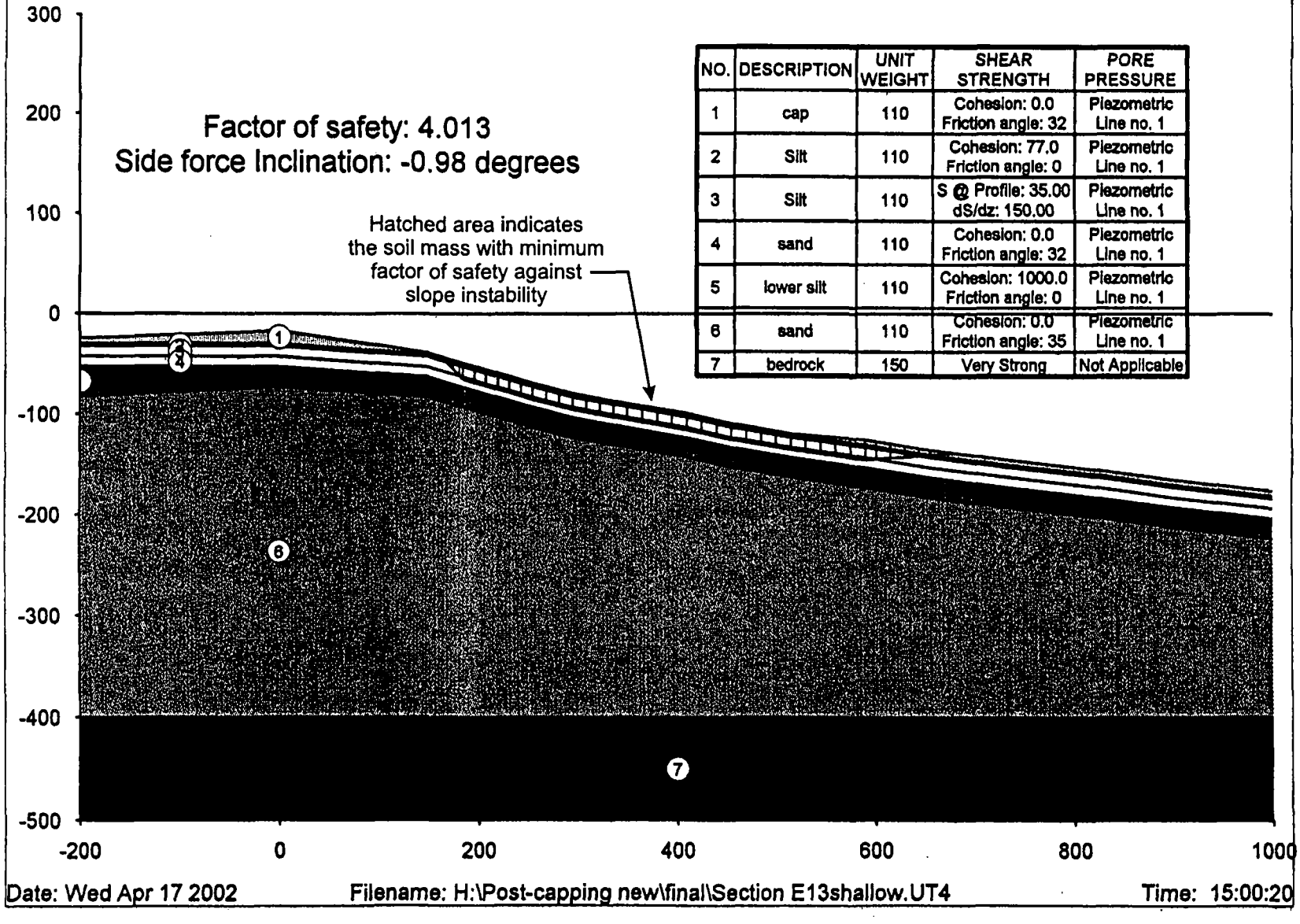
Job No. 53-F4006500.06

Note: This figure shows the initial failure planes predicted by UTEXAS 4.0.
Subsequent movement and runout of material is not shown.

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

PS[illegible] MSU



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 77.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 35.00 dS/dz: 150.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Figure C-3

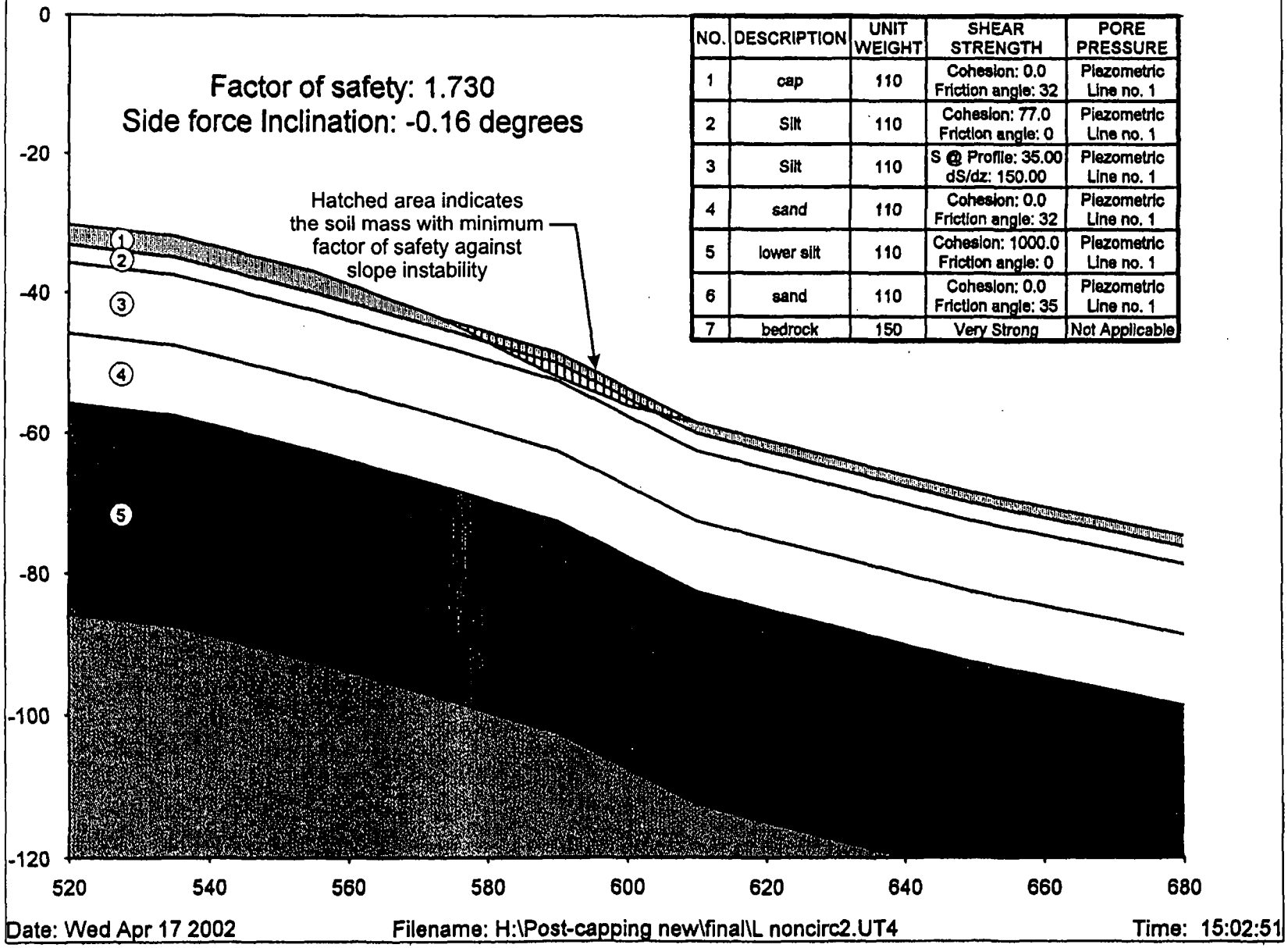
Job No. 53-F4006500.06

Graphical Results of Post-Capping Static Slope Stability Analysis at SECTION 1 – Shallow

EPA REGION 10

Note: This figure shows the initial failure planes predicted by UTEXAS 4.0.
Subsequent movement and runout of material is not shown.

065-RD-RD-101L
PSR Superfund Site



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 77.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 35.00 dS/dz: 150.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Figure C-4

Graphical Results of Post-Capping Static Slope Stability Analysis at SECTION 2

Job No. 53-F4006500.06

Note: This figure shows the initial failure planes predicted by UTEXAS 4.0.
Subsequent movement and runout of material is not shown.

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

F4006500.06_09.cdr

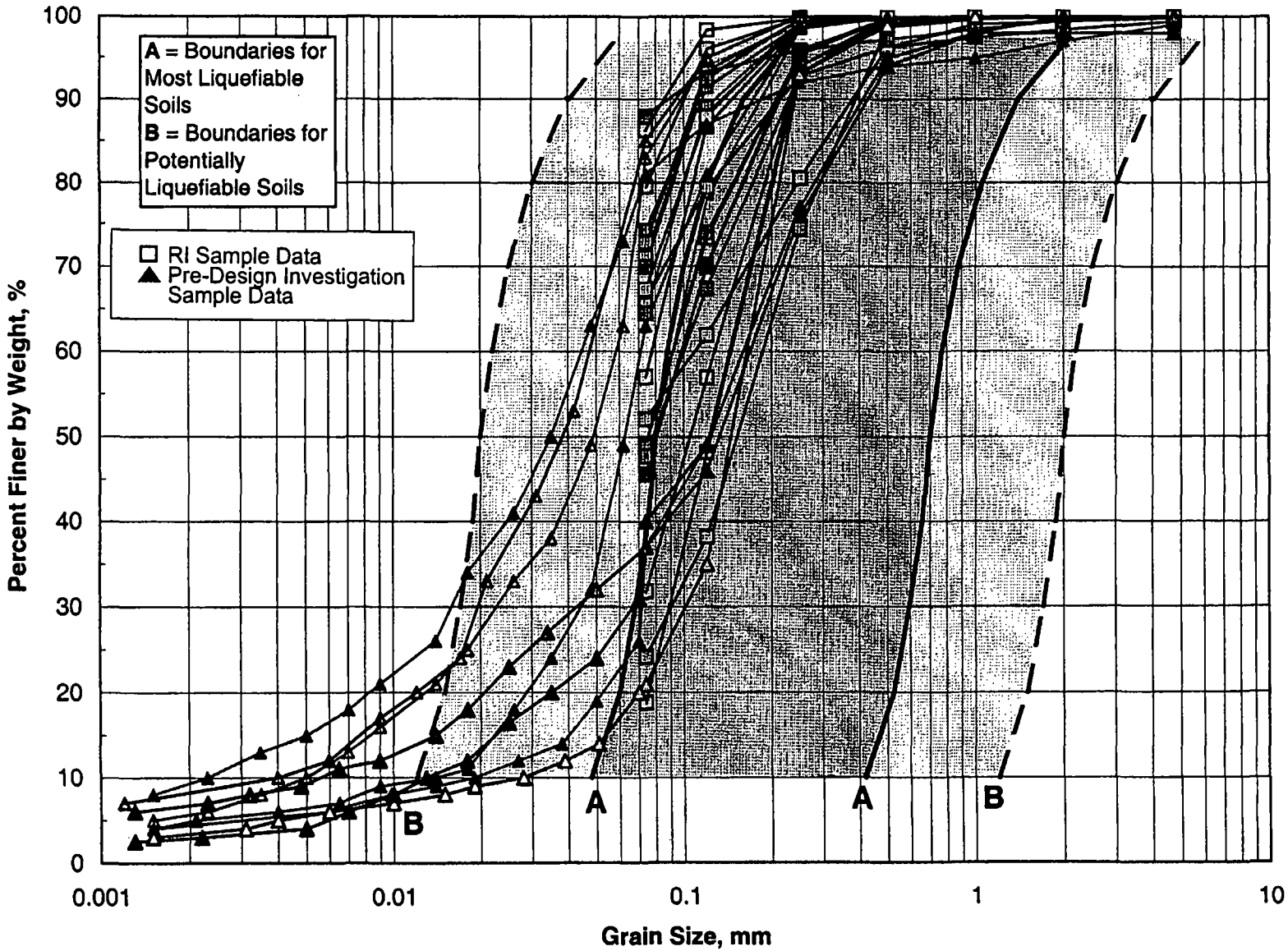


Figure C-5

Job No. 53-F4006500.06

Gradation Curves Defining Limits of Liquefiable Soils After Tsuchida (1970)

Note: Fines content less than 10% by weight are not considered in the Tsuchida criteria

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065-RD-RD-101L
PSR Superfund Site

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-5 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.8
Acceleration=0.22g

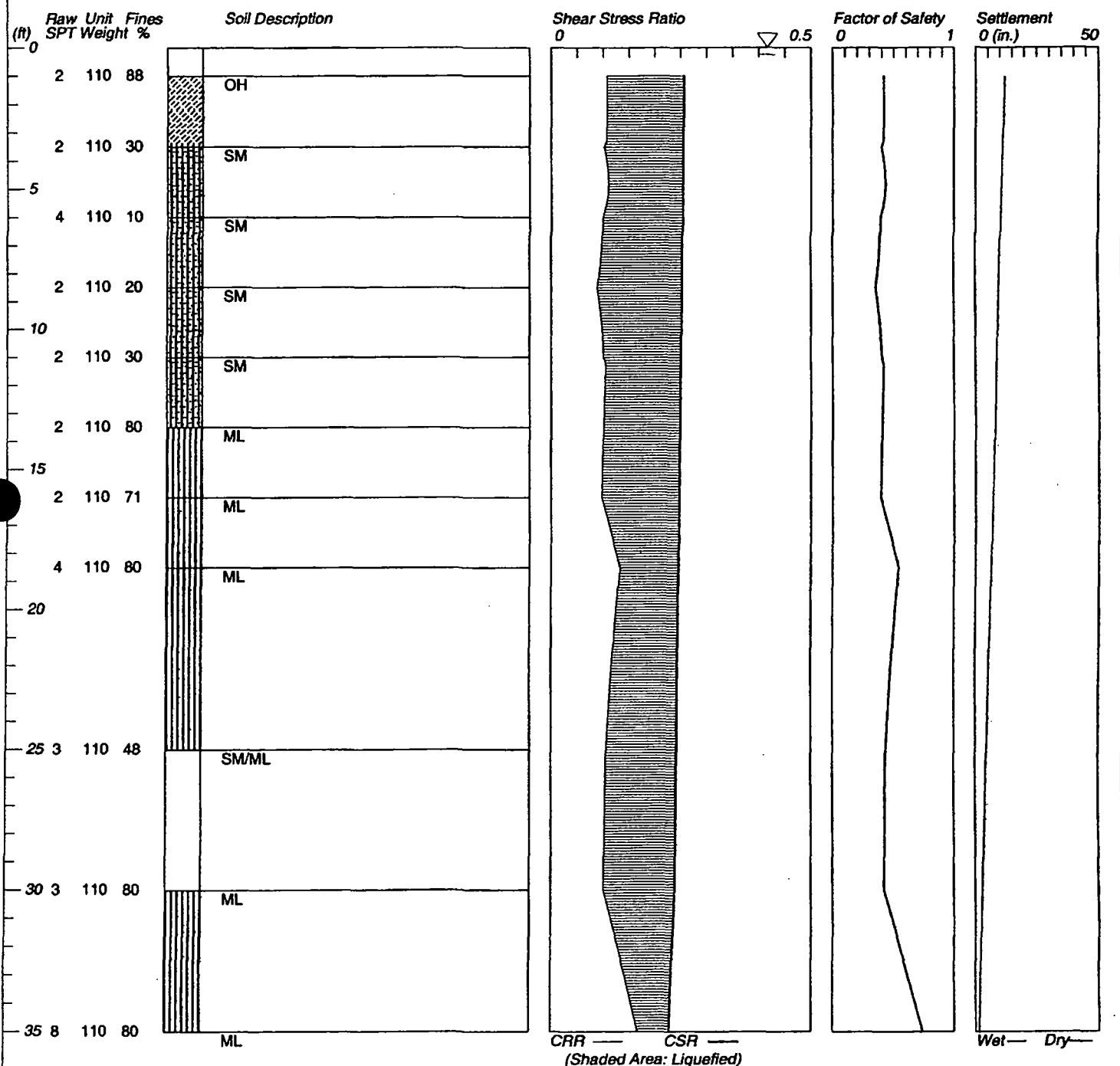


Figure C-6

Results of Liquefaction Analysis for PGA of 0.22g at Boring B5

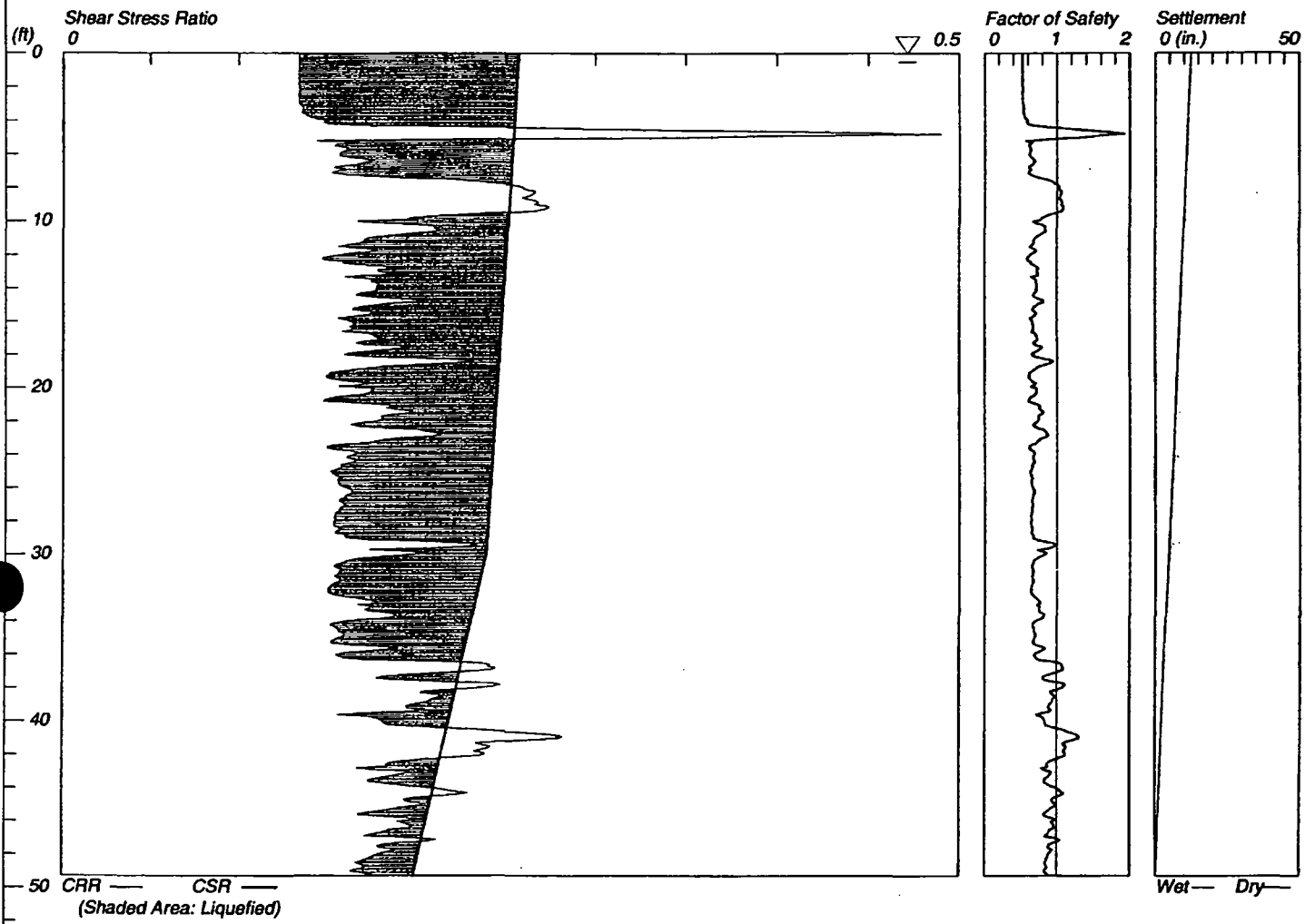
Job No. 53-F4006500.06

LIQUEFACTION ANALYSIS

PSR-MSU - CPT-P12

Hole No.=P12 Water Depth=0 ft Surface Elev.=-28.2

Magnitude=6.8
Acceleration=0.22g



LiquefyPro Version 2.1 CivilTech Software USA www.civiltech.com

Figure C-7

Results of Liquefaction Analysis for PGA of 0.22g at Cone Probe P12

Job No. 53-F4006500.06

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-5 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.8
Acceleration=0.09g

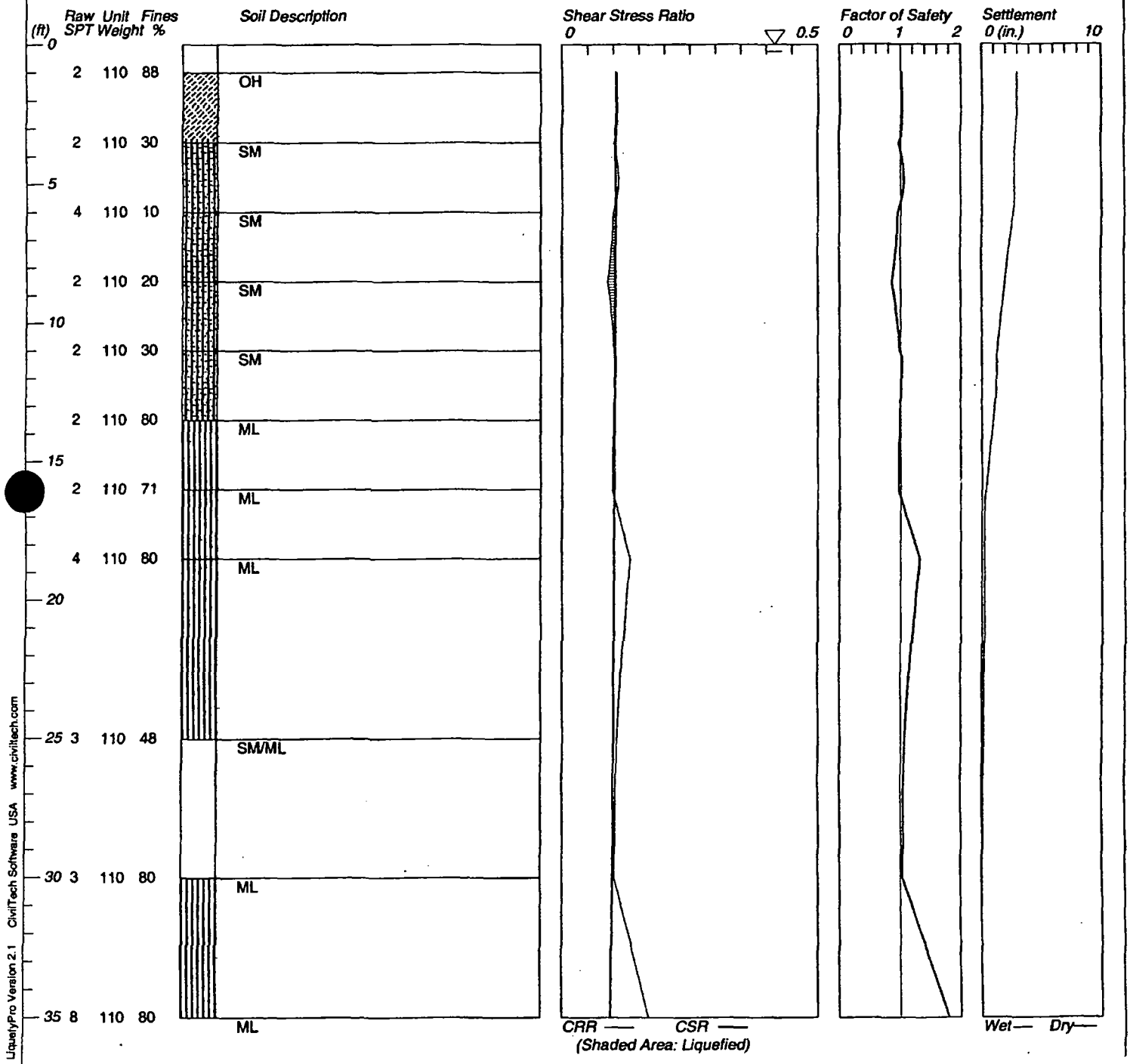


Figure C-8

Results of Liquefaction Analysis for PGA of 0.09g at Boring B5

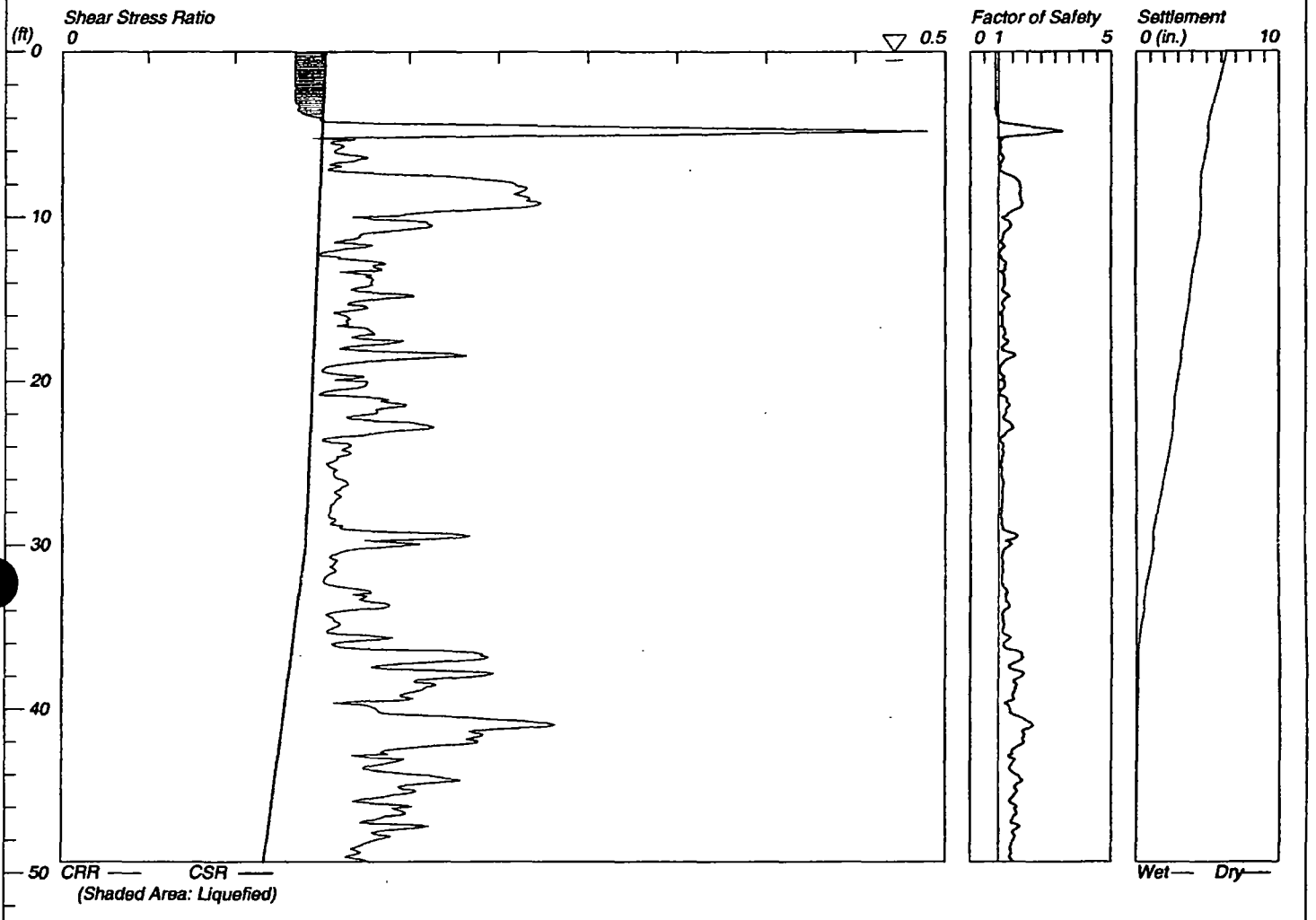
Job No. 53-F4006500.06

LIQUEFACTION ANALYSIS

PSR-MSU - CPT-P12

Hole No.=P12 Water Depth=0 ft Surface Elev.=-28.2

Magnitude=6.8
Acceleration=0.13g

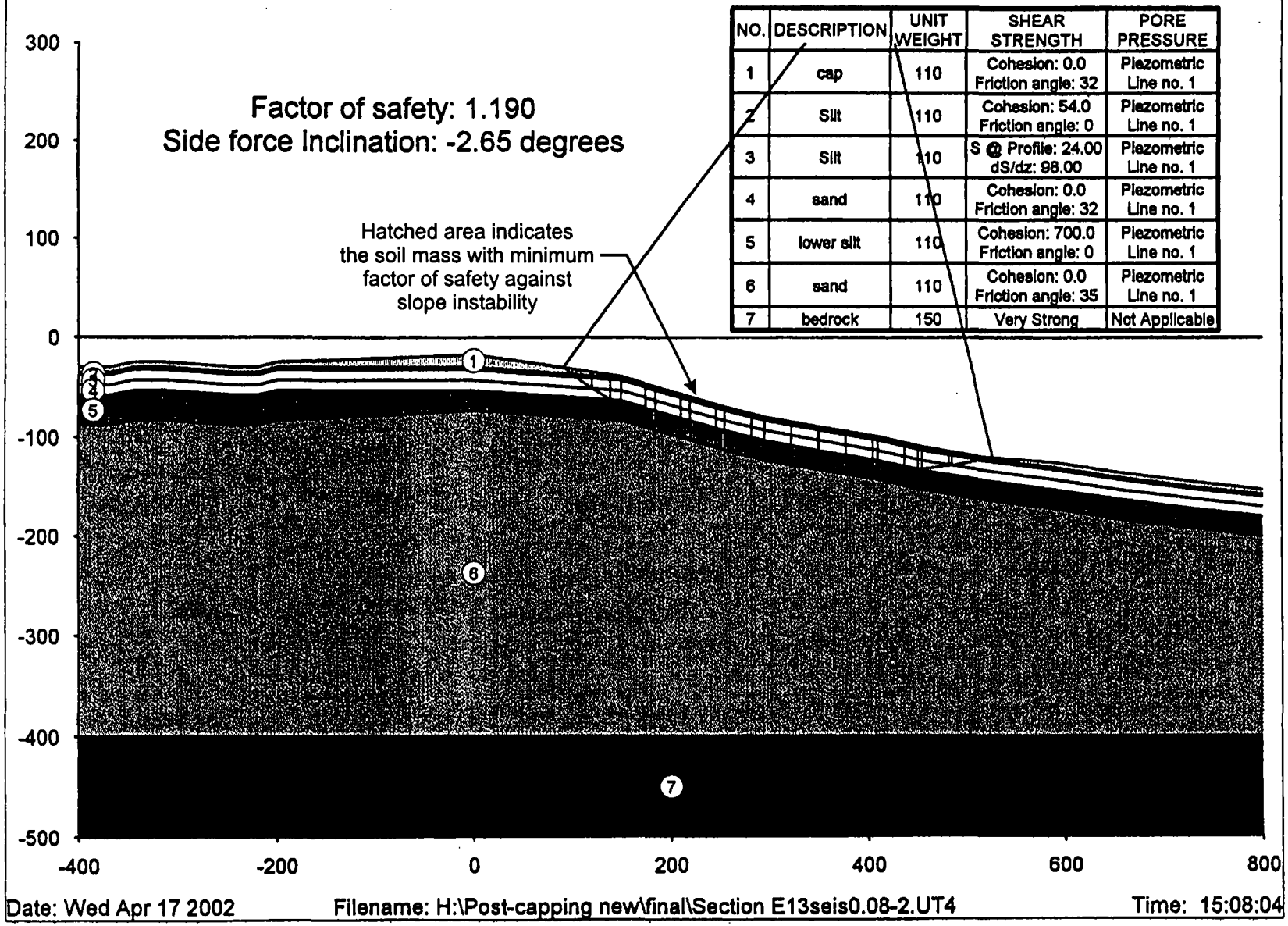


LiquefyPro Version 2.1 CivilTech Software USA www.civiltech.com

Figure C-9

Results of Liquefaction Analysis for PGA of 0.13g at Cone Probe P12

Job No. 53-F4006500.06



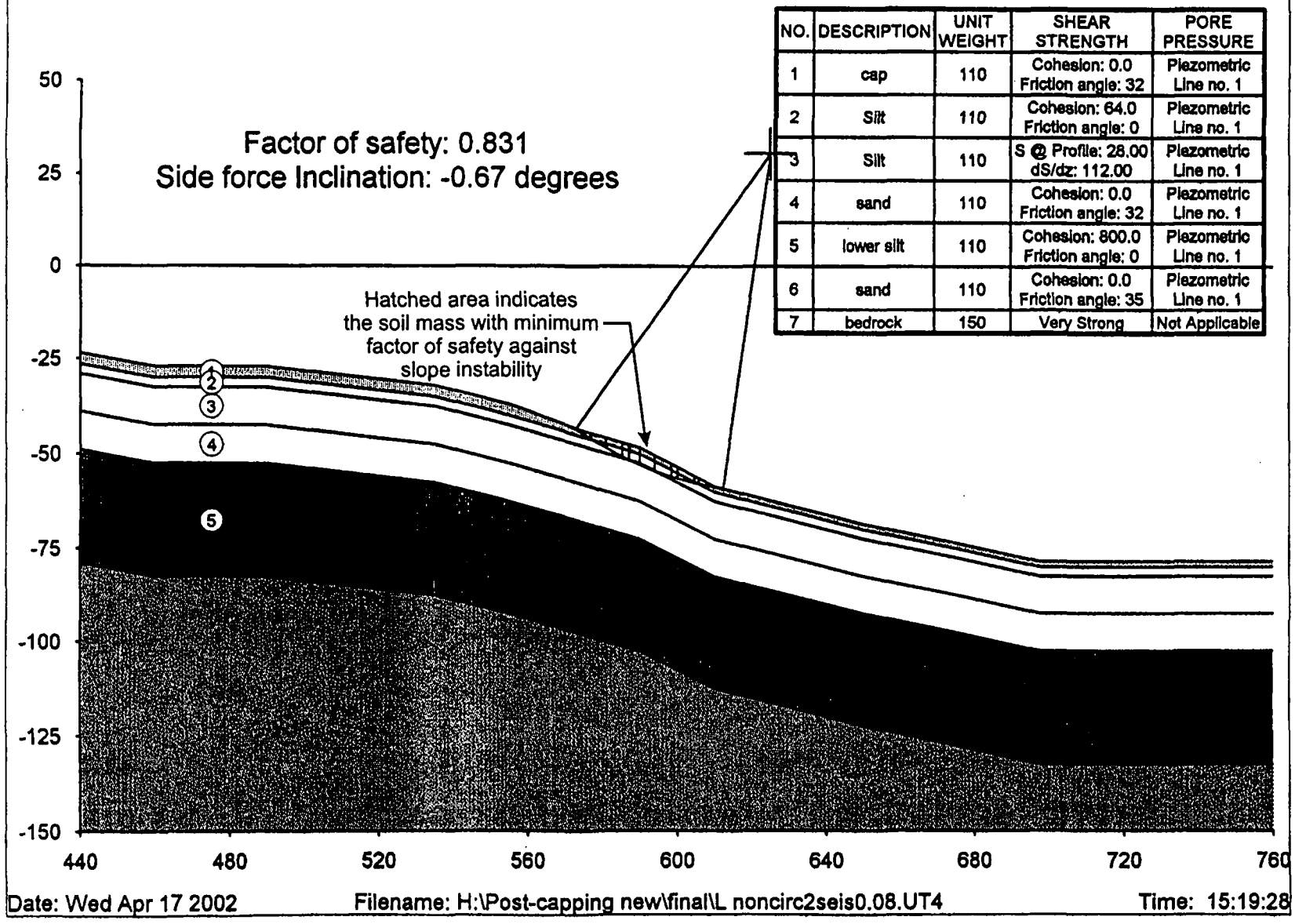
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 54.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 24.00 dS/dz: 98.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 700.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Figure C-10

Job No. 53-F4006500.06

Graphical Results of Post-Capping Seismic Slope Stability Analysis – SECTION 1

Note: This figure shows the initial failure planes predicted by UTEXAS 4.0.
Subsequent movement and runout of material is not shown.



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 64.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 28.00 dS/dz: 112.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Figure C-11

Graphical Results of Post-Capping Seismic Slope Stability Analysis – SECTION 2

Job No. 53-F4006500.06

Note: This figure shows the initial failure planes predicted by UTEXAS 4.0.
Subsequent movement and runout of material is not shown.

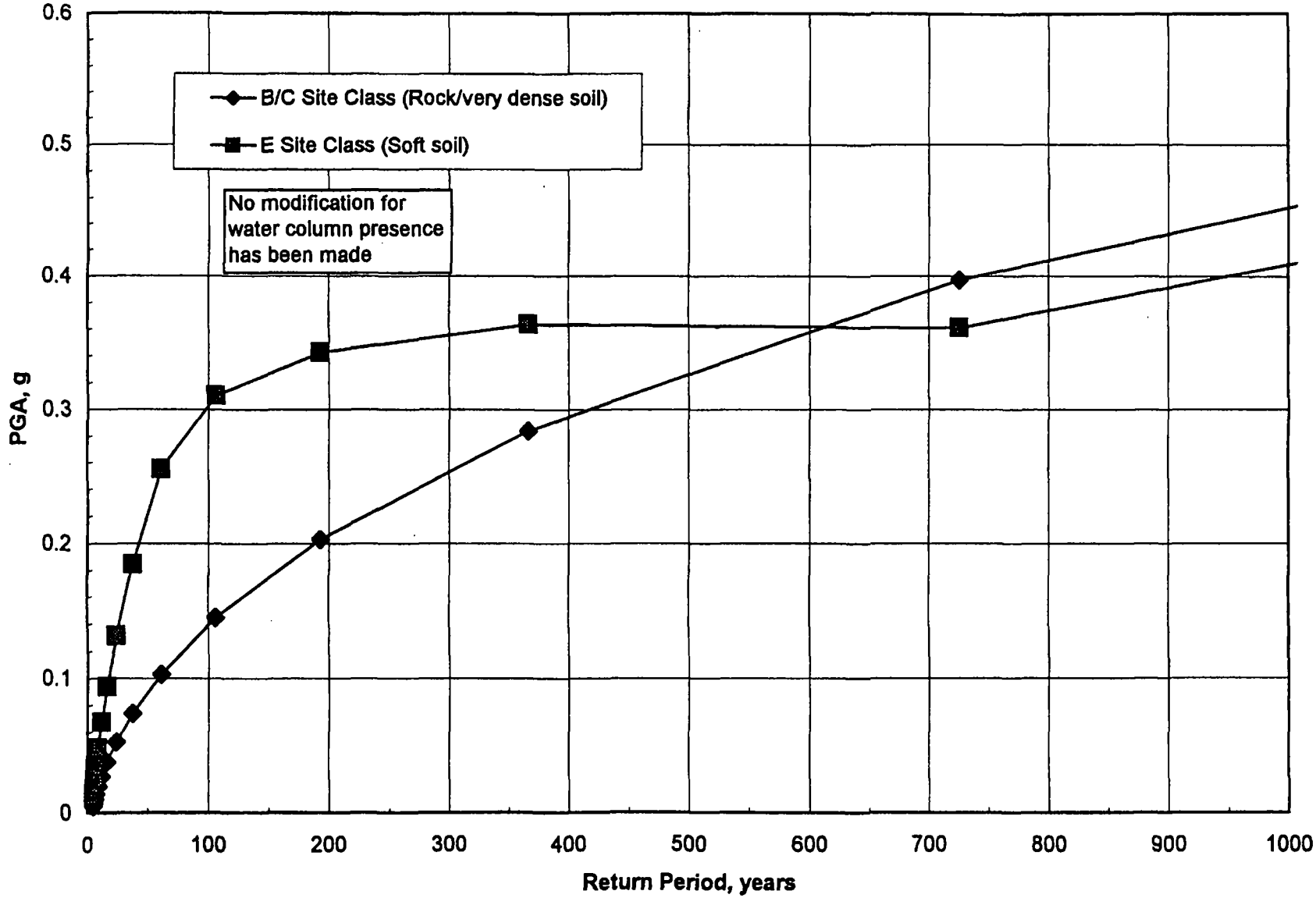


Figure C-12

Hazard Curve for PGA for Harbor Island, Seattle, from USGS Data

Job No. 53-F4006500.06

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

Table C-1
Estimated Primary Settlement of Sediments

Remediation Area	Assumed Cap Thickness (ft)	Subsurface Profile	Primary Settlement (inches)
RA1	5	A	17
RA2, RA3	3	A	12
RA4	1.5	A	5
RA5	5	B	13
RA5	3	B	8
RA5	1.5	B	4.5

Table C-2
Summary of Shear Strength Parameters Used For Slope Stability Analyses

Soil Layer Description	Total Unit Wt. (pcf)	Friction Angle - Phi (degrees)	Undrained Shear Strength (psf)
Cap	110	32	0
Organic Silt	110	0	35
Intermediate Silt	110	0	35 to 1,000
Silty Sand	110	32	0
Lower Silt	110	0	1,000
Silty Sand	110	35	0

Table C-3
Calculated Factors of Safety from Static Slope Stability Analyses

Model	Pre-capping FS	Post-capping FS
SECTION 1	3.21	3.03
SECTION 1 – Shallow Failure	3.94	4.01
SECTION 2	1.58	1.73

Table C-4
Post-Capping Factors of Safety for Seismic Slope Stability Analyses
(Pseudostatic Approach)

MODEL	Calculated FS (20% shear strength reduction)	Calculated FS (30% shear strength reduction)
SECTION 1	1.45	1.30
SECTION 1 – Shallow Failure	1.98	1.94
SECTION 2	0.90	0.78

Note: Assumes Seismic Coefficient of 0.065 (1/2 of PGA)

Table C-5
Calculated Seismic Coefficients Corresponding to a Factor of Safety of 1.0

MODEL	Calculated Seismic Coefficient (20% shear strength reduction)	Calculated Seismic Coefficient (30% shear strength reduction)
SECTION 1	0.14	0.11
SECTION 1 – Shallow Failure	0.20	0.19
SECTION 2	0.03	0.01

Note: Seismic Coefficient = ½ PGA

ATTACHMENT C-1
GEOTECHNICAL ANALYSES

CONSOLIDATION ANALYSIS

CONSOL OUTPUT FILE PRINTOUT FOR MODEL A WITH CAP THICKNESS = 5 FT

CONSOL -- 1-D CONSOLIDATION ANALYSIS

-- VERSION 2.0 --

VIRGINIA TECH DEPARTMENT OF CIVIL ENGINEERING

DATE: 3- 8-2002
INPUT FILE: H:\Consol\Psr-5.DAT
OUTPUT FILE: H:\Consol\Psr-5.OUT
PLOT FILE: H:\Consol\Psr-5.PLT

TITLE: PSR_MSU - Consolidation settlement - 5 ft cap

**** C O N T R O L D A T A ****

NUMBER OF COMPRESSIBLE UNITS	9
NUMBER OF SOIL LAYERS	16
NUMBER OF DIFFERENT SOILS	2
ELEVATION OF THE GROUND SURFACE	-31.40
ELEVATION OF THE TOP OF THE COMPRESSIBLE SOIL MASS	-31.40
GROUND WATER ELEVATION	.00
UNIT WEIGHT OF WATER	62.40
MST. UT. WT. OF SOIL BTWN. GS & COMP. SOIL MASS	130.00
SAT. UT. WT. OF SOIL BTWN. GS & COMP. SOIL MASS	130.00

**** U N I T B O U N D A R Y D A T A ****

UNIT NUMBER	TOP BOUNDARY	BOTTOM BOUNDARY	DRAINAGE CONDITION
1	1	4	2
2	5	5	2
3	6	8	2
4	9	11	2
5	12	12	2
6	13	13	2
7	14	14	2
8	15	15	2
9	16	16	2

**** S O I L P R O P E R T Y D A T A ****

SOIL TYPE	UNIT WEIGHT	VOID RATIO	Cc	Ccs	Cv	Cvs
1	92.80	2.14	.57	.06	500.00	999.00
2	110.00	1.09	.20	.02	990.00	999.00

**** S U B L A Y E R D A T A ****

	CENTER	BOTTOM		OVERBN	PRECONS	SOIL

LAYER	ELEV	ELEV	THICK	PRESSURE	PRESSURE	TYPE
1	-33.20	-35.00	3.60	54.72	54.72	1
2	-37.50	-40.00	5.00	228.44	228.44	2
3	-42.50	-45.00	5.00	466.44	466.44	2
4	-47.50	-50.00	5.00	704.44	704.44	2
5	-52.50	-55.00	5.00	942.44	942.44	2
6	-57.50	-60.00	5.00	1180.44	1180.44	2
7	-62.50	-65.00	5.00	1418.44	1418.44	2
8	-65.50	-66.00	1.00	1561.24	1561.24	2
9	-69.00	-72.00	6.00	1727.84	1727.84	2
10	-75.00	-78.00	6.00	2013.44	2013.44	2
11	-83.00	-88.00	10.00	2394.24	2394.24	2
12	-93.00	-98.00	10.00	2870.24	2870.24	2
13	-103.00	-108.00	10.00	3346.24	3346.24	2
14	-113.00	-118.00	10.00	3822.24	3822.24	2
15	-123.00	-128.00	10.00	4298.24	4298.24	2
16	-133.00	-138.00	10.00	4774.24	4774.24	2

**** NUMBER OF LOADCASES TO BE ANALYSED: 1

**** L O A D C A S E : 1 ****
**** L A R G E A R E A L F I L L ****

TIME INTERVALS: .00 .05 .10 .25 .50 1.00
2.00 5.00 10.00 20.00 50.00

OLD FILL ELEVATION ..... -31.40
NEW FILL ELEVATION ..... -26.40
CHANGE IN FILL THICKNESS 5.00
MOIST UNIT WEIGHT OF FILL 130.00
SATURATED UNIT WEIGHT OF FILL 130.00

LAYER	THICK.	VOID RATIO	INITIAL PRESSURE	PRECONS. PRESSURE	FINAL PRESSURE	ULT. SETTL.
1	3.60	2.14	54.72	54.72	392.72	.56
2	5.00	1.09	228.44	228.44	566.44	.19
3	5.00	1.09	466.44	466.44	804.44	.11
4	5.00	1.09	704.44	704.44	1042.44	.08
5	5.00	1.09	942.44	942.44	1280.44	.06
6	5.00	1.09	1180.44	1180.44	1518.44	.05
7	5.00	1.09	1418.44	1418.44	1756.44	.04
8	1.00	1.09	1561.24	1561.24	1899.24	.00
9	6.00	1.09	1727.84	1727.84	2065.84	.04
10	6.00	1.09	2013.44	2013.44	2351.44	.04
11	10.00	1.09	2394.24	2394.24	2732.24	.05
12	10.00	1.09	2870.24	2870.24	3208.24	.05
13	10.00	1.09	3346.24	3346.24	3684.24	.04
14	10.00	1.09	3822.24	3822.24	4160.24	.04
15	10.00	1.09	4298.24	4298.24	4636.24	.03
16	10.00	1.09	4774.24	4774.24	5112.24	.03

ULTIMATE SETTLEMENT WITHOUT CORRECTION FOR BUOYANCY : 1.43

**** TIME SINCE LOAD WAS APPLIED: .00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.56	308.45	84.27
-39.56	359.92	206.52
-44.48	682.19	122.25
-49.39	704.44	.00
-54.29	942.44	.00
-59.21	1436.31	82.13
-64.18	1674.31	82.13
-67.15	1561.24	.00
-70.62	1963.23	102.61
-76.59	2248.83	102.61
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: .01 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.57	314.71	78.01
-39.57	371.53	194.91
-44.48	687.54	116.90
-49.39	704.44	.00
-54.29	942.44	.00
-59.22	1442.66	75.78
-64.18	1680.66	75.78
-67.15	1561.24	.00
-70.62	1968.78	97.06
-76.59	2254.38	97.06
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: .05 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.75	388.11	4.61
-39.68	550.25	16.19
-44.54	792.86	11.58
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1515.77	2.67
-64.20	1753.77	2.67
-67.17	1561.24	.00
-70.64	2055.76	10.08
-76.60	2341.36	10.08

-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: .10 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.54	.18
-39.69	565.81	.63
-44.54	803.98	.46
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.40	.04
-64.21	1756.40	.04
-67.17	1561.24	.00
-70.64	2065.26	.57
-76.60	2350.86	.57
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: .25 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: .50 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00

-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 1.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 2.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 5.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 10.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 20.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00

-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

**** TIME SINCE LOAD WAS APPLIED: 50.00 ****

ELEVATION	EFFECTIVE STRESS	PORE PRESSURE
-35.76	392.72	.00
-39.69	566.44	.00
-44.54	804.44	.00
-49.43	704.44	.00
-54.33	942.44	.00
-59.25	1518.44	.00
-64.21	1756.44	.00
-67.17	1561.24	.00
-70.64	2065.84	.00
-76.60	2351.44	.00
-84.45	2394.24	.00
-94.20	2870.24	.00
-103.94	3346.24	.00
-113.68	3822.24	.00
-123.41	4298.24	.00
-133.14	4774.24	.00

FOR THIS LOAD CASE		ACCUMULATED		SURFACE
TIME	SETTLEMENT	TIME	SETTLEMENT	ELEVATION
.01	2.62	.01	2.62	-29.02
.05	2.83	.05	2.83	-29.23
.10	2.84	.10	2.84	-29.24
.25	2.84	.25	2.84	-29.24
.50	2.84	.50	2.84	-29.24
1.00	2.84	1.00	2.84	-29.24
2.00	2.84	2.00	2.84	-29.24
5.00	2.84	5.00	2.84	-29.24
10.00	2.84	10.00	2.84	-29.24
20.00	2.84	20.00	2.84	-29.24
50.00	2.84	50.00	2.84	-29.24

**** C O M P L E T E T I M E S E T T L E M E N T R E C O R D ****

TIME	SETTLEMENT
.01	2.62
.05	2.83
.10	2.84
.25	2.84
.50	2.84
1.00	2.84
2.00	2.84

5.00	2.84
10.00	2.84
20.00	2.84
50.00	2.84

LIQUEFACTION ANALYSES

FIGURES

1) CPT-analyses, PGA = 0.22 g

2) SPT-analyses, PGA = 0.22 g

3) CPT-analyses, PGA corresponding to Factor of Safety = 1

4) SPT-analyses, PGA corresponding to Factor of Safety = 1

LIQUEFY-PRO OUTPUT FILE PRINTOUTS

1) CPT-analysis for probe P12, PGA = 0.22 g

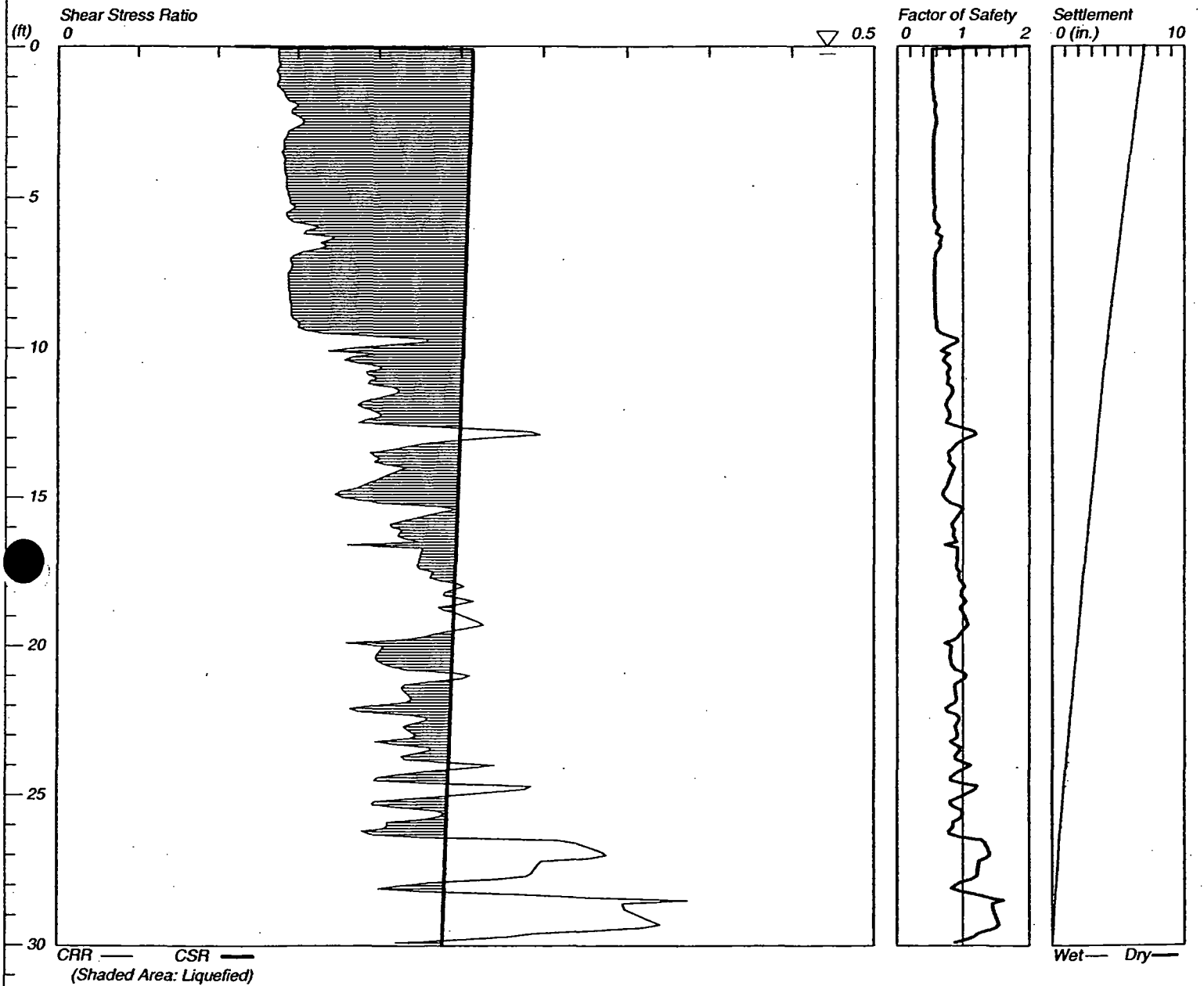
2) SPT-analysis for boring B5, PGA = 0.22 g

LIQUEFACTION ANALYSIS

PSR-MSU CPT P1

Hole No.=P1 Water Depth=0 ft Surface Elev.=-26.3

Magnitude=6.8
Acceleration=0.22g



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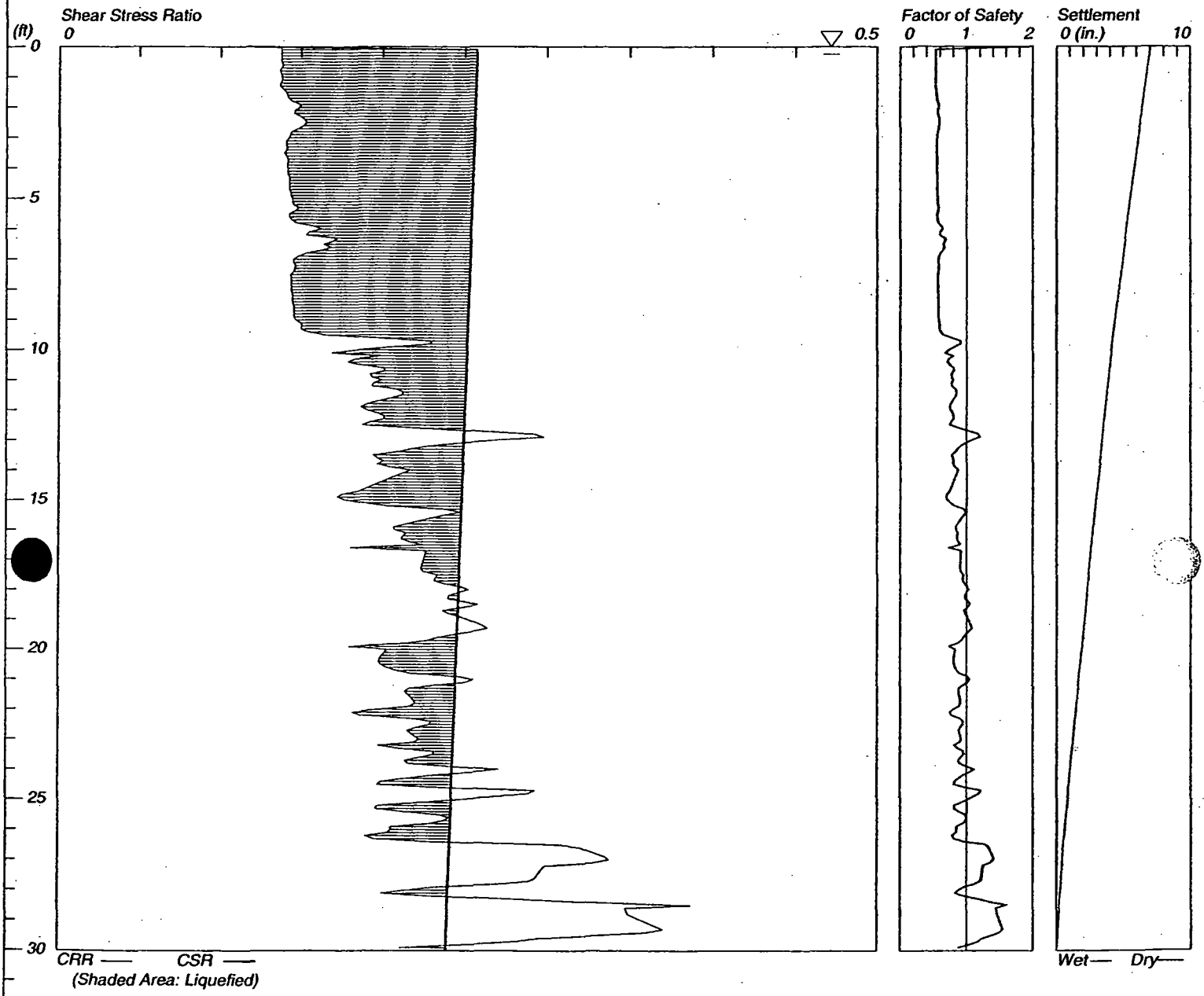
LIQUEFACTION ANALYSIS

PSR-MSU CPT P1

Hole No.=P1 Water Depth=0 ft Surface Elev.=-26.3

Magnitude=6.5
Acceleration=0.22g



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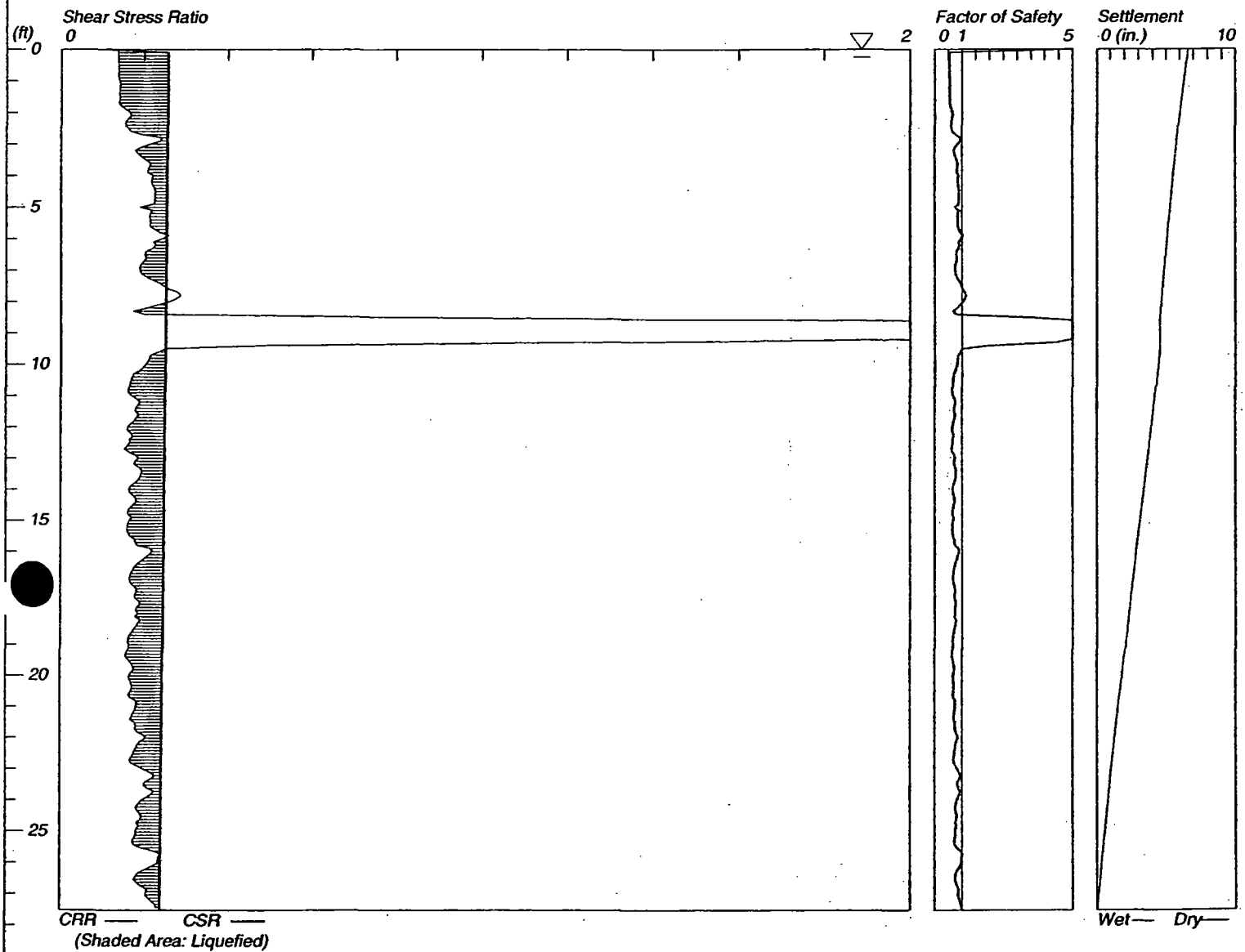
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=P2 Water Depth=0 ft Surface Elev.=-32.5

Magnitude=6.8
Acceleration=0.22g



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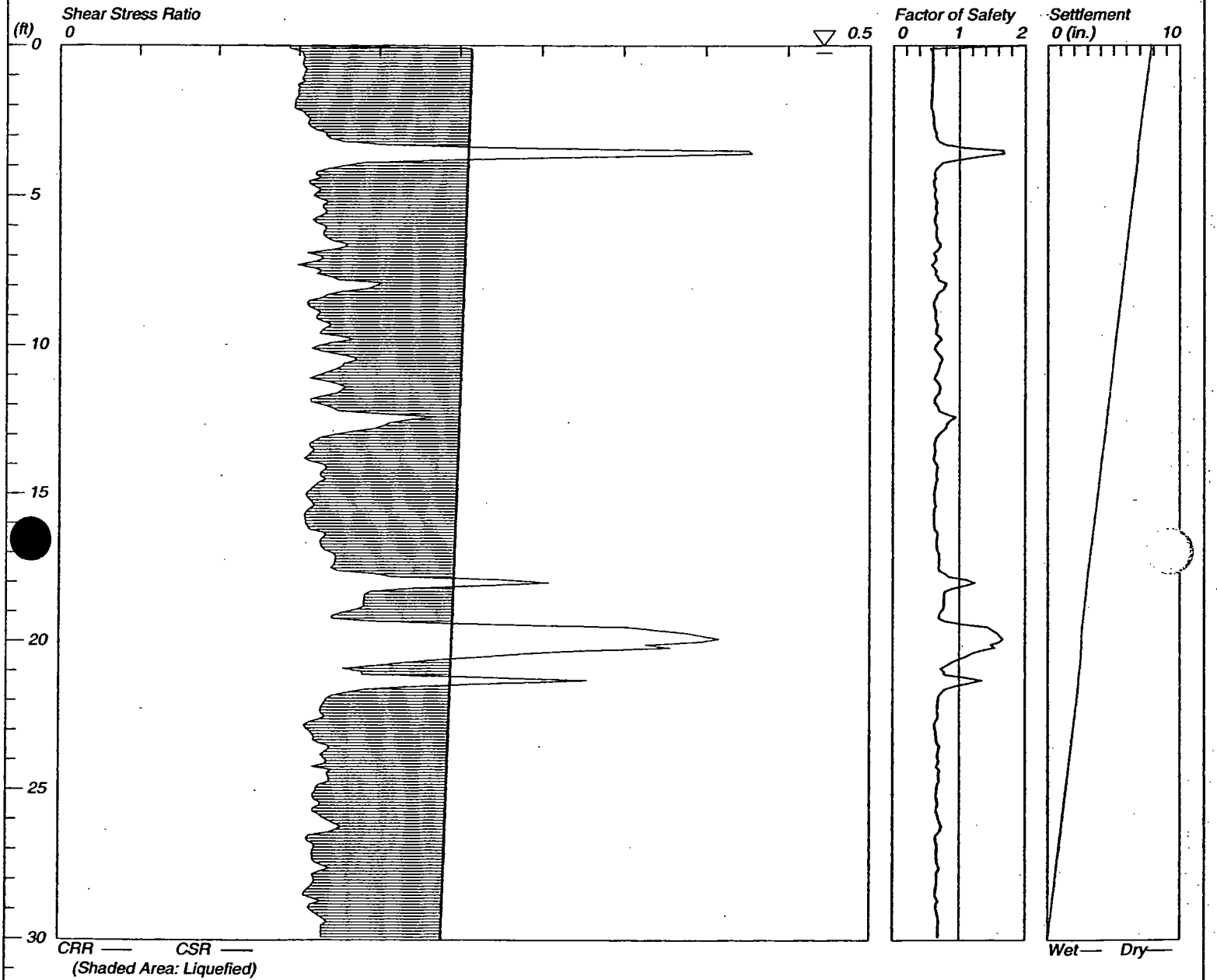
LIQUEFACTION ANALYSIS

PSR-MSU CPT P3

Hole No.=P3 Water Depth=0 ft Surface Elev.=-125.

Magnitude=6.6
Acceleration=0.22g



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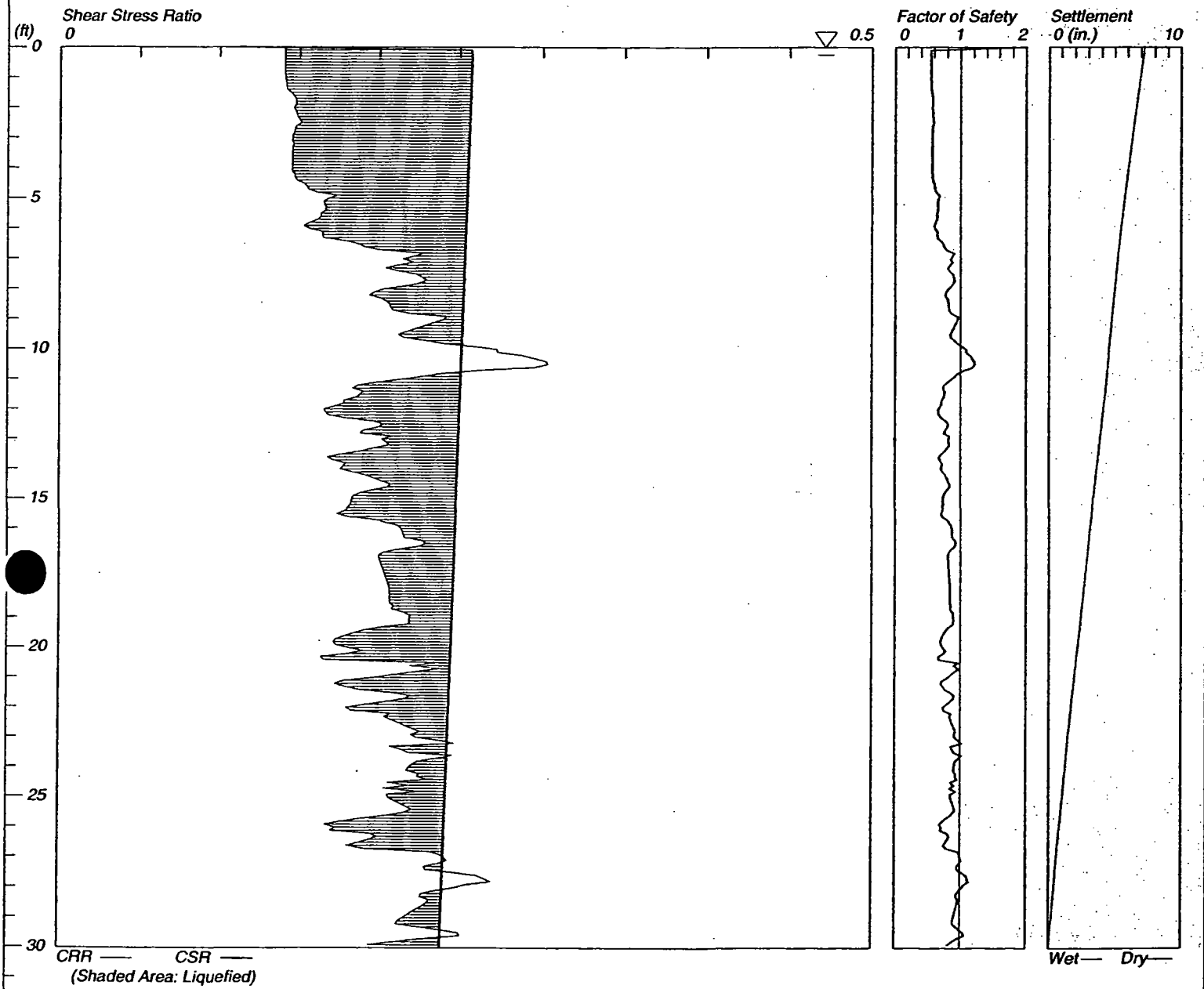
LIQUEFACTION ANALYSIS

PSR-MSU P4

Hole No.=P4 Water Depth=0 ft Surface Elev.=-20.9

Magnitude=6.8
Acceleration=0.22g



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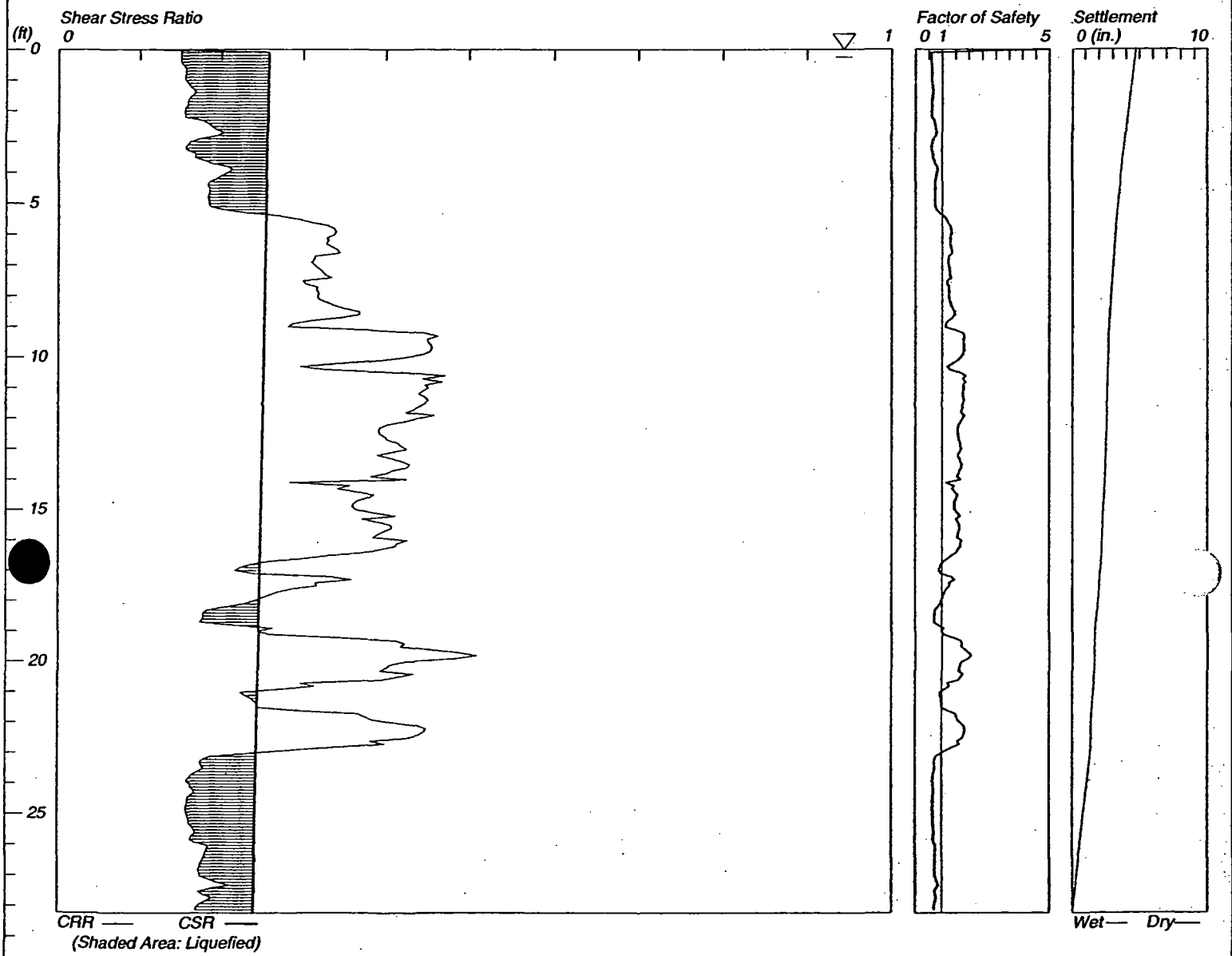
LIQUEFACTION ANALYSIS

PSR-MSU CPT P5

Hole No.=P5 Water Depth=0 ft Surface Elev.=-126.

Magnitude=6.
Acceleration=0.22g



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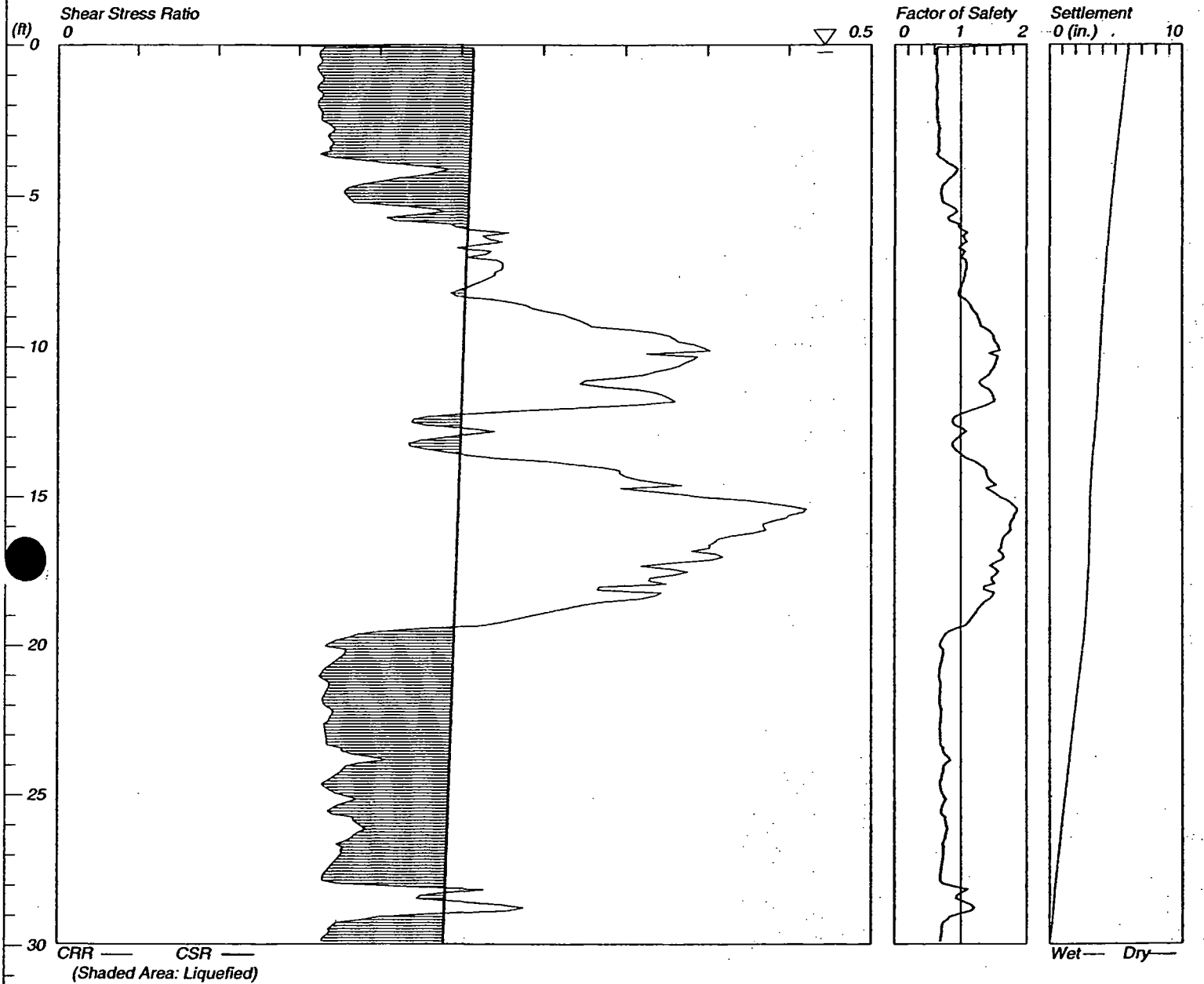
LIQUEFACTION ANALYSIS

PSR-MSU CPT P6

Hole No.=P6 Water Depth=0 ft Surface Elev.=-181.

Magnitude=6.8
Acceleration=0.22g



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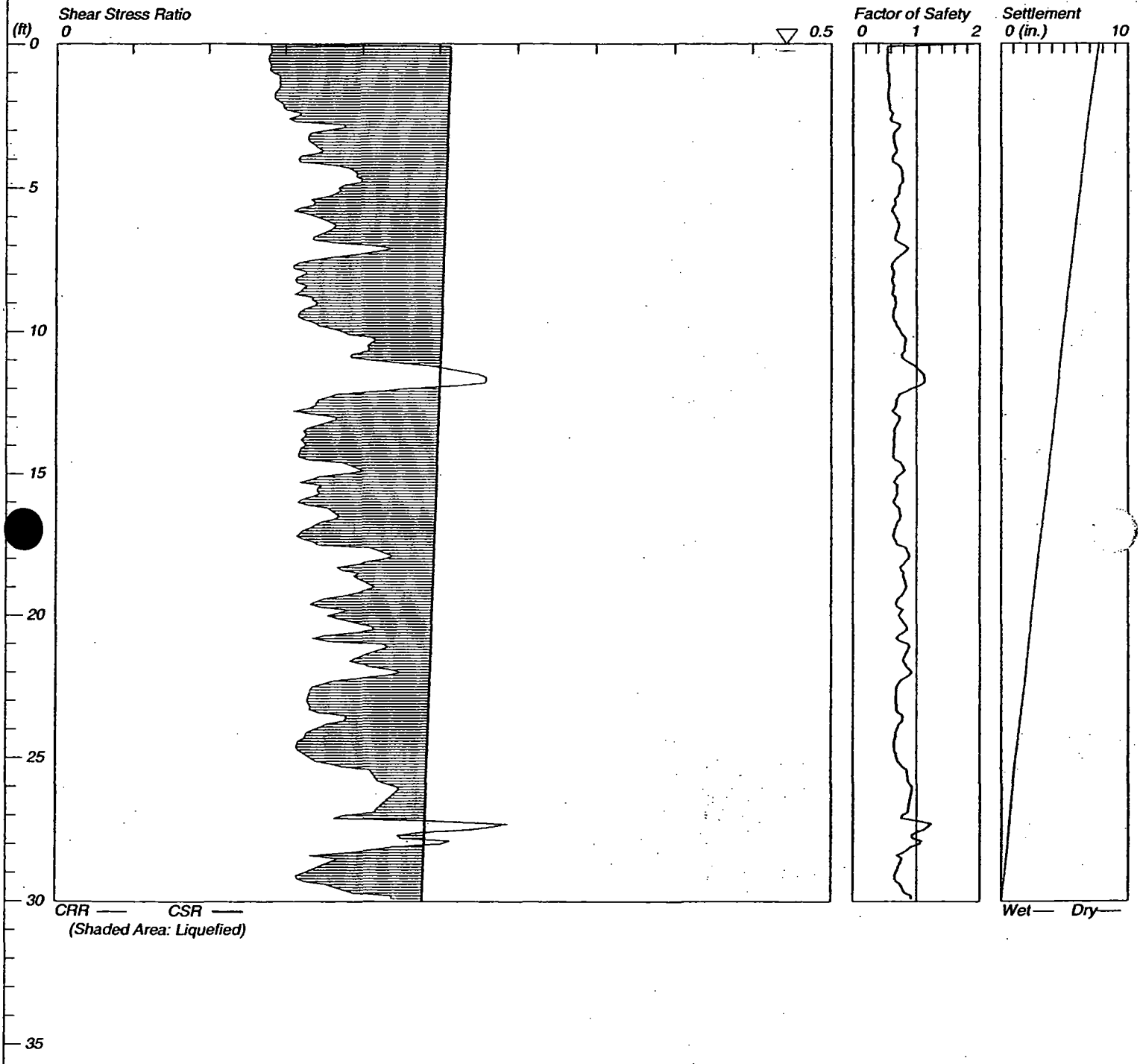
LIQUEFACTION ANALYSIS

PSR-MSU CPT P7

Hole No.=P7 Water Depth=0 ft Surface Elev.=-20.3

Magnitude=6.0
Acceleration=0.22g



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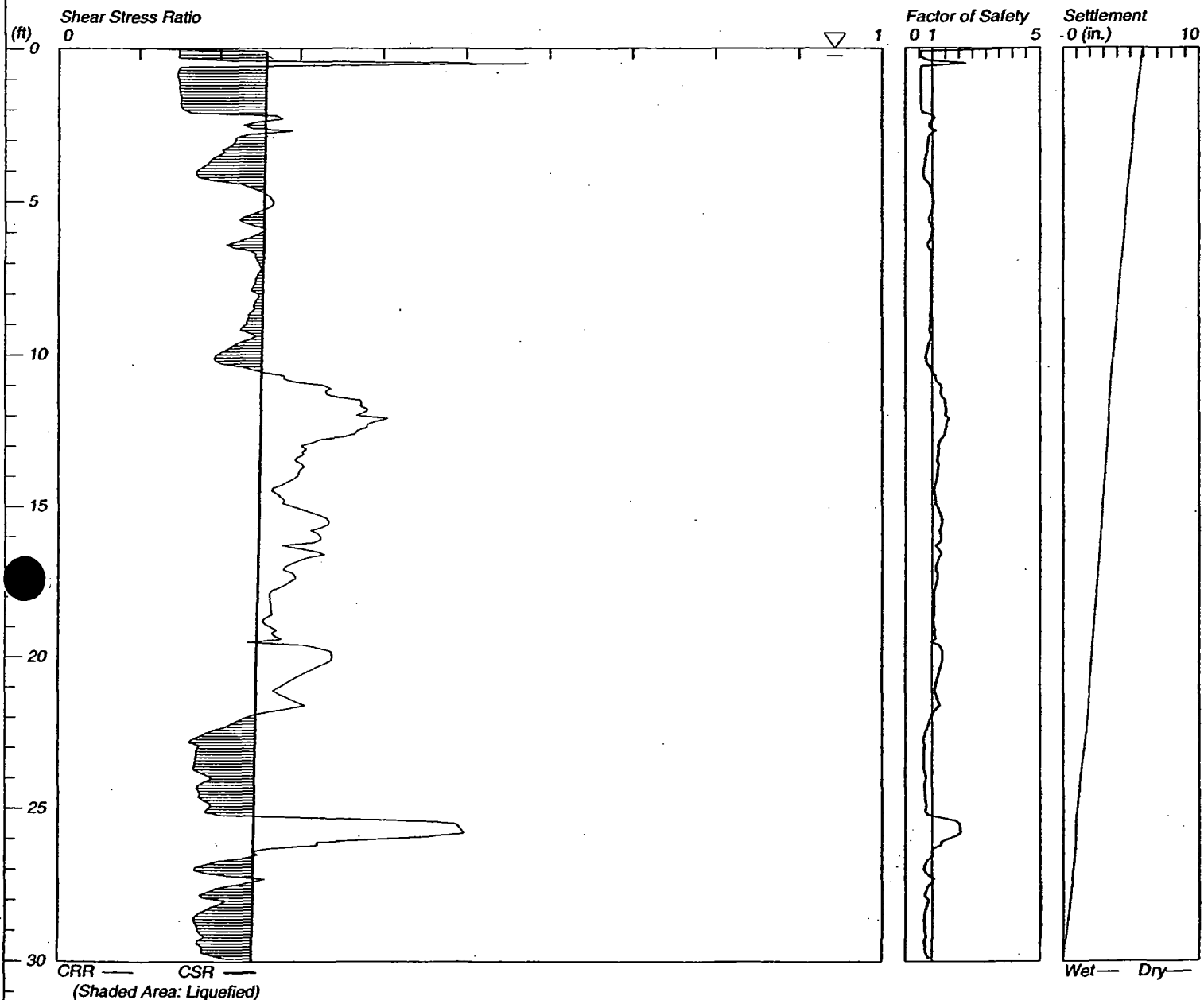
LIQUEFACTION ANALYSIS

PSR-MSU CPT P8

Hole No.=P8 Water Depth=0 ft Surface Elev.=-82.4

Magnitude=6.8
Acceleration=0.22g



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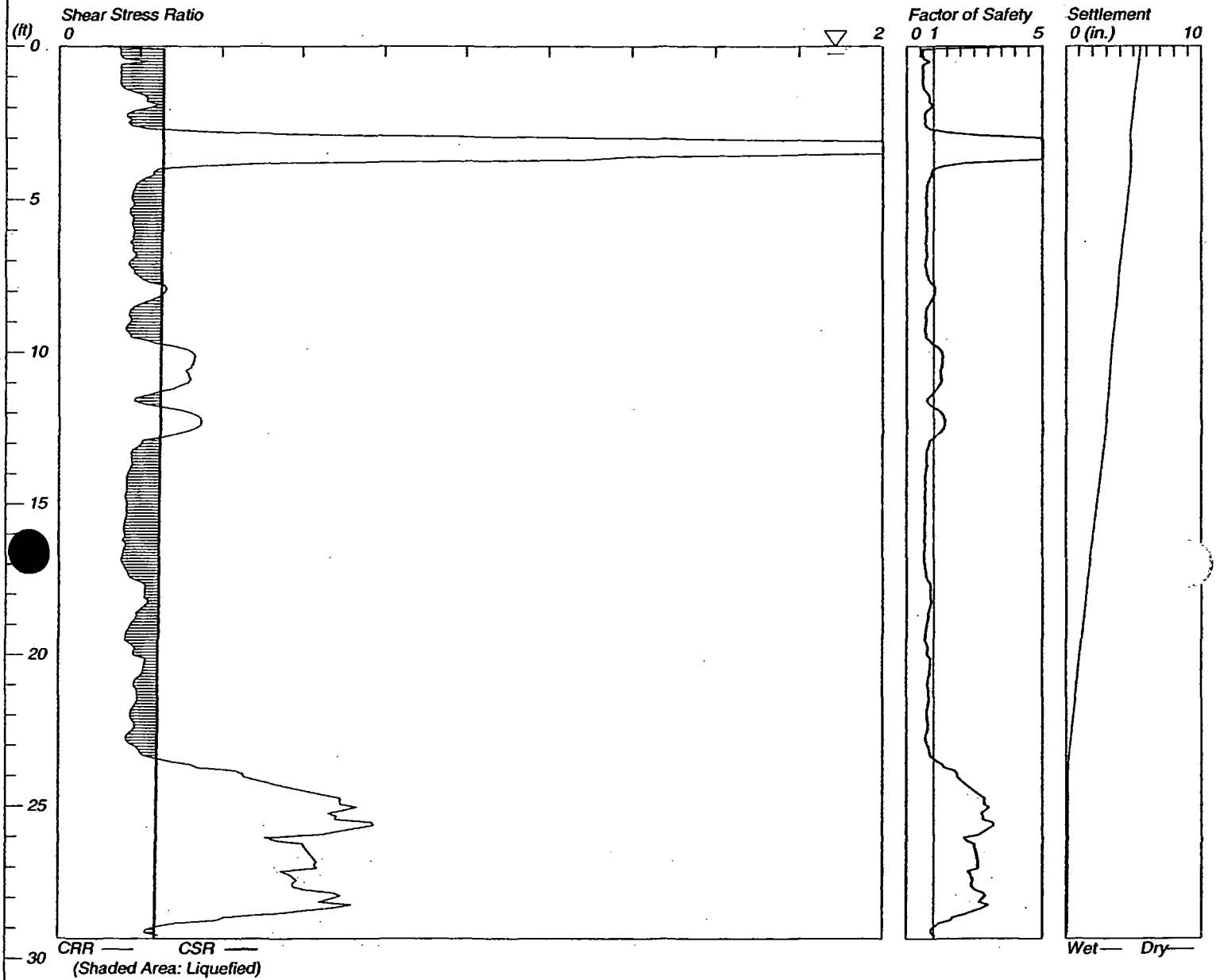
LIQUEFACTION ANALYSIS

PSR-MSU CPT P9

Hole No.=P9 Water Depth=0 ft Surface Elev.=-133.

Magnitude=6.8
Acceleration=0.22g



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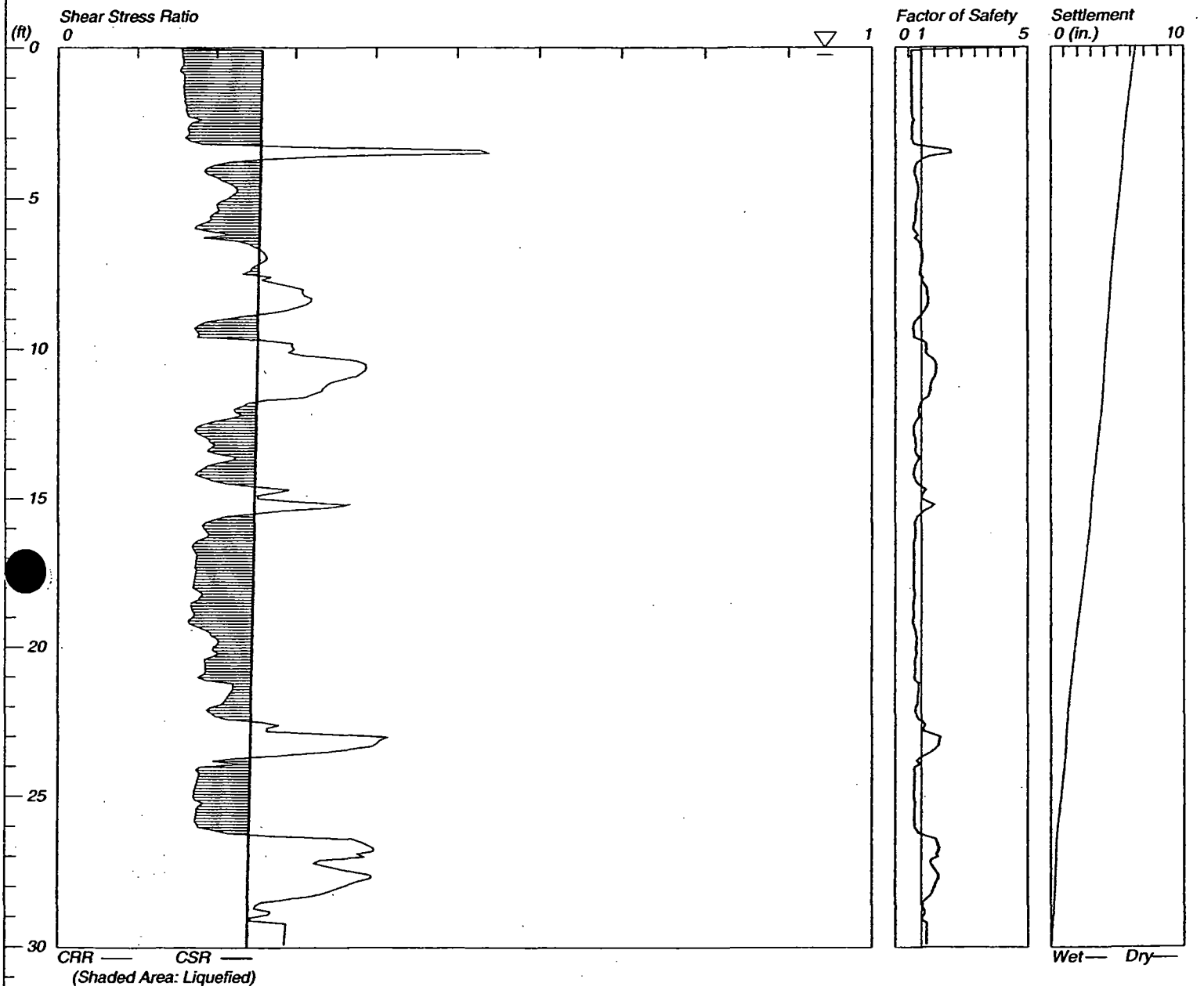
LIQUEFACTION ANALYSIS

PSR-MSU CPT P10

Hole No.=P10 Water Depth=0 ft Surface Elev.=-155

Magnitude=6.8
Acceleration=0.22g



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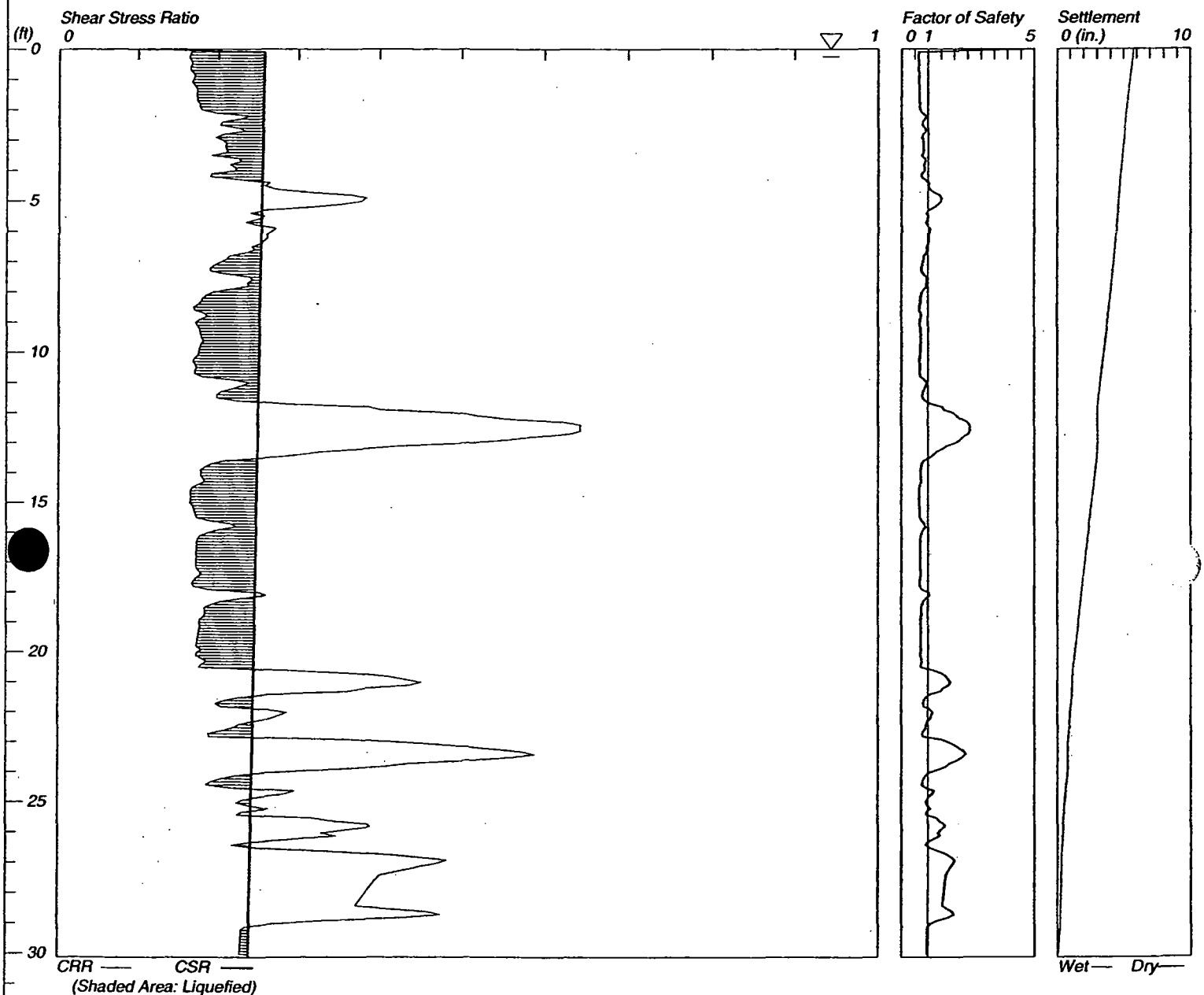
LIQUEFACTION ANALYSIS

PSR-MSU CPT P11

Hole No.=P11 Water Depth=0 ft Surface Elev.=-196.

Magnitude=6.
Acceleration=0.22g



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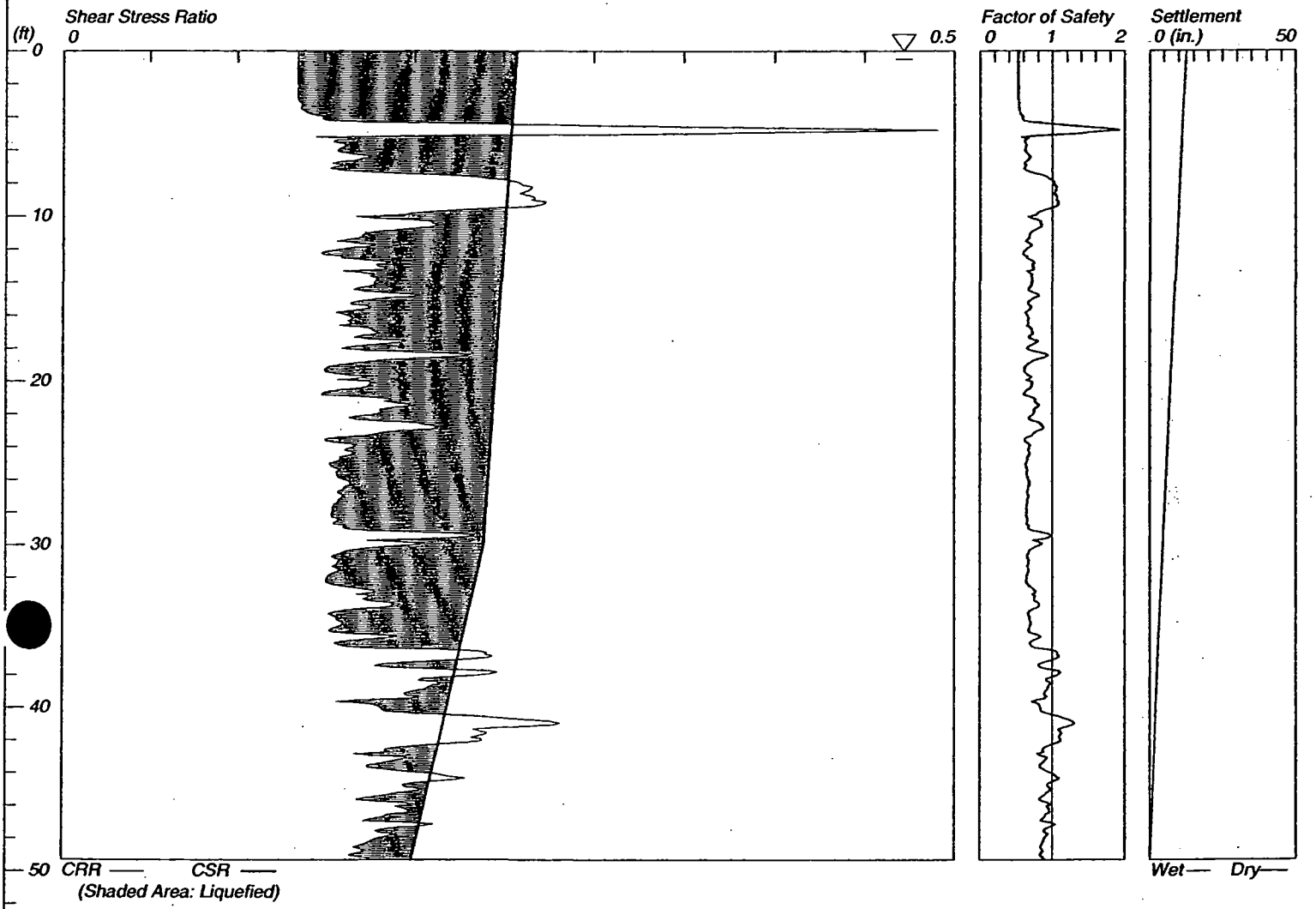
LIQUEFACTION ANALYSIS

PSR-MSU - CPT-P12

Hole No.=P12 Water Depth=0 ft Surface Elev.=-28.2

Magnitude=6.8
Acceleration=0.22g



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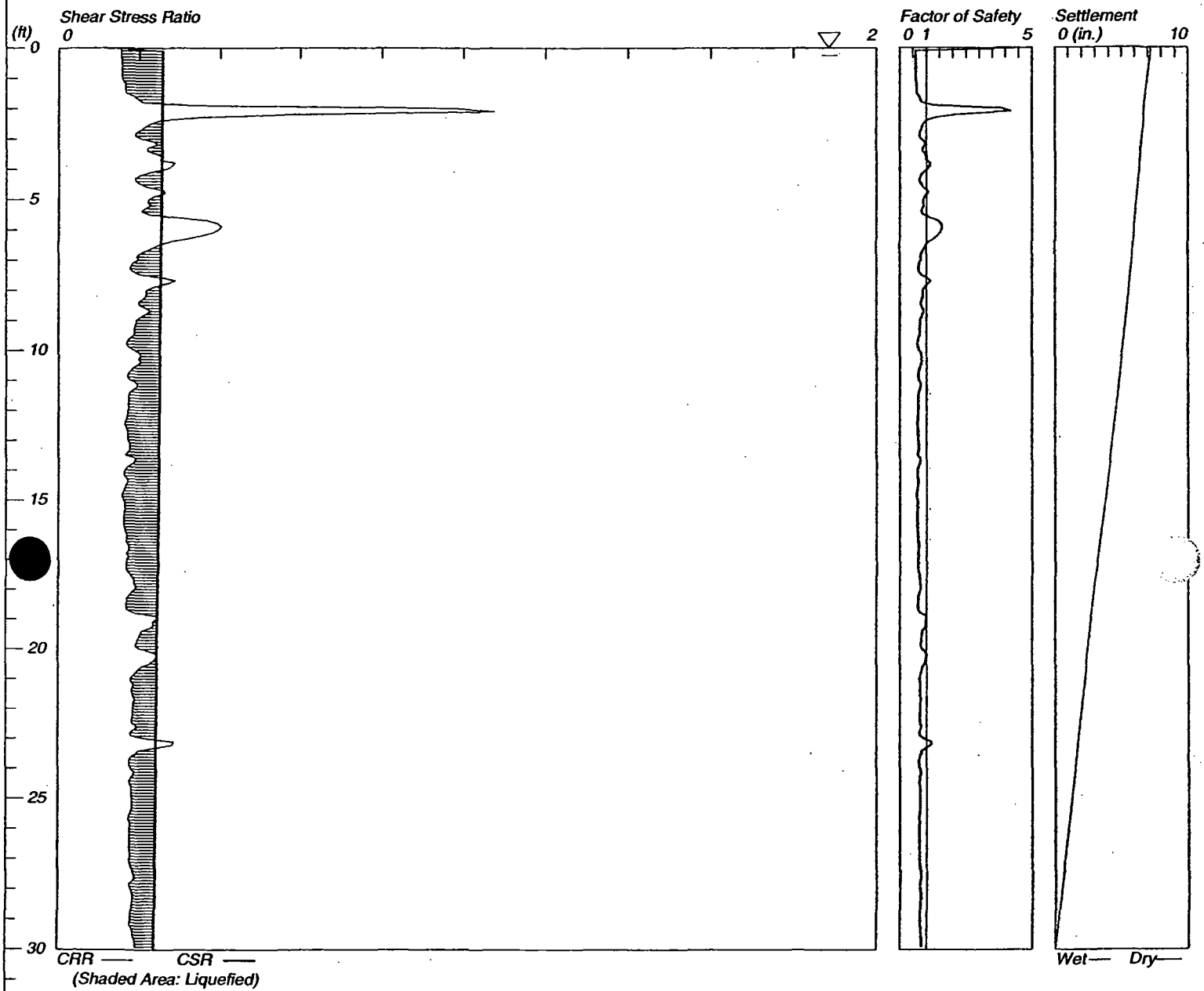
LIQUEFACTION ANALYSIS

PSR-MSU CPT P13

Hole No.=P13 Water Depth=0 ft Surface Elev.=-115.

Magnitude=6.5
Acceleration=0.22g



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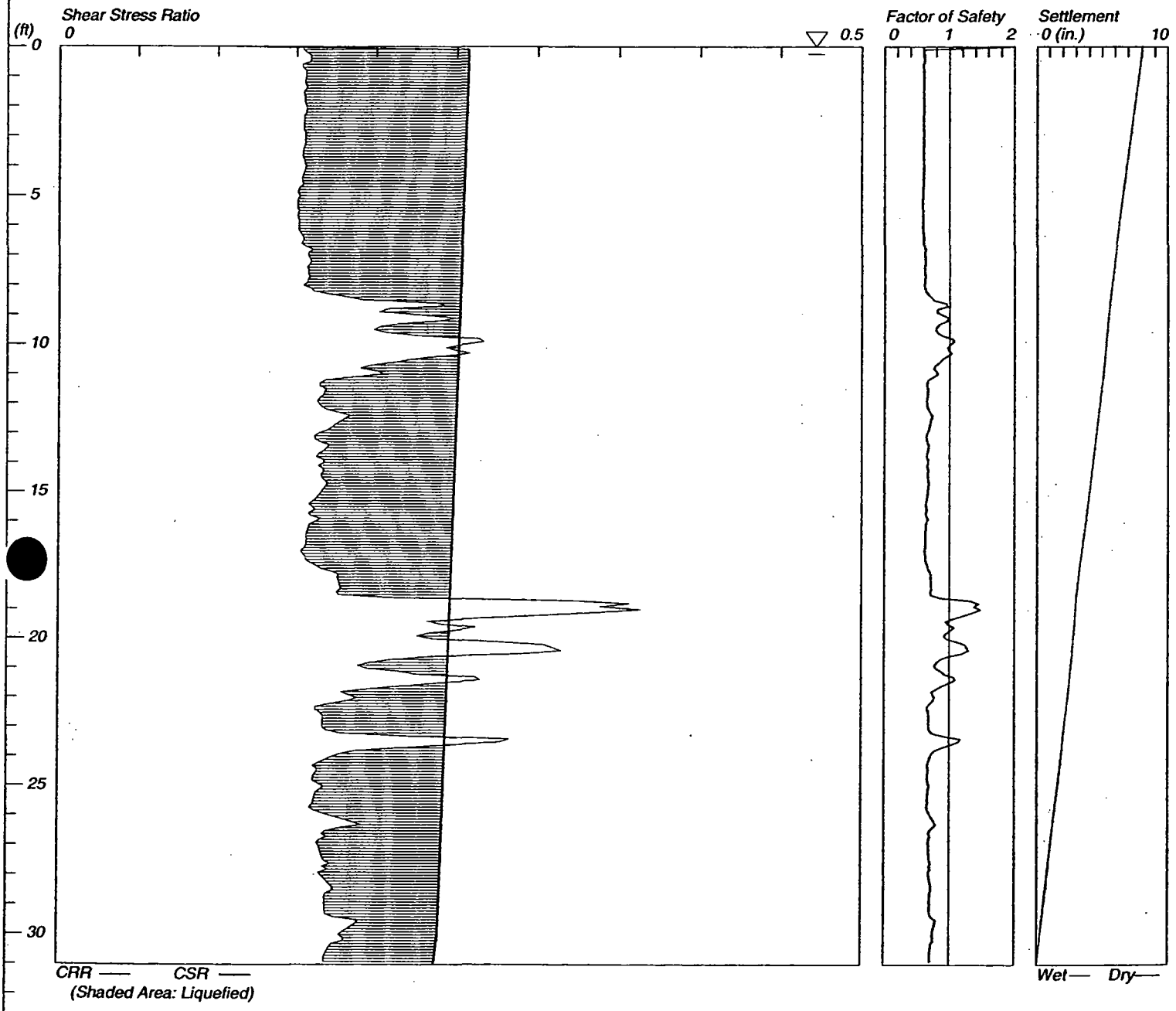
LIQUEFACTION ANALYSIS

PSR-MSU CPT P14

Hole No.=P14 Water Depth=0 ft Surface Elev.=-136.

Magnitude=6.8
Acceleration=0.22g



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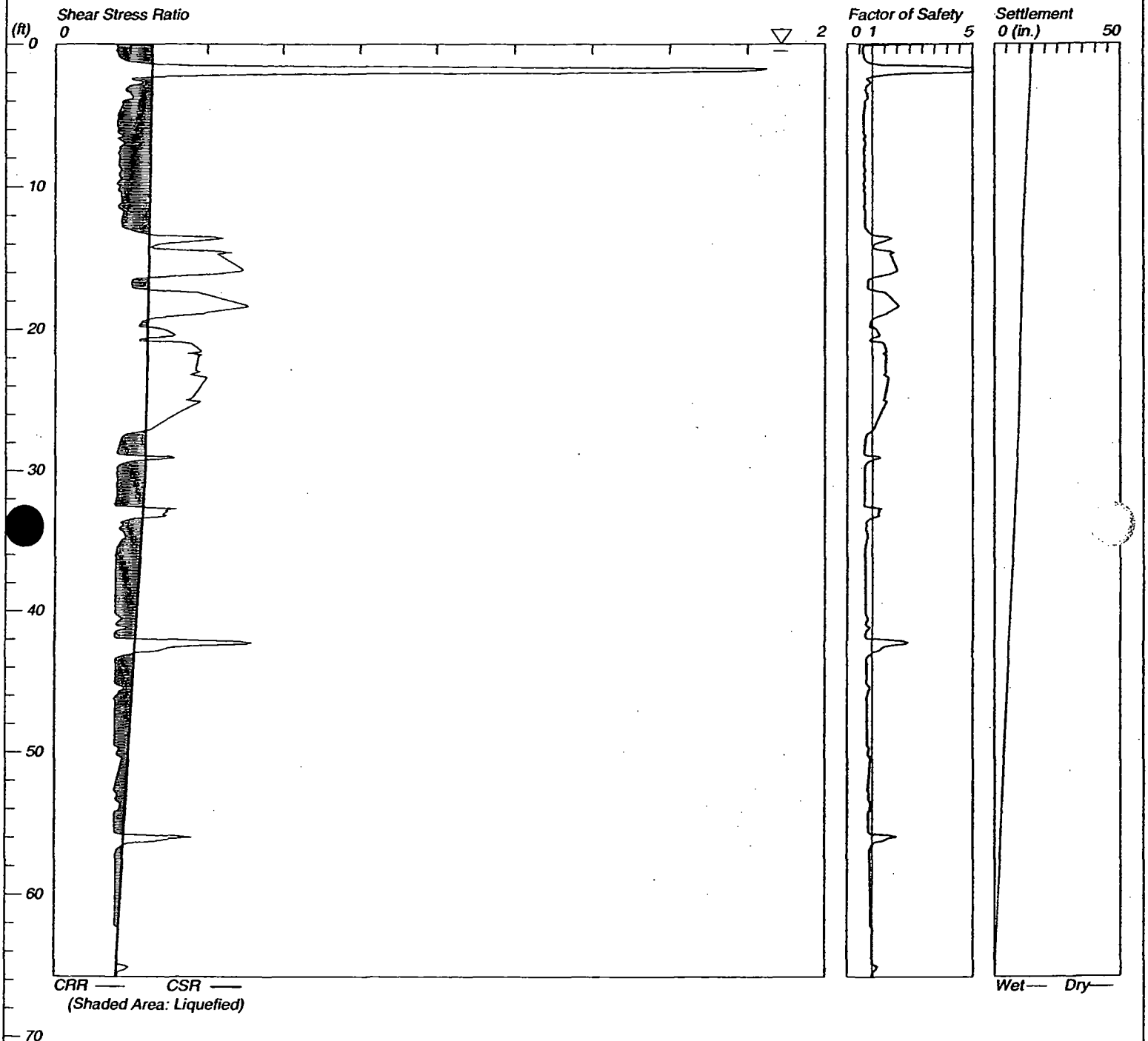
LIQUEFACTION ANALYSIS

PSR-MSU CPT P15

Hole No.=P15 Water Depth=0 ft Surface Elev.=-195.

Magnitude=6.6
Acceleration=0.22g



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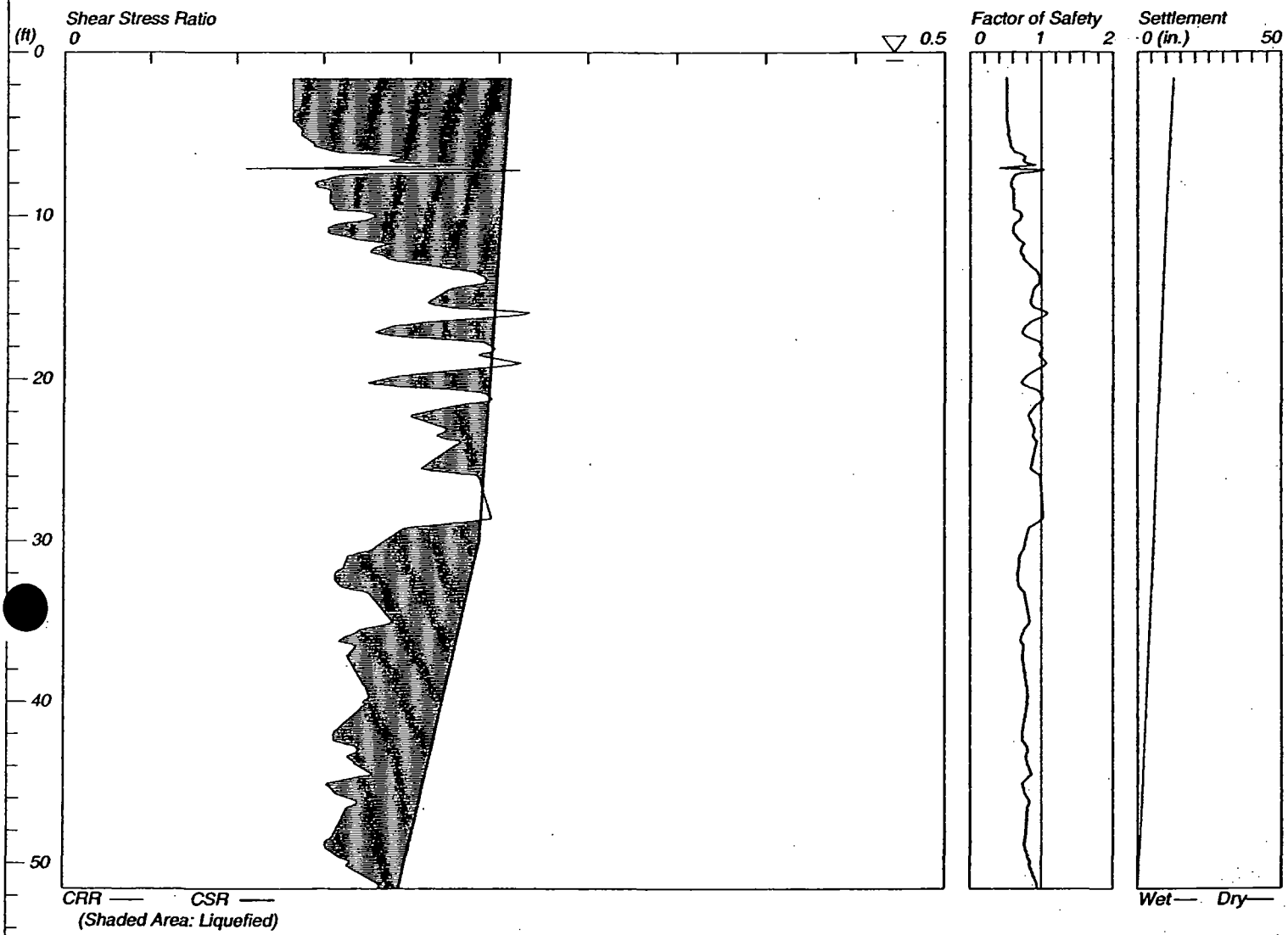
LIQUEFACTION ANALYSIS

PSR-MSU CPT P16

Hole No.=P16 Water Depth=0 ft Surface Elev.=-30.9

Magnitude=6.8
Acceleration=0.22g



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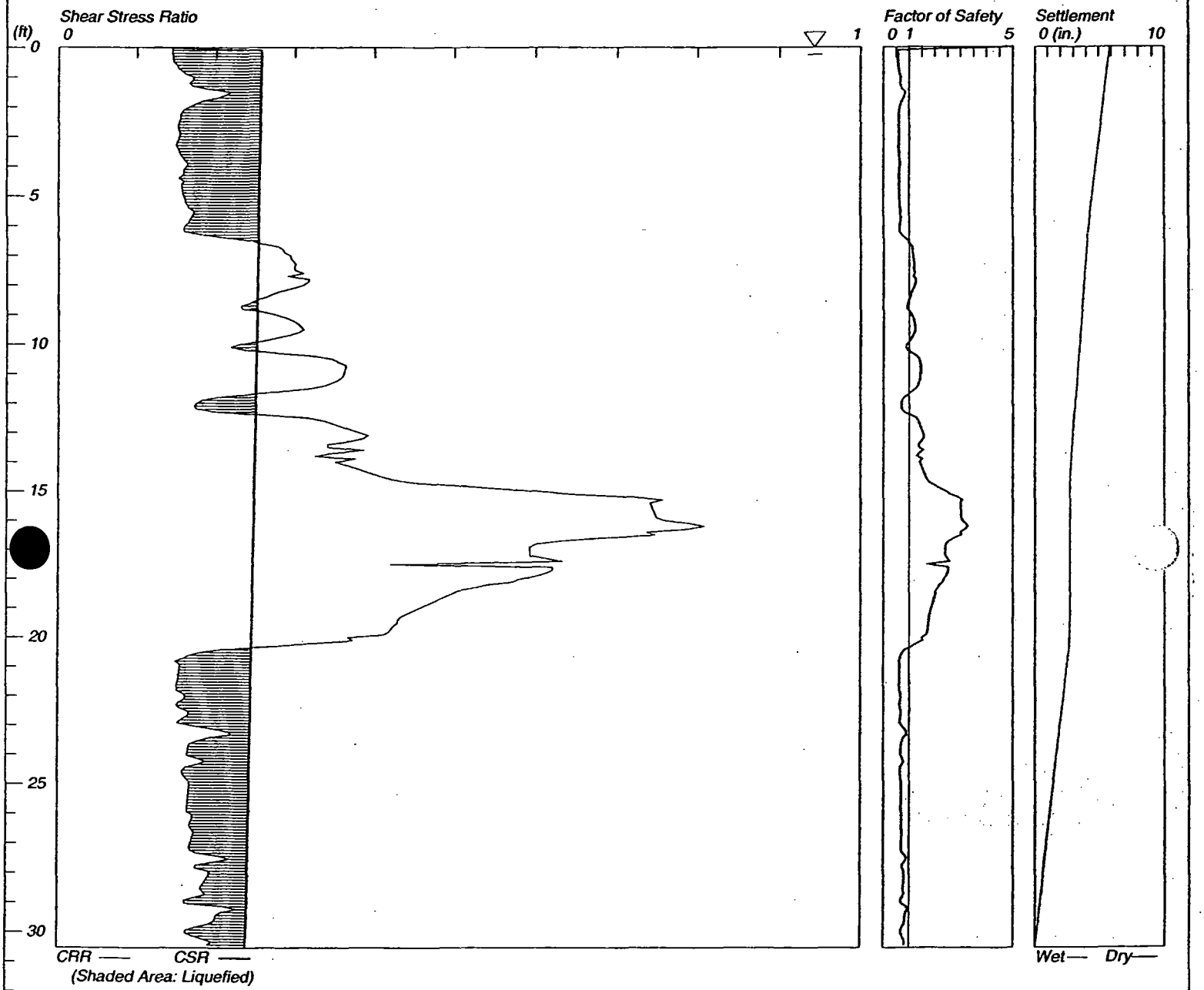
LIQUEFACTION ANALYSIS

PSR_MSU P17

Hole No.=P17 Water Depth=0 ft Surface Elev.=-89

Magnitude=6.8
Acceleration=0.22g



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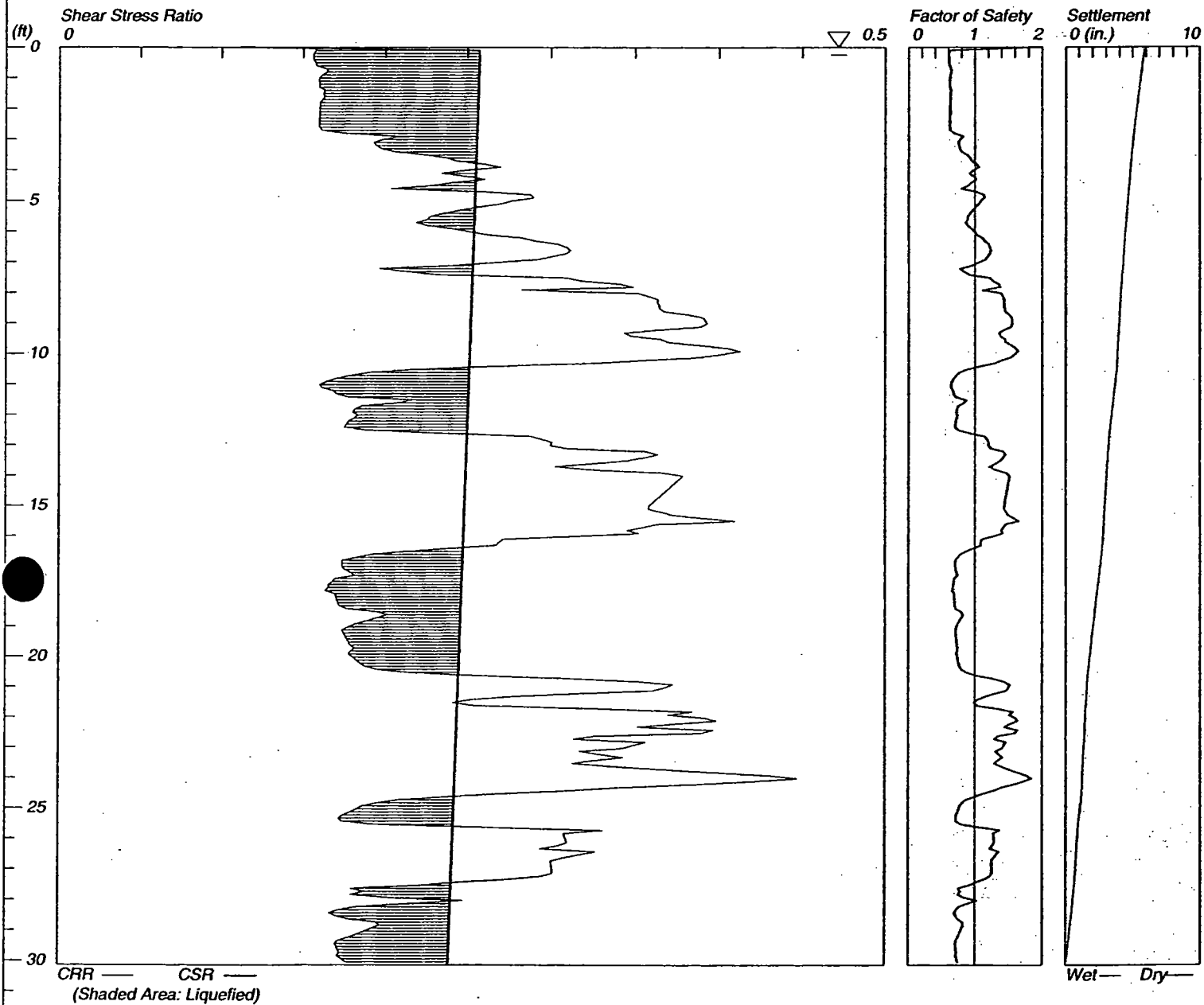
LIQUEFACTION ANALYSIS

PSR-MSU CPT P18

Hole No.=P18 Water Depth=0 ft Surface Elev.=-143.

Magnitude=6.8
Acceleration=0.22g



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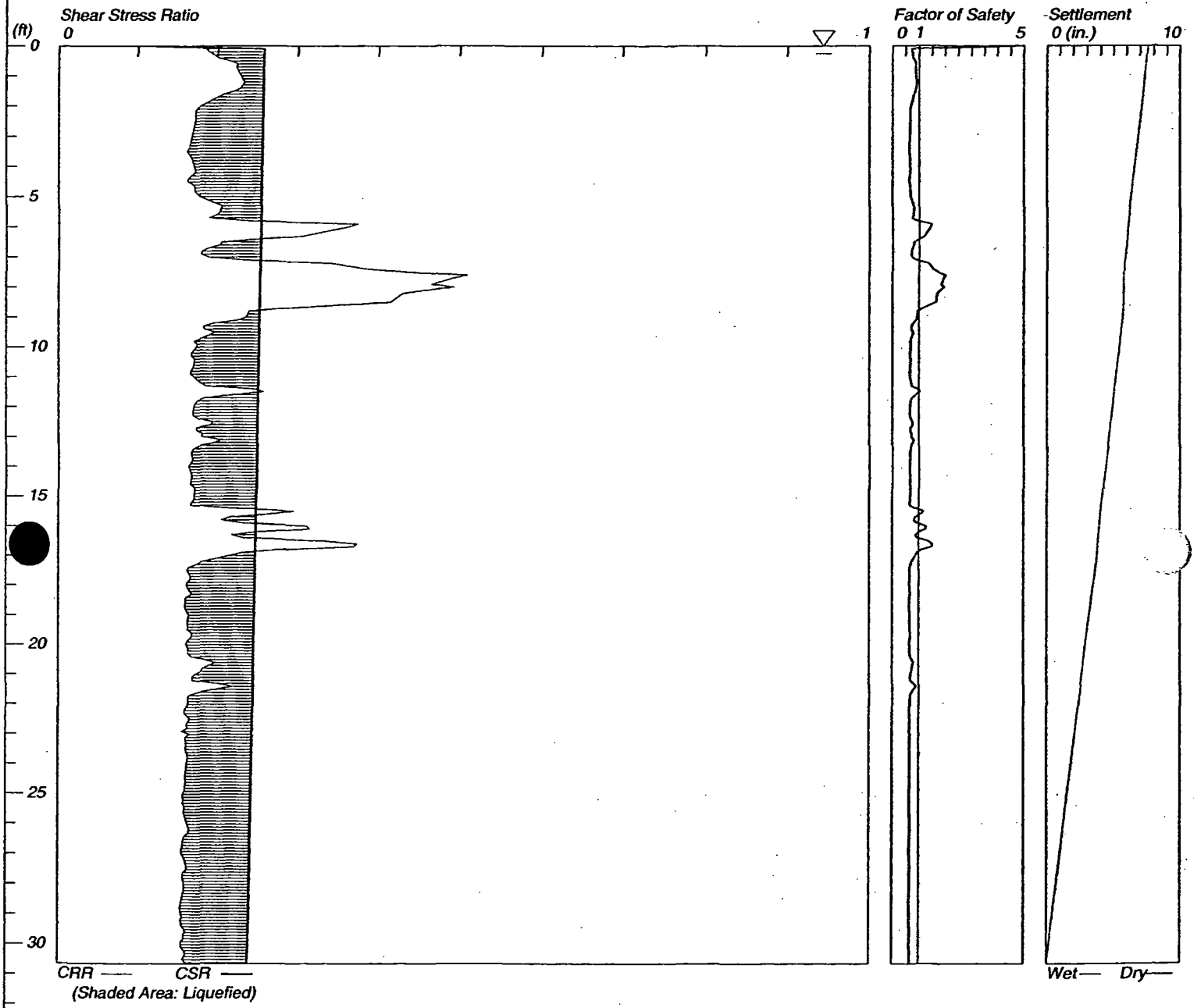
LIQUEFACTION ANALYSIS

PSR-MSU CPT 19

Hole No.=P19 Water Depth=0 ft Surface Elev.=-177.

Magnitude=6.8
Acceleration=0.22g



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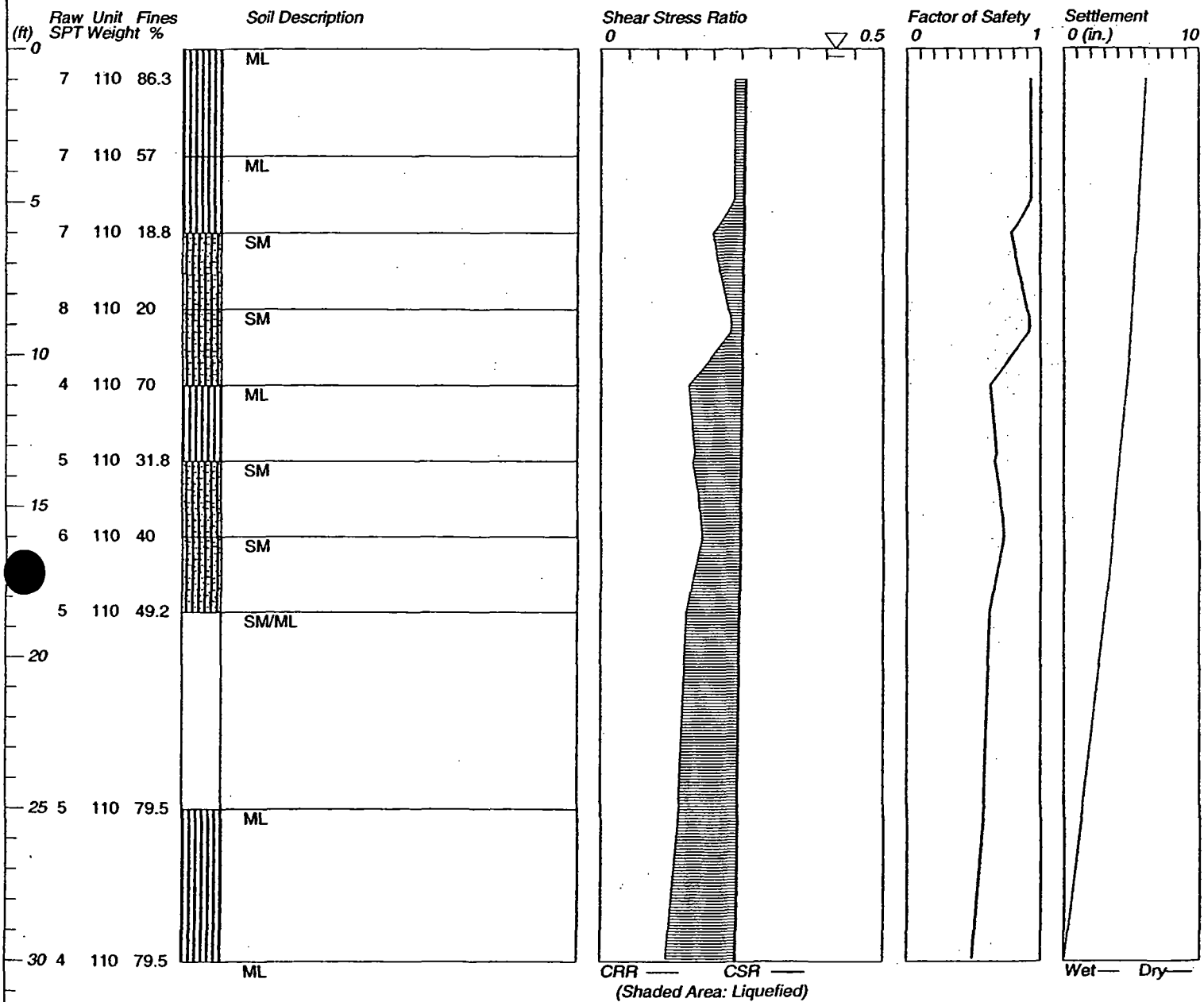
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-1 Water Depth=0 ft Surface Elev.=-43.3

Magnitude=6.8
Acceleration=0.22g



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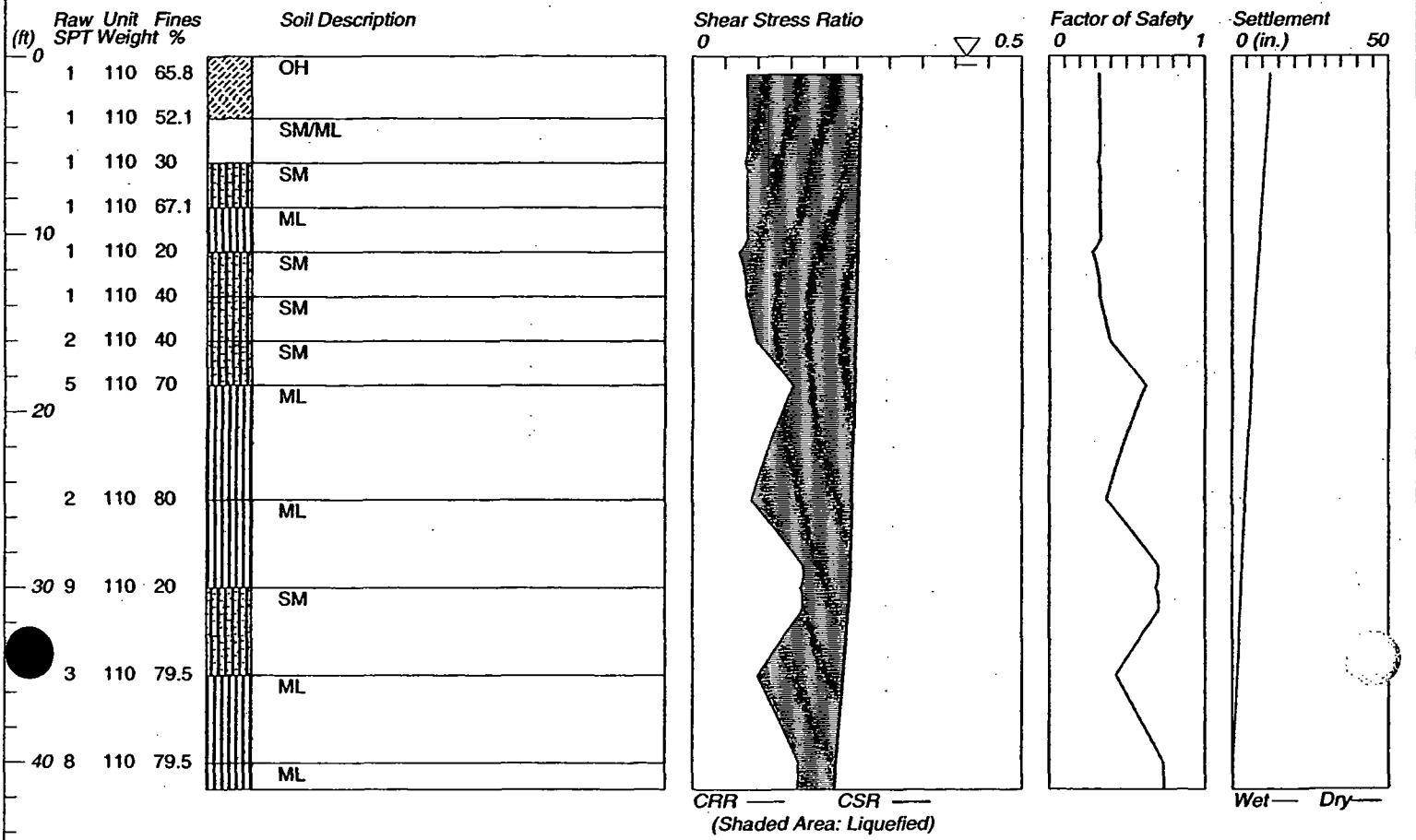
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-2 Water Depth=0 ft Surface Elev.=-31.4

Magnitude=6.5
Acceleration=0.22g



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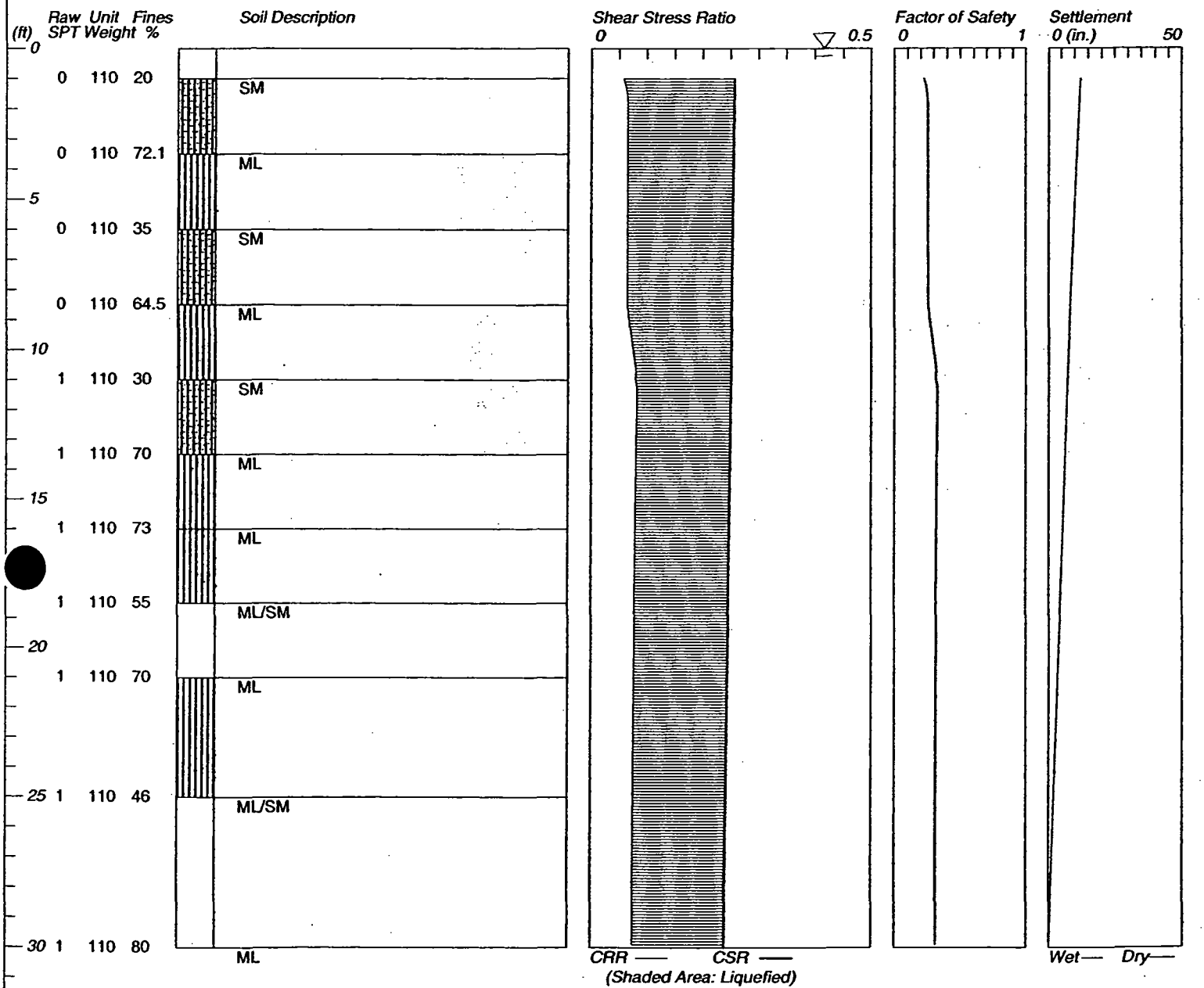
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-3 Water Depth=0 ft Surface Elev.=-73.4

Magnitude=6.8
Acceleration=0.22g



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URS

SPT LIQUEFACTION ANALYSIS

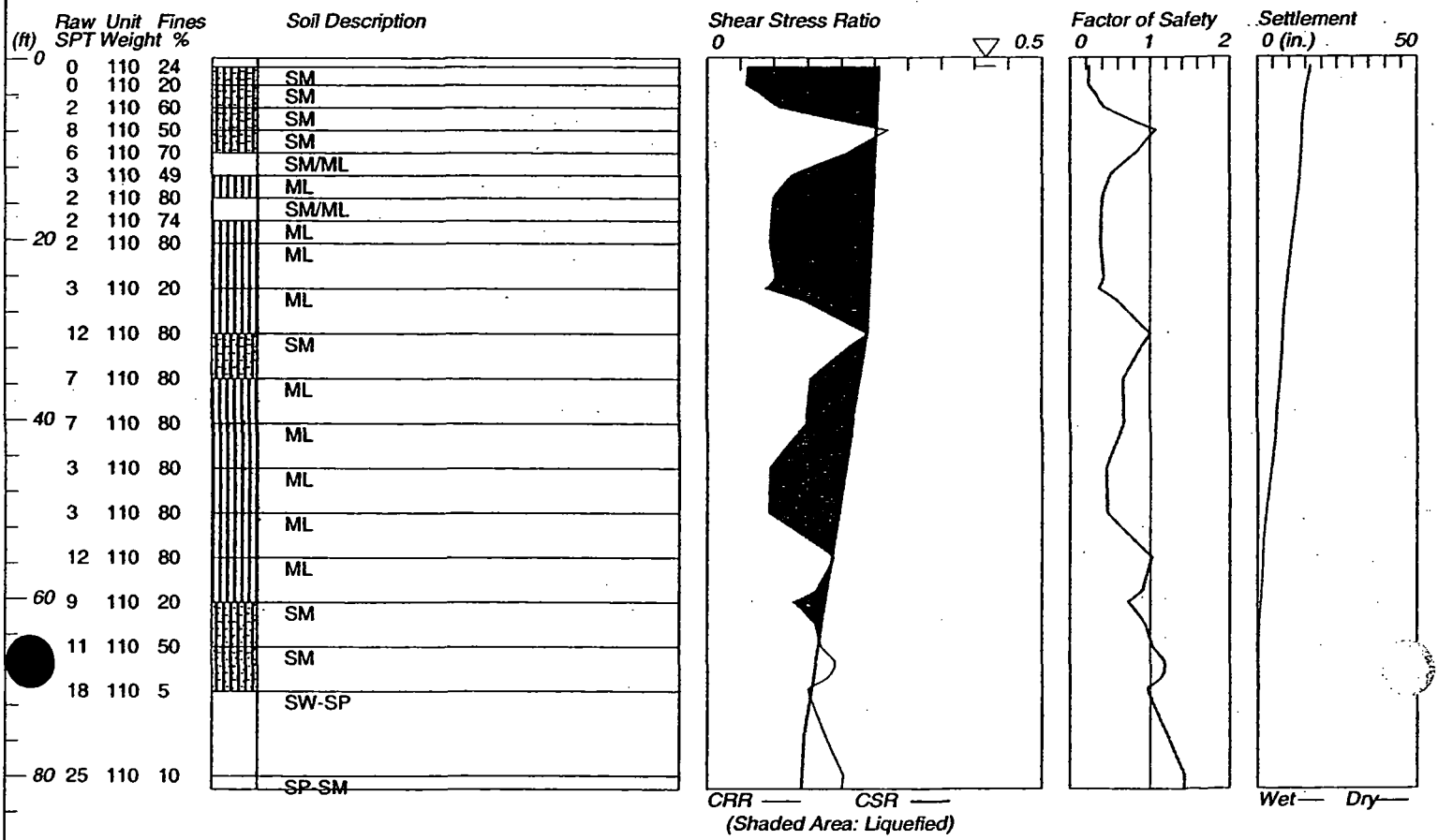
Plate A-1

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-4 Water Depth=0 ft Surface Elev.=-71.9

Magnitude=6.5
Acceleration=0.22g



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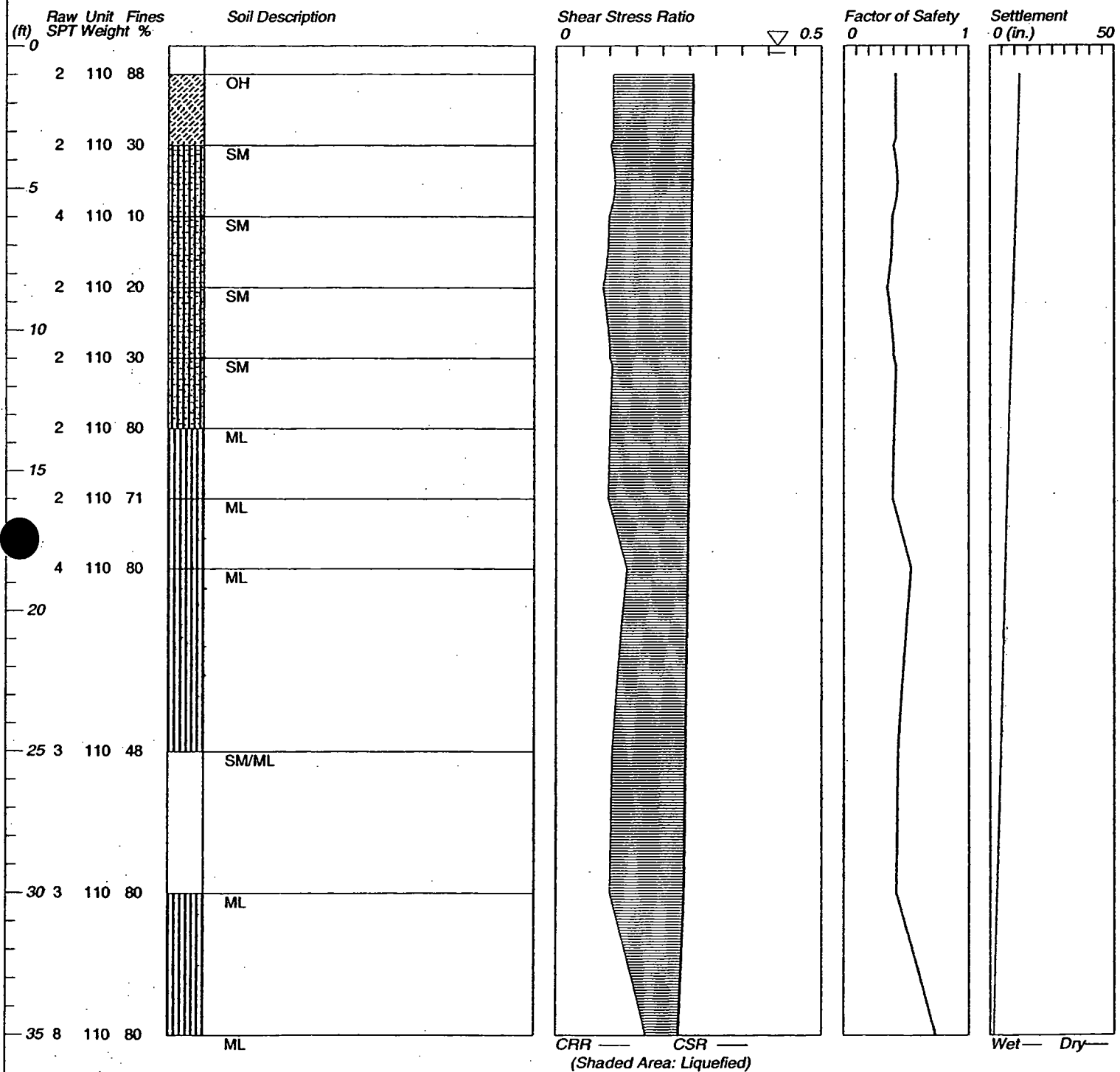
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-5 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.8
Acceleration=0.22g



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URS

SPT LIQUEFACTION ANALYSIS

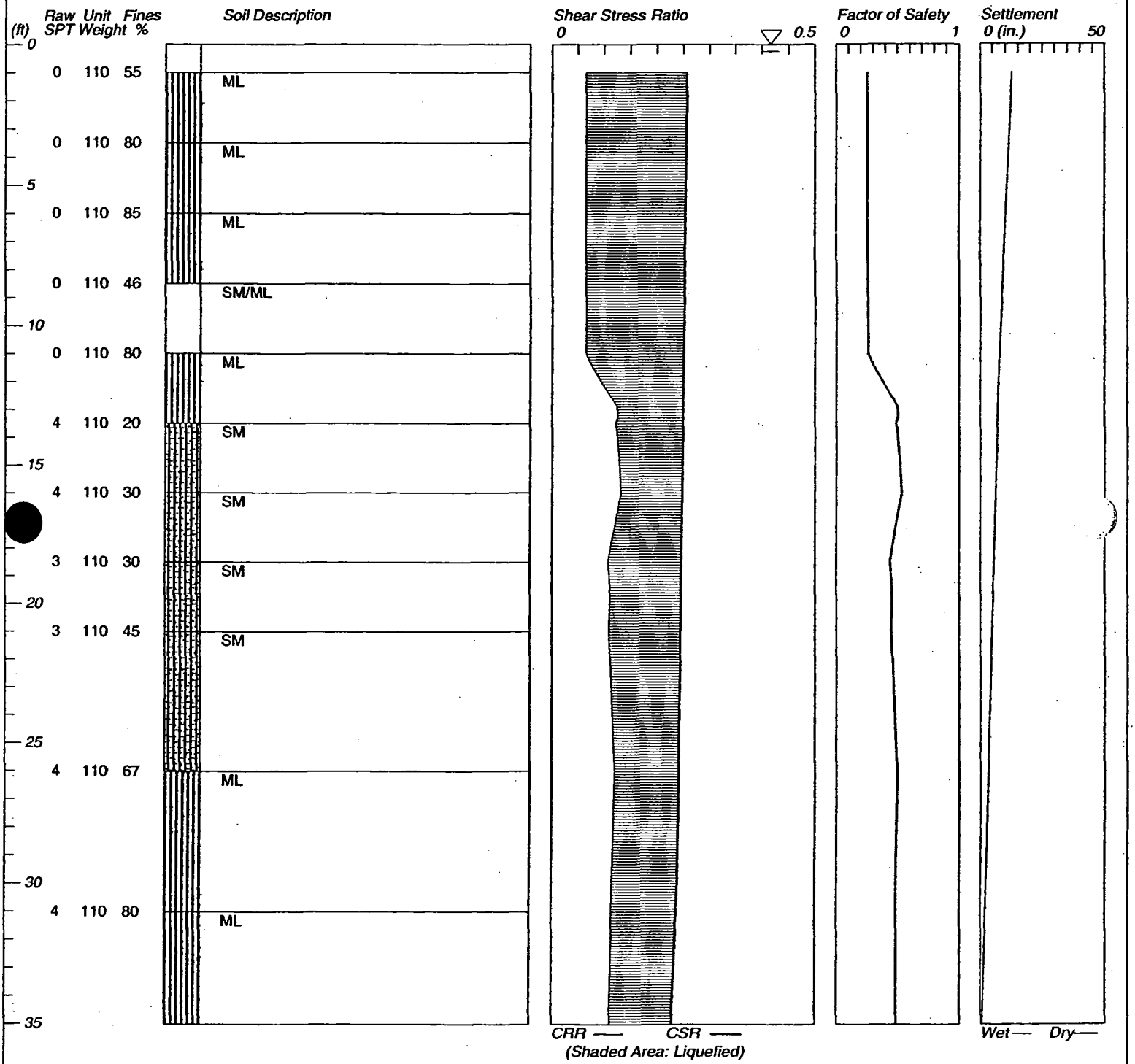
Plate A-1

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-6 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.6
Acceleration=0.22g



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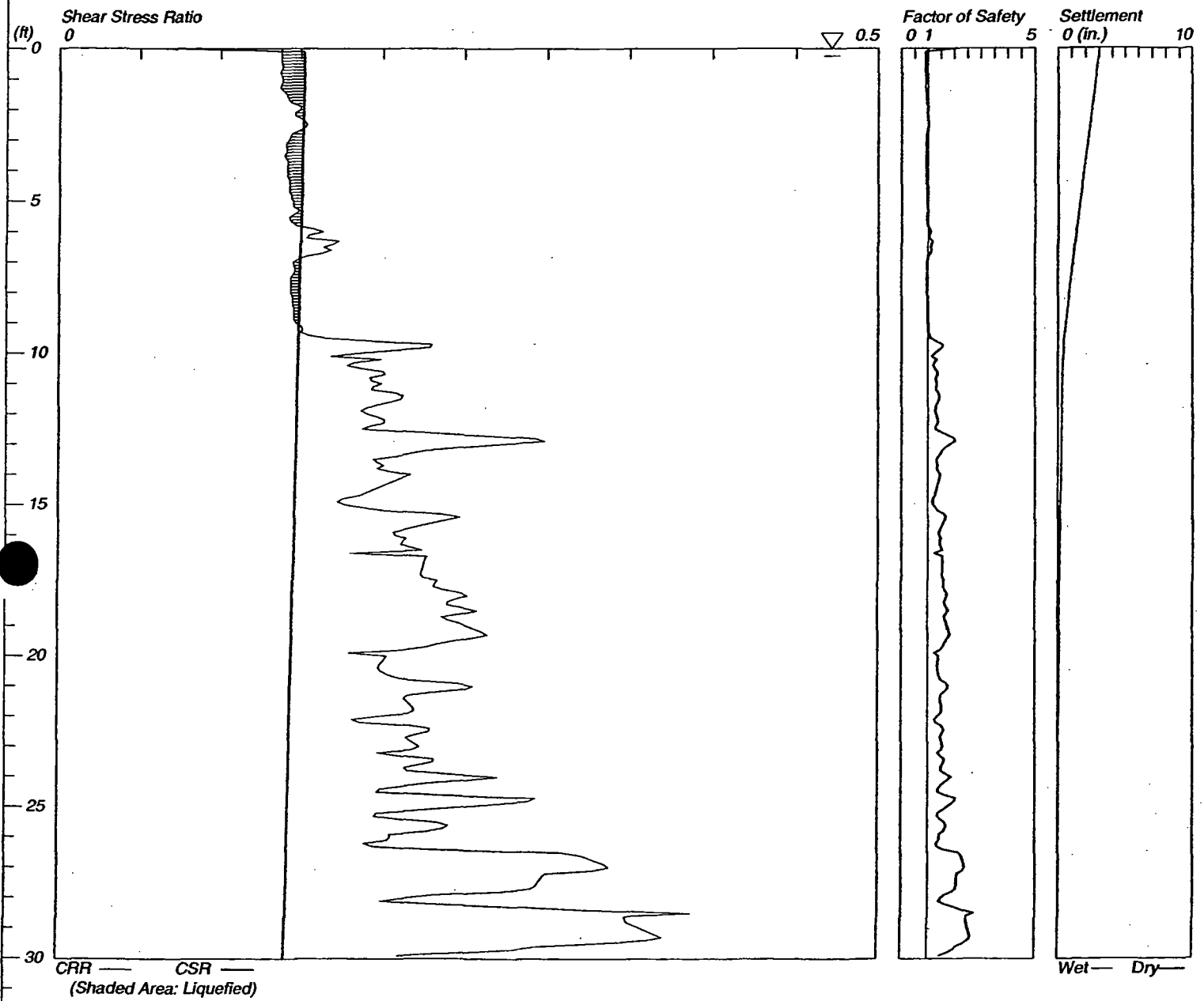
LIQUEFACTION ANALYSIS

PSR-MSU CPT P1

Hole No.=P1 Water Depth=0 ft Surface Elev.=-26.3

Magnitude=6.8
Acceleration=0.13g



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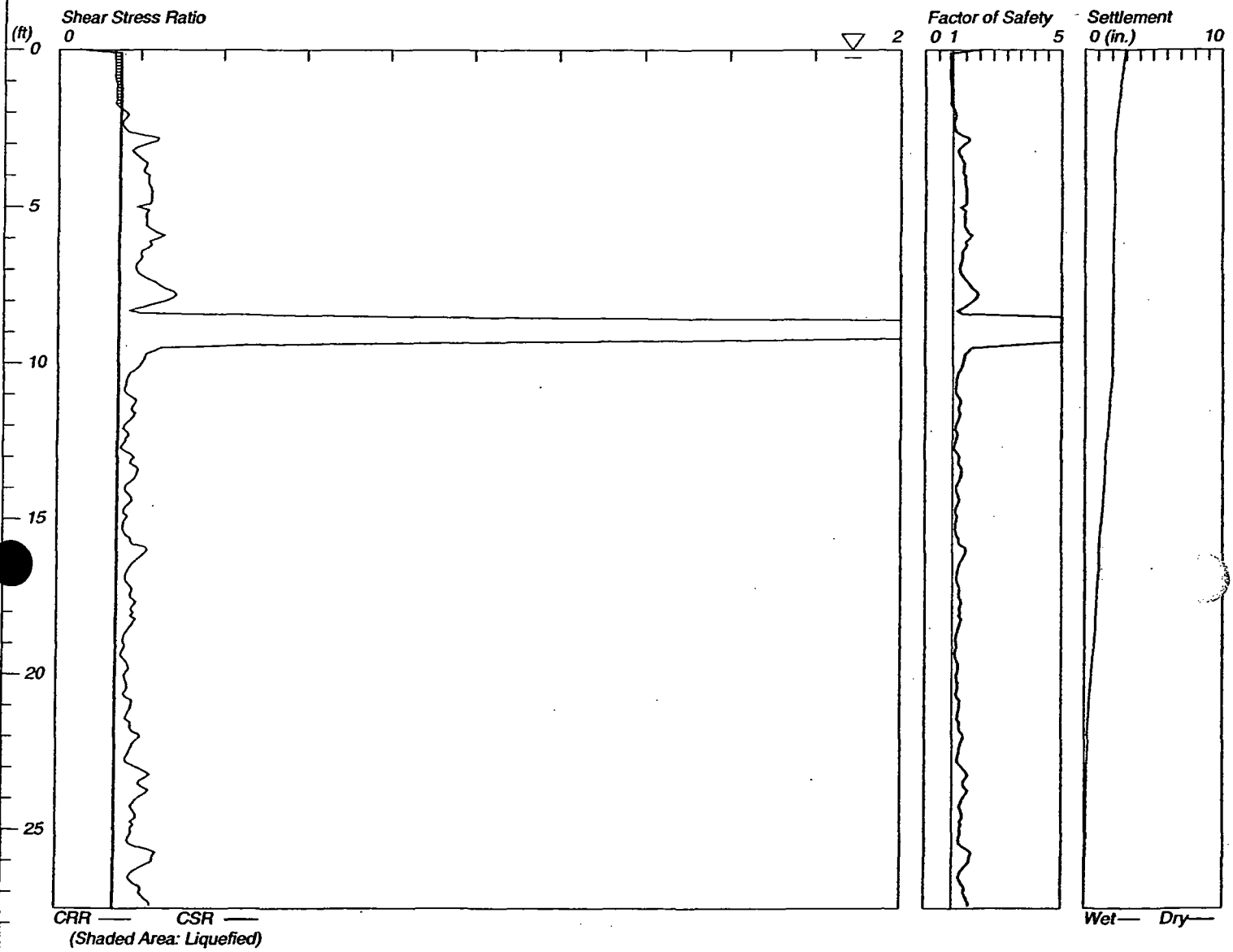
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=P2 Water Depth=0 ft Surface Elev.=-32.5

Magnitude=6.8
Acceleration=0.13g



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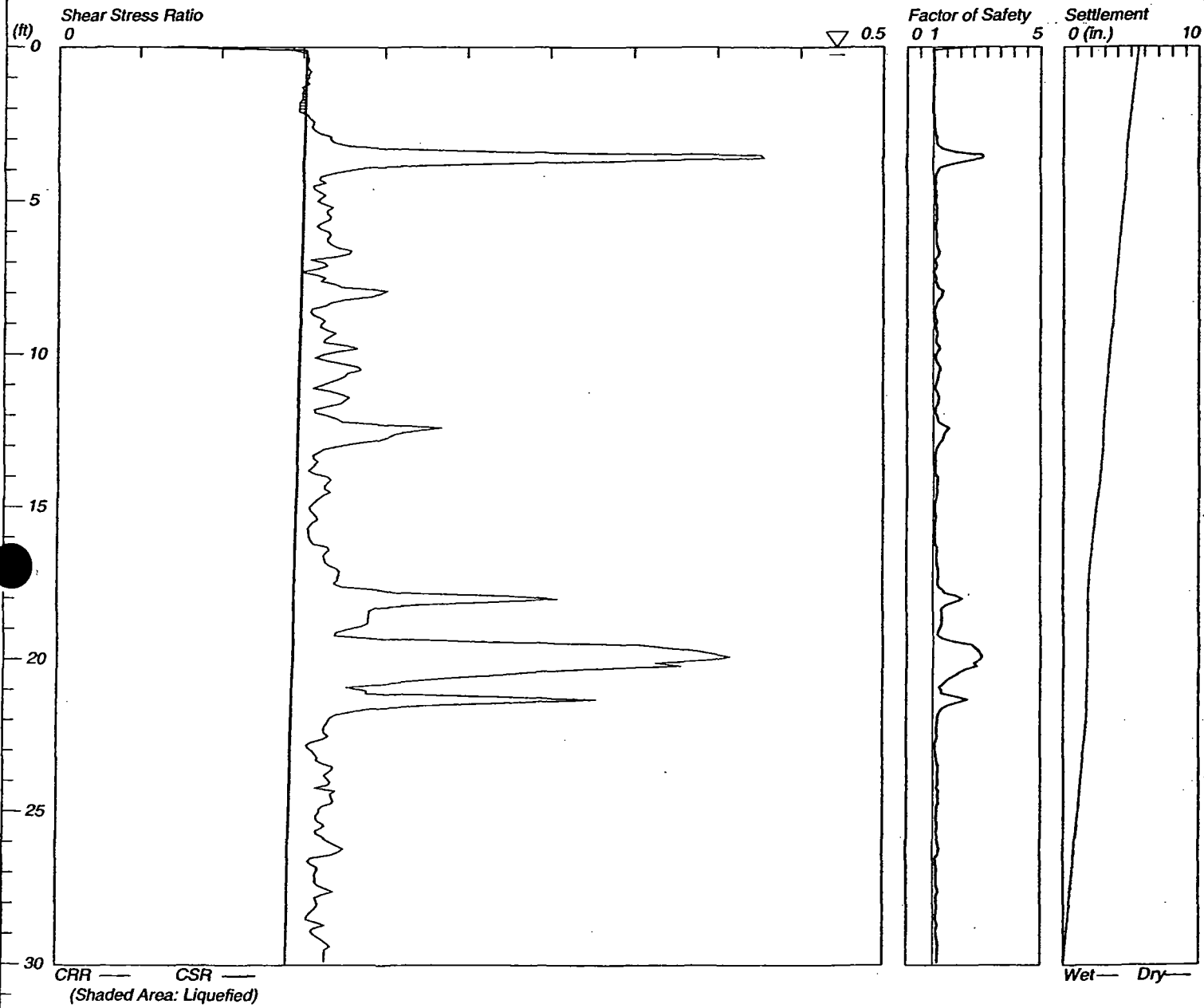
LIQUEFACTION ANALYSIS

PSR-MSU CPT P3

Hole No.=P3 Water Depth=0 ft Surface Elev.=-125.

Magnitude=6.8
Acceleration=0.13g



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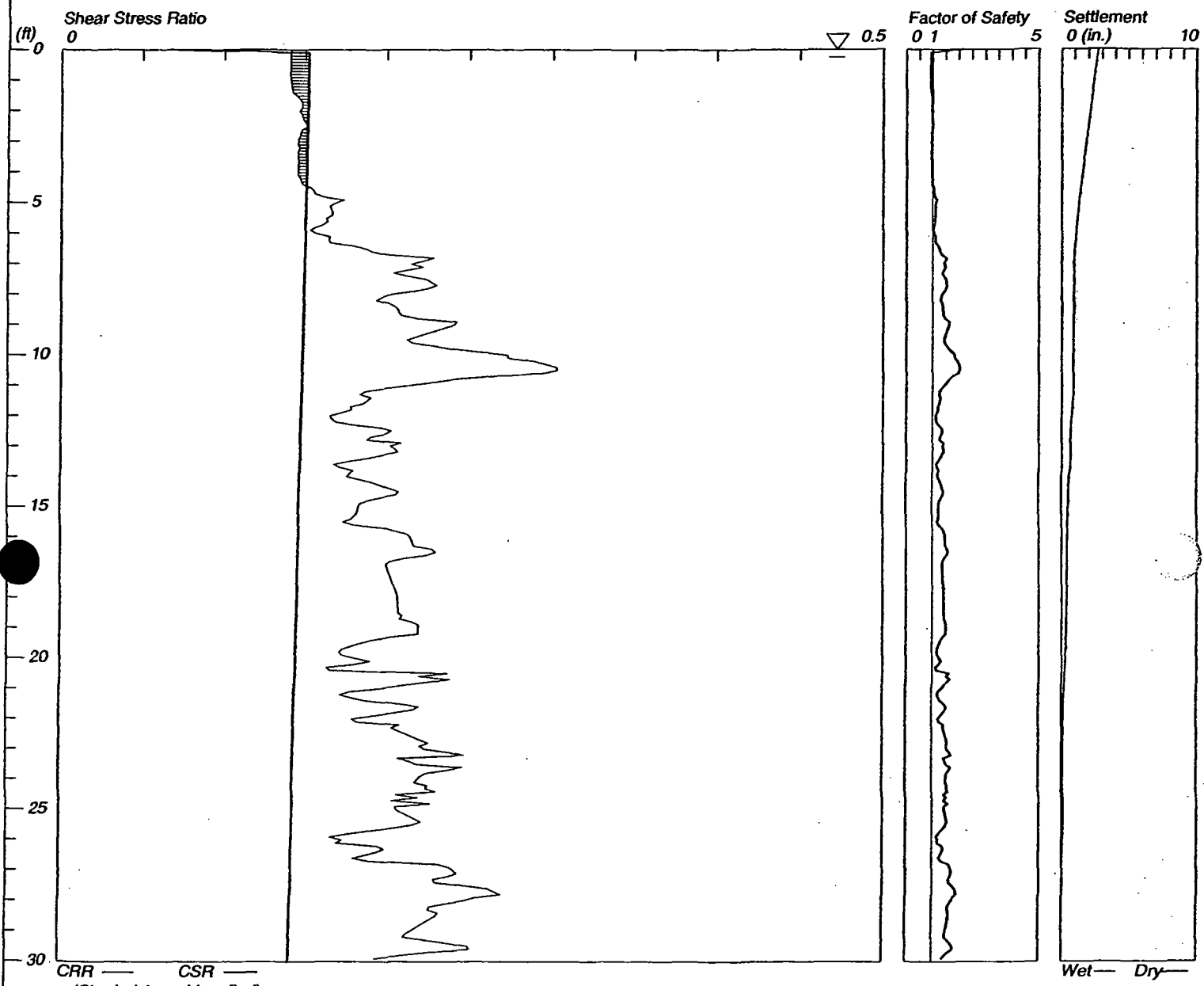
LIQUEFACTION ANALYSIS

PSR-MSU P4

Hole No.=P4 Water Depth=0 ft Surface Elev.=-20.9

Magnitude=6.8
Acceleration=0.13g



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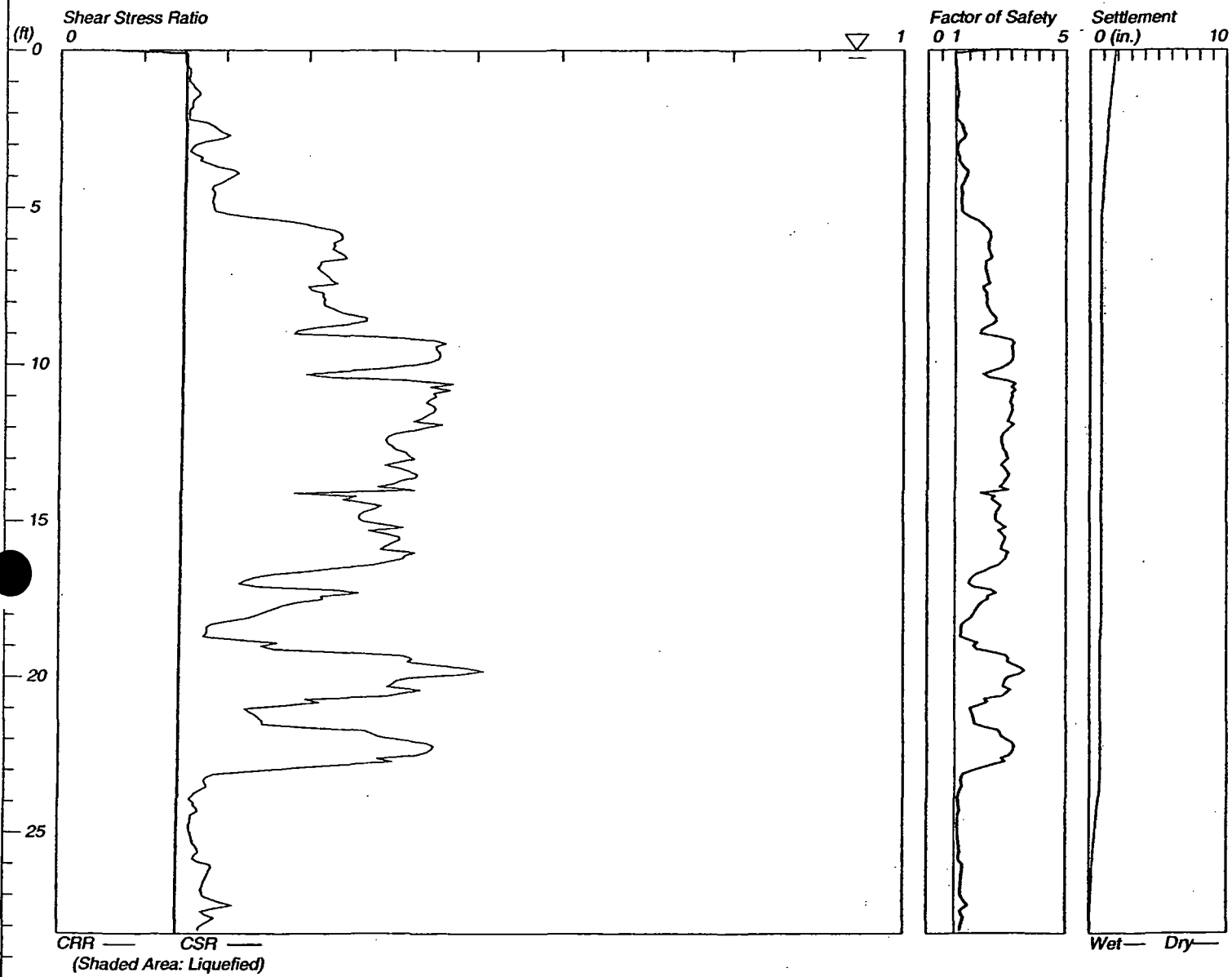
LIQUEFACTION ANALYSIS

PSR-MSU CPT P5

Hole No.=P5 Water Depth=0 ft Surface Elev.=-126.

Magnitude=6.8
Acceleration=0.13g



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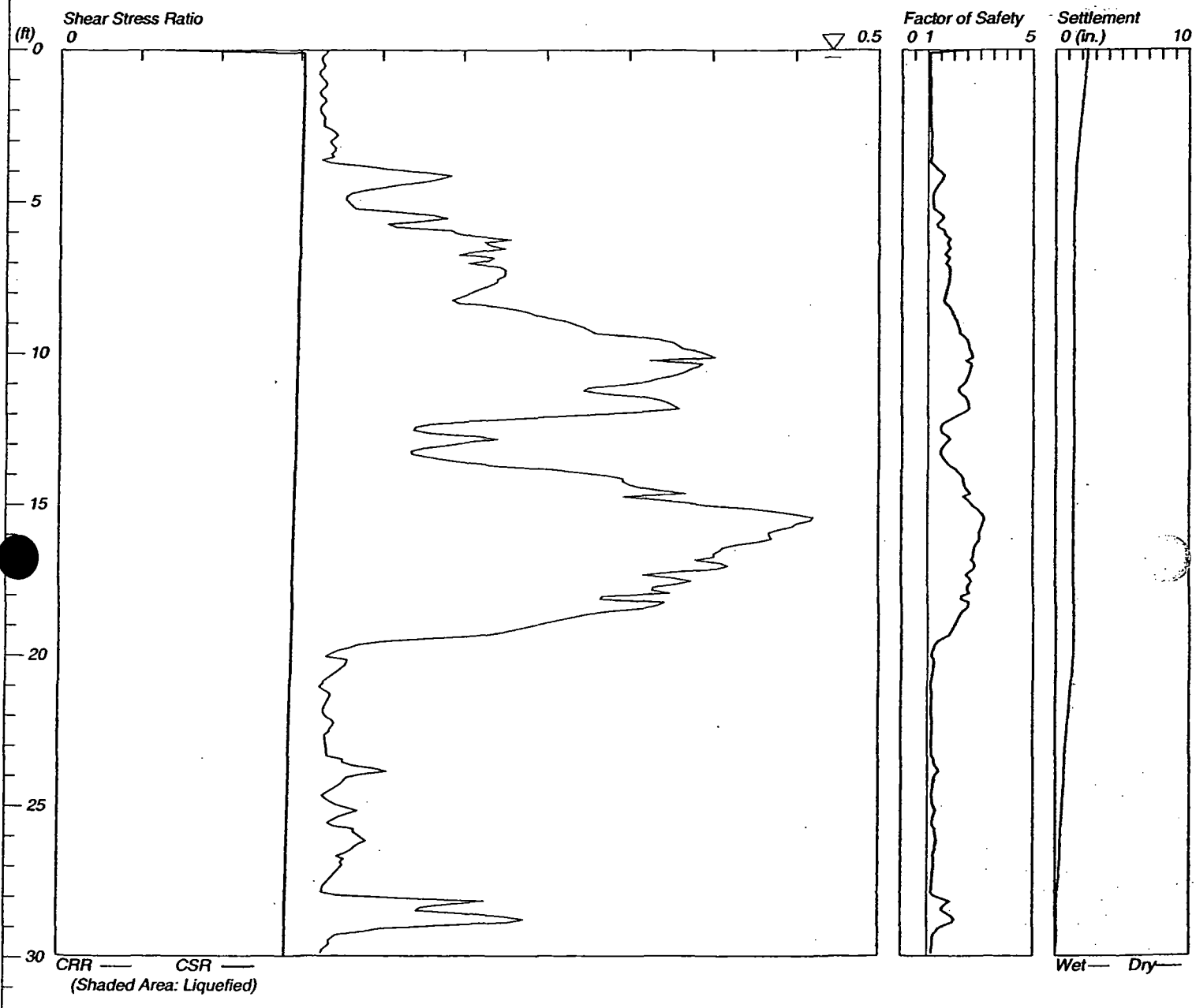
LIQUEFACTION ANALYSIS

PSR-MSU CPT P6

Hole No.=P6 Water Depth=0 ft Surface Elev.=-181.

Magnitude=6.8
Acceleration=0.13g



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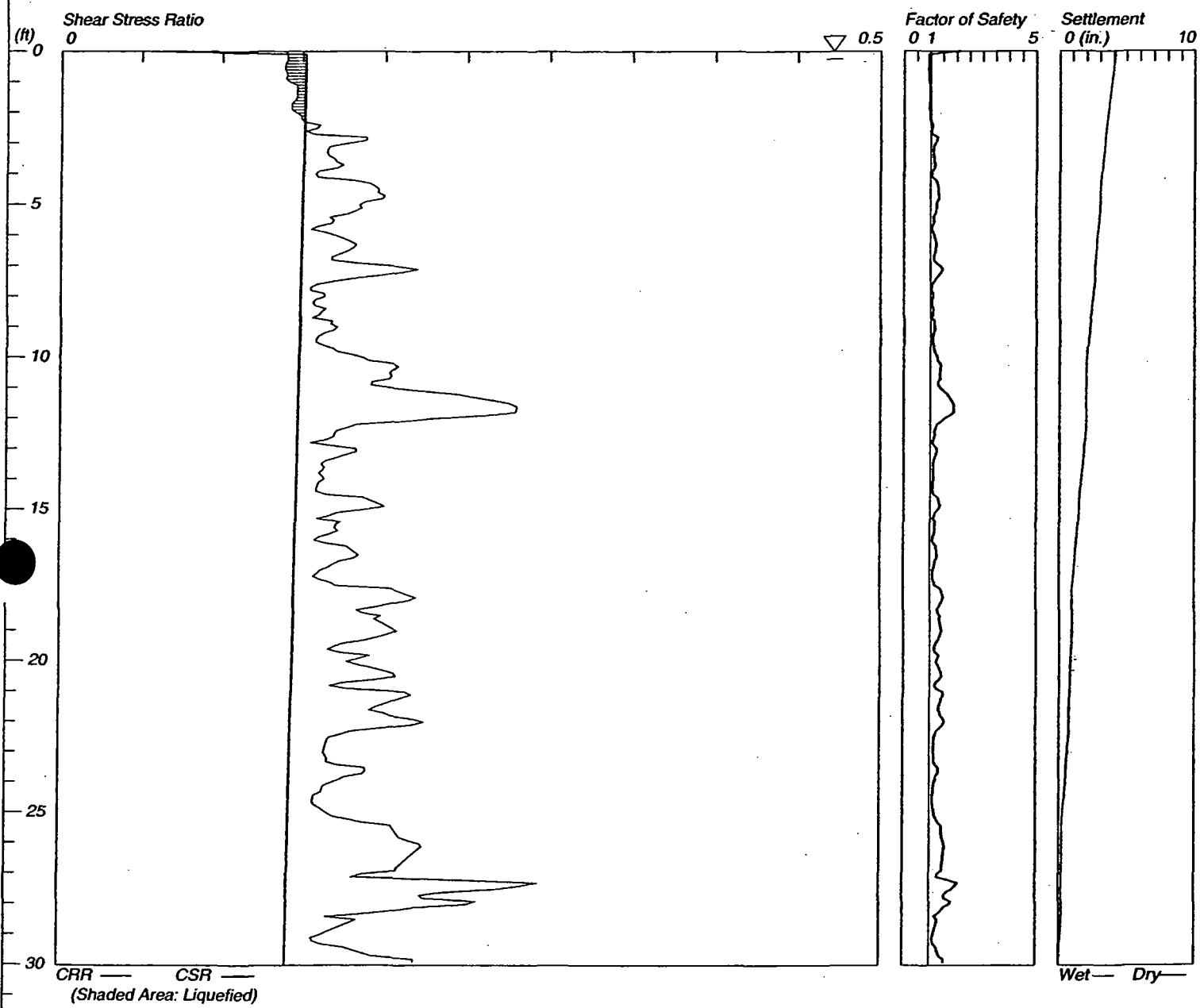
LIQUEFACTION ANALYSIS

PSR-MSU CPT P7

Hole No.=P7 Water Depth=0 ft Surface Elev.=-20.3

Magnitude=6.8
Acceleration=0.13g



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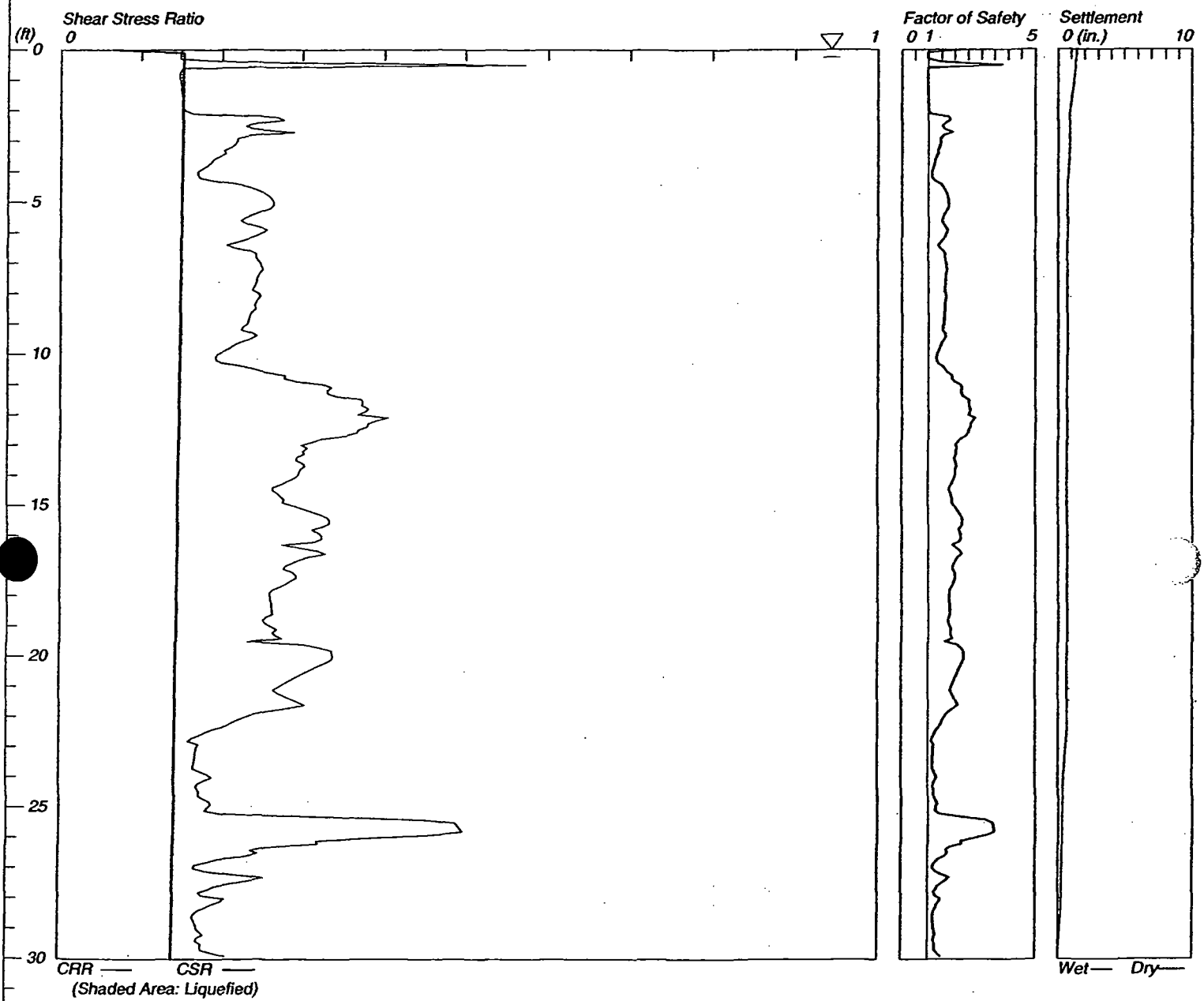
LIQUEFACTION ANALYSIS

PSR-MSU CPT P8

Hole No.=P8 Water Depth=0 ft Surface Elev.=-82.4

Magnitude=6.6
Acceleration=0.13g



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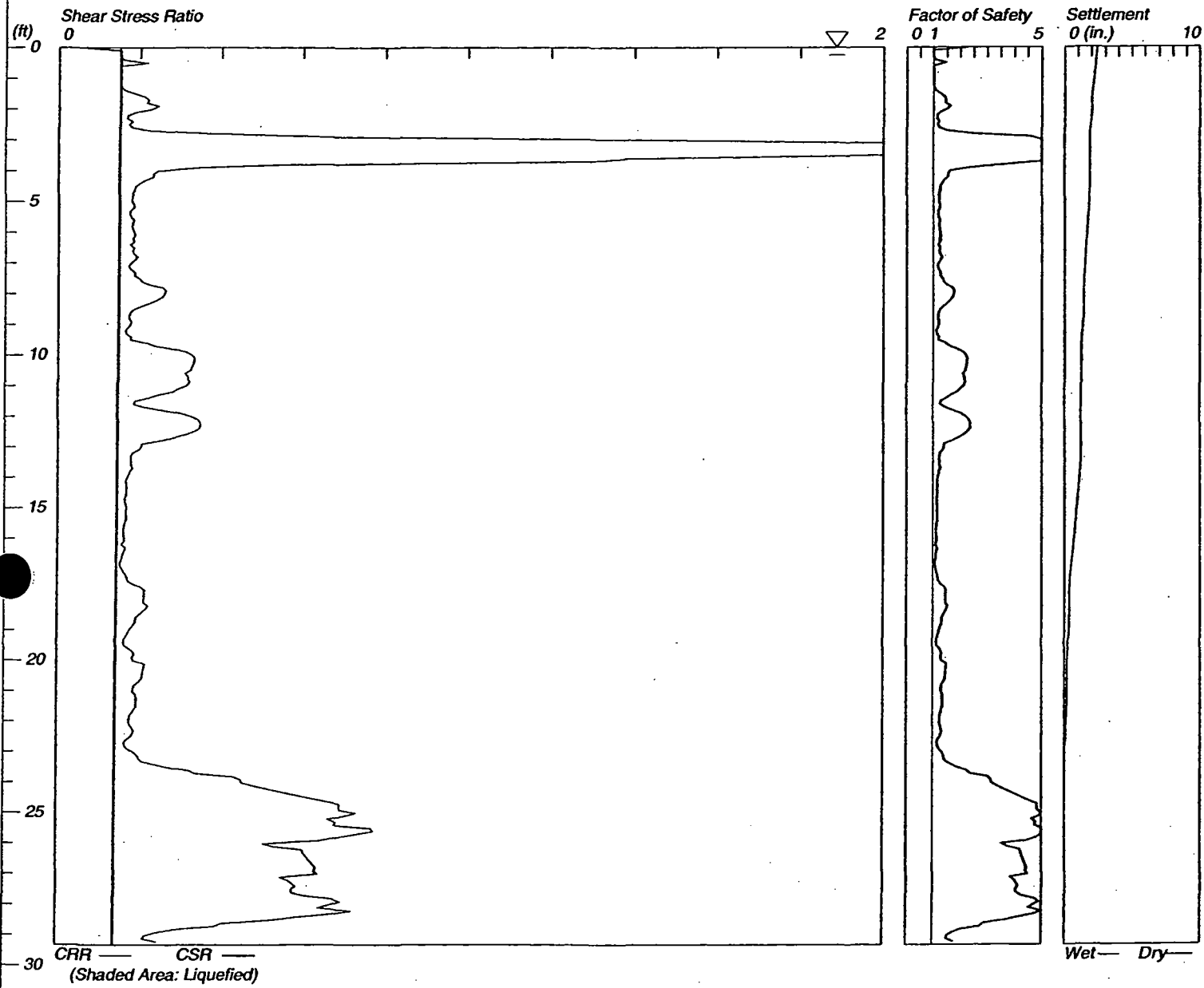
LIQUEFACTION ANALYSIS

PSR-MSU CPT P9

Hole No.=P9 Water Depth=0 ft Surface Elev.=-133.

Magnitude=6.8
Acceleration=0.13g



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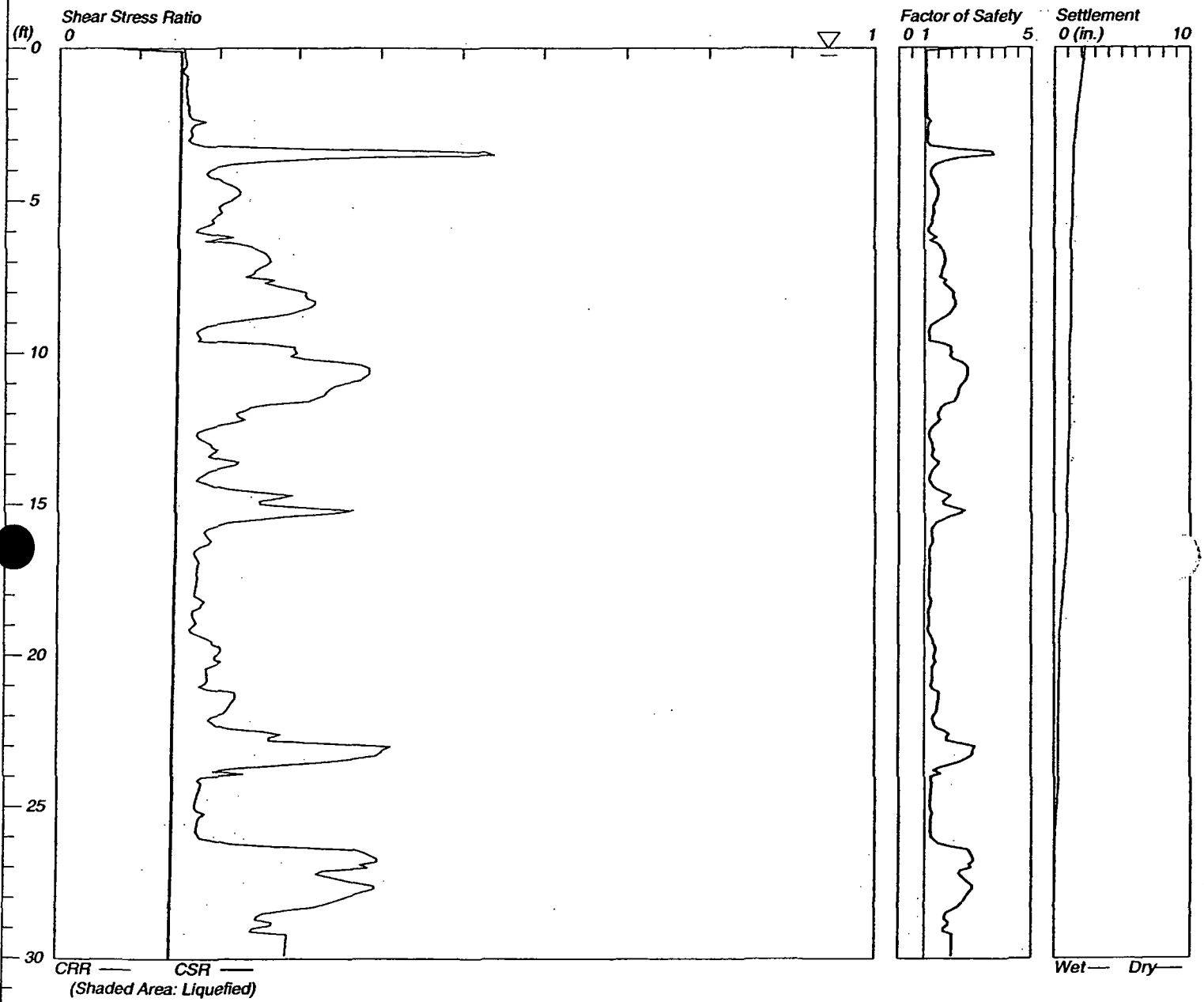
LIQUEFACTION ANALYSIS

PSR-MSU CPT P10

Hole No.=P10 Water Depth=0 ft Surface Elev.=-155

Magnitude=6.8
Acceleration=0.13g



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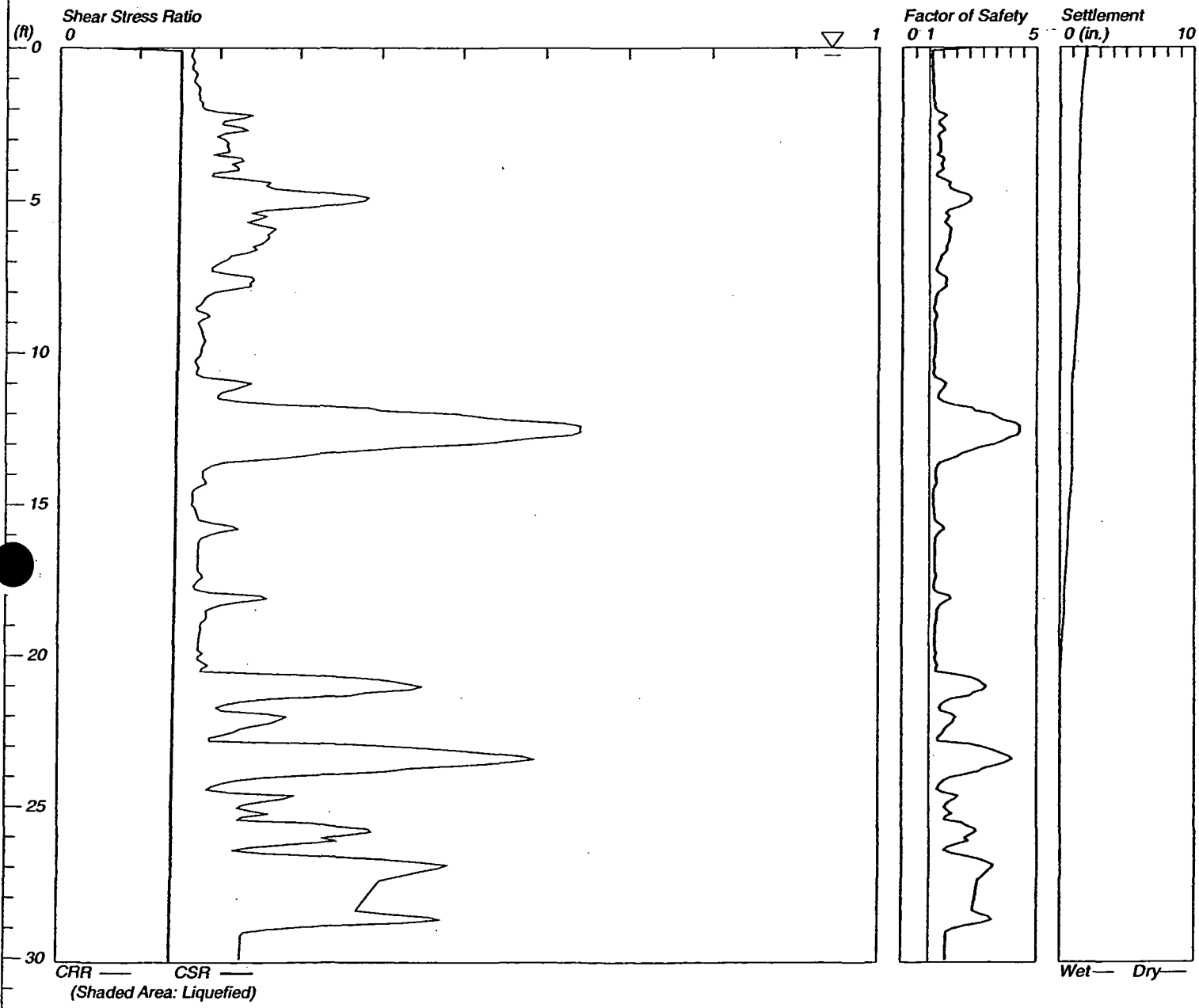
LIQUEFACTION ANALYSIS

PSR-MSU CPT P11

Hole No.=P11 Water Depth=0 ft Surface Elev.=-196.

Magnitude=6.8
Acceleration=0.13g



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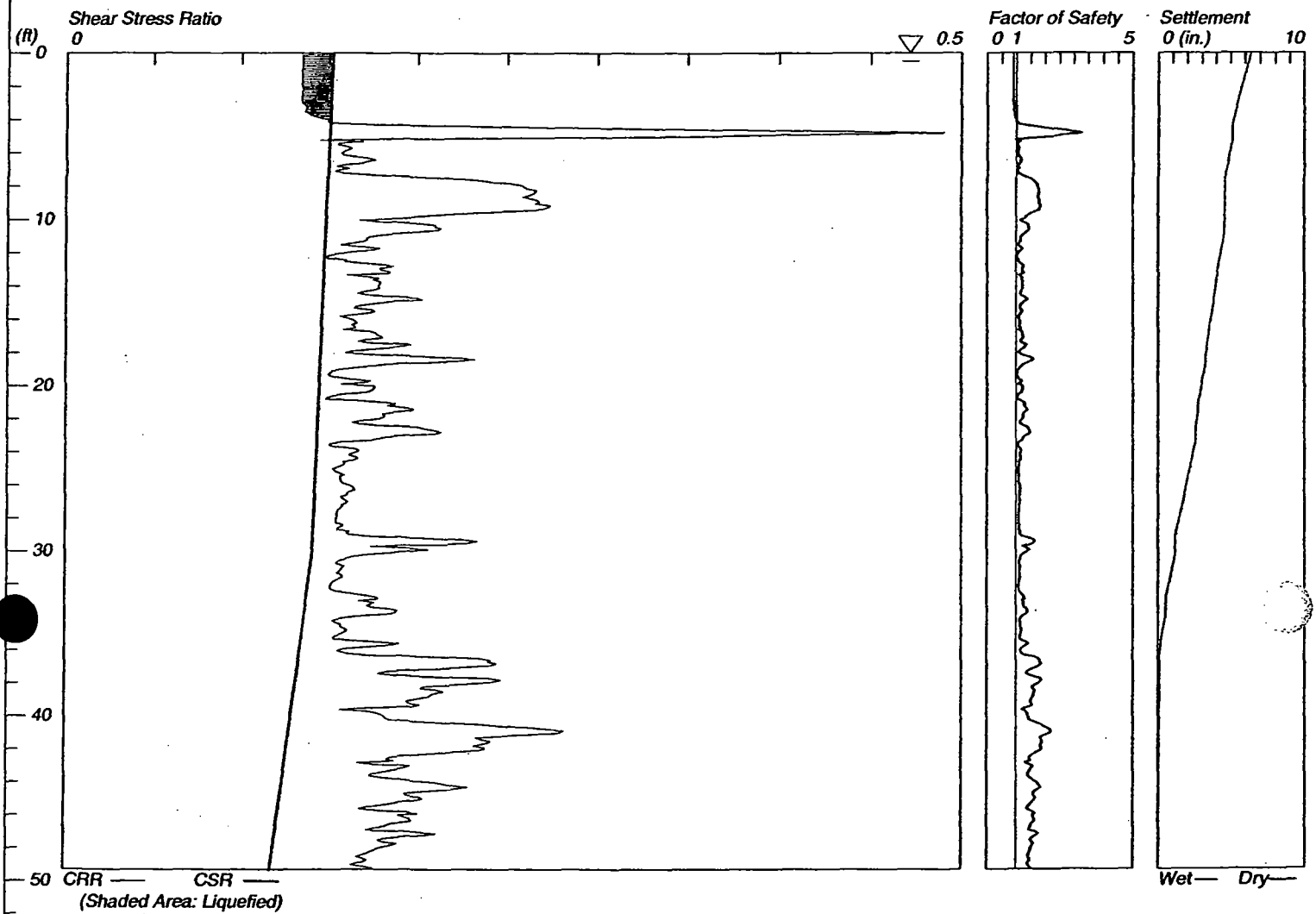
LIQUEFACTION ANALYSIS

PSR-MSU - CPT-P12

Hole No.=P12 Water Depth=0 ft Surface Elev.=-28.2

Magnitude=6.8
Acceleration=0.13g



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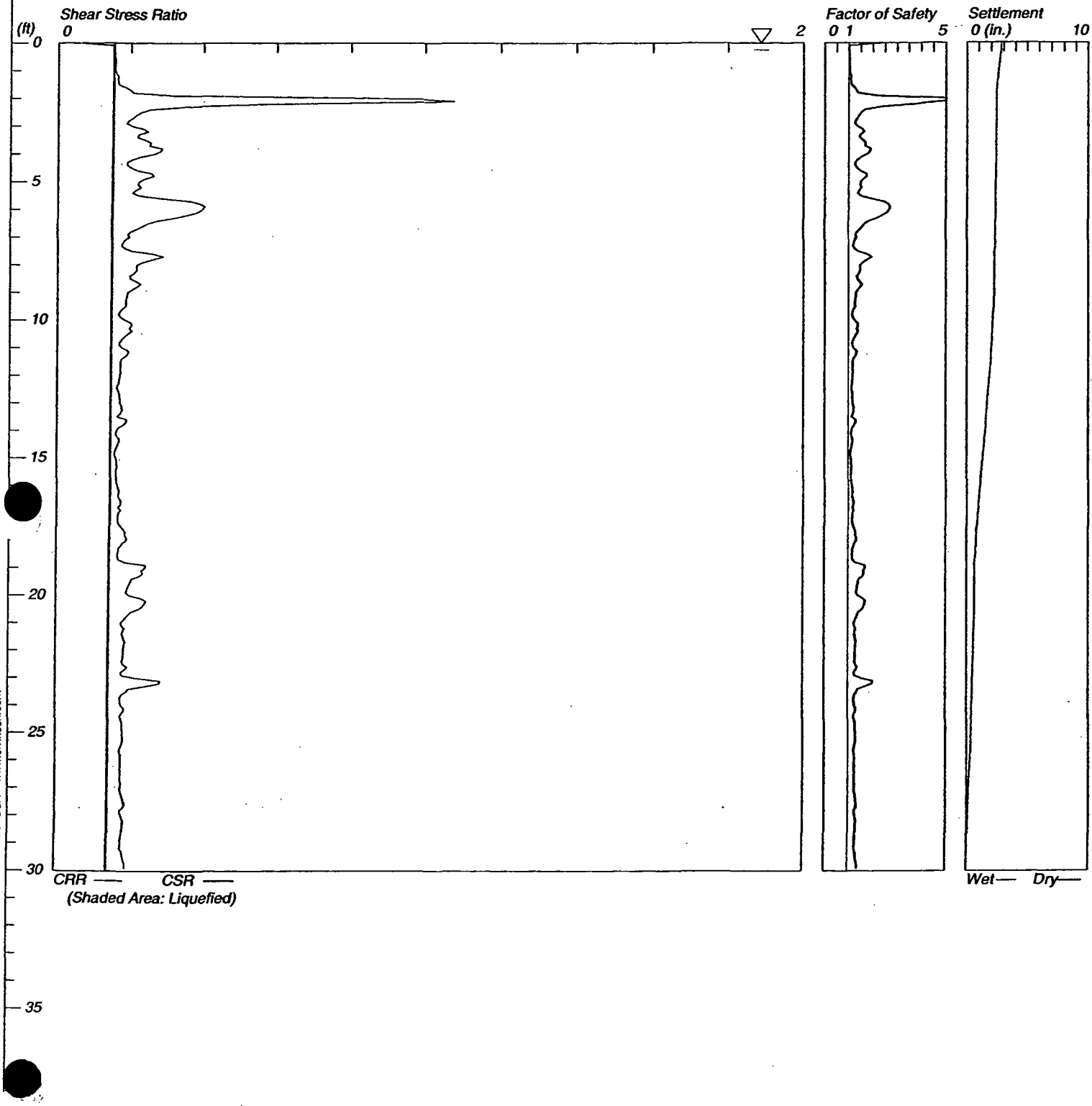
LIQUEFACTION ANALYSIS

PSR-MSU CPT P13

Hole No.=P13 Water Depth=0 ft Surface Elev.=-115.

Magnitude=6.8
Acceleration=0.13g

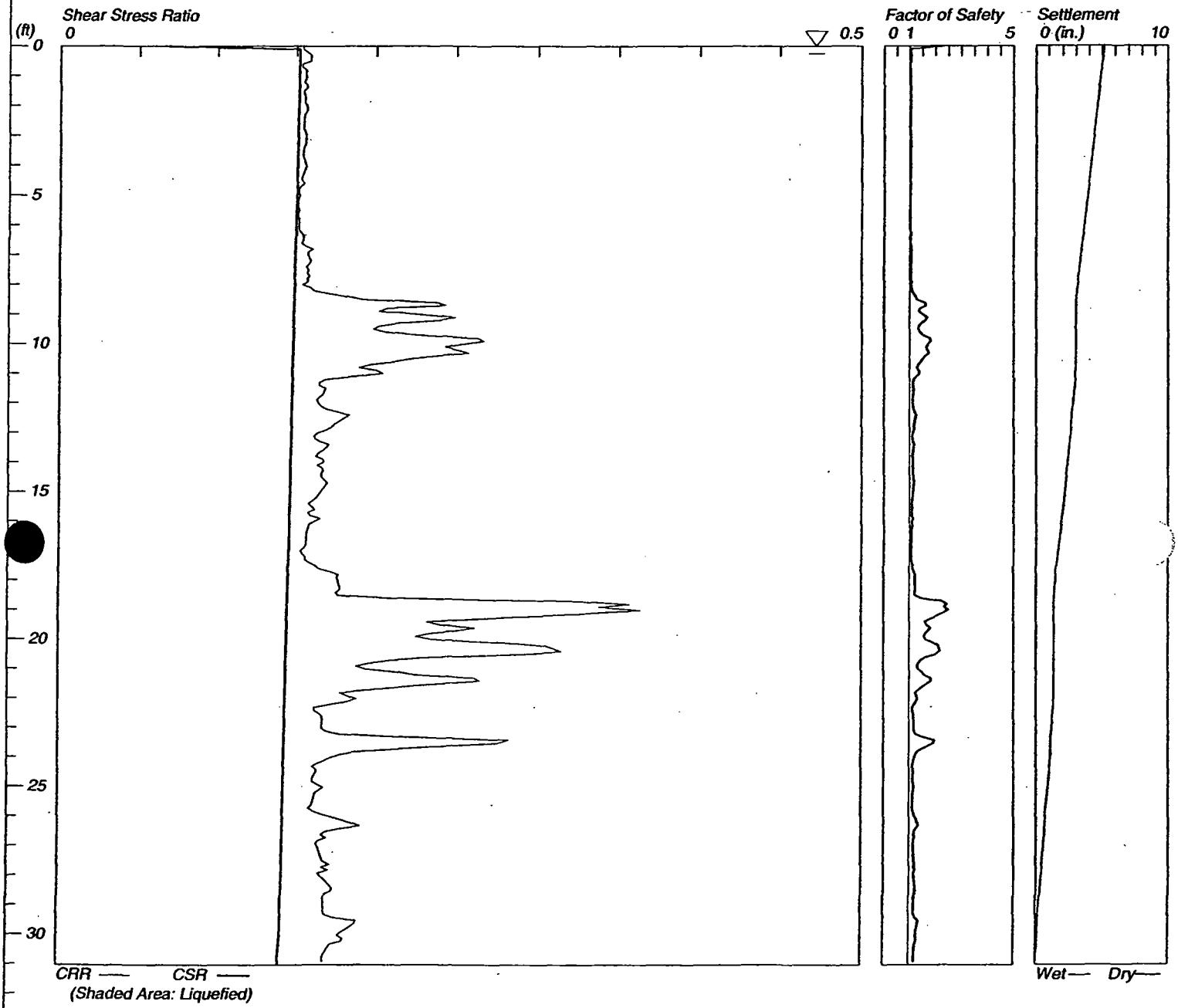


LIQUEFACTION ANALYSIS

PSR-MSU CPT P14

Hole No.=P14 Water Depth=0 ft Surface Elev.=-136.

Magnitude=6.8
Acceleration=0.13g



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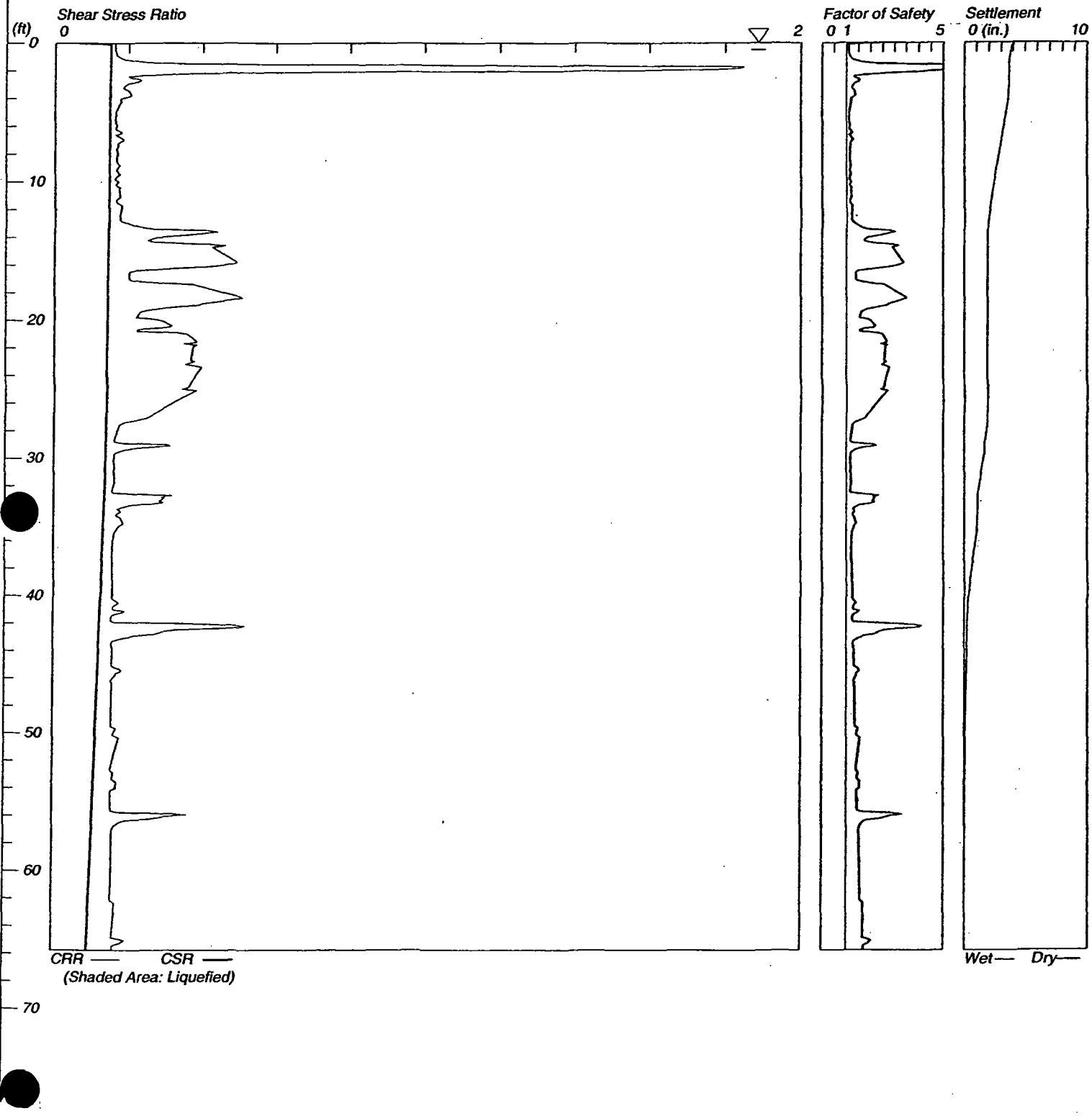
LIQUEFACTION ANALYSIS

PSR-MSU CPT P15

Hole No.=P15 Water Depth=0 ft Surface Elev.=-195.

Magnitude=6.8
Acceleration=0.13g



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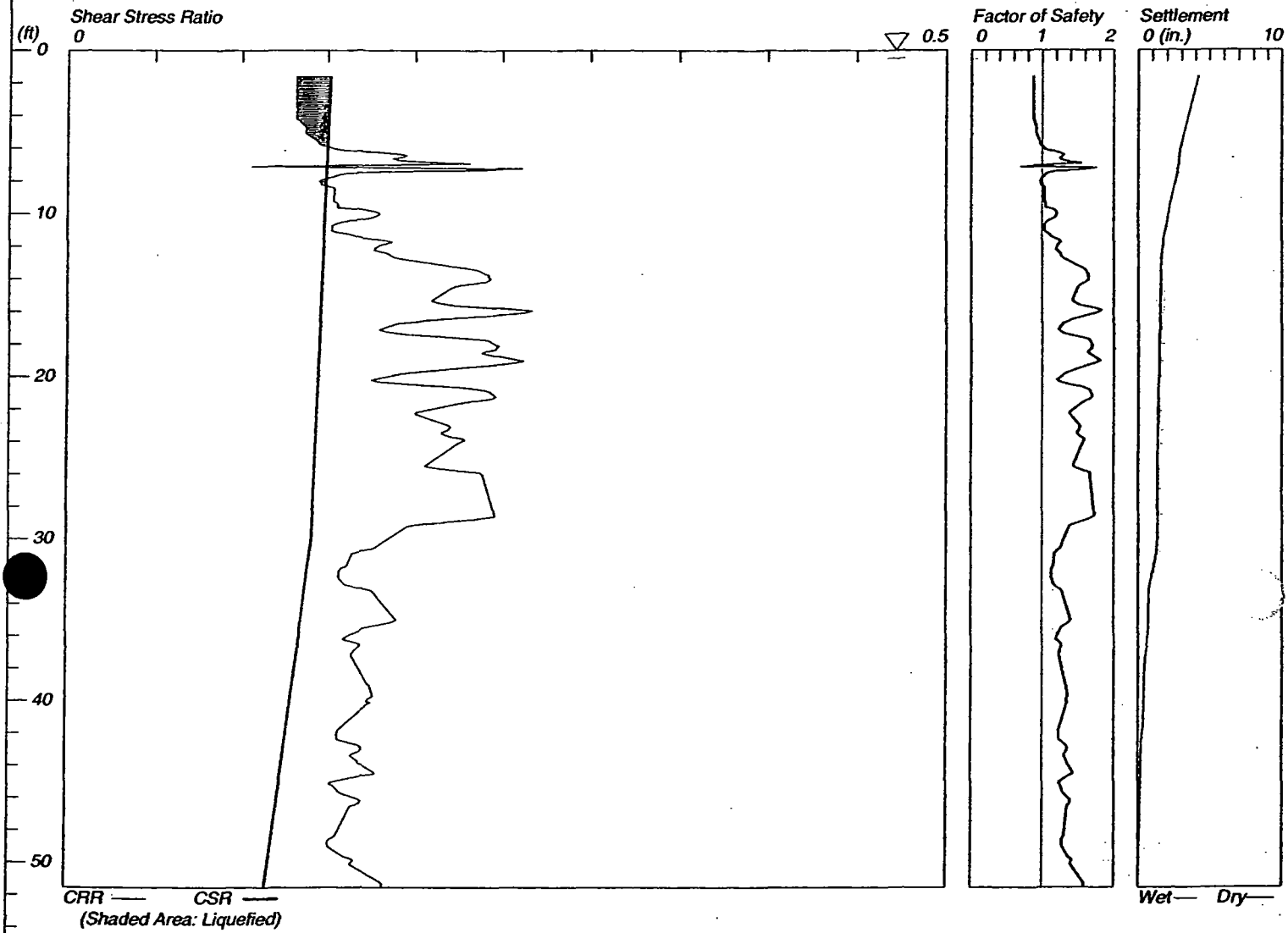
LIQUEFACTION ANALYSIS

PSR-MSU CPT P16

Hole No.=P16 Water Depth=0 ft Surface Elev.=-30.9

Magnitude=6.8
Acceleration=0.13g



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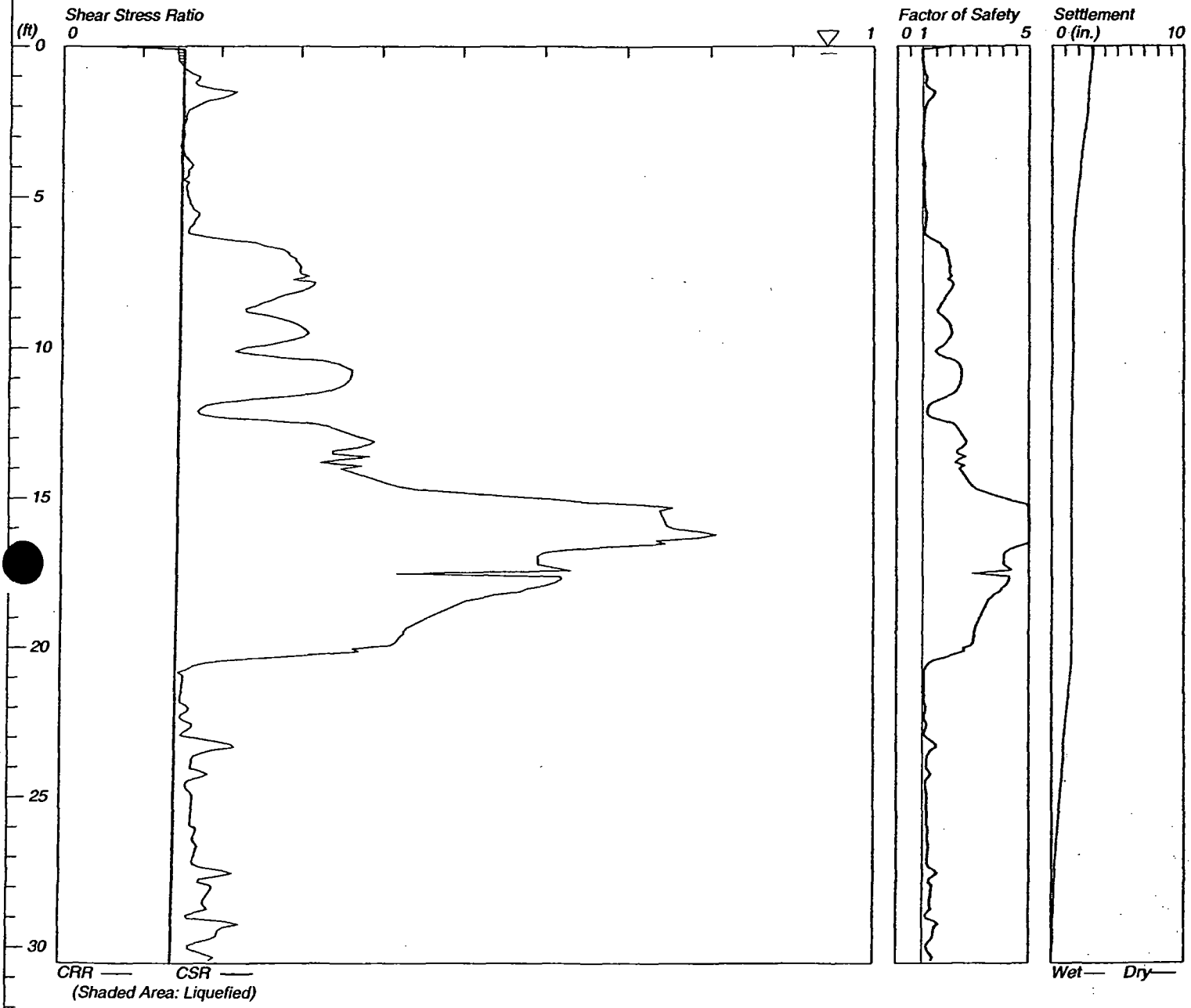
LIQUEFACTION ANALYSIS

PSR_MSU P17

Hole No.=P17 Water Depth=0 ft Surface Elev.=-89

Magnitude=6.8
Acceleration=0.13g



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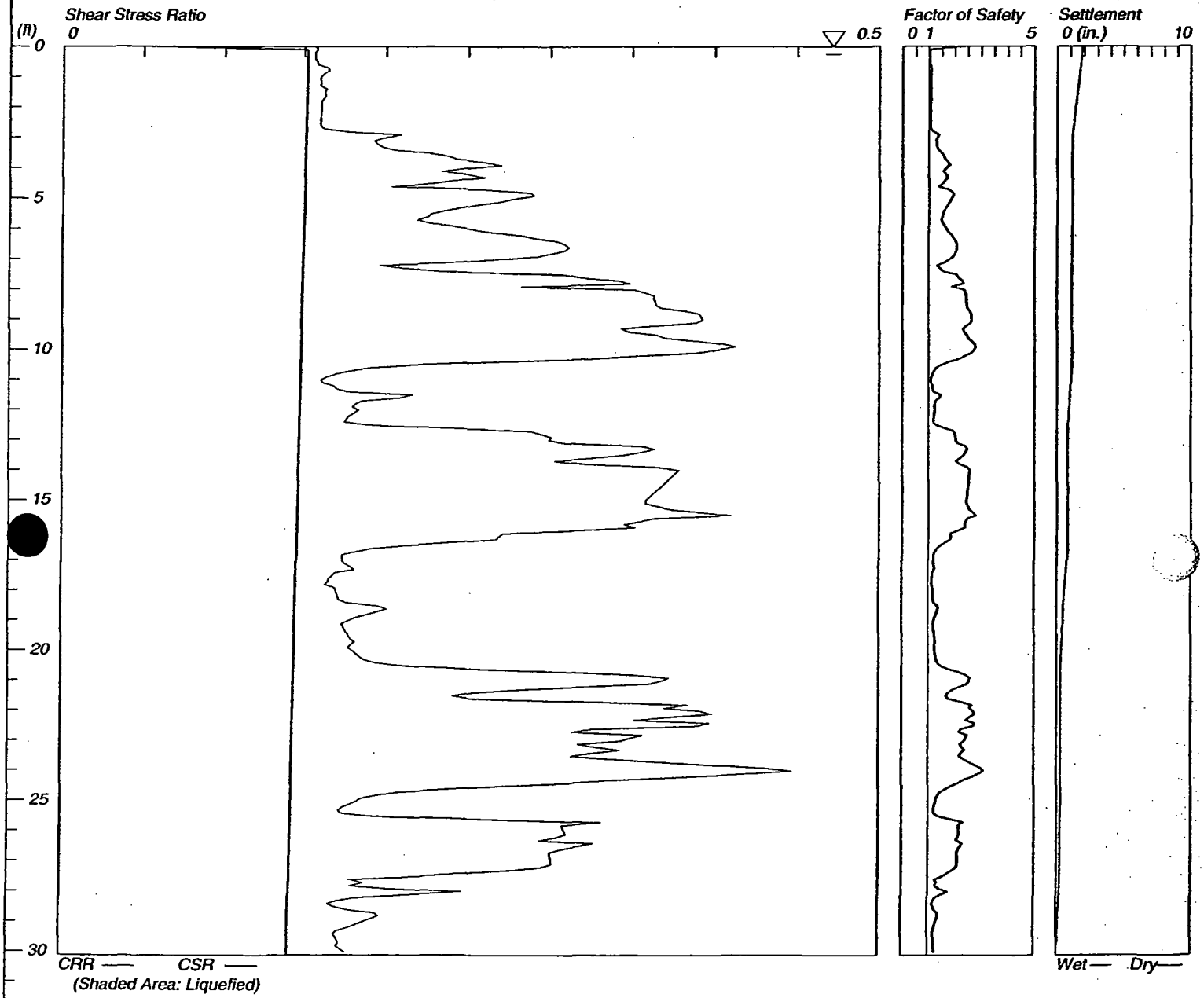
LIQUEFACTION ANALYSIS

PSR-MSU CPT P18

Hole No.=P18 Water Depth=0 ft Surface Elev.=-143.

Magnitude=6.6
Acceleration=0.13g



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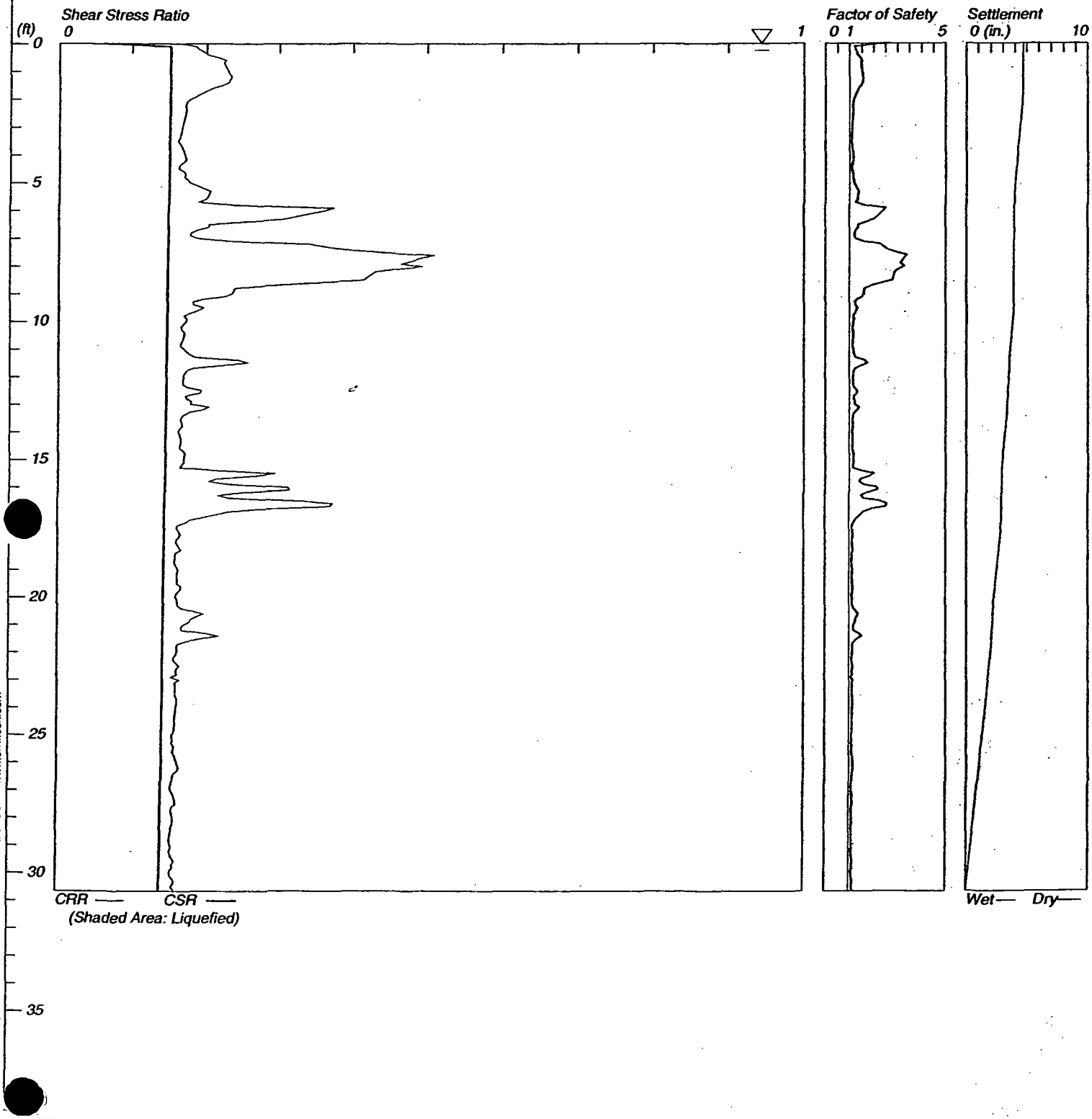
LIQUEFACTION ANALYSIS

PSR-MSU CPT 19

Hole No.=P19 Water Depth=0 ft Surface Elev.=-177.

Magnitude=6.8
Acceleration=0.13g



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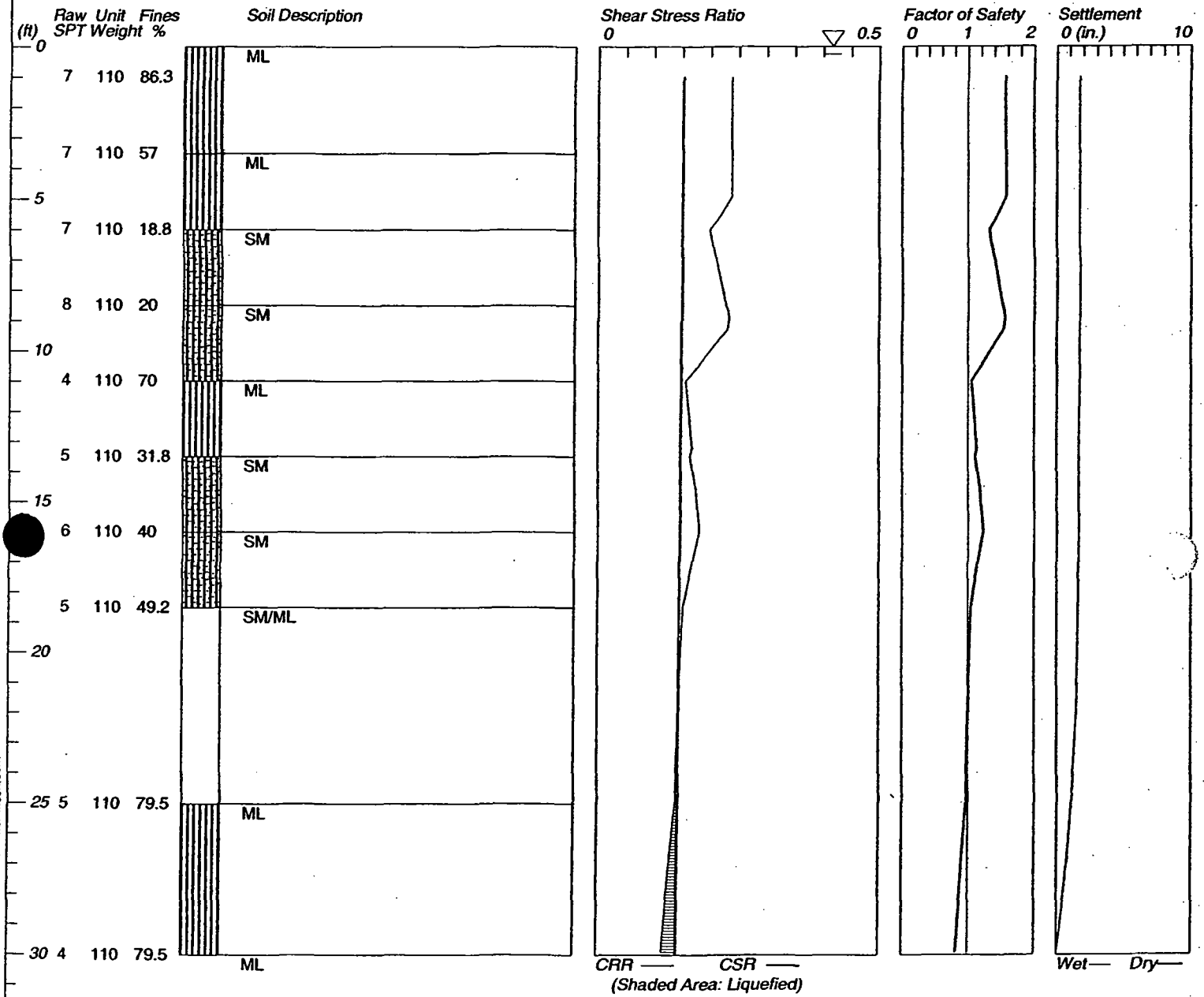
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-1 Water Depth=0 ft Surface Elev.=-43.3

Magnitude=6.6
Acceleration=0.13g



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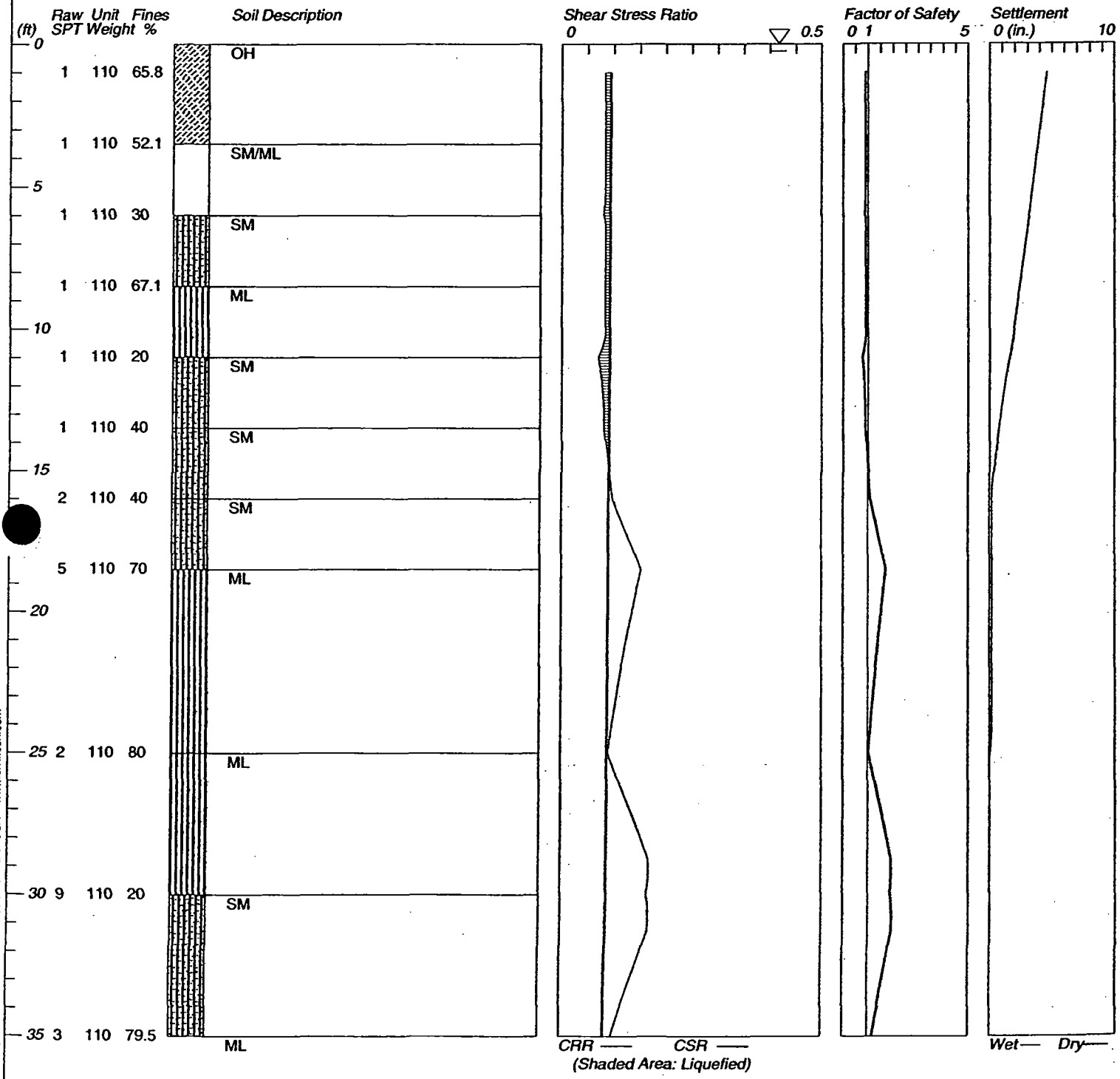
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-2 Water Depth=0 ft Surface Elev.=-31.4

Magnitude=6.8
Acceleration=0.08g



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SPT LIQUEFACTION ANALYSIS

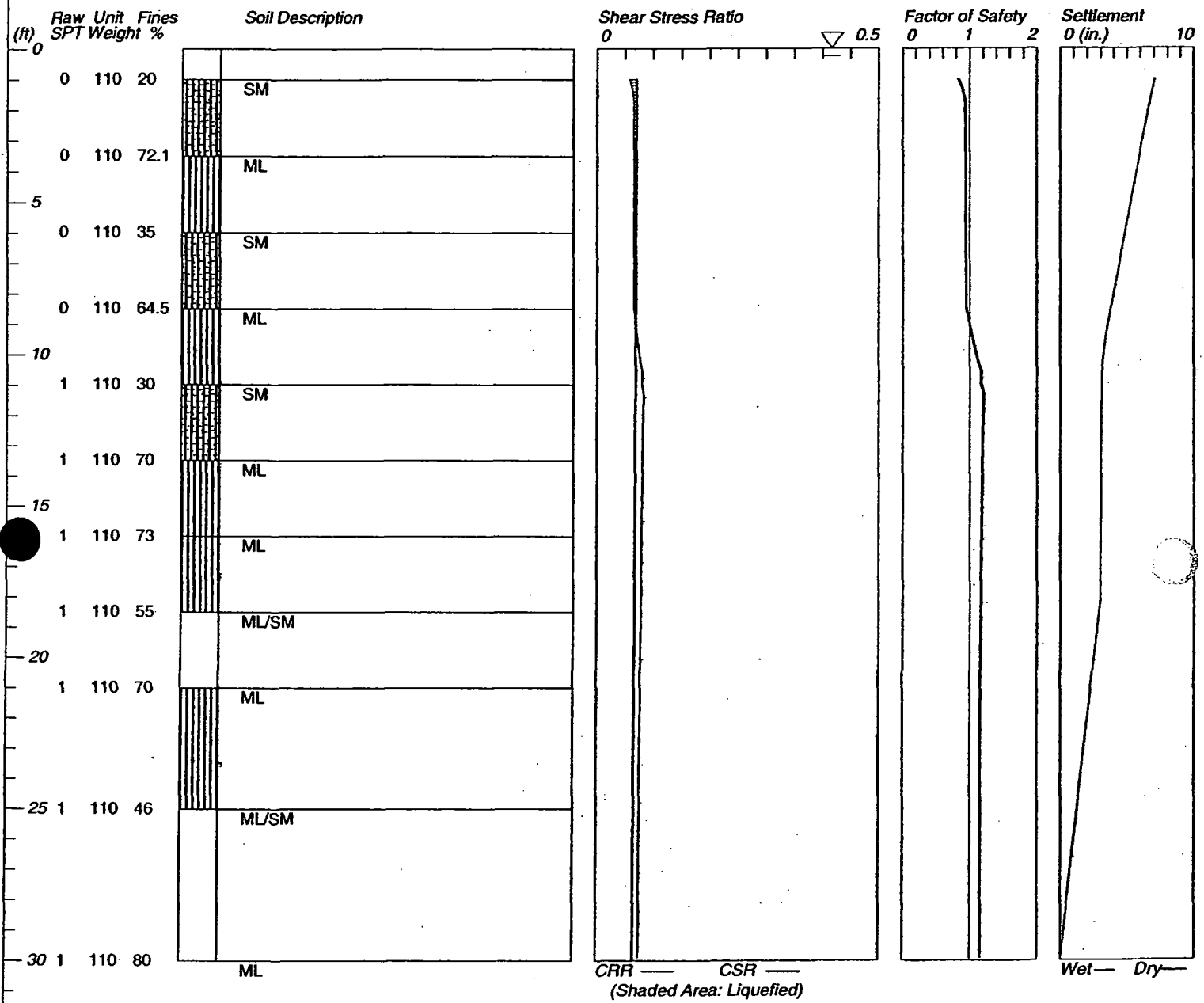
Plate A-1

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-3 Water Depth=0 ft Surface Elev.=-73.4

Magnitude=6.6
Acceleration=0.06g



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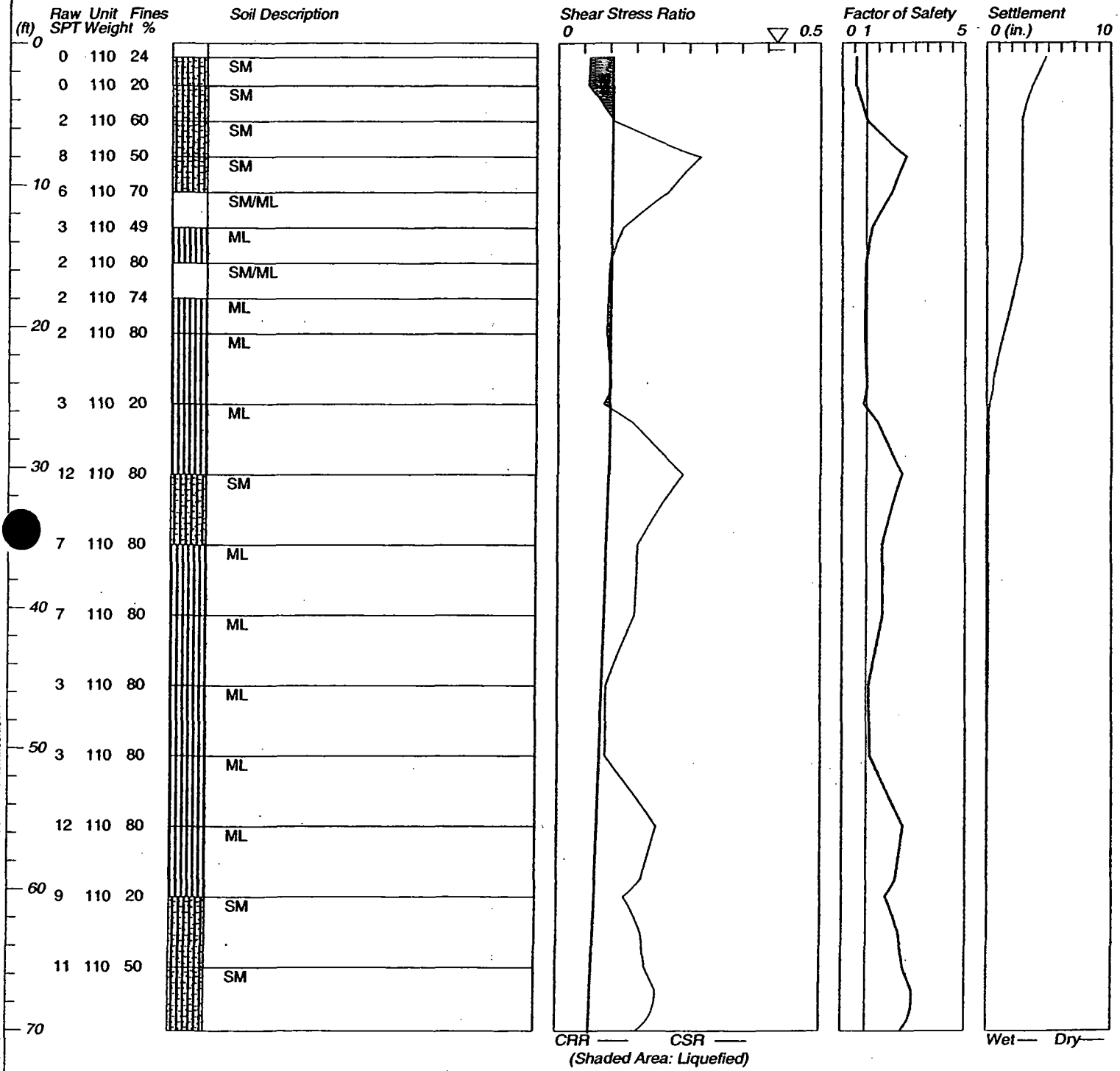
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-4 Water Depth=0 ft Surface Elev.=-71.9

Magnitude=6.8
Acceleration=0.09g



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URS

SPT LIQUEFACTION ANALYSIS

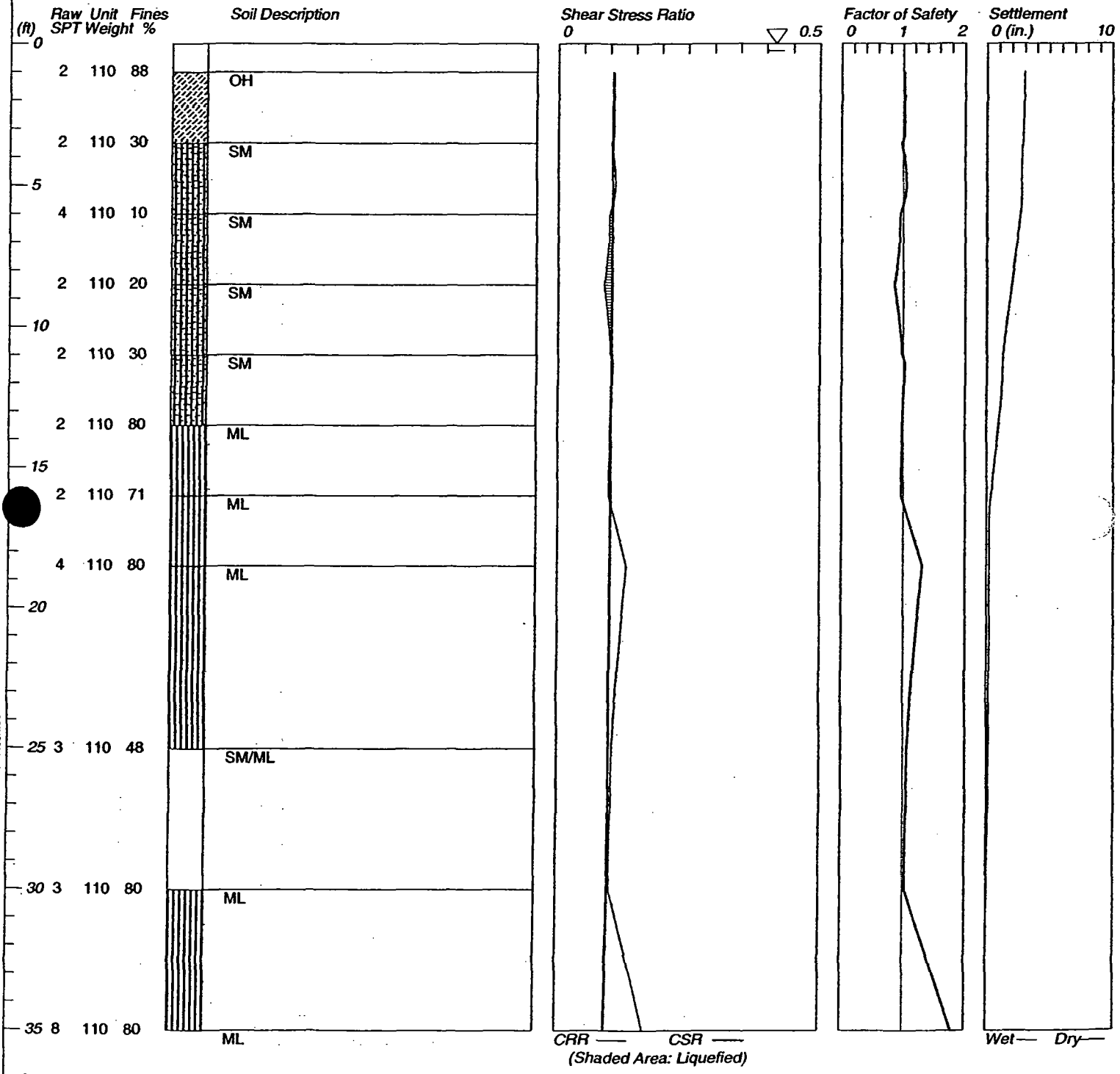
Plate A-1

LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-5 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.8
Acceleration=0.09g



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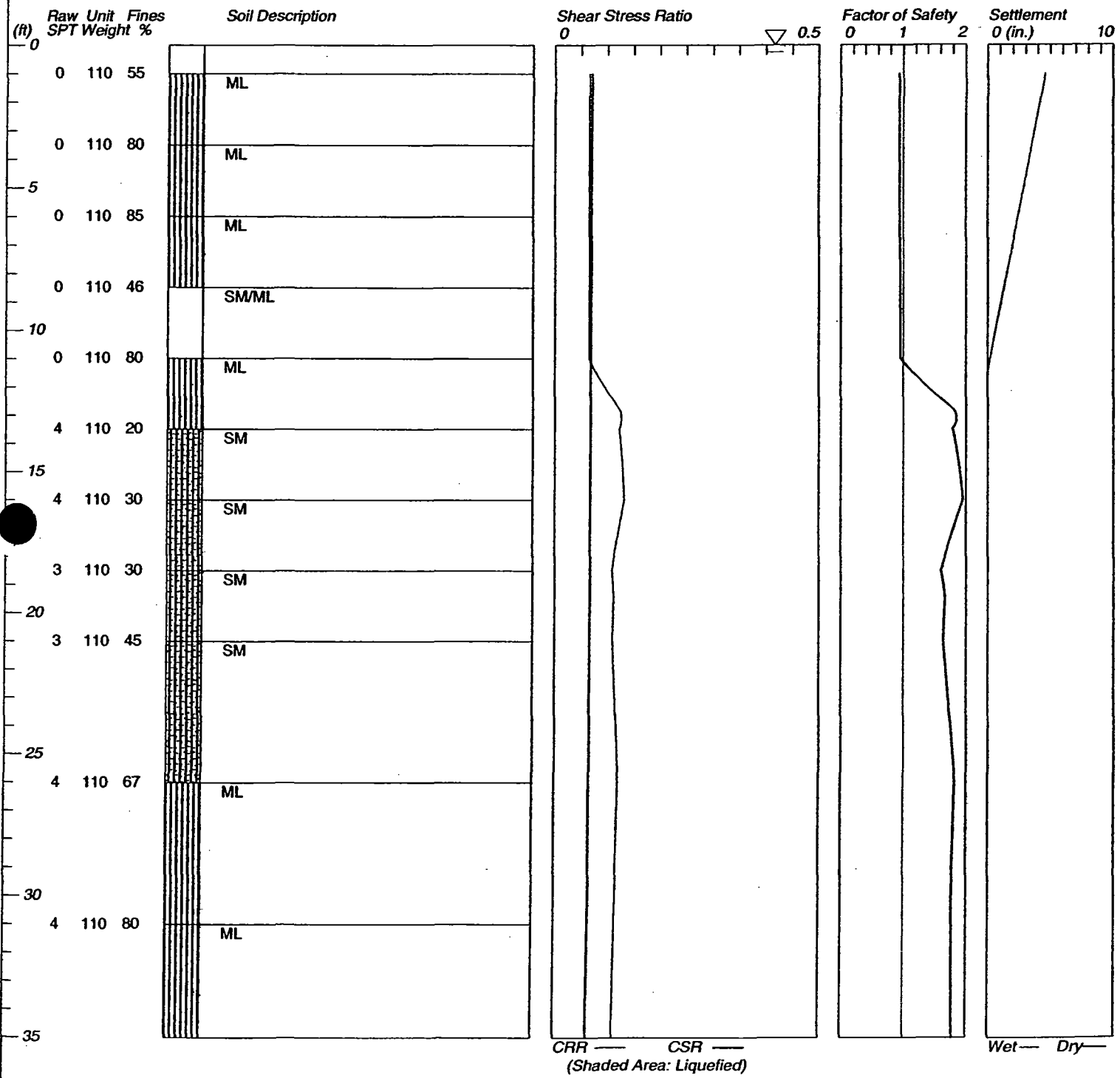
LIQUEFACTION ANALYSIS

PSR-MSU

Hole No.=B-6 Water Depth=0 ft Surface Elev.=-35.3

Magnitude=6.8
Acceleration=0.06g



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LIQUEFACTION ANALYSIS CALCULATION SHEET

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Earthquake Magnitude= 6.8 Max. Acceleration= 0.22 g
Depth of Hole= 49.3 ft Depth of Water Table= 0.0 ft

Input Data:

No.	Depth ft	qc tsf	fs tsf	Gamma pcf	Fines %	D50 mm
1	0.1	0.5	0.0	110.0	88.0	0.1
2	0.2	0.5	0.0	110.0	88.0	0.1
3	0.3	0.5	0.0	110.0	88.0	0.1
4	0.5	0.5	0.0	110.0	88.0	0.1
5	0.6	0.5	0.0	110.0	88.0	0.1
6	0.7	0.5	0.0	110.0	88.0	0.1
7	0.9	0.5	0.0	110.0	88.0	0.1
8	1.0	0.5	0.0	110.0	88.0	0.1
9	1.1	0.5	0.0	110.0	88.0	0.1
10	1.2	0.5	0.0	110.0	88.0	0.1
11	1.4	0.5	0.0	110.0	88.0	0.1
12	1.5	0.5	0.0	110.0	88.0	0.1
13	1.6	0.5	0.0	110.0	88.0	0.1
14	1.8	0.5	0.0	110.0	88.0	0.1
15	1.9	0.5	0.0	110.0	88.0	0.1
16	2.0	0.5	0.0	110.0	88.0	0.1
17	2.2	0.7	0.0	110.0	88.0	0.1
18	2.3	0.5	0.0	110.0	88.0	0.1
19	2.4	0.5	0.0	110.0	88.0	0.1
20	2.6	0.5	0.0	110.0	88.0	0.1
21	2.7	0.5	0.0	110.0	88.0	0.1
22	2.8	0.5	0.0	110.0	88.0	0.1
23	3.0	0.5	0.0	110.0	88.0	0.1
24	3.1	0.7	0.0	110.0	88.0	0.1
25	3.2	0.9	0.0	110.0	88.0	0.1
26	3.3	0.9	0.0	110.0	88.0	0.1
27	3.5	0.7	0.0	110.0	88.0	0.1
28	3.6	1.1	0.0	110.0	88.0	0.1
29	3.7	1.4	0.0	110.0	88.0	0.1
30	3.9	2.1	0.1	110.0	80.0	0.1
31	4.0	3.2	0.1	110.0	80.0	0.1
32	4.1	2.8	0.1	110.0	80.0	0.1
33	4.3	3.9	0.1	110.0	80.0	0.1
34	4.4	15.6	0.1	110.0	50.0	0.1
35	4.5	24.3	0.1	110.0	40.0	0.1
36	4.7	33.0	0.2	110.0	40.0	0.1
37	4.8	39.7	0.1	110.0	40.0	0.1
38	4.9	29.8	0.2	110.0	40.0	0.1
39	5.1	25.5	0.1	110.0	40.0	0.1
40	5.2	11.5	0.1	110.0	50.0	0.8
41	5.3	5.5	0.1	110.0	88.0	0.1
42	5.4	3.4	0.1	110.0	80.0	0.1
43	5.6	4.8	0.1	110.0	75.0	0.1
44	5.7	5.3	0.1	110.0	75.0	0.1
45	5.8	4.8	0.1	110.0	75.0	0.1
46	6.0	4.4	0.1	110.0	80.0	0.1
47	6.1	4.6	0.1	110.0	80.0	0.1
48	6.2	6.0	0.1	110.0	75.0	0.1
49	6.4	7.8	0.2	110.0	75.0	0.1
50	6.5	6.6	0.2	110.0	75.0	0.1
51	6.6	6.2	0.1	110.0	75.0	0.1
52	6.8	3.4	0.1	110.0	80.0	0.1
53	6.9	5.3	0.1	110.0	75.0	0.1
54	7.0	4.1	0.1	110.0	80.0	0.1
55	7.2	3.7	0.1	110.0	80.0	0.1
56	7.3	6.9	0.1	110.0	70.0	0.1
57	7.4	10.5	0.1	110.0	70.0	0.1
58	7.5	15.6	0.1	110.0	50.0	0.1
59	7.7	16.5	0.1	110.0	50.0	0.1
60	7.8	18.4	0.1	110.0	50.0	0.1
61	7.9	19.3	0.1	110.0	50.0	0.1
62	8.1	19.3	0.1	110.0	50.0	0.1
63	8.2	20.2	0.1	110.0	50.0	0.1

64	8.3	20.2	0.1	110.0	40.0	0.1
65	8.5	20.0	0.1	110.0	40.0	0.1
66	8.6	19.5	0.1	110.0	50.0	0.1
67	8.7	20.2	0.1	110.0	40.0	0.1
68	8.9	20.9	0.1	110.0	40.0	0.1
69	9.0	20.4	0.1	110.0	40.0	0.1
70	9.1	21.8	0.1	110.0	40.0	0.1
71	9.3	21.3	0.1	110.0	40.0	0.1
72	9.4	21.1	0.1	110.0	40.0	0.1
73	9.5	17.4	0.1	110.0	50.0	0.1
74	9.6	14.4	0.1	110.0	50.0	0.1
75	9.8	11.7	0.1	110.0	50.0	0.1
76	9.9	11.0	0.1	110.0	70.0	0.1
77	10.0	5.3	0.1	110.0	70.0	0.1
78	10.2	11.7	0.2	110.0	70.0	0.1
79	10.3	13.5	0.1	110.0	50.0	0.1
80	10.4	13.5	0.1	110.0	50.0	0.1
81	10.6	14.4	0.2	110.0	50.0	0.1
82	10.7	12.4	0.2	110.0	70.0	0.1
83	10.8	10.5	0.2	110.0	70.0	0.1
84	10.9	8.0	0.2	110.0	70.0	0.1
85	11.1	7.6	0.2	110.0	70.0	0.1
86	11.2	7.6	0.2	110.0	70.0	0.1
87	11.4	6.9	0.2	110.0	70.0	0.1
88	11.5	4.6	0.1	110.0	80.0	0.1
89	11.6	7.3	0.2	110.0	75.0	0.1
90	11.7	9.6	0.2	110.0	70.0	0.1
91	11.9	6.6	0.2	110.0	75.0	0.1
92	12.0	5.3	0.2	110.0	80.0	0.1
93	12.1	3.7	0.2	110.0	80.0	0.1
94	12.3	3.0	0.2	110.0	80.0	0.1
95	12.4	5.7	0.2	110.0	80.0	0.1
96	12.5	5.5	0.1	110.0	80.0	0.1
97	12.7	9.6	0.2	110.0	70.0	0.1
98	12.8	10.5	0.2	110.0	70.0	0.1
99	12.9	8.9	0.2	110.0	70.0	0.1
100	13.1	9.6	0.2	110.0	70.0	0.1
101	13.2	11.0	0.2	110.0	70.0	0.1
102	13.3	5.1	0.2	110.0	70.0	0.1
103	13.4	9.6	0.2	110.0	70.0	0.1
104	13.6	8.5	0.2	110.0	70.0	0.1
105	13.7	9.4	0.2	110.0	70.0	0.1
106	13.8	9.4	0.2	110.0	70.0	0.1
107	14.0	9.2	0.2	110.0	70.0	0.1
108	14.1	9.4	0.2	110.0	70.0	0.1
109	14.2	8.7	0.2	110.0	70.0	0.1
110	14.4	6.9	0.1	110.0	75.0	0.1
111	14.5	8.3	0.2	110.0	75.0	0.1
112	14.6	11.5	0.2	110.0	70.0	0.1
113	14.8	14.9	0.2	110.0	50.0	0.1
114	14.9	11.0	0.1	110.0	70.0	0.1
115	15.0	9.2	0.2	110.0	70.0	0.1
116	15.1	7.3	0.2	110.0	75.0	0.1
117	15.3	6.6	0.2	110.0	80.0	0.1
118	15.4	9.2	0.2	110.0	75.0	0.1
119	15.6	9.2	0.2	110.0	75.0	0.1
120	15.7	7.3	0.2	110.0	75.0	0.1
121	15.8	5.3	0.2	110.0	80.0	0.1
122	15.9	6.6	0.2	110.0	80.0	0.1
123	16.1	7.1	0.2	110.0	75.0	0.1
124	16.2	7.3	0.2	110.0	75.0	0.1
125	16.3	6.6	0.2	110.0	75.0	0.1
126	16.5	7.6	0.2	110.0	75.0	0.1
127	16.6	6.0	0.2	110.0	80.0	0.1
128	16.7	9.6	0.2	110.0	70.0	0.1
129	16.9	9.4	0.2	110.0	70.0	0.1
130	17.0	10.1	0.2	110.0	70.0	0.1
131	17.1	10.3	0.2	110.0	70.0	0.1
132	17.3	7.3	0.2	110.0	75.0	0.1
133	17.4	8.3	0.3	110.0	80.0	0.1
134	17.5	13.8	0.3	110.0	70.0	0.1
135	17.6	12.1	0.2	110.0	70.0	0.1
136	17.8	9.4	0.2	110.0	75.0	0.1
137	17.9	6.9	0.2	110.0	80.0	0.1
138	18.0	6.2	0.2	110.0	80.0	0.1
139	18.2	12.4	0.3	110.0	70.0	0.1
140	18.3	18.6	0.2	110.0	50.0	0.1
141	18.4	20.2	0.2	110.0	50.0	0.1

142	18.6	16.0	0.2	110.0	50.0	0.1
143	18.7	11.0	0.2	110.0	70.0	0.1
144	18.8	8.9	0.2	110.0	75.0	0.1
145	19.0	6.6	0.2	110.0	80.0	0.1
146	19.1	4.8	0.2	110.0	80.0	0.1
147	19.2	4.6	0.2	110.0	80.0	0.1
148	19.4	4.1	0.2	110.0	80.0	0.1
149	19.5	5.3	0.2	110.0	80.0	0.1
150	19.6	7.3	0.2	110.0	75.0	0.1
151	19.8	10.8	0.2	110.0	70.0	0.1
152	19.9	5.3	0.3	110.0	80.0	0.1
153	20.0	10.3	0.2	110.0	70.0	0.1
154	20.1	9.9	0.2	110.0	70.0	0.1
155	20.3	9.9	0.2	110.0	70.0	0.1
156	20.4	8.9	0.2	110.0	75.0	0.1
157	20.5	5.7	0.2	110.0	80.0	0.1
158	20.7	4.4	0.2	110.0	80.0	0.1
159	20.8	4.1	0.2	110.0	80.0	0.1
160	20.9	9.9	0.2	110.0	70.0	0.1
161	21.1	13.1	0.2	110.0	70.0	0.1
162	21.2	11.7	0.2	110.0	70.0	0.1
163	21.3	13.3	0.2	110.0	70.0	0.1
164	21.5	15.6	0.2	110.0	50.0	0.1
165	21.6	12.8	0.2	110.0	70.0	0.1
166	21.7	11.2	0.2	110.0	70.0	0.1
167	21.9	11.7	0.3	110.0	70.0	0.1
168	22.0	11.2	0.2	110.0	70.0	0.1
169	22.1	8.7	0.2	110.0	75.0	0.1
170	22.2	7.3	0.2	110.0	75.0	0.1
171	22.4	10.1	0.2	110.0	70.0	0.1
172	22.5	15.6	0.2	110.0	50.0	0.1
173	22.6	16.5	0.2	110.0	50.0	0.1
174	22.8	18.4	0.3	110.0	50.0	0.1
175	22.9	17.4	0.3	110.0	50.0	0.1
176	23.0	13.1	0.2	110.0	70.0	0.1
177	23.2	11.2	0.2	110.0	70.0	0.1
178	23.3	10.5	0.2	110.0	70.0	0.1
179	23.4	5.7	0.2	110.0	80.0	0.1
180	23.5	4.4	0.2	110.0	80.0	0.1
181	23.7	5.5	0.2	110.0	80.0	0.1
182	23.8	8.5	0.3	110.0	75.0	0.1
183	24.0	8.9	0.3	110.0	75.0	0.1
184	24.1	7.8	0.2	110.0	75.0	0.1
185	24.2	7.6	0.2	110.0	80.0	0.1
186	24.3	8.9	0.3	110.0	75.0	0.1
187	24.5	8.5	0.2	110.0	75.0	0.1
188	24.6	6.9	0.2	110.0	75.0	0.1
189	24.7	7.1	0.2	110.0	75.0	0.1
190	24.9	6.6	0.2	110.0	75.0	0.1
191	25.0	5.5	0.2	110.0	80.0	0.1
192	25.1	5.7	0.2	110.0	80.0	0.1
193	25.3	6.2	0.2	110.0	80.0	0.1
194	25.4	7.1	0.2	110.0	80.0	0.1
195	25.5	6.4	0.2	110.0	80.0	0.1
196	25.6	6.6	0.2	110.0	80.0	0.1
197	25.8	6.6	0.2	110.0	80.0	0.1
198	25.9	7.1	0.2	110.0	80.0	0.1
199	26.0	8.3	0.2	110.0	75.0	0.1
200	26.2	8.5	0.2	110.0	75.0	0.1
201	26.3	8.7	0.2	110.0	75.0	0.1
202	26.4	7.6	0.2	110.0	75.0	0.1
203	26.6	7.8	0.2	110.0	75.0	0.1
204	26.7	6.9	0.2	110.0	80.0	0.1
205	26.8	6.9	0.2	110.0	80.0	0.1
206	27.0	7.8	0.2	110.0	75.0	0.1
207	27.1	7.6	0.2	110.0	75.0	0.1
208	27.2	6.9	0.2	110.0	75.0	0.1
209	27.4	7.1	0.2	110.0	80.0	0.1
210	27.5	6.4	0.2	110.0	80.0	0.1
211	27.6	6.4	0.2	110.0	80.0	0.1
212	27.8	6.2	0.2	110.0	80.0	0.1
213	27.9	6.4	0.2	110.0	80.0	0.1
214	28.0	6.2	0.2	110.0	80.0	0.1
215	28.1	6.2	0.2	110.0	80.0	0.1
216	28.3	6.2	0.2	110.0	80.0	0.1
217	28.4	7.3	0.2	110.0	75.0	0.1
218	28.5	7.1	0.2	110.0	75.0	0.1
219	28.7	6.0	0.2	110.0	80.0	0.1

220	28.8	8.3	0.2	110.0	75.0	0.1
221	28.9	7.8	0.2	110.0	75.0	0.1
222	29.1	8.7	0.2	110.0	75.0	0.1
223	29.2	17.2	0.3	110.0	50.0	0.1
224	29.3	24.5	0.3	110.0	50.0	0.1
225	29.5	24.3	0.2	110.0	30.0	0.1
226	29.6	21.3	0.2	110.0	50.0	0.1
227	29.7	9.6	0.3	110.0	75.0	0.1
228	29.9	19.7	0.3	110.0	50.0	0.1
229	30.0	17.2	0.2	110.0	50.0	0.1
230	30.1	13.5	0.2	110.0	70.0	0.1
231	30.2	9.9	0.3	110.0	75.0	0.1
232	30.4	8.3	0.3	110.0	80.0	0.1
233	30.5	7.8	0.3	110.0	80.0	0.1
234	30.6	6.4	0.3	110.0	80.0	0.1
235	30.8	6.6	0.2	110.0	80.0	0.1
236	30.9	7.8	0.2	110.0	75.0	0.1
237	31.0	7.3	0.2	110.0	75.0	0.1
238	31.2	7.3	0.2	110.0	75.0	0.1
239	31.3	6.6	0.2	110.0	80.0	0.1
240	31.4	7.3	0.2	110.0	75.0	0.1
241	31.6	7.8	0.2	110.0	75.0	0.1
242	31.7	6.9	0.2	110.0	75.0	0.1
243	31.8	6.2	0.2	110.0	80.0	0.1
244	32.0	6.0	0.2	110.0	80.0	0.1
245	32.1	5.7	0.2	110.0	80.0	0.1
246	32.2	5.7	0.2	110.0	80.0	0.1
247	32.3	6.0	0.2	110.0	80.0	0.1
248	32.5	7.6	0.2	110.0	75.0	0.1
249	32.6	10.1	0.2	110.0	70.0	0.1
250	32.7	12.1	0.2	110.0	70.0	0.1
251	32.9	13.8	0.2	110.0	70.0	0.1
252	33.0	10.3	0.1	110.0	70.0	0.1
253	33.1	13.1	0.2	110.0	70.0	0.1
254	33.3	11.2	0.2	110.0	70.0	0.1
255	33.4	11.9	0.2	110.0	70.0	0.1
256	33.5	15.8	0.2	110.0	50.0	0.1
257	33.7	15.8	0.2	110.0	50.0	0.1
258	33.8	15.4	0.2	110.0	50.0	0.1
259	33.9	10.3	0.2	110.0	70.0	0.1
260	34.0	7.8	0.2	110.0	75.0	0.1
261	34.2	6.2	0.2	110.0	80.0	0.1
262	34.3	6.9	0.2	110.0	80.0	0.1
263	34.4	7.8	0.2	110.0	75.0	0.1
264	34.6	7.6	0.2	110.0	75.0	0.1
265	34.7	8.5	0.2	110.0	75.0	0.1
266	34.8	8.7	0.3	110.0	75.0	0.1
267	35.0	8.0	0.3	110.0	80.0	0.1
268	35.1	7.1	0.2	110.0	80.0	0.1
269	35.2	6.4	0.2	110.0	80.0	0.1
270	35.4	6.9	0.2	110.0	75.0	0.1
271	35.5	13.8	0.2	110.0	70.0	0.1
272	35.6	17.2	0.2	110.0	50.0	0.1
273	35.8	13.1	0.2	110.0	70.0	0.1
274	35.9	8.9	0.2	110.0	75.0	0.1
275	36.0	7.1	0.3	110.0	80.0	0.1
276	36.2	8.5	0.3	110.0	75.0	0.1
277	36.3	9.9	0.1	110.0	70.0	0.1
278	36.4	24.3	0.3	110.0	50.0	0.1
279	36.5	29.1	0.3	110.0	40.0	0.1
280	36.7	28.2	0.3	110.0	40.0	0.1
281	36.8	29.6	0.3	110.0	40.0	0.1
282	36.9	28.7	0.3	110.0	40.0	0.1
283	37.1	23.9	0.3	110.0	50.0	0.1
284	37.2	18.1	0.3	110.0	50.0	0.1
285	37.3	14.0	0.3	110.0	70.0	0.1
286	37.5	14.0	0.3	110.0	70.0	0.1
287	37.6	21.5	0.4	110.0	50.0	0.1
288	37.7	30.7	0.3	110.0	40.0	0.1
289	37.9	30.3	0.3	110.0	40.0	0.1
290	38.0	28.0	0.3	110.0	40.0	0.1
291	38.1	23.4	0.3	110.0	50.0	0.1
292	38.3	19.0	0.3	110.0	50.0	0.1
293	38.4	22.7	0.3	110.0	50.0	0.1
294	38.5	23.6	0.3	110.0	50.0	0.1
295	38.6	21.8	0.3	110.0	50.0	0.1
296	38.8	22.0	0.3	110.0	50.0	0.1
297	38.9	20.4	0.3	110.0	50.0	0.1

298	39.0	18.8	0.2	110.0	50.0	0.1
299	39.2	18.4	0.2	110.0	50.0	0.1
300	39.3	20.6	0.2	110.0	50.0	0.1
301	39.4	19.3	0.2	110.0	50.0	0.1
302	39.6	6.2	0.1	110.0	75.0	0.1
303	39.7	12.8	0.3	110.0	70.0	0.1
304	39.8	14.7	0.3	110.0	70.0	0.1
305	40.0	15.4	0.3	110.0	70.0	0.1
306	40.1	15.6	0.3	110.0	50.0	0.1
307	40.2	16.3	0.3	110.0	50.0	0.1
308	40.3	22.2	0.3	110.0	50.0	0.1
309	40.5	29.1	0.3	110.0	40.0	0.1
310	40.6	32.1	0.3	110.0	40.0	0.1
311	40.7	37.2	0.3	110.0	40.0	0.1
312	40.9	39.5	0.3	110.0	40.0	0.1
313	41.0	38.8	0.3	110.0	40.0	0.1
314	41.1	34.4	0.3	110.0	40.0	0.1
315	41.3	28.7	0.3	110.0	40.0	0.1
316	41.4	29.6	0.3	110.0	40.0	0.1
317	41.5	31.2	0.3	110.0	40.0	0.1
318	41.7	30.0	0.3	110.0	40.0	0.1
319	41.8	28.7	0.3	110.0	40.0	0.1
320	41.9	30.5	0.3	110.0	40.0	0.1
321	42.1	30.0	0.3	110.0	40.0	0.1
322	42.2	24.8	0.3	110.0	50.0	0.1
323	42.3	20.9	0.3	110.0	50.0	0.1
324	42.5	17.2	0.3	110.0	50.0	0.1
325	42.6	16.3	0.3	110.0	50.0	0.1
326	42.7	17.7	0.3	110.0	50.0	0.1
327	42.8	8.9	0.2	110.0	70.0	0.1
328	43.0	20.4	0.3	110.0	50.0	0.1
329	43.1	19.5	0.2	110.0	50.0	0.1
330	43.2	17.9	0.2	110.0	50.0	0.1
331	43.4	16.0	0.3	110.0	50.0	0.1
332	43.5	14.0	0.3	110.0	70.0	0.1
333	43.6	13.8	0.3	110.0	70.0	0.1
334	43.8	17.4	0.3	110.0	50.0	0.1
335	43.9	20.2	0.3	110.0	50.0	0.1
336	44.0	25.0	0.3	110.0	50.0	0.1
337	44.2	25.9	0.3	110.0	40.0	0.2
338	44.3	29.1	0.3	110.0	40.0	0.2
339	44.4	26.6	0.4	110.0	50.0	0.1
340	44.5	21.8	0.3	110.0	50.0	0.1
341	44.7	19.7	0.3	110.0	50.0	0.1
342	44.8	20.2	0.3	110.0	50.0	0.1
343	44.9	23.2	0.3	110.0	50.0	0.1
344	45.1	22.0	0.3	110.0	50.0	0.1
345	45.2	18.8	0.3	110.0	50.0	0.1
346	45.3	17.2	0.3	110.0	50.0	0.1
347	45.5	14.0	0.3	110.0	70.0	0.1
348	45.6	12.4	0.3	110.0	70.0	0.1
349	45.7	16.5	0.3	110.0	70.0	0.1
350	45.9	23.6	0.3	110.0	50.0	0.1
351	46.0	19.0	0.2	110.0	50.0	0.1
352	46.1	20.2	0.2	110.0	50.0	0.1
353	46.3	21.3	0.3	110.0	50.0	0.1
354	46.4	21.3	0.3	110.0	50.0	0.1
355	46.5	17.4	0.3	110.0	50.0	0.1
356	46.7	17.4	0.3	110.0	50.0	0.1
357	46.8	14.9	0.3	110.0	70.0	0.1
358	46.9	13.8	0.3	110.0	70.0	0.1
359	47.0	25.7	0.4	110.0	50.0	0.1
360	47.2	24.8	0.3	110.0	50.0	0.1
361	47.3	19.7	0.3	110.0	50.0	0.1
362	47.4	16.0	0.3	110.0	50.0	0.1
363	47.6	16.0	0.3	110.0	70.0	0.1
364	47.7	19.3	0.3	110.0	50.0	0.1
365	47.8	18.1	0.3	110.0	50.0	0.1
366	48.0	16.3	0.3	110.0	50.0	0.1
367	48.1	15.6	0.3	110.0	70.0	0.1
368	48.2	14.7	0.3	110.0	70.0	0.1
369	48.3	14.0	0.2	110.0	70.0	0.1
370	48.5	12.4	0.2	110.0	70.0	0.1
371	48.6	13.8	0.3	110.0	70.0	0.1
372	48.8	14.7	0.3	110.0	70.0	0.1
373	48.9	12.6	0.2	110.0	70.0	0.1
374	49.0	11.5	0.2	110.0	70.0	0.1
375	49.1	14.9	0.3	110.0	50.0	0.1

376 49.3 16.0 0.3 110.0 50.0 0.1

CSR Calculation:

Depth ft	SigT tsf	SigE tsf	rd	CSR
0.10	0.006	0.002	1.00	0.33
2.10	0.116	0.050	1.00	0.33
4.10	0.226	0.098	0.99	0.33
6.10	0.335	0.145	0.99	0.33
8.10	0.445	0.193	0.98	0.32
10.10	0.555	0.240	0.98	0.32
12.10	0.666	0.288	0.97	0.32
14.10	0.776	0.336	0.97	0.32
16.10	0.886	0.383	0.96	0.32
18.10	0.996	0.431	0.96	0.32
20.10	1.106	0.478	0.95	0.31
22.10	1.215	0.526	0.95	0.31
24.10	1.325	0.574	0.94	0.31
26.10	1.435	0.621	0.94	0.31
28.10	1.545	0.669	0.93	0.31
30.10	1.655	0.716	0.93	0.31
32.10	1.765	0.764	0.91	0.30
34.10	1.875	0.812	0.90	0.30
36.10	1.985	0.859	0.88	0.29
38.10	2.095	0.907	0.86	0.29
40.10	2.205	0.954	0.85	0.28
42.10	2.315	1.002	0.83	0.27
44.10	2.425	1.050	0.82	0.27
46.10	2.536	1.097	0.80	0.26
48.10	2.646	1.145	0.78	0.26

CPT Calculation using Seed's Method:

Depth ft	CPT tsf	fric. tsf	Cq	D50 mm	qc1+ tsf	dqc1= tsf	qc1 tsf	CRRraw
0.10	0.5	0.0	2.2	0.1	1.03	60.00	61.03	0.13
2.10	0.6	0.0	2.1	0.1	1.22	60.00	61.22	0.14
4.10	2.9	0.1	2.0	0.1	5.76	60.00	65.76	0.15
6.10	4.6	0.1	1.9	0.1	8.74	60.00	68.74	0.16
8.10	19.5	0.1	1.8	0.1	35.29	60.00	95.29	0.26
10.10	8.5	0.1	1.7	0.1	14.68	60.00	74.68	0.18
12.10	4.0	0.2	1.7	0.1	6.69	60.00	66.69	0.15
14.10	9.4	0.2	1.6	0.1	14.90	60.00	74.90	0.18
16.10	7.2	0.2	1.5	0.1	10.89	60.00	70.89	0.17
18.10	9.1	0.2	1.5	0.1	13.24	60.00	73.24	0.17
20.10	10.0	0.2	1.4	0.1	14.08	60.00	74.08	0.18
22.10	8.9	0.2	1.4	0.1	12.09	60.00	72.09	0.17
24.10	7.8	0.2	1.3	0.1	10.17	60.00	70.17	0.16
26.10	8.3	0.2	1.3	0.1	10.57	60.00	70.57	0.16
28.10	6.2	0.2	1.2	0.1	7.60	60.00	67.60	0.15
30.10	13.8	0.2	1.2	0.1	16.39	60.00	76.39	0.18
32.10	5.7	0.2	1.2	0.1	6.61	60.00	66.61	0.15
34.10	7.2	0.2	1.1	0.1	8.02	60.00	68.02	0.16
36.10	8.0	0.3	1.1	0.1	8.63	60.00	68.63	0.16
38.10	24.1	0.3	1.1	0.1	25.41	60.00	85.41	0.22
40.10	15.7	0.3	1.0	0.1	16.06	60.00	76.06	0.18
42.10	28.4	0.3	1.0	0.1	28.40	60.00	88.40	0.23
44.10	25.5	0.3	1.0	0.1	24.84	60.00	84.84	0.22
46.10	20.0	0.2	0.9	0.1	18.98	60.00	78.98	0.19
48.10	15.5	0.3	0.9	0.1	14.37	60.00	74.37	0.18

Factor of Safety Calculation:
Earthquake Magnitude= 6.8

Depth ft	SigC	Ksigma	CRR	MSF	CSRm	F.S.
0.10	0.76	1.00	0.13	1.28	0.26	0.52 *
2.10	0.76	1.00	0.14	1.28	0.26	0.53 *
4.10	0.76	1.00	0.15	1.28	0.25	0.58 *
6.10	0.76	1.00	0.16	1.28	0.25	0.62 *
8.10	0.76	1.00	0.26	1.28	0.25	1.03
10.10	0.76	1.00	0.18	1.28	0.25	0.71 *
12.10	0.76	1.00	0.15	1.28	0.25	0.61 *
14.10	0.76	1.00	0.18	1.28	0.25	0.72 *
16.10	0.76	1.00	0.17	1.28	0.25	0.67 *
18.10	0.76	1.00	0.17	1.28	0.25	0.70 *
20.10	0.76	1.00	0.18	1.28	0.25	0.72 *

22.10	0.76	1.00	0.17	1.28	0.24	0.69 *
24.10	0.76	1.00	0.16	1.28	0.24	0.67 *
26.10	0.76	1.00	0.16	1.28	0.24	0.68 *
28.10	0.76	1.00	0.15	1.28	0.24	0.64 *
30.10	0.76	1.00	0.18	1.28	0.24	0.77 *
32.10	0.76	1.00	0.15	1.28	0.23	0.64 *
34.10	0.76	1.00	0.16	1.28	0.23	0.68 *
36.10	0.76	1.00	0.16	1.28	0.23	0.70 *
38.10	0.76	1.00	0.22	1.28	0.22	0.98 *
40.10	0.76	1.00	0.18	1.28	0.22	0.84 *
42.10	0.76	1.00	0.23	1.28	0.21	1.08
44.10	0.76	1.00	0.22	1.28	0.21	1.03
46.10	0.76	1.00	0.19	1.28	0.21	0.94 *
48.10	0.76	1.00	0.18	1.28	0.20	0.88 *

* F.S.<1

Settlement of Saturated Soils:

Depth ft	CSR	F.S.	qc1 tsf	Dr %	epsvol %	ds/dz in.	Settlement in.
48.1	0.20	0.88	74.37	57.00	2.110	0.025	0.312 *
46.1	0.21	0.94	78.98	59.20	1.938	0.023	0.787 *
44.1	0.21	1.03	84.84	61.81	1.645	0.020	1.238 *
42.1	0.21	1.08	88.40	63.30	1.502	0.018	1.714 *
40.1	0.22	0.84	76.06	57.82	2.093	0.025	2.071 *
38.1	0.22	0.98	85.41	62.06	1.711	0.021	2.541 *
36.1	0.23	0.70	68.63	54.05	2.347	0.028	2.967 *
34.1	0.23	0.68	68.02	53.73	2.370	0.028	3.521 *
32.1	0.23	0.64	66.61	52.96	2.417	0.029	4.057 *
30.1	0.24	0.77	76.39	57.98	2.115	0.025	4.619 *
28.1	0.24	0.64	67.60	53.50	2.388	0.029	5.132 *
26.1	0.24	0.68	70.57	55.07	2.296	0.028	5.695 *
24.1	0.24	0.67	70.17	54.87	2.309	0.028	6.257 *
22.1	0.24	0.69	72.09	55.86	2.250	0.027	6.779 *
20.1	0.25	0.72	74.08	56.86	2.190	0.026	7.305 *
18.1	0.25	0.70	73.24	56.44	2.217	0.027	7.831 *
16.1	0.25	0.67	70.89	55.24	2.288	0.027	8.365 *
14.1	0.25	0.72	74.90	57.26	2.168	0.026	8.895 *
12.1	0.25	0.61	66.69	53.01	2.417	0.029	9.431 *
10.1	0.25	0.71	74.68	57.15	2.176	0.026	9.945 *
8.1	0.25	1.03	95.29	65.98	1.503	0.018	10.333 *
6.1	0.25	0.62	68.74	54.11	2.355	0.028	10.835 *
4.1	0.25	0.58	65.76	52.50	2.445	0.029	11.265 *
2.1	0.26	0.53	61.22	49.91	2.612	0.031	11.885 *
0.1	0.26	0.52	61.03	49.80	2.620	0.031	12.514 *

* Below Water Table
Settlement of Saturated Soils=12.514 in.

Settlement of Dry Soils:

Depth ft	SigC tsf	Gmax tsf	gamG/G	gameff %	ep7.5 %	ep/7.5	epsvol %	ds/dz in.	Settlement in.
48.1	0.74	616.2	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
46.1	0.71	646.1	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
44.1	0.68	675.3	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
42.1	0.65	681.8	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
40.1	0.62	576.7	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
38.1	0.59	630.2	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
36.1	0.56	468.1	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
34.1	0.53	446.6	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
32.1	0.50	412.8	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
30.1	0.47	501.9	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
28.1	0.43	400.4	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
26.1	0.40	419.4	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
24.1	0.37	399.8	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
22.1	0.34	400.6	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
20.1	0.31	398.0	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
18.1	0.28	373.2	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
16.1	0.25	336.8	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
14.1	0.22	343.1	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
12.1	0.19	262.3	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
10.1	0.16	295.1	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
8.1	0.13	334.3	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
6.1	0.09	209.4	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
4.1	0.06	160.5	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *
2.1	0.03	83.5	0.0E0	0.0E0	0.0E0	6.1E0	2.6E0	0.0E0	0.000 *

0.1 0.00 25.2 0.0E0 0.0E0 0.0E0 6.1E0 2.6E0 0.0E0 0.000 *

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* Below Water Table
Settlement of Dry Soils=0.000 in.
Total Settlement of Wet and Dry Soils=12.514 in.

Units	Depth=ft, Stress=tsf (atm), gamma=pcf, Sett.=in.
Gamma	Unit weight of soil
Fines	Fines content [%]
D50	Mean grain size
SigT	Total vertical stress [tsf]
SigE	Effective vertical stress [tsf]
rd	Stress reduction coefficient
CSR	Cyclic stress ratio by a given earthquake
SPT	Result from Standard Penetration Test (SPT)
BPT	Result from Becker Penetration Test (BPT)
Cer	Hammer energy efficiency correction factor
Cn	Overburden stress correction factor
d(N1)60	Fines correction of SPT
(N1)60	SPT after Fines and Overburden correction
CPT	Tip resistance from Cone Penetration Test (CPT)
fric.	Friction from CPT testing
Cq	Overburden stress correction factor
D50	Mean grain size
qc1	CPT after Overburden stress correction
dqc1	Fines correction of CPT
qc	CPT after Fines and Overburden correction
SigC	Effective confining pressure [tsf]
Ksigma	Overburden stress correction factor for CRR
CRRraw	Before overburden stress correction. CRR=CRRraw*Ksigma
CRR	Cyclic resistance ratio
MSF	Magnitude scaling factor for FS.
CSRm	After magnitude scaling correction. CSRm=CSR/MSF
F.S.	Factor of safety against liquefaction
Dr	Relative Density
epsvol	Volumetric strain
ds/dz	Settlement in each sublayer dz
dz	Height of sublayer for calculation, dz=0.10 ft
gamG/G	Strain-modulus ratio
ep7.5	Volumetric Strain for M=7.5
ep/7.5	Magnitude correction factor for any M

Input File: K:\163\Pacific Sound Resources\Geotech\Analyses\Liquefaction analysis\final\PGA=0.22\P12seed.liq
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Earthquake Magnitude= 6.8 Max. Acceleration= 0.22 g
Depth of Hole= 41.5 ft Depth of Water Table= 0.0 ft

Input Data:

No.	Depth ft	SPTraw	Gamma pcf	Fines %
1	1.0	2.0	110.0	88.0
2	3.5	2.0	110.0	30.0
3	6.0	4.0	110.0	10.0
4	8.5	2.0	110.0	20.0
5	11.0	2.0	110.0	30.0
6	13.5	2.0	110.0	80.0
7	16.0	2.0	110.0	71.0
8	18.5	4.0	110.0	80.0
9	25.0	3.0	110.0	48.0
10	30.0	3.0	110.0	80.0
11	35.0	8.0	110.0	80.0
12	40.0	7.0	110.0	70.0

CSR Calculation:

Depth ft	SigT tsf	SigE tsf	rd	CSR
1.00	0.055	0.024	1.00	0.33
3.00	0.165	0.071	0.99	0.33
5.00	0.275	0.119	0.99	0.33
7.00	0.385	0.167	0.98	0.33
9.00	0.495	0.214	0.98	0.32
11.00	0.605	0.262	0.97	0.32
13.00	0.715	0.309	0.97	0.32
15.00	0.825	0.357	0.97	0.32
17.00	0.935	0.405	0.96	0.32
19.00	1.045	0.452	0.96	0.32
21.00	1.155	0.500	0.95	0.31
23.00	1.265	0.547	0.95	0.31
25.00	1.375	0.595	0.94	0.31
27.00	1.485	0.643	0.94	0.31
29.00	1.595	0.690	0.93	0.31
31.00	1.705	0.738	0.92	0.30
33.00	1.815	0.785	0.91	0.30
35.00	1.925	0.833	0.89	0.29
37.00	2.035	0.881	0.87	0.29
39.00	2.145	0.928	0.86	0.28
41.00	2.255	0.976	0.84	0.28

CRR Calculation from SPT or BPT data:

Depth ft	SPT BPT	Cer	Cn	d(N1)60	(N1)60	CRRraw
1.00	2.0	1.0	2.0	5.80	9.80	0.11
3.00	2.0	1.0	2.0	5.80	9.80	0.11
5.00	3.2	1.0	2.0	3.66	10.06	0.11
7.00	3.2	1.0	2.0	2.48	8.88	0.10
9.00	2.0	1.0	2.0	4.30	8.30	0.09
11.00	2.0	1.0	2.0	5.31	9.22	0.10
13.00	2.0	1.0	1.8	5.72	9.31	0.10
15.00	2.0	1.0	1.7	5.67	9.02	0.10
17.00	2.8	1.0	1.6	5.88	10.28	0.11
19.00	3.9	1.0	1.5	6.17	12.00	0.13
21.00	3.6	1.0	1.4	6.02	11.14	0.12
23.00	3.3	1.0	1.4	5.89	10.36	0.11
25.00	3.0	1.0	1.3	5.78	9.67	0.11
27.00	3.0	1.0	1.2	5.75	9.49	0.10
29.00	3.0	1.0	1.2	5.72	9.33	0.10
31.00	4.0	1.0	1.2	5.93	10.59	0.11
33.00	6.0	1.0	1.1	6.35	13.12	0.14
35.00	8.0	1.0	1.1	6.75	15.52	0.17
37.00	7.6	1.0	1.1	6.62	14.72	0.16
39.00	7.2	1.0	1.0	6.49	13.97	0.15

41.00	7.0	1.0	1.0	6.42	13.50	0.15

Factor of Safety Calculation:
Earthquake Magnitude= 6.8

Depth ft	SigC	Ksigma	CRR	MSF	CSRm	F.S.
1.00	0.64	1.00	0.11	1.28	0.26	0.41 *
3.00	0.64	1.00	0.11	1.28	0.26	0.42 *
5.00	0.64	1.00	0.11	1.28	0.25	0.43 *
7.00	0.64	1.00	0.10	1.28	0.25	0.38 *
9.00	0.64	1.00	0.09	1.28	0.25	0.36 *
11.00	0.64	1.00	0.10	1.28	0.25	0.40 *
13.00	0.64	1.00	0.10	1.28	0.25	0.41 *
15.00	0.64	1.00	0.10	1.28	0.25	0.40 *
17.00	0.64	1.00	0.11	1.28	0.25	0.45 *
19.00	0.64	1.00	0.13	1.28	0.25	0.53 *
21.00	0.64	1.00	0.12	1.28	0.24	0.49 *
23.00	0.64	1.00	0.11	1.28	0.24	0.46 *
25.00	0.64	1.00	0.11	1.28	0.24	0.43 *
27.00	0.64	1.00	0.10	1.28	0.24	0.43 *
29.00	0.64	1.00	0.10	1.28	0.24	0.42 *
31.00	0.64	1.00	0.11	1.28	0.24	0.48 *
33.00	0.64	1.00	0.14	1.28	0.23	0.61 *
35.00	0.64	1.00	0.17	1.28	0.23	0.73 *
37.00	0.64	1.00	0.16	1.28	0.22	0.71 *
39.00	0.64	1.00	0.15	1.28	0.22	0.69 *
41.00	0.64	1.00	0.15	1.28	0.22	0.68 *

* F.S.<1

Settlement of Saturated Soils:

Depth ft	CSR	F.S.	(N1)60	Dr %	epsvol %	ds/dz in.	Settlement in.
41.0	0.22	0.68	13.50	58.29	2.058	0.025	0.124 *
39.0	0.22	0.69	13.97	59.23	2.003	0.024	0.613 *
37.0	0.22	0.71	14.72	60.73	1.864	0.022	1.076 *
35.0	0.23	0.73	15.52	62.28	1.725	0.021	1.506 *
33.0	0.23	0.61	13.12	57.50	2.139	0.026	1.976 *
31.0	0.24	0.48	10.59	51.93	2.477	0.030	2.532 *
29.0	0.24	0.42	9.33	48.91	2.684	0.032	3.166 *
27.0	0.24	0.43	9.49	49.30	2.657	0.032	3.807 *
25.0	0.24	0.43	9.67	49.73	2.627	0.032	4.441 *
23.0	0.24	0.46	10.36	51.40	2.508	0.030	5.056 *
21.0	0.24	0.49	11.14	53.19	2.406	0.029	5.645 *
19.0	0.25	0.53	12.00	55.11	2.296	0.028	6.209 *
17.0	0.25	0.45	10.28	51.21	2.522	0.030	6.778 *
15.0	0.25	0.40	9.02	48.12	2.738	0.033	7.426 *
13.0	0.25	0.41	9.31	48.87	2.687	0.032	8.076 *
11.0	0.25	0.40	9.22	48.63	2.703	0.032	8.715 *
9.0	0.25	0.36	8.30	46.27	2.860	0.034	9.380 *
7.0	0.25	0.38	8.88	47.76	2.761	0.033	10.062 *
5.0	0.25	0.43	10.06	50.68	2.558	0.031	10.706 *
3.0	0.26	0.42	9.80	50.06	2.602	0.031	11.330 *
1.0	0.26	0.41	9.80	50.06	2.602	0.031	11.955 *

* Below Water Table
Settlement of Saturated Soils=11.955 in.

Settlement of Dry Soils:

Depth ft	SigC tsf	Gmax tsf	gamG/G	gameff %	ep7.5 %	ep/7.5	epsvol %	ds/dz in.	Settlement in.
41.0	0.63	840.8	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
39.0	0.60	829.3	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
37.0	0.57	821.8	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
35.0	0.54	813.3	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
33.0	0.51	747.3	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
31.0	0.48	674.7	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
29.0	0.45	626.0	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
27.0	0.42	607.4	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
25.0	0.39	588.0	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
23.0	0.36	577.1	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
21.0	0.32	564.7	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
19.0	0.29	550.5	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
17.0	0.26	494.9	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
15.0	0.23	445.1	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *

13.0	0.20	418.8	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
11.0	0.17	384.0	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
9.0	0.14	335.5	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
7.0	0.11	302.5	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
5.0	0.08	266.4	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
3.0	0.05	204.6	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *
1.0	0.02	118.1	0.0E0	0.0E0	0.0E0	0.0E0	2.6E0	0.0E0	0.000 *

* Below Water Table
Settlement of Dry Soils=0.000 in.
Total Settlement of Wet and Dry Soils=11.955 in.

Units	Depth=ft, Stress=tsf (atm), gamma=pcf, Sett.=in.
Gamma	Unit weight of soil
Fines	Fines content [%]
D50	Mean grain size
SigT	Total vertical stress [tsf]
SigE	Effective vertical stress [tsf]
rd	Stress reduction coefficient
CSR	Cyclic stress ratio by a given earthquake
SPT	Result from Standard Penetration Test (SPT)
BPT	Result from Becker Penetration Test (BPT)
Cer	Hammer energy efficiency correction factor
Cn	Overburden stress correction factor
d(N1)60	Fines correction of SPT
(N1)60	SPT after Fines and Overburden correction
CPT	Tip resistance from Cone Penetration Test (CPT)
fric.	Friction from CPT testing
Cq	Overburden stress correction factor
D50	Mean grain size
qc1	CPT after Overburden stress correction
dqc1	Fines correction of CPT
qc	CPT after Fines and Overburden correction
SigC	Effective confining pressure [tsf]
Ksigma	Overburden stress correction factor for CRR
CRRraw	Before overburden stress correction. CRR=CRRraw*Ksigma
CRR	Cyclic resistance ratio
MSF	Magnitude scaling factor for FS.
CSRm	After magnitude scaling correction. CSRm=CSR/MSF
F.S.	Factor of safety against liquefaction
Dr	Relative Density
epsvol	Volumetric strain
ds/dz	Settlement in each sublayer dz
dz	Height of sublayer for calculation, dz=0.10 ft
gamG/G	Strain-modulus ratio
ep7.5	Volumetric Strain for M=7.5
ep/7.5	Magnitude correction factor for any M

Input File: K:\163\Pacific Sound Resources\Geotech\Analyses\Liquefaction analysis\SPT\B5.liq
04/22/2002 4:48:10 PM

SLOPE STABILITY ANALYSES

FIGURES

1) Pre-capping conditions, seismic loading, failure surface passing through the upper soft organic silt (file name: BAL-singlenoncirc).

2) Pre-capping, section 1, static, automatic search of critical failure surface (file name: Section E13)

3) Pre-capping, static, section 1, shallow surface resembling existing failure zones (file name: Section E13shallow)

4) Pre-capping, section 2, static, failure surface passing through the upper soft organic silt (file name: L-singlenoncirc)

5) Post-capping, section 1, static, automatic search of critical failure surface (file name : Section E13)

6) Post-capping, section 1, static, failure surface passing through cap and upper soft organic silt (file name : Section E13new)

7) Post-capping, static, section 1, shallow surface resembling existing failure zones (file name : Section E13shallow)

8) Post-capping, section 2, static, failure surface passing through the upper soft organic silt (file name : L noncirc2)

9) Post-capping, section 1, seismic, silt strength 80% of static, automatic search of critical failure surface (Section E13seis0.08)

10) Post-capping, section 1, seismic, silt strength 70% of static, automatic search of critical failure surface (file name: Section E13seis0.08-2)

11) Post-capping, section 1, seismic, silt strength 80% of static, failure surface passing through cap and upper soft organic silt (file name : Section E13newseis0.08)

12) Post-capping, section 1, seismic, silt strength 70% of static, failure surface passing through cap and upper soft organic silt (file name: Section E13newseis0.08-2)

13) Post-capping, section 1, seismic, silt strength 80% of static, shallow surface resembling existing failure zones (file name : Section E13shallowseis0.08)

14) Post-capping, section 1, seismic, silt strength 70% of static, shallow surface resembling existing failure zones (file name: Section E13shallowseis0.08-2)

15) Post-capping, section 2, seismic, silt strength 80% of static, failure surface passing through the upper soft organic silt (file name: Lnoncircseis0.08)

16) Post-capping, section 2, seismic, silt strength 70% of static, failure surface passing through the upper soft organic silt (file name: L noncircseis0.08-2)

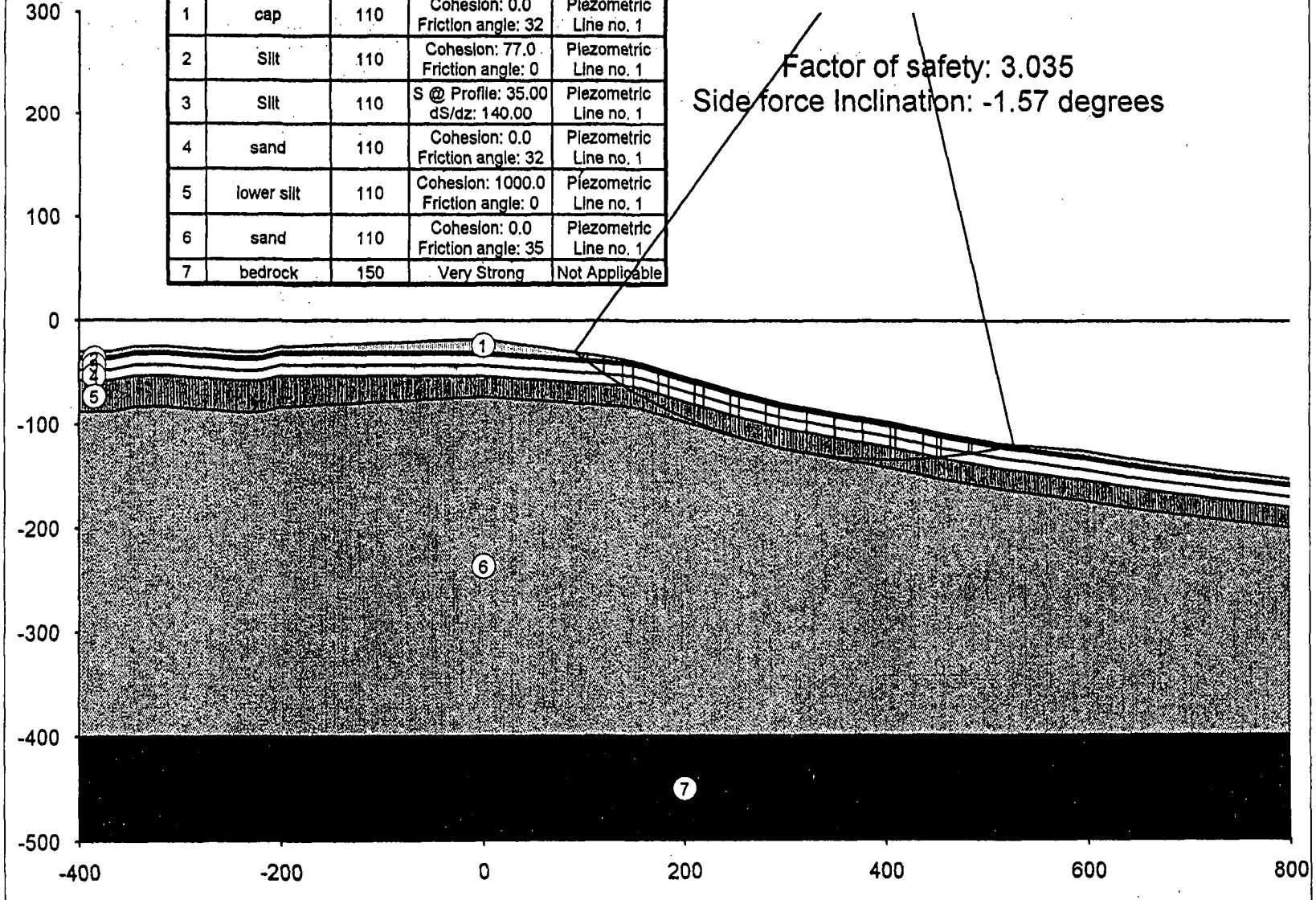
UTEXAS 4.0 OUTPUT FILE PRINTOUT

1) Post-capping, section 1, static, automatic search of critical failure surface (file name : Section E13)

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 77.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 35.00 dS/dz: 140.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Factor of safety: 3.035
Side force Inclination: -1.57 degrees



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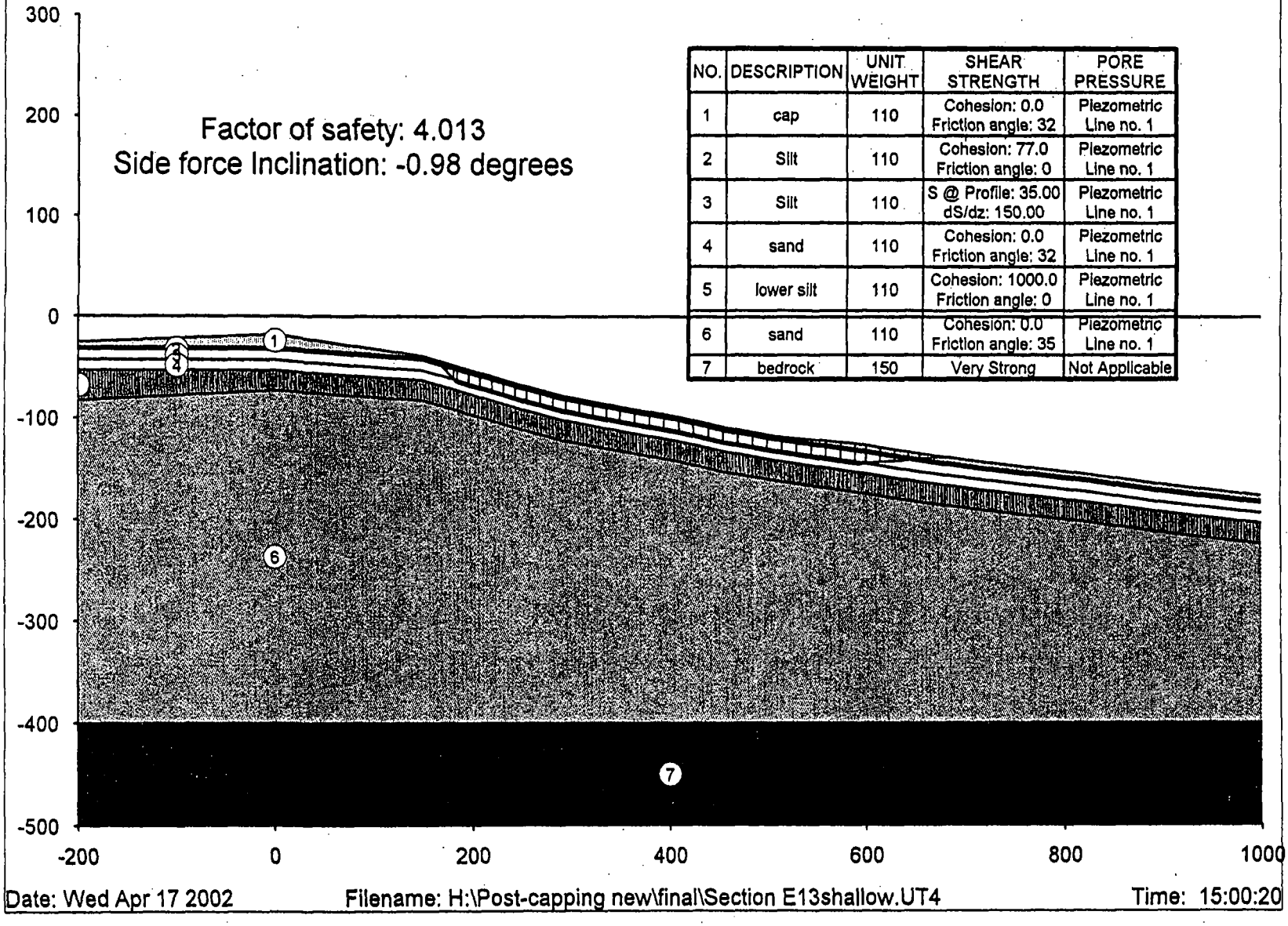
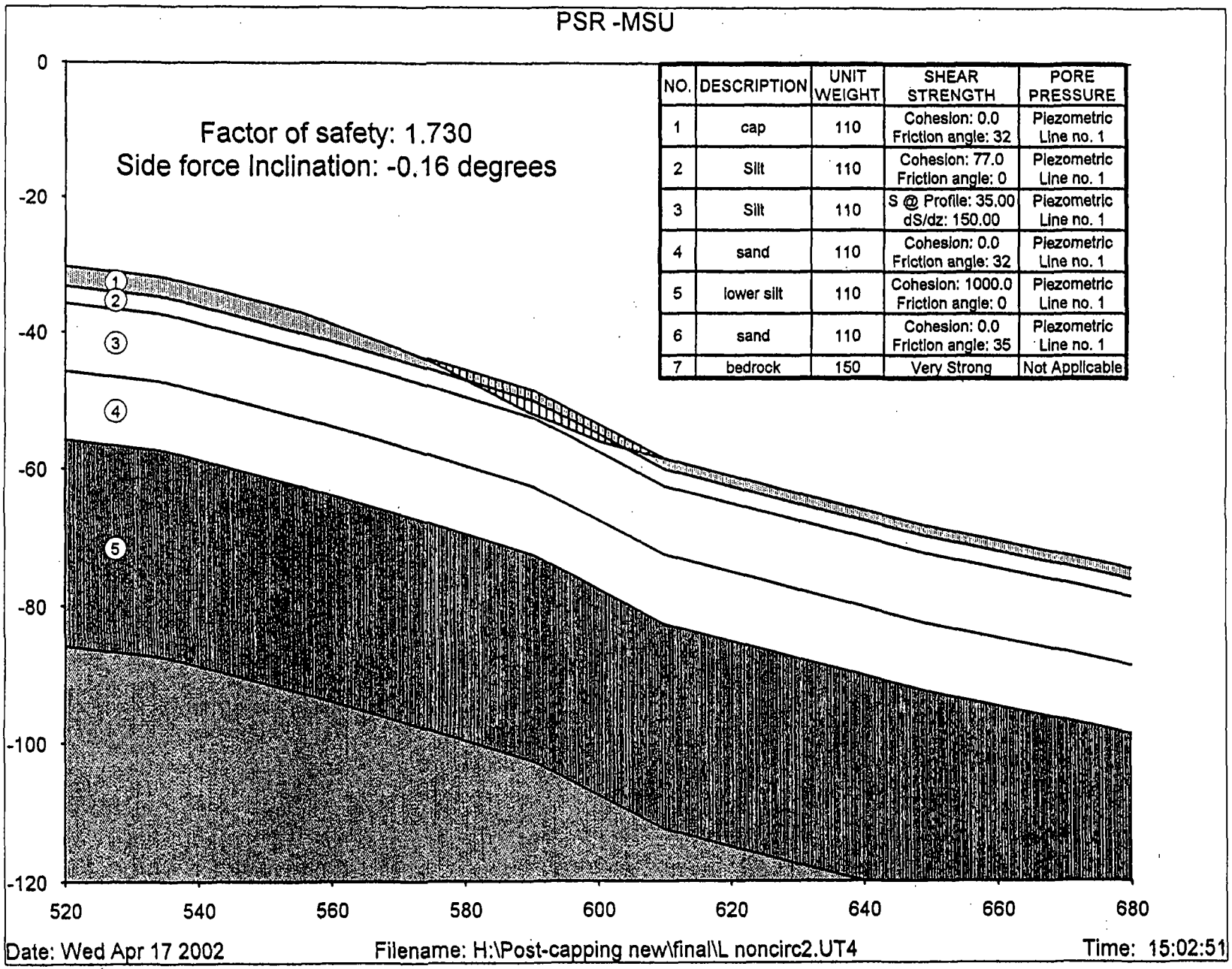
PSR -MSU



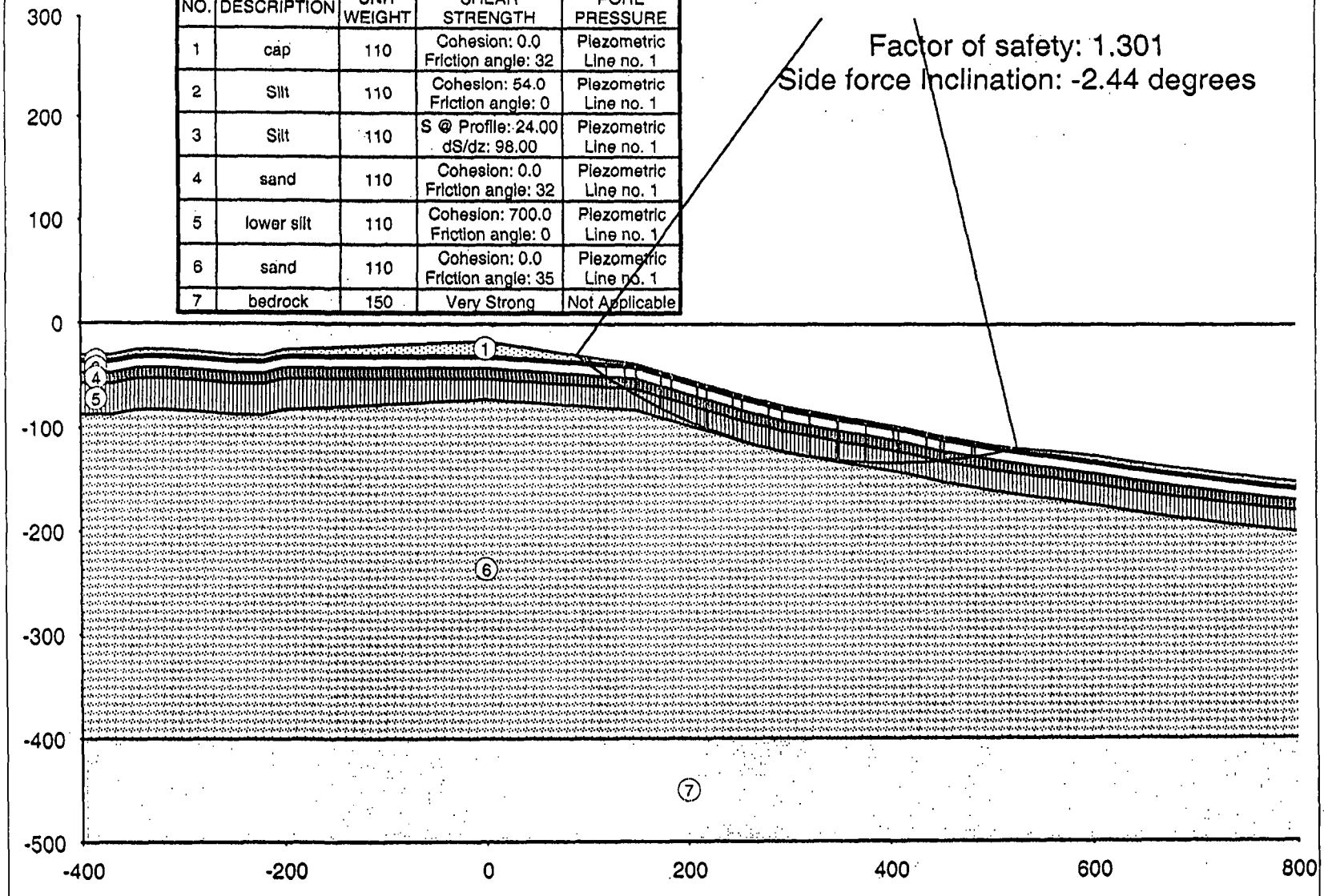
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 77.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 35.00 dS/dz: 150.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Date: Wed Apr 17 2002 Filename: H:\Post-capping new\final\Section E13shallow.UT4 Time: 15:00:20


PSR -MSU
Factor of safety: 1.730
Side force Inclination: -0.16 degrees
NO. | DESCRIPTION | UNIT WEIGHT | SHEAR STRENGTH | PORE PRESSURE
1 | cap | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
2 | Silt | 110 | Cohesion: 77.0 Friction angle: 0 | Piezometric Line no. 1
3 | Silt | 110 | S @ Profile: 35.00 dS/dz: 150.00 | Piezometric Line no. 1
4 | sand | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
5 | lower silt | 110 | Cohesion: 1000.0 Friction angle: 0 | Piezometric Line no. 1
6 | sand | 110 | Cohesion: 0.0 Friction angle: 35 | Piezometric Line no. 1
7 | bedrock | 150 | Very Strong | Not Applicable
0
-20
-40
-60
-80
-100
-120
520
540
560
580
600
620
640
660
680
Date: Wed Apr 17 2002
Filename: H:\Post-capping new\final\L noncirc2.UT4
Time: 15:02:51

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 54.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 24.00 dS/dz: 98.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 700.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable



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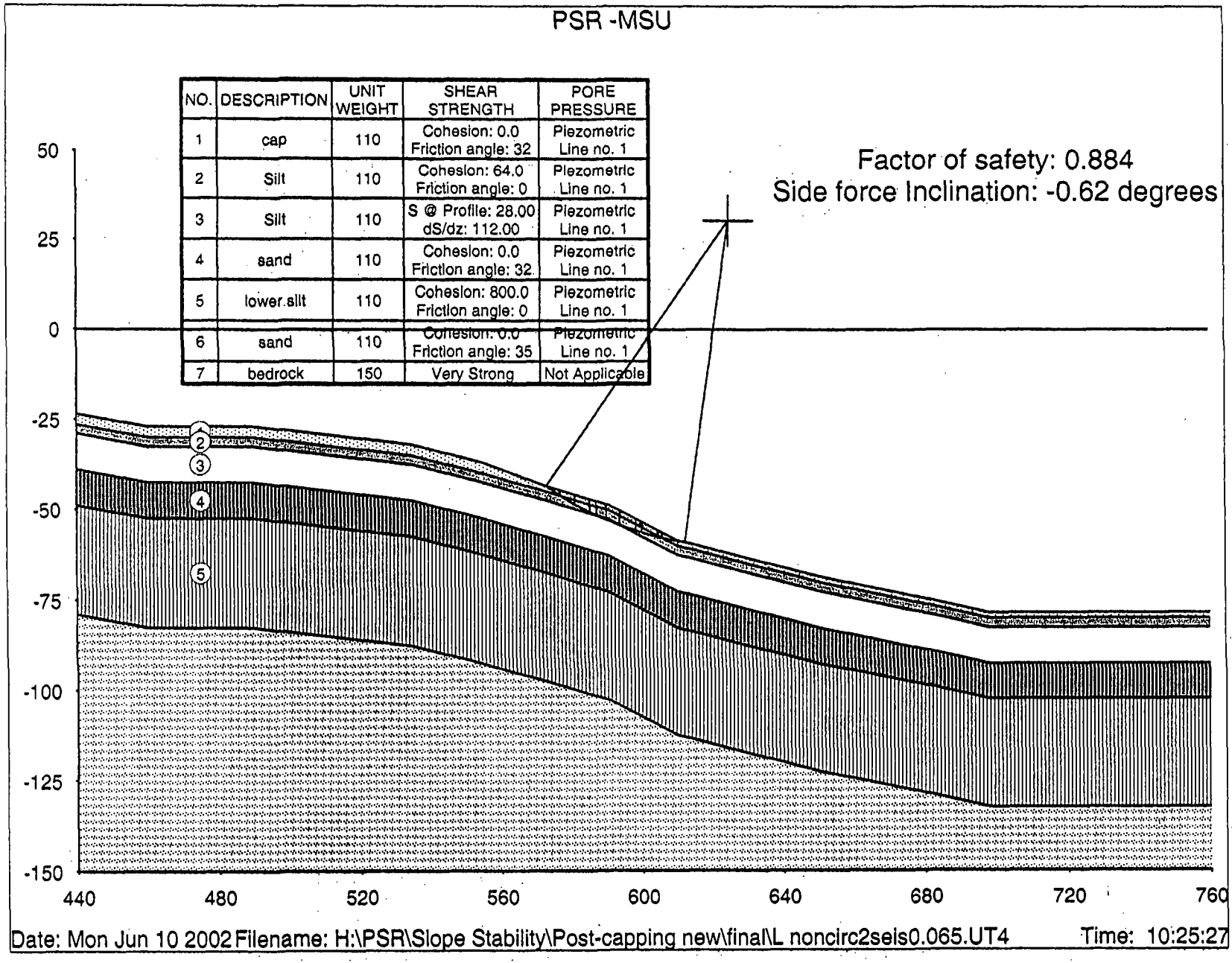
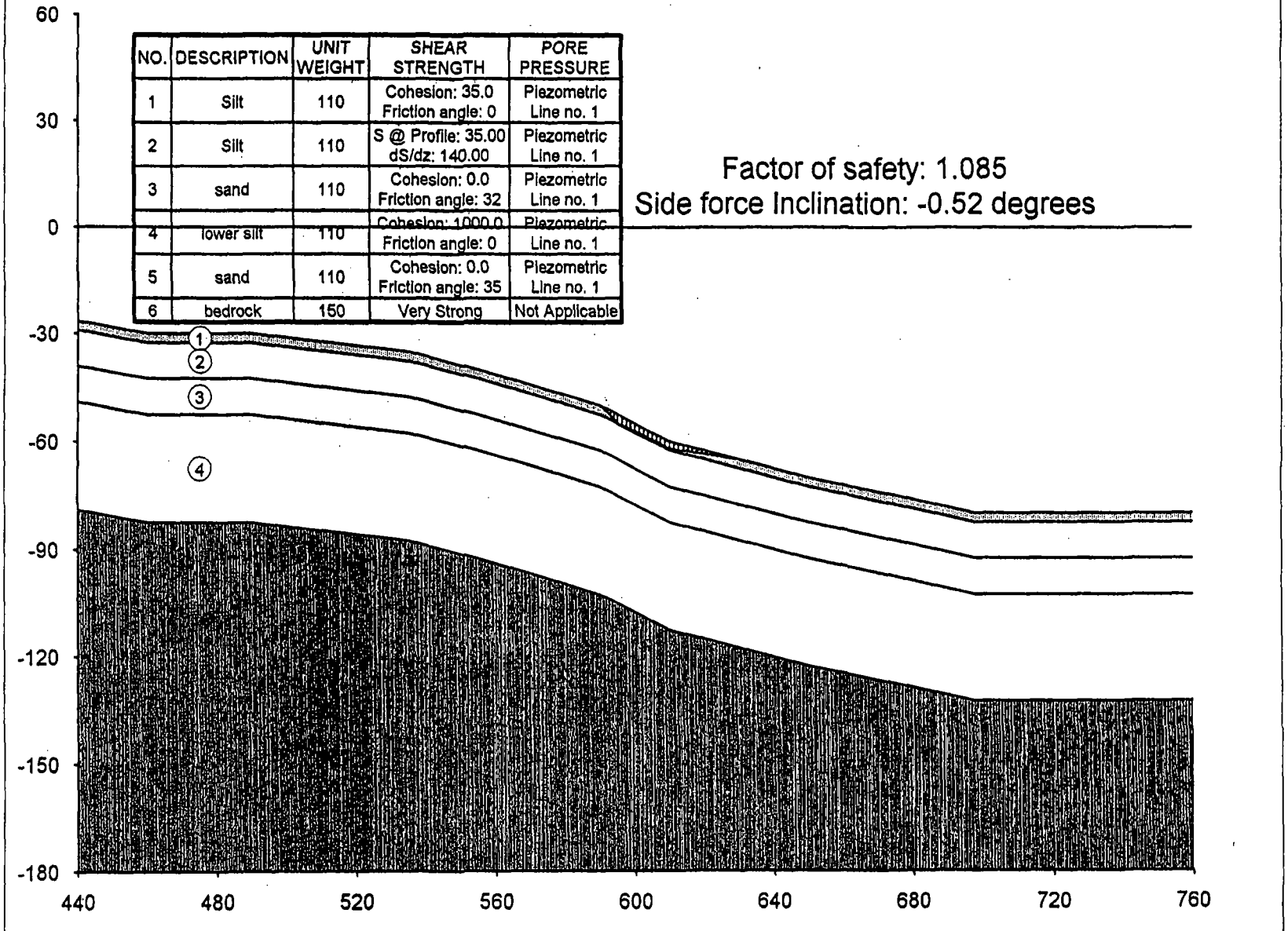

PSR -MSU
NO. | DESCRIPTION | UNIT WEIGHT | SHEAR STRENGTH | PORE PRESSURE
1 | cap | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
2 | Silt | 110 | Cohesion: 64.0 Friction angle: 0 | Piezometric Line no. 1
3 | Silt | 110 | S @ Profile: 28.00 dS/dz: 112.00 | Piezometric Line no. 1
4 | sand | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
5 | lower silt | 110 | Cohesion: 800.0 Friction angle: 0 | Piezometric Line no. 1
6 | sand | 110 | Cohesion: 0.0 Friction angle: 35 | Piezometric Line no. 1
7 | bedrock | 150 | Very Strong | Not Applicable
Factor of safety: 0.884
Side force Inclination: -0.62 degrees
50
25
0
-25
-50
-75
-100
-125
-150
440
480
520
560
600
640
680
720
760
Date: Mon Jun 10 2002 Filename: H:\PSR\Slope Stability\Post-capping new\final\L noncirc2seis0.065.UT4 Time: 10:25:27

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Silt	110	Cohesion: 35.0 Friction angle: 0	Piezometric Line no. 1
2	Silt	110	S @ Profile: 35.00 dS/dz: 140.00	Piezometric Line no. 1
3	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
4	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
5	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
6	bedrock	150	Very Strong	Not Applicable

Factor of safety: 1.085
Side force Inclination: -0.52 degrees



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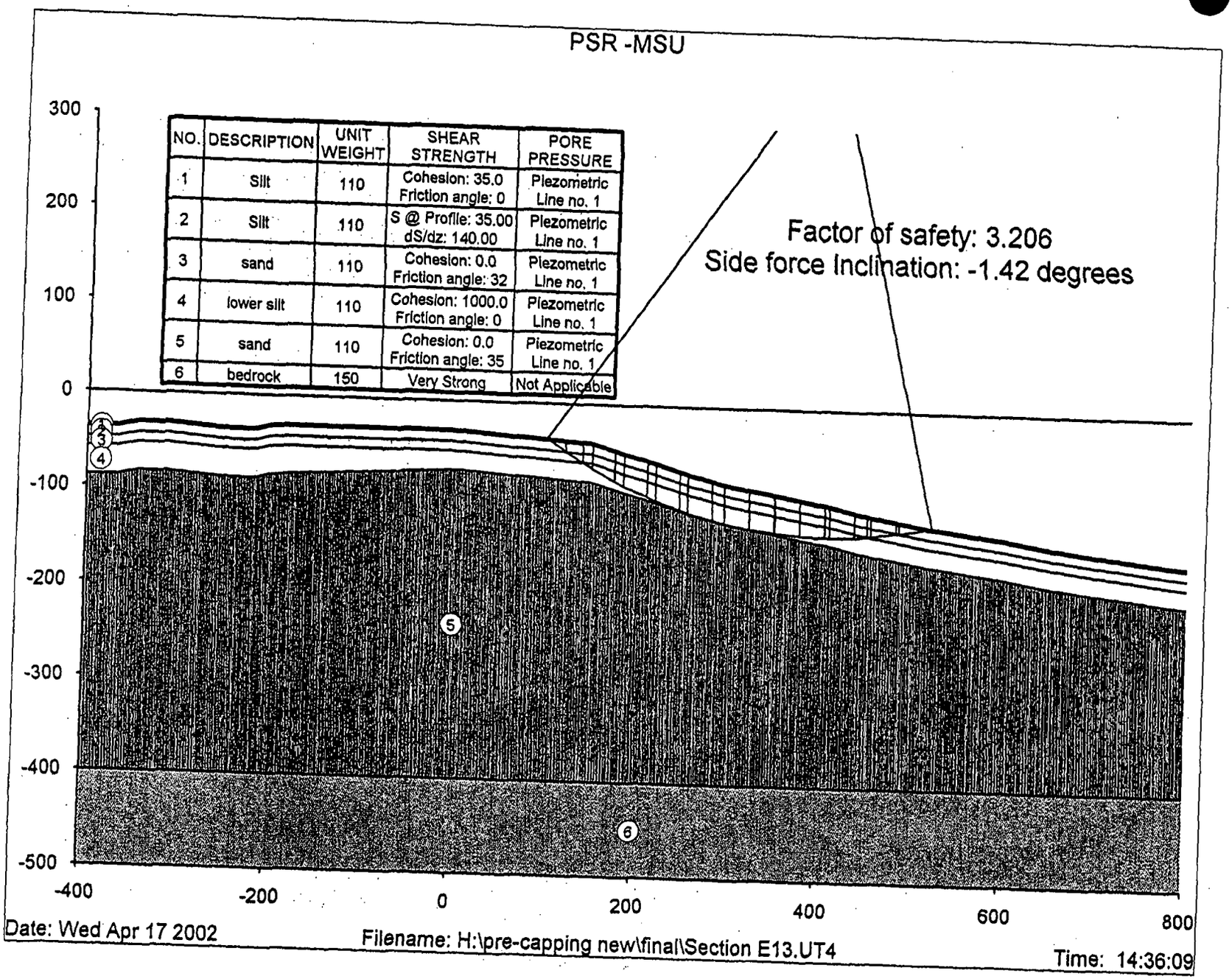
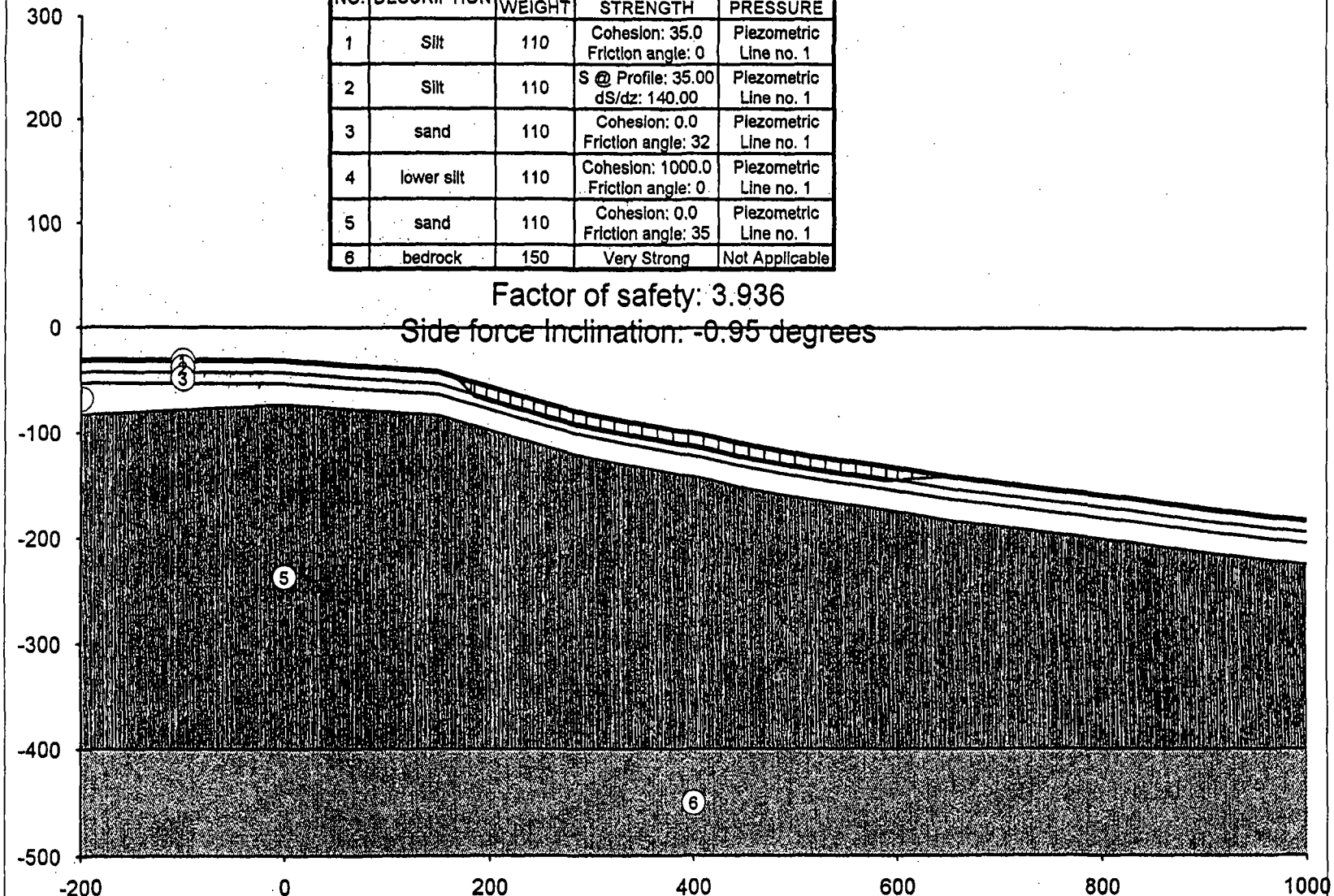

PSR -MSU
NO. | DESCRIPTION | UNIT WEIGHT | SHEAR STRENGTH | PORE PRESSURE
1 | Silt | 110 | Cohesion: 35.0 Friction angle: 0 | Piezometric Line no. 1
2 | Silt | 110 | S @ Profile: 35.00 dS/dz: 140.00 | Piezometric Line no. 1
3 | sand | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
4 | lower silt | 110 | Cohesion: 1000.0 Friction angle: 0 | Piezometric Line no. 1
5 | sand | 110 | Cohesion: 0.0 Friction angle: 35 | Piezometric Line no. 1
6 | bedrock | 150 | Very Strong | Not Applicable
Factor of safety: 3.206
Side force Inclination: -1.42 degrees
300
200
100
0
-100
-200
-300
-400
-500
-400
-200
0
200
400
600
800
Date: Wed Apr 17 2002
Filename: H:\pre-capping new\final\Section E13.UT4
Time: 14:36:09

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Silt	110	Cohesion: 35.0 Friction angle: 0	Piezometric Line no. 1
2	Silt	110	S @ Profile: 35.00 dS/dz: 140.00	Piezometric Line no. 1
3	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
4	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
5	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
6	bedrock	150	Very Strong	Not Applicable



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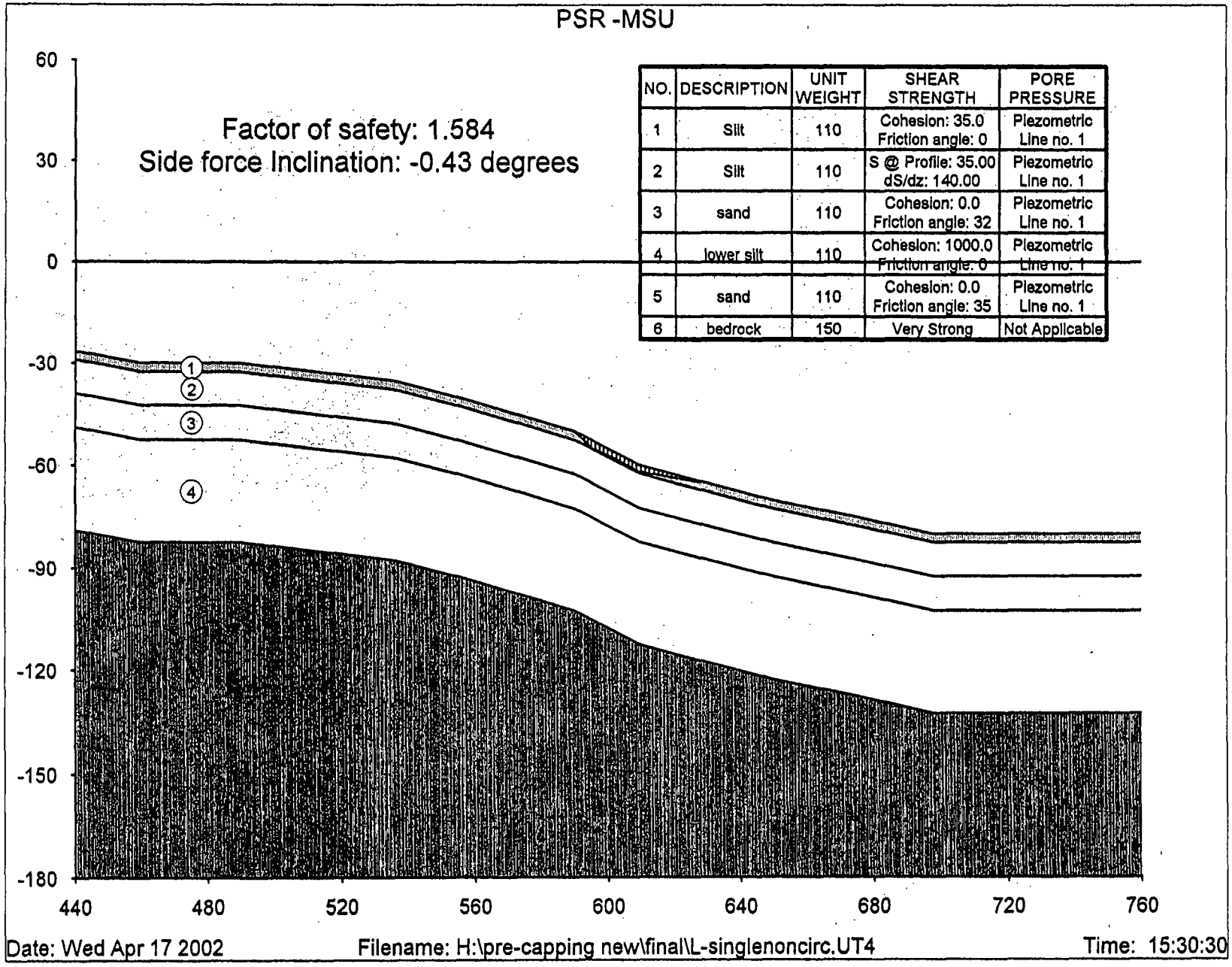
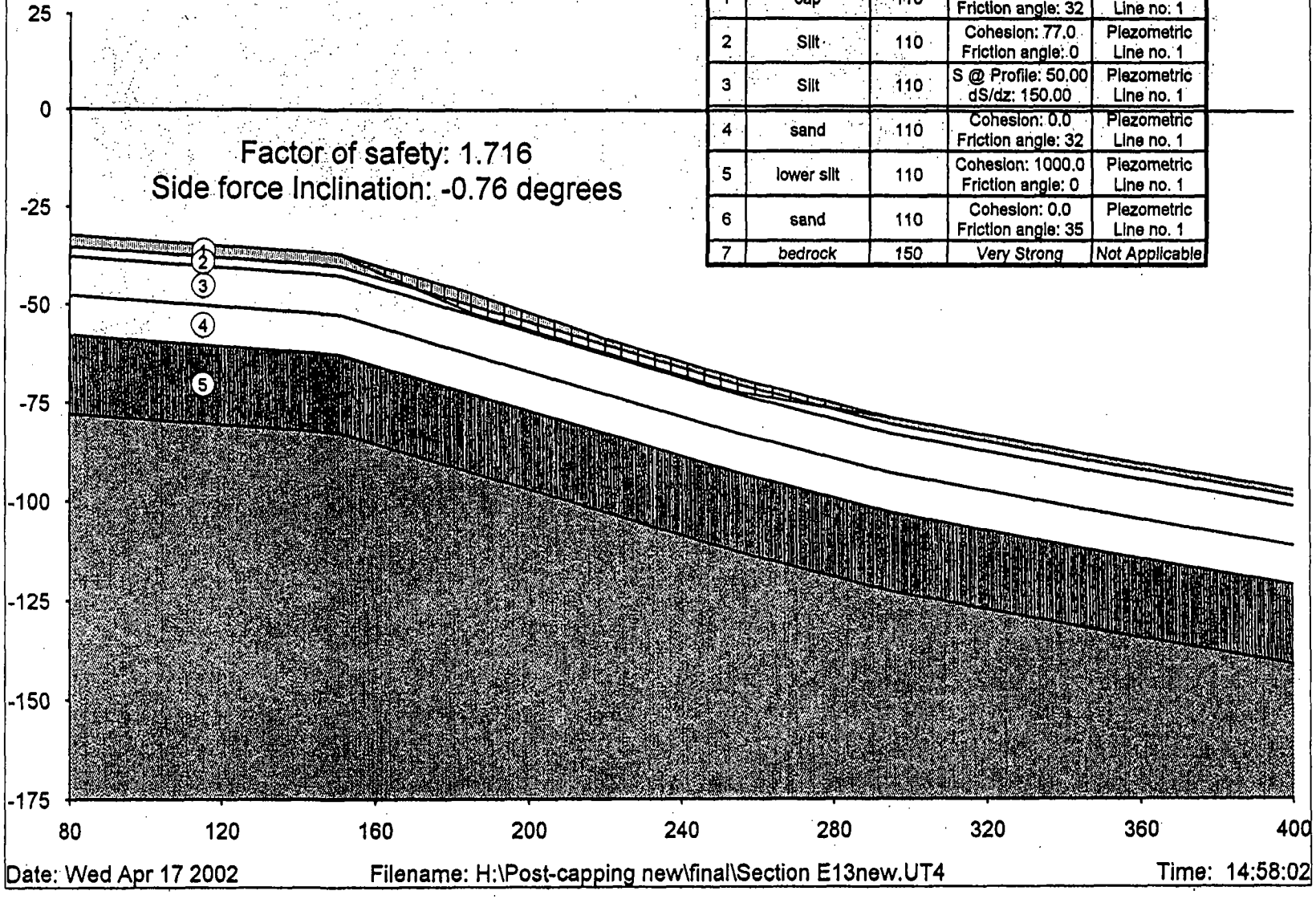

PSR -MSU
Factor of safety: 1.584
Side force Inclination: -0.43 degrees
NO. | DESCRIPTION | UNIT WEIGHT | SHEAR STRENGTH | PORE PRESSURE
1 | Silt | 110 | Cohesion: 35.0 Friction angle: 0 | Piezometric Line no. 1
2 | Silt | 110 | S @ Profile: 35.00 dS/dz: 140.00 | Piezometric Line no. 1
3 | sand | 110 | Cohesion: 0.0 Friction angle: 32 | Piezometric Line no. 1
4 | lower silt | 110 | Cohesion: 1000.0 Friction angle: 0 | Piezometric Line no. 1
5 | sand | 110 | Cohesion: 0.0 Friction angle: 35 | Piezometric Line no. 1
6 | bedrock | 150 | Very Strong | Not Applicable
60
30
0
-30
-60
-90
-120
-150
-180
440
480
520
560
600
640
680
720
760
1
2
3
4
Date: Wed Apr 17 2002
Filename: H:\pre-capping new\final\L-singlenoncirc.UT4
Time: 15:30:30

PSR -MSU

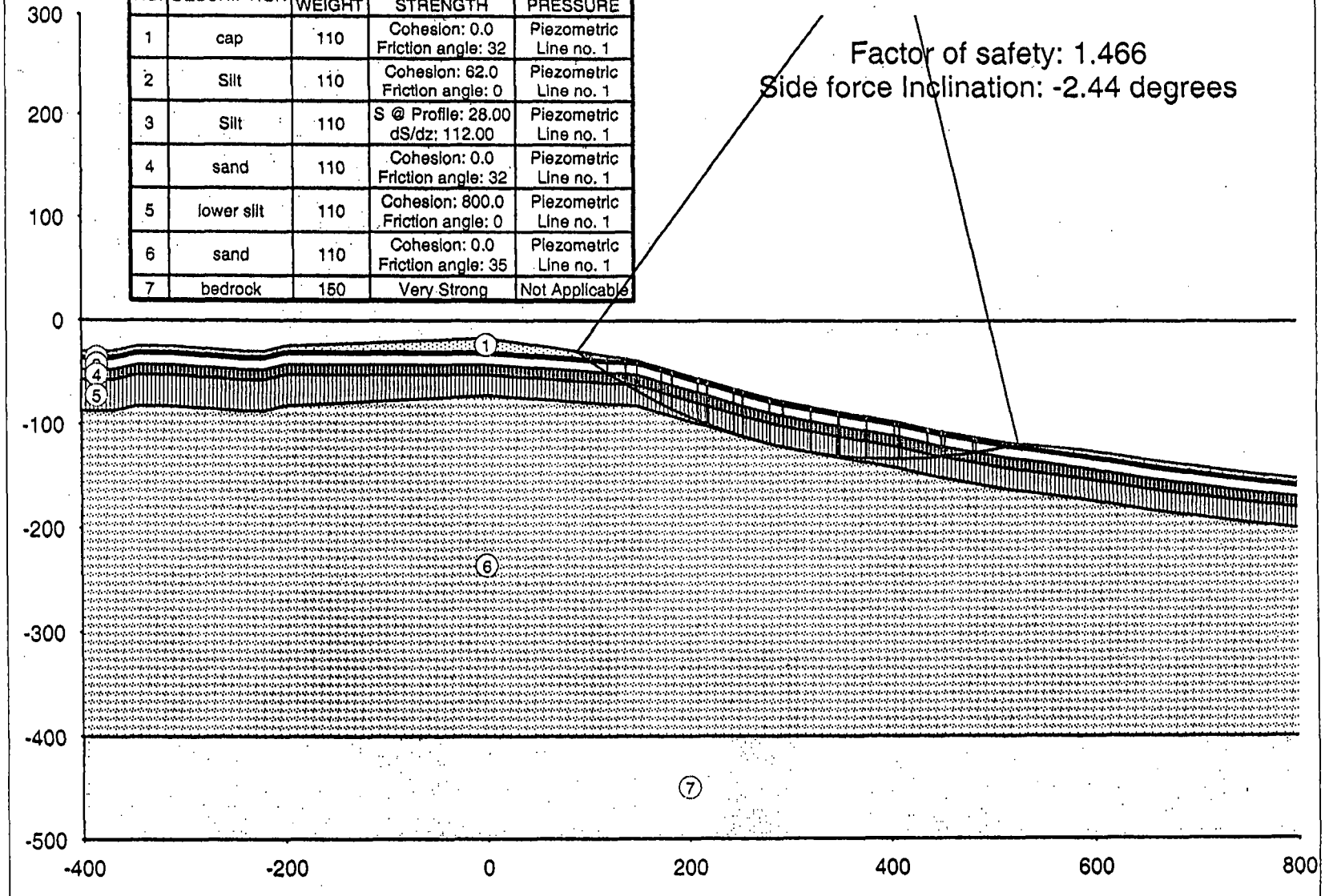
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 77.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 50.00 dS/dz: 150.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable



Date: Wed Apr 17 2002 Filename: H:\Post-capping new\final\Section E13new.UT4 Time: 14:58:02

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 62.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 28.00 dS/dz: 112.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

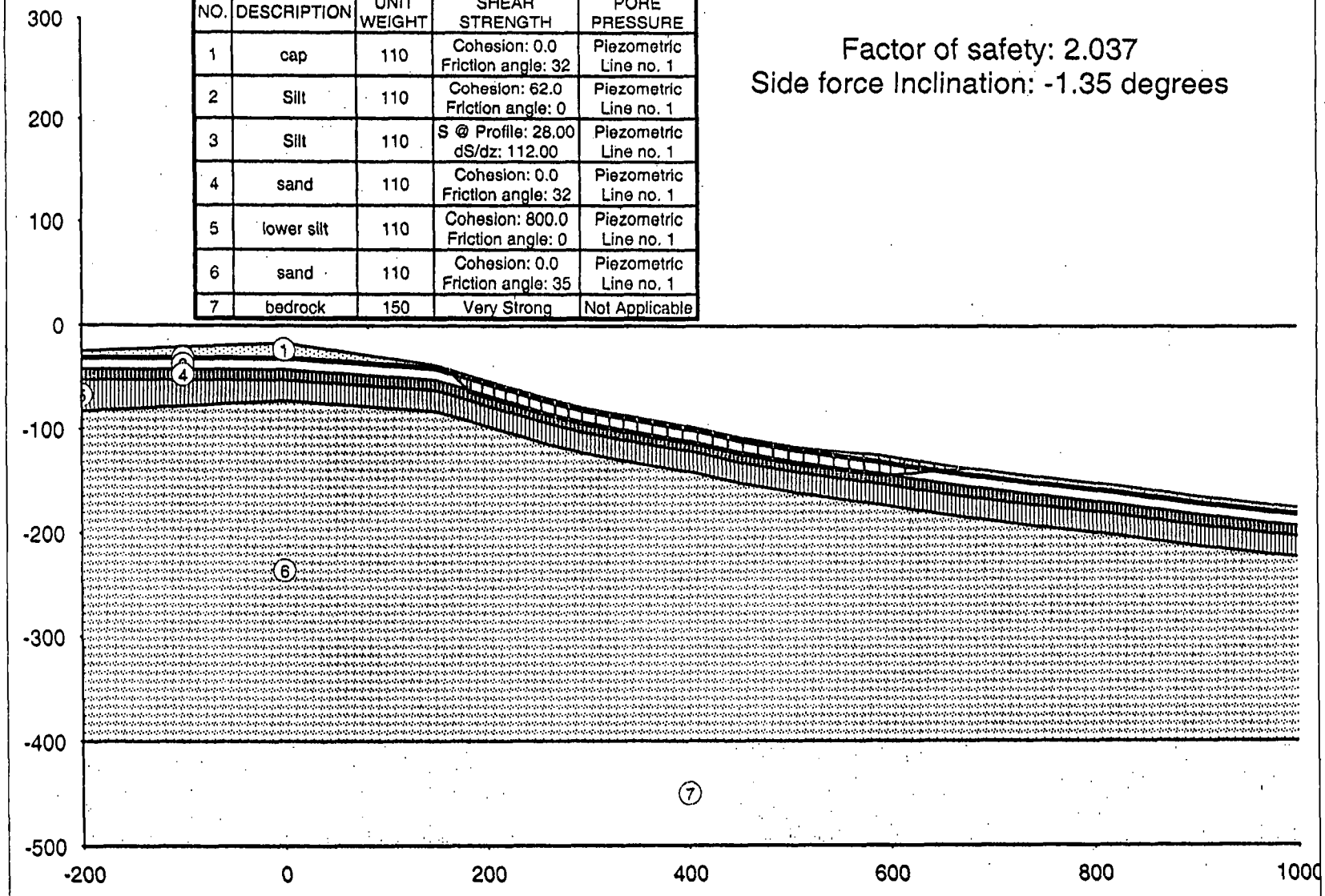


Date: Mon Jun 10 2002 Filename: H:\PSR\Slope Stability\Post-capping new\final\Section I a=0.065.UT4 Time: 10:16:11

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 62.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 28.00 dS/dz: 112.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Factor of safety: 2.037
Side force Inclination: -1.35 degrees

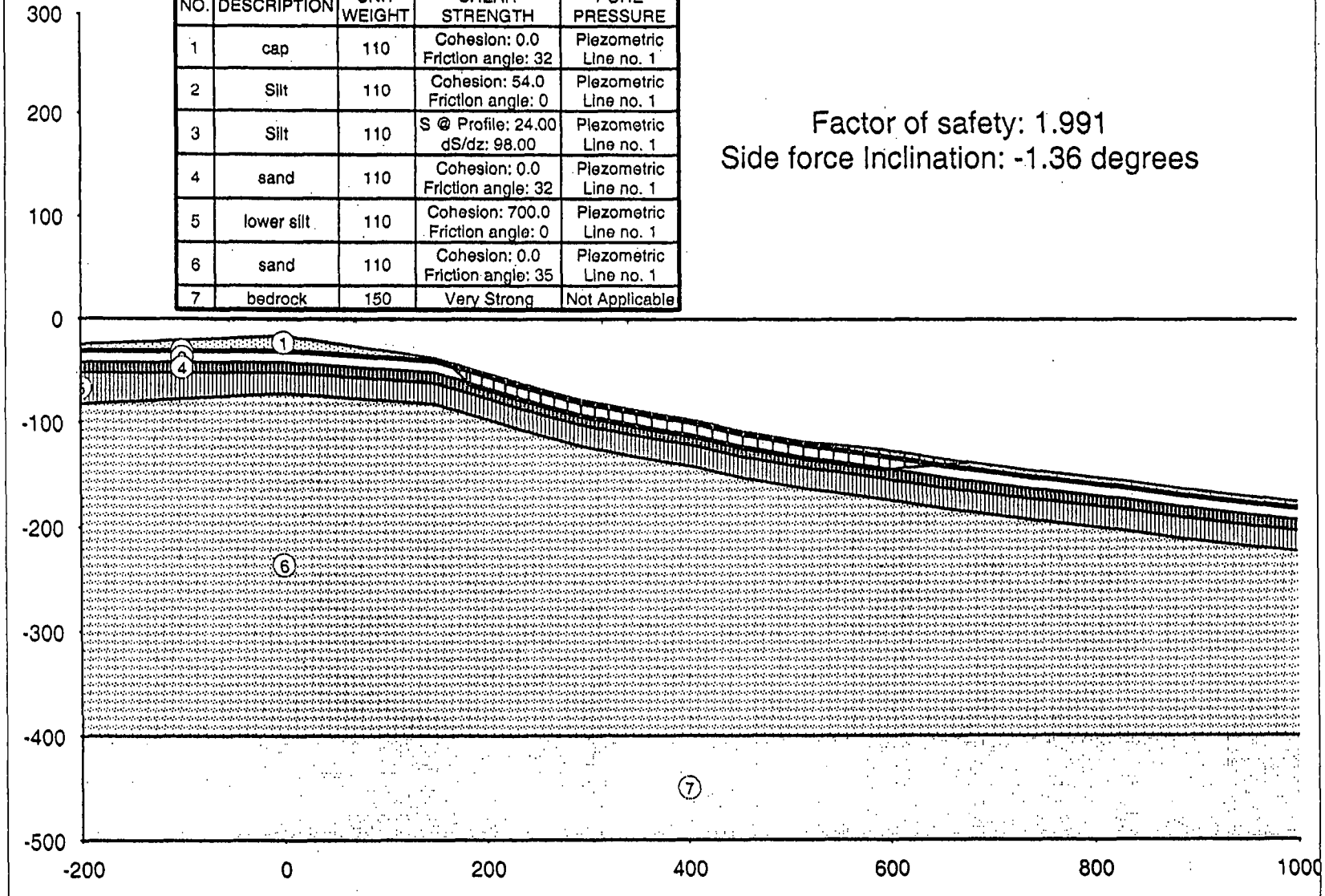


Date: Mon Jun 10 ;Filename: H:\PSR\Slope Stability\Post-capping new\final\Section E13shallowseis0.065.UT4 Time: 10:19:40

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 54.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 24.00 dS/dz: 98.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 700.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Factor of safety: 1.991
Side force Inclination: -1.36 degrees



Date: Mon Jun 10 Filename: H:\PSR\Slope Stability\Post-capping new\final\Section E13shallowseis0.065-2.UT4 Time: 10:33:58

PSR -MSU

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	Silt	110	Cohesion: 54.0 Friction angle: 0	Piezometric Line no. 1
3	Silt	110	S @ Profile: 24.00 dS/dz: 98.00	Piezometric Line no. 1
4	sand	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
5	lower silt	110	Cohesion: 700.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

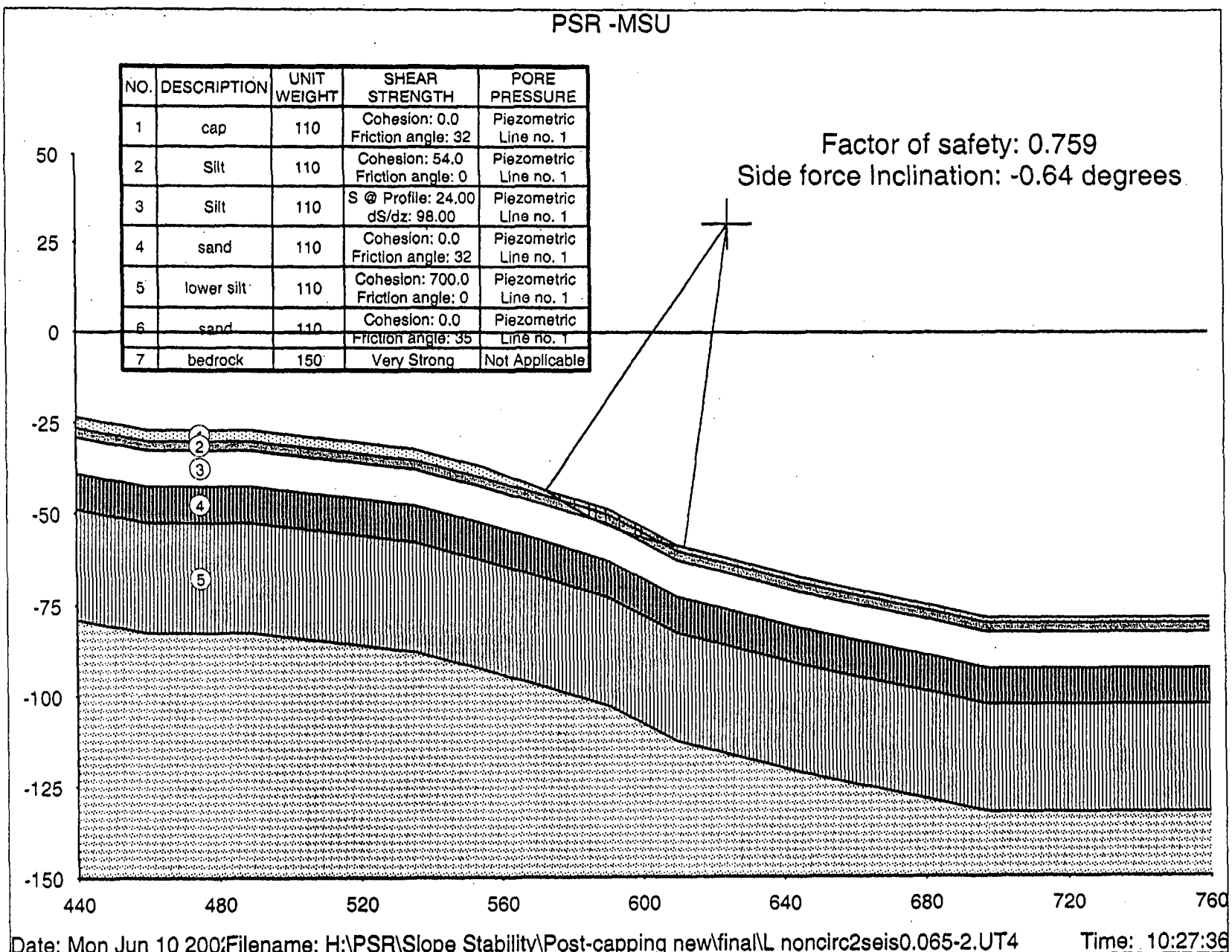


TABLE NO. 1
COMPUTER PROGRAM DESIGNATION: UTEXAS4
Originally Coded By Stephen G. Wright
Version No. 4.0.0.10 - Last Revision Date: 08/10/2001
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```
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```

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PSR -MSU
SECTION E

TABLE NO. 3

```
*************************
* NEW PROFILE LINE DATA *
*************************
```

----- Profile Line No. 1 - Material Type (Number): 1 -----

Description: cap

Point	X	Y
1	-600.00	-15.00
2	-510.00	-20.00
3	-490.00	-25.00
4	-450.00	-30.00
5	-370.00	-30.00
6	-345.00	-25.00
7	-310.00	-25.00
8	-240.00	-30.00
9	-220.00	-30.00
10	-200.00	-25.00
11	0.00	-17.00
12	150.00	-38.50
13	185.00	-48.50
14	220.00	-58.50
15	255.00	-68.50
16	295.00	-78.50
17	350.00	-88.50
18	410.00	-98.50
19	455.00	-108.50
20	515.00	-118.50
21	590.00	-125.00
22	655.00	-135.00
23	735.00	-145.00

24	825.00	-155.00
25	900.00	-165.00
26	990.00	-175.00
27	1105.00	-185.00
28	1205.00	-195.00
29	1375.00	-205.00

----- Profile Line No. 2 - Material Type (Number): 2 -----

Description: upper silt

Point	X	Y
1	-600.00	-20.00
2	-510.00	-25.00
3	-490.00	-30.00
4	-450.00	-35.00
5	-370.00	-35.00
6	-345.00	-30.00
7	-310.00	-30.00
8	-240.00	-35.00
9	-220.00	-35.00
10	-200.00	-30.00
11	0.00	-30.00
12	150.00	-40.00
13	185.00	-50.00
14	220.00	-60.00
15	255.00	-70.00
16	295.00	-80.00
17	350.00	-90.00
18	410.00	-100.00
19	455.00	-110.00
20	515.00	-120.00
21	590.00	-130.00
22	655.00	-140.00
23	735.00	-150.00
24	825.00	-160.00
25	900.00	-170.00
26	990.00	-180.00
27	1105.00	-190.00
28	1205.00	-200.00
29	1375.00	-210.00

----- Profile Line No. 3 - Material Type (Number): 3 -----

Description: intermediate silt

Point	X	Y
1	-600.00	-22.50
2	-510.00	-27.50
3	-490.00	-32.50
4	-450.00	-37.50
5	-370.00	-37.50
6	-345.00	-32.50
7	-310.00	-32.50
8	-240.00	-37.50
9	-220.00	-37.50
10	-200.00	-32.50

11	0.00	-32.50
12	150.00	-42.50
13	185.00	-52.50
14	220.00	-62.50
15	255.00	-72.50
16	295.00	-82.50
17	350.00	-92.50
18	410.00	-102.50
19	455.00	-112.50
20	515.00	-122.50
21	590.00	-132.50
22	655.00	-142.50
23	735.00	-152.50
24	825.00	-162.50
25	900.00	-172.50
26	990.00	-182.50
27	1105.00	-192.50
28	1205.00	-202.50
29	1375.00	-212.50

----- Profile Line No. 4 - Material Type (Number): 4 -----

Description: sand

Point	X	Y
1	-600.00	-32.50
2	-510.00	-37.50
3	-490.00	-42.50
4	-450.00	-47.50
5	-370.00	-47.50
6	-345.00	-42.50
7	-310.00	-42.50
8	-240.00	-47.50
9	-220.00	-47.50
10	-200.00	-42.50
11	0.00	-42.50
12	150.00	-52.50
13	185.00	-62.50
14	220.00	-72.50
15	255.00	-82.50
16	295.00	-92.50
17	350.00	-102.50
18	410.00	-112.50
19	455.00	-122.50
20	515.00	-132.50
21	590.00	-142.50
22	655.00	-152.50
23	735.00	-162.50
24	825.00	-172.50
25	900.00	-182.50
26	990.00	-192.50
27	1105.00	-202.50
28	1205.00	-212.50
29	1375.00	-222.50

----- Profile Line No. 5 - Material Type (Number): 5 -----

Description: lower silt

Point	X	Y
1	-600.00	-42.50
2	-510.00	-47.50
3	-490.00	-52.50
4	-450.00	-57.50
5	-370.00	-57.50
6	-345.00	-52.50
7	-310.00	-52.50
8	-240.00	-57.50
9	-220.00	-57.50
10	-200.00	-52.50
11	0.00	-52.50
12	150.00	-62.50
13	185.00	-72.50
14	220.00	-82.50
15	255.00	-92.50
16	295.00	-102.50
17	350.00	-112.50
18	410.00	-122.50
19	455.00	-132.50
20	515.00	-142.50
21	590.00	-152.50
22	655.00	-162.50
23	735.00	-172.50
24	825.00	-182.50
25	900.00	-192.50
26	990.00	-202.50
27	1105.00	-212.50
28	1205.00	-222.50
29	1375.00	-232.50

----- Profile Line No. 6 - Material Type (Number): 6 -----

Description: lower sand

Point	X	Y
1	-600.00	-72.50
2	-510.00	-77.50
3	-490.00	-82.50
4	-450.00	-87.50
5	-370.00	-87.50
6	-345.00	-82.50
7	-310.00	-82.50
8	-240.00	-87.50
9	-220.00	-87.50
10	-200.00	-82.50
11	0.00	-72.50
12	150.00	-82.50
13	185.00	-92.50
14	220.00	-102.50
15	255.00	-112.50
16	295.00	-122.50
17	350.00	-132.50
18	410.00	-142.50
19	455.00	-152.50
20	515.00	-162.50
21	590.00	-172.50

```
  22      655.00     -182.50
  23      735.00     -192.50
  24      825.00     -202.50
  25      900.00     -212.50
  26      990.00     -222.50
  27     1105.00     -232.50
  28     1205.00     -242.50
  29     1375.00     -252.50

------------------------------------------------------------
----- Profile Line No. 7 - Material Type (Number): 7 -----
------------------------------------------------------------
Description: bedrock

Point        X           Y

   1     -600.00     -400.00
   2     1375.00     -400.00

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SECTION E

TABLE NO. 4
**************************************************************************
* NEW MATERIAL PROPERTY DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
**************************************************************************

------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 1 -------------------
------------------------------------------------------------
Description: cap

Unit weight of soil (material): 110.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.0
Friction angle - - - - - 32.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 2 -------------------
------------------------------------------------------------
Description: Silt

Unit weight of soil (material): 110.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 77.0
Friction angle - - - - - 0.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.
```

---------- DATA FOR MATERIAL NUMBER 3 ----------

Description: Silt

Unit weight of soil (material): 110.0

LINEAR STRENGTH INCREASE BELOW PROFILE LINE
Shear strength at profile line elevation(s) - - - - - - - - - 35.0
Rate of increase in strength below profile line - - - - - - - 140.0

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

---------- DATA FOR MATERIAL NUMBER 4 ----------

Description: sand

Unit weight of soil (material): 110.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 0.0
Friction angle - - - - - 32.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

---------- DATA FOR MATERIAL NUMBER 5 ----------

Description: lower silt

Unit weight of soil (material): 110.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 1000.0
Friction angle - - - - - 0.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

---------- DATA FOR MATERIAL NUMBER 6 ----------

Description: sand

Unit weight of soil (material): 110.0

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 0.0
Friction angle - - - - - 35.00 (degrees)

Pore water pressures are defined by a piezometric line.
Piezometric line number: 1
Negative pore water pressures are NOT allowed - set to zero.

```
------------------------------------------------------------
------------------- DATA FOR MATERIAL NUMBER 7 -------------------
------------------------------------------------------------
Description: bedrock

Unit weight of soil (material): 150.0

SHEAR STRENGTH IS VERY LARGE (INFINITE)
```



```
TABLE NO. 6
**************************************************************************
* NEW PIEZOMETRIC LINE DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
**************************************************************************

------------------------------------------------------
--------------- Piezometric Line Number 1 ---------------
------------------------------------------------------
Description: all
Unit weight of fluid (water): 62.4

Point        X           Y

  1      -600.00        0.00
  2      1375.00        0.00
```



```
TABLE NO. 11
**************************************************************************
* NEW DISTRIBUTED LOAD DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
**************************************************************************
                                  Normal        Shear
Point       X           Y         Pressure      Stress

Distributed loads will be generated from piezometric line number 1
See Output Table number 27
```



```
TABLE NO. 16
```

```
**********************************
* NEW ANALYSIS/COMPUTATION DATA *
**********************************

Starting Center Coordinate for Search at -
                                              X: 400.00
                                              Y: 400.00

Required accuracy for critical center
(= minimum spacing between grid points): 1.000

Critical shear surface not allowed to pass below Y: -400.00

For the initial mode of search circles pass through the fixed
point at - X: 99.99, Y: -36.67


------------------------------------------------------------------------------
--
The following represent default values or values that were prevously defined:
Subtended angle for slice subdivision: 3.00(degrees)
There is no crack.
There is no water in a crack.
Conventional (single-stage) computations will be performed.
Seismic coefficient: 0.000
Unit weight of water (or other fluid) in crack: 62.4
Automatic search output will be in long form.
Search will be continued after the initial mode to find a most critical
circle.
Maximum number of trial grids for a given search mode: 50
No restrictions exist on the lateral extent of the search.
No shear surfaces other than the most critical will be saved for display
later.
Neither slope face was explicitly designated for analysis.
Standard sign convention used for direction of shear stress on shear surface.
Procedure of Analysis: Spencer

Iteration limit: 100
Force imbalance: 1.000000e-005 (fraction of total weight)
Moment imbalance: 1.000000e-005 (fraction of moment due to total weight)
Minimum weight required for computations to be performed: 100
Initial trial factor of safety: 3.000
Initial trial side force inclination: 17.189 (degrees)
Minimum (most negative) side force inclination allowed in Spencer's procedure:
-10.00
v
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TABLE NO. 26
**************************************
* NEW, COMPUTED SLOPE GEOMETRY DATA *
**************************************

These slope geometry were generated from the Profile Lines.
```

Point	X	Y
1	-600.00	-15.00
2	-510.00	-20.00
3	-490.00	-25.00
4	-450.00	-30.00
5	-370.00	-30.00
6	-345.00	-25.00
7	-310.00	-25.00
8	-240.00	-30.00
9	-220.00	-30.00
10	-200.00	-25.00
11	0.00	-17.00
12	150.00	-38.50
13	185.00	-48.50
14	220.00	-58.50
15	255.00	-68.50
16	295.00	-78.50
17	350.00	-88.50
18	410.00	-98.50
19	455.00	-108.50
20	515.00	-118.50
21	590.00	-125.00
22	655.00	-135.00
23	735.00	-145.00
24	825.00	-155.00
25	900.00	-165.00
26	990.00	-175.00
27	1105.00	-185.00
28	1205.00	-195.00
29	1375.00	-205.00

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TABLE NO. 27
****
* NEW DISTRIBUTED LOAD DATA - CONVENTIONAL/FIRST-STAGE COMPUTATIONS *
****

Point	X	Y	Normal Pressure	Shear Stress
1	-600.00	-15.00	936.0	0.0
2	-510.00	-20.00	1248.0	0.0
3	-490.00	-25.00	1560.0	0.0
4	-450.00	-30.00	1872.0	0.0
5	-370.00	-30.00	1872.0	0.0
6	-345.00	-25.00	1560.0	0.0
7	-310.00	-25.00	1560.0	0.0
8	-240.00	-30.00	1872.0	0.0
9	-220.00	-30.00	1872.0	0.0
10	-200.00	-25.00	1560.0	0.0
11	0.00	-17.00	1060.8	0.0
12	150.00	-38.50	2402.4	0.0
13	185.00	-48.50	3026.4	0.0
14	220.00	-58.50	3650.4	0.0

15	255.00	-68.50	4274.4	0.0
16	295.00	-78.50	4898.4	0.0
17	350.00	-88.50	5522.4	0.0
18	410.00	-98.50	6146.4	0.0
19	455.00	-108.50	6770.4	0.0
20	515.00	-118.50	7394.4	0.0
21	590.00	-125.00	7800.0	0.0
22	655.00	-135.00	8424.0	0.0
23	735.00	-145.00	9048.0	0.0
24	825.00	-155.00	9672.0	0.0
25	900.00	-165.00	10296.0	0.0
26	990.00	-175.00	10920.0	0.0
27	1105.00	-185.00	11544.0	0.0
28	1205.00	-195.00	12168.0	0.0
29	1375.00	-205.00	12792.0	0.0

The above data were generated automatically from piezometric line number 1.

Search will be conducted for RIGHT face of slope

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SECTION E

TABLE NO. 29
****
* OUTPUT FOR TYPE 1 AUTOMATIC SEARCH WITH CIRCLES *
****

------ Output for Circles Through a Fixed Point ------
------ Fixed point at - X: 99.99 Y: -36.67

Center Coordinates			1-Stage Factor of Safety	Side Force Inclination (degrees)	Iterations
X	Y	Radius			
Messages					
370.00	370.00	488.14	3.423	-1.584	8
400.00	370.00	505.36	3.372	-1.676	8
430.00	370.00	523.72	3.753	-1.785	8
370.00	400.00	513.40	3.649	-1.600	8
400.00	400.00	529.80	3.157	-1.578	8
430.00	400.00	547.34	3.646	-1.737	8
370.00	430.00	539.15	3.848	-1.597	8
400.00	430.00	554.78	3.392	-1.605	8
430.00	430.00	571.56	3.520	-1.691	8
- - - - - - New 9-Point Grid (only new points calculated) - - - - - -					
395.00	395.00	522.85	3.204	-1.581	8
400.00	395.00	525.68	3.119	-1.574	8
405.00	395.00	528.55	3.042	-1.574	8
395.00	400.00	526.98	3.244	-1.586	8
405.00	400.00	532.64	3.078	-1.577	8
395.00	405.00	531.13	3.284	-1.590	8
400.00	405.00	533.93	3.196	-1.579	8
405.00	405.00	536.75	3.114	-1.578	8

```
- - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    400.00    390.00    521.59   3.082     -1.571          8
    405.00    390.00    524.48   3.267     -1.640          8
    410.00    390.00    527.40   3.419     -1.684          8
    410.00    395.00    531.45   3.371     -1.663          8
    410.00    400.00    535.52   3.300     -1.648          8
- - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    402.00    392.00    524.37   3.065     -1.572          8
    405.00    392.00    526.11   3.216     -1.627          8
    408.00    392.00    527.85   3.348     -1.661          8
    402.00    395.00    526.83   3.087     -1.573          8
    408.00    395.00    530.29   3.307     -1.650          8
    402.00    398.00    529.29   3.109     -1.575          8
    405.00    398.00    531.01   3.063     -1.576          8
    408.00    398.00    532.73   3.246     -1.631          8
- - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    404.00    394.00    527.16   3.049     -1.574          8
    405.00    394.00    527.74   3.035     -1.574          8
    406.00    394.00    528.32   3.229     -1.629          8
    404.00    395.00    527.98   3.057     -1.575          8
    406.00    395.00    529.13   3.171     -1.609          8
    404.00    396.00    528.79   3.064     -1.575          8
    405.00    396.00    529.37   3.049     -1.575          8
    406.00    396.00    529.95   3.048     -1.569          8
- - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    404.00    393.00    526.34   3.042     -1.574          8
    405.00    393.00    526.92   3.142     -1.593          8
    406.00    393.00    527.50   3.249     -1.635          8
----- Critical Circle After the Current Mode of Search -----
X: 405.00     Y: 394.00     Radius: 527.737
Factor of safety: 3.035     Side force inclination: -1.574

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SECTION E

TABLE NO. 30
**************************************************
* OUTPUT FOR TYPE 1 AUTOMATIC SEARCH WITH CIRCLES *
**************************************************

------ Output for Circles Tangent to a Given Horizontal Line ------
------ Tangent line elevation, Y: -133.74

                                        1-Stage
Center Coordinates                      Factor   Side Force
                                          of     Inclination
     X          Y        Radius        Safety    (degrees)    Iterations
Messages

    375.00     364.00     497.74       3.428      -1.783          8
    405.00     364.00     497.74       3.109      -1.518          8
    435.00     364.00     497.74       3.664      -1.307          8
    375.00     394.00     527.74       3.440      -1.816          8
    435.00     394.00     527.74       3.546      -1.403          8
    375.00     424.00     557.74       3.442      -1.849          8
    405.00     424.00     557.74       3.268      -1.689          8
```

```
    435.00    424.00    557.74   3.445     -1.490          8
- - - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    400.00    389.00    522.74   3.292     -1.657          8
    405.00    389.00    522.74   3.046     -1.565          8
    410.00    389.00    522.74   3.124     -1.540          8
    400.00    394.00    527.74   3.298     -1.669          8
    410.00    394.00    527.74   3.111     -1.549          8
    400.00    399.00    532.74   3.304     -1.679          8
    405.00    399.00    532.74   3.089     -1.591          8
    410.00    399.00    532.74   3.099     -1.558          8
- - - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    402.00    391.00    524.74   3.256     -1.642          8
    405.00    391.00    524.74   3.042     -1.569          8
    408.00    391.00    524.74   3.087     -1.554          8
    402.00    394.00    527.74   3.264     -1.645          8
    408.00    394.00    527.74   3.080     -1.559          8
    402.00    397.00    530.74   3.271     -1.651          8
    405.00    397.00    530.74   3.075     -1.579          8
    408.00    397.00    530.74   3.073     -1.565          8
- - - - - - - New 9-Point Grid (only new points calculated) - - - - - -
    404.00    393.00    526.74   3.149     -1.602          8
    405.00    393.00    526.74   3.037     -1.572          8
    406.00    393.00    526.74   3.052     -1.567          8
    404.00    394.00    527.74   3.159     -1.608          8
    406.00    394.00    527.74   3.050     -1.569          8
    404.00    395.00    528.74   3.169     -1.614          8
    405.00    395.00    528.74   3.049     -1.571          8
    406.00    395.00    528.74   3.047     -1.571          8
----- Critical Circle After the Current Mode of Search -----
X: 405.00     Y: 394.00     Radius: 527.737
Factor of safety: 3.035     Side force inclination: -1.574
```

```
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TABLE NO. 33
*********************************************
* 1-STAGE FINAL CRITICAL CIRCLE INFORMATION *
*********************************************
X Coordinate of Center . . . . . 405.00
Y Coordinate of Center . . . . . 394.00
Radius . . . . . 527.74
Factor of Safety . . . . . 3.035
Side Force Inclination (degrees) . . . . . -1.57
Number of Circles Tried  . . . . . 73
Number of Circles F Calculated for . . . . . 73
Time Required for Search (seconds) . . . . . 1.8
```


```
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```

TABLE NO. 43

****
* Coordinate, Weight, Strength and Pore Water Pressure *
* Information for Individual Slices for Conventional *
* Computations or First Stage of Multi-Stage Computations. *
* (Information is for the critical shear surface in the *
* case of an automatic search.) *
****

Slice No.	X	Y	Slice Weight	Matl. No.	Cohesion	Friction Angle	Pore Pressure
	90.81	-30.02					
1	95.40	-33.34	2693	1	0.0	32.00	2080.5
	99.99	-36.67					
2	101.96	-38.05	2787	2	77.0	0.00	2374.1
	103.93	-39.43					
3	112.26	-44.98	21798	3	735.0	0.00	2807.0
	120.59	-50.54					
4	129.76	-56.15	41498	4	0.0	32.00	3503.8
	138.94	-61.76					
5	144.47	-64.90	33075	5	1000.0	0.00	4049.9
	150.00	-68.04					
6	162.27	-74.40	87406	5	1000.0	0.00	4642.3
	174.53	-80.75					
7	179.77	-83.22	41710	5	1000.0	0.00	5193.1
	185.00	-85.69					
8	197.70	-91.12	108974	5	1000.0	0.00	5686.0
	210.41	-96.55					
9	215.20	-98.40	43550	5	1000.0	0.00	6140.1
	220.00	-100.25					
10	233.06	-104.75	122168	5	1000.0	0.00	6536.4
	246.12	-109.25					
11	250.56	-110.61	42371	5	1000.0	0.00	6902.2
	255.00	-111.97					
12	268.34	-115.55	128319	5	1000.0	0.00	7210.3
	281.69	-119.13					
13	288.34	-120.64	64148	5	1000.0	0.00	7527.7
	295.00	-122.15					
14	308.58	-124.67	130578	5	1000.0	0.00	7779.4
	322.16	-127.20					
15	335.86	-129.01	129789	5	1000.0	0.00	8049.9
	349.55	-130.82					
16	349.78	-130.84	2077	5	1000.0	0.00	8164.4
	350.00	-130.86					
17	363.77	-131.94	124672	5	1000.0	0.00	8233.2
	377.54	-133.02					
18	391.27	-133.38	114766	5	1000.0	0.00	8322.9
	405.00	-133.74					
19	407.50	-133.72	19603	5	1000.0	0.00	8344.4
	410.00	-133.71					
20	423.81	-133.22	96138	5	1000.0	0.00	8313.0
	437.61	-132.73					
21	444.49	-132.21	39441	5	1000.0	0.00	8250.0
	451.38	-131.70					
22	453.19	-131.53	9337	4	0.0	32.00	8207.4
	455.00	-131.36					
23	468.71	-129.69	57047	4	0.0	32.00	8092.9
	482.43	-128.03					
24	483.93	-127.80	4783	4	0.0	32.00	7974.7
	485.43	-127.57					
25	499.02	-125.11	27729	3	773.1	0.00	7806.8

	512.62	-122.65					
26	513.34	-122.50	680	3	73.1	0.00	7643.7
	514.06	-122.34					
27	514.53	-122.24	394	2	77.0	0.00	7628.1
	515.00	-122.15					
28	518.04	-121.48	1817	2	77.0	0.00	7580.2
	521.08	-120.81					
29	523.89	-120.16	551	1	0.0	32.00	7498.1
	526.70	-119.51					

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SECTION E

TABLE NO. 44

```
**********************************************************
* Seismic Forces and Forces Due to Distributed Loads for *
* Individual Slices for Conventional Computations or the *
* First Stage of Multi-Stage Computations.               *
* (Information is for the critical shear surface in the  *
* case of an automatic search.)                          *
**********************************************************
```

Slices No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
				FORCES DUE TO DISTRIBUTED LOADS			
1	95.40	0	-32.01	17748	0	95.43	-30.68
2	101.96	0	-34.83	7849	0	101.96	-31.61
3	112.26	0	-39.04	34754	0	112.36	-33.10
4	129.76	0	-45.88	41194	0	129.88	-35.62
5	144.47	0	-51.30	26283	0	144.51	-37.71
6	162.27	0	-58.20	66870	0	162.61	-42.10
7	179.77	0	-65.11	31936	0	179.82	-47.02
8	197.70	0	-71.63	85952	0	198.00	-52.21
9	215.20	0	-77.76	35567	0	215.24	-57.14
10	233.06	0	-83.49	105491	0	233.32	-62.31
11	250.56	0	-88.92	38742	0	250.59	-67.24
12	268.34	0	-93.69	123303	0	268.55	-71.89
13	288.34	0	-98.74	65799	0	288.39	-76.85
14	308.58	0	-102.82	139495	0	308.72	-80.99
15	335.86	0	-107.47	149276	0	335.99	-85.95
16	349.78	0	-109.65	2500	0	349.78	-88.46
17	363.77	0	-111.37	158210	0	363.89	-90.81
18	391.27	0	-114.38	165659	0	391.38	-95.40
19	407.50	0	-115.90	31024	0	407.50	-98.08
20	423.81	0	-117.39	179266	0	423.94	-101.60
21	444.49	0	-119.19	93421	0	444.53	-106.17
22	453.19	0	-119.81	25030	0	453.19	-108.10
23	468.71	0	-120.24	192218	0	468.81	-110.80
24	483.93	0	-120.56	21532	0	483.93	-113.32
25	499.02	0	-120.47	199223	0	499.11	-115.85
26	513.34	0	-120.36	10822	0	513.34	-118.22
27	514.53	0	-120.33	7011	0	514.53	-118.42
28	518.04	0	-120.12	45258	0	518.04	-118.76
29	523.89	0	-119.72	41921	0	523.89	-119.27

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SECTION E

TABLE NO. 47
****
* Information for the Iterative Solution for the Factor of *
* Safety and Side Force Inclination by Spencer's Procedure *
****
Allowable force imbalance for convergence: 15
Allowable moment imbalance for convergence: 4478

Iteration	Trial Factor of Safety	Trial Side Force Inclination (degrees)	Force Imbalance (lbs.)	Moment Imbalance (ft.-lbs.)	Delta-F	Delta Theta (degrees)
1	3.00000	-17.1887	5.778e+004	-2.578e+007		
First-order corrections to F and Theta					0.1685	12.6045
Reduced values - Deltas were too large					0.0383	2.8648
2	3.03830	-14.3239	4.500e+004	-2.020e+007		
First-order corrections to F and Theta					0.0990	10.8348
Reduced values - Deltas were too large					0.0262	2.8648
3	3.06448	-11.4592	3.334e+004	-1.509e+007		
First-order corrections to F and Theta					0.0390	8.7999
Reduced values - Deltas were too large					0.0127	2.8648
4	3.07716	-8.5944	2.263e+004	-1.037e+007		
First-order corrections to F and Theta					-0.0051	6.5125
Reduced values - Deltas were too large					-0.0022	2.8648
5	3.07493	-5.7296	1.273e+004	-5.980e+006		
First-order corrections to F and Theta					-0.0266	3.9945
Reduced values - Deltas were too large					-0.0191	2.8648
6	3.05582	-2.8648	3.591e+003	-1.834e+006		
First-order corrections to F and Theta					-0.0199	1.2778
Second-order corrections to F and Theta					-0.0211	1.2912
7	3.03476	-1.5736	-1.859e+000	3.347e+002		
First-order corrections to F and Theta					-0.0000	-0.0003
Second-order corrections to F and Theta					-0.0000	-0.0003
8	3.03474	-1.5739	8.731e-011	-1.793e-008		
First-order corrections to F and Theta					0.0000	0.0000

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SECTION E

TABLE NO. 55

```
**************************************************************************
* Check of Computations by Spencer's Procedure (Results are for the      *
* critical shear surface in the case of an automatic search.)            *
**************************************************************************
```

Summation of Horizontal Forces: 2.47383e-010

Summation of Vertical Forces: 2.40107e-010

Summation of Moments: 1.72877e-008

Mohr Coulomb Shear Force/Shear Strength Check Summation: 5.74261e-011

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Name of input data file: H:\Post-capping new\final\Section E13.txt

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SECTION E

TABLE NO. 58

```
**************************************************************************
* Final Results for Stresses Along the Shear Surface                     *
* (Results are for the critical shear surface in the case of a search.) *
**************************************************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY
Factor of Safety: 3.035 Side Force Inclination: -1.57

Slice No.	X-Center	Y-Center	Total Normal Stress	Effective Normal Stress	Shear Stress
	-------- VALUES AT CENTER OF BASE OF SLICE --------				
1	95.40	-33.34	2160.5	80.0	16.5
2	101.96	-38.05	2620.5	246.4	25.4
3	112.26	-44.98	3168.3	361.4	242.2
4	129.76	-56.15	4320.1	816.3	168.1
5	144.47	-64.90	5096.0	1046.2	329.5
6	162.27	-74.40	5958.2	1315.9	329.5
7	179.77	-83.22	6706.7	1513.6	329.5
8	197.70	-91.12	7349.6	1663.5	329.5
9	215.20	-98.40	7930.6	1790.5	329.5
10	233.06	-104.75	8406.6	1870.2	329.5
11	250.56	-110.61	8833.9	1931.7	329.5
12	268.34	-115.55	9174.9	1964.6	329.5
13	288.34	-120.64	9520.6	1992.9	329.5
14	308.58	-124.67	9782.7	2003.2	329.5
15	335.86	-129.01	10056.1	2006.2	329.5
16	349.78	-130.84	10154.3	1989.9	329.5
17	363.77	-131.94	10179.1	1945.9	329.5
18	391.27	-133.38	10152.2	1829.3	329.5
19	407.50	-133.72	10080.9	1736.5	329.5
20	423.81	-133.22	9888.8	1575.9	329.5
21	444.49	-132.21	9583.8	1333.8	329.5
22	453.19	-131.53	9417.3	1209.9	249.1
23	468.71	-129.69	9085.5	992.6	204.4
24	483.93	-127.80	8761.5	786.9	162.0
25	499.02	-125.11	8376.1	569.3	254.8

26	513.34	-122.50	7932.3	288.6	24.1
27	514.53	-122.24	7896.0	267.9	25.4
28	518.04	-121.48	7780.3	200.0	25.4
29	523.89	-120.16	7612.8	114.7	23.6

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SECTION E

TABLE NO. 59

****
* Final Results for Side Forces and Stresses Between Slices *
* (Results are for the critical shear surface in the case of a search.) *
****

---------- VALUES AT RIGHT SIDE OF SLICE ----------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	99.99	11702	-33.99	0.501	2212.2	2173.6
2	103.93	17730	-35.86	0.474	1979.7	2726.2
3	120.59	43977	-42.88	0.471	2235.7	3173.0
4	138.94	83549	-50.93	0.436	2067.4	4655.0
5	150.00	108175	-55.31	0.431	2143.5	5177.7
6	174.53	157484	-65.48	0.433	2677.1	6256.3
7	185.00	178407	-69.61	0.433	2853.5	6736.3
8	210.41	226231	-78.73	0.437	3440.6	7647.4
9	220.00	242630	-81.97	0.438	3638.2	7981.0
10	246.12	280757	-90.03	0.444	4311.1	8655.1
11	255.00	291199	-92.59	0.446	4524.3	8868.2
12	281.69	318175	-99.26	0.452	5149.3	9322.2
13	295.00	326565	-102.30	0.455	5442.8	9516.1
14	322.16	342065	-107.18	0.457	5820.0	9809.2
15	349.55	342750	-111.27	0.461	6188.5	9974.0
16	350.00	342632	-111.33	0.461	6193.4	9976.6
17	377.54	329519	-114.48	0.464	6487.4	10010.6
18	405.00	300483	-116.83	0.469	6769.9	9884.8
19	410.00	293493	-117.18	0.469	6805.0	9858.2
20	437.61	235745	-119.22	0.481	7425.4	9351.8
21	451.38	201028	-120.00	0.487	7739.1	9007.0
22	455.00	191564	-120.19	0.489	7797.9	8953.5
23	482.43	124017	-120.65	0.493	7951.1	8628.1
24	485.43	116006	-120.68	0.492	7884.9	8681.2
25	512.62	35052	-120.23	0.532	9204.7	6215.0
26	514.06	30829	-120.21	0.534	9290.5	6118.1
27	515.00	28084	-120.19	0.536	9364.8	6036.9
28	521.08	13635	-119.85	0.536	9308.4	5972.8
29	526.70	0	-119.51	1.000	0.0	0.0

Read end-of-file on input while looking for another command word.
End of input data assumed - normal termination.

ATTACHMENT C-2
BEARING CAPACITY CALCULATIONS

URS

CALCULATION COVER SHEET

Client: EPA REGION 10 Project Name: PSR-MSU

Project/Calculation Number:

Title: Bearing Capacity of Marine Sediments and Allowable Cap Lift Thickness

Total Number of Pages (including cover sheet): 15

Total Number of Computer Runs: 8

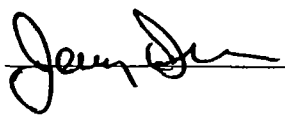
Prepared by: V. Schifano Date: 6/27/02

Checked by: M. McCabe Date: 6/27/02

Description and Purpose:
Compute the Bearing Capacity of Marine Sediments and Allowable Cap Lift Thickness

Design Basis/References/Assumptions
Stated in the Text

Remarks/Conclusions/Results:
Stated in the Text

Calculation Approved by: 
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

CALCULATION SHEET

PROJECT: PACIFIC SOUND RESOURCES – MARINE SEDIMENT UNIT

PROJECT NO: 53-F4006500

TITLE: BEARING CAPACITY OF MARINE SEDIMENTS AND ALLOWABLE CAP LIFT THICKNESS

PERFORMED BY: Vito Schifano DATE: 06/27/02

REVIEWED BY: Martin McCabe DATE: 06/27/02

OBJECTIVES: Compute the lift thickness values versus factor of safety against bearing capacity failure of the marine sediments upon placement of cap layer for the following conditions:

- RA 1, 2, 3, FS = 1, su = 10 psf, buoyant unit weight of the cap 50 pcf.
- RA 4, FS = 2, su = 10 psf, buoyant unit weight of the cap 50 pcf
- RA 5 (above 175 feet MLLW), FS = 3, su = 10 psf, buoyant unit weight of the cap 50 pcf
- RA 5 (below 175 feet MLLW),, FS = 3, su = 200 psf, buoyant unit weight of the cap 50 pcf

- - - where "su" is the undrained shear strength and "FS" is the factor of safety.

ASSUMPTIONS

- Two profile models were used for bearing capacity computations:

  MODEL A consisting of an upper highly compressible 3.5 ft thick overlying a 10 ft thick layer of silt/sand sediments. This model applies to the zones RA 1, 2, 3, 4, and 5 above 175 feet MLLW where the field investigation revealed the presence of organic silt or sensitive fine-grained deposits in the upper few feet of sediments.

  MODEL B consisting of silt/sand sediments without the upper compressible layer. This model is relevant to zone RA 5 below 175 feet MLLW where CPT profiles P11, P15, and P19 show no presence of highly compressible deposits in the upper few feet of sediments.

- Loaded area = 10 ft x 10 ft V Schifano assumption based on conversation with D. Schuchardt. (An analysis was also carried out using a 50ft x 50ft loaded area. A larger factor of safety was computed for the larger loaded area).

- The strength properties used for the evaluation of the FS against bearing failure are:

  MODEL A:
  - Upper silt: suo = 10 psf (lowest value measured using the field vane shear test).
  - Intermediate silt: suo = f(depth), $s_{uo\ top}$ = 50 psf, $s_{uo\ bottom}$ = 1500 psf (these values were originally used in the slope stability analyses. Later $s_{uo\ bottom}$ was reduced to 1000 psf. However, it must be noticed that, for the selected load area, the strength of the intermediate silt has little or no effect on the bearing capacity analysis results).

  MODEL B:
  Silt: suo = 200 – 500 psf (average range estimated from result of CPT tests)

- The shear strength of the upper silt is assumed to increase due to the pressure applied by the cap. The increase in strength is assumed proportional to the increase in effective vertical stress according to the relationship (Terzaghi et al, 1996):

  $\text{Log}\,[(\sigma'_{vo}+\Delta\sigma_v)/\sigma'_{vo}] = \text{Log}\,[(s_{uo}+\Delta s_u)/s_{uo}]$

- The time rate for strength increase is assumed to be the same as for consolidation. The coefficient of consolidation in the compression range was assumed to be equal to about 5 times the average coefficient of consolidation back-calculated form the results of the consolidation tests. Thus the strength increase is expected to take place in 2 – 3 days from the deposition of the cap layer.

COMPUTATIONS

- The ultimate load for the first lift placement was computed using the bearing capacity equation for footing foundations:

  $Qult = 5.14 \times su$

  The results of the computations for the different zones of the MSU are presented in Table below.

	Buoyant Unit Weight (pcf)	Su (psf)	Qult (psf)	FS	Thickness (ft)
RA 1,2,3	50	10	50	1	1
RA 4	50	10	50	2	0.5
RA 5 above 175 feet MLLW	50	10	50	2	0.3
RA5 below 175 feet MLLW	50	200-500	1200 – 3000	2	8

Because for a layered system constituted by cohesionless and cohesive soils a rigorous solution of the bearing problem is not readily available, the allowable load for the subsequent lifts of cap was computed using the commercially available software SLOPE/W (Geoslope International, Ltd) according to the instructions provided by the SLOPE/W user's manual for bearing capacity analysis. Output sheets from analyses are attached.

RESULTS

- The allowable thickness for the first lift placement for RA1,2,3 and FS = 1 is 1 foot.
- The allowable thickness for the first lift placement for RA 4, and FS=2 is 0.5 feet.
- The allowable thickness for the first lift placement for RA 5 above 175 feet MLLW, FS=3, and su = 10 psf is 0.3 feet
- The allowable thickness for the first lift placement for RA 5 below 175 feet MLLW, FS=3, and su = 200 psf is> 3 ft.

- The allowable thickness of the subsequent lifts is reported in the table below.

	RA 1, 2, 3, su =10 psf γ = 50 pcf (FS=1)	RA 4, su =10 psf γ = 50 pcf (FS=2)	RA 5, su =10 psf γ = 50 pcf (FS=3)
1st lift	1 ft	0.5 ft	0.3ft
2nd lift	2 ft	0.75 ft	0.5 ft
3rd lift	5 ft	1.75 ft	0.6 ft
4th lift		2.5 ft	0.8ft

- In RA 5 below 175 feet MLLW a 8 ft cap can be placed in one single lift.

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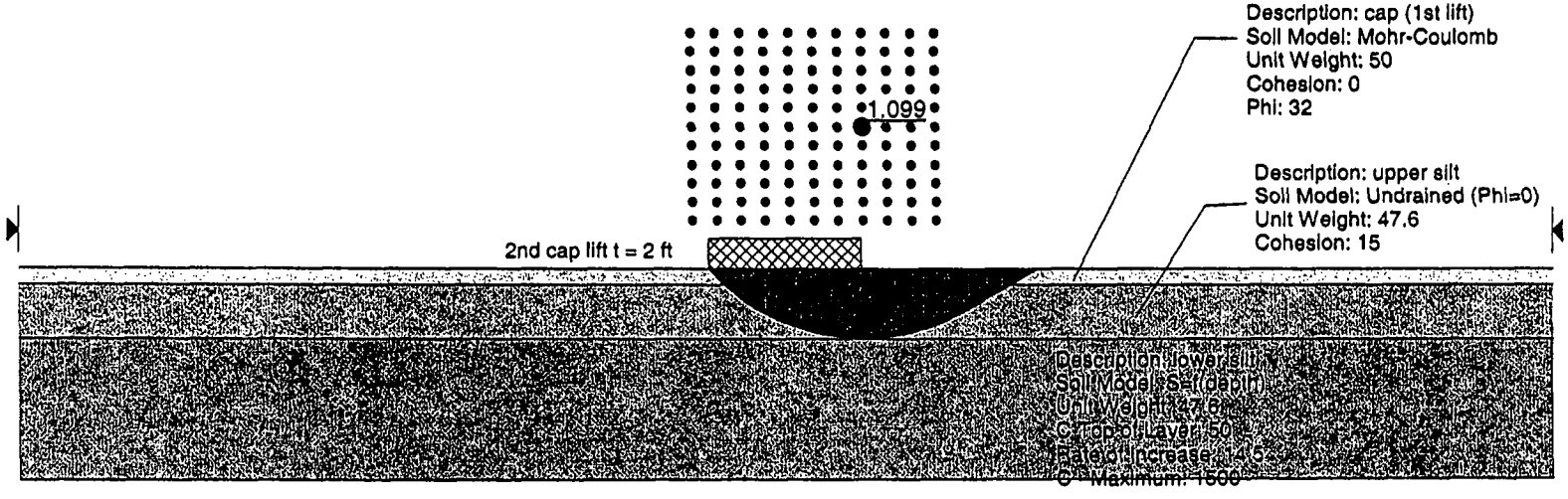
Analysis Method: Spencer



URS

Figure - Bearing Capacity
RA 1, 2, and 3 - 2nd stage capping

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Comments: Bearing Capacity
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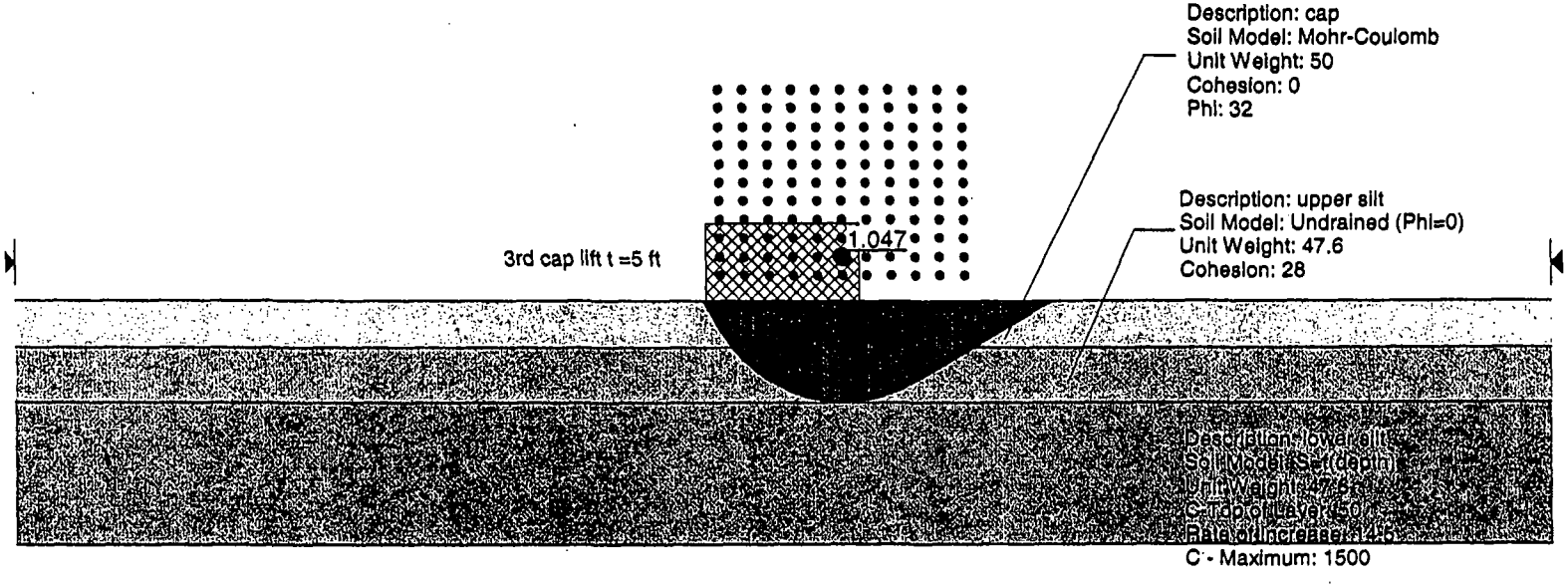

URS

Figure - Bearing capacity
RA 1,2, and 3 - 3rd stage capping

PSR-MSU

CAP PLACEMENT SEQUENCE RA 1, 2, AND 3
Factor of safety for bearing capacity

	initial	cap	end of cons	stage 2	cap	end of cons	stage 3	cap
sv (psf)	83.3	1	133.3	133.3	2	233.3	233.3	5
su (psf)	10		16.00240096	16.002401		28.00720288	28.0072029	
		FS=1			FS=1			FS=1

Assume the following profile:
1. 3.5 ft of organic silt, suo = 10 psf
2. 10 ft of sandy silt su = f(depth), sutop = 50 psf, subot = 1500 psf
3. 10 ft of silty sand with friction angle = 32 degrees

The strength of the upper silt is assumed to increase due to pressure applied by a cap layer.
The increase in strength is assumed to be proportional to the increase in effective vertical stress.
The time rate from strength increase is the same as the one for consolidation.

Buoyant unit weight of cap = 50 pcf

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Analysis Method: Spencer

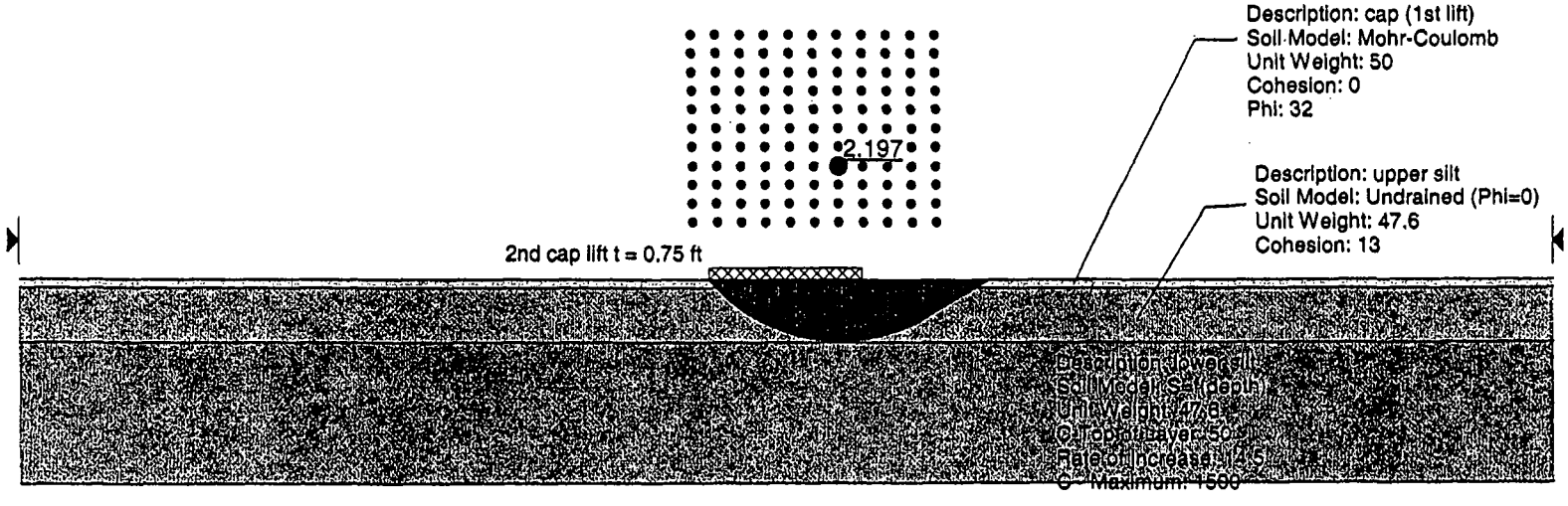

Figure - Bearing Capacity
RA 4 - 2nd stage capping

URS

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Comments: Bearing Capacity
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Analysis Method: Spencer

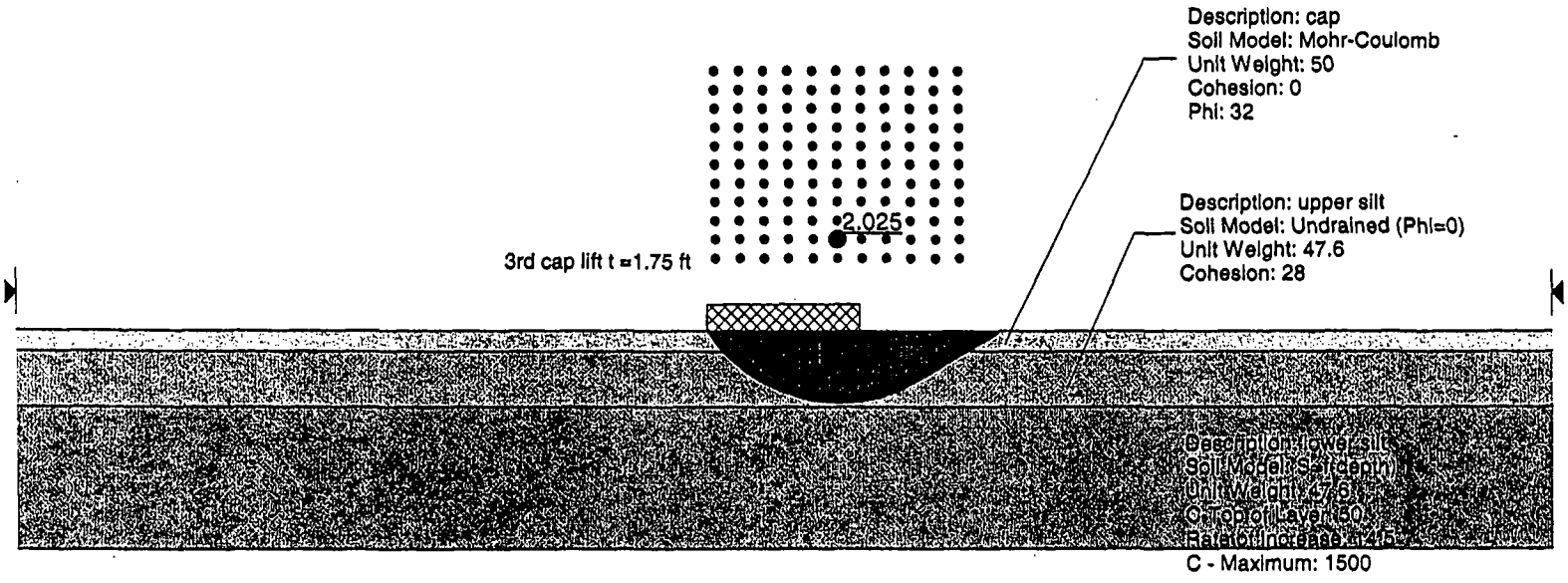

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Figure - Bearing capacity
RA 4 - 3rd stage capping

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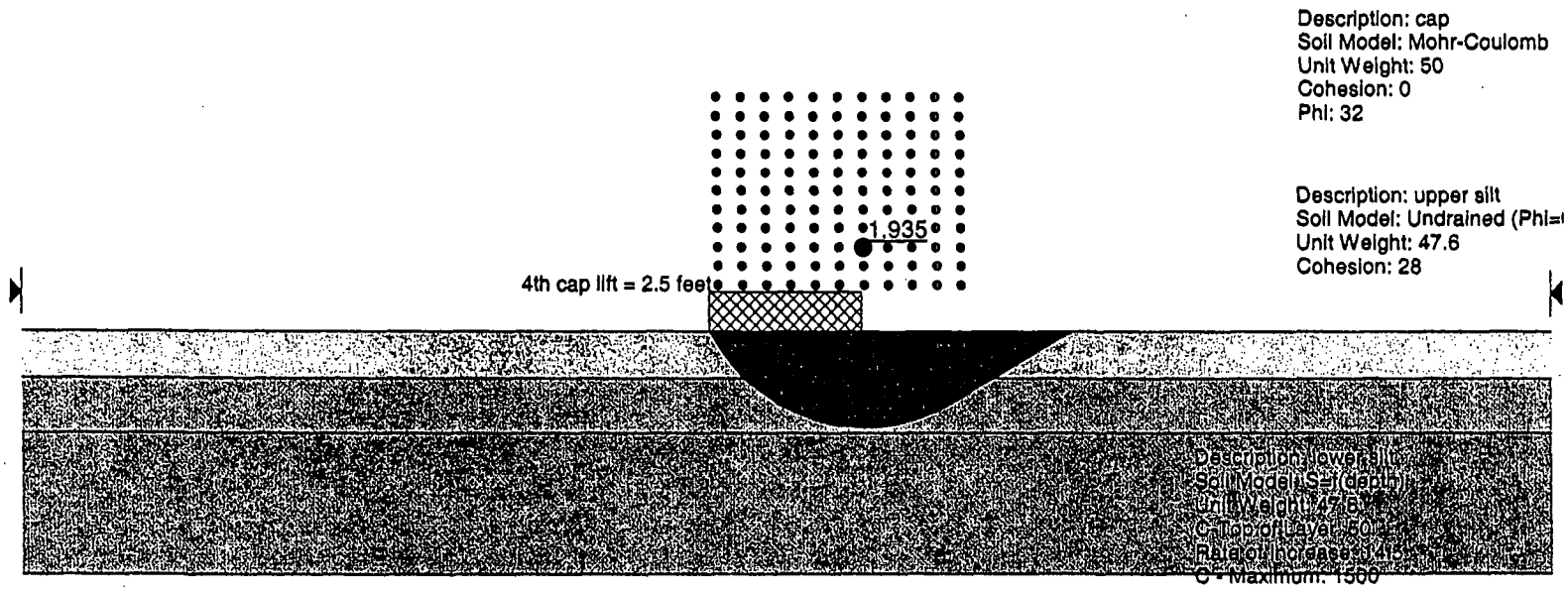

Figure - Bearing Capacity
RA 4 - 4th stage capping

PSR-MSU

CAP PLACEMENT SEQUENCE RA 4
Factor of safety for bearing capacity

	Initial	cap	end of cons	stage 2	cap	end of cons	stage 3	cap	end of cons	stage 4	cap	end of cons
sv (psf)	83.3	0.5	108.3	108.3	0.75	145.8	145.8	1.75	233.3	233.3	2.5	358.3
su (psf)	10		13.00120048	13.0012		17.5030012	17.5030012		28.00720288	28.0072029		43.01320528
		FS=2			FS=2			FS=2			FS=1.9	

Assume the following profile:
1. 3.5 ft of organic silt, suo = 10 psf
2. 10 ft of sandy silt su = f(depth), sutop = 50 psf, subot = 1500 psf
3. 10 ft of silty sand with friction angle = 32 degrees

The strength of the upper silt is assumed to increase due to pressure applied by a cap layer.
The increase in strength is assumed to be proportional to the increase in effective vertical stress.
The time rate from strength increase is the same as the one for consolidation.

Buoyant unit weight of cap material = 50 pcf

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Analysis Method: Spencer

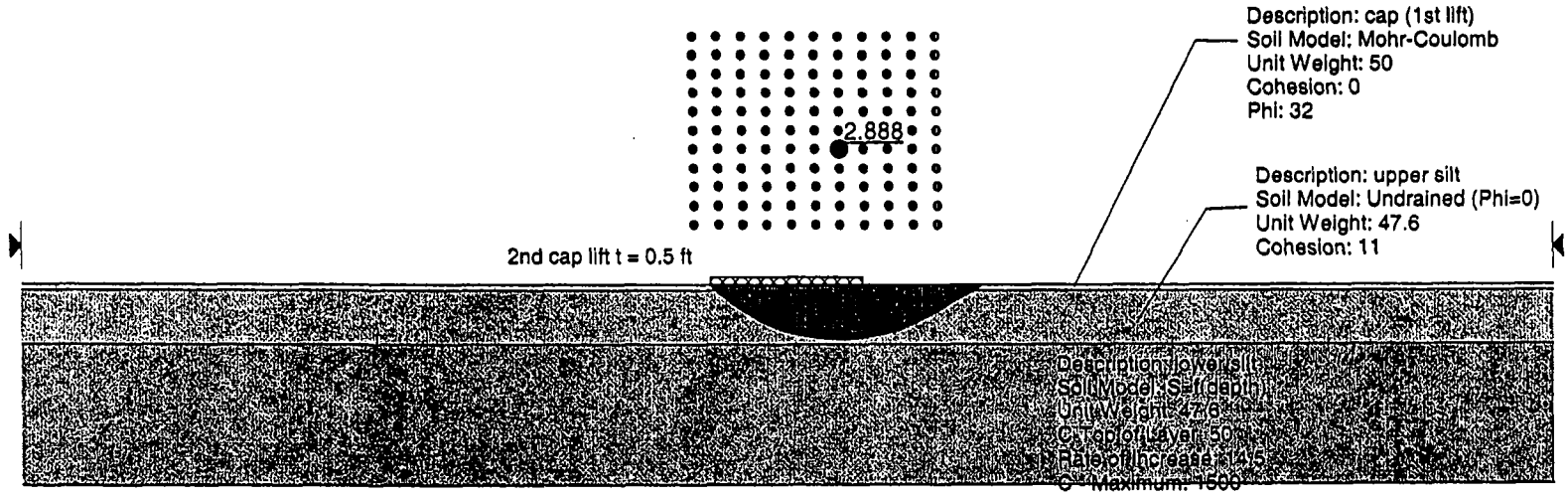

Figure - Bearing Capacity
RA 5 - 2nd stage capping
Above -175 feet MLLW

URS

Description: PSR-MSU
Comments: Bearing Capacity
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Analysis Method: Spencer

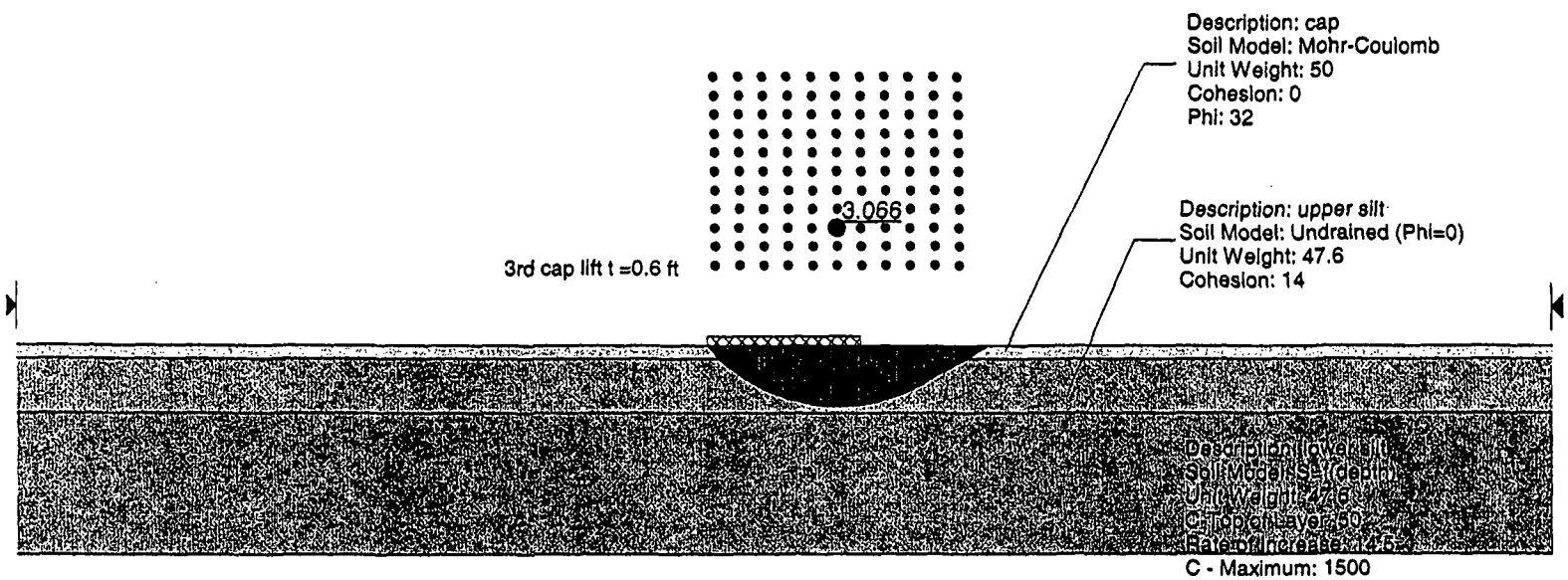

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Figure - Bearing capacity
RA 5 - 3rd stage capping
Above -175 feet MLLW

Description: PSR-MSU
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Analysis Method: Spencer

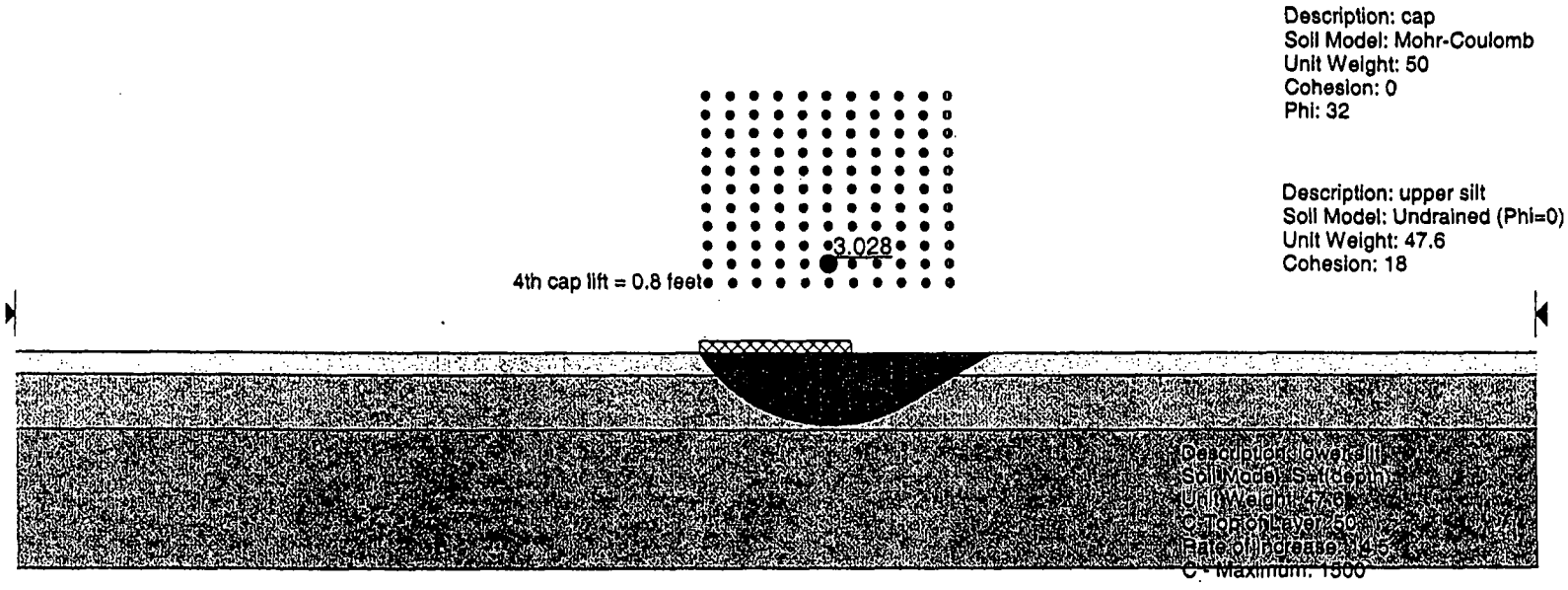


Figure - Bearing Capacity
RA 5 - 4th stage capping
Above -175 feet MLLW

PSR-MSU

CAP PLACEMENT SEQUENCE RA 5
Factor of safety for bearing capacity

	Initial	cap	end of cons	**stage 2**	cap	end of cons	**stage 3**	cap	end of cons	**stage 4**	cap	end of cons
sv (psf)	83.3	0.3	98.3	98.3	0.5	123.3	123.3	0.6	153.3	153.3	0.8	193.3
su (psf)	10		11.80072029	11.80072		14.80192077	14.8019208		18.40336134	18.4033613		23.20528211
		FS=3			FS=3			FS=3			FS=3	

Assume the following profile:
1. 3.5 ft of organic silt, suo = 10 psf
2. 10 ft of sandy silt su = f(depth), sutop = 50 psf, subot = 1500 psf
3. 10 ft of silty sand with friction angle = 32 degrees

The strength of the upper silt is assumed to increase due to pressure applied by a cap layer.
The increase in strength is assumed to be proportional to the increase in effective vertical stress.
The time rate from strength increase is the same as the one for consolidation.

ATTACHMENT C-3
SLOPE STABILITY ANALYSES OF RA1 CAP

MEMORANDUM

TO: J. DeMuro, D. Schuchardt
FROM: W.M. McCabe
Date: 10/28/02
Project: PSR 90% Design
Job No.: 33753970 (Old # is 53-F4006500)

Re: Results of Geotechnical Analyses, Tasks G1, G2 and G3

The following discussion of results of the geotechnical analyses are slightly changed from the preliminary results presented in our conversation of 9/17/02. Since that conversation, the seismic factors of safety for the slopes have changed slightly since we had not reduced the soil shear strength values by 20 percent to account for pore pressure increases and strength deterioration during seismic shaking.

Task G1 - Slope Stability Analysis at 3 Selected Stations

METHOD OF APPROACH: The general approach to slope stability analysis consisted of estimating the soil profile and shear strength parameters based on URS cone probes closest to the section in question, checking to see that those parameters were not too low by calculating the factor of safety (FS) of the existing unfailed slope for the Nisqually earthquake case (factor of safety should be greater than 1 to match observations of no failure), then calculating the FS of the proposed capped/rip-rapped slope for static and seismic conditions. The typical soil profile in the near-shore region consists of a very soft Upper Silt (1.5 ft thick typical, but possibly up to 3 ft) underlain by a soft to medium stiff Intermediate Silt (1.5 to 3.5 ft thick) followed by a medium stiff Lower Silt (5 to 15 ft thick) then a mixed Sandy Silt/Silty Sand of intermediate strength (12 to 20 ft thick). The deepest layer encountered is a medium dense sand. The cap design was taken as the profiles, layers and materials shown on Drawings dated July 26, 2002. The typical section consists of an upper rip-rap layer followed by a "cap filter" sand then a "cap subgrade" soil. The effect of adding a rip rap toe buttress was also examined.

For the seismic portion of the analyses, a slightly more conservative approach was taken for these shallow-water RA-1 slopes than was previously taken for the deep-water RA-4 slopes in Tech Memo 2. In the previous RA-4 analysis, the measured dry ground surface Peak Ground Acceleration (PGA) was 0.22g on Harbor Island, but the apparent absence of submarine slope liquefaction indicated that the equivalent PGA at the deep-water slope location was only about 0.12 g. For this RA-1 analysis, the full 0.22g PGA was assumed to act at the shallow slope locations, despite that fact that liquefaction would be predicted for this PGA but was apparently not observed. The higher PGA was used because it is difficult to justify a smaller value given the closer proximity of the shallow RA-1 slopes to the measured PGA location and ground condition. The slope stability effect of liquefaction of the new fill was also examined.

The industry –standard seismic safety factor target for slopes associated with civil works projects is 1.1. When FS values were less than 1, seismic shaking induced downslope displacements were roughly estimated using charts from Martin and Qui (1994, "Effects of Liquefaction on Vulnerability Assessment", NCEER Highway Project on Seismic Vulnerability of New and Existing Highway Construction, Year One Research Tasks – Technical Research Papers.)

RESULTS AND CONCLUSIONS:

- Station 9+00 : Using data from Cone Probe P1, the safety factor for the proposed cut was estimated at 1.55 for static conditions. Seismic conditions not applicable here, as final slope configuration was deemed to be more stable than the two other sections being evaluated. It should be noted that there are 2 published case histories of excavated submarine slopes failing despite analyses showing them to be stable (Newby, J.E. and Singh, J.P., "Puget Sound Alluvium: A Challenge in Design of Pile Supported Port Facilities with Dredged Slopes", Ports 86 - Proceedings of a Specialty Conference on Innovations in Port Engineering and Development in the 1990's", American Society of Civil Engineers, 1986; Kraft, L.M., Gavin, T.M. and Burtom, J.C., "Submarine Flow Slide in Puget Sound", Journal of Geotechnical Engineer, ASCE, V.118, N.10, 1992). The case histories are a reminder that the actual stability of submarine slopes can be difficult to predict accurately, and that dredging on slopes should be performed cautiously. **CONCLUSION** - Cut slope expected to be stable, but proceed with caution (avoid over-cutting, limit length of cut and duration the cut is left open before backfilling).

- Station 16+50: For the proposed slope configuration and using data from Cone Probes P4 and P7, the static FS is 1.52 and the seismic FS is 0.97 to 1.07 depending on the nature of the cap subgrade fill (see Table 1). The seismic FS was obtained by assuming that liquefaction does not occur, and that the 1.5-foot thick layer of "upper silt", typically characterized by an un-improved undrained shear strength of 100 psf, gets mixed with and/or displaced by the first few lifts of a granular "cap subgrade" consisting of either a reasonably well graded sand or a crushed stone product. The final "improved" shear strength of the upper silt is represented by a friction angle of 33 degrees if cap filter sand is used for the first few lifts, and by a friction angle of 35 degrees if a crushed stone select fill is used for the first few lifts. Use of a crushed stone or rockfill product produces the seismic FS of 1.07, which is considered sufficiently close to the desired 1.1 value.
  The liquefaction potential of the cap subgrade sand, considered the most seismically vulnerable of the types of fill contemplated in the design, was evaluated for liquefaction susceptibility using the LiquefyPro software. The relative density of the fill was estimated using published information on characteristics of hydraulic fill placed below water by various methods. The residual shear strength of the fill in a liquefied condition was estimated using an overburden relationship developed by Dobry and Baziar (1992, "Modeling of Lateral Spread in Silty Sands by Sliding Blocks", in Stability and Performance of Slopes and Embankments, ASCE Geotechnical Special Publication No.31, Berkley, CA) for the lower bound value , and using the Seed and Harder (1990, "SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength", Proceedings of the H. Bolton Seed Memorial Symposium, Univ. of Calif.., Berkeley, CA, V.2) N-value related curve for the upper bound (400 psf). The stability analyses were again conducted using the two residual strength values, which resulted in minimum seismic FS values of 0.8 and 1.6. An average value was assumed to representative of the actual situation, and an acceptable seismic FS is obtained.
  CONCLUSION – The first 2 feet of fill should be a well graded angular select fill to eliminate the weak zone that is producing seismic FS values less than 1.0 . The select granular fill should have a loose-condition friction angle of at least 37 degrees. A crushed stone or rockfill product would be appropriate for this select fill. If the select crushed stone or rockfill is not used for the first few lifts, seismic shaking at the design earthquake level would likely result in a small amount of downslope deformation of less than a few inches by rough estimation. The subgrade sand fill is potentially liquefiable at the design level PGA of 0.22g,

but the residual strength of the fill appears to be high enough to provide a seismic FS of at least 1.1.

Station 17+85: For the proposed slope configuration, the static FS is 1.49 and the seismic FS is 0.97 to an estimated 1.07 depending on the nature of the cap subgrade fill. These results were obtained assuming that the 1.5 foot thick layer of "upper silt" (typical un-improved undrained shear strength of 100 psf) gets mixed with or displaced by the first few lifts of "cap subgrade" consisting of either a reasonably well graded sand or a crushed stone product. The final "improved" shear strength is represented by a friction angle of 33 degrees if cap filter sand is used for the first few lifts, and the seismic FS of 0.97 results. If a well graded angular select fill such as crushed stone or a rockfill product is used for the first few lifts in the "cap subgrade" zone, the strength of the improved upper silt can be represented by a friction angle of 35 degrees, and the seismic FS is expected to increase to at least 1.07 , similar to the Station 16+50 situation. As the slope angles are slightly steeper at Station 16+50 than at Station 17+85, only the static and seismic case without the new buttress were actually analysed using UTEXAS, while the FS values for other situations were assumed to be related proportionally in a manner similar to the results for Station 16+50.
CONCLUSION - The first 2 feet of fill should be a well graded angular select fill to eliminate the weak zone that is producing seismic FS values less than 1.0 . For Station 17+85, this essentially means replacing the entire layer of cap subgrade with the select fill. The select fill should have a loose-condition friction angle of at least 37 degrees. A crushed stone or rockfill product would be appropriate for this select fill. If the select crushed stone or rockfill is not used for the first few lifts, seismic shaking at the design earthquake level would likely result in small amount of downslope deformation of less than a few inches by rough estimation.

OVERALL GENERAL CONCLUSIONS: Slopes that are configured similar to those at Stations 16+50 and 17+85 cannot achieve that target seismic FS of 1.1 unless select fill such as rockfill or crushed stone is used as the initial lifts to strengthen and/or replace the existing very soft Upper Silt and to improve the upper portion of the Intermediate Silt layer.

TABLE 1 - Summary of Stability Analyses at Selected Stations

STA	Cap Config	Static FS		Seismic FS		
		Silt phi 33 deg	Silt phi 35 deg	Silt phi 33 deg	Silt phi 35 deg	Fill liquefies
16+50	No Buttress	1.52		0.97	1.07	1.17 ave.
	With Buttress	1.82		1.03	> 1.07	1.38 ave.
17+85	No Buttress	1.49		0.97		

Note: "Silt phi" refers to the friction angle of the upper silt layer after mixing/displacement with either filter sand (producing silt phi of 33 degrees) or select crushed stone fill (producing silt phi of 35 degrees).

Task G2 - Slope Stability Analysis For Steeper Rip Rap Considerations

Analyses performed using a simple "infinite slope" approach and collected data on the properties of loose sand indicates that the reasonably well graded "cap subgrade" sand can probably be placed underwater using backhoe or similar bucket methods to achieve a relative density that would be associated with an angle of repose of approximately 30 to 31 degrees. Placing this material on a 2 Horizontal on 1 Vertical slope (26.5 degree angle) will result in a temporary safety factor of approximately 1.2. This situation is adequate until placement of overlying materials (filter sand and rip rap) further densifies the cap subgrade to its final assumed friction angle of 33 degrees. Placing the cap subgrade sand at angles steeper than 2H:1V would result in a high likelihood of local sloughing and instability.
CONCLUSION: Placing cap subgrade at 2 Horizontal –to- 1 Vertical will result in adequate temporary safety factor, but sloughing and stability problems may occur for steeper inclinations.

Task G3 - Preliminary Pile Downdrag Analysis at Observation Pier

In order to bracket the possible response of the piles to the placement of as much as 10 feet of fill, two separate possible soil profiles were examined:

Profile 1 - 3.5 ft of highly compressible silt overlying at least 30 feet of compressible silt and sand mixture.

Profile 2 – 3.5 ft of highly compressible silt, underlain by 16.5 ft of compressible silt and sand mix, underlain by at least 20 ft of medium dense sand.

As the actual length of the piles is unknown, an embedment of 30 feet below the mudline was assumed on the basis that longer piles would not likely have been use for such a minor structure.

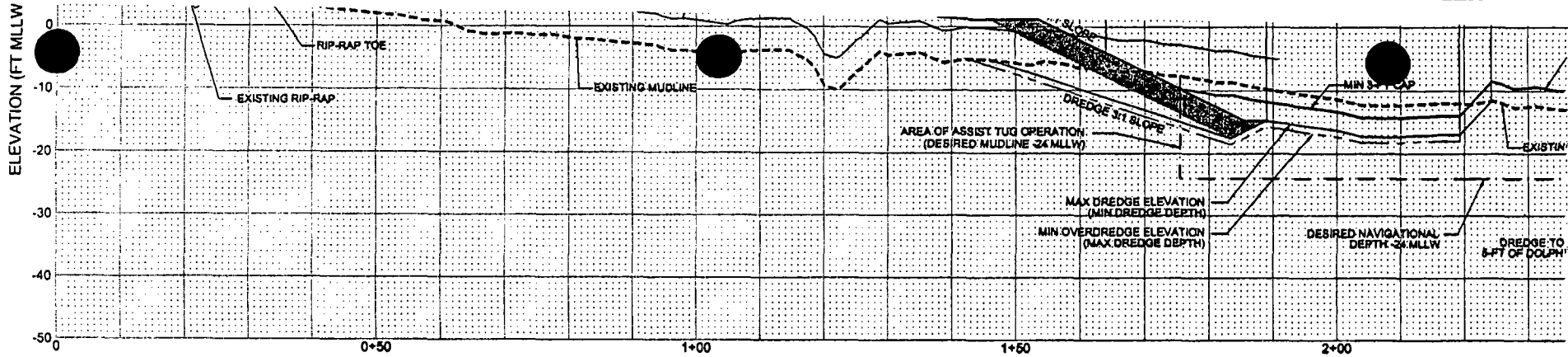
For Soil Profile 1, the pile tip is embedded in compressible soil and is expected to settle with the soil by an amount approximately equal to 20 inches. This maximum amount of settlement would occur at the location of the thickest fill, and settlement at the entrance to the pier and at the end of the pier would be very small.

For Soil Profile 2, the pile tip is embedded in a medium dense low compressibility sand that will settle only a small amount from the effects of the future fill placement, and will offer resistance to downdrag loads applied to the pile. Overall, the pile settlement is expected to be approximately 2 inches.

CONCLUSION - In the worst case scenario, the piles near the center of the pier could settle approximately 20 inches. It is also likely that a small amount of downslope lateral deformation of the piles on the steepest portion of the slope could occur during fill placement.

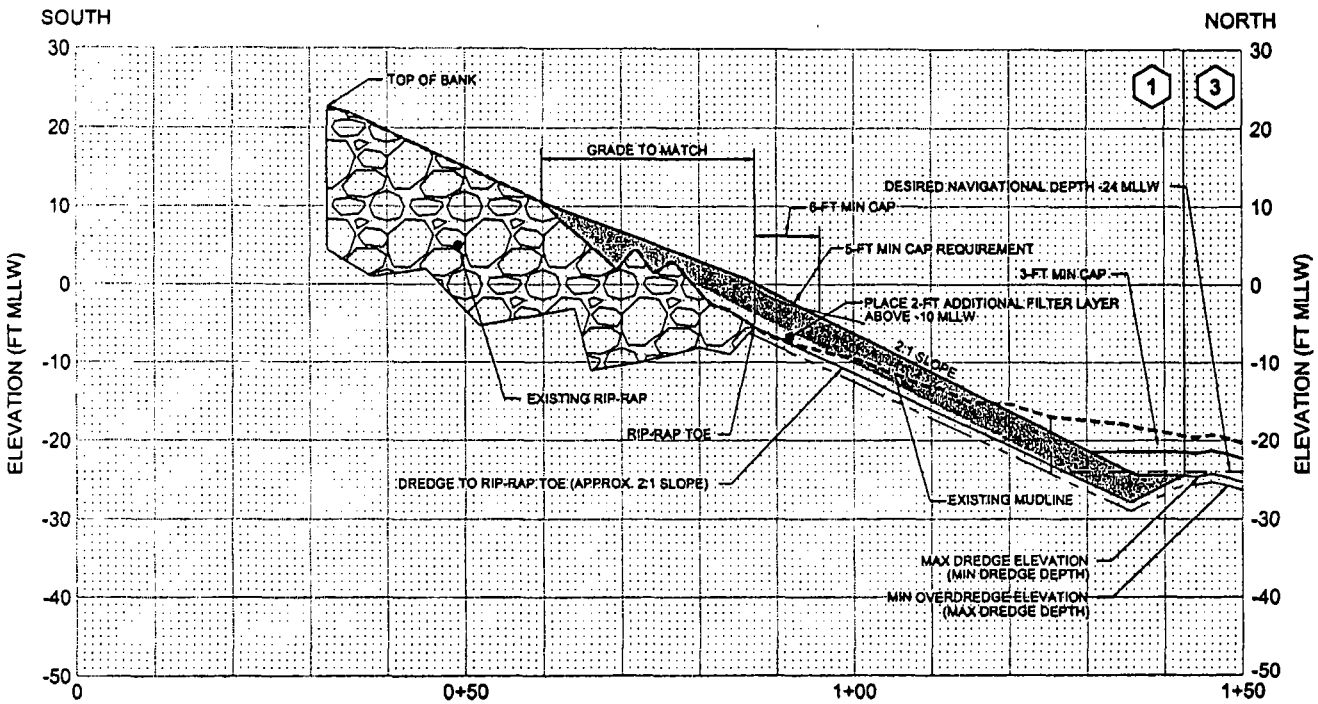
FIGURES FOR ATTACHMENT C-3
GEOTECHNICAL – SLOPE STABILITY

Fig G1 - Station 9+00 Profile per plan
Fig G2 - Station 9+00 Utexas analysis results
Fig G3 – Station 16+50 Profile per plan with buttress
Fig G4 – Station 16+50 Utexas analysis results, static, no buttress
Fig G5 – Station 16+50 Utexas analysis results, static, with buttress
Fig G6 – Station 16+50 Utexas analysis results, seismic with silt phi = 33 degrees
Fig G7 – Station 16+50 Utexas analysis results, seismic with silt phi = 35 degrees
Fig G8- Station 16+50 Utexas results, seismic with liquefaction, upper bound strength
Fig G9 – Station 16+50 Utexas results, seismic with liquefaction, lower bound strength
Fig G10 – Station 17+85 Profile per plan, no buttress
Fig G11 – Station 17+85 Utexas results, static, no buttress
Fig G12 – Station 17+85 Utexas results, seismic, no buttress



CAP TRANSECT STATION 7+00

7+00
C-8



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9+00
C-8

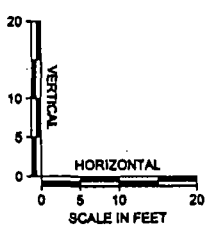
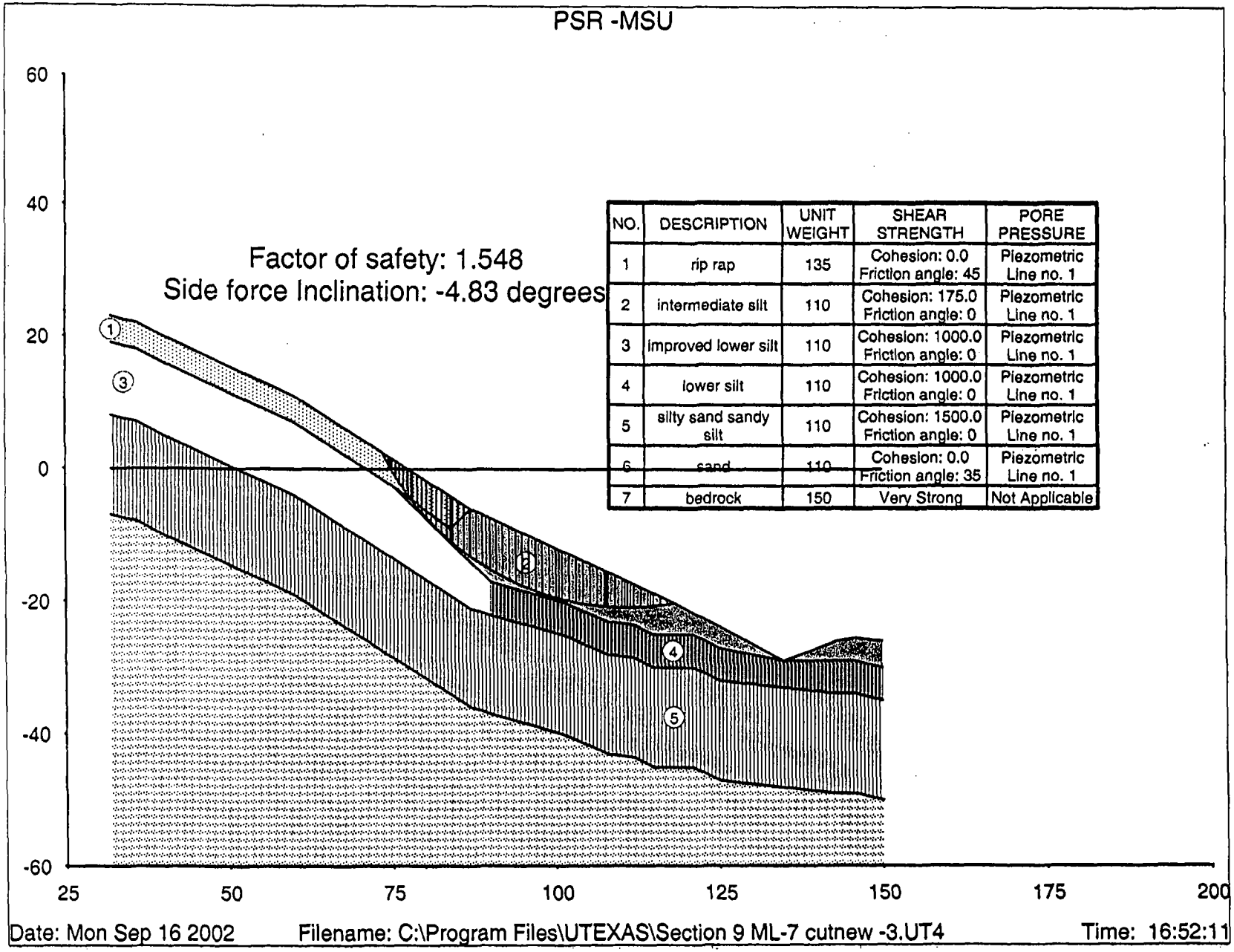


Fig G1

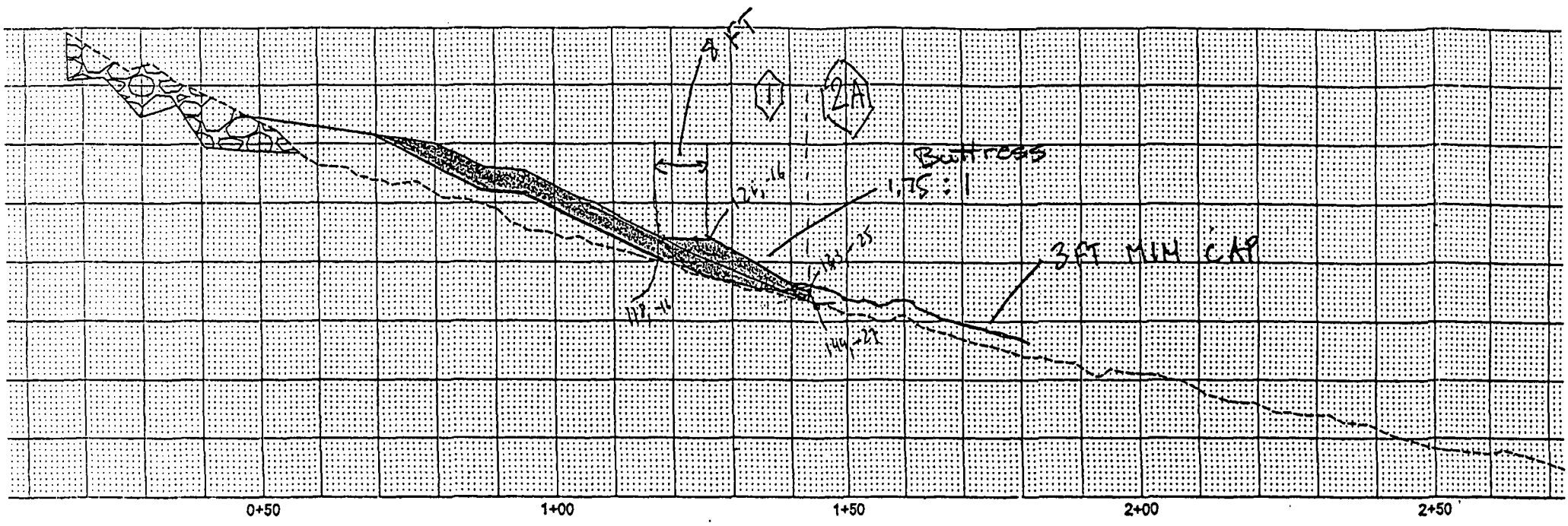
C
B
A
5
4
3
2



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	intermediate silt	110	Cohesion: 175.0 Friction angle: 0	Piezometric Line no. 1
3	improved lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
4	lower silt	110	Cohesion: 1000.0 Friction angle: 0	Piezometric Line no. 1
5	silty sand sandy silt	110	Cohesion: 1500.0 Friction angle: 0	Piezometric Line no. 1
6	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	bedrock	150	Very Strong	Not Applicable

Stability after cut

Fig G2



CAP TRANSECT STATION 16+50

16+50
C-9

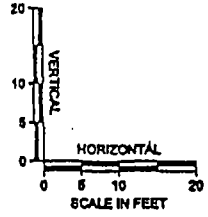
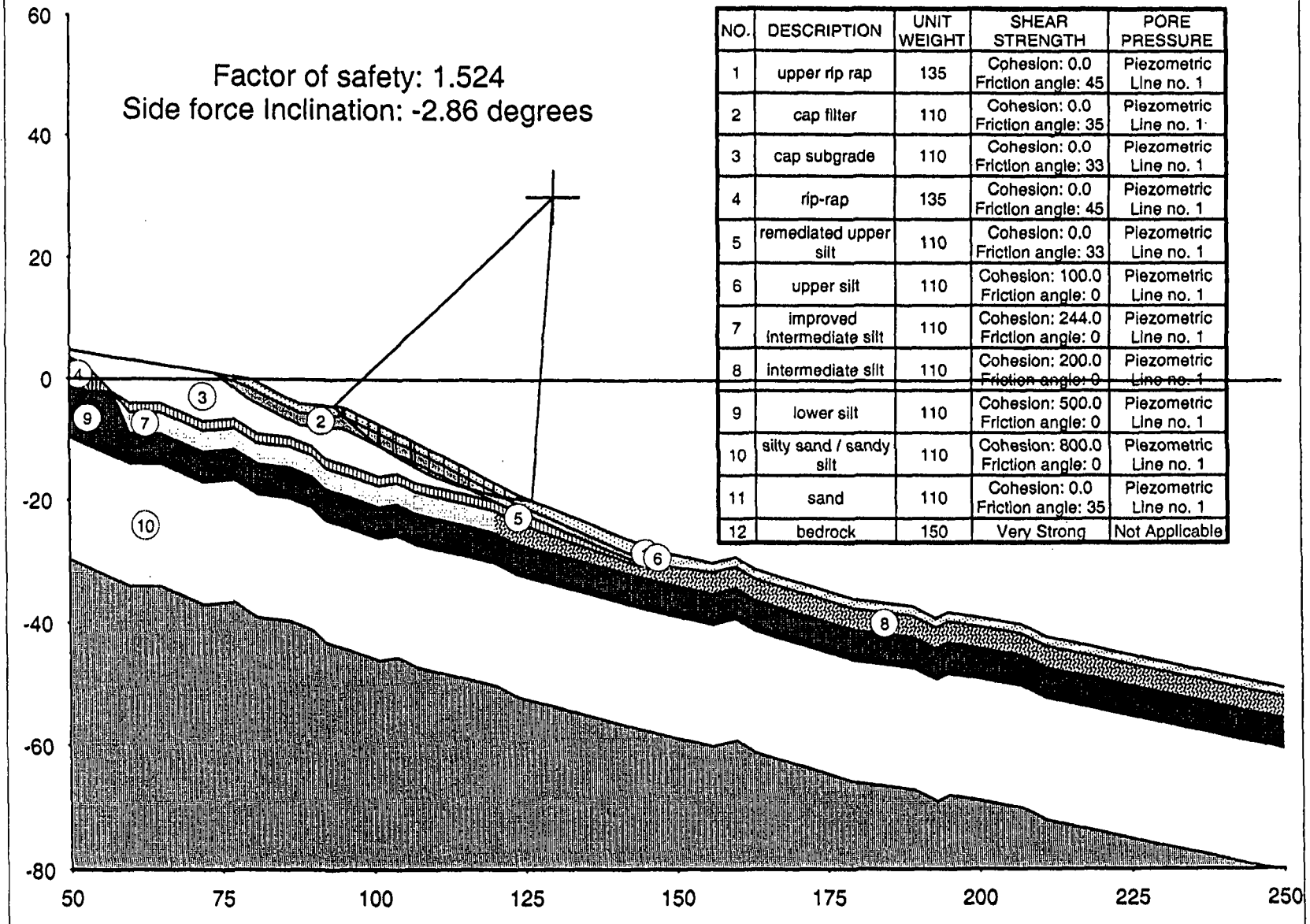


Fig G3

PSR -MSU



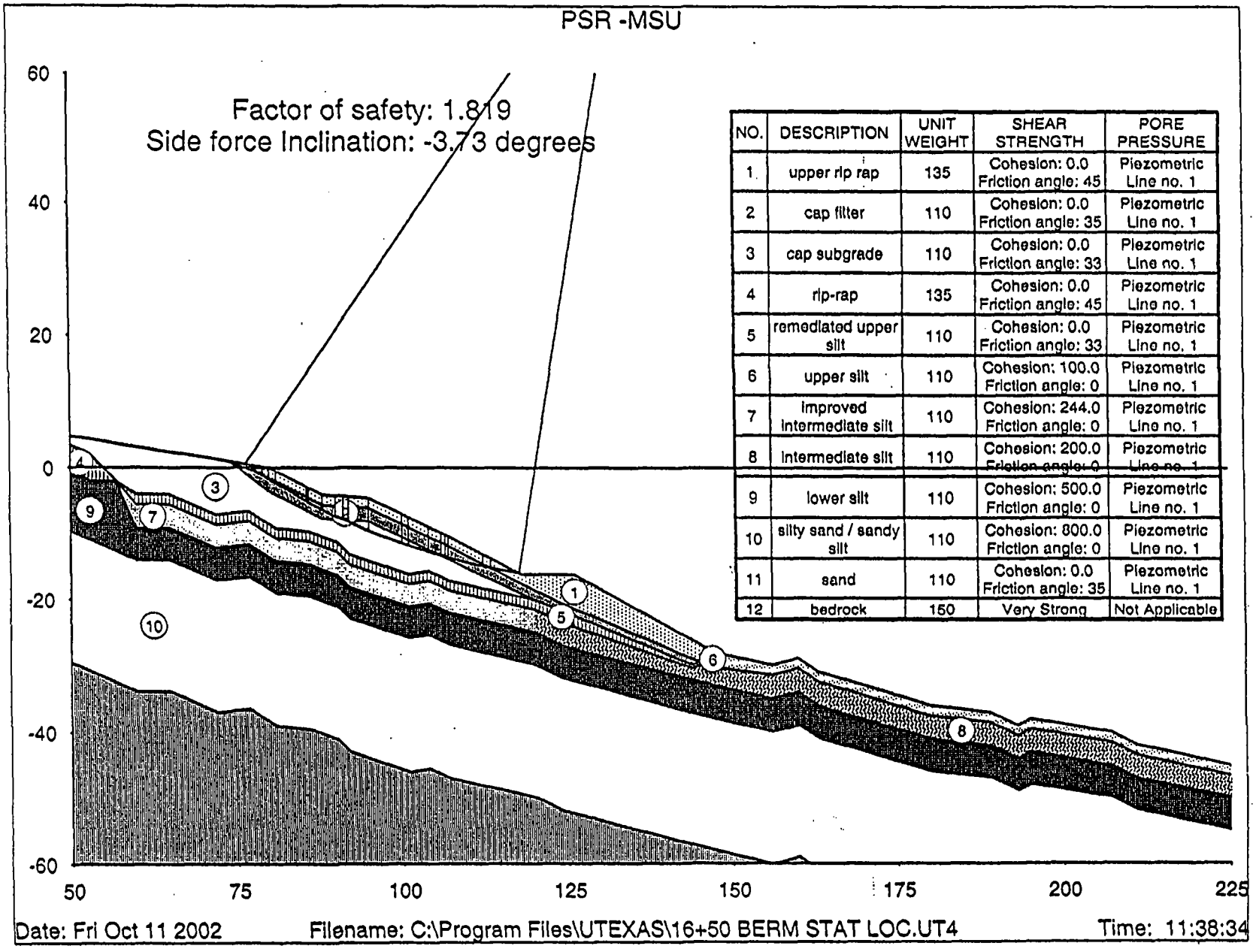
NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	cap subgrade	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
6	upper silt	110	Cohesion: 100.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 244.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 200.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

Date: Fri Sep 20 2002 Filename: C:\Program Files\UTEXAS\16+50 post-capnewstat.UT4 Time: 11:05:26

Case: SPA 16+50 No Buttress; static

Fig G4

Section 16+50 :

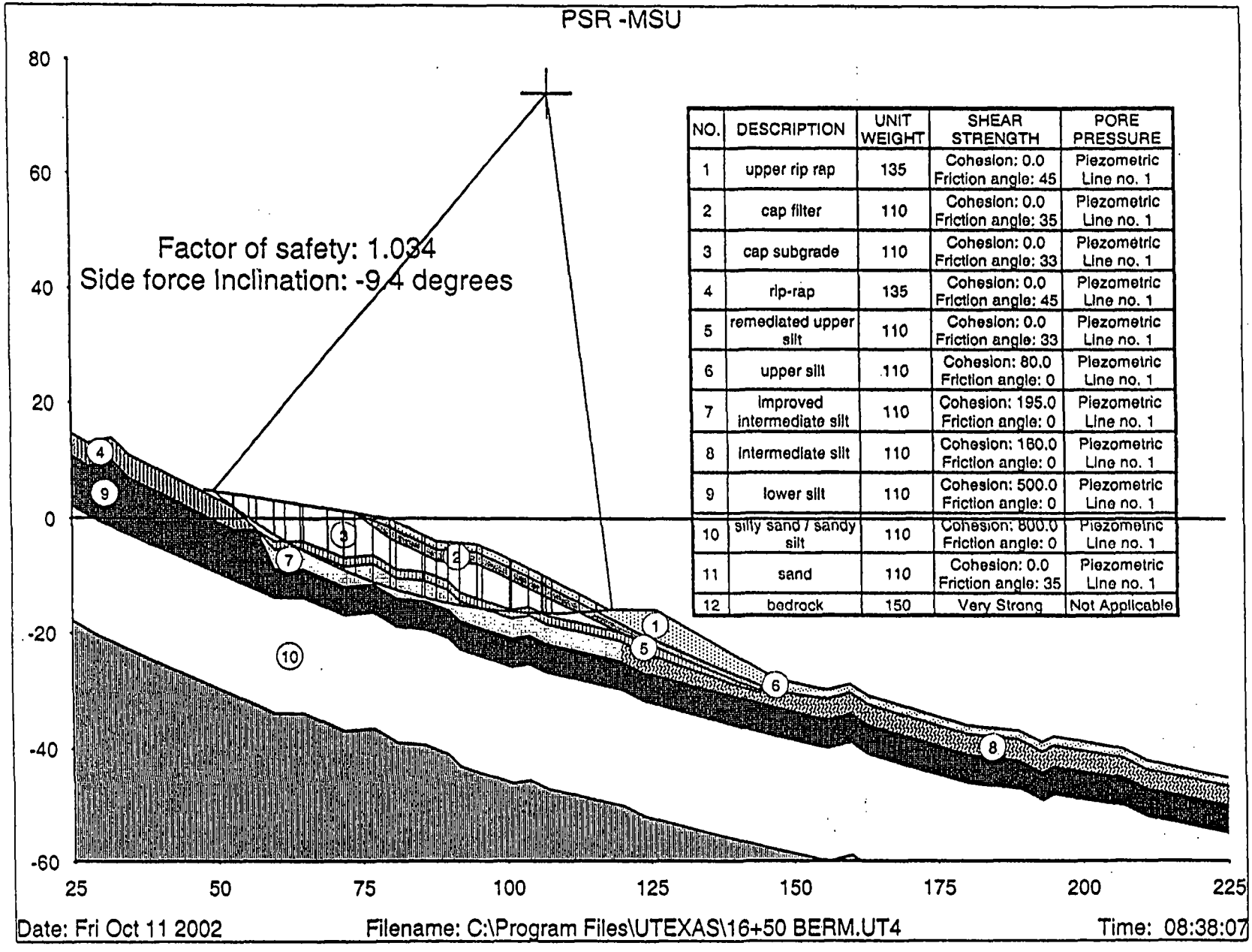


NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	cap subgrade	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
6	upper silt	110	Cohesion: 100.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 244.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 200.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

Case: STA 16+50 w/ Buttress ; Static

Fig G5

Seismic coefficient $K_y = 0.11$

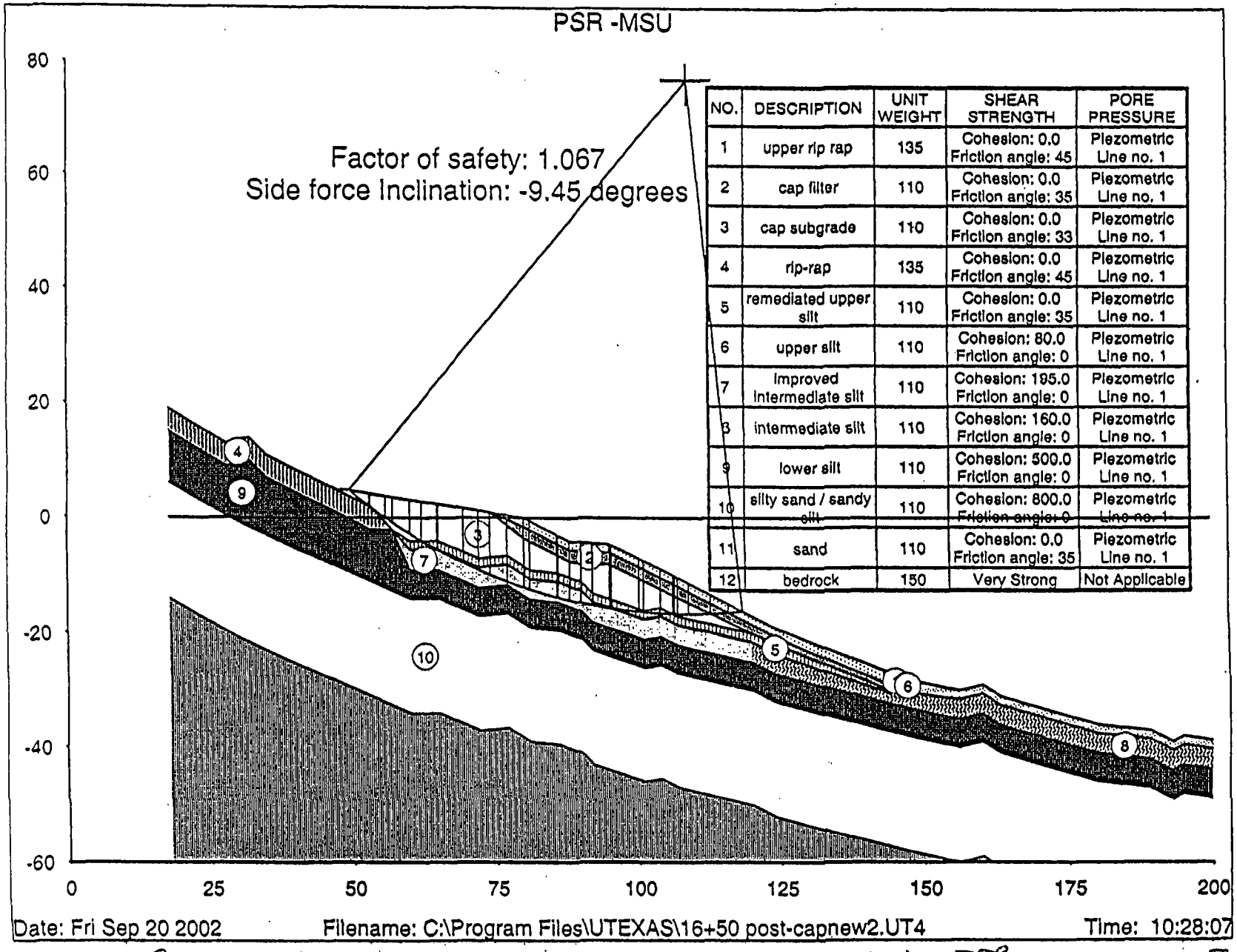


NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	cap subgrade	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
6	upper silt	110	Cohesion: 80.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 195.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 160.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

Case : STA 16+50 w/Buttress ; Seismic w/ Silt $\Phi = 33°$

Fig G6

Section 16+50: Seismic Analysis. Remediated upper silt modeled with $\phi' = 35°$

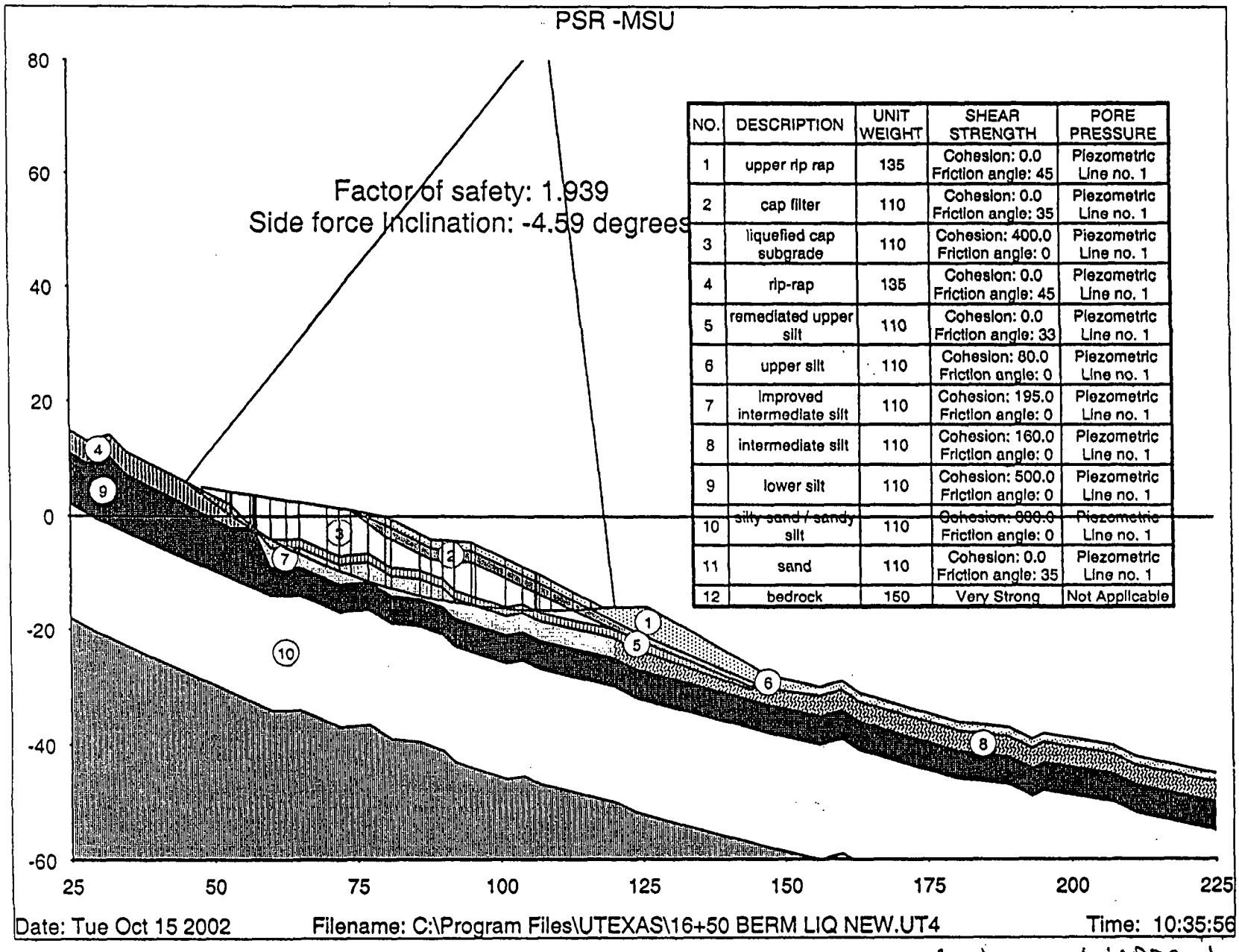


NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	cap subgrade	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
6	upper silt	110	Cohesion: 80.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 195.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 160.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

Case: STA 16+50 ; seismic w/ silt $\phi = 35°$

Fig G7

Section 16+50 : Static Analysis. Liquefied cap subgrade
Berm in place

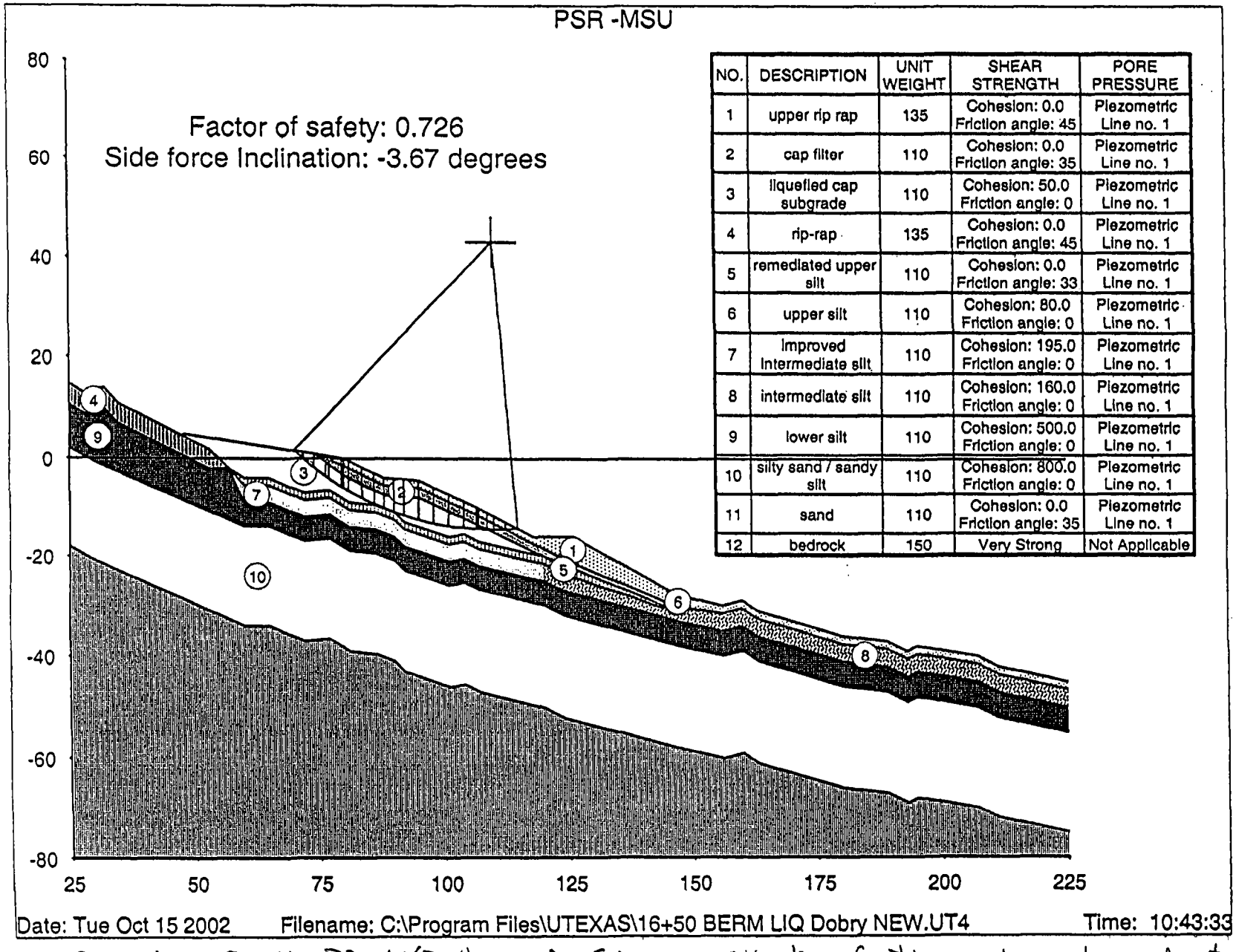


NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	liquefied cap subgrade	110	Cohesion: 400.0 Friction angle: 0	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
6	upper silt	110	Cohesion: 80.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 195.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 160.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 600.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

Case : STA 16+50 w/ Buttress ; seismic with liquefaction - ~~lower~~ upper bound strength

Fig C8

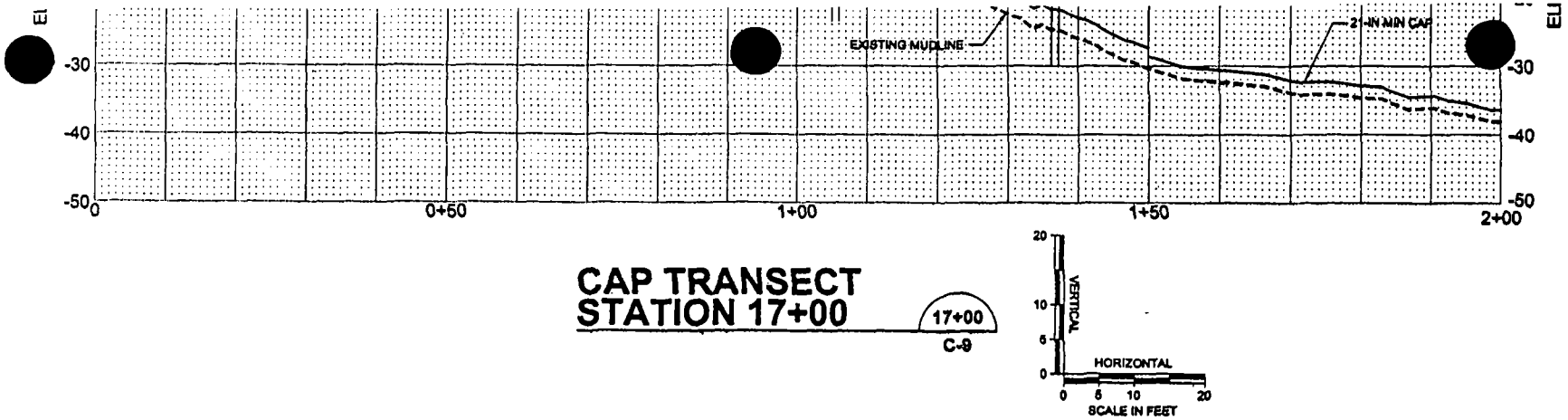
Section 16+50: Static Analysis : Liquefied cap subgrade Strength from Dobry. Berm in place



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
2	cap filter	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
3	liquefied cap subgrade	110	Cohesion: 50.0 Friction angle: 0	Piezometric Line no. 1
4	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	remediated upper silt	110	Cohesion: 0.0 Friction angle: 33	Piezometric Line no. 1
6	upper silt	110	Cohesion: 80.0 Friction angle: 0	Piezometric Line no. 1
7	improved intermediate silt	110	Cohesion: 195.0 Friction angle: 0	Piezometric Line no. 1
8	intermediate silt	110	Cohesion: 160.0 Friction angle: 0	Piezometric Line no. 1
9	lower silt	110	Cohesion: 500.0 Friction angle: 0	Piezometric Line no. 1
10	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
11	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
12	bedrock	150	Very Strong	Not Applicable

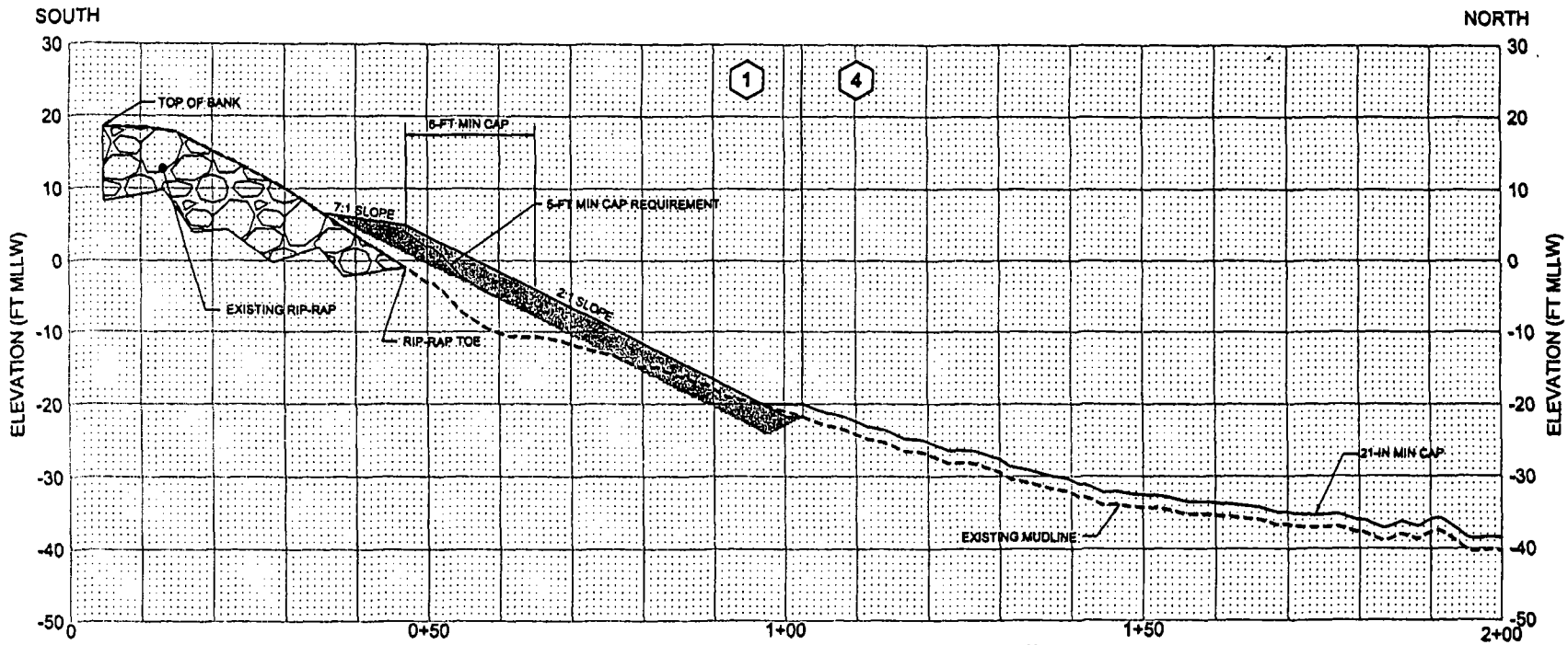
Case: STA 16+50 w/Buttress ; Seismic with liquefaction – lower bound strength

Fig G9



CAP TRANSECT STATION 17+00

17+00
C-9



CAP TRANSECT STATION 17+85

17+85
C-9

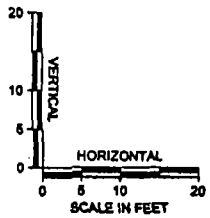
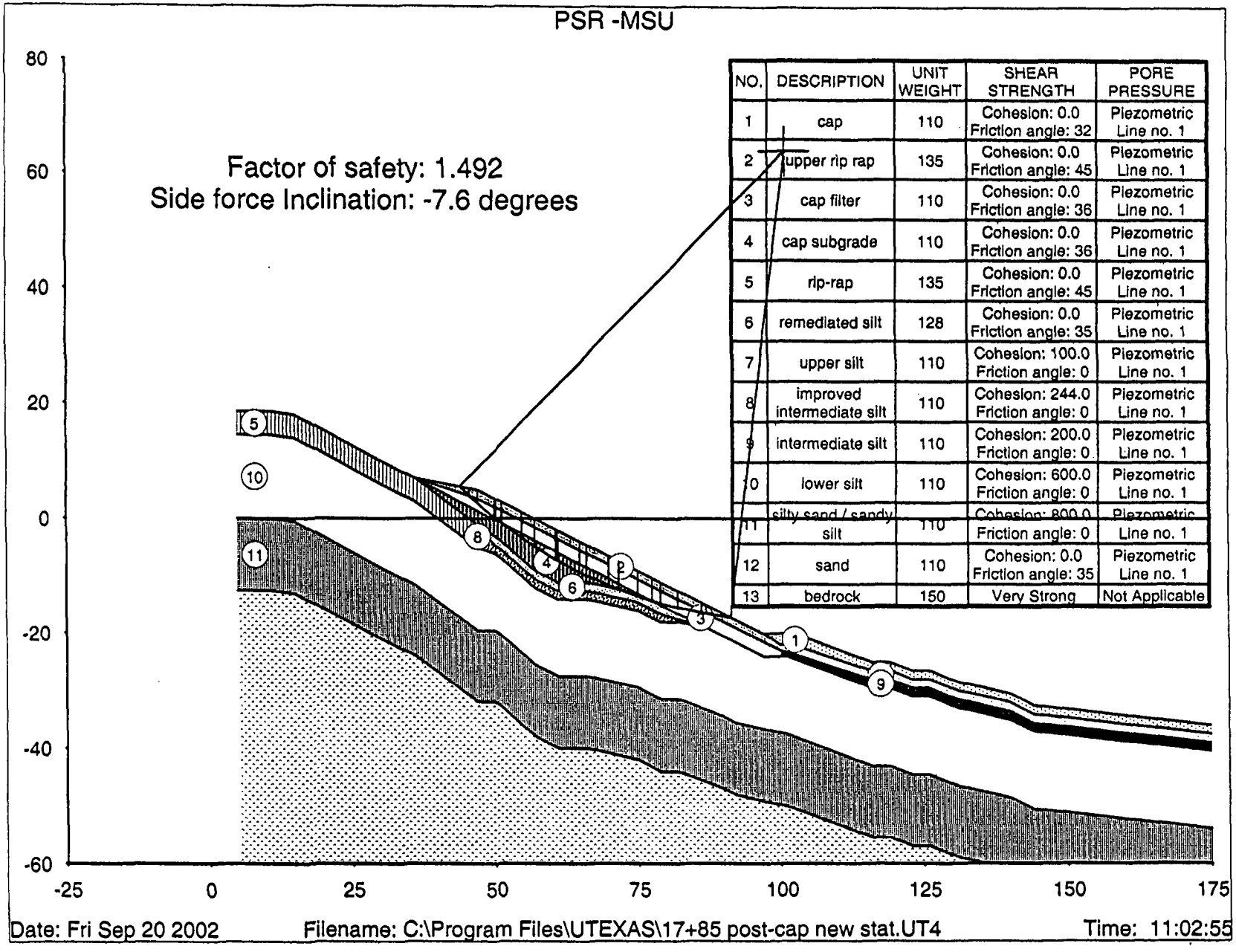


Fig 6.10

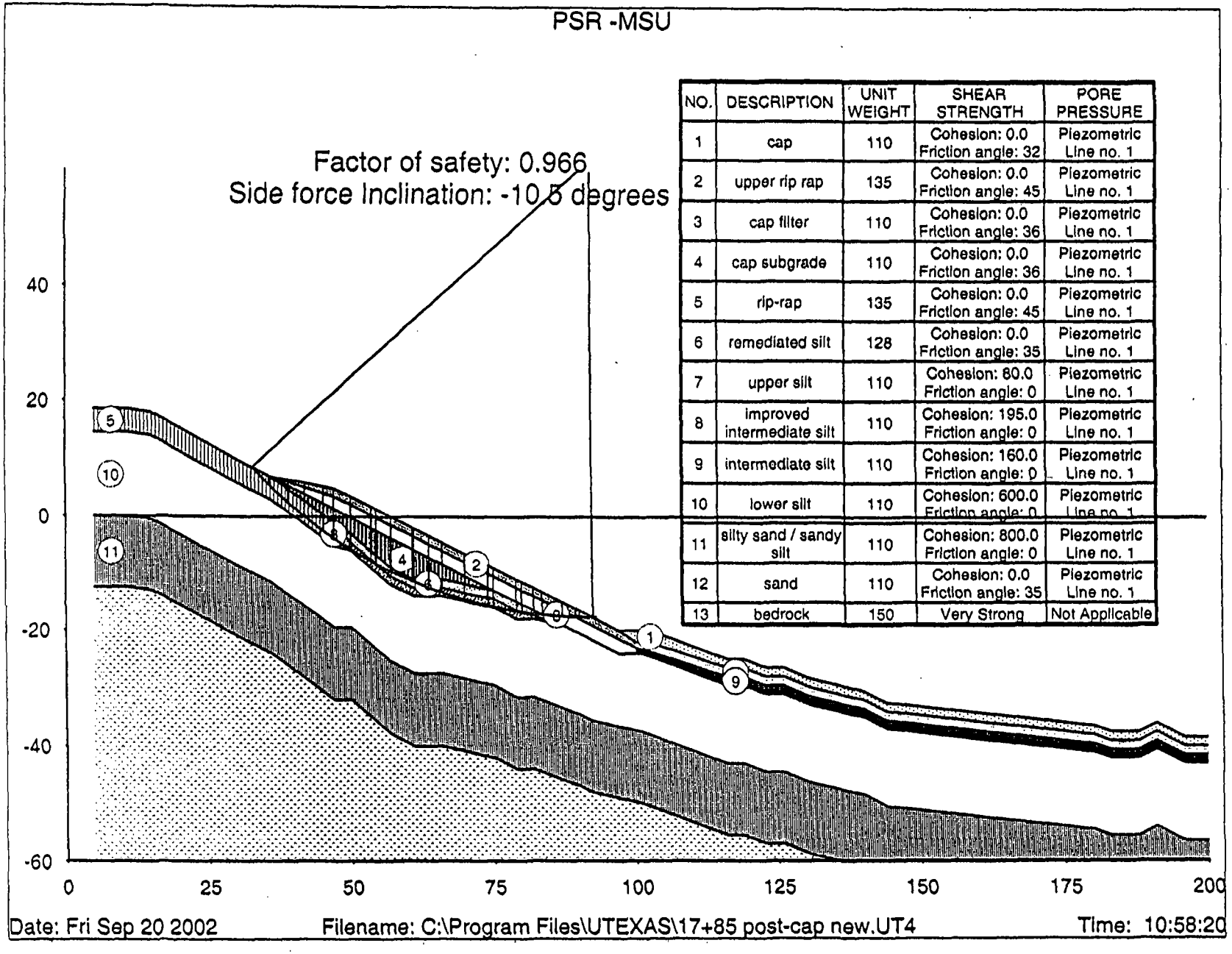


NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
3	cap filter	110	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
4	cap subgrade	110	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
5	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
6	remediated silt	128	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	upper silt	110	Cohesion: 100.0 Friction angle: 0	Piezometric Line no. 1
8	improved intermediate silt	110	Cohesion: 244.0 Friction angle: 0	Piezometric Line no. 1
9	intermediate silt	110	Cohesion: 200.0 Friction angle: 0	Piezometric Line no. 1
10	lower silt	110	Cohesion: 600.0 Friction angle: 0	Piezometric Line no. 1
11	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
12	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
13	bedrock	150	Very Strong	Not Applicable

Case : STA 17+85 No Buttress; Static

Fig G11

Section 17+85: Seismic Analysis. Both cap filter and cap subgrade modeled with $\phi' = 36°$. Remediated upper silt modeled with $\phi' = 35°$.



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	cap	110	Cohesion: 0.0 Friction angle: 32	Piezometric Line no. 1
2	upper rip rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
3	cap filter	110	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
4	cap subgrade	110	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
5	rip-rap	135	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
6	remediated silt	128	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
7	upper silt	110	Cohesion: 60.0 Friction angle: 0	Piezometric Line no. 1
8	improved intermediate silt	110	Cohesion: 195.0 Friction angle: 0	Piezometric Line no. 1
9	intermediate silt	110	Cohesion: 160.0 Friction angle: 0	Piezometric Line no. 1
10	lower silt	110	Cohesion: 600.0 Friction angle: 0	Piezometric Line no. 1
11	silty sand / sandy silt	110	Cohesion: 800.0 Friction angle: 0	Piezometric Line no. 1
12	sand	110	Cohesion: 0.0 Friction angle: 35	Piezometric Line no. 1
13	bedrock	150	Very Strong	Not Applicable

Case: STA 17+85 No Buttress, seismic w/ silt phi = 35°

Fig G12

Appendix D

APPENDIX D

CAP PLACEMENT MODELING

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D-2 Calculations of Offsite Transport in RA2a, RA2b, and RA4; and Evaluation of RA5 Offset Near RA4/RA5 Boundary

APPENDIX D

CAP PLACEMENT MODELING

D.1 RA-SPECIFIC CAP PLACEMENT MODELING

Modeling was conducted to evaluate the placement of capping material in the MSU. The purposes of this modeling are:

- Predict the mound geometries from instantaneous bottom-dump placement of capping material in representative locations of the MSU
- Assess the need for controlled methods of placement based on the instantaneous bottom-dump mound geometries
- Assess the placement approach for multiple instantaneous bottom-dump placement events in RA5 to accomplish a desired cap thickness
- Evaluate the short-term water quality impacts from release of suspended solids during placement
- Assess off-site transport of cap material during placement

Model results pertaining to the last objective (short-term water quality impacts) are discussed separately in Section 5.0.

The model used in this analysis is STFATE (Short-Term FATE of dredged material in the open water) developed by Johnson et al. in 1994 to simulate discrete discharges from barges and hoppers. In the model, the behavior of the material during disposal is assumed to be separated into three phases: convective descent, during which the disposal cloud falls under the influence of gravity and its initial momentum is imparted by gravity; dynamic collapse, occurring when the descending cloud either impacts the bottom or arrives at a level of buoyancy where descent is retarded and horizontal spreading dominates; and passive transport-dispersion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation.

In RA5, instantaneous bottom-dump placement is the anticipated method of cap construction, and so these STFATE model results directly apply to this placement technique. In RA1 through

RA4, actual placement specifications will be performance-based, potentially with prescriptive constraints. The STFATE model results are useful in these areas to define constraints on where instantaneous bottom-dump placement methods may be allowed. Attachment D-1 presents the model inputs and output results.

The STFATE model used in these analyses is known to have limitations in modeling material deposition on steep slopes or controlled placement procedures. However, the modeling is considered suitable for the objectives described above. Where the modeling indicates instantaneous bottom-dump placement is not appropriate, controlled placement methods are specified. These methods will not be modeled, but rather performance requirements will be set and the placement results will be verified in the field. It is also stressed that bottom-dump barges can be used for controlled placement of capping material, and there is a distinction between such controlled placement (using a towed, split-hull bottom-dump barge that slowly releases material) and instantaneous release, which is the method used at the Puget Sound Dredged Disposal Analysis disposal sites.

D.1.1 Model Scenarios

Placement of dredged material or upland material for capping was simulated for four different representative locations in the MSU. Five scenarios, or "runs," were developed to simulate the different physical conditions expected at the site and the associated capping materials that may be used. The runs are as follows:

- **Run 1 – RA2b.** This run assumed placement at sample location EB016, which represents the eastern shallow nearshore area. Placement was modeled for a 1,000-cubic-yard (cy) barge of typical dredged material. (Note: representative sample locations were chosen for modeling purposes. The sample locations for STFATE modeling are shown on Figure D-1.)

- **Run 2 – RA2b.** This run also assumed placement at sample location EB016. Placement was modeled for a 1,000-cy barge of an upland cap material of mostly medium sand (as defined by STFATE standard parameters). Together with Run 1, this run was designed to compare the effects of upland material to dredged material on the mound geometry in a location where either material source may meet the materials specifications.

- **Run 3 – RA2a.** This run assumed placement at sample location 203, which represents the western shallow nearshore area. Placement was modeled for a 1,000-cy barge of an upland cap material of mostly coarse sand (as defined by

STFATE standard parameters). Coarse sand was specified consistent with the requirements indicated by the erosion analysis.

- **Run 4 – RA4.** This run assumed placement at sample location B3, in the steep offshore area. Placement was modeled for a 1,000-cy barge of mostly medium sand (as defined by STFATE standard parameters).

- **Run 5 – RA5.** This run assumed placement at sample location P19, in the deep offshore area. Placement was modeled for a 1,000-cy barge of a typical dredged material.

Model runs were not attempted for RA1or RA3 because placement in these areas will likely be accomplished with mechanical equipment from shore or barge.

D.1.2 Model Input Parameters

The STFATE Model input data are grouped into the following category areas: (1) description of the cap site, (2) description of the site velocities, (3) controls for input, execution, and output, (4) description of cap materials, (5) description of the disposal operation, and (6) model coefficients.

Cap Site

The cap site description was based on the bathymetry for each area. Each run was considered individually, and an appropriate bathymetric grid was input into the model. For Runs 1 to 4, idealized bathymetry was assumed to approximate local site conditions, because a significant level of effort would be required to input the detailed bathymetric data into the model. Runs 1 to 3 assume a constant depth for the entire model grid, consistent with the relatively flat local bathymetry in RA2. For Run 4, the model assumes a steep (26 percent) and constant slope for the entire width of the grid, approximating conditions in RA4. The downgradient limits of the model grid in Run 4 extend deeper than the true bathymetry, but this artifact is well beyond the limits of significant mound height and so is not detrimental. Run 5, the deep-water run simulating RA5, is the only run to use a true bathymetric grid across its entirety.

Water Velocities

The model assumed a 0.1 ft/sec water velocity in the direction towards shore. This magnitude is based on the average velocities measured at CM-1 and CM-2, as reported in the pre-design investigation data summary (USEPA 2002). The true velocities varied in magnitude and

direction. The velocity was applied as constant throughout the water column, and always in the same direction.

Controls for Input, Execution, and Output

The model analysis was performed for descent, collapse, and transport-diffusion. Simulation for all runs was performed over the 3,600 seconds immediately following the material dump, modeled in 300-second time segments. Long term transport-diffusion results were requested at the bottom of the water body, at 5 feet above the bottom, and at the halfway point between the bottom and the water surface. For the deep water scenario (Run 5), the results were requested at the one-third and two-thirds points between top and bottom instead of the half-way point.

Description of Cap Materials, Disposal Operation, and Model Coefficients

The description of cap materials varied according to the materials types appropriate to each RA. For the dredged material, an "average" from the Snohomish and Duwamish Rivers was used. Attachment D-1 includes the calculation of the average dredge materials gradation. Water content of the dredged material was assumed approximately 55 percent by volume.

For upland materials, representative materials consisting of either a medium sand mix or a coarse sand mix were used as defined by STFATE standard parameters. The upland cap material was assumed to contain 55 percent water by volume. The upland materials specifications have not yet been developed, but for the purposes of this modeling, the assumed materials types are considered to be sufficiently similar to the materials ultimately used.

All runs simulated 1,000 cubic yards of material dumped from a split hull barge. Duration of disposal and vessel velocity for all runs was 20 seconds and 0.0 ft/sec respectively. The assumed vessel velocity was not found to significantly affect the final mound geometry.

Model coefficients used were all standard inputs used in the model. Material void ratios for silt and clay are lower than the suggested model inputs. The lower void ratios are viewed as representative of long-term conditions in the mounds.

Overview of Inputs for Each Run

The following is an explanation of the inputs to each of the model runs.

Run 1 – Sample Site EB016 – RA2b

Grid Size: 4,800 x 1,600 square feet – 32 x 32 grid with 150-foot spacing in the X-Direction (offshore), and 50-foot spacing in the Z-Direction (along shore)
Grid Depth: Constant 30.0 feet
Dump Location: Point #17 from left, Point #12 from top
Depth at Dump Location: 30.0 feet
Transport-Diffusion Results at:
15 feet below water surface
25 feet below water surface
Material Description: Typical Duwamish Dredgeate; 1 layer
Gravel – 0.39%
Medium Sand – 24.57%
Silt – 14.85%
Clay – 3.24%
Void Ratios: Long-Term
Gravel – 0.5
Medium Sand – 0.6
Silt – 2.25
Clay – 2.5

Run 2 – Sample Site EB016 – RA2b

Grid Size: 4,800 x 1,600 square feet – 32 x 32 grid with 150-foot spacing in the X-Direction (offshore), and 50-foot spacing in the Z-Direction (along shore)
Grid Depth: Constant 30.0 feet
Dump Location: Point #17 from left, Point #12 from top
Depth at Dump Location: 30.0 feet
Transport-Diffusion Results at:
15 feet below water surface
25 feet below water surface
Material Description: Medium Upland Sand mix; 1 layer
Gravel – 2.25%
Medium Sand – 27%
Fine Sand – 9%
Silt – 6.75%
Void Ratios: Long-Term
Gravel – 0.5
Medium Sand – 0.6
Silt – 2.25
Clay – 2.5

Run 3 – Sample Site 203 – RA2a

Grid Size: 3,200 x 3,200 square feet – 32 x 32 grid with 100-foot spacing
Grid Depth: Constant 43.0 feet
Dump Location: Point #17 from left, Point #17 from top – center of grid
Depth at Dump Location: 43 feet
Transport-Diffusion Results at:
20 feet below water surface
38 feet below water surface
Material Description: Coarse Upland Sand mix; 1 layer
Gravel – 2.25%
Coarse Sand – 27%
Medium Sand – 9%
Silt – 6.75%
Void Ratios: Long-Term
Gravel – 0.5
Medium Sand – 0.6
Silt – 2.25
Clay – 2.5

Run 4 – Sample Site B3 – RA4

Grid Size: 1,600 x 4,200 square feet – 32 x 42 grid with 100-foot spacing in the X-Direction (offshore), and 50-foot spacing in the Z-Direction (along shore)
Grid Depth: Range from 0 feet to 475 feet. Approximate 26% grade at dump location
Dump Location: Point #17 from left, Point #18 from top, center from left, 1,700 feet from top
Depth at Dump Location: 72 feet
Transport-Diffusion Results at:
35 feet below water surface
65 feet below water surface
Material Description: Medium Upland Sand mix; 1 layer
Gravel – 2.25%
Medium Sand – 27%
Fine Sand – 9%
Silt – 6.75%
Void Ratios: Long-Term
Gravel – 0.5
Medium Sand – 0.6
Silt – 2.25
Clay – 2.5

Run 5 – Sample Site P19 – RA5

True Grid (deep water, sloped with true bathymetric grid)
Grid Size: 1,500 x 1,000 square feet – 30 x 20 grid with 50-foot spacing
Grid Depth: Range from 37 ft to 237 ft. Approximate 9% grade from top to bottom, 5% left to right
Dump Location: Point #11 from left, Point #16 from top – center of grid
Depth at Dump Location: 171 feet
Transport-Diffusion Results at:
- 50 feet below water surface
- 100 feet below water surface
- 165 feet below water surface

Material Description: Duwamish Dredgeate; 1 layer
- Gravel – 0.39%
- Medium Sand – 24.57%
- Silt – 14.85%
- Clay – 3.24%

Void Ratios: Long-Term
- Gravel – 0.5
- Medium Sand – 0.6
- Silt – 2.25
- Clay – 2.5

D.1.3 Placement Modeling Results

Results of each of the model runs are included in Attachment D-1. Included for each model output are summary tables that present the final mound thickness (ft) across the bottom of each grid, and the transport diffusion concentrations above background (mg/L) at specified depths across each grid. The transport diffusion results are presented for each sediment type at each specified depth, and as a sum total of all the concentrations of each sediment type. A complete model output file is provided for Run 5.

Table D-1 summarizes the maximum mound thickness for each run and the amount of material settled and suspended after model completion (3,600 seconds after the dump).

Model Sensitivity and Limitations

Grid size was a limiting factor in determining whether the model would run to completion. The model stops running when the centroid of one of the sediment clouds passes out of the model grid. Therefore, the model has to be run with large grid sizes. This constraint made it difficult to

use a true bathymetric grid, as the true grid for the shallow runs would be too small near the dump points for the model to complete its simulation (because of the presence of the shoreline).

The water velocity, barge dump time and barge velocity had little effect on final mound geometry and thickness. These input parameters, when changed, would have some effect on predicted mound shape and thickness, but before the maximum thickness could change significantly, the sediment clouds would pass outside the grid, causing the model to stop running. In general, it was not possible to modify dump time and barge velocity to accurately simulate specialized placement methods in RA2 or RA4.

USACE has indicated that one controlled placement method (towed split-hull barge placement) can be approximated by inputting extremely long barge lengths (e.g., 1,000-foot long barges). This has not been attempted, as other placement methods (such as hydraulic washing from a flat-deck barge) are likely to be used in these areas.

Placement in RA2

Run 1, Run 2, and Run 3 each produced similar mound geometries for the flat, shallow conditions in RA2 (a and b). Maximum mound heights ranged from 0.6 to 1.0 foot, with mound heights substantially tapering off within less than 100 feet of the dump point. Material types (upland versus dredged materials) appeared to have a limited effect on the mound heights, as evidenced by the results of Run 1 compared to Run 2 (0.7 foot mound height for dredgeate versus 0.6 foot mound height for medium sand). Within 3,600 seconds of the placement, 98 to 99 percent of the material would be deposited on the bottom.

STFATE predicts relatively "tight" mounds associated with instantaneous bottom-dump placement in the shallow waters of RA2. Thus, it is considered impractical to place a relatively uniform cap through a series of instantaneous bottom-dump placement events. Even assuming ideal barge positioning on tightly-spaced grids, the final surface would resemble a series of discrete mounds and valleys, and a substantial amount of additional cap material would be required to ensure the minimum cap thickness is achieved everywhere (i.e., T_o would be large). Relatively small errors in barge positioning would exacerbate this effect.

Based on the discussions in Section 4.2.2, the maximum mound heights are somewhat lower that the 1-foot allowable lift height to avoid bearing capacity failures. However, this allowable lift height was calculated assuming the factor of safety (FS) is 1 for this area, based on the presumed use of controlled placement methods. A higher FS of 2 to 3 would be appropriate for instantaneous bottom-dump placement in RA2, and it is likely that bearing capacity failures would be predicted under this scenario.

In summary, the STFATE results indicate that instantaneous bottom-dump placement is not appropriate for RA2a or RA2b.

Placement in RA4

Run 4 produced a maximum mound height of 0.76 foot in RA4, with a mound geometry similar to but somewhat broader than Run 2, which also used a medium sand. The model indicates that there is 95 cubic feet suspended after 3,600 seconds, but the sediment clouds are not encountered at 30- or 65-foot depths. The cloud of suspended silt may be deeper than the dump point, which is at 72 feet. Within 3,600 seconds of the placement, 99 percent of the material would be deposited on the bottom.

Based on the discussions in Section 4.2.2, it is concluded that bearing capacity failures would be expected with bottom-dump placement in RA4. Also, based on the Run 1 and Run 2 results (which showed similar mound heights for dredged and upland materials), use of dredged material rather than upland sand in RA4 would also be expected to result in bearing capacity failures.

Placement in RA5

The mounds modeled in RA5 are much broader and flatter than the other model runs, due to the dispersion of the relatively fine-grained material and the deep bathymetry. The predicted mound geometry for a single disposal from a typical 1,000-cy barge in RA5 is shown in Attachment D-1. The resulting single mound is several hundred feet in diameter with a maximum height of only 0.29 foot. This broad, flat geometry implies that this type of placement is readily amenable to a process of building up the desired cap thickness through multiple bottom dumps on a regular grid. Further, the maximum mound height from a single dump is below the anticipated bearing capacity of the bottom sediments at the modeled depth of -175 feet MLLW, indicating that failures of the bottom sediments are not anticipated to result from bottom dump placement.

Within 3,600 seconds of the placement, 97 percent of the material would be deposited on the bottom. A broader area would be expected to receive an additional very thin deposit over time as the fine-grained material continues to settle out of the water column. While much of this material would likely settle within the desired capping area, a significant portion may be transported off site.

Multiple Bottom-Dump Placement in RA5

To simulate the multiple disposals that will be required to create the cap in RA5, the STFATE mound geometry for a single mound was assumed to be relatively constant and independent of

position within RA5. With this assumption, several mounds were superimposed on each other with additive placement of material by disposal on a regular grid. This grid was defined with 25 nodes on 200-foot spacings. (This hypothetical grid is expanded in the design to cover the entire area of RA5.) This grid disposal was simulated on an Excel spreadsheet, similar to an approach recently used by USACE at Commencement Bay (USACE 2001). The selection of 200 feet as the grid spacing is based on the overlap required to create a fairly uniform superposition of mounds. Figure D-2 depicts the mound geometry resulting from a single pass of disposal events on a 200-foot grid. This simulation shows that a relatively uniform cap lift of approximately 0.5 foot can be accomplished by disposal on a regular 200-foot grid.

To simulate the buildup of several lifts to achieve the desired cap thickness, multiple placement events were modeled additively. The modeling indicates that a series of 4.5 idealized disposal events (assuming a typical 1,000-cy barge) will be required at each target location. This translates to a minimum of 4,500 cy placed at each target location. The target locations are spaced at regular 200-foot intervals. All STFATE mound heights are based on the long-term, post-consolidation properties of the deposited cap material. Thus, the results are evaluated against the required post-consolidation minimum cap thickness of 24 inches.

Figure D-3 and Figure D-4 depict the resulting long-term mound geometry for an idealized 800-foot by 800-foot capping area. This simulation shows that a relatively uniform cap averaging 30 inches thick can be accomplished by this method. The outer nodes of the grid exhibit slightly diminished cap thicknesses because they do not experience the additive effects of mound aprons beyond the defined grid. Along the perimeter defined by the outer nodes, a minimum mound height of 23 inches was predicted. Thus, one additional 1,000 cy disposal event is specified around the RA5 cap perimeter to compensate for these edge effects.

The assumption of constant mound geometry in RA5 is required for the above analysis. In reality, each individual barge dump will create a unique mound geometry, due to such factors as actual loaded volume in each barge, the properties of the materials within each barge, varying depths and tidal elevations associated with each grid node at each point in time, and prevailing currents. With the exception of depth, these factors are unknown until the actual placement occurs, and thus *a priori* modeling requires assumptions. Nonetheless, these effects may largely cancel each other out as the mounds are superimposed upon one another from more than 100 individual bottom-dump placement events.

The deposition of dredged material (in RA5) and sand cap material (in RA4) was evaluated in the transition area along the RA4/RA5 boundary. The combined deposition in this transition area (based on STFATE model runs 4 and 5) was evaluated to determine an appropriate offset distance for the target locations in RA5. The overlapping mound geometries were summed for

three assumed offset distances (i.e., RA5 target locations offset 50-ft, 100-ft, and 150-ft from the RA4/RA5 boundary). An offset of 100-ft was found to produce an acceptable overlap geometry, with a moderate (1 ft) excess mound height in the transition area. This slight excess mound height is considered an appropriate margin of safety given the uncertainty in the model results. In particular, the RA4 placement method may result in less broad deposits than those modeled by STFATE Run 4. Based on these considerations, the target locations in RA5 are offset 100-ft from the RA4/RA5 boundary. Attachment D-2 includes the worksheet used for this calculation.

The design drawings include the dredged material placement plan for RA5 based on the above analysis.

D.1.5 Using STFATE to Estimate Operational Thickness Allowance

In RA5, STFATE modeling of instantaneous bottom-dump placement on a regular grid can be used to define T_o. The modeling indicates that the variation in cap thickness is approximately 4.3 inches for the designated placement of 3,500 cy of dredged material per grid node. Greater variations are expected on the outer nodes of the grid, and as discussed previously, additional dumps may be required around the cap perimeter. Given the inherent uncertainties of the modeling, T_o for RA5 can reasonably be estimated as three times the modeled variation in cap thickness, or 1.1 foot (13 inches).

For RA1 through RA4, controlled placement techniques will be required that cannot be adequately modeled using STFATE. Operational thicknesses for RA1 through RA4 are based on engineering judgement.

D.1.6 Cohesive Materials

The USACE has interest in exploring the potential for use of cohesive materials for capping in RA5, as some off-site dredged material could exhibit cohesive properties. To evaluate the resulting mound geometry of cohesive materials, an additional STFATE run was conducted using a hypothetical dredged material with cohesive clumps.

All run parameters were as described for Run 5 (presented in Section D.1.2), with the exception of the following material properties:

Material Description: Hypothetical cohesive dredged material; 1 layer
Medium Sand – 16%
Clumps – 8%

Silt (cohesive) – 8%
Clay (cohesive) – 8%

The resulting (long-term) mound geometry is exhibited in Attachment D-1. Compared to the results using non-cohesive dredged materials, the cohesive mound had a much greater mound height (0.49 foot versus 0.29 foot) and exhibited steeper transitions in mound height away from the dump location. It is also important to note that these effects would be more pronounced if the material were to have more than 8 percent clumps.

As discussed in Section 2 of the Basis of Design, the tighter mounds and greater mound heights are among the reasons why cohesive material should not be allowed for capping at PSR.

D.2 RA4/RA5 BOUNDARY MODELING

This section presents the engineering analyses used to define the RA4/RA5 boundary, with consideration of the material types and placement methods to be used. The primary assumption of this analysis is that instantaneous bottom-dump placement of dredged material will be used to construct the cap in RA5, while controlled-placement techniques will be used in RA4 to avoid bearing capacity failures.

Key parameters that were used to define this boundary are the load bearing strength of the existing sediments (discussed in Section 4.2.2) and the STFATE-modeled mound geometry for instantaneous bottom-dump placement. The RA4/RA5 boundary was located such that mound heights from instantaneous bottom-dump placement do not exceed the load bearing strength of the sediments.

D.2.1 Estimate of Buoyant Unit Weight of Dredged Material

A buoyant unit weight of 50 pounds per cubic feet (pcf) (long-term) is used to represent dredged materials placed in RA5. This estimate is based on the STFATE-modeled dredged material mound heights and the USACE-suggested void ratios for long-term mound configurations. The buoyant unit weight calculations are shown in Attachment D-1 for long-term and short-term conditions, respectively.

It is important to note the distinction between the calculated long-term buoyant unit weight (50 pcf) and the calculated short-term buoyant unit weight (35 pcf). This difference arises from the fact that the void ratios for the silt and clay fractions are quite high immediately after placement. These void ratios decrease substantially over several months as the mound

self-consolidates, with a corresponding decrease in mound height. This consolidation will be accelerated by placement of additional loads of dredged material over existing mounds. Because the short-term void ratios and mound heights are transient, the long-term parameters (void ratios, mound heights, and buoyant unit weights) were used to provide a consistent analysis in the calculations of both acceptable lift heights and STFATE mound heights.

D.2.2 Allowable Lift Height for RA5

The range of allowable mound heights varies significantly according to the model assumptions used in the bearing capacity analysis. The RA4/RA5 boundary is based on the criterion that the maximum mound heights (long-term) from instantaneous bottom-dump placement should not exceed 0.3 to 1.3 feet. This bearing capacity analysis is discussed in Section 4.2.2, with supporting calculations in Appendix C. The analysis is based on the long-term mound height.

In the short term, the mounds will be somewhat thicker and the buoyant unit weights somewhat lower. However, the loads to the existing sediments will be identical for a given placement event, and thus the bearing capacity analysis is unchanged.

D.2.3 Predicted Long-Term Mound Geometry versus Depth

Figure D-5 depicts the maximum mound heights predicted from STFATE modeling of instantaneous bottom-dump placement at various water depths. The mound heights increase in shallower waters as less dispersion of the deposited material occurs. As seen in Figure D-5, the modeled mound heights vary approximately linearly with depth, ranging from 0.29 foot at -171 foot MLLW to 0.7 foot at -30 feet MLLW.

D.2.4 Determination of RA4/RA5 Boundary Location

Based on the STFATE analysis, and considering the uncertainties inherent in the bearing capacity analysis, it is concluded that a target mound height at the lower end of the calculated range of allowable heights is most protective and appropriate. Also, there is a fairly distinct slope break at approximately -140 to -150 feet MLLW, above which elevations the slope increases to greater than 15 percent. The associated predicted long-term mound height at the 15 percent slope break is 0.35 foot, which is at the lower end of the calculated range of allowable heights. Therefore, it is at this depth that the RA4/RA5 boundary is established.

The RA4/RA5 boundary is drawn as a straight line for constructability purposes. The boundary is located approximately along the -140 feet MLLW contour as shown in Figure 2-1.

D.2.5 Predicted Short-Term Mound Geometries and Construction Monitoring in RA5

The long-term parameters (void ratios, mound heights, and buoyant unit weights) are used for consistency in the bearing capacity analysis, and these are the parameters that are of interest for ensuring that sufficient cap material has been placed and for long-term monitoring of cap thickness. However, the short-term mound geometries will be of interest for construction monitoring purposes. Specifically, construction monitoring, described in the construction quality assurance plan, will be used to verify the modeled results, and intensive monitoring of mound heights from individual dumps will be required for the target locations near the RA5/RA4 border. As an adaptive management approach, the USACE may require other placement methods if the monitoring results are not acceptable near the RA5/RA4 border.

Using USACE-suggested short-term void ratios and the corresponding short-term buoyant weight of 35 pcf, a short-term mound height of 0.5 foot is predicted near the RA4/RA5 boundary (versus the corresponding long-term mound height of 0.35 foot). Thus, construction monitoring immediately following placement of material near the RA4/RA5 boundary should be used to verify that the short-term mounds are not substantially thicker than 0.5 foot.

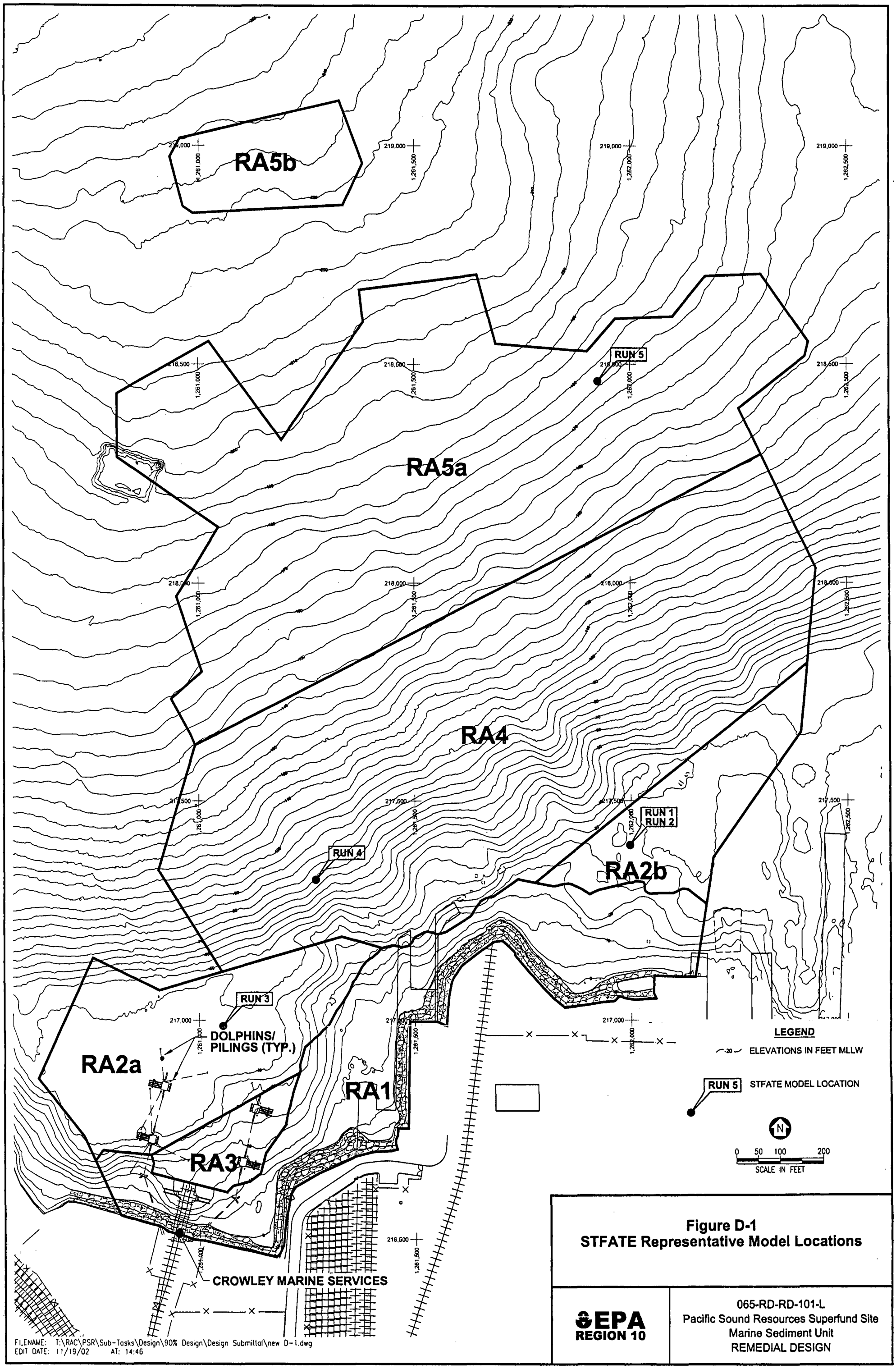


Figure D-1
STFATE Representative Model Locations

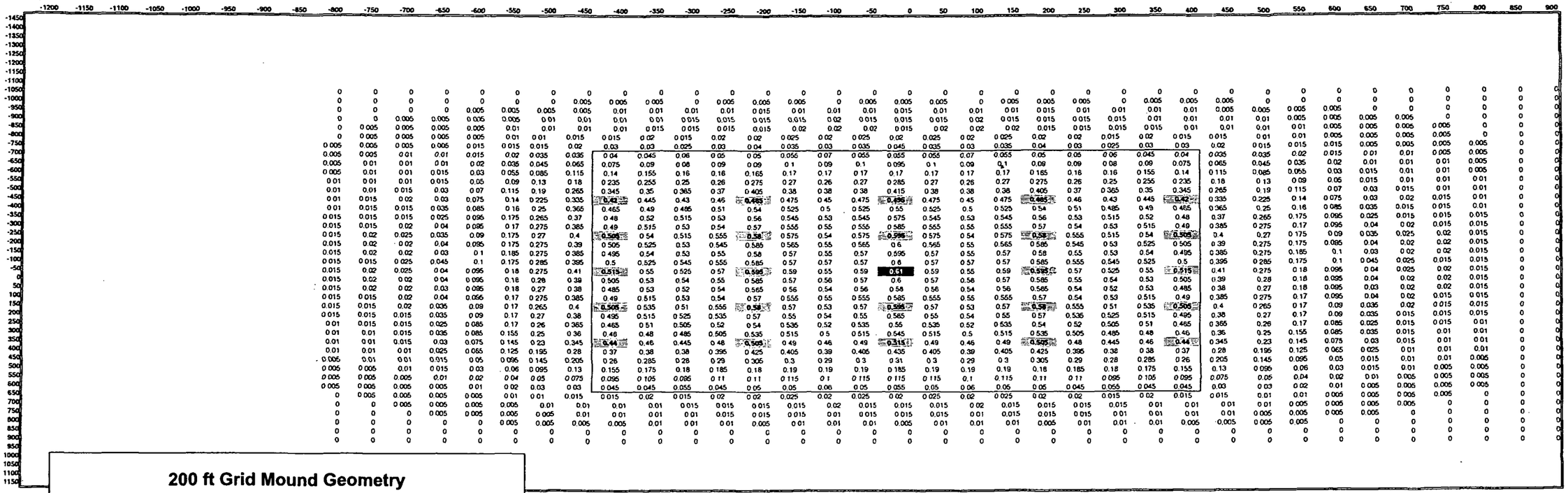
EPA REGION 10

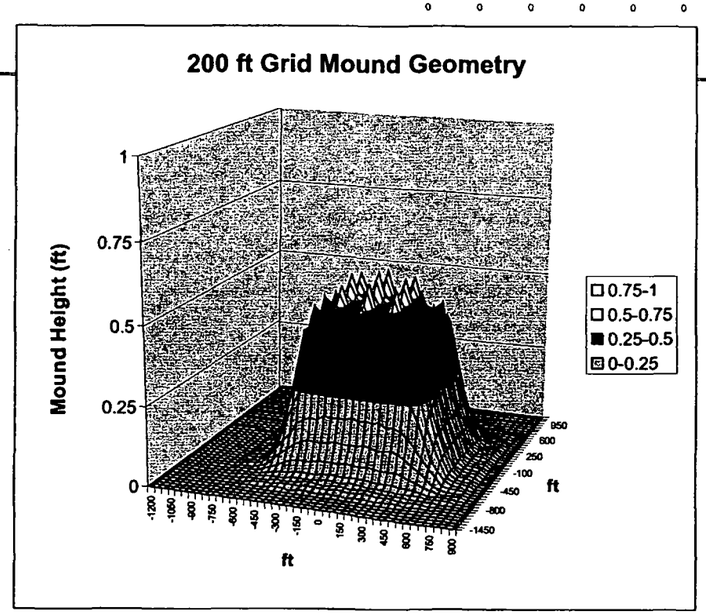
065-RD-RD-101-L
Pacific Sound Resources Superfund Site
Marine Sediment Unit
REMEDIAL DESIGN

53-F4006500.06-18

Mound Geometry for Single Pass 200-foot Grid Bottom-Dump Placement in RA 5

(Single -Pass Grid Placement)





Job No. 53-F4006500.06

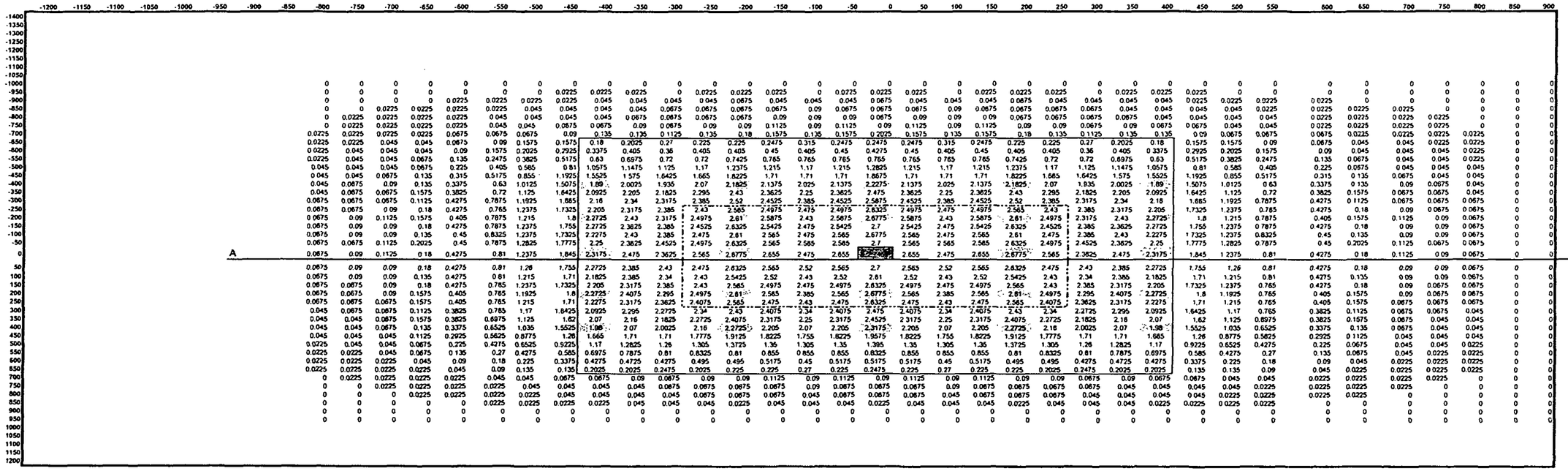
Figure D-2
Mound Geometry for Single Pass 200-foot Grid Bottom-Dump Placement in RA 5

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

33755206-1

Figure D-3
Simulated Multiple Pass 200-foot Grid Bottom-Dump Placement in RA 5



A -A' = Transect Location

2.5745 = Dump Point at 0,0

2.8775 = Multiple Dump Points on 200 ft grids

= Single Dump STFATE Domain

= Approximate area unaffected by additional grid placement

ESTIMATION OF To - OPERATIONAL THICKNESS

Max Mound Height	2.745 ft	32.94 inches	Mean =	2.54045 ft	30.4855 inches
Min Mound Height	2.385 ft	28.62 inches	To =	1.08 ft	12.96 inches
Delta	0.36 ft	4.32 inches	Mean - 0.5 To =	2.00045 ft	24.0055 inches
Minimum Mound Height on Node Perimiter			*Mean + 0.5 To =*	3.08045 ft	36.9655 inches
1.89 ft		22.68 inches	(Assume To = 3x Delta)		

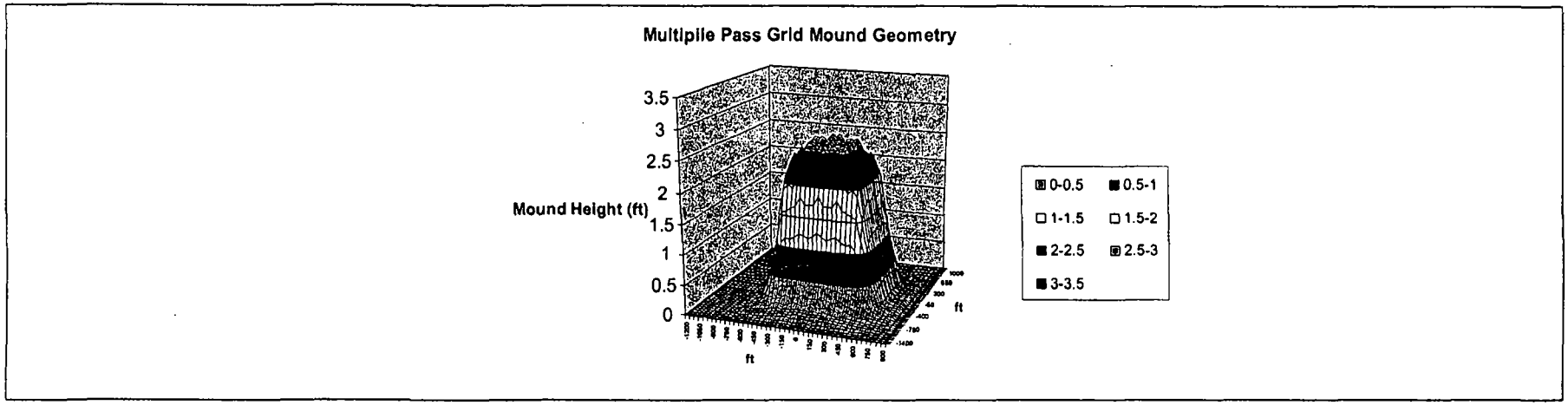
Job No. 33755206.08000

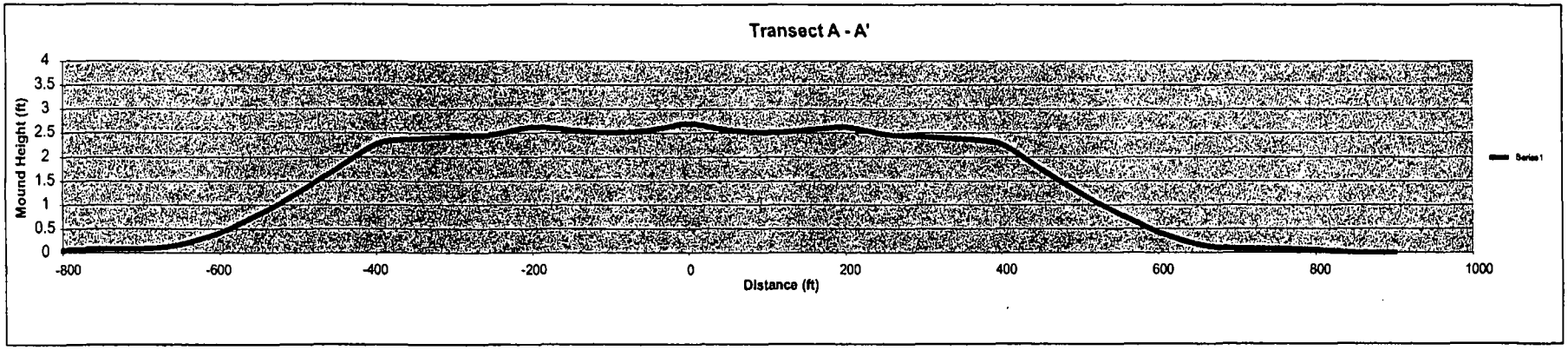
EPA REGION 10

Figure D-3
Simulated Multiple Pass 200-foot Grid Bottom-Dump Placement in RA 5

065-RD-RD-101L
PSR Superfund Site

33755206-2





Job No. 33755206.08000

Figure D-4
Multiple Pass Grid Mound Geometry in RA 5

EPA REGION 10

065-RD-RD-101L
PSR Superfund Site

Analysis of Maximum Mound Height vs. Depth

STFATE Analysis
PSR Superfund Site

Dump Location Dist from P19 (towards shore) (ft)	Water Depth (Ft MLLW)	STFATE Mound Ht (ft)	Model Run
0	171	0.29	RUN 5 - Sample Site P19
50	166	0.31	RUN 5 - New dump point
100	161	0.32	RUN 5 - New dump point
150	155	0.34	RUN 5 - New dump point
175	153	0.34	RUN 5 - New dump point
200	151	0.35	RUN 5 - New dump point
225	149	0.35	RUN 5 - New dump point
250	147	0.36	RUN 5 - New dump point
275	143.5	0.37	RUN 5 - New dump point
1060	30	0.7	(RUN 1 results)
300	140	N/C	(RUN 5 out of domain)

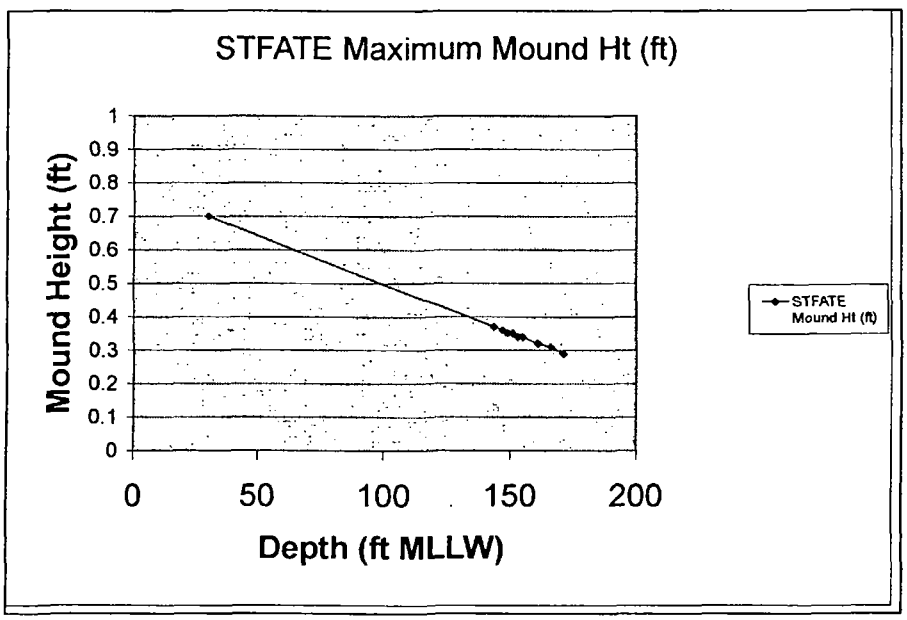


Figure D-5
Analysis of Maximum Mound Height vs. Depth

Table D-1
Maximum Mound Heights and Settled Volumes for Bottom-Dump Placement

Run No.	Maximum Mound Height (ft)	Volume Settled[1] (cu ft)	Volume Suspended[1] (cu ft)	Percent Settled after 3,600 seconds
1	0.7	11,375	249	98%
2	0.6	12,028	122	99%
3	1.0	12,021	129	99%
4	0.76	12,055	95	99%
5	0.29	10,439	358	97%

[1]Volumes settled and suspended after 3,600 seconds

ATTACHMENT D-1
CAP DEPOSITION CALCULATIONS AND USACE STFATE MODEL OUTPUT

Attachment D-1
CAP DEPOSITION CALCULATIONS AND USACE STFATE MODEL OUTPUT

Included in this attachment are:

- A summary of dredged material characteristics used in the deposition modeling
- Calculations of buoyant unit weights of deposited material, under short-term and long-term (consolidated) conditions
- A summary of materials balances for each model run
- Model outputs

Notes on STFATE Output

Included are summary Excel sheets for STFATE Run 1 through Run 5. These runs model long-term mound height using USACE-suggested long-term void ratios. These summary sheets depict the mound geometry and suspended clay, silt, and total suspended solids (TSS) for each run. A complete example output of STFATE (.DUO file) is included only for Run 5.

Also included are summary Excel sheets depicting the mound geometry for Run 5, under two alternative scenarios: Run5COHE, which models deposition of cohesive material, and RUN5MODFLUFF, which models short-term mound height using USACE-suggested short-term void ratios.

The .DUO files for all runs are available electronically on request. The .DUO files also echo all input parameters to each model run.

Notes on Running STFATE from Windows NT

Running the model consists of several steps:

1. To input the model parameters, use the "Stfate.bat" operation from the Windows Explorer window. Model inputs are recorded and saved through this function.
2. After the model parameters have been saved, STFATE can be run using the Execute STFATE command within the STFATE operation.

3. Upon completion of the command to execute, STFATE automatically shuts down. At this time, another executable file "dumpx.bat" appears in Windows Explorer. Opening this function starts the simulation.
4. After completion of the simulation, results are found through the "view results" command, or by opening the appropriate output file (with a .duo extension) in Wordpad.

However, since STFATE is designed to run from a DOS operating system, several problems were encountered while running from Windows. Printing and graphic functions within STFATE would not work properly. Graphics files could be created on the screen, but the numerical axes would not be correct, and it was not possible to print or save these files.

Pacific Sound Resources Superfund Site
STFATE Model Analysis
Typical Duwamish Dredged Material - Determine Particle Size Distribution

Station	% Gravel	%Sand	% Silt	% Clay	Solids %
S1	0.30	51.60	39.40	8.70	58.30
S2	0.00	20.80	63.70	15.50	49.90
S3	0.10	26.70	59.90	13.30	51.60
S4	0.00	28.30	58.80	12.80	53.60
S5	0.00	43.60	44.90	11.50	55.20
S6	0.00	25.90	59.60	14.50	51.10
S7	0.00	55.20	35.10	9.60	58.70
C1	0.10	34.80	52.50	12.50	47.70
C2	2.70	93.90	2.20	1.30	72.70
C3	3.40	83.00	10.30	3.40	70.60
C1*	1.00	50.00	43.00	6.00	
C2*	2.00	57.00	37.00	4.00	
C3*	2.00	81.00	15.00	2.00	
C4*	1.00	85.00	14.00	0.00	
C5*	3.00	68.00	26.00	3.00	
C6*	0.00	71.00	23.00	6.00	
C7*	1.00	56.00	35.00	8.00	
C8*	1.00	51.00	38.00	10.00	
C9*	1.00	42.00	45.00	12.00	
C10*	1.00	84.00	13.00	2.00	
C11*	1.00	88.00	9.00	2.00	
C12*	0.00	80.00	18.00	2.00	
Ave Vol.:	**0.94**	**58.04**	**33.75**	**7.28**	**56.94**
Adj. Vol.	**0.40319818**	**24.990458**	**14.530793**	**3.1335936**	

Sample data from USACE Seattle Branch Memo CENWS-OD-TS-DM (Dec 20, 1998) except *
* Sample data from Science Applications International Corp "Partial and Full Characterizations of Lower Shohomish River Cahnnel Sediments" (March 19, 1993)

Calculation of Buoyant Unit Weight of Deposited Sediments

Based on STFATE Parameters from Run 5fluff, RA5
Short-term Conditions

Basis: 1 square foot of deposited material

Parameter	Gravel	Medium Sand	Silt	Clay	Total	Comments
Void Ratio (VR)	0.5	0.6	6	9		STFATE Input parameters - Short-term conditions, Parameters suggested in STFATE documentation
Specific Gravity	2.7	2.7	2.65	2.65		STFATE Input parameters
Max Mound Height (ft)	0.0093	0.15	0.23	0.02	0.409	STFATE Output
Sediment Volume (ft^3)					0.409	Mound height times 1ft^2 basis
Percent Solid =1/(1+VR)	0.667	0.625	0.143	0.100		
Solid Volume (ft^3)	0.0062	0.09375	0.032857	0.002	0.135	Volume of solid particles in 1ft^2 of mound
Percent Solids = solid vol/sediment vol					**0.329**	
Porosity n = 1-percent solids					0.671	
Unit Weight of saturated sediment (lbs/ft^3)					98	Sum of mass of water and solids in one ft^ of deposited material
Buoyant Unit Weight (lbs/ft^3)					**34.5**	Unit weight minus weight of displaced water

Ratio of Short-term mound height to Long-term mound height: 1.520
Short-term mounds will be approximately 52 percent higher

Calculation of Buoyant Unit Weight of Deposited Sediments

Based on STFATE Parameters from Run 5mod, RA5
Long-term Conditions

Basis: 1 square foot of deposited material

Parameter	Gravel	Medium Sand	Silt	Clay	Total	Comments
Void Ratio (VR)	0.5	0.6	2.25	2.5		STFATE Input parameters - Long-term conditions, Parameters suggested by P.Schroeder, USACE
Specific Gravity	2.7	2.7	2.65	2.65		STFATE Input parameters
Max Mound Height (ft)	0.0093	0.15	0.11	0.000028	0.269	STFATE Output
Sediment Volume (ft^3)					0.269	Mound height times 1ft^2 basis
Percent Solid =1/(1+VR)	0.667	0.625	0.308	0.286		
Solid Volume (ft^3)	0.0062	0.09375	0.033846	0.000008	0.134	Volume of solid particles in 1ft^2 of mound
Percent Solids = solid vol/sediment vol					**0.497**	
Porosity n = 1-percent solids					0.503	
Unit Weight of saturated sediment (lbs/ft^3)					116	Sum of mass of water and solids in one ft^ of deposited material
Buoyant Unit Weight (lbs/ft^3)					**52.1**	Unit weight minus weight of displaced water

Pacific Sound Resources Superfund Site
STFATE Model Analysis

SEDIMENT VOLUME SUMMARIES

Run 1 MOD	Bottom Sed (cu. ft.)	Sus. Sed. (cu.ft.)
Gravel	105.3	0
Sand	6633.9	0
Clay	768.77	106.1
Silt	3866.7	142.7
Total	11374.67	248.8

Run 2 MOD	Bottom Sed (cu. ft.)	Sus. Sed. (cu.ft.)
Gravel	607.5	0
M. Sand	7290	0
F. Sand	2430	0
Silt	1700.2	122.25
Total	12027.7	122.25

Run 3 MOD	Bottom Sed (cu. ft.)	Sus. Sed. (cu.ft.)
Gravel	1215	0
C. Sand	7290	0
M. Sand	2430	0
Silt	1086.2	128.82
Total	12021.2	128.82

Run 4 MOD	Bottom Sed (cu. ft.)	Sus. Sed. (cu.ft.)
Gravel	607.5	0
C. Sand	7290	0
M. Sand	2430	0
Silt	1727.7	94.823
Total	12055.2	94.823

Run 5 MOD	Bottom Sed (cu. ft.)	Sus. Sed. (cu.ft.)
Gravel	105.3	0
Sand	6632.9	0
Clay	1.1524	52.837
Silt	3700	305.35
Total	10439.3524	358.187

Model Outputs

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 1 - SAMPLE SITE EB016 - SHALLOW EAST

Sample Site: EB016 (Shallow East)
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 150 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
4	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
5	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
6	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
7	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
8	OOOO	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	OOOO
9	OOOO	0	0	0	0	0	0	0	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	0	0	0	0	0	0	OOOO
10	OOOO	0	0	0	0	0	0	.	.	.	.	+	+	+	+	+	+	+	+	+	.	.	.	.	0	0	0	0	0	OOOO
11	OOOO	0	0	0	0	0	0	.	.	.	+	+	0.02	0.12	0.37	0.7	0.37	0.12	0.02	+	+	.	.	.	0	0	0	0	0	OOOO
12	OOOO	0	0	0	0	0	0	0	.	.	+	+	0.02	0.13	0.38	0.59	0.38	0.13	0.02	+	+	.	.	0	0	0	0	0	0	OOOO
13	OOOO	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	OOOO
14	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
15	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
16	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
17	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
18	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
19	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
31	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 1 - SAMPLE SITE EB016 - SHALLOW EAST

Sample Site: EB016 (Shallow East)
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 150 ft Z dir = 50 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF CLAY 15 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
4	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
5	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
6	0000	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	0000
7	0000	0	0	0	0	0	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	0	0	0	0	0	0	0000
8	0000	0	0	0	0	.	.	+	+	+	+	0.01	0.03	0.05	0.07	0.08	0.07	0.05	0.03	0.01	+	+	+	0	0	0	0	0	0	0000
9	0000	0	0	0	0	.	+	+	+	+	0.02	0.07	0.14	0.23	0.32	0.35	0.32	0.23	0.14	0.07	0.02	+	+	0	0	0	0	0	0	0000
10	0000	0	0	0	0	.	.	+	+	+	0.01	0.04	0.09	0.16	0.21	0.23	0.21	0.16	0.09	0.04	0.01	+	+	0	0	0	0	0	0	0000
11	0000	0	0	0	0	.	.	.	+	+	+	+	0.01	0.01	0.02	0.02	0.02	0.01	0.01	+	+	+	+	0	0	0	0	0	0	0000
12	0000	0	0	0	0	0	0	0	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	0	0	0	0	0	0	0000
13	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
14	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
15	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
16	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
17	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
18	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
19	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
20	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
26	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
27	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
28	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
29	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
30	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
31	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 1 - SAMPLE SITE EB016 - SHALLOW EAST

Sample Site: EB016 (Shallow East)
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 150 ft Z dir = 50 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF SEDIMENT 25 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
4	OOOO	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	OOOO
5	OOOO	0	0	0	0	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	0	0	0	0	0	OOOO
6	OOOO	0	0	0	0	+	+	+	+	0.02	0.05	0.08	0.12	0.17	0.2	0.21	0.2	0.17	0.12	0.08	0.05	0.02	+	0	0	0	0	0	0	OOOO
7	OOOO	0	0	0	0	0.01	0.05	0.13	0.33	0.72	1.44	2.5	4.2	6	7.4	8.1	7.4	6	4.2	2.5	1.44	0.72	0.33	0	0	0	0	0	0	OOOO
8	OOOO	0	0	0	0	0.15	0.47	1.3	3.3	7.8	17.4	36	65	102	134	148	134	102	65	36	17.4	7.8	3.3	0	0	0	0	0	0	OOOO
9	OOOO	0	0	0	0	0.52	1.56	4.2	11.3	29	67	143	271	439	590	654	590	439	271	143	67	29	11.3	0	0	0	0	0	0	OOOO
10	OOOO	0	0	0	0	0.63	1.83	4.9	12.1	29	63	125	225	350	461	506	461	350	225	125	63	29	12.1	0	0	0	0	0	0	OOOO
11	OOOO	0	0	0	0	0.3	0.82	2.05	4.8	10.3	20.5	35	56	79	97	105	97	79	56	35	20.5	10.3	4.8	0	0	0	0	0	0	OOOO
12	OOOO	0	0	0	0	0.05	0.15	0.37	0.85	1.71	3	5	7.4	9.9	11.7	12.5	11.7	9.9	7.4	5	3	1.71	0.85	0	0	0	0	0	0	OOOO
13	OOOO	0	0	0	0	+	+	0.01	0.03	0.07	0.13	0.2	0.3	0.39	0.46	0.49	0.46	0.39	0.3	0.2	0.13	0.07	0.03	0	0	0	0	0	0	OOOO
14	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
15	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
16	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
17	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
18	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
19	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
31	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 2 - SAMPLE SITE EB016 - SHALLOW EAST

Sample Site: EB016 (Shallow East)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 150 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
4	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
5	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
6	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
7	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
8	0000	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0000
9	0000	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0000
10	0000	0	0	0	0	0	0	0	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	0	0	0	0	0	0	0000
11	0000	0	0	0	0	0	0	0	.	.	+	+	0.01	0.1	0.3	0.6	0.3	0.1	0.01	+	+	.	.	0	0	0	0	0	0	0000
12	0000	0	0	0	0	0	0	0	0	.	+	+	0.02	0.11	0.34	0.54	0.34	0.11	0.02	+	+	.	0	0	0	0	0	0	0	0000
13	0000	0	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	0	0000
14	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
15	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
16	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
17	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
18	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
19	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
20	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
26	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
27	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
28	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
29	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
30	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
31	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 2 - SAMPLE SITE EB016 - SHALLOW EAST

Sample Site: EB016 (Shallow East)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 150 ft Z dir = 50 ft

CONCENTRATION ABOVE BACKGROUND (MG/L) OF SILT AT 25 FT BELOW THE WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
4	OOOO	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0		OOOO
5	OOOO	0	0	0	0	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	0	0	0	0	0		OOOO
6	OOOO	0	0	0	0	+	+	+	+	0.01	0.02	0.04	0.07	0.09	0.11	0.12	0.11	0.09	0.07	0.04	0.02	0.01	+	0	0	0	0	0	0		OOOO
7	OOOO	0	0	0	0	0.01	0.03	0.07	0.18	0.39	0.77	1.3	2.1	3	3.7	4	3.7	3	2.1	1.3	0.77	0.39	0.18	0	0	0	0	0	0		OOOO
8	OOOO	0	0	0	0	0.09	0.26	0.7	1.7	4	8.5	16	27	41	51	56	51	41	27	16	8.5	4	1.7	0	0	0	0	0	0		OOOO
9	OOOO	0	0	0	0	0.29	0.85	2.3	5.8	14	30	58	101	153	197	214	197	153	101	58	30	14	5.8	0	0	0	0	0	0		OOOO
10	OOOO	0	0	0	0	0.35	1	2.6	6.3	14	30	55	93	136	172	187	172	136	93	55	30	14	6.3	0	0	0	0	0	0		OOOO
11	OOOO	0	0	0	0	0.17	0.46	1.1	2.6	5.4	10	18	27	38	46	49	46	38	27	18	10	5.4	2.6	0	0	0	0	0	0		OOOO
12	OOOO	0	0	0	0	0.03	0.09	0.22	0.48	0.95	1.7	2.7	4	5.3	6.2	6.6	6.2	5.3	4	2.7	1.7	0.95	0.48	0	0	0	0	0	0		OOOO
13	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
14	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
15	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
16	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
17	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
18	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
19	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
30	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		OOOO
31	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 3 - SAMPLE SITE 201 - SHALLOW WEST

Sample Site: 203 (Shallow West)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 100 ft Z dir = 100 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
4	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
5	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
6	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
7	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
8	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
9	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
10	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
11	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
12	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	0	OOOO
13	OOOO	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	OOOO
14	OOOO	0	0	0	0	0	0	0	0	0	0	0	.	.	.	+	.	.	.	0	0	0	0	0	0	0	0	0	0	OOOO
15	OOOO	0	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	0	OOOO
16	OOOO	0	0	0	0	0	0	0	0	0	0	.	.	+	0.06	0.3	0.06	+	.	.	0	0	0	0	0	0	0	0	0	OOOO
17	OOOO	0	0	0	0	0	0	0	0	0	0	0	.	+	0.19	1	0.19	+	.	0	0	0	0	0	0	0	0	0	0	OOOO
18	OOOO	0	0	0	0	0	0	0	0	0	0	0	.	+	0.02	0.12	0.02	+	.	0	0	0	0	0	0	0	0	0	0	OOOO
19	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	.	+	+	+	.	0	0	0	0	0	0	0	0	0	0	0	OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	.	.	.	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
31	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 3 - SAMPLE SITE 201 - SHALLOW WEST

Sample Site: 203 (Shallow West)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 100 ft Z dir = 100 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF SILT 20 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
4	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
5	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
6	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
7	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
8	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	0	OOOO
9	OOOO	0	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	0	OOOO
10	OOOO	0	0	0	0	0	0	0	0	0	.	.	+	0.01	0.04	0.06	0.04	0.01	+	.	0	0	0	0	0	0	0	0	0	OOOO
11	OOOO	0	0	0	0	0	0	0	0	0	.	+	0.01	0.16	0.7	1.1	0.7	0.16	0.01	+	0	0	0	0	0	0	0	0	0	OOOO
12	OOOO	0	0	0	0	0	0	0	0	0	.	+	0.09	1	5	8.6	5	1	0.09	+	0	0	0	0	0	0	0	0	0	OOOO
13	OOOO	0	0	0	0	0	0	0	0	.	+	+	0.22	2.7	14	24	14	2.7	0.22	+	0	0	0	0	0	0	0	0	0	OOOO
14	OOOO	0	0	0	0	0	0	0	0	.	+	+	0.21	2.5	12	22	12	2.5	0.21	+	0	0	0	0	0	0	0	0	0	OOOO
15	OOOO	0	0	0	0	0	0	0	0	0	.	+	0.07	0.84	3.9	6.6	3.9	0.84	0.07	+	0	0	0	0	0	0	0	0	0	OOOO
16	OOOO	0	0	0	0	0	0	0	0	0	.	+	0.01	0.11	0.47	0.78	0.47	0.11	0.01	+	0	0	0	0	0	0	0	0	0	OOOO
17	OOOO	0	0	0	0	0	0	0	0	0	0	.	+	+	0.02	0.04	0.02	+	+	.	0	0	0	0	0	0	0	0	0	OOOO
18	OOOO	0	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	0	OOOO
19	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	0	OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
31	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 3 - SAMPLE SITE 201 - SHALLOW WEST

Sample Site: 203 (Shallow West)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 100 ft Z dir = 100 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF SILT 38 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
4	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
5	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
6	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
7	0000	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0000
8	0000	0	0	0	0	0	0	0	.	.	+	+	+	0.01	0.03	0.03	0.03	0.01	+	+	0	0	0	0	0	0	0	0	0	0000
9	0000	0	0	0	0	0	0	0	.	+	+	0.01	0.06	0.18	0.35	0.44	0.35	0.18	0.06	0.01	0	0	0	0	0	0	0	0	0	0000
10	0000	0	0	0	0	0	0	0	+	+	0.02	0.12	0.49	1.4	2.8	3.6	2.8	1.4	0.49	0.12	0	0	0	0	0	0	0	0	0	0000
11	0000	0	0	0	0	0	0	0	+	0.01	0.09	0.57	2.4	7.8	16	21	16	7.8	2.4	0.57	0	0	0	0	0	0	0	0	0	0000
12	0000	0	0	0	0	0	0	0	+	0.03	0.31	1.8	6.4	27	60	79	60	27	8.4	1.8	0	0	0	0	0	0	0	0	0	0000
13	0000	0	0	0	0	0	0	0	+	0.08	0.69	4	18	60	130	171	130	60	18	4	0	0	0	0	0	0	0	0	0	0000
14	0000	0	0	0	0	0	0	0	0.01	0.13	1	5.9	26	80	167	217	167	80	26	5.9	0	0	0	0	0	0	0	0	0	0000
15	0000	0	0	0	0	0	0	0	0.01	0.14	1	6	24	70	138	175	138	70	24	6	0	0	0	0	0	0	0	0	0	0000
16	0000	0	0	0	0	0	0	0	0.01	0.1	0.8	4.2	16	44	82	101	82	44	16	4.2	0	0	0	0	0	0	0	0	0	0000
17	0000	0	0	0	0	0	0	0	+	0.05	0.42	2.1	8	21	37	44	37	21	8	2.1	0	0	0	0	0	0	0	0	0	0000
18	0000	0	0	0	0	0	0	0	+	0.02	0.15	0.79	2.8	7.1	12	15	12	7.1	2.8	0.79	0	0	0	0	0	0	0	0	0	0000
19	0000	0	0	0	0	0	0	0	+	+	0.04	0.2	0.73	1.8	3.1	3.7	3.1	1.8	0.73	0.2	0	0	0	0	0	0	0	0	0	0000
20	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
26	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
27	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
28	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
29	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
30	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
31	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 4 - SAMPLE SITE B3 - STEEP SECTION

Sample Site: B3 (Steep Section)
Medium Sand Mix 1,000 cy dump
Gridpiont Spacing: X dir = 100 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
4	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
5	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
6	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
7	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
8	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
9	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
10	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
11	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
12	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
13	0000	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	0000
14	0000	0	0	0	0	0	0	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	0	0	0	0	0	0000
15	0000	0	0	0	0	0	0	0	0	.	.	.	+	+	+	+	+	+	+	.	.	.	0	0	0	0	0	0	0	0000
16	0000	0	0	0	0	0	0	0	.	.	+	+	+	0.01	0.03	0.03	0.03	0.01	+	+	+	.	.	0	0	0	0	0	0	0000
17	0000	0	0	0	0	0	0	0	.	.	+	+	0.03	0.14	0.33	0.45	0.33	0.14	0.03	+	+	.	.	0	0	0	0	0	0	0000
18	0000	0	0	0	0	0	0	0	.	.	+	+	0.05	0.22	0.53	0.76	0.53	0.22	0.05	+	+	.	.	0	0	0	0	0	0	0000
19	0000	0	0	0	0	0	0	0	0	.	+	+	0.01	0.03	0.09	0.12	0.09	0.03	0.01	+	+	.	0	0	0	0	0	0	0	0000
20	0000	0	0	0	0	0	0	0	0	0	.	.	+	+	+	+	+	+	+	.	.	0	0	0	0	0	0	0	0	0000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	0	0	0	0	0	0	0000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
26	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
27	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
28	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
29	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
30	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
31	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
32	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
33	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
34	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
35	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
36	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
37	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
38	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
39	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
40	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
41	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 5 - SAMPLE SITE P19 - DEEP WATER

Sample Site: P19
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 50 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 . 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	OOOO	
4	OOOO	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	OOOO	
5	OOOO	.	.	.	.	+	+	+	+	+	+	+	+	+	.	.	.	.	OOOO	
6	OOOO	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	OOOO	
7	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO	
8	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO	
9	OOOO	+	+	+	+	+	+	+	0.01	0.01	0.01	+	+	+	+	+	+	+	OOOO	
10	OOOO	+	+	+	+	+	0.01	0.02	0.02	0.02	0.02	0.02	0.01	+	+	+	+	+	OOOO	
11	OOOO	+	+	+	+	0.01	0.02	0.03	0.05	0.05	0.05	0.03	0.02	0.01	+	+	+	+	OOOO	
12	OOOO	+	+	+	0.01	0.02	0.04	0.07	0.09	0.1	0.09	0.07	0.04	0.02	0.01	+	+	+	OOOO	
13	OOOO	+	+	+	0.01	0.03	0.07	0.11	0.15	0.17	0.15	0.11	0.07	0.03	0.01	+	+	+	OOOO	
14	OOOO	+	+	+	0.02	0.05	0.09	0.15	0.21	0.25	0.21	0.15	0.09	0.05	0.02	+	+	+	OOOO	
15	OOOO	+	+	0.01	0.02	0.05	0.1	0.17	0.25	0.29	0.25	0.17	0.1	0.05	0.02	0.01	+	+	OOOO	
16	OOOO	+	+	+	0.02	0.05	0.1	0.16	0.23	0.27	0.23	0.16	0.1	0.05	0.02	+	+	+	OOOO	
17	OOOO	+	+	+	0.01	0.04	0.08	0.13	0.18	0.2	0.18	0.13	0.08	0.04	0.01	+	+	+	OOOO	
18	OOOO	+	+	+	0.01	0.02	0.05	0.08	0.11	0.12	0.11	0.08	0.05	0.02	0.01	+	+	+	OOOO	
19	OOOO	+	+	+	+	0.01	0.03	0.04	0.06	0.07	0.06	0.04	0.03	0.01	+	+	+	+	OOOO	
20	OOOO	+	+	+	+	+	0.01	0.02	0.02	0.03	0.02	0.02	0.01	+	+	+	+	+	OOOO	
21	OOOO	.	+	+	+	+	+	+	0.01	0.01	0.01	+	+	+	+	+	+	.	OOOO	
22	OOOO	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	OOOO	
23	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO	
24	OOOO	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	OOOO	
25	OOOO	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	OOOO	
26	OOOO	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	OOOO	
27	OOOO	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	0	OOOO	
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO	
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO	
30	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 5 - SAMPLE SITE P19 - DEEP WATER

Sample Site: P19
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 50 ft Z dir = 50 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF SEDIMENT 100 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N=2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0	0	0	0	0	0	0	0	0	0	0	2.14	1.32	0.71	0.33	0.13	0.04	0000
4	0000	0	0	0	0	0	0	0	0	0	0	6.43	4.49	2.75	1.43	0.7	0.28	0.1	0000
5	0000	0	0	0	0	0	0	0	0	16.32	15.3	12.24	8.37	5.1	2.65	1.22	0.52	0.18	0000
6	0000	0	0	0	0	0	0	0	24.47	25.51	24.47	19.38	13.27	8.17	4.29	1.94	0.82	0.19	0000
7	0000	0	0	0	0	0	19.38	27.53	33.65	36.7	33.65	27.53	19.38	11.23	6.02	2.75	1.12	0.4	0000
8	0000	0	0	3.37	7.25	14.28	23.45	33.64	41.79	44.85	41.79	33.64	23.45	14.28	7.25	3.37	1.32	0.49	0000
9	0000	0.51	1.43	3.47	7.65	14.29	24.48	34.67	43.83	47.89	43.83	34.67	24.48	14.29	7.65	3.47	1.43	0.51	0000
10	0000	0.47	1.22	3.16	6.94	13.27	22.43	31.61	39.76	42.81	39.76	31.61	22.43	13.27	6.94	3.16	1.22	0.47	0000
11	0000	0.36	1.02	2.55	5.51	10.21	17.34	24.49	31.6	33.65	31.6	24.49	17.34	10.21	5.51	2.55	1.02	0.36	0000
12	0000	0.25	0.72	1.73	3.78	7.15	12.24	17.34	21.42	22.45	21.42	17.34	12.24	7.15	3.78	1.73	0.72	0.25	0000
13	0000	0.15	0.43	1.02	2.24	4.29	7.04	10.2	12.25	13.27	12.25	10.2	7.04	4.29	2.24	1.02	0.43	0.15	0000
14	0000	0.08	0.22	0.57	1.12	2.24	3.67	5.2	6.43	6.84	6.43	5.2	3.67	2.24	1.12	0.57	0.22	0.08	0000
15	0000	0.03	0.1	0.25	0.55	1.02	1.63	2.35	2.86	3.06	2.86	2.35	1.63	1.02	0.55	0.25	0.1	0.03	0000
16	0000	0.01	0.04	0.1	0.22	0.4	0.66	0.95	1.12	1.22	1.12	0.95	0.66	0.4	0.22	0.1	0.04	0.01	0000
17	0000	+	0.01	0.03	0.07	0.14	0.23	0.32	0.39	0.42	0.39	0.32	0.23	0.14	0.07	0.03	0.01	+	0000
18	0000	+	+	0.01	0.02	0.04	0.07	0.09	0.12	0.13	0.12	0.09	0.07	0.04	0.02	0.01	+	+	0000
19	0000	+	+	+	+	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.01	0.01	+	+	+	+	0000
20	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
26	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
27	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
28	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
29	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000
30	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

Pacific Sound Resources Superfund Site
STFATE Model Analysis
RUN 5 - SAMPLE SITE P19 - DEEP WATER

Sample Site: P19
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 50 ft Z dir = 50 ft

CONCENTRATIONS ABOVE BACKGROUND (MG/L) OF SEDIMENT 50 FT BELOW WATER SURFACE, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	0	0	0	0.06	0.18	0.41	0.74	1	1.1	1	0.74	0.41	0.18	0.06	0.01	+	+	OOOO
4	OOOO	+	0.01	0.06	0.22	0.63	1.41	2.51	3.62	4.12	3.62	2.51	1.41	0.63	0.22	0.06	0.01	+	OOOO
5	OOOO	+	0.03	0.17	0.61	1.71	4.02	7.25	10.07	12.07	10.07	7.25	4.02	1.71	0.61	0.17	0.03	+	OOOO
6	OOOO	0.01	0.08	0.37	1.31	3.82	8.86	16.1	23.14	26.16	23.14	16.1	8.86	3.82	1.31	0.37	0.08	0.01	OOOO
7	OOOO	0.02	0.14	0.64	2.31	6.74	16.1	28.17	41.25	46.27	41.25	28.17	16.1	6.74	2.31	0.64	0.14	0.02	OOOO
8	OOOO	0.03	0.19	0.88	3.12	9.26	21.13	39.24	56.33	64.37	56.33	39.24	21.13	9.26	3.12	0.88	0.19	0.03	OOOO
9	OOOO	0.03	0.21	0.95	3.42	10.08	23.14	43.26	61.36	69.4	61.36	43.26	23.14	10.06	3.42	0.95	0.21	0.03	OOOO
10	OOOO	0.03	0.18	0.82	2.92	8.65	20.12	36.22	52.31	59.35	52.31	36.22	20.12	8.65	2.92	0.82	0.18	0.03	OOOO
11	OOOO	0.02	0.12	0.55	2.01	5.84	13.08	24.15	35.21	39.24	35.21	24.15	13.08	5.84	2.01	0.55	0.12	0.02	OOOO
12	OOOO	0.01	0.06	0.3	1	3.12	7.14	13.08	18.12	21.13	18.12	13.08	7.14	3.12	1	0.3	0.06	0.01	OOOO
13	OOOO	+	0.03	0.13	0.46	1.31	2.92	5.43	7.75	8.65	7.75	5.43	2.92	1.31	0.46	0.13	0.03	+	OOOO
14	OOOO	+	0.01	0.04	0.15	0.44	1	1.81	2.51	2.82	2.51	1.81	1	0.44	0.15	0.04	0.01	+	OOOO
15	OOOO	+	+	0.01	0.04	0.12	0.27	0.48	0.68	0.77	0.68	0.48	0.27	0.12	0.04	0.01	+	+	OOOO
16	OOOO	+	+	+	+	0.02	0.05	0.1	0.14	0.16	0.14	0.1	0.05	0.02	+	+	+	+	OOOO
17	OOOO	.	+	+	+	+	0.01	0.01	0.02	0.02	0.02	0.01	0.01	+	+	+	+	.	OOOO
18	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO
19	OOOO	0	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	0	OOOO
20	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
21	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
22	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
23	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
24	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
25	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
26	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Pacific Sound Re[illegible]ces Superfund Site
STFATE Model Analysis - COHESIVE MATERIAL
RUN 5 - SAMPLE SITE P19 - DEEP WATER

Sample Site: P19
Cohesive Sediment 1,000 cy dump
Gridpiont Spacing: X dir = 50 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	OOOO
4	OOOO	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	OOOO
5	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO
6	OOOO	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	OOOO
7	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO
8	OOOO	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	OOOO
9	OOOO	+	+	+	+	+	+	+	0.01	0.01	0.01	+	+	+	+	+	+	+	OOOO
10	OOOO	+	+	+	+	+	0.01	0.01	0.02	0.02	0.02	0.01	0.01	+	+	+	+	+	OOOO
11	OOOO	+	+	+	+	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.01	+	+	+	+	OOOO
12	OOOO	+	+	+	0.01	0.02	0.04	0.06	0.08	0.08	0.08	0.06	0.04	0.02	0.01	+	+	+	OOOO
13	OOOO	+	+	+	0.01	0.03	0.06	0.09	0.12	0.14	0.12	0.09	0.06	0.03	0.01	+	+	+	OOOO
14	OOOO	+	+	+	0.02	0.04	0.07	0.13	0.2	0.25	0.2	0.13	0.07	0.04	0.02	+	+	+	OOOO
15	OOOO	+	+	+	0.02	0.04	0.09	0.16	0.31	0.41	0.31	0.16	0.09	0.04	0.02	+	+	+	OOOO
16	OOOO	+	+	+	0.02	0.04	0.08	0.17	0.36	0.49	0.36	0.17	0.08	0.04	0.02	+	+	+	OOOO
17	OOOO	+	+	+	0.01	0.03	0.06	0.13	0.24	0.32	0.24	0.13	0.06	0.03	0.01	+	+	+	OOOO
18	OOOO	+	+	+	0.01	0.02	0.04	0.07	0.11	0.13	0.11	0.07	0.04	0.02	0.01	+	+	+	OOOO
19	OOOO	+	+	+	+	0.01	0.02	0.03	0.05	0.05	0.05	0.03	0.02	0.01	+	+	+	+	OOOO
20	OOOO	+	+	+	+	+	0.01	0.01	0.02	0.02	0.02	0.01	0.01	+	+	+	+	+	OOOO
21	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO
22	OOOO	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	OOOO
23	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO
24	OOOO	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	OOOO
25	OOOO	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	OOOO
26	OOOO	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	OOOO
27	OOOO	0	0	0	0	0	0	0	.	.	.	0	0	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Short-term Mound Height in RA5

***This run assumes short-term void ratios of unconsolidated materials
Sample Site: P19
Typical Duwamish Dredgeate 1,000 cy dump
Gridpiont Spacing: X dir = 50 ft Z dir = 50 ft

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP
MULTIPLY DISPLAYED VALUES BY 1.000
LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
3	OOOO	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	OOOO
4	OOOO	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	OOOO
5	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO
6	OOOO	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	OOOO
7	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO
8	OOOO	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	OOOO
9	OOOO	+	+	+	+	+	0.01	0.01	0.01	0.02	0.01	0.01	0.01	+	+	+	+	+	OOOO
10	OOOO	+	+	+	+	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.01	+	+	+	+	OOOO
11	OOOO	+	+	+	0.01	0.02	0.04	0.06	0.08	0.09	0.08	0.06	0.04	0.02	0.01	+	+	+	OOOO
12	OOOO	+	+	+	0.02	0.04	0.07	0.11	0.15	0.17	0.15	0.11	0.07	0.04	0.02	+	+	+	OOOO
13	OOOO	+	+	0.01	0.03	0.06	0.11	0.18	0.25	0.28	0.25	0.18	0.11	0.06	0.03	0.01	+	+	OOOO
14	OOOO	+	+	0.01	0.03	0.08	0.15	0.24	0.35	0.42	0.35	0.24	0.15	0.08	0.03	0.01	+	+	OOOO
15	OOOO	+	+	0.01	0.04	0.09	0.17	0.28	0.41	0.49	0.41	0.28	0.17	0.09	0.04	0.01	+	+	OOOO
16	OOOO	+	+	0.01	0.04	0.09	0.16	0.27	0.38	0.44	0.38	0.27	0.16	0.09	0.04	0.01	+	+	OOOO
17	OOOO	+	+	0.01	0.03	0.07	0.13	0.21	0.29	0.33	0.29	0.21	0.13	0.07	0.03	0.01	+	+	OOOO
18	OOOO	+	+	+	0.02	0.04	0.09	0.14	0.19	0.21	0.19	0.14	0.09	0.04	0.02	+	+	+	OOOO
19	OOOO	+	+	+	0.01	0.02	0.05	0.08	0.1	0.11	0.1	0.08	0.05	0.02	0.01	+	+	+	OOOO
20	OOOO	+	+	+	+	0.01	0.02	0.03	0.04	0.05	0.04	0.03	0.02	0.01	+	+	+	+	OOOO
21	OOOO	.	+	+	+	+	+	0.01	0.01	0.02	0.01	0.01	+	+	+	+	+	.	OOOO
22	OOOO	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	OOOO
23	OOOO	.	.	.	+	+	+	+	+	+	+	+	+	+	+	.	.	.	OOOO
24	OOOO	.	.	.	.	+	+	+	+	+	+	+	+	+	.	.	.	.	OOOO
25	OOOO	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	OOOO
26	OOOO	0	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	0	OOOO
27	OOOO	0	0	0	0	0	.	.	.	.	.	.	.	0	0	0	0	0	OOOO
28	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
29	OOOO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OOOO
30	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Run 5 - PSR Sample Site P19 - Duwamish Dredgeate, MODIFIED

fl
MODEL: SHORT-TERM FATE OF DREDGED MATERIAL FROM SPLIT HULL BARGE OR HOPPER DREDGE
(PC Version 5.01 MAY, 1993)

TITLE: Run 5 - PSR Sample Site P19 - Duwamish Dredgeate, MODIFIED

FILE: RUN5MOD .DUE

AREA: THE PROJECT AREA IS DESCRIBED BY A 21 X 31 GRID.

THERE ARE 21 GRID POINTS (NMAX) IN THE Z-DIRECTION (FROM LEFT TO RIGHT)
AND 31 GRID POINTS (MMAX) IN THE X-DIRECTION (FROM TOP TO BOTTOM).

EXECUTION PARAMETERS:

MODEL COEFFICIENTS SPECIFIED IN INPUT DATA (KEY1 = 1).

PERFORM COMPLETE ANALYSIS INCLUDING DESCENT, COLLAPSE, AND TRANSPORT-DIFFUSION (KEY2 = 0).

NO CONTAMINANT OR TRACER TRANSPORT-DIFFUSION COMPUTIONS DESIRED (KEY3 = 0).

PRINTING OF CONVECTIVE DESCENT RESULTS REQUESTED (IPCN = 1).

PRINTING OF CONVECTIVE DESCENT RESULTS REQUESTED (IPCN = 1).

PRINTING OF DYNAMIC COLLAPSE RESULTS REQUESTED (IPCL = 1).

QUARTERLY PRINTING OF LONG-TERM TRANSPORT DIFFUSION RESULTS REQUESTED (IPLT = 0).

LONG-TERM TRANSPORT DIFFUSION RESULTS REQUESTED AT THE FOLLOWING 3 DEPTH(S):
50.00 FT
100.00 FT
165.00 FT

GRID: NUMBER OF LONG TERM GRID POINTS IN Z-DIRECTION (NMAX) = 21

NUMBER OF LONG TERM GRID POINTS IN X-DIRECTION (MMAX) = 31

GRID SPACING IN Z-DIRECTION (DZ) = 50.00000 FT

GRID SPACING IN X-DIRECTION (DX) = 50.00000 FT

DEPTH GRID, FEET:

M N = 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	37.	35.	36.	37.	45.	51.	54.	58.	60.	70.	86.	89.	87.	94.	99.	101.	107.
2	40.	42.	42.	47.	54.	63.	68.	72.	76.	82.	88.	98.	100.	102.	106.	109.	113.
3	45.	52.	57.	60.	65.	72.	77.	82.	88.	92.	99.	106.	110.	111.	116.	118.	120.
4	49.	60.	69.	72.	77.	83.	87.	90.	96.	104.	110.	113.	116.	122.	123.	128.	130.
5	63.	70.	80.	84.	86.	92.	95.	98.	104.	112.	118.	120.	124.	129.	131.	132.	138.
6	76.	84.	90.	92.	94.	99.	103.	106.	111.	119.	125.	127.	130.	132.	136.	139.	142.
7	88.	96.	99.	102.	104.	106.	112.	116.	120.	126.	132.	134.	134.	137.	140.	147.	149.
8	98.	103.	106.	110.	113.	116.	120.	123.	128.	133.	138.	142.	142.	143.	151.	153.	157.
9	104.	110.	113.	116.	120.	123.	126.	129.	134.	140.	144.	148.	150.	150.	156.	160.	164.
10	113.	117.	119.	122.	125.	129.	132.	135.	141.	147.	150.	154.	157.	157.	161.	167.	169.
11	121.	125.	126.	128.	131.	134.	139.	142.	147.	151.	155.	158.	162.	164.	166.	171.	175.
12	128.	132.	135.	135.	137.	140.	143.	148.	150.	155.	159.	162.	166.	169.	172.	175.	180.
13	135.	138.	140.	142.	142.	144.	149.	154.	157.	161.	165.	168.	171.	174.	177.	181.	185.
14	140.	143.	146.	149.	150.	151.	154.	158.	161.	166.	170.	173.	176.	180.	183.	185.	187.
15	144.	148.	151.	154.	155.	157.	159.	162.	166.	171.	175.	178.	181.	185.	187.	189.	190.
16	148.	152.	155.	158.	161.	162.	165.	167.	172.	176.	180.	183.	186.	189.	191.	193.	194.
17	151.	155.	159.	162.	164.	167.	170.	173.	176.	180.	183.	187.	190.	193.	195.	198.	199.
18	154.	158.	162.	165.	168.	170.	173.	177.	180.	184.	188.	191.	193.	195.	198.	201.	201.
19	158.	161.	165.	169.	172.	174.	176.	180.	183.	187.	191.	195.	197.	199.	201.	203.	205.
20	161.	165.	169.	172.	176.	178.	180.	183.	186.	190.	195.	199.	201.	204.	205.	205.	207.
21	163.	168.	171.	175.	178.	181.	184.	188.	190.	194.	198.	204.	207.	208.	208.	209.	210.
22	164.	169.	173.	177.	180.	183.	186.	189.	193.	197.	202.	206.	209.	211.	211.	213.	213.
23	164.	169.	174.	179.	182.	185.	187.	191.	194.	198.	203.	208.	211.	213.	215.	216.	217.
24	165.	170.	174.	180.	184.	186.	188.	190.	195.	199.	204.	209.	213.	216.	217.	219.	221.
25	166.	170.	175.	180.	184.	186.	190.	193.	197.	201.	204.	209.	214.	217.	220.	221.	223.
26	167.	170.	176.	181.	184.	187.	191.	195.	197.	201.	205.	209.	214.	217.	220.	221.	223.
27	168.	172.	177.	181.	185.	189.	192.	195.	198.	201.	205.	209.	213.	217.	220.	222.	225.
28	168.	173.	177.	183.	185.	189.	193.	197.	199.	202.	205.	208.	212.	217.	220.	223.	226.
29	167.	173.	178.	184.	187.	190.	193.	197.	199.	202.	205.	207.	211.	216.	221.	223.	226.
30	168.	172.	178.	184.	187.	190.	193.	197.	200.								

202.	204.	206.	209.	215.	221.	225.	226.		
31	167.	172.	177.	184.	187.	190.	193.	197.	200.
202.	203.	205.	209.	216.	221.	223.	228.		

M N =	18	19	20	21
1	115.	120.	123.	127.
2	122.	128.	131.	135.
3	128.	135.	139.	141.
4	135.	141.	143.	146.
5	143.	146.	148.	149.
6	146.	149.	152.	155.
7	152.	155.	156.	158.
8	157.	158.	161.	163.
9	164.	164.	156.	166.
10	171.	170.	170.	174.
11	176.	178.	179.	181.
12	181.	183.	186.	185.
13	185.	185.	187.	189.
14	187.	190.	192.	194.
15	192.	193.	194.	196.
16	193.	194.	196.	198.
17	197.	197.	198.	202.
18	201.	200.	201.	204.
19	205.	206.	208.	211.
20	208.	209.	210.	212.
21	211.	212.	213.	216.
22	214.	216.	217.	219.
23	219.	219.	221.	223.
24	223.	223.	224.	225.
25	224.	225.	227.	227.
26	225.	227.	229.	230.
27	227.	228.	231.	233.
28	228.	229.	232.	235.
29	229.	231.	233.	235.
30	229.	231.	233.	236.
31	231.	233.	235.	237.

CODED GRID:

RANGE OF N IS 1 TO 21

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X X X X X X X X X X X X X X X X X X X X X
X O O O O O O O O O O O O O O O O O O O X
X O W W W W W W W W W W W W W W W W W O X
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X O W W W W W W W W W W W W W W W W W O X
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X O W W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W W O X
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X O W W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W W O X
X O W W W W W W W W D W W W W W W W W O X
X O W W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W W O X
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X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O W W W W W W W W W W W W W W W W O X
X O O O O O O O O O O O O O O O O O O X
X X X X X X X X X X X X X X X X X X X
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LEGEND FOR CODED GRID:
W = WATER POINT
L = LAND POINT
O = OPEN BOUNDARY
B = DISPOSAL SITE BOUNDARY
D = DUMP LOCATION
X = DUMMY POINT

NUMBER OF GRID POINTS WITHIN ESTUARY = 459

DISPOSAL LOCATION:

THE DUMP LOCATION IS 750.0 FT (XBARGE) OR ABOUT GRID POINT #16 FROM THE TOP OF THE GRID
AND 500.0 FT (ZBARGE) OR ABOUT GRID POINT #11 FROM THE LEFT EDGE OF THE GRID.

THE BOTTOM SLOPE IN THE X-DIRECTION AT THE DUMP SITE (SLOPEX, POSITIVE IF DEPTH INCREASES
FROM TOP OF GRID TO BOTTOM OF GRID) IS 5.00 DEGREES.

THE BOTTOM SLOPE IN THE Z-DIRECTION AT THE DUMP SITE (SLOPEZ, POSITIVE IF DEPTH INCREASES
FROM LEFT SIDE OF GRID TO RIGHT SIDE OF GRID) IS 3.00 DEGREES.

THE DISPOSAL LOCATION IS NOT AT A HOLE OR DEPRESSION. (DHOLE = 0.0)

AMBIENT DENSITY PROFILE:

DEPTH (FT)	DENSITY (G/CC)
0.0000E+00	1.0223
235.0	1.0231

COMPUTED DEPTH:

THE DEPTH AT THE DUMP LOCATION WAS INTERPOLATED TO BE 171.0 FT.

SINGLE VELOCITY PLANE WITH DEPTH AVERAGED VALUES READ IN
- NO LOGARITHMIC VARIATION

VELOCITY GRID: X-DIRECTION, FPS

M N=	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17				
1	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
2	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
3	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
4	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
5	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
6	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
7	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
8	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
9	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
10	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
11	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
12	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
13	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
14	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
15	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
16	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
17	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
18	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
19	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
20	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
21	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
22	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
23	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
24	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
25	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
26	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
27	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100				
28	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100

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0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100
 29  -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -
0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100
 30  -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -
0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100
 31  -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -
0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100 -0.100
```

M N=	18	19	20	21
1	-0.100	-0.100	-0.100	-0.100
2	-0.100	-0.100	-0.100	-0.100
3	-0.100	-0.100	-0.100	-0.100
4	-0.100	-0.100	-0.100	-0.100
5	-0.100	-0.100	-0.100	-0.100
6	-0.100	-0.100	-0.100	-0.100
7	-0.100	-0.100	-0.100	-0.100
8	-0.100	-0.100	-0.100	-0.100
9	-0.100	-0.100	-0.100	-0.100
10	-0.100	-0.100	-0.100	-0.100
11	-0.100	-0.100	-0.100	-0.100
12	-0.100	-0.100	-0.100	-0.100
13	-0.100	-0.100	-0.100	-0.100
14	-0.100	-0.100	-0.100	-0.100
15	-0.100	-0.100	-0.100	-0.100
16	-0.100	-0.100	-0.100	-0.100
17	-0.100	-0.100	-0.100	-0.100
18	-0.100	-0.100	-0.100	-0.100
19	-0.100	-0.100	-0.100	-0.100
20	-0.100	-0.100	-0.100	-0.100
21	-0.100	-0.100	-0.100	-0.100
22	-0.100	-0.100	-0.100	-0.100
23	-0.100	-0.100	-0.100	-0.100
24	-0.100	-0.100	-0.100	-0.100
25	-0.100	-0.100	-0.100	-0.100
26	-0.100	-0.100	-0.100	-0.100
27	-0.100	-0.100	-0.100	-0.100
28	-0.100	-0.100	-0.100	-0.100
29	-0.100	-0.100	-0.100	-0.100
30	-0.100	-0.100	-0.100	-0.100
31	-0.100	-0.100	-0.100	-0.100

VELOCITY GRID: Z-DIRECTION, FPS

M N=	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17				
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

M	N= 18	19	20	21
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000

13	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000

BOTTOM SHEAR STRESS, LBS/SQ FT:

M N=	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17				
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 20 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 21 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 22 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 23 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 24 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 25 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 26 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 27 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 28 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 29 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 30 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 31 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

M	N= 18	19	20	21
1	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	0.0000	0.0000
24	0.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	0.0000	0.0000
26	0.0000	0.0000	0.0000	0.0000
27	0.0000	0.0000	0.0000	0.0000
28	0.0000	0.0000	0.0000	0.0000
29	0.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	0.0000	0.0000
31	0.0000	0.0000	0.0000	0.0000

TIME PARAMETERS:

DURATION OF THE DISPOSAL, TREL = 20.00 SECONDS

DURATION OF THE SIMULATION, TSTOP = 3600.00 SECONDS

LONG-TERM TIME STEP USED IN THE SIMULATION, DTL = 300.00 SECONDS

BARGE DESCRIPTION:

LENGTH OF BARGE, BARGL = 0.20E+03 FT

WIDTH OF BARGE, BARGW = 50. FT

DRAFT OF LOADED BARGE, DREL1 = 17.0 FT

DRAFT OF UNLOADED BARGE, DREL2 = 5.00 FT

MODEL COEFFICIENTS READ FROM INPUT:

TURBULENT THERMAL ENTRAINMENT	ALPHA0 =	0.2350
SETTLING COEFFICIENT	BETA =	0.0000
APPARENT MASS COEFFICIENT	CM =	1.0000
DRAG COEFFICIENT FOR A SPHERE	CD =	0.5000
RATIO--CLOUD/AMBIENT DENSITY GRADIENTS	GAMA =	0.2500
FORM DRAG FOR COLLAPSING CLOUD	CDRAG =	1.0000
SKIN FRICTION FOR COLLAPSING CLOUD	CFRIC =	0.0100
DRAG FOR AN ELLIPSOIDAL WEDGE	CD3 =	0.1000
DRAG FOR A PLATE	CD4 =	1.0000
ENTRAINMENT IN COLLAPSE	ALPHAC =	0.1000
FRICTION BETWEEN CLOUD AND BOTTOM	FRICTN =	0.0100
4/3 LAW HORIZ. DIFF. DISSIPATION FACTOR	ALAMDA =	0.0010
UNSTRATIFIED WATER VERT. DIFF. COEF.	AKY0 =	0.0250
STRIPPING COEF. OF FINES DURING CONVERTIVE DESCENT=		0.0030

MATERIAL DESCRIPTION: 4 SOLIDS FRACTIONS

L A Y E R 1

DESCRIPTION	SPEC. GRAV. OR DENSITY (GM/CC)	VOLUMETRIC CONCENTRATION (VOL/VOL)	FALL VELOCITY (FPS)	DEPOSITIONAL VOID RATIO	CHARACTER

GRAVEL 2.700 0.3900E-02 1.00000 0.5000
NONCOHESIVE
CRITICAL SHEAR STRESS FOR DEPOSITION = 99.00
LBS/SQ. FT.
SEDIMENT FRACTION WILL NOT BE STRIPPED DURING CONVECTIVE
DESCENT.

SAND 2.700 0.2457 0.10000 0.6000
NONCOHESIVE
CRITICAL SHEAR STRESS FOR DEPOSITION = 0.2500E-01
LBS/SQ. FT.
SEDIMENT FRACTION WILL BE STRIPPED DURING CONVECTIVE
DESCENT.

SILT 2.650 0.1485 0.01000 2.250
COHESIVE
CRITICAL SHEAR STRESS FOR DEPOSITION = 0.9000E-02
LBS/SQ. FT.
SEDIMENT FRACTION WILL BE STRIPPED DURING CONVECTIVE
DESCENT.

CLAY 2.650 0.2000E-02 0.00200 2.500
COHESIVE
CRITICAL SHEAR STRESS FOR DEPOSITION = 0.2000E-02
LBS/SQ. FT.
SEDIMENT FRACTION WILL BE STRIPPED DURING CONVECTIVE
DESCENT.

DESCRIPTION	SPEC. GRAV. OR DENSITY (GM/CC)	VOLUMETRIC CONCENTRATION (VOL/VOL)
FLUID	0.9987	0.5999

DISCHARGE PARAMETERS:

VOLUME OF LAYER 1 = 1000. CU YD

INITIAL RADIUS OF CLOUD, RB = 23.44779 FT

INITIAL DEPTH OF CLOUD CENTROID, DREL = 24.65 FT

INITIAL CLOUD VELOCITIES...

X-DIRECTION (FROM TOP TO BOTTOM OF GRID), CU(1) = 0.0000E+00
FPS

Y-DIRECTION (FROM SURFACE TO BOTTOM), CV(1) = 0.1138 FPS

Z-DIRECTION (FROM LEFT TO RIGHT OF GRID), CW(1) = 0.0000E+00
FPS

BULK PARAMETERS:

BULK DENSITY, ROO = 1.671841 G/CC

AGGREGATE OR BULK VOIDS RATIO, BVOID = 1.221

CONVECTIVE DESCENT PHASE:

IN TRIAL #1 THE DESCENT PHASE TIME STEP (DT) WAS 0.12114137E-01 SECONDS.

THE TOTAL NUMBER OF INTEGRATION TIME STEPS (ISTEP) WAS 828.

THE BOTTOM WAS ENCOUNTERED DURING CONVECTIVE DESCENT.

THE DISCHARGE DID NOT OBTAIN A NEUTRALLY BUOYANT CONDITION DURING CONVECTIVE DESCENT.

IN TRIAL #2 THE DESCENT PHASE TIME STEP (DT) WAS 0.25076265E-01 SECONDS.

THE TOTAL NUMBER OF INTEGRATION TIME STEPS (ISTEP) WAS 401.

THE BOTTOM WAS ENCOUNTERED DURING CONVECTIVE DESCENT.

THE DISCHARGE DID NOT OBTAIN A NEUTRALLY BUOYANT CONDITION DURING CONVECTIVE DESCENT.

IN TRIAL #3 THE DESCENT PHASE TIME STEP (DT) WAS 0.25138956E-01 SECONDS.

THE TOTAL NUMBER OF INTEGRATION TIME STEPS (ISTEP) WAS 400.

THE BOTTOM WAS ENCOUNTERED DURING CONVECTIVE DESCENT.

THE DISCHARGE DID NOT OBTAIN A NEUTRALLY BUOYANT CONDITION DURING CONVECTIVE DESCENT.

CONVECTIVE DESCENT RESULTS:

TIME FROM DISPOSAL (SEC)	PLUME CENTROID (DISTANCE FROM BARGE) X-DIR (FT)	Z-DIR (FT)	PLUME VELOCITY X-DIR (FPS)	DOWN (FPS)	Z-DIR (FPS)	DIFFERENCE OF PLUME & WATER DENSITIES (G/CC)	VOLUME OF PLUME RADIUS (FT)	SOLIDS VOL. TRACER CONC. (MG/L)	SOLID DEPTH FRACTIONS (CU FT)	CONC. BY Z-DIR FRACTION (VOL/VOL)
20.00	0.00	24.65	0.00	0.00	0.114	0.00	0.6495E+00	23.45	0.1740E+00	0.1053E+03	0.3900E-02
							0.6634E+04		0.2457E+00	
							0.4010E+04		0.1485E+00	
							0.5400E+02		0.2000E-02	
20.15	0.00	24.79	0.00	0.00	1.994	0.00	0.6468E+00			

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23.48  0.1733E+00  0.1053E+03  0.3884E-02

0.6634E+04  0.2447E+00

0.4009E+04  0.1479E+00

0.5400E+02  0.1992E-02
   20.30    0.00   25.21    0.00   0.00  3.835   0.00   0.6387E+00
23.58  0.1711E+00  0.1053E+03  0.3836E-02

0.6632E+04  0.2416E+00

0.4009E+04  0.1460E+00

0.5399E+02  0.1967E-02
   20.45    0.00   25.90    0.00   0.00  5.599   0.00   0.6256E+00
23.74  0.1677E+00  0.1053E+03  0.3758E-02

0.6631E+04  0.2367E+00

0.4008E+04  0.1430E+00

0.5397E+02  0.1926E-02
   20.60    0.00   26.85    0.00   0.00  7.255   0.00   0.6081E+00
23.96  0.1631E+00  0.1053E+03  0.3655E-02

0.6628E+04  0.2301E+00

0.4006E+04  0.1391E+00

0.5396E+02  0.1873E-02
   20.75    0.00   28.04    0.00  -0.01  8.778   0.00   0.5872E+00
24.24  0.1575E+00  0.1053E+03  0.3530E-02

0.6625E+04  0.2221E+00

0.4004E+04  0.1343E+00

0.5393E+02  0.1808E-02
   20.90    0.00   29.45    0.00  -0.01 10.150   0.00   0.5635E+00
24.57  0.1513E+00  0.1053E+03  0.3390E-02

0.6622E+04  0.2132E+00

0.4002E+04  0.1289E+00

0.5390E+02  0.1735E-02
   21.06    0.00   31.06    0.00  -0.01 11.362   0.00   0.5381E+00
24.94  0.1446E+00  0.1053E+03  0.3239E-02

0.6618E+04  0.2036E+00

0.4000E+04  0.1231E+00

0.5387E+02  0.1657E-02
   21.21   -0.01   32.84    0.00  -0.02 12.411   0.00   0.5118E+00
25.36  0.1376E+00  0.1053E+03  0.3083E-02

0.6614E+04  0.1936E+00

0.3997E+04  0.1170E+00
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0.5384E+02  0.1576E-02
   21.36   -0.01   34.77    0.00  -0.02 13.301   0.00   0.4851E+00
25.81  0.1305E+00  0.1053E+03  0.2924E-02

0.6609E+04  0.1835E+00

0.3995E+04  0.1109E+00

0.5380E+02  0.1494E-02
   21.51   -0.01   36.83    0.00  -0.02 14.041   0.00   0.4587E+00
26.29  0.1235E+00  0.1053E+03  0.2767E-02

0.6605E+04  0.1735E+00

0.3992E+04  0.1049E+00

0.5376E+02  0.1413E-02
   21.66   -0.02   38.98    0.00  -0.03 14.642   0.00   0.4330E+00
26.79  0.1167E+00  0.1053E+03  0.2614E-02

0.6600E+04  0.1638E+00

0.3989E+04  0.9902E-01

0.5372E+02  0.1334E-02
   21.81   -0.02   41.22    0.00  -0.03 15.118   0.00   0.4083E+00
27.32  0.1101E+00  0.1053E+03  0.2467E-02

0.6595E+04  0.1545E+00

0.3986E+04  0.9337E-01

0.5368E+02  0.1257E-02
   21.96   -0.03   43.53    0.00  -0.04 15.484   0.00   0.3848E+00
27.85  0.1039E+00  0.1053E+03  0.2326E-02

0.6590E+04  0.1456E+00

0.3983E+04  0.8799E-01

0.5364E+02  0.1185E-02
   22.11   -0.03   45.88    0.00  -0.04 15.753   0.00   0.3626E+00
28.40  0.9797E-01  0.1053E+03  0.2194E-02

0.6585E+04  0.1372E+00

0.3980E+04  0.8292E-01

0.5360E+02  0.1117E-02
   22.26   -0.04   48.27    0.00  -0.04 15.940   0.00   0.3417E+00
28.96  0.9243E-01  0.1053E+03  0.2070E-02

0.6580E+04  0.1293E+00

0.3977E+04  0.7816E-01

0.5356E+02  0.1053E-02
   22.41   -0.05   50.68    0.00  -0.05 16.058   0.00   0.3223E+00
29.53  0.8725E-01  0.1053E+03  0.1953E-02
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0.6575E+04  0.1220E+00

0.3974E+04  0.7372E-01

0.5352E+02  0.9928E-03
   22.56   -0.05    53.11    0.00  -0.05 16.117   0.00   0.3042E+00
30.09  0.8242E-01  0.1053E+03  0.1845E-02

0.6570E+04  0.1151E+00

0.3971E+04  0.6958E-01

0.5348E+02  0.9370E-03
   22.71   -0.06    55.54    0.00  -0.05 16.128   0.00   0.2874E+00
30.66  0.7793E-01  0.1053E+03  0.1744E-02

0.6566E+04  0.1088E+00

0.3968E+04  0.6573E-01

0.5344E+02  0.8852E-03
   22.87   -0.07    57.97    0.00  -0.05 16.100   0.00   0.2717E+00
31.23  0.7376E-01  0.1053E+03  0.1651E-02

0.6561E+04  0.1028E+00

0.3965E+04  0.6216E-01

0.5341E+02  0.8372E-03
   23.02   -0.08    60.40    0.00  -0.06 16.040   0.00   0.2573E+00
31.80  0.6990E-01  0.1053E+03  0.1564E-02

0.6556E+04  0.9738E-01

0.3963E+04  0.5885E-01

0.5337E+02  0.7927E-03
   23.17   -0.08    62.81    0.00  -0.06 15.954   0.00   0.2439E+00
32.36  0.6631E-01  0.1053E+03  0.1484E-02

0.6552E+04  0.9231E-01

0.3960E+04  0.5579E-01

0.5333E+02  0.7514E-03
   23.32   -0.09    65.21    0.00  -0.06 15.848   0.00   0.2314E+00
32.92  0.6299E-01  0.1053E+03  0.1409E-02

0.6548E+04  0.8761E-01

0.3957E+04  0.5295E-01

0.5330E+02  0.7131E-03
   23.47   -0.10    67.60    0.00  -0.06 15.726   0.00   0.2199E+00
33.48  0.5990E-01  0.1053E+03  0.1340E-02

0.6543E+04  0.8325E-01

0.3955E+04  0.5032E-01

0.5326E+02  0.6777E-03
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   23.62   -0.11   69.96    0.00  -0.06 15.591   0.00   0.2092E+00
34.03  0.5704E-01  0.1053E+03  0.1275E-02

0.6539E+04  0.7921E-01

0.3952E+04  0.4787E-01

0.5323E+02  0.6447E-03
   23.77   -0.12   72.30    0.00  -0.07 15.448   0.00   0.1993E+00
34.58  0.5438E-01  0.1053E+03  0.1216E-02

0.6535E+04  0.7545E-01

0.3950E+04  0.4560E-01

0.5320E+02  0.6142E-03
   23.92   -0.13   74.62    0.00  -0.07 15.298   0.00   0.1901E+00
35.12  0.5190E-01  0.1053E+03  0.1160E-02

0.6531E+04  0.7196E-01

0.3947E+04  0.4349E-01

0.5316E+02  0.5858E-03
   24.07   -0.14   76.92    0.00  -0.07 15.144   0.00   0.1815E+00
35.66  0.4960E-01  0.1053E+03  0.1109E-02

0.6527E+04  0.6872E-01

0.3945E+04  0.4153E-01

0.5313E+02  0.5594E-03
   24.22   -0.15   79.19    0.00  -0.07 14.986   0.00   0.1735E+00
36.19  0.4745E-01  0.1053E+03  0.1060E-02

0.6524E+04  0.6569E-01

0.3943E+04  0.3970E-01

0.5310E+02  0.5347E-03
   24.37   -0.16   81.45    0.00  -0.07 14.827   0.00   0.1660E+00
36.72  0.4545E-01  0.1053E+03  0.1015E-02

0.6520E+04  0.6287E-01

0.3941E+04  0.3800E-01

0.5307E+02  0.5118E-03
   24.52   -0.18   83.67    0.00  -0.07 14.667   0.00   0.1591E+00
37.24  0.4357E-01  0.1053E+03  0.9733E-03

0.6517E+04  0.6023E-01

0.3939E+04  0.3640E-01

0.5305E+02  0.4903E-03
   24.68   -0.19   85.87    0.00  -0.07 14.508   0.00   0.1525E+00
37.76  0.4182E-01  0.1053E+03  0.9339E-03

0.6513E+04  0.5777E-01
```

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0.3937E+04  0.3491E-01

0.5302E+02  0.4702E-03
   24.83   -0.20   88.05    0.00  -0.08 14.350   0.00   0.1464E+00
38.27  0.4018E-01  0.1053E+03  0.8971E-03

0.6510E+04  0.5546E-01

0.3934E+04  0.3352E-01

0.5299E+02  0.4514E-03
   24.98   -0.21   90.21    0.00  -0.08 14.193   0.00   0.1407E+00
38.77  0.3864E-01  0.1053E+03  0.8625E-03

0.6506E+04  0.5329E-01

0.3932E+04  0.3221E-01

0.5296E+02  0.4338E-03
   25.13   -0.22   92.34    0.00  -0.08 14.038   0.00   0.1353E+00
39.27  0.3719E-01  0.1053E+03  0.8300E-03

0.6503E+04  0.5126E-01

0.3931E+04  0.3098E-01

0.5294E+02  0.4173E-03
   25.28   -0.23   94.45    0.00  -0.08 13.886   0.00   0.1303E+00
39.77  0.3583E-01  0.1053E+03  0.7995E-03

0.6500E+04  0.4935E-01

0.3929E+04  0.2983E-01

0.5291E+02  0.4017E-03
   25.43   -0.24   96.53    0.00  -0.08 13.736   0.00   0.1255E+00
40.25  0.3455E-01  0.1053E+03  0.7708E-03

0.6497E+04  0.4756E-01

0.3927E+04  0.2874E-01

0.5289E+02  0.3871E-03
   25.58   -0.26   98.59    0.00  -0.08 13.589   0.00   0.1211E+00
40.74  0.3334E-01  0.1053E+03  0.7436E-03

0.6494E+04  0.4586E-01

0.3925E+04  0.2772E-01

0.5286E+02  0.3733E-03
   25.73   -0.27  100.63    0.00  -0.08 13.445   0.00   0.1168E+00
41.22  0.3220E-01  0.1053E+03  0.7181E-03

0.6491E+04  0.4426E-01

0.3923E+04  0.2675E-01

0.5284E+02  0.3603E-03
   25.88   -0.28  102.65    0.00  -0.08 13.304   0.00   0.1128E+00
41.69  0.3112E-01  0.1053E+03  0.6939E-03
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0.6488E+04  0.4276E-01

0.3922E+04  0.2584E-01

0.5282E+02  0.3480E-03
   26.03   -0.29  104.65    0.00  -0.08 13.166   0.00   0.1091E+00
42.16  0.3010E-01  0.1053E+03  0.6710E-03

0.6486E+04  0.4133E-01

0.3920E+04  0.2498E-01

0.5279E+02  0.3364E-03
   26.18   -0.31  106.63    0.00  -0.08 13.030   0.00   0.1055E+00
42.62  0.2914E-01  0.1053E+03  0.6494E-03

0.6483E+04  0.3998E-01

0.3918E+04  0.2416E-01

0.5277E+02  0.3254E-03
   26.33   -0.32  108.59    0.00  -0.08 12.898   0.00   0.1021E+00
43.08  0.2822E-01  0.1053E+03  0.6288E-03

0.6480E+04  0.3870E-01

0.3917E+04  0.2339E-01

0.5275E+02  0.3150E-03
   26.49   -0.33  110.52    0.00  -0.08 12.769   0.00   0.9890E-01
43.53  0.2736E-01  0.1053E+03  0.6094E-03

0.6478E+04  0.3749E-01

0.3915E+04  0.2266E-01

0.5273E+02  0.3051E-03
   26.64   -0.34  112.44    0.00  -0.08 12.643   0.00   0.9586E-01
43.98  0.2653E-01  0.1053E+03  0.5909E-03

0.6475E+04  0.3633E-01

0.3913E+04  0.2196E-01

0.5271E+02  0.2958E-03
   26.79   -0.36  114.34    0.00  -0.09 12.520   0.00   0.9296E-01
44.43  0.2575E-01  0.1053E+03  0.5733E-03

0.6473E+04  0.3524E-01

0.3912E+04  0.2130E-01

0.5269E+02  0.2868E-03
   26.94   -0.37  116.22    0.00  -0.09 12.399   0.00   0.9021E-01
44.87  0.2500E-01  0.1053E+03  0.5566E-03

0.6470E+04  0.3420E-01

0.3910E+04  0.2067E-01
```

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0.5267E+02  0.2784E-03
   27.09   -0.38  118.08    0.00  -0.09 12.282   0.00   0.8758E-01
45.31  0.2429E-01  0.1053E+03  0.5406E-03

0.6468E+04  0.3321E-01

0.3909E+04  0.2007E-01

0.5265E+02  0.2703E-03
   27.24   -0.40  119.93    0.00  -0.09 12.167   0.00   0.8508E-01
45.74  0.2361E-01  0.1053E+03  0.5254E-03

0.6465E+04  0.3226E-01

0.3908E+04  0.1950E-01

0.5263E+02  0.2626E-03
   27.39   -0.41  121.76    0.00  -0.09 12.055   0.00   0.8270E-01
46.17  0.2297E-01  0.1053E+03  0.5109E-03

0.6463E+04  0.3136E-01

0.3906E+04  0.1895E-01

0.5261E+02  0.2553E-03
   27.54   -0.42  123.57    0.00  -0.09 11.945   0.00   0.8042E-01
46.59  0.2235E-01  0.1053E+03  0.4971E-03

0.6461E+04  0.3050E-01

0.3905E+04  0.1843E-01

0.5259E+02  0.2483E-03
   27.69   -0.44  125.36    0.00  -0.09 11.838   0.00   0.7825E-01
47.01  0.2176E-01  0.1053E+03  0.4838E-03

0.6458E+04  0.2968E-01

0.3903E+04  0.1794E-01

0.5257E+02  0.2416E-03
   27.84   -0.45  127.14    0.00  -0.09 11.734   0.00   0.7617E-01
47.43  0.2120E-01  0.1053E+03  0.4712E-03

0.6456E+04  0.2889E-01

0.3902E+04  0.1746E-01

0.5255E+02  0.2352E-03
   27.99   -0.46  128.91    0.00  -0.09 11.632   0.00   0.7418E-01
47.84  0.2066E-01  0.1053E+03  0.4591E-03

0.6454E+04  0.2814E-01

0.3901E+04  0.1701E-01

0.5254E+02  0.2290E-03
   28.14   -0.48  130.65    0.00  -0.09 11.532   0.00   0.7227E-01
48.25  0.2014E-01  0.1053E+03  0.4475E-03

0.6452E+04  0.2742E-01
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0.3900E+04  0.1657E-01

0.5252E+02  0.2232E-03
   28.30   -0.49  132.39    0.00  -0.09 11.435   0.00   0.7045E-01
48.66  0.1965E-01  0.1053E+03  0.4363E-03

0.6450E+04  0.2673E-01

0.3898E+04  0.1615E-01

0.5250E+02  0.2176E-03
   28.45   -0.50  134.11    0.00  -0.09 11.340   0.00   0.6870E-01
49.06  0.1917E-01  0.1053E+03  0.4257E-03

0.6448E+04  0.2607E-01

0.3897E+04  0.1575E-01

0.5249E+02  0.2122E-03
   28.60   -0.52  135.81    0.00  -0.09 11.246   0.00   0.6702E-01
49.46  0.1871E-01  0.1053E+03  0.4154E-03

0.6446E+04  0.2543E-01

0.3896E+04  0.1537E-01

0.5247E+02  0.2070E-03
   28.75   -0.53  137.50    0.00  -0.09 11.155   0.00   0.6540E-01
49.86  0.1828E-01  0.1053E+03  0.4056E-03

0.6444E+04  0.2482E-01

0.3895E+04  0.1500E-01

0.5245E+02  0.2020E-03
   28.90   -0.54  139.18    0.00  -0.09 11.066   0.00   0.6385E-01
50.25  0.1785E-01  0.1053E+03  0.3962E-03

0.6442E+04  0.2424E-01

0.3893E+04  0.1465E-01

0.5244E+02  0.1973E-03
   29.05   -0.56  140.84    0.00  -0.09 10.979   0.00   0.6236E-01
50.64  0.1745E-01  0.1053E+03  0.3871E-03

0.6440E+04  0.2367E-01

0.3892E+04  0.1431E-01

0.5242E+02  0.1927E-03
   29.20   -0.57  142.49    0.00  -0.09 10.894   0.00   0.6093E-01
51.03  0.1706E-01  0.1053E+03  0.3783E-03

0.6438E+04  0.2313E-01

0.3891E+04  0.1398E-01

0.5241E+02  0.1883E-03
   29.35   -0.58  144.13    0.00  -0.09 10.811   0.00   0.5955E-01
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51.42  0.1668E-01  0.1053E+03  0.3699E-03

0.6436E+04  0.2261E-01

0.3890E+04  0.1367E-01

0.5239E+02  0.1840E-03
   29.50   -0.60  145.76    0.00  -0.09 10.729   0.00   0.5822E-01
51.80  0.1632E-01  0.1053E+03  0.3618E-03

0.6434E+04  0.2211E-01

0.3889E+04  0.1336E-01

0.5238E+02  0.1800E-03
   29.65   -0.61  147.37    0.00  -0.09 10.649   0.00   0.5694E-01
52.18  0.1597E-01  0.1053E+03  0.3540E-03

0.6433E+04  0.2162E-01

0.3888E+04  0.1307E-01

0.5236E+02  0.1760E-03
   29.80   -0.63  148.97    0.00  -0.09 10.571   0.00   0.5571E-01
52.55  0.1564E-01  0.1053E+03  0.3464E-03

0.6431E+04  0.2116E-01

0.3887E+04  0.1279E-01

0.5235E+02  0.1722E-03
   29.95   -0.64  150.56    0.00  -0.09 10.494   0.00   0.5452E-01
52.92  0.1531E-01  0.1053E+03  0.3392E-03

0.6429E+04  0.2071E-01

0.3886E+04  0.1252E-01

0.5233E+02  0.1686E-03

 CLOUD COLLAPSE PHASE:


          IN TRIAL #1 THE COLLAPSE PHASE TIME STEP (DT) WAS
0.25138956E-01 SECONDS.
                      THE TOTAL NUMBER OF INTEGRATION TIME STEPS (ISTEP)
FOR CONVECTIVE DESCENT AND COLAPSE WAS 1199.
                      THE INTEGRATION TIME STEP NUMBER WHEN THE BED WAS
ENCOUNTERED (IBED) WAS  400.
                      THE BOTTOM WAS ENCOUNTERED DURING CONVECTIVE
DESCENT.
                      THE DISCHARGE DID NOT OBTAIN A NEUTRALLY BUOYANT
CONDITION DURING CONVECTIVE DESCENT.

 COLLAPSE PHASE RESULTS:

   TIME       CLOUD CENTROID          VELOCITY OF     DIFFERENCE OF
ELLIPSOIDAL CLOUD                VOLUME OF  SOLIDS VOL.
   FROM    (DISTANCE FROM BARGE)     CLOUD CENTROID   CLOUD & WATER
CLOUD     AXIS LENGTHS      TRACER        SOLID     CONC. BY
 DISPOSAL  X-DIR   DEPTH   Z-DIR  X-DIR  DOWN   Z-DIR   DENSITIES
```

THICKNESS (SEC) (FT)	MINOR (FT)	MAJOR (FT)	CONC. (FT) (MG/L)	FRACTIONS (FPS) (CU FT)	(FPS) (VOL/VOL)	FRACTION (G/CC)
30.03	-0.65	151.35	0.00	-0.09	10.46	0.00	0.5394E-01
53.11	106.22	106.22	0.1516E-01	0.1053E+03	0.3356E-03		
0.6428E+04	0.2049E-01						
0.3885E+04	0.1238E-01						
0.5233E+02	0.1668E-03						
30.36	-0.67	153.28	0.00	-0.08	6.42	0.00	0.5265E-01
47.26	113.81	113.81	0.1484E-01	0.1044E+03	0.3256E-03		
0.6410E+04	0.2000E-01						
0.3874E+04	0.1209E-01						
0.5218E+02	0.1628E-03						
30.68	-0.70	155.23	0.00	-0.08	5.60	0.00	0.5131E-01
42.05	122.04	122.04	0.1451E-01	0.1032E+03	0.3148E-03		
0.6391E+04	0.1949E-01						
0.3862E+04	0.1178E-01						
0.5202E+02	0.1586E-03						
31.01	-0.73	156.91	0.00	-0.08	4.77	0.00	0.4997E-01
37.56	130.65	130.65	0.1418E-01	0.1020E+03	0.3037E-03		
0.6372E+04	0.1898E-01						
0.3851E+04	0.1147E-01						
0.5187E+02	0.1545E-03						
31.34	-0.76	158.34	0.00	-0.08	4.03	0.00	0.4865E-01
33.76	139.47	139.47	0.1385E-01	0.1006E+03	0.2924E-03		
0.6355E+04	0.1848E-01						
0.3841E+04	0.1117E-01						
0.5173E+02	0.1504E-03						
31.66	-0.78	159.54	0.00	-0.08	3.40	0.00	0.4736E-01
30.55	148.41	148.41	0.1352E-01	0.9904E+02	0.2811E-03		
0.6338E+04	0.1799E-01						
0.3831E+04	0.1087E-01						
0.5159E+02	0.1464E-03						
31.99	-0.81	160.56	0.00	-0.08	2.89	0.00	0.4609E-01
27.84	157.41	157.41	0.1319E-01	0.9740E+02	0.2697E-03		
0.6323E+04	0.1751E-01						
0.3822E+04	0.1058E-01						
0.5147E+02	0.1425E-03						
32.32	-0.84	161.43	0.00	-0.08	2.46	0.00	0.4486E-01

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25.53   166.42   166.42   0.1288E-01  0.9562E+02  0.2583E-03

0.6309E+04  0.1704E-01

0.3813E+04  0.1030E-01

0.5136E+02  0.1387E-03
   32.64   -0.86  162.17    0.00  -0.08   2.11   0.00   0.4367E-01
23.55   175.44   175.44   0.1256E-01  0.9373E+02  0.2470E-03

0.6296E+04  0.1659E-01

0.3805E+04  0.1003E-01

0.5125E+02  0.1350E-03
   32.97   -0.89  162.81    0.00  -0.08   1.83   0.00   0.4251E-01
21.84   184.44   184.44   0.1226E-01  0.9173E+02  0.2358E-03

0.6284E+04  0.1615E-01

0.3798E+04  0.9761E-02

0.5115E+02  0.1315E-03
   33.30   -0.92  163.36    0.00  -0.08   1.59   0.00   0.4139E-01
20.37   193.40   193.40   0.1196E-01  0.8963E+02  0.2247E-03

0.6272E+04  0.1572E-01

0.3791E+04  0.9504E-02

0.5106E+02  0.1280E-03
   33.63   -0.94  163.84    0.00  -0.08   1.39   0.00   0.4031E-01
19.08   202.29   202.29   0.1168E-01  0.8743E+02  0.2138E-03

0.6262E+04  0.1532E-01

0.3785E+04  0.9257E-02

0.5097E+02  0.1247E-03
   33.95   -0.97  164.27    0.00  -0.08   1.22   0.00   0.3927E-01
17.95   211.11   211.11   0.1140E-01  0.8515E+02  0.2032E-03

0.6252E+04  0.1492E-01

0.3779E+04  0.9019E-02

0.5089E+02  0.1215E-03
   34.28   -0.99  164.64    0.00  -0.07   1.07   0.00   0.3828E-01
16.96   219.82   219.82   0.1113E-01  0.8279E+02  0.1929E-03

0.6243E+04  0.1455E-01

0.3773E+04  0.8792E-02

0.5082E+02  0.1184E-03
   34.61   -1.02  164.97    0.00  -0.07   0.95   0.00   0.3733E-01
16.09   228.40   228.40   0.1088E-01  0.8037E+02  0.1829E-03

0.6234E+04  0.1419E-01

0.3768E+04  0.8575E-02
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0.5075E+02  0.1155E-03
   34.93   -1.04  165.26    0.00  -0.07   0.84   0.00   0.3643E-01
15.31   236.83   236.83   0.1064E-01  0.7790E+02  0.1732E-03

0.6227E+04  0.1385E-01

0.3763E+04  0.8369E-02

0.5068E+02  0.1127E-03
   35.26   -1.06  165.52    0.00  -0.07   0.75   0.00   0.3558E-01
14.62   245.08   245.08   0.1040E-01  0.7539E+02  0.1639E-03

0.6219E+04  0.1352E-01

0.3759E+04  0.8173E-02

0.5062E+02  0.1101E-03
   35.59   -1.08  165.75    0.00  -0.07   0.67   0.00   0.3477E-01
14.01   253.14   253.14   0.1018E-01  0.7285E+02  0.1550E-03

0.6212E+04  0.1322E-01

0.3755E+04  0.7989E-02

0.5057E+02  0.1076E-03
   35.91   -1.10  165.95    0.00  -0.06   0.60   0.00   0.3401E-01
13.46   260.98   260.98   0.9977E-02  0.7029E+02  0.1465E-03

0.6206E+04  0.1293E-01

0.3751E+04  0.7815E-02

0.5052E+02  0.1053E-03
   36.24   -1.13  166.14    0.00  -0.06   0.54   0.00   0.3330E-01
12.97   268.58   268.58   0.9782E-02  0.6773E+02  0.1383E-03

0.6200E+04  0.1266E-01

0.3747E+04  0.7652E-02

0.5047E+02  0.1031E-03
   36.57   -1.14  166.30    0.00  -0.06   0.48   0.00   0.3263E-01
12.52   275.94   275.94   0.9599E-02  0.6518E+02  0.1305E-03

0.6194E+04  0.1241E-01

0.3744E+04  0.7498E-02

0.5042E+02  0.1010E-03
   36.89   -1.16  166.45    0.00  -0.06   0.44   0.00   0.3200E-01
12.12   283.05   283.05   0.9426E-02  0.6263E+02  0.1231E-03

0.6189E+04  0.1217E-01

0.3741E+04  0.7355E-02

0.5038E+02  0.9906E-04
   37.22   -1.18  166.59    0.00  -0.05   0.39   0.00   0.3141E-01
11.76   289.89   289.89   0.9265E-02  0.6011E+02  0.1161E-03
```

```
0.6184E+04  0.1195E-01

0.3738E+04  0.7221E-02

0.5034E+02  0.9725E-04
   37.55   -1.20  166.71    0.00  -0.05   0.36   0.00   0.3086E-01
11.44   296.47   296.47   0.9114E-02  0.5762E+02  0.1095E-03

0.6180E+04  0.1174E-01

0.3735E+04  0.7095E-02

0.5031E+02  0.9556E-04
   37.87   -1.22  166.82    0.00  -0.05   0.32   0.00   0.3035E-01
11.14   302.79   302.79   0.8973E-02  0.5517E+02  0.1031E-03

0.6176E+04  0.1155E-01

0.3733E+04  0.6978E-02

0.5027E+02  0.9398E-04
   38.20   -1.23  166.92    0.00  -0.05   0.30   0.00   0.2987E-01
10.87   308.84   308.84   0.8840E-02  0.5277E+02  0.9716E-04

0.6172E+04  0.1136E-01

0.3730E+04  0.6869E-02

0.5024E+02  0.9251E-04
   38.53   -1.25  167.01    0.00  -0.05   0.27   0.00   0.2942E-01
10.63   314.65   314.65   0.8717E-02  0.5041E+02  0.9150E-04

0.6168E+04  0.1119E-01

0.3728E+04  0.6766E-02

0.5021E+02  0.9113E-04
   38.85   -1.26  167.10    0.00  -0.04   0.25   0.00   0.2900E-01
10.40   320.21   320.21   0.8601E-02  0.4811E+02  0.8614E-04

0.6165E+04  0.1104E-01

0.3726E+04  0.6671E-02

0.5018E+02  0.8984E-04
   39.18   -1.28  167.18    0.00  -0.04   0.23   0.00   0.2861E-01
10.20   325.54   325.54   0.8492E-02  0.4588E+02  0.8107E-04

0.6162E+04  0.1089E-01

0.3724E+04  0.6581E-02

0.5016E+02  0.8863E-04
   39.51   -1.29  167.25    0.00  -0.04   0.21   0.00   0.2824E-01
10.01   330.64   330.64   0.8390E-02  0.4370E+02  0.7628E-04

0.6159E+04  0.1075E-01

0.3722E+04  0.6497E-02

0.5013E+02  0.8750E-04
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   39.83   -1.30  167.31    0.00  -0.04   0.19   0.00   0.2790E-01
9.83   335.52   335.52   0.8295E-02  0.4159E+02  0.7175E-04

0.6156E+04  0.1062E-01

0.3721E+04  0.6418E-02

0.5011E+02  0.8644E-04
   40.16   -1.32  167.37    0.00  -0.04   0.18   0.00   0.2757E-01
9.67   340.21   340.21   0.8205E-02  0.3955E+02  0.6747E-04

0.6153E+04  0.1050E-01

0.3719E+04  0.6344E-02

0.5009E+02  0.8545E-04
   40.49   -1.33  167.43    0.00  -0.03   0.17   0.00   0.2727E-01
9.52   344.71   344.71   0.8120E-02  0.3758E+02  0.6342E-04

0.6151E+04  0.1038E-01

0.3718E+04  0.6275E-02

0.5007E+02  0.8451E-04
   40.81   -1.34  167.48    0.00  -0.03   0.15   0.00   0.2698E-01
9.38   349.02   349.02   0.8040E-02  0.3568E+02  0.5961E-04

0.6149E+04  0.1027E-01

0.3716E+04  0.6209E-02

0.5005E+02  0.8362E-04
   41.14   -1.35  167.53    0.00  -0.03   0.14   0.00   0.2671E-01
9.25   353.17   353.17   0.7965E-02  0.3385E+02  0.5600E-04

0.6146E+04  0.1017E-01

0.3715E+04  0.6147E-02

0.5003E+02  0.8279E-04
   41.47   -1.36  167.58    0.00  -0.03   0.14   0.00   0.2645E-01
9.13   357.16   357.16   0.7893E-02  0.3208E+02  0.5260E-04

0.6144E+04  0.1007E-01

0.3714E+04  0.6088E-02

0.5002E+02  0.8200E-04
   41.80   -1.37  167.62    0.00  -0.03   0.13   0.00   0.2621E-01
9.02   361.00   361.00   0.7826E-02  0.3039E+02  0.4939E-04

0.6142E+04  0.9982E-02

0.3712E+04  0.6033E-02

0.5000E+02  0.8125E-04
   42.12   -1.38  167.66    0.00  -0.02   0.12   0.00   0.2598E-01
8.91   364.71   364.71   0.7761E-02  0.2877E+02  0.4637E-04

0.6141E+04  0.9894E-02
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0.3711E+04  0.5980E-02

0.4998E+02  0.8054E-04
   42.45   -1.38  167.70    0.00  -0.02   0.11   0.00   0.2576E-01
8.81   368.28   368.28   0.7700E-02  0.2722E+02  0.4351E-04

0.6139E+04  0.9811E-02

0.3710E+04  0.5930E-02

0.4997E+02  0.7987E-04
   42.78   -1.39  167.73    0.00  -0.02   0.11   0.00   0.2555E-01
8.71   371.74   371.74   0.7642E-02  0.2574E+02  0.4082E-04

0.6137E+04  0.9732E-02

0.3709E+04  0.5882E-02

0.4996E+02  0.7922E-04
   43.10   -1.40  167.77    0.00  -0.02   0.10   0.00   0.2535E-01
8.62   375.08   375.08   0.7586E-02  0.2432E+02  0.3828E-04

0.6135E+04  0.9657E-02

0.3708E+04  0.5837E-02

0.4994E+02  0.7861E-04
   43.43   -1.40  167.80    0.00  -0.02   0.10   0.00   0.2516E-01
8.54   378.32   378.32   0.7533E-02  0.2297E+02  0.3589E-04

0.6134E+04  0.9585E-02

0.3707E+04  0.5793E-02

0.4993E+02  0.7802E-04
   43.76   -1.41  167.83    0.00  -0.02   0.09   0.00   0.2498E-01
8.46   381.46   381.46   0.7482E-02  0.2168E+02  0.3364E-04

0.6132E+04  0.9516E-02

0.3706E+04  0.5751E-02

0.4992E+02  0.7746E-04
   44.08   -1.41  167.86    0.00  -0.01   0.09   0.00   0.2480E-01
8.38   384.51   384.51   0.7433E-02  0.2045E+02  0.3152E-04

0.6131E+04  0.9450E-02

0.3705E+04  0.5711E-02

0.4991E+02  0.7692E-04
   44.41   -1.42  167.88    0.00  -0.01   0.08   0.00   0.2463E-01
8.31   387.47   387.47   0.7386E-02  0.1928E+02  0.2953E-04

0.6129E+04  0.9386E-02

0.3705E+04  0.5673E-02

0.4989E+02  0.7641E-04
   44.74   -1.42  167.91    0.00  -0.01   0.08   0.00   0.2447E-01
8.24   390.35   390.35   0.7341E-02  0.1817E+02  0.2765E-04
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0.6128E+04  0.9325E-02

0.3704E+04  0.5636E-02

0.4988E+02  0.7591E-04
   45.06   -1.43  167.94    0.00  -0.01   0.08   0.00   0.2432E-01
8.17   393.16   393.16   0.7297E-02  0.1711E+02  0.2588E-04

0.6127E+04  0.9267E-02

0.3703E+04  0.5601E-02

0.4987E+02  0.7543E-04
   45.39   -1.43  167.96    0.00  -0.01   0.07   0.00   0.2417E-01
8.10   395.90   395.90   0.7255E-02  0.1611E+02  0.2422E-04

0.6126E+04  0.9210E-02

0.3702E+04  0.5566E-02

0.4986E+02  0.7497E-04
   45.72   -1.43  167.98    0.00   0.00   0.07   0.00   0.2402E-01
8.04   398.57   398.57   0.7215E-02  0.1516E+02  0.2266E-04

0.6124E+04  0.9155E-02

0.3702E+04  0.5533E-02

0.4985E+02  0.7452E-04
   46.04   -1.43  168.01    0.00   0.00   0.07   0.00   0.2388E-01
7.98   401.18   401.18   0.7176E-02  0.1426E+02  0.2120E-04

0.6123E+04  0.9102E-02

0.3701E+04  0.5501E-02

0.4984E+02  0.7409E-04
   46.37   -1.43  168.03    0.00   0.00   0.06   0.00   0.2375E-01
7.93   403.73   403.73   0.7138E-02  0.1340E+02  0.1982E-04

0.6122E+04  0.9051E-02

0.3700E+04  0.5470E-02

0.4983E+02  0.7368E-04
   46.70   -1.43  168.05    0.00   0.00   0.06   0.00   0.2362E-01
7.87   406.22   406.22   0.7101E-02  0.1260E+02  0.1852E-04

0.6121E+04  0.9002E-02

0.3700E+04  0.5440E-02

0.4983E+02  0.7327E-04
   47.02   -1.43  168.07    0.00   0.00   0.06   0.00   0.2349E-01
7.82   408.66   408.66   0.7065E-02  0.1183E+02  0.1731E-04

0.6120E+04  0.8953E-02

0.3699E+04  0.5411E-02
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0.4982E+02  0.7288E-04
   47.35   -1.43  168.09    0.00   0.00   0.06   0.00   0.2337E-01
7.77   411.06   411.06   0.7031E-02  0.1111E+02  0.1617E-04

0.6119E+04  0.8907E-02

0.3698E+04  0.5383E-02

0.4981E+02  0.7250E-04
   47.68   -1.43  168.11    0.00   0.00   0.06   0.00   0.2325E-01
7.72   413.40   413.40   0.6997E-02  0.1043E+02  0.1510E-04

0.6118E+04  0.8861E-02

0.3698E+04  0.5356E-02

0.4980E+02  0.7213E-04
   48.00   -1.43  168.12    0.00   0.00   0.05   0.00   0.2313E-01
7.67   415.71   415.71   0.6964E-02  0.9780E+01  0.1410E-04

0.6117E+04  0.8817E-02

0.3697E+04  0.5329E-02

0.4979E+02  0.7177E-04
   48.33   -1.43  168.14    0.00   0.00   0.05   0.00   0.2302E-01
7.62   417.97   417.97   0.6932E-02  0.9171E+01  0.1316E-04

0.6116E+04  0.8774E-02

0.3696E+04  0.5303E-02

0.4978E+02  0.7142E-04
   48.66   -1.43  168.16    0.00   0.00   0.05   0.00   0.2291E-01
7.57   420.19   420.19   0.6901E-02  0.8597E+01  0.1228E-04

0.6115E+04  0.8733E-02

0.3696E+04  0.5278E-02

0.4978E+02  0.7108E-04
   48.99   -1.43  168.18    0.00   0.00   0.05   0.00   0.2280E-01
7.53   422.38   422.38   0.6871E-02  0.8056E+01  0.1145E-04

0.6114E+04  0.8692E-02

0.3695E+04  0.5253E-02

0.4977E+02  0.7075E-04
   49.31   -1.43  168.19    0.00   0.00   0.05   0.00   0.2270E-01
7.49   424.53   424.53   0.6842E-02  0.7545E+01  0.1068E-04

0.6113E+04  0.8652E-02

0.3695E+04  0.5229E-02

0.4976E+02  0.7043E-04
   49.64   -1.43  168.21    0.00   0.00   0.05   0.00   0.2260E-01
7.45   426.64   426.64   0.6813E-02  0.7065E+01  0.9956E-05

0.6112E+04  0.8613E-02
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0.3694E+04  0.5206E-02

0.4975E+02  0.7011E-04
   49.97   -1.43  168.22    0.00    0.00    0.05    0.00    0.2250E-01
7.41   428.73   428.73   0.6785E-02  0.6612E+01  0.9278E-05

0.6111E+04  0.8575E-02

0.3694E+04  0.5183E-02

0.4975E+02  0.6980E-04


 FALL VELOCITY OF COHESIVE MATERIAL IS   0.006900 FT/SEC COMPUTED FOR
SILT


 FALL VELOCITY OF COHESIVE MATERIAL IS   0.000191 FT/SEC COMPUTED FOR
CLAY

     TIME FROM        CLOUD CENTROID       CLOUD X-Z   DEPTH OF   CLOUD
VERT.  T O T A L  ENTRAINED   TIME STEP WHEN   TIME STEP WHEN
      DISPOSAL   X-LOCATION  Z-LOCATION   DIAMETER  TOP OF CLOUD
THICKNESS     M A S S       MASS        THIS CLOUD     PREVIOUS CLOUD
       (SEC)         (FT)         (FT)         (FT)         (FT)         (FT)
(CU FT)     (CU FT)     WAS CREATED      WAS CREATED

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    1
       31.97       749.2       500.0       138.9       170.9
0.1000E-02   7.773       0.0000E+00       477             400

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    2
       34.96       749.0       500.0       210.4       170.9
0.1000E-02   19.82       0.0000E+00       596             477

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    3
       37.95       748.8       500.0       269.6       170.9
0.1000E-02   23.09       0.0000E+00       715             596

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    4
       40.94       748.7       500.0       310.7       170.9
0.1000E-02   19.65       0.0000E+00       834             715

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    5
       43.93       748.6       500.0       339.5       170.9
0.1000E-02   13.95       0.0000E+00       953             834

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    6
       46.92       748.6       500.0       361.5       170.9
0.1000E-02   8.948       0.0000E+00      1072             953

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    7
       49.92       748.6       500.0       379.7       170.9
0.1000E-02   5.382       0.0000E+00      1191             1072

     NEW CLOUD CREATED, NTCLD(K) (K =     1) =    8
       50.12       748.6       500.0       380.8       163.5       7.387
6.680      0.0000E+00      1199             1191
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NOTE -- When all solid material has settled from a cloud, the cloud is erased and
the remaining clouds for this solids type are renumbered.

TIME FROM DISPOSAL (SEC)	CLOUD CENTROID X-LOCATION (FT)	Z-LOCATION (FT)	CLOUD X-Z DIAMETER (FT)	TIME STEP WHEN THIS CLOUD WAS CREATED	DEPTH OF TOP OF CLOUD (FT)	CLOUD VERT. THICKNESS (FT)	T O T A L M A S S (CU FT)	ENTRAINED MASS (CU FT)	TIME STEP WHEN PREVIOUS CLOUD WAS CREATED
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 1									
22.99	749.9	500.0	56.19		15.86	35.34	76.78	0.0000E+00	120
				1					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 2									
25.98	749.7	500.0	74.45		51.20	43.99	70.62	0.0000E+00	239
				120					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 3									
28.97	749.5	500.0	89.42		95.19	36.02	45.50	0.0000E+00	358
				239					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 4									
31.97	749.2	500.0	138.9		131.2	25.08	116.8	0.0000E+00	477
				400					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 5									
34.96	749.0	500.0	210.4		156.3	12.77	98.28	0.0000E+00	596
				477					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 6									
37.95	748.8	500.0	269.6		166.7	4.178	51.01	0.0000E+00	715
				596					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 7									
40.94	748.7	500.0	310.7		169.1	1.746	27.14	0.0000E+00	834
				715					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 8									
43.93	748.6	500.0	339.5		169.9	0.9167	16.28	0.0000E+00	953
				834					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 9									
46.92	748.6	500.0	361.5		170.3	0.5830	11.26	0.0000E+00	1072
				953					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 10									
49.92	748.6	500.0	379.7		170.4	0.4217	8.662	0.0000E+00	1191
				1072					
NEW CLOUD CREATED, NTCLD(K) (K = 2) = 11									
50.12	748.6	500.0	380.8		163.5	7.387	6112.	0.0000E+00	1199
				1191					

NOTE -- When all solid material has settled from a cloud, the cloud

is erased and
the remaining clouds for this solids type are renumbered.

TIME FROM DISPOSAL (SEC)	CLOUD CENTROID X-LOCATION (FT)	CLOUD CENTROID Z-LOCATION (FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF TIME STEP WHEN TOP OF CLOUD PREVIOUS CLOUD (FT)	CLOUD VERT. THICKNESS (FT)
T O T A L M A S S (CU FT)	ENTRAINED MASS (CU FT)	TIME STEP WHEN THIS CLOUD WAS CREATED	TIME STEP WHEN THIS CLOUD WAS CREATED		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 1					
22.99	749.9	500.0	56.19	15.86	35.34
46.40	0.0000E+00	120	1		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 2					
25.98	749.7	500.0	74.45	51.20	43.99
42.68	0.0000E+00	239	120		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 3					
28.97	749.5	500.0	89.42	95.19	36.02
27.50	0.0000E+00	358	239		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 4					
31.97	749.2	500.0	138.9	131.2	25.08
70.58	0.0000E+00	477	400		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 5					
34.96	749.0	500.0	210.4	156.3	12.77
59.40	0.0000E+00	596	477		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 6					
37.95	748.8	500.0	269.6	166.7	4.178
30.83	0.0000E+00	715	596		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 7					
40.94	748.7	500.0	310.7	169.1	1.746
16.40	0.0000E+00	834	715		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 8					
43.93	748.6	500.0	339.5	169.9	0.9167
9.837	0.0000E+00	953	834		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 9					
46.92	748.6	500.0	361.5	170.3	0.5830
6.808	0.0000E+00	1072	953		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 10					
49.92	748.6	500.0	379.7	170.4	0.4217
5.235	0.0000E+00	1191	1072		
NEW CLOUD CREATED, NTCLD(K) (K = 3) = 11					
50.12	748.6	500.0	380.8	163.5	7.387
3694.	0.0000E+00	1199	1191		

NOTE -- When all solid material has settled from a cloud, the cloud is erased and
the remaining clouds for this solids type are renumbered.

TIME FROM DISPOSAL (SEC)	CLOUD CENTROID X-LOCATION (FT)	Z-LOCATION (FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF TIME STEP WHEN THIS CLOUD WAS CREATED	CLOUD TIME STEP WHEN TOP OF PREVIOUS CLOUD WAS CREATED	VERT. THICKNESS (FT)
T O T A L M A S S (CU FT)	ENTRAINED MASS (CU FT)					
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 1						
22.99	749.9	500.0	56.19	15.86	35.34	
0.6249	0.0000E+00	120	1			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 2						
25.98	749.7	500.0	74.45	51.20	43.99	
0.5749	0.0000E+00	239	120			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 3						
28.97	749.5	500.0	89.42	95.19	36.02	
0.3704	0.0000E+00	358	239			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 4						
31.97	749.2	500.0	138.9	131.2	25.08	
0.9505	0.0000E+00	477	400			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 5						
34.96	749.0	500.0	210.4	156.3	12.77	
0.8000	0.0000E+00	596	477			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 6						
37.95	748.8	500.0	269.6	166.7	4.178	
0.4152	0.0000E+00	715	596			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 7						
40.94	748.7	500.0	310.7	169.1	1.746	
0.2210	0.0000E+00	834	715			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 8						
43.93	748.6	500.0	339.5	169.9	0.9167	
0.1325	0.0000E+00	953	834			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 9						
46.92	748.6	500.0	361.5	170.3	0.5830	
0.9167E-01	0.0000E+00	1072	953			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 10						
49.92	748.6	500.0	379.7	170.4	0.4217	
0.7051E-01	0.0000E+00	1191	1072			
NEW CLOUD CREATED, NTCLD(K) (K = 4) = 11						
50.12	748.6	500.0	380.8	163.5	7.387	
49.75	0.0000E+00	1199	1191			

NOTE -- When all solid material has settled from a cloud, the cloud is erased and
the remaining clouds for this solids type are renumbered.

LONG TERM DIFFUSION RESULTS:

BEGIN LONG TERM SIMULATION OF FATE OF GRAVEL

SUMMARY OF GRAVEL DISTRIBUTIONS AFTER 300.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 0.00000E+00
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 105.30

COMPUTATIONS FOR GRAVEL TERMINATED AT 300.00 SEC. ELAPSED TIME...MATERIAL SETTLED TO BOTTOM

BOTTOM ACCUMULATION OF GRAVEL (CU FT/GRID SQUARE) , 300.00 SECONDS AFTER DUMP
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
6	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
7	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
8	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
9	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
10	O	O	O	O	O	O	O	O	.	O	O	O	O	O	O	O	O	O	O
11	O	O	O	O	O	.	.	+	+	+	.	.	O	O	O	O	O	O	O
12	O	O	O	O	.	+	+	+	.01	+	+	+	.	O	O	O	O	O	O
13	O	O	O	.	+	+	.04	.18	.29	.18	.04	+	+	.	O	O	O	O	O
14	O	O	O	.	+	.04	.42	1.7	2.8	1.7	.42	.04	+	.	O	O	O	O	O
15	O	O	O	.	+	.15	1.6	6.5	11	6.5	1.6	.15	+	.	O	O	O	O	O
16	O	O	O	+	+	.22	2.3	10	16	10	2.3	.22	+	+	O	O	O	O	O
17	O	O	O	.	+	.13	1.3	5.7	9.1	5.7	1.3	.13	+	.	O	O	O	O	O
18	O	O	O	.	+	.03	.32	1.3	2.1	1.3	.32	.03	+	.	O	O	O	O	O

```
 19 0000   0   0   0   .   +   + .02 .11 .19 .11 .02   +   +   .   0   0
00000
 20 0000   0   0   0   0   .   .   +   +   +   +   +   .   .   0   0   0
00000
 21 0000   0   0   0   0   0   .   .   .   .   .   .   .   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO

 THICKNESS (FT) OF GRAVEL   ACCUMULATED ON BOTTOM,      300.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY  0.1000E-02     (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  8 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 0000   0   0   0   0   0   .   .   .   +   .   .   .   0   0   0   0
00000
 12 0000   0   0   0   0   .   +   +   +   +   +   +   +   .   0   0   0
00000
 13 0000   0   0   0   .   .   + .02 .11 .17 .11 .02   +   .   .   0   0
00000
 14 0000   0   0   0   .   + .02 .25 1.0 1.6 1.0 .25 .02   +   .   0   0
00000
 15 0000   0   0   0   .   + .09 .96 3.9 6.3 3.9 .96 .09   +   .   0   0
00000
```

```
 16 0000   0   0   0   .   + .13 1.4 5.8 9.3 5.8 1.4 .13   +   .   0   0
00000
 17 0000   0   0   0   .   + .07 .83 3.4 5.4 3.4 .83 .07   +   .   0   0
00000
 18 0000   0   0   0   .   + .01 .19 .79 1.2 .79 .19 .01   +   .   0   0
00000
 19 0000   0   0   0   0   .   + .01 .07 .11 .07 .01   +   .   0   0   0
00000
 20 0000   0   0   0   0   .   .   +   +   +   +   +   .   .   0   0   0
00000
 21 0000   0   0   0   0   0   0   .   .   .   .   .   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000
0000
```

BEGIN LONG TERM SIMULATION OF FATE OF SAND

SUMMARY OF SAND DISTRIBUTIONS AFTER 300.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 237.50
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6395.4

SUMMARY OF SAND DISTRIBUTIONS AFTER 600.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 147.65
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6485.3

SUMMARY OF SAND DISTRIBUTIONS AFTER 900.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 86.923
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6546.0

MAX CONC IS 0.00000001 OUTPUT SUPPRESSED AT 50.00 FT

CONCENTRATIONS ABOVE BACKGROUND OF SAND (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2																			
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	.	.	+	.	.	0	0	0	0	0	0	0	0
12	0	0	0	0	0	.	+	.06	.23	.06	+	0	0	0	0	0	0	0	0
13	0	0	0	0	0	+	.12	5.9	22	5.9	.12	0	0	0	0	0	0	0	0
14	0	0	0	0	0	+	.83	40	147	40	.83	0	0	0	0	0	0	0	0
15	0	0	0	0	0	+	.43	21	76	21	.43	0	0	0	0	0	0	0	0
16	0	0	0	0	0	.	.01	.81	2.9	.81	.01	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

```
 27 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF SAND (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

165.00 FT BELOW THE WATER SURFACE

```
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
  3 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  8 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 12 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 13 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 14 OOOO   0   0   0   0   0   0   0   0   0  26 1.0   0   0   0   0   0
00000
 15 OOOO   0   0   0   0   0   0   0   0  45  15 .63   0   0   0   0   0
00000
 16 OOOO   0   0   0   0   0   0   0 1.0 2.8 1.0 .05   0   0   0   0   0
00000
 17 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 18 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 19 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 20 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
```

```
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000
0000
˅
 BOTTOM ACCUMULATION OF SAND     (CU FT/GRID SQUARE) ,    900.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000         (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
  4 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
  5 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
  6 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
  7 0000   +   +   + .01 .04 .08 .14 .18 .20 .18 .14 .08 .04 .01   +   +
+0000
  8 0000   +   + .03 .08 .20 .40 .64 .85 .93 .85 .64 .40 .20 .08 .03   +
+0000
  9 0000   + .03 .11 .33 .77 1.5 2.4 3.1 3.5 3.1 2.4 1.5 .77 .33 .11 .03
+0000
 10 0000 .02 .10 .36 1.0 2.3 4.6 7.4  10  11  10 7.4 4.6 2.3 1.0 .36 .10
.020000
 11 0000 .06 .27 .92 2.6 6.1  12  19  25  28  25  19  12 6.1 2.6 .92 .27
.060000
 12 0000 .13 .57 1.9 5.5  13  25  41  55  60  55  41  25  13 5.5 1.9 .57
.130000
 13 0000 .24 1.0 3.4  10  23  45  73 100 113 100  73  45  23  10 3.4 1.0
.240000
 14 0000 .35 1.4 5.0  14  33  65 108 157 191 157 108  65  33  14 5.0 1.4
.350000
 15 0000 .42 1.7 6.0  17  40  79 131 195 238 195 131  79  40  17 6.0 1.7
.420000
 16 0000 .42 1.7 5.9  17  40  79 130 184 214 184 130  79  40  17 5.9 1.7
.420000
 17 0000 .34 1.4 4.9  14  33  64 105 143 160 143 105  64  33  14 4.9 1.4
.340000
 18 0000 .23 .97 3.3  10  22  44  71  95 105  95  71  44  22  10 3.3 .97
.230000
 19 0000 .13 .55 1.8 5.3  13  24  39  53  58  53  39  24  13 5.3 1.8 .55
.130000
```

```
 20 0000 .06 .25 .88 2.4 5.8  11  18  24  27  24  18  11 5.8 2.4 .88 .25
.060000
 21 0000 .02 .09 .34 .96 2.2 4.3 7.0 9.3  10 9.3 7.0 4.3 2.2 .96 .34 .09
.020000
 22 0000   + .03 .10 .30 .72 1.4 2.2 2.9 3.2 2.9 2.2 1.4 .72 .30 .10 .03
+0000
 23 0000   +   + .02 .08 .19 .37 .59 .78 .86 .78 .59 .37 .19 .08 .02   +
+0000
 24 0000   +   +   + .01 .04 .08 .13 .17 .18 .17 .13 .08 .04 .01   +   +
+0000
 25 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
 26 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 27 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 28 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
 29 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

SMALL CLOUDS AT 900.00 SECONDS ELAPSED TIME FOR SAND

CLOUD #	LOCATION OF CLOUD CENTROID DISTANCE FROM TOP OF GRID (FT)	DISTANCE FROM LEFT OF GRID (FT)	CLOUD VERT. THICKNESS (FT)	SOLIDS FALL VELOCITY (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF CLOUD
1	662.2	500.0	58.05	0.0000E+00	110.3	93.65	68.57	0.100000
2	662.3	500.0	28.87	0.0000E+00	132.8	128.7	33.51	0.100000

SUMMARY OF SAND DISTRIBUTIONS AFTER 1200.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 35.999
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6596.9

SUMMARY OF SAND DISTRIBUTIONS AFTER 1500.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 7.7074
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6625.2

SUMMARY OF SAND DISTRIBUTIONS AFTER 1800.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 0.00000E+00
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 6632.9

BOTTOM ACCUMULATION OF SAND (CU FT/GRID SQUARE) , 1800.00 SECONDS AFTER DUMP
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 OOOO   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
  4 OOOO   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
  5 OOOO   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
  6 OOOO   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
  7 OOOO   +   +   + .01 .04 .08 .14 .18 .20 .18 .14 .08 .04 .01   +   +
+0000
  8 OOOO   +   + .03 .08 .20 .40 .64 .85 .93 .85 .64 .40 .20 .08 .03   +
+0000
  9 OOOO   + .03 .11 .33 .77 1.5 2.4 3.2 3.5 3.2 2.4 1.5 .77 .33 .11 .03
+0000
 10 OOOO .02 .10 .36 1.0 2.3 4.6 7.4  10  11  10 7.4 4.6 2.3 1.0 .36 .10
.020000
 11 OOOO .06 .27 .92 2.6 6.1  12  19  26  29  26  19  12 6.1 2.6 .92 .27
.060000
 12 OOOO .13 .57 1.9 5.5  13  25  41  57  66  57  41  25  13 5.5 1.9 .57
.130000
 13 OOOO .24 1.0 3.4  10  23  45  74 107 129 107  74  45  23  10 3.4 1.0
.240000
 14 OOOO .35 1.4 5.0  14  33  65 109 164 206 164 109  65  33  14 5.0 1.4
.350000
 15 OOOO .42 1.7 6.0  17  40  79 132 196 242 196 132  79  40  17 6.0 1.7
.420000
 16 OOOO .42 1.7 5.9  17  40  79 130 184 214 184 130  79  40  17 5.9 1.7
.420000
 17 OOOO .34 1.4 4.9  14  33  64 105 143 160 143 105  64  33  14 4.9 1.4
.340000
 18 OOOO .23 .97 3.3  10  22  44  71  95 105  95  71  44  22  10 3.3 .97
.230000
 19 OOOO .13 .55 1.8 5.3  13  24  39  53  58  53  39  24  13 5.3 1.8 .55
.130000
 20 OOOO .06 .25 .88 2.4 5.8  11  18  24  27  24  18  11 5.8 2.4 .88 .25
.060000
 21 OOOO .02 .09 .34 .96 2.2 4.3 7.0 9.3  10 9.3 7.0 4.3 2.2 .96 .34 .09
.020000
 22 OOOO   + .03 .10 .30 .72 1.4 2.2 2.9 3.2 2.9 2.2 1.4 .72 .30 .10 .03
+0000
 23 OOOO   +   + .02 .08 .19 .37 .59 .78 .86 .78 .59 .37 .19 .08 .02   +
+0000
 24 OOOO   +   +   + .01 .04 .08 .13 .17 .18 .17 .13 .08 .04 .01   +   +
+0000
 25 OOOO   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
 26 OOOO   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
```

```
.0000
 27 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 28 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
 29 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
```

COMPUTATIONS FOR SAND TERMINATED AT 1800.00 SEC. ELAPSED TIME...MATERIAL SETTLED TO BOTTOM

BOTTOM ACCUMULATION OF SAND (CU FT/GRID SQUARE) , 1800.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
  3 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
  4 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
  5 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
  6 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
  7 0000   +   +   + .01 .04 .08 .14 .18 .20 .18 .14 .08 .04 .01   +   +
+0000
  8 0000   +   + .03 .08 .20 .40 .64 .85 .93 .85 .64 .40 .20 .08 .03   +
+0000
  9 0000   + .03 .11 .33 .77 1.5 2.4 3.2 3.5 3.2 2.4 1.5 .77 .33 .11 .03
+0000
 10 0000 .02 .10 .36 1.0 2.3 4.6 7.4  10  11  10 7.4 4.6 2.3 1.0 .36 .10
.020000
 11 0000 .06 .27 .92 2.6 6.1  12  19  26  29  26  19  12 6.1 2.6 .92 .27
.060000
 12 0000 .13 .57 1.9 5.5  13  25  41  57  66  57  41  25  13 5.5 1.9 .57
.130000
 13 0000 .24 1.0 3.4  10  23  45  74 107 129 107  74  45  23  10 3.4 1.0
.240000
 14 0000 .35 1.4 5.0  14  33  65 109 164 206 164 109  65  33  14 5.0 1.4
.350000
 15 0000 .42 1.7 6.0  17  40  79 132 196 242 196 132  79  40  17 6.0 1.7
.420000
 16 0000 .42 1.7 5.9  17  40  79 130 184 214 184 130  79  40  17 5.9 1.7
.420000
 17 0000 .34 1.4 4.9  14  33  64 105 143 160 143 105  64  33  14 4.9 1.4
.340000
 18 0000 .23 .97 3.3  10  22  44  71  95 105  95  71  44  22  10 3.3 .97
.230000
 19 0000 .13 .55 1.8 5.3  13  24  39  53  58  53  39  24  13 5.3 1.8 .55
.130000
 20 0000 .06 .25 .88 2.4 5.8  11  18  24  27  24  18  11 5.8 2.4 .88 .25
.060000
```

```
 21 0000 .02 .09 .34 .96 2.2 4.3 7.0 9.3  10 9.3 7.0 4.3 2.2 .96 .34 .09
.020000
 22 0000   + .03 .10 .30 .72 1.4 2.2 2.9 3.2 2.9 2.2 1.4 .72 .30 .10 .03
+0000
 23 0000   +   + .02 .08 .19 .37 .59 .78 .86 .78 .59 .37 .19 .08 .02   +
+0000
 24 0000   +   +   + .01 .04 .08 .13 .17 .18 .17 .13 .08 .04 .01   +   +
+0000
 25 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
 26 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 27 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 28 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
 29 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

```
 THICKNESS (FT) OF SAND     ACCUMULATED ON BOTTOM,     1800.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   .   .   .   .   .   .   .   0   0   0   0
00000
  6 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
  7 0000   0   .   .   .   .   .   .   +   +   +   .   .   .   .   .   .
00000
  8 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
  9 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 10 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 11 0000   .   +   +   +   +   + .01 .01 .01 .01 .01   +   +   +   +   +
.0000
 12 0000   .   +   +   +   + .01 .02 .03 .04 .03 .02 .01   +   +   +   +
.0000
 13 0000   +   +   +   + .01 .02 .04 .06 .08 .06 .04 .02 .01   +   +   +
+0000
 14 0000   +   +   +   + .02 .04 .06 .10 .13 .10 .06 .04 .02   +   +   +
+0000
 15 0000   +   +   + .01 .02 .05 .08 .12 .15 .12 .08 .05 .02 .01   +   +
+0000
 16 0000   +   +   + .01 .02 .05 .08 .11 .13 .11 .08 .05 .02 .01   +   +
+0000
 17 0000   +   +   +   + .02 .04 .06 .09 .10 .09 .06 .04 .02   +   +   +
+0000
```

```
 18 0000   +   +   +   + .01 .02 .04 .06 .06 .06 .04 .02 .01   +   +   +
+0000
 19 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
 20 0000   .   +   +   +   +   + .01 .01 .01 .01 .01   +   +   +   +   +
.0000
 21 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 22 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 23 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 24 0000   0   .   .   .   .   .   .   +   +   +   .   .   .   .   .   .
00000
 25 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
 26 0000   0   0   0   0   0   .   .   .   .   .   .   .   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000
0000
```

BEGIN LONG TERM SIMULATION OF FATE OF SILT

SUMMARY OF SILT DISTRIBUTIONS AFTER 300.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 3165.0
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 844.41

SUMMARY OF SILT DISTRIBUTIONS AFTER 600.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 2214.5
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 1794.5

SUMMARY OF SILT DISTRIBUTIONS AFTER 900.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 1348.4
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 2659.6

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2																			
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	.	.	.	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	.	+	+	+	+	+	.	0	0	0	0	0	0	0
12	0	0	0	0	0	+	.03	.55	1.5	.55	.03	+	0	0	0	0	0	0	0
13	0	0	0	0	.	+	.90	22	70	22	.90	+	.	0	0	0	0	0	0
14	0	0	0	0	.	.03	4.2	125	413	125	4.2	.03	.	0	0	0	0	0	0
15	0	0	0	0	.	.01	2.4	69	223	69	2.4	.01	.	0	0	0	0	0	0
16	0	0	0	0	.	+	.19	4.1	12	4.1	.19	+	.	0	0	0	0	0	0
17	0	0	0	0	0	.	+	.04	.12	.04	+	.	0	0	0	0	0	0	0
18	0	0	0	0	0	0	.	+	+	+	.	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

30
0000000000000000000000000000000000000000000000000000000000000000000000000
0000

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

M	N= 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19 20
2	0000000000000000000000000000000000000000000000000000000000000000000000000 0000																	
3	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
4	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
5	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
6	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
7	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
8	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
9	0000	0	0	0	0	0	0	0	.	.	.	0	0	0	0	0	0	00000
10	0000	0	0	0	0	0	.	.	+	+	+	.	.	0	0	0	0	00000
11	0000	0	0	0	0	.	+	.01	.08	.16	.08	.01	+	.	0	0	0	00000
12	0000	0	0	0	.	+	.01	.48	4.0	8.4	4.0	.48	.01	+	.	0	0	00000
13	0000	0	0	0	.	+	.16	5.8	54	115	54	5.8	.16	+	.	0	0	00000
14	0000	0	0	0	.	+	.47	17	169	375	169	17	.47	+	.	0	0	00000
15	0000	0	0	0	.	+	.33	12	114	250	114	12	.33	+	.	0	0	00000
16	0000	0	0	0	.	+	.05	1.9	17	36	17	1.9	.05	+	.	0	0	00000
17	0000	0	0	0	0	.	+	.08	.67	1.3	.67	.08	+	.	0	0	0	00000
18	0000	0	0	0	0	.	.	+	+	.01	+	+	.	.	0	0	0	00000
19	0000	0	0	0	0	0	0	.	.	.	.	.	0	0	0	0	0	00000
20	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
21	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
22	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
23	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
24	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000
25	0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00000

```
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

165.00 FT BELOW THE WATER SURFACE

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  8 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   +   0
00000
 12 0000   0   0   0   0   0   0   0   0   0   0   0   0   0 .02   +   0
00000
 13 0000   0   0   0   0   0   0   0   0   0   0   0 1.5 .31 .05   +   0
00000
 14 0000   0   0   0   0   0   0   0   0   0  21 8.4 2.1 .43 .07   +   0
00000
 15 0000   0   0   0   0   0   0   0   0  24  18 7.2 1.9 .39 .06   +   0
00000
 16 0000   0   0   0   0   0   0   0 8.4  11 8.4 3.6 1.0 .23 .04   +   0
00000
 17 0000   0   0   0   0   0 .38 1.1 2.4 3.1 2.4 1.1 .38 .09 .01   +   0
00000
 18 0000   0   0   0   0 .02 .10 .28 .53 .66 .53 .28 .10 .02   +   +   0
00000
 19 0000   0   0   +   +   + .02 .05 .09 .11 .09 .05 .02   +   +   +   0
00000
 20 0000   0   .   .   +   +   +   + .01 .01 .01   +   +   +   +   .   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
```

```
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
˘
 BOTTOM ACCUMULATION OF SILT     (CU FT/GRID SQUARE) ,    900.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
  4 0000   +   +   +   +   +   + .01 .01 .01 .01 .01   +   +   +   +   +
+0000
  5 0000   +   +   +   + .01 .02 .04 .05 .05 .05 .04 .02 .01   +   +   +
+0000
  6 0000   +   + .01 .03 .06 .10 .15 .19 .20 .19 .15 .10 .06 .03 .01   +
+0000
  7 0000   + .01 .04 .10 .20 .34 .49 .62 .66 .62 .49 .34 .20 .10 .04 .01
+0000
  8 0000 .01 .05 .13 .29 .57 .96 1.4 1.7 1.8 1.7 1.4 .96 .57 .29 .13 .05
.010000
  9 0000 .04 .12 .32 .72 1.4 2.4 3.5 4.3 4.7 4.3 3.5 2.4 1.4 .72 .32 .12
.040000
 10 0000 .08 .25 .67 1.5 3.0 5.2 7.6  10  10  10 7.6 5.2 3.0 1.5 .67 .25
.080000
 11 0000 .15 .47 1.2 2.9 5.8  10  15  19  20  19  15  10 5.8 2.9 1.2 .47
.150000
 12 0000 .24 .75 2.0 4.7  10  17  25  32  34  32  25  17  10 4.7 2.0 .75
.240000
 13 0000 .33 1.0 2.8 6.7  14  24  36  46  50  46  36  24  14 6.7 2.8 1.0
.330000
 14 0000 .39 1.2 3.4 8.3  17  30  45  58  63  58  45  30  17 8.3 3.4 1.2
.390000
 15 0000 .40 1.3 3.6 8.8  18  32  49  63  68  63  49  32  18 8.8 3.6 1.3
.400000
 16 0000 .36 1.1 3.2 7.9  17  30  45  58  63  58  45  30  17 7.9 3.2 1.1
.360000
 17 0000 .27 .89 2.5 6.1  13  23  35  45  49  45  35  23  13 6.1 2.5 .89
.270000
 18 0000 .17 .58 1.6 4.0 8.4  15  23  30  32  30  23  15 8.4 4.0 1.6 .58
.170000
```

```
 19 0000 .09 .32 .91 2.2 4.7 8.4  13  17  18  17  13 8.4 4.7 2.2 .91 .32
.090000
 20 0000 .04 .15 .43 1.0 2.2 3.9 6.0 7.8 8.5 7.8 6.0 3.9 2.2 1.0 .43 .15
.040000
 21 0000 .01 .06 .17 .42 .89 1.5 2.4 3.1 3.3 3.1 2.4 1.5 .89 .42 .17 .06
.010000
 22 0000   + .02 .06 .14 .30 .54 .82 1.0 1.1 1.0 .82 .54 .30 .14 .06 .02
+0000
 23 0000   +   + .01 .04 .08 .15 .23 .30 .32 .30 .23 .15 .08 .04 .01   +
+0000
 24 0000   +   +   + .01 .02 .03 .05 .07 .08 .07 .05 .03 .02 .01   +   +
+0000
 25 0000   +   +   +   +   +   + .01 .01 .01 .01 .01   +   +   +   +   +
+0000
 26 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 27 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 28 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 29 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

SMALL CLOUDS AT 900.00 SECONDS ELAPSED TIME FOR SILT

CLOUD #	LOCATION OF CLOUD CENTROID: DISTANCE FROM TOP OF GRID (FT)	CLOUD VERT. THICKNESS (FT)	SOLIDS FALL VELOCITY LEFT OF GRID (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF TOP OF CLOUD (FT)
1	662.2	90.42	0.170634E-03	46.40	0.0000E+00	110.3	6.630
2	662.3	72.00	0.125352E-03	42.68	0.0000E+00	132.8	41.57
3	662.3	39.32	0.111544E-03	27.50	0.0000E+00	150.8	85.50
4	662.4	39.85	0.142947E-03	70.58	0.0000E+00	208.6	121.6
5	662.5	15.17	0.157115E-03	59.40	0.0000E+00	289.4	146.7
6	662.6	5.126	0.158444E-03	29.57	0.0000E+00	354.5	157.1
7	662.8	2.343	0.148273E-03	14.82	0.0000E+00	399.2	159.9
8	663.0	1.140	0.118691E-03	8.258	0.0000E+00	430.2	161.2
9	663.3	0.8197	0.942961E-04	5.331	0.0000E+00	453.6	161.5
10	663.6	0.6642	0.768692E-04	3.826	0.0000E+00	472.9	161.7
11	663.6	2.651	0.690000E-02	1040.	0.0000E+00	474.1	159.7

SUMMARY OF SILT DISTRIBUTIONS AFTER 1200.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 608.09
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3398.4

SUMMARY OF SILT DISTRIBUTIONS AFTER 1500.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 307.03
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3698.4

SUMMARY OF SILT DISTRIBUTIONS AFTER 1800.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 306.64
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3698.7

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
1800.00 SECONDS AFTER DUMP

```
               50.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   1.000         (LEGEND... + = .LT. .01
. = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   .   .   .   .   .   0   0   0   0   0
00000
  7 0000   0   0   0   0   .   .   +   +   +   +   +   .   .   0   0   0
00000
  8 0000   0   0   0   .   +   + .01 .03 .04 .03 .01   +   +   .   0   0
00000
  9 0000   0   0   .   .   + .03 .23 .78 1.1 .78 .23 .03   +   .   .   0
00000
 10 0000   0   0   .   + .02 .33 2.6 9.3  14 9.3 2.6 .33 .02   +   .   0
00000
 11 0000   0   0   .   + .09 1.6  14  51  80  51  14 1.6 .09   +   .   0
00000
 12 0000   0   0   .   + .20 3.6  31 119 187 119  31 3.6 .20   +   .   0
00000
 13 0000   0   0   .   + .19 3.4  30 113 178 113  30 3.4 .19   +   .   0
00000
 14 0000   0   0   .   + .08 1.4  12  44  69  44  12 1.4 .08   +   .   0
00000
 15 0000   0   0   .   + .01 .26 2.0 7.3  11 7.3 2.0 .26 .01   +   .   0
```

```
00000
 16 0000   0   0   0   .   + .02 .17 .57 .86 .57 .17 .02   +   .   0   0
00000
 17 0000   0   0   0   .   .   +   + .02 .03 .02   +   +   .   .   0   0
00000
 18 0000   0   0   0   0   .   .   +   +   +   +   +   .   .   0   0   0
00000
 19 0000   0   0   0   0   0   0   .   .   .   .   .   0   0   0   0   0
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
1800.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   .   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   .   .   .   .   .   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   +   +   +   +   +   .   .   0   0
00000
  7 0000   0   0   0   0   0   +   + .01 .01 .01   +   +   +   .   .   0
00000
  8 0000   0   0   .   +   + .02 .08 .20 .27 .20 .08 .02   +   +   .   .
00000
  9 0000   .   .   +   + .02 .19 .88 2.2 3.0 2.2 .88 .19 .02   +   +   .
00000
 10 0000   .   .   + .01 .14 1.1 5.5  14  20  14 5.5 1.1 .14 .01   +   .
00000
 11 0000   .   +   + .03 .45 3.8  19  50  70  50  19 3.8 .45 .03   +   +
```

```
00000
 12 0000   .   +   + .05 .80 7.0  35  93 130  93  35 7.0 .80 .05   +   +
00000
 13 0000   .   +   + .05 .77 6.8  34  90 126  90  34 6.8 .77 .05   +   +
00000
 14 0000   .   +   + .03 .41 3.5  17  45  63  45  17 3.5 .41 .03   +   +
00000
 15 0000   .   .   + .01 .12 .98 4.6  12  17  12 4.6 .98 .12 .01   +   .
00000
 16 0000   0   .   +   + .02 .15 .70 1.7 2.4 1.7 .70 .15 .02   +   +   .
00000
 17 0000   0   .   .   +   + .01 .06 .15 .20 .15 .06 .01   +   +   .   .
00000
 18 0000   0   0   .   .   +   +   +   + .01   +   +   +   +   .   .   0
00000
 19 0000   0   0   0   .   .   +   +   +   +   +   +   +   .   .   0   0
00000
 20 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
00000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
1800.00 SECONDS AFTER DUMP

165.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
00000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
00000
  8 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   +   .
00000
 12 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   +   +   +
00000
 13 0000   0   0   0   0   0   0   0   0   0   0   0 .18 .04   +   +   +
00000
 14 0000   0   0   0   0   0   0   0   0   0 .53 .30 .12 .03   +   +   .
00000
 15 0000   0   0   0   0   0   0   0   0 .30 .25 .14 .05 .01   +   +   .
00000
 16 0000   0   0   0   0   0   0   0 .08 .09 .08 .04 .01   +   +   +   .
00000
 17 0000   0   0   0   0   0   + .01 .01 .02 .01 .01   +   +   +   .   .
00000
 18 0000   0   0   0   0   +   +   +   +   +   +   +   +   +   .   .   0
00000
 19 0000   0   0   0   .   .   .   +   +   +   +   +   .   .   .   0   0
00000
 20 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
˘
 BOTTOM ACCUMULATION OF SILT      (CU FT/GRID SQUARE) ,   1800.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
  3 0000   +   +   +   + .01 .02 .03 .03 .04 .03 .03 .02 .01   +   +   +
+0000
  4 0000   +   + .01 .03 .05 .07 .10 .12 .12 .12 .10 .07 .05 .03 .01   +
```

```
+0000
  5 0000    + .02 .04 .08 .14 .21 .28 .34 .36 .34 .28 .21 .14 .08 .04 .02
+0000
  6 0000 .02 .05 .11 .21 .37 .56 .76 .91 .96 .91 .76 .56 .37 .21 .11 .05
.020000
  7 0000 .05 .12 .26 .50 .87 1.3 1.8 2.2 2.3 2.2 1.8 1.3 .87 .50 .26 .12
.050000
  8 0000 .10 .25 .55 1.0 1.9 2.9 4.0 4.9 5.2 4.9 4.0 2.9 1.9 1.0 .55 .25
.100000
  9 0000 .18 .47 1.0 2.1 3.7 5.9 8.2  10  11  10 8.2 5.9 3.7 2.1 1.0 .47
.180000
 10 0000 .31 .80 1.8 3.7 6.7  11  15  19  20  19  15  11 6.7 3.7 1.8 .80
.310000
 11 0000 .47 1.2 2.9 6.0  11  18  25  31  34  31  25  18  11 6.0 2.9 1.2
.470000
 12 0000 .65 1.7 4.1 8.6  16  27  38  47  51  47  38  27  16 8.6 4.1 1.7
.650000
 13 0000 .78 2.1 5.1  11  21  35  51  64  69  64  51  35  21  11 5.1 2.1
.780000
 14 0000 .85 2.3 5.7  13  25  41  60  76  82  76  60  41  25  13 5.7 2.3
.850000
 15 0000 .81 2.2 5.7  13  25  42  62  79  85  79  62  42  25  13 5.7 2.2
.810000
 16 0000 .67 1.9 4.9  11  22  38  55  70  76  70  55  38  22  11 4.9 1.9
.670000
 17 0000 .49 1.4 3.6 8.3  17  29  42  54  58  54  42  29  17 8.3 3.6 1.4
.490000
 18 0000 .31 .91 2.3 5.4  11  19  28  35  38  35  28  19  11 5.4 2.3 .91
.310000
 19 0000 .17 .51 1.3 3.0 6.0  10  16  20  21  20  16  10 6.0 3.0 1.3 .51
.170000
 20 0000 .08 .24 .63 1.4 2.8 4.9 7.3 9.3  10 9.3 7.3 4.9 2.8 1.4 .63 .24
.080000
 21 0000 .03 .10 .26 .59 1.1 2.0 3.0 3.8 4.1 3.8 3.0 2.0 1.1 .59 .26 .10
.030000
 22 0000 .01 .03 .09 .21 .41 .71 1.0 1.3 1.4 1.3 1.0 .71 .41 .21 .09 .03
.010000
 23 0000    + .01 .02 .06 .12 .21 .31 .39 .42 .39 .31 .21 .12 .06 .02 .01
+0000
 24 0000    +   +   + .01 .03 .05 .08 .10 .11 .10 .08 .05 .03 .01   +   +
+0000
 25 0000    +   +   +   +   + .01 .01 .02 .02 .02 .01 .01   +   +   +   +
+0000
 26 0000    .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
 27 0000    .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 28 0000    .   .   .   .   .   .   +   +   +   +   +   .   .   .   .   .
.0000
 29 0000    0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000
0000
```

SMALL CLOUDS AT 1800.00 SECONDS ELAPSED TIME FOR SILT

CLOUD	LOCATION OF CLOUD CENTROID DISTANCE FROM			MASS FROM DISPOSAL	ENTRAINED MASS	CLOUD X-Z DIAMETER
DEPTH OF CLOUD	CLOUD VERT. DISTANCE	SOLIDS FALL				

TOP OF CLOUD # (FT)	THICKNESS TOP OF GRID (FT)	VELOCITY LEFT OF GRID (FPS)	(CU FT)	(CU FT)	(FT)
1	572.2	500.0	46.40	0.0000E+00	177.8
0.0000E+00	92.74	0.570657E-04			
2	572.3	500.0	42.68	0.0000E+00	204.2
31.03	74.33	0.503009E-04			
3	572.3	500.0	27.50	0.0000E+00	225.0
74.95	41.65	0.480908E-04			
4	572.4	500.0	70.58	0.0000E+00	290.6
111.1	41.46	0.653723E-04			
5	572.5	500.0	59.20	0.0000E+00	380.1
136.2	16.63	0.770702E-04			
6	572.6	500.0	29.12	0.0000E+00	451.2
146.6	6.203	0.739218E-04			
7	572.8	500.0	14.46	0.0000E+00	499.6
149.4	3.436	0.584563E-04			
8	573.0	500.0	7.920	0.0000E+00	533.0
150.6	2.238	0.486567E-04			
9	573.3	500.0	5.107	0.0000E+00	558.2
151.3	1.544	0.388309E-04			
10	573.6	500.0	3.672	0.0000E+00	578.8
151.5	1.397	0.340000E-04			

SUMMARY OF SILT DISTRIBUTIONS AFTER 2100.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 306.33
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3699.0

SUMMARY OF SILT DISTRIBUTIONS AFTER 2400.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 306.08
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3699.3

SUMMARY OF SILT DISTRIBUTIONS AFTER 2700.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 305.86
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3699.5

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
2700.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)
M N= 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
19 20
2

```
000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0    0    0    .    .    +    +    +    +    +    +    +    .    .    0    0
00000
  4 0000   0    0    .    .    +    +    +    +  .01    +    +    +    +    .    .    0
00000
  5 0000   0    .    +    +    +  .02  .06  .11  .13  .11  .06  .02    +    +    +    .
00000
  6 0000   .    .    +    +  .04  .18  .50  .93  1.1  .93  .50  .18  .04    +    +    .
.0000
  7 0000   .    +    +  .03  .23  .99  2.8  5.2  6.5  5.2  2.8  .99  .23  .03    +    +
.0000
  8 0000   .    +  .01  .13  .85  3.6   11   20   25   20   11  3.6  .85  .13  .01    +
.0000
  9 0000   +    +  .03  .32  2.0  9.0   26   51   63   51   26  9.0  2.0  .32  .03    +
+0000
 10 0000   +    +  .05  .52  3.3   15   43   83  104   83   43   15  3.3  .52  .05    +
+0000
 11 0000   +    +  .05  .55  3.5   16   46   89  110   89   46   16  3.5  .55  .05    +
+0000
 12 0000   +    +  .04  .38  2.5   11   32   61   76   61   32   11  2.5  .38  .04    +
+0000
 13 0000   .    +  .02  .18  1.1  4.9   14   27   34   27   14  4.9  1.1  .18  .02    +
.0000
 14 0000   .    +    +  .05  .35  1.5  4.2  8.0   10  8.0  4.2  1.5  .35  .05    +    +
.0000
 15 0000   .    +    +  .01  .07  .30  .86  1.6  1.9  1.6  .86  .30  .07  .01    +    +
.0000
 16 0000   0    .    +    +  .01  .04  .11  .21  .26  .21  .11  .04  .01    +    +    .
00000
 17 0000   0    .    .    +    +    +  .01  .02  .02  .02  .01    +    +    +    .    .
00000
 18 0000   0    0    .    .    .    +    +    +    +    +    +    +    .    .    .    0
00000
 19 0000   0    0    0    0    .    .    .    .    .    .    .    .    .    0    0    0
00000
 20 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 21 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 22 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 23 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 24 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 25 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 26 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 27 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 28 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 29 0000   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF SILT   (MG/L) IN THE CLOUD

2700.00 SECONDS AFTER DUMP

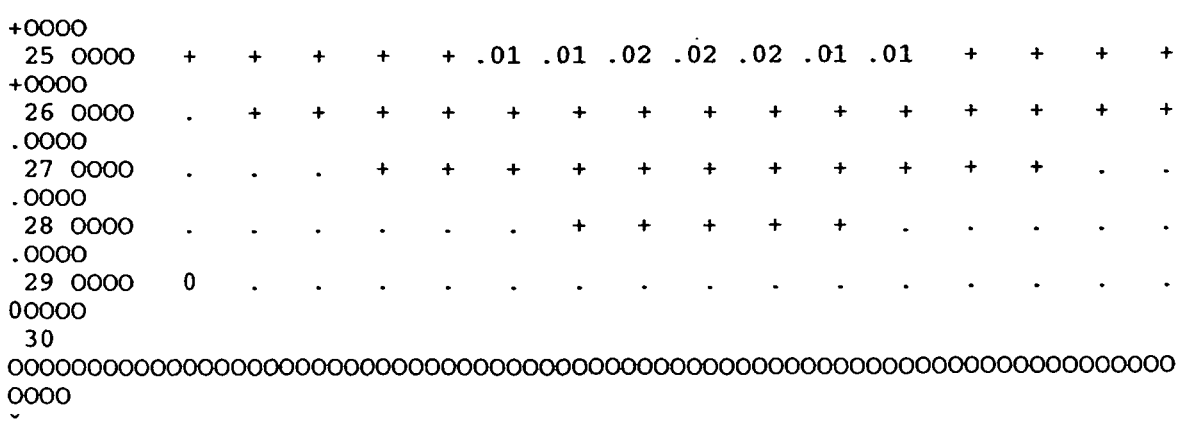
100.00 FT BELOW THE WATER SURFACE

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O	O	O	+	+	+	+	.	.	O
4	O	O	O	O	O	O	O	O	O	O	O	.06	.03	.01	+	+	+	.	O
5	O	O	O	O	O	O	O	O	O	.46	.40	.27	.14	.06	.02	+	+	+	O
6	O	O	O	O	O	O	O	O	1.6	1.8	1.6	1.0	.55	.22	.07	.02	+	+	O
7	O	O	O	O	O	O	1.6	3.4	5.3	6.2	5.3	3.4	1.6	.65	.20	.05	.01	+	O
8	O	O	O	.11	.45	1.5	4.1	8.7	14	16	14	8.7	4.1	1.5	.45	.11	.02	+	O
9	O	O	+	.04	.19	.80	2.8	7.8	17	28	32	28	17	7.8	2.8	.80	.19	.04	+	O
10	O	O	+	.05	.26	1.1	3.9	11	25	40	47	40	25	11	3.9	1.1	.26	.05	+	O
11	O	O	+	.05	.27	1.1	4.0	12	26	42	49	42	26	12	4.0	1.1	.27	.05	+	O
12	O	O	+	.04	.21	.91	3.1	9.0	20	32	37	32	20	9.0	3.1	.91	.21	.04	+	O
13	O	O	+	.02	.13	.55	1.8	5.1	11	18	21	18	11	5.1	1.8	.55	.13	.02	+	O
14	O	O	+	.01	.06	.26	.86	2.2	4.6	7.2	8.4	7.2	4.6	2.2	.86	.26	.06	.01	+	O
15	O	O	+	+	.02	.10	.31	.78	1.5	2.3	2.7	2.3	1.5	.78	.31	.10	.02	+	+	O
16	O	O	+	+	+	.03	.09	.22	.42	.62	.71	.62	.42	.22	.09	.03	+	+	+	O
17	O	O	+	+	+	+	.02	.05	.09	.14	.15	.14	.09	.05	.02	+	+	+	+	O
18	O	O	.	+	+	+	+	.01	.01	.02	.03	.02	.01	.01	+	+	+	+	.	O
19	O	O	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	O
20	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
21	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
22	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
23	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
24	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
25	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
26	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
27	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O
28	O	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O

```
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000
0000

     MAX CONC IS 0.00000000 OUTPUT SUPPRESSED AT  165.00 FT
 BOTTOM ACCUMULATION OF SILT      (CU FT/GRID SQUARE) ,   2700.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   +   +   +   + .01 .02 .03 .03 .04 .03 .03 .02 .01   +   +   +
+0000
  4 0000   +   + .01 .03 .05 .07 .10 .12 .12 .12 .10 .07 .05 .03 .01   +
+0000
  5 0000   + .02 .04 .08 .14 .21 .29 .34 .36 .34 .29 .21 .14 .08 .04 .02
+0000
  6 0000 .02 .05 .11 .21 .37 .56 .76 .91 .97 .91 .76 .56 .37 .21 .11 .05
.020000
  7 0000 .05 .12 .26 .50 .87 1.3 1.8 2.2 2.3 2.2 1.8 1.3 .87 .50 .26 .12
.050000
  8 0000 .10 .25 .55 1.0 1.9 2.9 4.0 4.9 5.2 4.9 4.0 2.9 1.9 1.0 .55 .25
.100000
  9 0000 .19 .47 1.0 2.1 3.7 5.9 8.2  10  11  10 8.2 5.9 3.7 2.1 1.0 .47
.190000
 10 0000 .31 .80 1.8 3.7 6.7  11  15  19  20  19  15  11 6.7 3.7 1.8 .80
.310000
 11 0000 .48 1.2 2.9 6.0  11  18  25  31  34  31  25  18  11 6.0 2.9 1.2
.480000
 12 0000 .65 1.7 4.1 8.6  16  27  38  47  51  47  38  27  16 8.6 4.1 1.7
.650000
 13 0000 .78 2.1 5.1  11  21  35  51  64  69  64  51  35  21  11 5.1 2.1
.780000
 14 0000 .85 2.3 5.8  13  25  41  60  76  82  76  60  41  25  13 5.8 2.3
.850000
 15 0000 .81 2.2 5.7  13  25  42  62  79  85  79  62  42  25  13 5.7 2.2
.810000
 16 0000 .67 1.9 4.9  11  22  38  56  70  76  70  56  38  22  11 4.9 1.9
.670000
 17 0000 .49 1.4 3.6 8.3  17  29  42  54  58  54  42  29  17 8.3 3.6 1.4
.490000
 18 0000 .31 .91 2.3 5.4  11  19  28  35  38  35  28  19  11 5.4 2.3 .91
.310000
 19 0000 .17 .51 1.3 3.0 6.0  10  16  20  21  20  16  10 6.0 3.0 1.3 .51
.170000
 20 0000 .08 .24 .63 1.4 2.8 4.9 7.3 9.3  10 9.3 7.3 4.9 2.8 1.4 .63 .24
.080000
 21 0000 .03 .10 .26 .59 1.1 2.0 3.0 3.8 4.1 3.8 3.0 2.0 1.1 .59 .26 .10
.030000
 22 0000 .01 .03 .09 .21 .41 .71 1.0 1.3 1.4 1.3 1.0 .71 .41 .21 .09 .03
.010000
 23 0000   + .01 .02 .06 .12 .21 .31 .39 .42 .39 .31 .21 .12 .06 .02 .01
+0000
 24 0000   +   +   + .01 .03 .05 .08 .10 .11 .10 .08 .05 .03 .01   +   +
```



SMALL CLOUDS AT 2700.00 SECONDS ELAPSED TIME FOR SILT

CLOUD #	LOCATION OF CLOUD CENTROID: DISTANCE FROM TOP OF GRID (FT)	DISTANCE FROM LEFT OF GRID (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF CLOUD (FT)	CLOUD VERT. THICKNESS	SOLIDS FALL VELOCITY
1	482.2	500.0	46.40	0.0000E+00	255.8	0.0000E+00	95.07	0.340000E-04
2	482.3	500.0	42.68	0.0000E+00	285.6	21.64	76.65	0.340000E-04
3	482.3	500.0	27.50	0.0000E+00	308.8	65.56	43.97	0.340000E-04
4	482.4	500.0	70.52	0.0000E+00	381.4	101.7	42.82	0.414605E-04
5	482.5	500.0	59.03	0.0000E+00	478.9	126.8	17.74	0.484931E-04
6	482.6	500.0	28.92	0.0000E+00	555.6	137.2	7.318	0.450430E-04
7	482.8	500.0	14.32	0.0000E+00	607.4	140.0	4.561	0.360547E-04
8	483.0	500.0	7.830	0.0000E+00	643.0	141.2	3.369	0.340000E-04
9	483.3	500.0	5.033	0.0000E+00	669.9	142.0	2.676	0.340000E-04
10	483.6	500.0	3.617	0.0000E+00	691.8	142.2	2.530	0.340000E-04

SUMMARY OF SILT DISTRIBUTIONS AFTER 3000.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 305.67
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 3699.7

SUMMARY OF SILT DISTRIBUTIONS AFTER 3300.00 SEC.

```
     TOTAL SUSPENDED MATERIAL (CU FT) =      305.50
     TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) =      3699.8



 SUMMARY OF SILT     DISTRIBUTIONS AFTER    3600.00 SEC.

     TOTAL SUSPENDED MATERIAL (CU FT) =      305.35
     TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) =      3700.0

 CONCENTRATIONS ABOVE BACKGROUND OF SILT     (MG/L) IN THE CLOUD
3600.00 SECONDS AFTER DUMP

                 50.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY    1.000          (LEGEND... + = .LT. .01
. = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0 .06 .18 .41 .74 1.0 1.1 1.0 .74 .41 .18 .06 .01   +
+0000
  4 0000   + .01 .06 .22 .63 1.4 2.5 3.6 4.1 3.6 2.5 1.4 .63 .22 .06 .01
+0000
  5 0000   + .03 .17 .61 1.7 4.0 7.2  10  12  10 7.2 4.0 1.7 .61 .17 .03
+0000
  6 0000 .01 .08 .37 1.3 3.8 8.8  16  23  26  23  16 8.8 3.8 1.3 .37 .08
.010000
  7 0000 .02 .14 .64 2.3 6.7  16  28  41  46  41  28  16 6.7 2.3 .64 .14
.020000
  8 0000 .03 .19 .88 3.1 9.2  21  39  56  64  56  39  21 9.2 3.1 .88 .19
.030000
  9 0000 .03 .21 .95 3.4  10  23  43  61  69  61  43  23  10 3.4 .95 .21
.030000
 10 0000 .03 .18 .82 2.9 8.6  20  36  52  59  52  36  20 8.6 2.9 .82 .18
.030000
 11 0000 .02 .12 .55 2.0 5.8  13  24  35  39  35  24  13 5.8 2.0 .55 .12
.020000
 12 0000 .01 .06 .30 1.0 3.1 7.1  13  18  21  18  13 7.1 3.1 1.0 .30 .06
.010000
 13 0000   + .03 .13 .46 1.3 2.9 5.4 7.7 8.6 7.7 5.4 2.9 1.3 .46 .13 .03
+0000
 14 0000   + .01 .04 .15 .44 1.0 1.8 2.5 2.8 2.5 1.8 1.0 .44 .15 .04 .01
+0000
 15 0000   +   + .01 .04 .12 .27 .48 .68 .77 .68 .48 .27 .12 .04 .01   +
+0000
 16 0000   +   +   +   + .02 .05 .10 .14 .16 .14 .10 .05 .02   +   +   +
+0000
 17 0000   .   +   +   +   + .01 .01 .02 .02 .02 .01 .01   +   +   +   +
.0000
 18 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 19 0000   0   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
```

```
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF SILT (MG/L) IN THE CLOUD
3600.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0 2.1 1.3 .70 .33 .13
.040000
  4 0000   0   0   0   0   0   0   0   0   0   0 6.3 4.4 2.7 1.4 .69 .28
.100000
  5 0000   0   0   0   0   0   0   0   0  16  15  12 8.2 5.0 2.6 1.2 .51
.180000
  6 0000   0   0   0   0   0   0   0  24  25  24  19  13 8.0 4.2 1.9 .81
.290000
  7 0000   0   0   0   0   0  19  27  33  36  33  27  19  11 5.9 2.7 1.1
.400000
  8 0000   0   0 3.3 7.1  14  23  33  41  44  41  33  23  14 7.1 3.3 1.3
.480000
  9 0000 .50 1.4 3.4 7.5  14  24  34  43  47  43  34  24  14 7.5 3.4 1.4
.500000
 10 0000 .46 1.2 3.1 6.8  13  22  31  39  42  39  31  22  13 6.8 3.1 1.2
.460000
 11 0000 .36 1.0 2.5 5.4  10  17  24  31  33  31  24  17  10 5.4 2.5 1.0
.360000
 12 0000 .25 .71 1.7 3.7 7.0  12  17  21  22  21  17  12 7.0 3.7 1.7 .71
.250000
 13 0000 .15 .43 1.0 2.2 4.2 6.9  10  12  13  12  10 6.9 4.2 2.2 1.0 .43
.150000
 14 0000 .08 .22 .56 1.1 2.2 3.6 5.1 6.3 6.7 6.3 5.1 3.6 2.2 1.1 .56 .22
.080000
 15 0000 .03 .10 .25 .54 1.0 1.6 2.3 2.8 3.0 2.8 2.3 1.6 1.0 .54 .25 .10
.030000
 16 0000 .01 .04 .10 .22 .40 .65 .93 1.1 1.2 1.1 .93 .65 .40 .22 .10 .04
.010000
 17 0000   + .01 .03 .07 .14 .23 .32 .39 .42 .39 .32 .23 .14 .07 .03 .01
+0000
```

```
 18 0000   +   + .01 .02 .04 .07 .09 .12 .13 .12 .09 .07 .04 .02 .01   +
+0000
 19 0000   +   +   +   + .01 .01 .02 .03 .03 .03 .02 .01 .01   +   +   +
+0000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO

     MAX CONC IS 0.00000000 OUTPUT SUPPRESSED AT  165.00 FT

 BOTTOM ACCUMULATION OF SILT     (CU FT/GRID SQUARE) ,   3600.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000         (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   +   +   + .01 .01 .02 .03 .03 .04 .03 .03 .02 .01 .01   +   +
+0000
  4 0000   +   + .01 .03 .05 .07 .10 .12 .12 .12 .10 .07 .05 .03 .01   +
+0000
  5 0000   + .02 .04 .08 .14 .21 .29 .34 .37 .34 .29 .21 .14 .08 .04 .02
+0000
  6 0000 .02 .05 .11 .21 .37 .56 .76 .91 .97 .91 .76 .56 .37 .21 .11 .05
.020000
  7 0000 .05 .12 .26 .51 .88 1.3 1.8 2.2 2.3 2.2 1.8 1.3 .88 .51 .26 .12
.050000
  8 0000 .10 .25 .55 1.0 1.9 2.9 4.0 4.9 5.2 4.9 4.0 2.9 1.9 1.0 .55 .25
.100000
  9 0000 .19 .47 1.0 2.1 3.7 5.9 8.2  10  11  10 8.2 5.9 3.7 2.1 1.0 .47
.190000
 10 0000 .31 .81 1.8 3.7 6.7  11  15  19  20  19  15  11 6.7 3.7 1.8 .81
.310000
 11 0000 .48 1.2 2.9 6.0  11  18  25  31  34  31  25  18  11 6.0 2.9 1.2
.480000
 12 0000 .65 1.7 4.1 8.6  16  27  38  47  51  47  38  27  16 8.6 4.1 1.7
.650000
 13 0000 .78 2.1 5.1  11  21  35  51  64  69  64  51  35  21  11 5.1 2.1
.780000
```

```
 14 0000 .85 2.3 5.8  13  25  41  60  76  82  76  60  41  25  13 5.8 2.3
.850000
 15 0000 .81 2.2 5.7  13  25  42  62  79  85  79  62  42  25  13 5.7 2.2
.810000
 16 0000 .67 1.9 4.9  11  22  38  56  70  76  70  56  38  22  11 4.9 1.9
.670000
 17 0000 .49 1.4 3.6 8.3  17  29  42  54  58  54  42  29  17 8.3 3.6 1.4
.490000
 18 0000 .31 .91 2.3 5.4  11  19  28  35  38  35  28  19  11 5.4 2.3 .91
.310000
 19 0000 .17 .51 1.3 3.0 6.0  10  16  20  21  20  16  10 6.0 3.0 1.3 .51
.170000
 20 0000 .08 .24 .63 1.4 2.8 4.9 7.3 9.3  10 9.3 7.3 4.9 2.8 1.4 .63 .24
.080000
 21 0000 .03 .10 .26 .59 1.1 2.0 3.0 3.8 4.1 3.8 3.0 2.0 1.1 .59 .26 .10
.030000
 22 0000 .01 .03 .09 .21 .41 .71 1.0 1.3 1.4 1.3 1.0 .71 .41 .21 .09 .03
.010000
 23 0000   + .01 .02 .06 .12 .21 .31 .39 .42 .39 .31 .21 .12 .06 .02 .01
+0000
 24 0000   +   +   + .01 .03 .05 .08 .10 .11 .10 .08 .05 .03 .01   +   +
+0000
 25 0000   +   +   +   +   + .01 .01 .02 .02 .02 .01 .01   +   +   +   +
+0000
 26 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
 27 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 28 0000   .   .   .   .   .   .   +   +   +   +   +   .   .   .   .   .
.0000
 29 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

SMALL CLOUDS AT 3600.00 SECONDS ELAPSED TIME FOR SILT

#	LOCATION OF CLOUD CENTROID: DISTANCE FROM TOP OF GRID (FT)	DISTANCE FROM LEFT OF GRID (FT)	CLOUD VERT. SOLIDS FALL VELOCITY (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF CLOUD (FT)
1	392.2	500.0	46.40	0.0000E+00	343.1	0.0000E+00	97.39
2	392.3	500.0	42.68	0.0000E+00	376.0	7.905	78.98
3	392.3	500.0	27.50	0.0000E+00	401.4	51.83	46.29
4	392.4	500.0	70.47	0.0000E+00	480.3	87.98	43.95
5	392.5	500.0	58.91	0.0000E+00	585.3	113.1	18.86
6	392.6	500.0	28.80	0.0000E+00	667.1	123.5	8.447
7	392.8	500.0	14.24	0.0000E+00	722.2	126.3	5.693
8	393.0	500.0	7.771	0.0000E+00	759.9		

0.340000E-04
0.340000E-04
0.340000E-04
0.361234E-04
0.340000E-04
0.340000E-04

```
127.5        4.501        0.340000E-04
   9         393.3           500.0        4.985        0.0000E+00    788.3
128.6        3.421        0.340000E-04
  10         393.6           500.0        3.580        0.0000E+00    811.5
128.8        3.275        0.340000E-04
```

BOTTOM ACCUMULATION OF SILT (CU FT/GRID SQUARE) , 3600.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
00000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   +   +   + .01 .01 .02 .03 .03 .04 .03 .03 .02 .01 .01   +   +
+0000
  4 0000   +   + .01 .03 .05 .07 .10 .12 .12 .12 .10 .07 .05 .03 .01   +
+0000
  5 0000   + .02 .04 .08 .14 .21 .29 .34 .37 .34 .29 .21 .14 .08 .04 .02
+0000
  6 0000 .02 .05 .11 .21 .37 .56 .76 .91 .97 .91 .76 .56 .37 .21 .11 .05
.020000
  7 0000 .05 .12 .26 .51 .88 1.3 1.8 2.2 2.3 2.2 1.8 1.3 .88 .51 .26 .12
.050000
  8 0000 .10 .25 .55 1.0 1.9 2.9 4.0 4.9 5.2 4.9 4.0 2.9 1.9 1.0 .55 .25
.100000
  9 0000 .19 .47 1.0 2.1 3.7 5.9 8.2  10  11  10 8.2 5.9 3.7 2.1 1.0 .47
.190000
 10 0000 .31 .81 1.8 3.7 6.7  11  15  19  20  19  15  11 6.7 3.7 1.8 .81
.310000
 11 0000 .48 1.2 2.9 6.0  11  18  25  31  34  31  25  18  11 6.0 2.9 1.2
.480000
 12 0000 .65 1.7 4.1 8.6  16  27  38  47  51  47  38  27  16 8.6 4.1 1.7
.650000
 13 0000 .78 2.1 5.1  11  21  35  51  64  69  64  51  35  21  11 5.1 2.1
.780000
 14 0000 .85 2.3 5.8  13  25  41  60  76  82  76  60  41  25  13 5.8 2.3
.850000
 15 0000 .81 2.2 5.7  13  25  42  62  79  85  79  62  42  25  13 5.7 2.2
.810000
 16 0000 .67 1.9 4.9  11  22  38  56  70  76  70  56  38  22  11 4.9 1.9
.670000
 17 0000 .49 1.4 3.6 8.3  17  29  42  54  58  54  42  29  17 8.3 3.6 1.4
.490000
 18 0000 .31 .91 2.3 5.4  11  19  28  35  38  35  28  19  11 5.4 2.3 .91
.310000
 19 0000 .17 .51 1.3 3.0 6.0  10  16  20  21  20  16  10 6.0 3.0 1.3 .51
.170000
 20 0000 .08 .24 .63 1.4 2.8 4.9 7.3 9.3  10 9.3 7.3 4.9 2.8 1.4 .63 .24
.080000
 21 0000 .03 .10 .26 .59 1.1 2.0 3.0 3.8 4.1 3.8 3.0 2.0 1.1 .59 .26 .10
.030000
 22 0000 .01 .03 .09 .21 .41 .71 1.0 1.3 1.4 1.3 1.0 .71 .41 .21 .09 .03
.010000
 23 0000   + .01 .02 .06 .12 .21 .31 .39 .42 .39 .31 .21 .12 .06 .02 .01
+0000
 24 0000   +   +   + .01 .03 .05 .08 .10 .11 .10 .08 .05 .03 .01   +   +
+0000
 25 0000   +   +   +   +   + .01 .01 .02 .02 .02 .01 .01   +   +   +   +
+0000
```

```
 26 0000    .    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +
.0000
 27 0000    .    .    .    +    +    +    +    +    +    +    +    +    +    +    .    .
.0000
 28 0000    .    .    .    .    .    .    +    +    +    +    +    .    .    .    .    .
.0000
 29 0000    0    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

THICKNESS (FT) OF SILT ACCUMULATED ON BOTTOM, 3600.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
.0000
  4 0000    .    .    .    .    .    +    +    +    +    +    +    +    .    .    .    .
.0000
  5 0000    .    .    .    +    +    +    +    +    +    +    +    +    +    +    .    .
.0000
  6 0000    .    .    +    +    +    +    +    +    +    +    +    +    +    +    +    .
.0000
  7 0000    .    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +
.0000
  8 0000    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +
+0000
  9 0000    +    +    +    +    +    + .01  .01  .01  .01  .01    +    +    +    +    +
+0000
 10 0000    +    +    +    +    + .01  .01  .02  .02  .02  .01  .01    +    +    +    +
+0000
 11 0000    +    +    +    + .01  .02  .03  .04  .04  .04  .03  .02  .01    +    +    +
+0000
 12 0000    +    +    + .01  .02  .03  .04  .06  .06  .06  .04  .03  .02  .01    +    +
+0000
 13 0000    +    +    + .01  .02  .04  .06  .08  .08  .08  .06  .04  .02  .01    +    +
+0000
 14 0000    +    +    + .01  .03  .05  .07  .09  .10  .09  .07  .05  .03  .01    +    +
+0000
 15 0000    +    +    + .01  .03  .05  .08  .10  .11  .10  .08  .05  .03  .01    +    +
+0000
 16 0000    +    +    + .01  .02  .04  .07  .09  .09  .09  .07  .04  .02  .01    +    +
+0000
 17 0000    +    +    + .01  .02  .03  .05  .07  .07  .07  .05  .03  .02  .01    +    +
+0000
 18 0000    +    +    +    + .01  .02  .03  .04  .04  .04  .03  .02  .01    +    +    +
+0000
 19 0000    +    +    +    +    + .01  .02  .02  .02  .02  .02  .01    +    +    +    +
+0000
 20 0000    +    +    +    +    +    +    + .01  .01  .01    +    +    +    +    +    +
+0000
 21 0000    .    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +
.0000
 22 0000    .    .    +    +    +    +    +    +    +    +    +    +    +    +    +    .
.0000
```

```
 23 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
 24 0000   .   .   .   .   .   .   +   +   +   +   +   .   .   .   .   .
.0000
 25 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 26 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
 27 0000   0   0   0   0   0   0   0   .   .   .   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

BEGIN LONG TERM SIMULATION OF FATE OF CLAY

SUMMARY OF CLAY DISTRIBUTIONS AFTER 300.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.797
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.20319

SUMMARY OF CLAY DISTRIBUTIONS AFTER 600.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.606
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.39345

SUMMARY OF CLAY DISTRIBUTIONS AFTER 900.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.458
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.54190

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE

```
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  8 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 0000   0   0   0   0   0   0   .   .   +   .   .   0   0   0   0   0
00000
 12 0000   0   0   0   0   0   .   +  .01  .03  .01   +   .   0   0   0   0
00000
 13 0000   0   0   0   0   0   +  .01  .29  .72  .29  .01   +   0   0   0   0
00000
 14 0000   0   0   0   0   .   +  .07  1.1  2.8  1.1  .07   +   .   0   0   0
00000
 15 0000   0   0   0   0   .   +  .04  .71  1.7  .71  .04   +   .   0   0   0
00000
 16 0000   0   0   0   0   0   .   +  .07  .18  .07   +   .   0   0   0   0
00000
 17 0000   0   0   0   0   0   .   .   +   +   +   .   .   0   0   0   0
00000
 18 0000   0   0   0   0   0   0   0   .   .   .   0   0   0   0   0   0
00000
 19 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  4 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  5 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  6 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  7 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  8 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
  9 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 10 OOOO  0   0   0   0   0   0   0   .   .   .   0   0   0   0   0   0   0
OOOOO
 11 OOOO  0   0   0   0   0   .   +   +   +   +   +   .   0   0   0   0   0
OOOOO
 12 OOOO  0   0   0   0   .   +   + .04 .09 .04   +   +   .   0   0   0   0
OOOOO
 13 OOOO  0   0   0   0   .   + .06 .55 1.1 .55 .06   +   .   0   0   0   0
OOOOO
 14 OOOO  0   0   0   0   .   + .19 1.5 3.1 1.5 .19   +   .   0   0   0   0
OOOOO
 15 OOOO  0   0   0   0   .   + .13 1.1 2.2 1.1 .13   +   .   0   0   0   0
OOOOO
 16 OOOO  0   0   0   0   .   + .02 .19 .38 .19 .02   +   .   0   0   0   0
OOOOO
 17 OOOO  0   0   0   0   0   .   +   + .01   +   +   .   0   0   0   0   0
OOOOO
 18 OOOO  0   0   0   0   0   0   .   .   +   .   .   0   0   0   0   0   0
OOOOO
 19 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 20 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 21 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 22 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 23 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 24 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 25 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 26 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 27 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 28 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 29 OOOO  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
OOOOO
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
```

```
0000

 CONCENTRATIONS ABOVE BACKGROUND OF CLAY      (MG/L) IN THE CLOUD
900.00 SECONDS AFTER DUMP

               165.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
 . = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  8 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  9 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 10 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 11 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0 .04   0
00000
 12 0000   0   0   0   0   0   0   0   0   0   0   0   0   0 .13 .06   0
00000
 13 0000   0   0   0   0   0   0   0   0   0   0   0 .53 .32 .17 .07   0
00000
 14 0000   0   0   0   0   0   0   0   0   0 1.0 .85 .59 .36 .19 .08   0
00000
 15 0000   0   0   0   0   0   0   0   0 1.1 1.0 .82 .57 .35 .18 .08   0
00000
 16 0000   0   0   0   0   0   0   0 .85 .92 .85 .69 .48 .29 .15 .07   0
00000
 17 0000   0   0   0   0   0 .35 .50 .62 .66 .62 .50 .35 .21 .11 .05   0
00000
 18 0000   0   0   0   0 .13 .22 .31 .39 .42 .39 .31 .22 .13 .07 .03   0
00000
 19 0000   0   0 .01 .04 .07 .12 .17 .21 .23 .21 .17 .12 .07 .04 .01   0
00000
 20 0000   0   +   + .01 .03 .05 .08 .10 .11 .10 .08 .05 .03 .01   +   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
```

```
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

BOTTOM ACCUMULATION OF CLAY (CU FT/GRID SQUARE) , 900.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 0.1000E-01 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
000000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
  4 0000   .   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
.0000
  5 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
  6 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
  7 0000   +   +   +   +   +   +   +  .01 .01 .01   +   +   +   +   +   +
+0000
  8 0000   +   +   +   +  .01 .01 .02 .03 .03 .03 .02 .01 .01   +   +   +
+0000
  9 0000   +   +   +  .01 .02 .04 .06 .08 .08 .08 .06 .04 .02 .01   +   +
+0000
 10 0000   +   +  .01 .02 .05 .09 .14 .18 .19 .18 .14 .09 .05 .02 .01   +
+0000
 11 0000   +   +  .02 .05 .11 .19 .28 .36 .39 .36 .28 .19 .11 .05 .02   +
+0000
 12 0000   +  .01 .03 .09 .18 .32 .48 .62 .67 .62 .48 .32 .18 .09 .03 .01
+0000
 13 0000   +  .01 .05 .13 .27 .48 .72 .93 1.0 .93 .72 .48 .27 .13 .05 .01
+0000
 14 0000   +  .02 .06 .16 .34 .61 .92 1.1 1.2 1.1 .92 .61 .34 .16 .06 .02
+0000
 15 0000   +  .02 .07 .17 .36 .66 1.0 1.3 1.4 1.3 1.0 .66 .36 .17 .07 .02
+0000
 16 0000   +  .02 .06 .15 .33 .61 .93 1.2 1.3 1.2 .93 .61 .33 .15 .06 .02
+0000
 17 0000   +  .01 .04 .12 .26 .47 .73 .94 1.0 .94 .73 .47 .26 .12 .04 .01
+0000
 18 0000   +  .01 .03 .08 .17 .31 .48 .62 .68 .62 .48 .31 .17 .08 .03 .01
+0000
 19 0000   +   +  .01 .04 .09 .17 .26 .34 .37 .34 .26 .17 .09 .04 .01   +
+0000
 20 0000   +   +   +  .02 .04 .08 .12 .16 .17 .16 .12 .08 .04 .02   +   +
+0000
 21 0000   +   +   +   +  .01 .03 .05 .06 .07 .06 .05 .03 .01   +   +   +
+0000
 22 0000   +   +   +   +   +  .01 .01 .02 .02 .02 .01 .01   +   +   +   +
+0000
 23 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
```

```
 24 OOOO    .    .    .    +    +    +    +    +    +    +    +    +    +    +    .    .
.OOOO
 25 OOOO    .    .    .    .    .    +    +    +    +    +    +    +    .    .    .    .
.OOOO
 26 OOOO    0    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
OOOOO
 27 OOOO    0    0    0    .    .    .    .    .    .    .    .    .    .    .    0    0
OOOOO
 28 OOOO    0    0    0    0    0    0    0    .    .    .    0    0    0    0    0    0
OOOOO
 29 OOOO    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
OOOOO
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

SMALL CLOUDS AT 900.00 SECONDS ELAPSED TIME FOR CLAY

CLOUD #	LOCATION OF CLOUD CENTROID: DISTANCE FROM TOP OF GRID (FT)	DISTANCE FROM LEFT OF GRID (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF CLOUD VERT. SOLIDS FALL THICKNESS (FT)	TOP OF CLOUD VELOCITY (FPS)
1	662.2	500.0	0.6249	0.0000E+00	110.3	5.977	37.63
0.340000E-04							
2	662.3	500.0	0.5749	0.0000E+00	132.8	41.35	46.28
0.340000E-04							
3	662.3	500.0	0.3704	0.0000E+00	150.8	85.37	38.31
0.340000E-04							
4	662.4	500.0	0.9505	0.0000E+00	208.6	121.4	27.36
0.340000E-04							
5	662.5	500.0	0.8000	0.0000E+00	289.4	146.5	14.48
0.340000E-04							
6	662.6	500.0	0.4127	0.0000E+00	354.5	157.0	5.288
0.340000E-04							
7	662.8	500.0	0.2179	0.0000E+00	399.2	159.8	2.503
0.340000E-04							
8	663.0	500.0	0.1291	0.0000E+00	430.2	161.0	1.284
0.340000E-04							
9	663.3	500.0	0.8826E-01	0.0000E+00	453.6	161.4	0.9478
0.340000E-04							
10	663.6	500.0	0.6712E-01	0.0000E+00	472.9	161.6	0.7825
0.340000E-04							
11	663.6	500.0	49.22	0.0000E+00	474.1	153.9	8.431
0.810023E-04							

SUMMARY OF CLAY DISTRIBUTIONS AFTER 1200.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.338
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.66131

SUMMARY OF CLAY DISTRIBUTIONS AFTER 1500.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.241
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.75843

SUMMARY OF CLAY DISTRIBUTIONS AFTER 1800.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.160
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.83899

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
1800.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

M N=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
6	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
7	O	O	O	O	O	.	.	.	.	.	.	.	O	O	O	O	O	O	O
8	O	O	O	O	.	.	+	+	+	+	+	.	.	O	O	O	O	O	O
9	O	O	O	.	.	+	+	.01	.02	.01	+	+	.	.	O	O	O	O	O
10	O	O	O	.	+	+	.05	.15	.23	.15	.05	+	+	.	O	O	O	O	O
11	O	O	.	.	+	.03	.22	.69	1.0	.69	.22	.03	+	.	.	O	O	O	O
12	O	O	.	+	+	.06	.45	1.4	2.0	1.4	.45	.06	+	+	.	O	O	O	O
13	O	O	.	+	+	.06	.43	1.3	1.9	1.3	.43	.06	+	+	.	O	O	O	O
14	O	O	.	.	+	.03	.19	.61	.89	.61	.19	.03	+	.	.	O	O	O	O
15	O	O	O	.	+	+	.04	.13	.19	.13	.04	+	+	.	O	O	O	O	O
16	O	O	O	.	.	+	+	.01	.01	.01	+	+	.	.	O	O	O	O	O
17	O	O	O	O	.	.	+	+	+	+	+	.	.	O	O	O	O	O	O
18	O	O	O	O	O	O	.	.	.	.	.	O	O	O	O	O	O	O	O
19	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
20	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

```
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
1800.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  5 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
  6 0000   0   0   0   0   0   0   0   .   .   .   .   0   0   0   0   0
00000
  7 0000   0   0   0   0   0   .   .   +   +   +   .   .   .   0   0   0
00000
  8 0000   0   0   0   .   .   +   +   +   +   +   +   +   .   .   0   0
00000
  9 0000   0   0   .   .   +   +  .01 .02 .03 .02 .01   +   +   .   .   0
00000
 10 0000   0   0   .   +   +  .01 .06 .15 .21 .15 .06 .01   +   +   .   0
00000
 11 0000   0   0   .   +   +  .04 .20 .52 .71 .52 .20 .04   +   +   .   0
00000
 12 0000   0   .   .   +   +  .07 .37 .94 1.2 .94 .37 .07   +   +   .   .
00000
 13 0000   0   .   .   +   +  .07 .36 .91 1.2 .91 .36 .07   +   +   .   .
00000
 14 0000   0   0   .   +   +  .04 .18 .47 .64 .47 .18 .04   +   +   .   0
00000
 15 0000   0   0   .   .   +  .01 .05 .13 .18 .13 .05 .01   +   .   .   0
00000
 16 0000   0   0   .   .   +   +   + .02 .02 .02   +   +   +   .   .   0
```

```
00000
 17 0000   0   0   0   .   .   +   +   +   +   +   +   +   .   .   0   0
00000
 18 0000   0   0   0   0   .   .   .   .   +   .   .   .   .   0   0   0
00000
 19 0000   0   0   0   0   0   0   .   .   .   .   .   0   0   0   0   0
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO

     MAX CONC IS 0.00000000 OUTPUT SUPPRESSED AT  165.00 FT

 BOTTOM ACCUMULATION OF CLAY      (CU FT/GRID SQUARE) ,   1800.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY  0.1000E-01      (LEGEND... + = .LT. .01
. = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
  4 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
  5 0000   +   +   +   +   + .01 .01 .01 .01 .01 .01 .01   +   +   +   +
+0000
  6 0000   +   +   + .01 .01 .02 .03 .03 .03 .03 .03 .02 .01 .01   +   +
+0000
  7 0000   +   + .01 .02 .03 .04 .06 .07 .08 .07 .06 .04 .03 .02 .01   +
+0000
  8 0000   + .01 .02 .03 .06 .09 .12 .14 .15 .14 .12 .09 .06 .03 .02 .01
+0000
  9 0000   + .01 .03 .06 .11 .16 .22 .27 .28 .27 .22 .16 .11 .06 .03 .01
+0000
 10 0000 .01 .02 .05 .10 .18 .27 .38 .46 .49 .46 .38 .27 .18 .10 .05 .02
.010000
 11 0000 .01 .03 .07 .15 .27 .43 .60 .73 .78 .73 .60 .43 .27 .15 .07 .03
.010000
 12 0000 .01 .04 .10 .21 .38 .61 .86 1.0 1.1 1.0 .86 .61 .38 .21 .10 .04
```

```
.010000
 13 0000 .02 .05 .12 .26 .48 .79 1.1 1.4 1.5 1.4 1.1 .79 .48 .26 .12 .05
.020000
 14 0000 .02 .05 .13 .28 .54 .91 1.3 1.6 1.7 1.6 1.3 .91 .54 .28 .13 .05
.020000
 15 0000 .02 .05 .13 .28 .54 .92 1.3 1.7 1.8 1.7 1.3 .92 .54 .28 .13 .05
.020000
 16 0000 .01 .04 .11 .24 .47 .81 1.2 1.5 1.6 1.5 1.2 .81 .47 .24 .11 .04
.010000
 17 0000 .01 .03 .08 .18 .36 .62 .92 1.1 1.2 1.1 .92 .62 .36 .18 .08 .03
.010000
 18 0000   + .02 .05 .11 .23 .40 .60 .76 .83 .76 .60 .40 .23 .11 .05 .02
+0000
 19 0000   + .01 .02 .06 .13 .22 .33 .42 .46 .42 .33 .22 .13 .06 .02 .01
+0000
 20 0000   +   + .01 .03 .06 .10 .15 .20 .21 .20 .15 .10 .06 .03 .01   +
+0000
 21 0000   +   +   + .01 .02 .04 .06 .08 .08 .08 .06 .04 .02 .01   +   +
+0000
 22 0000   +   +   +   +   + .01 .02 .02 .03 .02 .02 .01   +   +   +   +
+0000
 23 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
 24 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 25 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 26 0000   .   .   .   .   .   .   .   +   +   +   .   .   .   .   .   .
.0000
 27 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 28 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

SMALL CLOUDS AT 1800.00 SECONDS ELAPSED TIME FOR CLAY

CLOUD #	LOCATION OF CLOUD CENTROID DISTANCE FROM TOP OF GRID (FT)	DISTANCE FROM LEFT OF GRID (FT)	DEPTH OF CLOUD THICKNESS (FT)	CLOUD VERT. SOLIDS FALL VELOCITY (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)
1	572.2	500.0	0.6249	0.0000E+00	177.8	0.0000E+00	39.95
2	572.3	500.0	0.5749	0.0000E+00	204.2	30.77	48.60
3	572.3	500.0	0.3704	0.0000E+00	225.0	74.79	40.63
4	572.4	500.0	0.9505	0.0000E+00	290.6	110.8	29.68
5	572.5	500.0	0.8000	0.0000E+00	380.1	136.0	16.41
6	572.6	500.0	0.4107	0.0000E+00	451.2	146.4	6.421

```
   7        572.8          500.0       0.2158       0.0000E+00    499.6
149.2       3.636       0.340000E-04
   8        573.0          500.0       0.1270       0.0000E+00    533.0
150.4       2.417       0.340000E-04
   9        573.3          500.0      0.8644E-01    0.0000E+00    558.2
151.2       1.693       0.340000E-04
  10        573.6          500.0      0.6554E-01    0.0000E+00    578.8
151.4       1.528       0.340000E-04
  11        573.6          500.0       48.93        0.0000E+00    580.1
143.3       9.541       0.503191E-04
```

SUMMARY OF CLAY DISTRIBUTIONS AFTER 2100.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.090
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.90834

SUMMARY OF CLAY DISTRIBUTIONS AFTER 2400.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 53.030
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 0.96718

SUMMARY OF CLAY DISTRIBUTIONS AFTER 2700.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 52.976
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 1.0201

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
2700.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 OOOO   0   0   0   0   0   .   .   .   .   .   .   .   0   0   0   0
00000
  4 OOOO   0   0   0   .   .   .   +   +   +   +   +   .   .   .   0   0
00000
  5 OOOO   0   0   .   .   +   +   +   +   +   +   +   +   +   .   .   0
00000
  6 OOOO   0   .   .   +   +   +   + .01 .01 .01   +   +   +   +   .   .
00000
  7 OOOO   0   .   .   +   + .01 .04 .07 .08 .07 .04 .01   +   +   .   .
00000
  8 OOOO   .   .   +   + .01 .05 .14 .25 .30 .25 .14 .05 .01   +   +   .
.0000
```

```
  9 0000   .   .   +   + .03 .12 .32 .57 .69 .57 .32 .12 .03   +   +   .
.0000
 10 0000   .   .   +   + .04 .19 .50 .89 1.0 .89 .50 .19 .04   +   +   .
.0000
 11 0000   .   .   +   + .05 .20 .53 .95 1.1 .95 .53 .20 .05   +   +   .
.0000
 12 0000   .   .   +   + .03 .14 .38 .68 .82 .68 .38 .14 .03   +   +   .
.0000
 13 0000   .   .   +   + .01 .07 .18 .33 .40 .33 .18 .07 .01   +   +   .
.0000
 14 0000   0   .   +   +   + .02 .06 .11 .13 .11 .06 .02   +   +   +   .
00000
 15 0000   0   .   .   +   +   + .01 .02 .03 .02 .01   +   +   +   .   .
00000
 16 0000   0   0   .   .   +   +   +   +   +   +   +   +   +   .   .   0
00000
 17 0000   0   0   0   .   .   .   +   +   +   +   +   .   .   .   0   0
00000
 18 0000   0   0   0   0   .   .   .   .   .   .   .   .   .   0   0   0
00000
 19 0000   0   0   0   0   0   0   0   .   .   .   0   0   0   0   0   0
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
2700.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0   +   .   .   .   .
00000
  4 0000   0   0   0   0   0   0   0   0   0   0   +   +   +   .   .   .
.0000
```

```
  5 0000   0   0   0   0   0   0   0   0   +   +   +   +   +   +   +   .
.0000
  6 0000   0   0   0   0   0   0   0 .02 .02 .02 .01   +   +   +   +   .
.0000
  7 0000   0   0   0   0   0 .02 .04 .06 .07 .06 .04 .02   +   +   +   +
.0000
  8 0000   0   0   +   + .02 .05 .10 .16 .18 .16 .10 .05 .02   +   +   +
.0000
  9 0000   +   +   + .01 .03 .09 .19 .30 .35 .30 .19 .09 .03 .01   +   +
+0000
 10 0000   +   +   + .01 .05 .13 .27 .42 .49 .42 .27 .13 .05 .01   +   +
+0000
 11 0000   +   +   + .01 .05 .14 .28 .44 .51 .44 .28 .14 .05 .01   +   +
+0000
 12 0000   +   +   + .01 .04 .11 .22 .34 .39 .34 .22 .11 .04 .01   +   +
+0000
 13 0000   .   +   +   + .02 .06 .13 .20 .23 .20 .13 .06 .02   +   +   +
.0000
 14 0000   .   +   +   + .01 .03 .06 .09 .10 .09 .06 .03 .01   +   +   +
.0000
 15 0000   .   +   +   +   + .01 .02 .03 .03 .03 .02 .01   +   +   +   +
.0000
 16 0000   .   .   +   +   +   +   +   + .01   +   +   +   +   +   +   .
.0000
 17 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 18 0000   0   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
00000
 19 0000   0   0   .   .   .   .   .   .   .   .   .   .   .   .   .   0
00000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
000000000000000000000000000000000000000000000000000000000000000000000000
0000

     MAX CONC IS 0.00000000 OUTPUT SUPPRESSED AT  165.00 FT

 BOTTOM ACCUMULATION OF CLAY      (CU FT/GRID SQUARE) ,   2700.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY  0.1000E-01      (LEGEND... + = .LT. .01
. = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
```

```
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000    +    +    +    + .01  .01  .01  .01  .02  .01  .01  .01  .01    +    +    +
+0000
  4 0000    +    +    + .01  .02  .02  .03  .03  .03  .03  .03  .02  .02  .01    +    +
+0000
  5 0000    +    + .01  .02  .03  .04  .05  .06  .06  .06  .05  .04  .03  .02  .01    +
+0000
  6 0000    + .01  .02  .04  .05  .07  .09  .10  .11  .10  .09  .07  .05  .04  .02  .01
+0000
  7 0000 .01  .02  .04  .06  .09  .12  .15  .18  .18  .18  .15  .12  .09  .06  .04  .02
.010000
  8 0000 .01  .03  .05  .09  .14  .19  .24  .28  .30  .28  .24  .19  .14  .09  .05  .03
.010000
  9 0000 .02  .04  .08  .13  .20  .29  .37  .44  .46  .44  .37  .29  .20  .13  .08  .04
.020000
 10 0000 .03  .05  .10  .18  .29  .42  .55  .66  .69  .66  .55  .42  .29  .18  .10  .05
.030000
 11 0000 .03  .07  .13  .24  .39  .58  .79  .94  1.0  .94  .79  .58  .39  .24  .13  .07
.030000
 12 0000 .03  .08  .16  .29  .50  .77  1.0  1.2  1.3  1.2  1.0  .77  .50  .29  .16  .08
.030000
 13 0000 .04  .08  .17  .33  .59  .93  1.3  1.6  1.7  1.6  1.3  .93  .59  .33  .17  .08
.040000
 14 0000 .03  .08  .18  .35  .64  1.0  1.4  1.8  1.9  1.8  1.4  1.0  .64  .35  .18  .08
.030000
 15 0000 .03  .07  .16  .33  .62  1.0  1.4  1.8  1.9  1.8  1.4  1.0  .62  .33  .16  .07
.030000
 16 0000 .02  .06  .13  .28  .53  .88  1.2  1.6  1.7  1.6  1.2  .88  .53  .28  .13  .06
.020000
 17 0000 .01  .04  .09  .20  .39  .66  .97  1.2  1.3  1.2  .97  .66  .39  .20  .09  .04
.010000
 18 0000 .01  .02  .06  .13  .25  .43  .63  .80  .87  .80  .63  .43  .25  .13  .06  .02
.010000
 19 0000    + .01  .03  .07  .14  .24  .35  .45  .48  .45  .35  .24  .14  .07  .03  .01
+0000
 20 0000    +    + .01  .03  .07  .11  .17  .21  .23  .21  .17  .11  .07  .03  .01    +
+0000
 21 0000    +    +    + .01  .02  .04  .07  .08  .09  .08  .07  .04  .02  .01    +    +
+0000
 22 0000    +    +    +    + .01  .01  .02  .03  .03  .03  .02  .01  .01    +    +    +
+0000
 23 0000    +    +    +    +    +    +    + .01  .01  .01    +    +    +    +    +    +
+0000
 24 0000    .    +    +    +    +    +    +    +    +    +    +    +    +    +    +    +
.0000
 25 0000    .    .    +    +    +    +    +    +    +    +    +    +    +    +    +    .
.0000
 26 0000    .    .    .    .    .    +    +    +    +    +    +    +    .    .    .    .
.0000
 27 0000    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
.0000
 28 0000    0    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
00000
 29 0000    0    0    0    .    .    .    .    .    .    .    .    .    .    .    0    0
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

SMALL CLOUDS AT 2700.00 SECONDS ELAPSED TIME FOR CLAY

LOCATION OF CLOUD CENTROID			MASS FROM	ENTRAINED	CLOUD X-Z
DEPTH OF CLOUD	CLOUD VERT. DISTANCE FROM	SOLIDS FALL	DISPOSAL	MASS	DIAMETER
TOP OF CLOUD	THICKNESS	VELOCITY			
#	TOP OF GRID	LEFT OF GRID	(CU FT)	(CU FT)	(FT)
(FT)	(FT)	(FPS)			
1	482.2	500.0	0.6249	0.0000E+00	255.8
0.0000E+00	42.28	0.340000E-04			
2	482.3	500.0	0.5749	0.0000E+00	285.6
21.38	50.93	0.340000E-04			
3	482.3	500.0	0.3704	0.0000E+00	308.8
65.40	42.96	0.340000E-04			
4	482.4	500.0	0.9505	0.0000E+00	381.4
101.5	32.01	0.340000E-04			
5	482.5	500.0	0.7995	0.0000E+00	478.9
126.6	17.98	0.340000E-04			
6	482.6	500.0	0.4090	0.0000E+00	555.6
137.0	7.554	0.340000E-04			
7	482.8	500.0	0.2143	0.0000E+00	607.4
139.8	4.768	0.340000E-04			
8	483.0	500.0	0.1258	0.0000E+00	643.0
141.1	3.550	0.340000E-04			
9	483.3	500.0	0.8532E-01	0.0000E+00	669.9
141.8	2.826	0.340000E-04			
10	483.6	500.0	0.6462E-01	0.0000E+00	691.8
142.0	2.661	0.340000E-04			
11	483.6	500.0	48.76	0.0000E+00	693.2
134.0	10.67	0.369681E-04			

SUMMARY OF CLAY DISTRIBUTIONS AFTER 3000.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 52.930
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 1.0642

SUMMARY OF CLAY DISTRIBUTIONS AFTER 3300.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 52.883
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 1.1093

SUMMARY OF CLAY DISTRIBUTIONS AFTER 3600.00 SEC.

TOTAL SUSPENDED MATERIAL (CU FT) = 52.837
TOTAL MATERIAL SETTLED TO BOTTOM (CU FT) = 1.1524

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
3600.00 SECONDS AFTER DUMP

50.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01
. = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 OOOO   0   0   0   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.OOOO
  4 OOOO   .   +   +   +   + .01 .01 .02 .02 .02 .01 .01   +   +   +   +
.OOOO
  5 OOOO   .   +   +   + .01 .02 .05 .07 .07 .07 .05 .02 .01   +   +   +
.OOOO
  6 OOOO   +   +   + .01 .02 .06 .10 .14 .16 .14 .10 .06 .02 .01   +   +
+OOOO
  7 OOOO   +   +   + .01 .04 .10 .17 .25 .27 .25 .17 .10 .04 .01   +   +
+OOOO
  8 OOOO   +   +   + .02 .06 .13 .24 .33 .37 .33 .24 .13 .06 .02   +   +
+OOOO
  9 OOOO   +   +   + .02 .06 .14 .26 .36 .40 .36 .26 .14 .06 .02   +   +
+OOOO
 10 OOOO   +   +   + .02 .05 .12 .22 .31 .35 .31 .22 .12 .05 .02   +   +
+OOOO
 11 OOOO   +   +   + .01 .04 .08 .15 .21 .24 .21 .15 .08 .04 .01   +   +
+OOOO
 12 OOOO   +   +   +   + .02 .04 .08 .12 .13 .12 .08 .04 .02   +   +   +
+OOOO
 13 OOOO   .   +   +   + .01 .02 .03 .05 .05 .05 .03 .02 .01   +   +   +
.OOOO
 14 OOOO   .   +   +   +   +   + .01 .01 .02 .01 .01   +   +   +   +   +
.OOOO
 15 OOOO   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.OOOO
 16 OOOO   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.OOOO
 17 OOOO   0   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
0OOOO
 18 OOOO   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
0OOOO
 19 OOOO   0   0   0   0   0   .   .   .   .   .   .   .   0   0   0   0
0OOOO
 20 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 21 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 22 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 23 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 24 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 25 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 26 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
 27 OOOO   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0OOOO
```

```
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
0000000000000000000000000000000000000000000000000000000000000000000000
0000
```

CONCENTRATIONS ABOVE BACKGROUND OF CLAY (MG/L) IN THE CLOUD
3600.00 SECONDS AFTER DUMP

100.00 FT BELOW THE WATER SURFACE

```
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   0   0   0   0   0   0   0   0   0   0   0 .04 .02 .01   +   +
+0000
  4 0000   0   0   0   0   0   0   0   0   0   0 .13 .09 .05 .03 .01   +
+0000
  5 0000   0   0   0   0   0   0   0   0 .32 .30 .24 .17 .10 .05 .02 .01
+0000
  6 0000   0   0   0   0   0   0   0 .47 .51 .47 .38 .27 .17 .09 .04 .01
+0000
  7 0000   0   0   0   0   0 .38 .53 .65 .70 .65 .53 .38 .23 .12 .05 .02
+0000
  8 0000   0   0 .07 .15 .28 .45 .64 .79 .85 .79 .64 .45 .28 .15 .07 .02
.010000
  9 0000 .01 .03 .07 .15 .29 .48 .67 .83 .89 .83 .67 .48 .29 .15 .07 .03
.010000
 10 0000 .01 .02 .06 .14 .27 .43 .61 .76 .81 .76 .61 .43 .27 .14 .06 .02
.010000
 11 0000   + .02 .05 .11 .21 .34 .49 .60 .65 .60 .49 .34 .21 .11 .05 .02
+0000
 12 0000   + .01 .03 .08 .15 .24 .34 .42 .45 .42 .34 .24 .15 .08 .03 .01
+0000
 13 0000   +   + .02 .04 .09 .14 .20 .25 .27 .25 .20 .14 .09 .04 .02   +
+0000
 14 0000   +   + .01 .02 .04 .07 .10 .13 .14 .13 .10 .07 .04 .02 .01   +
+0000
 15 0000   +   +   + .01 .02 .03 .05 .06 .06 .06 .05 .03 .02 .01   +   +
+0000
 16 0000   +   +   +   +   + .01 .02 .02 .02 .02 .02 .01   +   +   +   +
+0000
 17 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
 18 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
 19 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 20 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 21 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 22 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 23 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
```

```
 24 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 25 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 26 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 27 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO

     MAX CONC IS 0.00000000 OUTPUT SUPPRESSED AT  165.00 FT

 BOTTOM ACCUMULATION OF CLAY      (CU FT/GRID SQUARE) ,   3600.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY  0.1000E-01      (LEGEND... + = .LT. .01
. = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   + .01 .02 .02 .03 .04 .05 .05 .06 .05 .05 .04 .03 .02 .02 .01
+0000
  4 0000 .01 .02 .03 .04 .05 .07 .08 .09 .09 .09 .08 .07 .05 .04 .03 .02
.010000
  5 0000 .01 .02 .04 .06 .08 .10 .12 .13 .13 .13 .12 .10 .08 .06 .04 .02
.010000
  6 0000 .02 .04 .06 .08 .11 .14 .17 .19 .20 .19 .17 .14 .11 .08 .06 .04
.020000
  7 0000 .03 .05 .08 .11 .16 .20 .25 .28 .29 .28 .25 .20 .16 .11 .08 .05
.030000
  8 0000 .03 .06 .10 .15 .21 .28 .35 .40 .41 .40 .35 .28 .21 .15 .10 .06
.030000
  9 0000 .04 .07 .12 .19 .28 .39 .49 .56 .59 .56 .49 .39 .28 .19 .12 .07
.040000
 10 0000 .05 .09 .15 .24 .37 .52 .67 .78 .82 .78 .67 .52 .37 .24 .15 .09
.050000
 11 0000 .05 .10 .18 .30 .47 .68 .89 1.0 1.1 1.0 .89 .68 .47 .30 .18 .10
.050000
 12 0000 .05 .10 .20 .35 .57 .85 1.1 1.3 1.4 1.3 1.1 .85 .57 .35 .20 .10
.050000
 13 0000 .05 .11 .21 .38 .65 1.0 1.3 1.7 1.8 1.7 1.3 1.0 .65 .38 .21 .11
.050000
 14 0000 .05 .10 .20 .39 .68 1.0 1.5 1.9 2.0 1.9 1.5 1.0 .68 .39 .20 .10
.050000
 15 0000 .04 .09 .18 .36 .65 1.0 1.5 1.9 2.0 1.9 1.5 1.0 .65 .36 .18 .09
.040000
 16 0000 .03 .07 .15 .30 .55 .91 1.3 1.6 1.7 1.6 1.3 .91 .55 .30 .15 .07
.030000
 17 0000 .02 .05 .11 .22 .41 .69 1.0 1.2 1.3 1.2 1.0 .69 .41 .22 .11 .05
.020000
 18 0000 .01 .03 .07 .14 .26 .44 .65 .82 .89 .82 .65 .44 .26 .14 .07 .03
.010000
 19 0000   + .01 .04 .08 .15 .25 .36 .46 .49 .46 .36 .25 .15 .08 .04 .01
+0000
```

```
 20 0000   +   + .02 .04 .07 .12 .17 .22 .23 .22 .17 .12 .07 .04 .02   +
+0000
 21 0000   +   +   + .01 .03 .05 .07 .09 .09 .09 .07 .05 .03 .01   +   +
+0000
 22 0000   +   +   +   + .01 .01 .02 .03 .03 .03 .02 .01 .01   +   +   +
+0000
 23 0000   +   +   +   +   +   +   + .01 .01 .01   +   +   +   +   +   +
+0000
 24 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
 25 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
 26 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 27 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
.0000
 28 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
.0000
 29 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
.0000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

SMALL CLOUDS AT 3600.00 SECONDS ELAPSED TIME FOR CLAY

CLOUD #	LOCATION OF CLOUD CENTROID: TOP OF GRID (FT)	LEFT OF GRID (FPS)	MASS FROM DISPOSAL (CU FT)	ENTRAINED MASS (CU FT)	CLOUD X-Z DIAMETER (FT)	DEPTH OF CLOUD (FT)	VERT. DISTANCE FROM TOP OF CLOUD (FT)	SOLIDS FALL THICKNESS (FT)	VELOCITY
1	392.2	500.0	0.6249	0.0000E+00	343.1	0.0000E+00	44.60	0.340000E-04	
2	392.3	500.0	0.5749	0.0000E+00	376.0	7.646	53.25	0.340000E-04	
3	392.3	500.0	0.3704	0.0000E+00	401.4	51.67	45.28	0.340000E-04	
4	392.4	500.0	0.9505	0.0000E+00	480.3	87.73	34.33	0.340000E-04	
5	392.5	500.0	0.7982	0.0000E+00	585.3	112.8	19.11	0.340000E-04	
6	392.6	500.0	0.4075	0.0000E+00	667.1	123.3	8.686	0.340000E-04	
7	392.8	500.0	0.2131	0.0000E+00	722.2	126.1	5.901	0.340000E-04	
8	393.0	500.0	0.1249	0.0000E+00	759.9	127.3	4.682	0.340000E-04	
9	393.3	500.0	0.8454E-01	0.0000E+00	788.3	128.5	3.572	0.340000E-04	
10	393.6	500.0	0.6400E-01	0.0000E+00	811.5	128.7	3.406	0.340000E-04	
11	393.6	500.0	48.62	0.0000E+00	812.9	120.3	11.80	0.340000E-04	

BOTTOM ACCUMULATION OF CLAY (CU FT/GRID SQUARE) , 3600.00 SECONDS AFTER DUMP
...MULTIPLY DISPLAYED VALUES BY 0.1000E-01 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 OOOO   + .01 .02 .02 .03 .04 .05 .05 .06 .05 .05 .04 .03 .02 .02 .01
+OOOO
  4 OOOO .01 .02 .03 .04 .05 .07 .08 .09 .09 .09 .08 .07 .05 .04 .03 .02
.010OOO
  5 OOOO .01 .02 .04 .06 .08 .10 .12 .13 .13 .13 .12 .10 .08 .06 .04 .02
.010OOO
  6 OOOO .02 .04 .06 .08 .11 .14 .17 .19 .20 .19 .17 .14 .11 .08 .06 .04
.020OOO
  7 OOOO .03 .05 .08 .11 .16 .20 .25 .28 .29 .28 .25 .20 .16 .11 .08 .05
.030OOO
  8 OOOO .03 .06 .10 .15 .21 .28 .35 .40 .41 .40 .35 .28 .21 .15 .10 .06
.030OOO
  9 OOOO .04 .07 .12 .19 .28 .39 .49 .56 .59 .56 .49 .39 .28 .19 .12 .07
.040OOO
 10 OOOO .05 .09 .15 .24 .37 .52 .67 .78 .82 .78 .67 .52 .37 .24 .15 .09
.050OOO
 11 OOOO .05 .10 .18 .30 .47 .68 .89 1.0 1.1 1.0 .89 .68 .47 .30 .18 .10
.050OOO
 12 OOOO .05 .10 .20 .35 .57 .85 1.1 1.3 1.4 1.3 1.1 .85 .57 .35 .20 .10
.050OOO
 13 OOOO .05 .11 .21 .38 .65 1.0 1.3 1.7 1.8 1.7 1.3 1.0 .65 .38 .21 .11
.050OOO
 14 OOOO .05 .10 .20 .39 .68 1.0 1.5 1.9 2.0 1.9 1.5 1.0 .68 .39 .20 .10
.050OOO
 15 OOOO .04 .09 .18 .36 .65 1.0 1.5 1.9 2.0 1.9 1.5 1.0 .65 .36 .18 .09
.040OOO
 16 OOOO .03 .07 .15 .30 .55 .91 1.3 1.6 1.7 1.6 1.3 .91 .55 .30 .15 .07
.030OOO
 17 OOOO .02 .05 .11 .22 .41 .69 1.0 1.2 1.3 1.2 1.0 .69 .41 .22 .11 .05
.020OOO
 18 OOOO .01 .03 .07 .14 .26 .44 .65 .82 .89 .82 .65 .44 .26 .14 .07 .03
.010OOO
 19 OOOO   + .01 .04 .08 .15 .25 .36 .46 .49 .46 .36 .25 .15 .08 .04 .01
+OOOO
 20 OOOO   +   + .02 .04 .07 .12 .17 .22 .23 .22 .17 .12 .07 .04 .02   +
+OOOO
 21 OOOO   +   +   + .01 .03 .05 .07 .09 .09 .09 .07 .05 .03 .01   +   +
+OOOO
 22 OOOO   +   +   +   + .01 .01 .02 .03 .03 .03 .02 .01 .01   +   +   +
+OOOO
 23 OOOO   +   +   +   +   +   +   + .01 .01 .01   +   +   +   +   +   +
+OOOO
 24 OOOO   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+OOOO
 25 OOOO   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.OOOO
 26 OOOO   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.OOOO
 27 OOOO   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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 28 OOOO   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
.OOOO
 29 OOOO   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
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˅
 THICKNESS (FT) OF CLAY      ACCUMULATED ON BOTTOM,      3600.00 SECONDS
AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY  0.1000E-04      (LEGEND... + = .LT. .01
. = .LT. .0001    0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
00000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000 .01 .02 .02 .04 .05 .06 .07 .08 .08 .08 .07 .06 .05 .04 .02 .02
.010000
  4 0000 .01 .02 .04 .06 .07 .09 .11 .12 .13 .12 .11 .09 .07 .06 .04 .02
.010000
  5 0000 .02 .04 .06 .08 .11 .14 .17 .18 .19 .18 .17 .14 .11 .08 .06 .04
.020000
  6 0000 .03 .05 .08 .12 .16 .20 .24 .27 .28 .27 .24 .20 .16 .12 .08 .05
.030000
  7 0000 .04 .07 .11 .16 .22 .29 .35 .39 .41 .39 .35 .29 .22 .16 .11 .07
.040000
  8 0000 .05 .09 .14 .21 .30 .40 .49 .56 .58 .56 .49 .40 .30 .21 .14 .09
.050000
  9 0000 .06 .11 .18 .27 .40 .54 .68 .78 .82 .78 .68 .54 .40 .27 .18 .11
.060000
 10 0000 .07 .12 .21 .34 .52 .73 .93 1.0 1.1 1.0 .93 .73 .52 .34 .21 .12
.070000
 11 0000 .07 .14 .25 .42 .65 .95 1.2 1.4 1.5 1.4 1.2 .95 .65 .42 .25 .14
.070000
 12 0000 .08 .15 .28 .49 .79 1.1 1.6 1.9 2.0 1.9 1.6 1.1 .79 .49 .28 .15
.080000
 13 0000 .07 .15 .29 .53 .91 1.4 1.9 2.3 2.5 2.3 1.9 1.4 .91 .53 .29 .15
.070000
 14 0000 .07 .14 .29 .54 .96 1.5 2.1 2.6 2.8 2.6 2.1 1.5 .96 .54 .29 .14
.070000
 15 0000 .06 .12 .26 .51 .92 1.4 2.1 2.6 2.8 2.6 2.1 1.4 .92 .51 .26 .12
.060000
 16 0000 .04 .10 .21 .42 .78 1.2 1.8 2.3 2.5 2.3 1.8 1.2 .78 .42 .21 .10
.040000
 17 0000 .03 .07 .15 .31 .58 .96 1.4 1.7 1.9 1.7 1.4 .96 .58 .31 .15 .07
.030000
 18 0000 .02 .04 .09 .20 .37 .62 .91 1.1 1.2 1.1 .91 .62 .37 .20 .09 .04
.020000
 19 0000 .01 .02 .05 .11 .21 .35 .51 .64 .69 .64 .51 .35 .21 .11 .05 .02
.010000
 20 0000   + .01 .02 .05 .10 .17 .24 .31 .33 .31 .24 .17 .10 .05 .02 .01
+0000
 21 0000   +   + .01 .02 .04 .07 .10 .12 .13 .12 .10 .07 .04 .02 .01   +
+0000
 22 0000   +   +   +   + .01 .02 .03 .04 .05 .04 .03 .02 .01   +   +   +
+0000
 23 0000   +   +   +   +   +   + .01 .01 .01 .01 .01   +   +   +   +   +
+0000
 24 0000   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
+0000
 25 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
 26 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
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 27 0000   .   .   .   .   .   .   +   +   +   +   +   .   .   .   .   .
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 28 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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 29 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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FINAL DISTRIBUTIONS OF TOTAL SETTLED MATERIAL FOLLOW.....

TOTAL ACCUMULATED SOLID VOLUME ON BOTTOM (CU FT/GRID SQR), 3600.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
0000000000000000000000000000000000000000000000000000000000000000000000
0000
  3 0000   +   +   + .01 .01 .02 .03 .04 .04 .04 .03 .02 .01 .01   +   +
+0000
  4 0000   +   + .01 .03 .05 .07 .10 .12 .13 .12 .10 .07 .05 .03 .01   +
+0000
  5 0000   + .02 .04 .08 .14 .22 .29 .35 .37 .35 .29 .22 .14 .08 .04 .02
+0000
  6 0000 .02 .05 .11 .22 .38 .58 .79 .95 1.0 .95 .79 .58 .38 .22 .11 .05
.020000
  7 0000 .05 .12 .27 .53 .92 1.4 1.9 2.4 2.5 2.4 1.9 1.4 .92 .53 .27 .12
.050000
  8 0000 .10 .26 .58 1.1 2.1 3.3 4.7 5.7 6.1 5.7 4.7 3.3 2.1 1.1 .58 .26
.100000
  9 0000 .19 .51 1.1 2.4 4.5 7.4  11  13  14  13  11 7.4 4.5 2.4 1.1 .51
.190000
 10 0000 .34 .91 2.2 4.7 9.1  15  23  29  31  29  23  15 9.1 4.7 2.2 .91
.340000
 11 0000 .54 1.5 3.8 8.6  17  30  45  57  63  57  45  30  17 8.6 3.8 1.5
.540000
 12 0000 .79 2.3 6.0  14  29  52  80 105 117 105  80  52  29  14 6.0 2.3
.790000
 13 0000 1.0 3.1 8.6  21  44  80 125 172 198 172 125  80  44  21 8.6 3.1
1.00000
 14 0000 1.2 3.8  11  27  58 107 170 242 291 242 170 107  58  27  11 3.8
1.20000
 15 0000 1.2 4.0  12  30  65 122 196 282 338 282 196 122  65  30  12 4.0
1.20000
 16 0000 1.1 3.6  11  28  62 116 188 264 306 264 188 116  62  28  11 3.6
1.10000
 17 0000 .84 2.8 8.5  22  49  93 149 203 228 203 149  93  49  22 8.5 2.8
.840000
 18 0000 .55 1.8 5.7  15  33  62  99 131 145 131  99  62  33  15 5.7 1.8
.550000
 19 0000 .31 1.0 3.2 8.3  19  35  55  72  79  72  55  35  19 8.3 3.2 1.0
.310000
 20 0000 .14 .50 1.5 3.9 8.7  16  26  34  37  34  26  16 8.7 3.9 1.5 .50
.140000
 21 0000 .06 .20 .60 1.5 3.4 6.4  10  13  14  13  10 6.4 3.4 1.5 .60 .20
.060000
 22 0000 .02 .06 .20 .52 1.1 2.1 3.2 4.3 4.7 4.3 3.2 2.1 1.1 .52 .20 .06
.020000
 23 0000   + .02 .05 .14 .31 .58 .90 1.1 1.2 1.1 .90 .58 .31 .14 .05 .02
+0000
```

```
 24 0000   +   + .01 .03 .07 .13 .21 .27 .30 .27 .21 .13 .07 .03 .01   +
+0000
 25 0000   +   +   +   + .01 .02 .04 .05 .05 .05 .04 .02 .01   +   +   +
+0000
 26 0000   .   +   +   +   +   +   +   + .01   +   +   +   +   +   +   +
.0000
 27 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 28 0000   .   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
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 29 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
```

TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM, 3600.00 SECONDS AFTER DUMP

...MULTIPLY DISPLAYED VALUES BY 1.000 (LEGEND... + = .LT. .01 . = .LT. .0001 0 = .LT. .000001)

```
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20
  2
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
OOOO
  3 0000   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
.0000
  4 0000   .   .   .   .   .   .   .   +   +   +   .   .   .   .   .   .
.0000
  5 0000   .   .   .   .   +   +   +   +   +   +   +   +   +   .   .   .
.0000
  6 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
  7 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
  8 0000   .   +   +   +   +   +   +   +   +   +   +   +   +   +   +   +
.0000
  9 0000   +   +   +   +   +   +   + .01 .01 .01   +   +   +   +   +   +
+0000
 10 0000   +   +   +   +   + .01 .02 .02 .02 .02 .02 .01   +   +   +   +
+0000
 11 0000   +   +   +   + .01 .02 .03 .05 .05 .05 .03 .02 .01   +   +   +
+0000
 12 0000   +   +   + .01 .02 .04 .07 .09 .10 .09 .07 .04 .02 .01   +   +
+0000
 13 0000   +   +   + .01 .03 .07 .11 .15 .17 .15 .11 .07 .03 .01   +   +
+0000
 14 0000   +   +   + .02 .05 .09 .15 .21 .25 .21 .15 .09 .05 .02   +   +
+0000
 15 0000   +   + .01 .02 .05 .10 .17 .25 .29 .25 .17 .10 .05 .02 .01   +
+0000
 16 0000   +   +   + .02 .05 .10 .16 .23 .27 .23 .16 .10 .05 .02   +   +
+0000
 17 0000   +   +   + .01 .04 .08 .13 .18 .20 .18 .13 .08 .04 .01   +   +
+0000
 18 0000   +   +   + .01 .02 .05 .08 .11 .12 .11 .08 .05 .02 .01   +   +
+0000
 19 0000   +   +   +   + .01 .03 .04 .06 .07 .06 .04 .03 .01   +   +   +
+0000
 20 0000   +   +   +   +   + .01 .02 .02 .03 .02 .02 .01   +   +   +   +
+0000
```

```
 21 0000   .   +   +   +   +   +   + .01 .01 .01   +   +   +   +   +   +
.0000
 22 0000   .   .   +   +   +   +   +   +   +   +   +   +   +   +   +   .
.0000
 23 0000   .   .   .   +   +   +   +   +   +   +   +   +   +   +   .   .
.0000
 24 0000   .   .   .   .   .   +   +   +   +   +   +   +   .   .   .   .
.0000
 25 0000   0   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
00000
 26 0000   0   0   0   .   .   .   .   .   .   .   .   .   .   .   0   0
00000
 27 0000   0   0   0   0   0   0   .   .   .   .   .   0   0   0   0   0
00000
 28 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 29 0000   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
00000
 30
OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO
0000

     *** RUN COMPLETED ***
```

ATTACHMENT D-2

- **Calculations of Off-Site Transport in RA2a, RA2b, and RA4**
- **Evaluation of RA5 Offset Near RA4/RA5 Boundary**

RA2a Tail Geometry

RA2a cap thickness:	4.50 ft		includes overplacement

Tail Geometry of cap: Assume Triangular at 10:1 slope

distance	0	45.00
height	4.50	0.00

Area = 1/2 (base x height)

Area = 101.25 SF

Linear edge of cap in RA2a:	750	ft
Affected Plan View Area	33750	SF
Tail Volume:	**2813**	**CY**

RA2b Tail Geometry

RA2b cap thickness:	3.50 ft		includes overplacement

Tail Geometry of cap: Assume Triangular at 10:1 slope

distance	0	35.00
height	3.50	0.00

Area = 1/2 (base x height)

Area = 61.25 SF

Linear edge of cap in RA2b:	650	ft
Affected Plan View Area	22750	SF
Tail Volume:	**1475**	**CY**

RA4 Tail Volumes

Tail Geometry from STFATE Run 4

distance	0	50	100	150	200 ft
height	0.76	0.53	0.22	0.05	0.01 ft

Simpson's Rule: Area = dx/3[y1+4y2+2y3+4y4+y5]

Area = 58.8 SF

RA4 cap thickness: [redacted] 3.50 ft includes overplacement allowance- conservative assumption for quantity estimation

Tail Geometry of RA4 cap

distance	0	50	100	150	200 ft
height	3.50	2.44	1.01	0.23	0.05 ft

Simpson's Rule: Area = dx/3[y1+4y2+2y3+4y4+y5]

Area = 270.9 SF

OFFSITE TRANSPORT:

Linear edge of cap in RA4:	[redacted] 1040 ft
Affected Plan View Area	156000 SF
Tail Volume (outside cap boundaries):	**10436 CY**

TRANSPORT INTO RA5

Linear edge of cap on RA4/RA5 Boundary:	[redacted] 1480 ft
Affected Plan View Area	222000 SF
STFATE Tail Volume (deposition into RA5):	**14852 CY**
Downslope movement contingency (20%)	2970 CY
TOTAL Tail Volume (deposition into RA5):	**17822 CY**

RA5 OFFSET: Evaluate Offset for RA5 Placement Locations

Assumed RA 4 cap thickness at RA5 boundary: [redacted] ft (assumes minimum RA4 cap thickness is met at boundary)

RA5 Mean Mound Height (away from RA4 effects) 2.54 ft

50 Foot Offset						
distance into RA5	0	50	100	150	200 ft	
Tail height from RA4	2.50	1.74	0.72	0.16	0.03 ft	
Mound height from RA 5 placement nodes	1.845	2.3175	2.475	2.3625	2.565 ft	assumes 50 ft offset
Total Mound height in RA 5	**4.35**	**4.06**	**3.20**	**2.53**	**2.60 ft**	**(See note 1)**
100 Foot Offset						
distance into RA5	0	50	100	150	200 ft	
Tail height from RA4	2.50	1.74	0.72	0.16	0.03 ft	
Mound height from RA 5 placement nodes	1.2375	1.845	2.3175	2.475	2.3625 ft	assumes 100 ft offset
Total Mound height in RA 5	**3.74**	**3.59**	**3.04**	**2.64**	**2.40 ft**	**(See note 1)**
150 Foot Offset						
distance into RA5	0	50	100	150	200 ft	
Tail height from RA4	2.50	1.74	0.72	0.16	0.03 ft	
Mound height from RA 5 placement nodes	0.81	1.2375	1.845	2.3175	2.475 ft	assumes 150 ft offset
Total Mound height in RA 5	**3.31**	**2.98**	**2.57**	**2.48**	**2.51 ft**	**(See note 1)**

Notes:

(1) - compare predicted total mound height to estimated mean mound height in RA5 (2.54 feet)

CONCLUSION: 100 foot offset gives modeled mound heights approximately 1 foot greater than the RA5 mean over an area about 100 feet wide along the RA4/RA5 boundary
This offset provides a measure of safety in the event that the RA4 cap material does not extend as far into RA5 as predicted by STFATE

Appendix E

APPENDIX E

VALUE ENGINEERING ANALYSIS

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APPENDIX E

VALUE ENGINEERING ANALYSIS

Value engineering assesses cap design and proposed construction approaches to ensure that the project can be successfully completed in a cost effective manner. This involves examining alternative means, methods, materials, and design approaches to potentially develop more cost effective design elements during the design process. The value engineering analysis evaluates the following technical design issues.

- **Section E.1: Use of Dredged Material.** This section considered the use of dredged material for construction of the cap in RA2b, RA4 and RA5. In particular, the analysis compared two alternatives for the use of dredged material and upland material in RA2b and RA4. Specific factors considered by the analysis included: ability to place materials using controlled methods; amount of materials required; cost; and impact on project schedule.

- **Section E.2: Material Placement Methods.** The design is based on performance based specifications that encourage competitive bidding and facilitate use of innovative material placement methods.

- **Section E.3: Construction Monitoring.** A variety of approaches to construction quality assurance and construction quality control monitoring were compared. Specific factors considered included: compatibility with probable construction methodologies; ability of the approaches to demonstrate the design performance objectives; and cost.

- **Section E.4: Remediation Area Boundaries.** The boundaries of each RA have been revised from those presented in the 30 percent design. Particular attention has been paid to refining the footprint of each remedial area to minimize capping outside the ROD-required cap boundaries and maximize the area that may be capped using dredged material and bottom dumping techniques.

- **Section E.5: Dredged Material Disposal Options.** The ROD specifies that dredged material, removed as part of the remedy, be disposed of at a suitable upland facility. A second alternative, deposition of the dredged material into RA5 with subsequent capping, has also been considered. Factors evaluated include potential cost savings and potential impacts to the environment.

- **Section E.6: Material Specifications**. To the maximum extent practical, material specifications have been designed to correspond with upland materials that are readily available at local sources. Where possible, the use of more expensive material types has been minimized to avoid unnecessary expense.

Conclusions of these analyses are summarized in Section E.7.

E.1 USE OF DREDGED MATERIAL

Because dredged material is far cheaper to obtain than upland material, its use was considered in all areas where the dredged material can satisfactorily fulfill the cap functions. Specifically, dredged material can potentially meet the materials requirements for the cap in RA2b, RA4, and RA5. However, use of dredged material affects the remedy cost, schedule, and contracting strategy. Two alternatives were considered:

- **Alternative 1** – Use dredged material in RA5 only. Use upland material in RA1, RA2a, RA2b, RA3 and RA4.

- **Alternative 2** – Use dredged material in RA2b, RA4 and RA5. Use upland material in RA1, RA2a and RA3.

Note: The following analysis is based on quantities, unit rates, and specific schedule dates developed for the 30 percent design submittal, some of which have been refined and modified as the design progressed. Notwithstanding this, revision of the analysis to reflect the modified values was not considered necessary because the analysis is based on the comparison of two alternatives. As such, its conclusion will not be impacted by minor changes to material quantities, unit rates, and schedules. **Refer to the Basis of Design for all updated information on quantities, unit rates, and schedule associated with the design.**

E.1.1 Amount of Materials Required

The amount of materials required was calculated as described in Section 4 of the basis of design report. Table E-1 shows the quantities required to construct the capping system for Alternative 1 and Table E-2 shows the material quantities for Alternative 2.

For the purpose of this analysis, the quantity of material required to construct the caps in RA2b and RA4 was considered to be independent of the material type. In practice, a slightly thicker

(3-inch) cross section will be required if dredged material is used. The additional thickness is required to compensate for consolidation of the dredged materials after placement.

E.1.2 Cost

The only significant cost variable considered in this analysis is the cost of material delivered to the site. As described below, the material placement cost is assumed to be independent of whether upland or dredged material is selected.

Material Supply Costs

Note: Refer to Basis of Design for all updated information on unit costs. Unit rates for each upland material type were established based on communication with a supplier capable of providing material meeting the designated specifications at the required quantities (Middling 2002). Calculations of the estimated upland material unit rates are summarized in Table E-3. At this time, certain unit costs for upland products include allowances for potential amendments that may be required, primarily to adjust TOC or gradation to meet the materials specifications. These unit costs will be further refined during preparation of the engineers cost estimate as the design proceeds. The upland materials unit costs are considered sufficiently accurate to analyze the relative cost differential between the two alternatives, and to inform the decision regarding the use of upland materials in RA2b and RA4.

Estimated total material costs are presented in Table E-4. The costs are calculated based on the estimated unit rates developed for upland materials in Table E-3, and the material quantities calculated in Tables E-1 and E-2. Table E-4 presents the estimated material costs for Alternative 1 and Alternative 2, as well as a comparison of the costs for each material type. Table E-4 includes a unit rate of $2.00 per cubic yard (cy) for dredged material. Although purchase of this material is not required, this allowance is included as a material cost in an attempt to compensate for any modifications that may be required to USACE dredging contracts. The dredged material unit rate includes costs associated with higher bids for transport of material that normally would be disposed of at locations far from Elliott Bay. The costs associated with dredging the material would be borne by other projects, and are therefore not considering in the analysis.

The estimated costs are summarized as follows:

- Material Cost for Alternative 1 = $ 3,800,000
- Material Cost for Alternative 2 = $ 2,400,000
- Cost Difference = $ 1,400,000

The only costs that are considered in the above comparison between Alternative 1 and Alternative 2 are the estimated cost of dredged material and the estimated cost of sand cap mix delivered to the site. Factors such as lengthened project schedule and associated increased construction monitoring and administrative costs, have not been evaluated. These costs, together with cost differences derived from the different material placement methods, may significantly erode the potential cost advantage of Alternative 2.

Material Placement Costs

The above analysis assumes that the cost of material placement in RA2b and RA4 is independent of whether upland or dredged materials are used.

In practice, the method of material placement may depend on whether dredged material or upland material is used. Under Alternative 1, hydraulic washing from a flat-deck barge would be used or the contractor may propose an alternative placement method and this alternative method may be used if deemed acceptable. Under Alternative 2, numerous dredging contractors may be contracted to place the material through modifications to their existing dredge and disposal contracts. Thus, under Alternative 2, hydraulic washing from a flat-deck barge would be specified and no contractor options permitted.

Under Alternative 1, one construction contractor would be used and could be required to correct, through rework at its cost, any placement problems resulting from deviations from the specifications. This creates an incentive for careful adherence to the specifications. A primary concern under Alternative 2 is the potential lack of incentive for the dredge and disposal contractors to achieve careful placement.

E.1.3 Impact on Project Schedule

The impact of the two alternative approaches to project schedule was considered by developing a conceptual construction schedule for each of the alternatives. Figures E-1 and E-2 present representative construction schedules for Alternatives 1 and 2, respectively. These schedules are based on the analyses described below.

Upland Materials

The schedule for placement of upland materials was estimated based on the estimated material quantities and anticipated placement productivity rates. Based on discussion with a material supplier, it is anticipated that the rate of material placement, rather than material supply will control the schedule for use of upland materials. The durations for placement of upland materials

for each area, by upland material type, are shown in Tables E-1 and E-2 for Alternatives 1 and 2 respectively. The assumptions made in estimating the schedule of upland material placement include 20 working days in a month and assumed placement rates depending on material type and location.

Dredged Materials

The schedule for placement of dredged materials was estimated based on consideration of the following factors.

- The schedule for placement will be dependent upon the schedule of dredged material availability, including the year and month during which dredging is scheduled to be completed, and the fraction of the available material that will be suitable for use in the cap.

- It was assumed that placement of dredged material in RA2b and RA4 will be completed by one operation. That is, material will be placed from only one dredge source at any given time, and the caps in these areas are constructed consecutively. This is consistent with the assumptions made for placement of upland materials.

- For RA2b, a material placement rate of 40,000 cy per month was estimated based on production rates experienced at Eagle Harbor. For RA4, a reduced material placement rate of 26,000 cy per month was estimated due to the steep slopes in RA4. These material placement rates are consistent with those assumed for placement of upland materials in the same areas.

- For RA4 and RA2b, the volume of material available from each source was reduced based on the estimated placement rate relative to the estimated rate of dredging. For example, if the estimated material placement rate was half the dredging rate, it was assumed that only half the available and suitable material would actually be able to be used.

- For RA4 and RA2b, where the material placement rate is limited, it was assumed that only 75 percent of the material volume from sources that are only partially suitable for cap construction will be available. The remaining 25 percent will be lost due to schedule uncertainties.

- Dredged material placed in RA5 will be placed at a rate corresponding to the estimated dredging rate. All of the material available from each area was assumed to be available to RA5.

- It was assumed that all of the potential sources of dredged material considered, and which contained suitable material, were available for the PSR cap construction.

The schedule calculations for dredged material placement are presented in Table E-5.

Results

The estimated construction durations for RA2b and RA4, using upland material, per Alternative 1, and dredged material, per Alternative 2, are summarized following. The estimated years of construction are also shown. The duration for material placement in RA1, RA2a, RA3 and RA5 are unaffected by the two alternatives. However, the construction sequencing of these areas will vary as shown on the schedules.

Alternative 1

- Placement of upland material in RA2b = 0.6 months (during 2004)
- Placement of upland material in RA4 = 5 months (during 2004 and 2005)
- Project completion = December 2005

Alternative 2

- Placement of dredged material in RA2b = 0.6 months (during 2004)
- Placement of dredged material in RA4 = 5 months (during 2004, 2005, 2006 and 2008 – no dredged material will be available in 2007)
- Project completion = December 2008

As shown above, the dredged material availability has a significant impact on the ability of the project to be completed in a timely fashion if dredged material is used in RA2b and RA4.

E.2 MATERIAL PLACEMENT METHODS

Performance based specifications have been developed to describe the remedy for each RA. These specifications have been developed to allow flexibility with respect to material placement options. In general, one acceptable placement option is specified, and the contractor may

propose alternative methods as long as those methods meet the performance requirements (e.g., lift heights). By allowing contractors to use innovative material placement methods that are optimized to suit their own work methodologies, bidding of the work is anticipated to be more competitive and innovative approaches will be encouraged.

As discussed above, allowing the contractor to select the material placement method will also reinforce the contractor's responsibility for the resultant work product. That is, the contractor can be required to correct, at its own cost, any placement problems resulting from its selected placement methodology. This creates an incentive for careful adherence to the performance requirements of the specifications. Conversely, specification of a particular placement methodology could limit the contractors' incentive to achieve careful placement in the most cost-effective way.

In practice the most inexpensive material placement method will be bottom dumping of dredged sediments. As discussed in Section E.4, the design seeks to maximize the footprint of RA5, which is the only area that is suitable for capping by instantaneous release bottom dumping of sediments.

E.3 CONSTRUCTION MONITORING

The construction monitoring program for RA1 through RA4 (summarized in the Construction Quality Assurance Plan) has three principal data quality objectives (DQOs):

1. Confirm that the dredging and cap are constructed to the required dimensions

2. Confirm that intermixing of the sediments with the capping material is minimized to within acceptable limits

3. Confirm compliance with the sediment quality standards (SQS) at the cap surface

A variety of approaches for achieving these DQOs were considered. Specific consideration was given to identifying testing methodologies that would:

- Address multiple DQOs with one test method

- Coordinate with long-term monitoring requirements prescribed by the Operations and Maintenance Monitoring Plan

- Be cost effective
- Minimize extraneous data
- Not interfere with physical execution of the work
- Provide results in a timely fashion, such that corrective actions are identified quickly and with minimal impact to project schedule

Water quality monitoring is prescribed by the Water Quality Certification issued by EPA and as such was not subject to any value engineering analysis. Construction quality control monitoring of material placed within RA5 will be completed by the USACE and was similarly excluded from this analysis.

E.3.1 Bathymetry

Bathymetry surveys within the areas to be capped will confirm that the required cap dimensions are being achieved. In particular, measurements will confirm that the thickness of the cap is greater than minimum requirements and identify the presence of any slope failures that need to be addressed.

Single-beam differential bathymetry will be used wherever suitably accurate results can be obtained to confirm the dredging and cap construction have been completed to the required dimensions. The accuracy of the single beam methodology is reduced in areas of deep water and steep slopes. In areas where the accuracy of single-beam bathymetry survey may be compromised, additional visual observations, using either sediment profile imaging (SPI) or cores, will be used to supplement the available information.

Multi-beam differential bathymetry is more accurate than the single beam approach and is less susceptible to losses of accuracy in deep water or on steep slopes. The multi-beam methodology does, however, produce a large quantity of data that is both expensive and time consuming to manipulate. Therefore, multi-beam differential bathymetry will only be used to determine bathymetry before and after cap construction as part of the record drawings.

Sub-bottom profiling was also considered for survey of the capped surface bathymetry. Sub-bottom profiling can also be used to directly measure layer thicknesses. The accuracy of sub-bottom profiling is affected by the acoustic properties of the capping materials and underlying sediments, and the slope of the bottom. Sub-bottom profiling was recently used to successfully measure a relatively thin (1-foot thick) sand cap layer placed over dredged material at Puget

Sound Naval Shipyard (FWENC, 2002). However, the data analysis can be complex and time consuming, and data interpretation may be inconclusive. Sub-bottom profiling was therefore not included in the monitoring regime.

E.3.2 Visual Observations

Visual analysis will be used to confirm whether intermixing of capping material and underlying sediments is occurring during placement of the cap. Visual observations will be made using either:

1. Sediment profile imaging (SPI), inserted through the cap; or
2. Cores taken from the cap and underlying sediment.

SPI can rapidly obtain a relatively large number of snapshots of emplaced cap thickness, depth of intermixing, and locations of slope failures. SPI is, however, limited in that it can only obtain images of up to 8 inches of the cap cross section. Deep water and steep slopes will limit the accuracy of single beam differential bathymetry in RA4. Therefore, SPI will be used during placement of the critical first lift of cap material in RA4 to enable early assessment of where the Contractor's placement methods are adequate. When used in conjunction with other test methods, SPI is useful for confirming that intermixing is not occurring and identifying areas of slope failure.

Visual observations will also be made from cores. Cores will be taken through the full depth of the cap cross section and into to the underlying sediment. Visual observation of the cores will provide confirmation that the minimum required cap thickness is being achieved and that no significant intermixing of the capping material and sediments is occurring. All cores taken as part of the construction monitoring will be visually observed.

E.3.3 Chemical Analysis

Chemical analysis will be completed on samples taken from cores. At least two cores will be taken from each remedial area at a distribution of approximately 1 core per acre in RA1 to RA3, and 1 core per 2 acres in RA4. Additional cores can be taken, as necessary, to address specific concerns that may result from the bathymetric or SPI surveys. The results of the chemical analysis will be used to verify that concentrations of COCs in the top 4 inches of the cap do not exceed the SQS, as required by the ROD. They will also represent the baseline data used for long term monitoring.

Chemical analysis was also considered as a means for evaluating potential intermixing of contaminated substrate in the first cap layer. However, analysis turn-around-times would be such that this approach would interfere with the construction schedule. Visual observations are less expensive, provide more timely results and are considered to be sufficient for achieving this objective.

E.4 REMEDIATION AREAS

The boundaries of each RA have been revised from those presented in the 30 percent basis of design. Particular attention has been paid to refining the footprint of each remedial area and maximizing the area that may be capped using bottom dumping techniques.

E.4.1 RA Boundary Simplification

The Record of Decision (ROD)-specified cap boundaries are based on sediment chemistry and are irregular in shape. The 30 percent design included simplified, "squared off" remediation area boundaries to simplify constructibility. As a result, the 30 percent design capping area was 66 acres, compared to the ROD-specified capping area of 55 acres. Two major changes in the RA boundaries have been made to reduce unnecessary capping:

- RA5 perimeter capping boundaries have been re-defined to coincide with the ROD-specified boundaries. This change does not affect the required capping volume (since the placement method in RA5 occurs on a grid system and the placement target locations have always been within the ROD-specified boundaries). However, this re-definition more accurately reflects the RA5 cap design area.

- RA 1 through RA4 perimeter capping boundaries have been re-defined to more closely match the ROD-specified boundaries, while still remaining simplified enough to facilitate construction.

The result of these changes is that the design capping boundaries now encompass 58.3 acres. An actual reduction in cap materials requirements has been brought about by the changes in the RA1 through RA4 boundaries, as 1.7 fewer acres are targeted for capping. This corresponds to roughly an 8,000 CY reduction in the required capping material, which represents an approximate cost savings of $100,000.

E.4.2 Maximization of RA5 Area

In practice the most inexpensive material placement method will be bottom dumping of dredged sediments. Within the area required to be capped, the design seeks to maximize the footprint of RA5, which is the only area that is suitable for capping by instantaneous release bottom dumping of sediments. Further, bottom dumping of sediments to form the cap will be accomplished by modification to USACE contracts. Placement of dredged cap material in RA5 will have a relatively small cost associated with transporting and placing the dredged material at RA5, since this material would otherwise be disposed of by similar methods at open-water PSDDA sites.

Engineering analyses were used to define the RA4/RA5 boundary with consideration of the material types and placement methods to be used. Key parameters that were used to define this boundary are the load-bearing strength of the existing sediments and the modeled mound geometry for instantaneous bottom-dump placement. The RA4/RA5 boundary was located such that mound heights from instantaneous bottom-dump placement do not exceed the load-bearing strength of the sediments. Appendix D presents this analysis.

The result of this analysis is that the RA4/RA5 boundary is located as far shoreward as possible. RA5 as defined covers approximately 21.9 acres, whereas the total design capping area is approximately 58.3 acres. Thus, RA5 constitutes approximately 38 percent of the total design capping area. The estimated cost savings of using dredged material in RA5 instead of upland material (based strictly on the difference in materials cost) is approximately $2,000,000.

E.5 DISPOSAL OF MATERIAL

Contaminated sediments, dredged from the area around the Crowley Pier, within RA1 and RA3, will require disposal as part of this remedy. This analysis compares two alternatives for disposal of this dredged material:

- **Alternative 3** - Upland disposal of the dredged material at a suitable landfill facility. This alternative is consistent with the ROD and is the approach specified in the design.

- **Alternative 4** - Offshore deposition of the dredged material in the deep water within RA5. The dredged material would subsequently be covered by the RA5 capping system and therefore isolated from future impact to the environment. This would be considered consolidation of contaminated material within an existing area of contamination, and under CERCLA would not constitute

"placement" or "disposal." This approach was considered in the FS but was not included in the Selected Remedy based on comments received during the public comment period.

E.5.1 Costs

The estimated cost of each alternative were compared based on the estimated unit rates developed for the 30 percent design submittal. These costs are considered sufficiently accurate for the propose of comparison between the two alternatives. For each alternative, the material dredging costs were assumed to be equal.

Estimated costs for Alternative 3, disposal of dredged material at a suitable upland facility, and Alternative 4, disposal of dredged material in RA5, are presented in Table E-6. The costs are calculated based on the estimated unit rates and quantities developed for the 30 percent design submittal.

The principal costs associated with disposal of dredged material at an upland location are:

- Draining liquids on a flat-deck barge, using best engineering practices, in preparation for transport and disposal
- Loading of the dewatered sediments into lined shipping containers
- Transport of the material to a regional landfill, assumed to be in Eastern Washington
- Disposal of the material in a suitable licenced and permitted facility

Deposition of the dredged material within RA5 would eliminate the costs associated with preparation of the material for transport ($5.00 per cy), and transport and disposal of the material in a suitably licenced and permitted facility ($30.00 per ton).

Costs associated with Alternative 4, that would not otherwise be incurred by the remedy include:

- A assumed unit rate of $3.00 per cy for the handling associated with deposition of dredged material in RA5;
- Additional water quality monitoring. The water quality monitoring program associated with placement of contaminated sediments would have to be expanded

from turbidity, DO, and temperature to include analysis of the primary contaminants of concern.

Table E-6 presents a comparison of the costs for Alternative 3 and Alternative 4. This comparison is summarized following:

- Cost for Alternative 3 = $ 600,000
- Cost for Alternative 4 = $ 300,000
- Cost Difference = $ 300,000

In addition to assuming that dredging costs are equal under both alternatives, the analysis assumes that the cost of constructing the cap in RA5 under each alternative will also be equal. Placement of additional sediment in RA5 prior to construction of the cap could increase the long-term monitoring requirements, which has not been included in the cost analysis

E.5.2 Environmental Impacts

The relative environmental impacts of Alternative 3 and Alternative 4 are primarily associated with the short-term water quality impacts of the actions. Under Alternative 3, the dredged material would be dewatered on site, with the return water entering the water column in the dredge area vicinity. The associated water quality impacts (e.g., turbidity, release of dissolved contaminants) have been assessed in Section 5 of the Basis of Design and are predicted to be acceptable outside the 300-foot mixing zone.

Under Alternative 4, short term water quality impacts would occur both at the dredge location and at the deposition location. While the additional impacts at the deposition location are expected to be acceptable outside a 300-foot mixing zone, these impacts have not specifically been quantified (e.g., with a standard elutriate test). The primary environmental concern under Alternative 4 is the additional area (the need for two mixing zones) that would be subject to short-term water quality impacts during an approximate 2 to 3 week period.

No significant long-term environmental impacts are associated with either alterative.

E.6 MATERIAL SPECIFICATIONS

Material specifications have been developed in consultation with material suppliers to ensure they describe materials that are readily and cost effectively available at local sources. Where ever possible, standard specifications commonly used in local and state earthworks projects have

been specified. To the maximum extent possible, the use of expensive material types has been minimized to avoid unnecessary expense while still accomplishing the minimum requirements of the remedy design. Specialized material specifications, such as filter layers for riprap revetments and habitat mix, have been developed such that they can be manufactured by combining materials that are readily available from local suppliers.

E.6.1 Total Organic Carbon

Total Organic Carbon (TOC) is required in materials that will be placed in the lower layers of the cap, in direct contact with contaminated sediments. In particular a minimum TOC content of 1 percent was specified by the 30 percent design for sand cap mix and filter layer materials (upland sources), and a minimum TOC of 2 percent was specified for dredged material in RA5.

E.6.1.1 Upland Material TOC

Discussions with material suppliers have indicated that, depending on the raw material source and processing methods, locally supplied materials may not achieve this minimum requirement. Two approaches were considered to address this potential problem:

1. Revision of the design, to reduce the minimum TOC content from 1 percent to 0.5 percent for upland material; and

2. Provision for the introduction of additives to the locally available materials that will increase TOC the content of the bulk product.

This design has adopted the first approach, by reducing the TOC requirement to 0.5 percent. This resulted in an increase in the thickness of the chemical isolation layer by 6 inches in RA2a, RA2b, and RA3, and 9 inches in RA4. However, in light of the potential difficulties and expense of providing upland material with 1 percent TOC it is concluded that the cost of supplying the additional material will be offset by the cost of introducing and mixing the additives necessary to achieve the minimum requirements.

The minimum 0.5 percent TOC requirement is needed for all of the sand cap mix material. However, TOC is only needed in filter material in locations where the filter material functions as the chemical isolation layer. Therefore, two filter materials have been specified, one with TOC and one without, to minimize any additional costs of incorporating TOC into this material type.

It is possible that some amendments may still be required to attain the 0.5 percent TOC specification, particularly in the gravelly filter material. The following methods have been

considered, in consultation with local material suppliers, for increasing the TOC content to 0.5 percent.

- Addition of activated charcoal. Activated charcoal, in granular form, has a very high raw material cost but would require addition of a very small quantity. The material would require hydration prior to blending, to increase its specific gravity so it will settle through the water column during placement. Granulated carbon could be added during loading of the base material onto the barge and be mixed as part of loading, transport and placement. Given the large quantities of sand cap mix required for completion of the work, the very high raw material cost will probably make this alternative impractical for sand cap mix. Activated charcoal may, however, be cost effective for the filter material.

- Addition of compost. Compost has a TOC content of around 30 percent to 40 percent and so would require the additional of a relatively small quantity. As with granulated carbon, it could be added as base material is loaded onto the barge and mixed as part of loading, transport and placement. Material costs vary, but would be considerably less than activated carbon. It is possible that certain elements of the compost will float or become suspended during placement of the material, causing potential water quality concerns.

- Addition of a secondary material such as topsoil. Material such as topsoil typically contains a significant proportion of TOC. However, the percentage of TOC would probably be considerably less than that of compost and therefore a more significant quantity of the secondary material would be required. Addition of a significant quantity of a secondary material could, in turn, impact the gradation of the base material. This approach is highly dependent on the properties, cost and availability of suitable secondary materials and would need to be approved on a case by case basis.

As per the approach adopted for material placement methodologies, a performance based specification will be developed with respect to the minimum TOC content. This approach will allow contractors and their material suppliers to use innovative methods to achieve the design requirements. It will also encourage competitive bidding of the work.

E.6.1.1 Dredged Material TOC

The dredged material TOC specification has be reduced to 1 percent on average. This is considered a more realistic assessment of the sandier dredged material that will likely be

available from the Snohomish River. The 30 percent design used a 2 percent TOC requirement, which was based on properties of the Duwamish River sediments. The revised TOC requirement results in a 6-inch thicker cap in RA5.

It is anticipated that the bulk of the available dredged material will originate from the Snohomish River. The revised TOC requirement will allow the unrestricted use of a greater volume of dredged material from various sources, lending flexibility to the capping program in RA5.

E.6.2 Material Gradation

The use of angular materials on the finished surface of exposed beaches is not desirable from an aesthetic, habitat or functional perspective. The 30 percent design called for placement of gravel mix on the exposed beaches. The gravel mix specification consisted of a crushed rock product, which did not meet the desired habitat or aesthetic properties required for beaches. Given the percentage of the total gravel mix material quantity that will actually be exposed on the beaches is very small, it was considered unreasonable to modify the complete gravel mix specification to require the use of more expensive rounded materials. Further, crushed material is desired for slope stability considerations. Given these considerations, creation of a new material specification for this relatively minor quantity and increasing the perceived complexity of the project was considered undesirable. Therefore, the design was modified to provide for a layer of habitat mix over the gravel mix. This approach accomplishes the requirements of the design while maintaining the simplicity of the specification and minimizing the quantity of more expensive rounded material required to complete the remedy.

E.7 CONCLUSIONS

Based on the results of the value engineering analysis, the following conclusions have been made:

- After considering contracting requirements, logistics, costs, and potential impacts to the project schedule, EPA has determined that it is most practicable to use upland material to construct the cap in RA2b and RA4. Thus, dredged material will be used for cap construction only in RA5.

- Performance-based specifications are used for construction of the cap in RA1-RA4. By allowing contractors to use innovative material placement methods that are optimized to suit their own work methodologies, bidding of the work is anticipated to be more competitive and innovative approaches will be encouraged.

- Construction monitoring methodologies have been developed that will demonstrate that the Data Quality Objectives are achieved, while minimizing the impact of the program to the project cost and schedule. In addition, the monitoring methods are designed to complement the long-term monitoring. Single beam differential bathymetry will be used in all areas where suitable accuracy can be achieved. This will be supplemented, where necessary, by visual observations from SPI and cores. The use of chemical analysis and differential bathymetry has been minimized and will be used primarily to demonstrate compliance with the SQS and document cap as-built conditions.

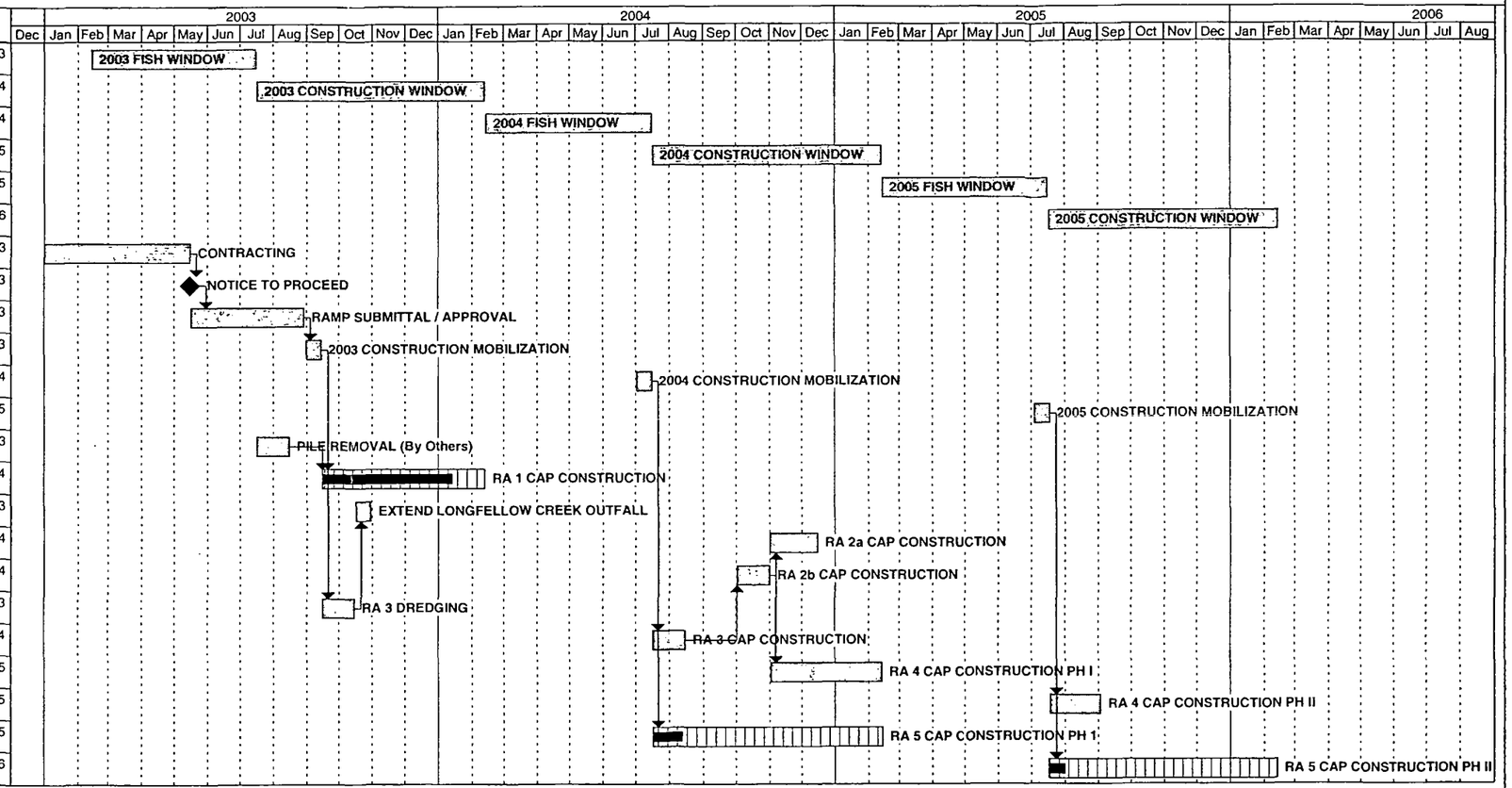
- The RA boundaries have been re-defined to minimize placement of capping material outside the ROD-required boundaries. The result of these changes is roughly an 8,000 CY reduction in the required capping material and a savings of approximately $100,000. RA5 has been maximized to approximately 38% of the total capping area, saving approximately $2,000,000 compared to the use of upland material in RA5.

- Dredged material will be disposed of at a permitted upland facility, as required by the ROD. However, a potential cost savings of $300,000 would be associated with depositing the contaminated dredged material in RA5 and subsequently capping the deposit.

- Material specifications have been developed in consultation with material suppliers to ensure they describe materials that are readily and cost effectively available at local sources. Where appropriate the design has been modified to accommodate the limitations of locally available material. The cap thickness has been modified to allow the use of more cost-effective materials with lower TOC content. Performance based specifications will encourage the use of innovative approaches for addressing specific material requirements that could be achieved through a variety of methodologies.

FIGURE E-1
CONSTRUCTION SCHEDULE FOR
ALTERNATIVE 1

ID	Task Name	Duration	Start	Finish
1	2003 FISH WINDOW	152 edays	Fri 2/14/03	Wed 7/16/03
2	2003 CONSTRUCTION WINDOW	211 edays	Thu 7/17/03	Fri 2/13/04
3	2004 FISH WINDOW	153 edays	Sat 2/14/04	Fri 7/16/04
4	2004 CONSTRUCTION WINDOW	211 edays	Sat 7/17/04	Sun 2/13/05
5	2005 FISH WINDOW	152 edays	Mon 2/14/05	Sat 7/16/05
6	2005 CONSTRUCTION WINDOW	211 edays	Sun 7/17/05	Mon 2/13/06
7	CONTRACTING	135 edays	Wed 1/1/03	Fri 5/16/03
8	NOTICE TO PROCEED	1 day	Fri 5/16/03	Fri 5/16/03
9	RAMP SUBMITTAL / APPROVAL	105 edays	Fri 5/16/03	Fri 8/29/03
10	2003 CONSTRUCTION MOBILIZATION	14 edays	Mon 9/1/03	Mon 9/15/03
11	2004 CONSTRUCTION MOBILIZATION	14 edays	Fri 7/2/04	Fri 7/16/04
12	2005 CONSTRUCTION MOBILIZATION	14 edays	Mon 7/4/05	Mon 7/18/05
13	PILE REMOVAL (By Others)	30 edays	Thu 7/17/03	Sat 8/16/03
14	RA 1 CAP CONSTRUCTION	150 edays	Tue 9/16/03	Fri 2/13/04
15	EXTEND LONGFELLOW CREEK OUTFALL	14 edays	Fri 10/17/03	Fri 10/31/03
16	RA 2a CAP CONSTRUCTION	45 edays	Mon 11/1/04	Thu 12/16/04
17	RA 2b CAP CONSTRUCTION	30 edays	Sat 10/2/04	Mon 11/1/04
18	RA 3 DREDGING	30 edays	Tue 9/16/03	Thu 10/16/03
19	RA 3 CAP CONSTRUCTION	30 edays	Sat 7/17/04	Mon 8/16/04
20	RA 4 CAP CONSTRUCTION PH I	103 edays	Tue 11/2/04	Sun 2/13/05
21	RA 4 CAP CONSTRUCTION PH II	47 edays	Mon 7/18/05	Sat 9/3/05
22	RA 5 CAP CONSTRUCTION PH 1	211.38 edays	Sat 7/17/04	Sun 2/13/05
23	RA 5 CAP CONSTRUCTION PH II	211 edays	Sun 7/17/05	Mon 2/13/06



Project: CONSTRUCTION SCHEDULE
Date: Wed 7/24/02

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks
Progress | Summary | Rolled Up Milestone | Split | Project Summary

Notes and Assumptions Associated with Schedule for Alternative 1

1. RA1 must be completed as quickly as practical to achieve habitat enhancements.

2. Removal of existing piles in RA1 must precede construction of the cap in RA1 (see Note 6).

3. Dredging in RA3 must precede construction of the cap in RA3 and adjacent parts of RA1 and RA2a.

4. Construction of the cap in RA4 and RA5 may precede independently.

5. Assume 1 month equals 20 working days. Round all months up to the nearest 0.5 month.

6. Assume a total of 600 piles will be removed at a rate of 30 piles per day.

7. The dredge volume in RA3 is approximately 10,500 cubic yards. Assume an average dredging rate of approximately 600 cubic yards/day based on difficulties associated with work around the Crowley Pier. RA3 dredging duration equals 17 days, plus 7 days for survey and possible re-dredging, 1 month total duration.

8. Assume only one operation placing upland material. Assume placement of dredged material in RA5 is independent of other cap construction.

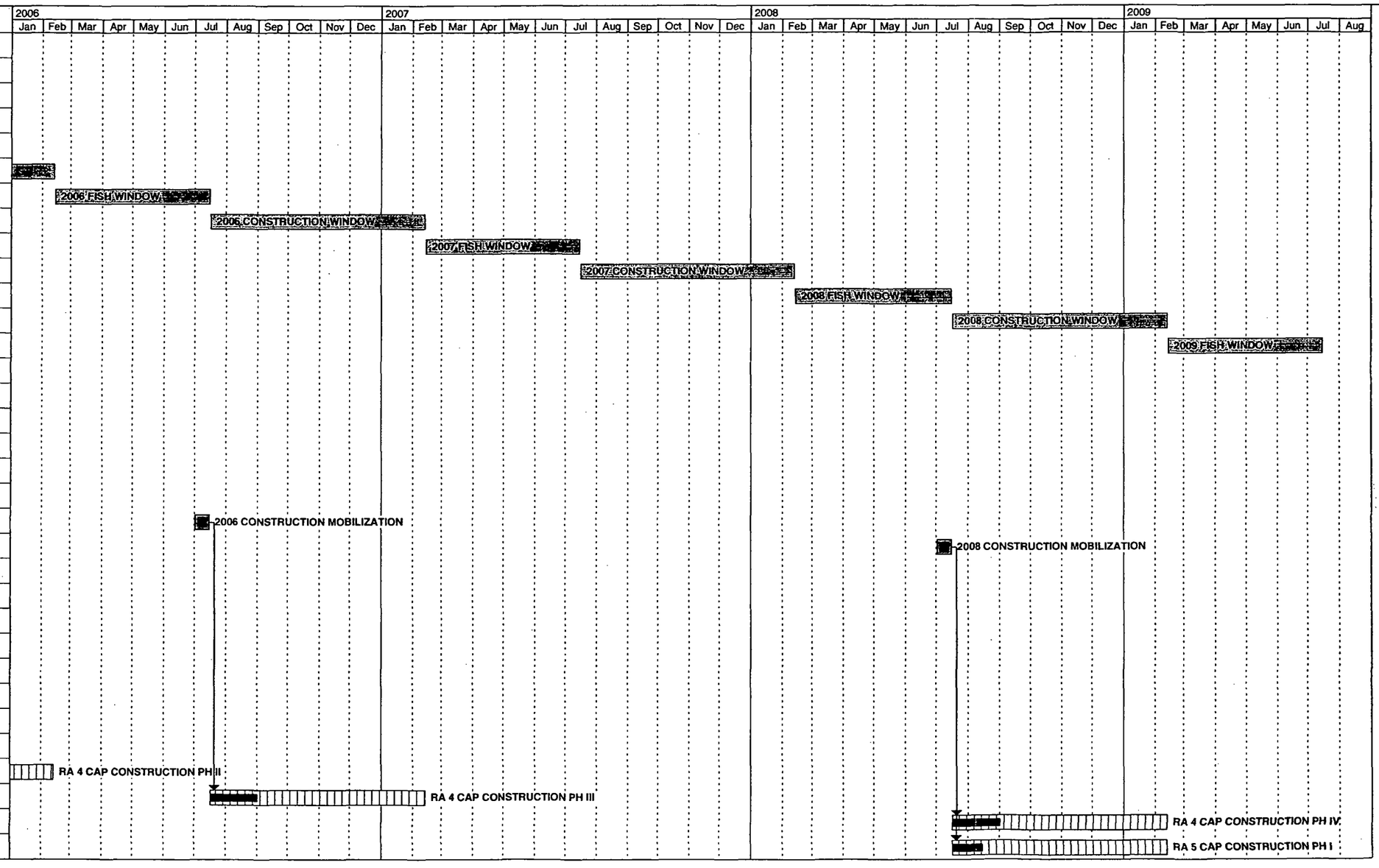
9. During 2004, material will be placed concurrently in RA5 from the following sources. Material could be available at any time during the 6-month dredging window.

    - 38,000 cy placed from Duwamish, at same rate as dredged (62,000 cy/month)
    - 35,000 cy placed from Swinomish, at same rate as dredged (32,000 cy/month)

10. During 2005, material placed from the Snohomish Upstream Basin in RA5 at same rate as dredged (228,000 cy/month). Material could be available at any time during the 6-month dredging window.

FIGURE E-2 Page 2 of 2
CONSTRUCTION SCHEDULE FOR
ALTERNATIVE 2

ID	Task Name
1	2003 FISH WINDOW
2	2003 CONSTRUCTION WINDOW
3	2004 FISH WINDOW
4	2004 CONSTRUCTION WINDOW
5	2005 FISH WINDOW
6	2005 CONSTRUCTION WINDOW
7	2006 FISH WINDOW
8	2006 CONSTRUCTION WINDOW
9	2007 FISH WINDOW
10	2007 CONSTRUCTION WINDOW
11	2008 FISH WINDOW
12	2008 CONSTRUCTION WINDOW
13	2009 FISH WINDOW
14	CONTRACTING
15	NOTICE TO PROCEED
16	RAMP SUBMITTAL / APPROVAL
17	2003 CONSTRUCTION MOBILIZATION
18	2004 CONSTRUCTION MOBILIZATION
19	2005 CONSTRUCTION MOB
20	2006 CONSTRUCTION MOBILIZATION
21	2008 CONSTRUCTION MOBILIZATION
22	PILE REMOVAL (By Others)
23	RA 1 CAP CONSTRUCTION
24	EXTEND LONGFELLOW CREEK OUTFALL
25	RA 2a CAP CONSTRUCTION
26	RA 2b CAP CONSTRUCTION
27	RA 3 DREDGING
28	RA 3 CAP CONSTRUCTION
29	RA 4 CAP CONSTRUCTION PH I
30	RA 4 CAP CONSTRUCTION PH II
31	RA 4 CAP CONSTRUCTION PH III
32	RA 4 CAP CONSTRUCTION PH IV
33	RA 5 CAP CONSTRUCTION PH I

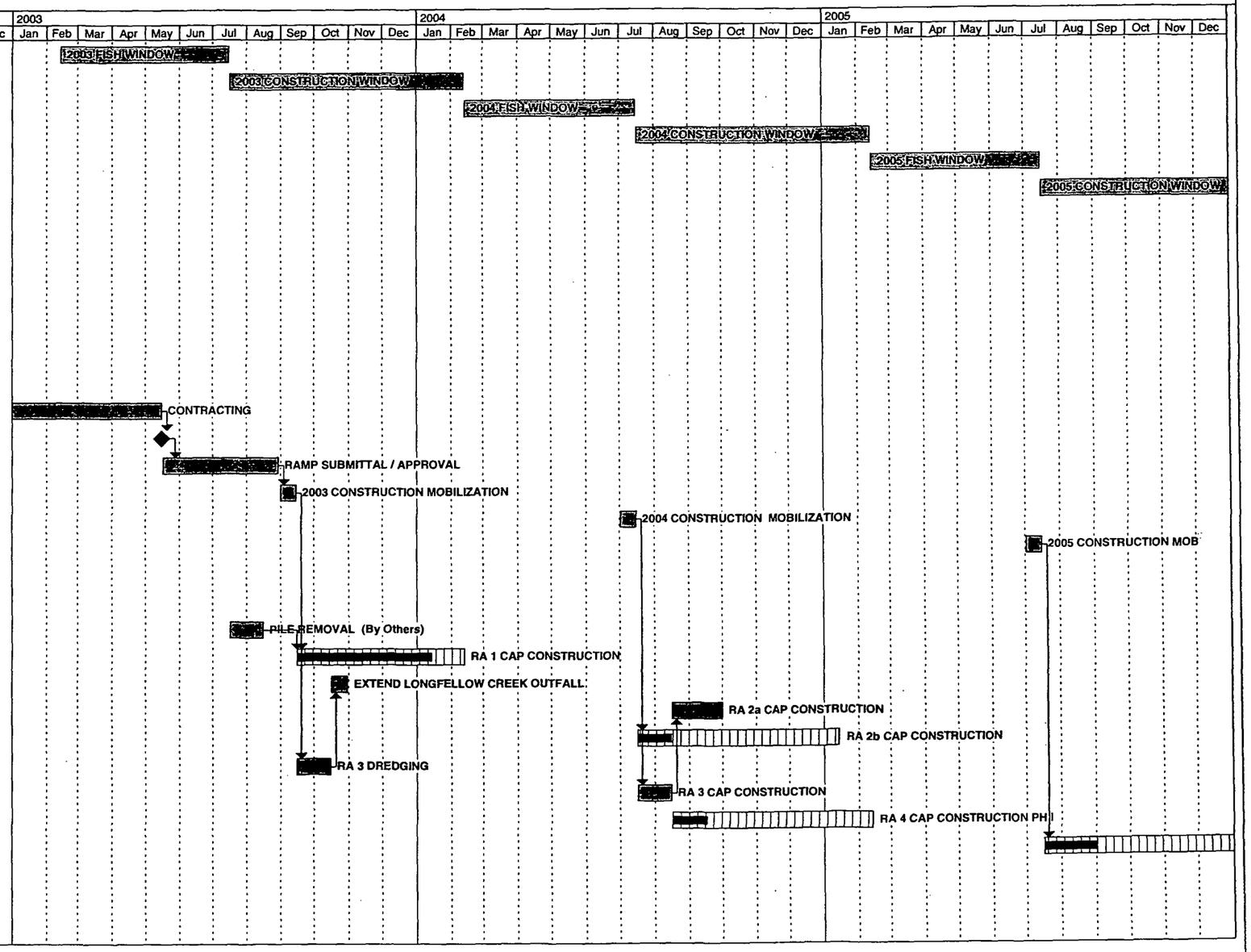


Project: CONSTRUCTION SCHEDULE
Date: Wed 7/24/02

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks
Progress | Summary | Rolled Up Milestone | Split | Project Summary

FIGURE E-2 Page 1 of 2
CONSTRUCTION SCHEDULE FOR
ALTERNATIVE 2

ID	Task Name	Duration	Start	Finish
1	2003 FISH WINDOW	152 edays	Fri 2/14/03	Wed 7/16/03
2	2003 CONSTRUCTION WINDOW	211 edays	Thu 7/17/03	Fri 2/13/04
3	2004 FISH WINDOW	153 edays	Sat 2/14/04	Fri 7/16/04
4	2004 CONSTRUCTION WINDOW	211 edays	Sat 7/17/04	Sun 2/13/05
5	2005 FISH WINDOW	152 edays	Mon 2/14/05	Sat 7/16/05
6	2005 CONSTRUCTION WINDOW	211 edays	Sun 7/17/05	Mon 2/13/06
7	2006 FISH WINDOW	152 edays	Tue 2/14/06	Sun 7/16/06
8	2006 CONSTRUCTION WINDOW	211 edays	Mon 7/17/06	Tue 2/13/07
9	2007 FISH WINDOW	152 edays	Wed 2/14/07	Mon 7/16/07
10	2007 CONSTRUCTION WINDOW	211 edays	Tue 7/17/07	Wed 2/13/08
11	2008 FISH WINDOW	153 edays	Thu 2/14/08	Wed 7/16/08
12	2008 CONSTRUCTION WINDOW	211 edays	Thu 7/17/08	Fri 2/13/09
13	2009 FISH WINDOW	152 edays	Sat 2/14/09	Thu 7/16/09
14	CONTRACTING	135 edays	Wed 1/1/03	Fri 5/16/03
15	NOTICE TO PROCEED	1 day	Fri 5/16/03	Fri 5/16/03
16	RAMP SUBMITTAL / APPROVAL	105 edays	Fri 5/16/03	Fri 8/29/03
17	2003 CONSTRUCTION MOBILIZATION	14 edays	Mon 9/1/03	Mon 9/15/03
18	2004 CONSTRUCTION MOBILIZATION	14 edays	Fri 7/2/04	Fri 7/16/04
19	2005 CONSTRUCTION MOB	14 edays	Sat 7/2/05	Sat 7/16/05
20	2006 CONSTRUCTION MOBILIZATION	14 edays	Sun 7/2/06	Sun 7/16/06
21	2008 CONSTRUCTION MOBILIZATION	14 edays	Wed 7/2/08	Wed 7/16/08
22	PILE REMOVAL (By Others)	30 edays	Thu 7/17/03	Sat 8/16/03
23	RA 1 CAP CONSTRUCTION	150 edays	Tue 9/16/03	Fri 2/13/04
24	EXTEND LONGFELLOW CREEK OUTFALL	14 edays	Fri 10/17/03	Fri 10/31/03
25	RA 2a CAP CONSTRUCTION	45 edays	Tue 8/17/04	Fri 10/1/04
26	RA 2b CAP CONSTRUCTION	181 edays	Sat 7/17/04	Fri 1/14/05
27	RA 3 DREDGING	30 edays	Tue 9/16/03	Thu 10/16/03
28	RA 3 CAP CONSTRUCTION	30 edays	Sat 7/17/04	Mon 8/16/04
29	RA 4 CAP CONSTRUCTION PH I	180 edays	Tue 8/17/04	Sun 2/13/05
30	RA 4 CAP CONSTRUCTION PH II	211 edays	Sun 7/17/05	Mon 2/13/06
31	RA 4 CAP CONSTRUCTION PH III	211 edays	Mon 7/17/06	Tue 2/13/07
32	RA 4 CAP CONSTRUCTION PH IV	211 edays	Thu 7/17/08	Fri 2/13/09
33	RA 5 CAP CONSTRUCTION PH I	211 edays	Thu 7/17/08	Fri 2/13/09



Project: CONSTRUCTION SCHEDULE
Date: Wed 7/24/02

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks
Progress | Summary | Rolled Up Milestone | Split | Project Summary

Notes and Assumptions Associated with Schedule for Alternative 2

1. RA1 must be completed as quickly as practical to achieve habitat enhancements.

2. Removal of existing piles in RA1 must precede construction of the cap in RA1 (see Note 6).

3. Dredging in RA3 must precede construction of the cap in RA3 and adjacent parts of RA1 and RA2a.

4. Construction of the cap in RA4 and RA5 may proceed independently.

5. Assume 1 month equals 20 working days. Round all months up to the nearest 0.5 month.

6. Assume a total of 600 piles will be removed at a rate of 30 piles per day.

7. The dredge volume in RA3 is approximately 10,500 cubic yards. Assume an average dredging rate of approximately 600 cubic yards/day based on difficulties associated with work around the Crowley Pier. RA3 dredging duration equals 17 days, plus 7 days for survey and possible re-dredging, 1 month total duration.

8. Assume only one operation placing upland material. Assume placement of dredged material in RA2b and RA4 is also by one operation, requiring sequential placement of material from different sources. Assume placement of dredged material in RA5 is independent of other cap construction.

9. During 2004, material is placed in RA2b concurrently from the following sources. Note the quantity of material available from the Duwamish is reduced because the dredging rate is greater than the placement rate. Material could be available at any time during the 6-month dredging window.

    - 15,016 cy placed from Duwamish, at a limited rate (40,000 cy/month)
    - 5,717 cy placed from Swinomish, at same rate as dredged (32,000 cy/month)

10. During 2004, material from Swinomish is not placed in placed in RA2b is placed in RA4. Material placed at the reduced rate of 26,000 cy/month due to the steep slope. Material could be available at any time during the 6-month dredging window.

11. During 2005, 28,509 cy from Snohomish U/S Basin is placed in RA4 at a rate of 26,000 cy/month. Placement rate in RA4 is limited due to steep slope. Note the quantity of material available is reduced because the dredging rate is greater than the placement rate. Material could be available at any time during the 6-month dredging window.

12. During 2006, material is placed in RA4 concurrently from the following sources. Note the quantity of material available from both sources is reduced because the dredging rate is greater than the placement rate. Placement rate in RA4 is limited due to steep slope. Material could be available at any time during the 6-month dredging window.

    - 6,453 cy placed from Duwamish, at a limited rate (26,000 cy/month)
    - 8,438 cy placed from Swinomish, at same rate as dredged (26,000 cy/month)

13. No dredged material will be available during 2007. Construction of the cap in RA4 is assumed to be completed to greater than 50 percent during 2006; therefore construction of the cap in RA5 can commence in parallel with that in RA4 when dredged material is available in 2008.

14. During 2008, material is placed in RA4 concurrently from the following sources. Note the quantity of material available from both sources is reduced because the dredging rate is greater than the placement rate. Placement rate in RA4 is limited due to steep slope. Material could be available at any time during the 6-month dredging window.

    - 28,509 cy placed from Snohomish U/S Basin, at a limited rate (26,000 cy/month)
    - 28,438 cy placed from Swinomish, at same rate as dredged (26,000 cy/month)

15. During 2008, all material from both Swinomish and Snohomish U/S Basin that is not placed in RA4 is placed in RA5. Material is placed at a rate equal to the dredging rates for the respective sites. Material could be available at any time during the 6-month dredging window.

Table 1
Estimated PSR Capping Volumes - Alternative 1 (Dredged Material in RA5 only)

RA	Area (Acres)	Minimum Cap Thickness (inches)	Over-Placement Allowance (inches)	Total Cap Volume (cubic yards) Estimated	Total Cap Volume (cubic yards) Plus Contingency	Estimated Volumes by Material Type (all volumes include contingency) Dredged Material (cubic yards)	Upland Materials TOTAL (cubic yards)	Sand Cap Mix (cubic yards)	Coarse Sand (cubic yards)	Gravel Mix (cubic yards)	Filter layer (cubic yards)	Rip Rap (cubic yards)	Fishmix (cubic yards)	Estimated Duration Days	Months [1]
1	3.86	72	12	84648	93113	0	93113	20%	0%	55%	10%	10%	5%		
								18,623	-	51,212	9,311	9,311	4,656		
								10	-	26	10	19.00	5	70	3.5
2a	3.86	36	12	37147	40862	0	40862	50%	50%	0%	0%	0%	0%		
								20,431	20,431	-	-	-	-		
								11	11.00	-	-	-	-	22	1.10
2b	6.04	24	12	18848	20733	0	20733	100%	0%	0%	0%	0%	0%		
								20,733	-	-	-	-	-		
								11	-	-	-	-	-	11	0.55
3	0.96	36	12	6525	7178	0	7178	50%	0%	50%	0%	0%	0%		
								3,589	-	3,589	-	-	-		
								2	-	2	-	-	-	4	0.20
4	18.21	21	12	117680	129448	0	129448	100%	0%	0%	0%	0%	0%		
								129,448	-	-	-	-	-		
								100	-	-	-	-	-	100	5.00
5	22.23	18	10	158000	173800	173800	0								
	Subtotal			422848											
	Contingency		10%	42285											
	TOTAL			465133	465133	173800	291333	192823	20431	54801	9311	9311	4656	207	10.35

Assumptions for schedule calculations

1 Assume 20 working days in a month

2 Placement rate for

sand cap mix	2000 cy/day	for areas other than RA4 - typical placement rate using controlled methods
	1300 cy/day	reduced placement rate in RA4 to account for placement on steep slope
coarse sand	2000 cy/day	typical placement rate using controlled methods
gravel mix	2000 cy/day	typical placement rate using controlled methods
filter layer	1000 cy/day	slower placement rate due to placement on a steep slope
rip rap	500 cy/day	slower placement rate due to requirement to construct an embankment
fishmix	1000 cy/day	slower placement rate due to placement above rip-rap over a steep slope

3 Placement rate for dredged material in RA5 is controlled by the dredge rate

4 Placement rate for dredged material in RA2b is limited to 2000 cy/day (independent of dredge rate or number of dredge operations)

5 Placement rate for dredged material in RA4 is limited to 1300 cy/day (independent of dredge rate or number of dredge operations)

Table 2
Estimated PSR Capping Volumes - Alternative 2 (Maximise Use of Dredged Material)

RA	Area (Acres)	Minimum Cap Thickness (inches)	Over-Placement Allowance (inches)	Total Cap Volume (cubic yards)		Estimated Volumes by Material Type (all volumes include contingency)								Estimated Duration	
				Estimated	Plus Contingency	Dredged Material (cubic yards)	Upland Materials TOTAL (cubic yards)	Sand Cap Mix (cubic yards)	Coarse Sand (cubic yards)	Gravel Mix (cubic yards)	Filter layer (cubic yards)	Rip Rap (cubic yards)	Fishmix (cubic yards)	Days	Months [1]
1	3.86	72	12	84848	93113	0	93113	20%	0%	55%	10%	10%	5%		
								18,623	-	51,212	9,311	9,311	4,656		
								10	-	26	10	19.00	5	70	3.5
2a	3.88	36	12	37147	40862	0	40862	50%	50%	0%	0%	0%	0%		
								20,431	20,431	-	-	-	-		
								11	11.00	-	-	-	-	22	1.10
2b	8.04	24	12	18848	20733	20733									
3	0.96	36	12	6525	7178	0	7178	50%	0%	50%	0%	0%	0%		
								3,589	-	3,589	-	-	-		
								2	-	2	-	-	-	4	0.20
4	18.21	21	12	117680	129448	129448	0								
5	22.23	18	10	158000	173800	173800	0								
		Subtotal		422848											
		Contingency	10%	42285											
		TOTAL		465133	465133	323981	141152	42642	20431	54801	9311	9311	4656	96	4.8

Assumptions for schedule calculations

1 Assume 20 working days in a month

2 Placement rate for

sand cap mix	2000 cy/day	for areas other than RA4 - typical placement reat controlled methods
	1300 cy/day	reduced placement rate in RA4 to accound for placement on steep slope
coarse sand	2000 cy/day	typical placement rate by controlled methods
gravel mix	2000 cy/day	typical placement rate by controlled methods
filter layer	1000 cy/day	slower placement rate due to placement on a steep slope
rip rap	500 cy/day	slower placement rate due to requirement to construct an embankment
fishmix	1000 cy/day	slower placement rate due to placement above rip-rap over a steep slope

3 Placement rate for dredged material in RA5 is controlled by the dredge rate

4 Placement rate for dredged material in RA2b is limited to 2000 cy/day (independent of dredge rate or number of dredge operations)

5 Placement rate for dredged material in RA4 is limited to 1300 cy/day (independent of dredge rate or number of dredge operations)

Table 3
Schedule of Unit Rates for Upland Material

Material Name	Material Type	Base Material Unit Rate [1] ($/ton)	Material Density (ton/cy)	Base Material Unit Rate ($/cy)	Amendment Allowance (see notes)	Delivery [2] ($/ton)	Delivery ($/cy)	Total Unit Rate (Delivered)	Notes
Sand Cap Mix	Sand Blend	$ 4.50	1.28	$ 5.77	50%	$ 2.00	$ 2.57	$ 11.22	Allowance for blending to produce requried TOC%
Sand Cap Mix - RA4	Sand Blend	$ 4.50	1.28	$ 5.77	50%	$ 2.00	$ 2.57	$ 11.22	Allowance for blending to produce requried TOC% and to increase silt content
Coarse Sand	Seattle No. 17	$ 5.25	1.35	$ 7.09	0%	$ 2.00	$ 2.70	$ 9.79	Armor material requires no amendment
Gravel Mix	Seattle No. 14	$ 7.50	1.35	$ 10.13	0%	$ 2.00	$ 2.70	$ 12.83	Armor material requires no amendment
Filter Layer	Seattle No. 14	$ 7.50	1.35	$ 10.13	50%	$ 2.00	$ 2.70	$ 17.89	Allowance for blending to produce requried TOC%
Rip Rap	500lb max stone	$ 8.50	1.40	$ 11.90	0%	$ 2.00	$ 2.80	$ 14.70	Armor material requires no amendment
Fishmix	Seattle No. 14	$ 7.50	1.35	$ 10.13	100%	$ 2.00	$ 2.70	$ 22.95	Allowance for anticipated specialty requirements of regulators

Notes

1 Material cost includes loading onto barges
2 Based on delivery by contractor

Table 4
Cost Comparison

Table 4a - Alternative 1 (Dredged Material in RA5 only)

RA		Costs by Material Type (all volumes include contingency)							RA Total Dredged	RA Total Upland
		Dredged Material	Upland Materials							
			Sand Cap Mix	Coarse Sand	Gravel Mix	Filter layer	Rip Rap	Fishmix		
	Unit Rate ($/cy)	$ 2.00	$ 11.22	$ 9.79	$ 12.83	$ 17.89	$ 14.70	$ 22.95		
1	Estimated Quantity (cy)	-	18,623	-	51,212	9,311	9,311	4,656	-	93,113
	Estimated Cost ($)	$ -	$ 208,980.04	$ -	$ 656,794.41	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ -	$ 1,276,052.73
2a	Estimated Quantity (cy)	-	20,431	20,431	-	-	-	-	-	40,862
	Estimated Cost ($)	$ -	$ 229,272.44	$ 199,966.94	$ -	$ -	$ -	$ -	$ -	$ 429,239.39
2b	Estimated Quantity (cy)	-	20,733	-	-	-	-	-	-	20,733
	Estimated Cost ($)	$ -	$ 232,660.89	$ -	$ -	$ -	$ -	$ -	$ -	$ 232,660.89
3	Estimated Quantity (cy)	-	3,589	-	3,589	-	-	-	-	7,178
	Estimated Cost ($)	$ -	$ 40,272.50	$ -	$ 46,025.72	$ -	$ -	$ -	$ -	$ 86,298.22
4	Estimated Quantity (cy)	-	129,448	-	-	-	-	-	-	129,448
	Estimated Cost ($)	$ -	$ 1,452,649.28	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,452,649.28
5	Estimated Quantity (cy)	173,800	-	-	-	-	-	-	173,800	-
	Estimated Cost ($)	$ 347,600.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 347,600.00	$ -
	Total Material Costs	$ 347,600.00	$ 2,163,835.15	$ 199,966.94	$ 702,820.13	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ 347,600.00	$ 3,476,900.51
	Total Estimated Material Cost (Delivered)									$ 3,824,500.51

Table 4b - Alternative 2 (Maximise Use of Dredged Material)

RA		Costs by Material Type (all volumes include contingency)							RA Total Dredged	RA Total Upland
		Dredged Material	Upland Materials							
			Sand Cap Mix	Coarse Sand	Gravel Mix	Filter layer	Rip Rap	Fishmix		
	Unit Rate ($/cy)	$ 2.00	$ 11.22	$ 9.79	$ 12.83	$ 17.89	$ 14.70	$ 22.95		
1	Estimated Quantity (cy)	-	18,623	-	51,212	9,311	9,311	4,656	-	93,113
	Estimated Cost ($)	$ -	$ 208,980.04	$ -	$ 656,794.41	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ -	$ 1,276,052.73
2a	Estimated Quantity (cy)	-	20,431	20,431	-	-	-	-	-	40,862
	Estimated Cost ($)	$ -	$ 229,272.44	$ 199,966.94	$ -	$ -	$ -	$ -	$ -	$ 429,239.39
2b	Estimated Quantity (cy)	20,733	-	-	-	-	-	-	20,733	-
	Estimated Cost ($)	$ 41,465.60	$ -	$ -	$ -	$ -	$ -	$ -	$ 41,465.60	$ -
3	Estimated Quantity (cy)	-	3,589	-	3,589	-	-	-	-	7,178
	Estimated Cost ($)	$ -	$ 40,272.50	$ -	$ 46,025.72	$ -	$ -	$ -	$ -	$ 86,298.22
4	Estimated Quantity (cy)	129,448	-	-	-	-	-	-	129,448	-
	Estimated Cost ($)	$ 258,896.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 258,896.00	$ -
5	Estimated Quantity (cy)	173,800	-	-	-	-	-	-	173,800	-
	Estimated Cost ($)	$ 347,600.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 347,600.00	$ -
	Total Material Costs	$ 647,961.60	$ 478,524.99	$ 199,966.94	$ 702,820.13	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ 647,961.60	$ 1,791,590.34
	Total Estimated Material Cost (Delivered)									$ 2,439,551.94

Table 4c - Summary

RA		Costs by Material Type (all volumes include contingency)							RA Total Dredged	RA Total Upland
		Dredged Material	Upland Materials							
			Sand Cap Mix	Coarse Sand	Gravel Mix	Filter layer	Rip Rap	Fishmix		
	Alternative 1 - Total Cost by Material	$ 347,600.00	$ 2,163,835.15	$ 199,966.94	$ 702,820.13	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ 347,600.00	$ 3,476,900.51
	Alternative 2 - Total Cost by Material	$ 647,961.60	$ 478,524.99	$ 199,966.94	$ 702,820.13	$ 166,555.52	$ 136,875.82	$ 106,846.94	$ 647,961.60	$ 1,791,590.34
	Difference (Alt - Alt 2) - by material	$ (300,361.60)	$ 1,685,310.17	$ -	$ -	$ -	$ -	$ -	$ (300,361.60)	$ 1,685,310.17
	Net Difference									$ 1,384,948.57

Table 5- Dredged Material Properties and Schedule

Project	Material Type	%TOC (Avg)	Average Grain Size	
			% Fines	% Sand
Duwamish River U/S Basin	Sand & Silt	0.4%	15	85
Snohomish River D/S Basin	Sand [1]	1.0%	30	70
Snohomish River U/S Basin	Sand	?	7	93
Swinomish Channel / LaConner	Sand	0.0%	3	97

Dredged Material Availability

Project	Estimated Quantities			Cycle	Last Dredged		Next Dredging Cycle			
	Total	Suitable (%) [2]	Suitable (cy)		Year	Disposal	Year [3]	Month [4]	Est. Rate [5]	Duration (mths)
Duwamish River U/S Basin	100,000	38%	38,000	2	2002	Elliot Bay	2004	Aug to Jan	62,000	1.6
Snohomish River D/S Basin	250,000	0%	-	2 to 3	2002	Port Gardner	2005 [6]	Aug to Jan	228,000	1.1
Snohomish River U/S Basin	250,000	100%	250,000	2 to 3	2002	Riverside	2005 [6]	Aug to Jan	228,000	1.1
Swinomish Channel / LaConner	35,000	100%	35,000	2	2000	Rosario Strait	2004 [3]	Aug to Jan	32,000	1.1

Note

(1) Question classification as sand, given average gradation
(2) Based on assessment of available grain size data. Primary criteria: % fines < 30%.
(3) Assume project will not be designed in time to receive material from dredging completed during 2002.
(4) Fish Window, during which dredging can not be completed, is typically February 15 to July 14 each year.
(5) Estimated dredge rate, in cubic yards per month, from USACE records of average productivity from previous dredging operations (assume a 20 day month).
(6) Conservatively assume a cycle of 3 years rather than 2 years

Dredging Schedule

Scheduling Notes

1 RA1 completed first to accomplish habitats enhancements
2 Piling removal must preceed cap placement in RA1 in the areas of the piles
3 Dredging in RA3 must preceed cap construction in RA3 and adjacent parts of RA2a
4 Cap construction in RA4 must preceed cap construction in adjacent areas of RA5. Assume 50% of RA4 must be completed before starting RA5
5 Estimated Placement Rate:
RA5 equals dredge rate (see table above)
RA1 to RA3 40,000 cy/month (or the dredge rate if less than 40,000cy/month)
RA4 26,000 cy/month (due to steep slopes)
6 For placement of dredged material in RA2b (Alternative 2 only), actual percentage of the suitable material that can be used is limited based on placement rates:
Duwamish River U/S Basin 40% Assumed rate of placement is slower than estimated dredge rate. Additonal 25% loss due to placement /
Snohomish River D/S Basin 0% No suitable material available
Snohomish River U/S Basin 18% Assumed rate of placement is slower than the estimated dredge rate
Swinomish Channel / LaConner 100% The assumed rate of placement is faster than the dredge rate, therefore assume 100% utilization
7 For placement of dredged material in RA4 (Alternative 2 only), actual percentage of the suitable material that can be used is limited based on placement rates:
Duwamish River U/S Basin 17% Assumed rate of placement is slower than estimated dredge rate. Additonal 25% loss due to placement /
Snohomish River D/S Basin 0% No suitable material available
Snohomish River U/S Basin 11% Assumed rate of placement is slower than the estimated dredge rate
Swinomish Channel / LaConner 81% The assumed rate of placement is faster than the dredge rate, therefore assume 100% utilization
8 For RA5, given placement rate equals dredging rate, assume 100% of the quantities available from each source can be utilized in RA5
9 Placement of dredged material in RA5 is independent of placement in all other areas, with the exception of RA4, per Note 4.

Alternative 1

RA	Volume Required (cy)	Year	Source	Quantity Available [5],[7],[8],[9] (cy)	Start Vol Required (cy)	Placed Quantity (cy)	Placement Rate [9] (cy/month)	Placement Duration (months)	Cummulative Quantity (cy)
5	173,800	2004	Duwamish	38,000	173,800	38,000	62,000	0.6	38,000
			Swinomish	35,000	135,800	35,000	32,000	1.1	73,000
		2005	Snohomish U/S	250,000	100,800	100,800	228,000	0.4	173,800
					-				
					Total Duration of Placement		2004	1.1	months
							2005	0.4	months

Alternative 2

RA	Volume Required (cy)	year	Source	Quantity Available [5],[7],[8],[9] (cy)	Start Vol Required (cy)	Placed Quantity (cy)	Placement Rate [9] (cy/month)	Placement Duration (months)	Cummulative Quantity (cy)	
2b	20,733	2004	Duwamish	15,016	20,733	15,016	40,000	0.4	15,016	
			Swinomish	35,000	5,717	5,717	32,000	0.2	20,733	
					-					
4	129,448	2004	Swinomish carry over from RA2b	22,721	129,448	22,721	26,000	0.9	22,721	
		2005	Snohomish U/S	28,509	108,727	28,509	26,000	1.1	51,230	
		2006	Duwamish	6,435	78,218	6,435	26,000	0.2	57,665	
			Swinomish	28,438	71,783	28,438	26,000	1.1	86,103	
		2007	No material available		43,345					50% of RA4 complete
		2008	Snohomish U/S	28,509	43,345	28,509	26,000	1.1	114,611	
			Swinomish	28,438	14,837	14,837	26,000	0.6	14,837	
					-					
5	173,800	2008	Swinomish not used in RA4	20,163	173,800	20,163	32,000	0.6	20,163	
			Snohomish U/S not used in RA4	221,491	153,637	153,637	228,000	0.7	153,637	
			Duwamish	38,000	-	-	40,000	-	-	
					Total Duration of Placement - RA2b		2004	0.6	months	
					Total Duration of Placement - RA4		2004	0.9	months	
							2005	1.1	months	
							2006	1.3	months	
							2007	no material available		
							2008	1.7	months	
					Total Duration of Placement - RA5		2008	0.7	months	

Table E6
Estimated Cost of Dredged Material Disposal

Alternative 3 - Upland Material Disposal (per 30% Design Submittal)

Description	Quantity	Unit	Unit Cost	Total Cost
RA3 Dredging[1]				
Dredge	10,500	CY	$ 10.00	$ 105,000.00
Dewater / Rehandle / Load	10,500	CY	$ 5.00	$ 52,500.00
Transport and Dispose	14,700	TON	$ 30.00	$ 441,000.00
Total				*$ 598,500.00*

Alternative 4 - Underwater Material Disposal

Description	Quantity	Unit	Unit Cost	Total Cost
RA3 Dredging[1]				
Dredge	10,500	CY	$ 10.00	$ 105,000.00
Rehandle / Deposit[2]	10,500	CY	$ 3.00	$ 31,500.00
Additional Water Quality Controls[1]				
Turbidity Controls[3]	1	LS	$ 10,000.00	$ 10,000.00
Water Quality Monitoring[4][5]	18	DAY	$ 4,000.00	$ 72,000.00
Additional Construction Quality Control[1]				
Bathymetry Survey (multibeam)[6]	2	EA	$ 17,000.00	$ 34,000.00
Subbottom Profile Surveys[6]	2	EA	$ 5,000.00	$ 10,000.00
Sediment Profile Camera Survey[7]	1	EA	$ 8,000.00	$ 8,000.00
Surface Sediment Sampling / Analysis[8][5]	4	EA	$ 2,000.00	$ 8,000.00
Sediment cores (visual and physical)[8]	4	EA	$ 1,000.00	$ 4,000.00
Additional CQC Reporting[3][6]	208	HR	$ 100.00	$ 20,800.00
Total				*$ 303,300.00*

Cost Comparison				
Option 1 - Upland Material Disposal				$ 598,500.00
Option 2 - Underwater Material Disposal				$ 303,300.00
Cost Difference				*$ 295,200.00*

Notes

1 Unless otherwise noted, assume unit rates and quantities from Engineer's Estimate in 30% Design Submittal
2 Increase unit rate for placement of dredged material in RA5 by 50% to account for management of contaminated sediments
3 Allow 10% of quantity in 30% design submittal to account for difficulties associated with placement of contaminated sediment
4 Assume duration of water quality monitoring equals duration of placement equals duration of dredging at 600 cy/day
5 Increase unit rate by 100% to account for additional analyses required for contaminated sediment
6 Allow for two additional surveys, one before and one after placement of the contaminated sediments, to record contaminated sediment location
7 Allow for one additional sediment profile capping survey to record contaminated sediment location
8 Allow 10% of quantity in 30% design submittal to account for additional sampling and analysis requried for contaminated sediment

Appendix F

APPENDIX F

RA5 DESIGN DRAWINGS AND EXAMPLE SPECIFICATIONS

CONTENTS

F.1 INTRODUCTION F-1

F.2 ORGANIZATION F-2

ATTACHMENTS

F-1 Materials Specifications for Dredged Cap Material
F-2 Example Specification for USACE Maintenance Dredging Projects
F-3 RA5 Design Drawings

APPENDIX F

RA5 DESIGN DRAWINGS AND EXAMPLE SPECIFICATIONS

F.1 INTRODUCTION

This appendix presents the design drawings and example specifications to be used by the U.S. Army Corps of Engineers, Seattle District (USACE) in construction of the sediment cap in remedial area 5 (RA5) at the Pacific Sound Resources (PSR) Superfund site. Because the cap in RA5 is to be constructed with dredged material that is placed using instantaneous release from bottom-dump barges, different contracting and construction approaches are used for RA5 compared to the other RAs. The construction and contracting strategies for RA5 are discussed in Section 8 of the Basis of Design.

The RA5 cap may constructed using dredged material from two types of projects:

- USACE maintenance dredging of local rivers; or
- Other dredging projects in the vicinity.

In the case of USACE maintenance dredging projects, future USACE contracts with private dredging contractors will include additional clauses and requirements that will allow dredged material to be used in construction of the RA5 cap. The dredging contracts will direct the contractors to place clean dredged material (that meets specifications for capping) in specific areas of RA5, in accordance with the design plans.

Other parties applying for Dredged Material Management Program (DMMP) open-water disposal of suitable material may consider placement of their material at PSR RA5. In this case, USACE would evaluate the material for suitability as capping material and, if suitable, would set forth the requirements for placement at PSR RA5. The third parties would place the material at PSR.

In contrast to the approach in RA1 through 4, contractors placing material in RA5 will not be responsible for cap placement monitoring or construction verification. Services for construction monitoring, oversight, and verification in RA5 will be provided under separate contract to USACE. Monitoring and verification will include sampling, surveying, construction oversight, reporting, and other activities described in the RA5 Construction Quality Assurance Plan (CQAP).

All dredged material placed in RA5 will be suitable for open-water disposal under DMMP guidelines, and will be as clean as or cleaner than the sediment quality standards (SQS) set forth in WAC 173-204-320.

The PSR Management Plan (PSRMP), discussed in Section 9 of the Basis of Design, was developed by the Seattle District, USACE to define the strategies and procedures for construction and maintenance of the remedy for the Marine Sediments Unit (MSU). The PSRMP includes:

- The CQAP for RA1 through RA4;
- The CQAP for RA5;
- The Operation, Maintenance, and Monitoring Plan (OMMP) that covers the entire MSU;
- The Management Guidelines, which covers procedures for use of dredged material for the cap in RA5.

The substantive information in this appendix will be incorporated into the PSRMP.

F.2 ORGANIZATION

This appendix includes three attachments:

- **Attachment F-1:** Materials specifications for "Dredged Cap Material" that USACE will use to evaluate dredged material for suitability as RA5 capping material;
- **Attachment F-2:** An example specification for maintenance dredging of local rivers, with provisions for placement of the material at PSR RA5;
- **Attachment F-3:** The RA5 design drawings, which include construction notes.

ATTACHMENT F-1
MATERIALS SPECIFICATIONS FOR DREDGED CAP MATERIAL

This attachment presents the materials specifications for determination of whether a particular source of dredged material is suitable for use as capping material in PSR RA5. These specifications assume candidate materials are determined suitable for open water disposal by the Dredged Material Management Office (DMMO). USACE, in consultation with EPA, will determine whether candidate materials are suitable for use as capping material in PSR RA5. Project proponents with material meeting this specification will be provided with placement requirements, similar to the example shown in Attachment F.2.

DREDGED CAP MATERIAL

Dredged material for use in capping at PSR RA5 shall meet the following requirements:

1. Dredged material shall be determined by the DMMO to be suitable for open water disposal and beneficial re-use.

2. Dredged material shall be determined by the USACE and EPA to meet the sediment quality standard (SQS) chemical requirements of WAC 173-204-320(2), or if exceeding the chemical requirements, meeting the SQS biological requirements of WAC 173-204-320(3). DMMP suitability determinations will be based on, first, a determination that the dredged material is suitable for open water disposal. This means that all of the DMMP guidelines must be met. Second, the modified PSR Guidelines, which are summarized in the following bullets, must be met:

   - Tier I Suitability Determination. Satisfies PSR dredged cap material SQS compliance specification.

   - Tier II Suitability Determination. USACE will examine Tier II chemical data for carbon-normalized concentrations (for those chemicals with carbon-normalized SQS) and compare to SQS chemical concentrations in WAC 173-204-320(2). Satisfies PSR dredged cap material SQS compliance specification if concentrations are below SQS.

   - Tier III Suitability Determination. USACE will examine Tier III bioassay data for compliance with the SQS biological interpretive requirements of WAC 173-204-320(3). Satisfies PSR dredged cap material SQS compliance specification if bioassay results meet the SQS biological requirements.

   - Tier IV Suitability Determination. This is unique to the DMMP guidelines and does not apply to the PSR material suitability. The PSR Management Guidelines include a PSR Users' Manual that displays these differences in detail.

   USACE may refine these procedures for making a suitability determination in the PSRMP, and may identify instances where best professional judgement may be required in making the determination.

3. The fines content of the dredged material (silt and clay, passing U.S. No. 200 sieve) shall not exceed 30 percent by weight unless approved by the USACE. The USACE will consider using dredged material with fines content exceeding 30 percent on a case-by-case basis, and the fines content will be treated as an operational parameter during construction. USACE will monitor and evaluate water quality and off-site cap material deposition implications.

4. The dredged material shall be non-cohesive, as characterized by a plasticity index less than 10. The USACE will consider using dredged material with a plasticity index greater than 10 on a case-by-case basis, and the plasticity index will be treated as an operational parameter during construction.

ATTACHMENT F-2
EXAMPLE SPECIFICATION FOR USACE MAINTENANCE DREDGING PROJECTS

The attached example specification is based on a recent USACE dredging contract from the Duwamish River. For illustration, the project-specific information from that contract has been left in place. Highlighted sections indicate example clauses that may be included in future contracts to allow placement as capping material at PSR RA5.

FINAL DRAFT

EXAMPLE SECTION 02482

DREDGING

1. SCOPE OF WORK

Dredging includes removal and disposal of all materials as specified herein or indicated on the drawings. All shoals shall be removed within the described area to the required dredging prism despite any changes that may have occurred in their volume, dimensions, or locations between the date of condition survey and date of predredging survey.

2. TYPE OF DREDGING

Dredging shall be made by mechanical dredging into bottom dump barges.

3. SEQUENCE OF DREDGING

Contractor shall commence dredging at station 254+00 and work upstream to station 275+56. Work will be inspected and accepted in a maximum of 500-foot-long full width sections.

4. DREDGING AND DISPOSAL RESTRICTION

a. Dredging shall not commence before 16 October 2001 for the protection of migrating juvenile and adult salmanoids.

b. Dredging and disposal of dredged materials is not allowed in areas when occupied by Tribal fishermen. A copy of the Muckleshoot Indian Tribe fishing season schedule for Elliott Bay and the Duwamish River, dated 6 September 2001, is attached as Exhibit 1. Prior to commencing dredging operations, the Contractor shall coordinate its dredging and disposal activities with Mr. Mike Mahovlich, Fisheries Biologist (Harvest Management), 39015-172nd Ave. SE, Auburn, Washington 98092, phone (206) 931-0652. The Contractor shall provide its final dredge and disposal work schedule to Mr. Mahovlich prior to performing dredging operations.

5. CHARACTER OF MATERIALS

Material to be removed to restore the project depth within the limits indicated on the drawings is composed of shoaling that has occurred since the channel was last dredged. Previous dredging

records indicate that the material to be removed from station 254+00 to 275+56 varies in lenses from sand (SP) and silty sand (SM) to sandy silt (ML). Gradation curves are available for inspection at Seattle District, Corps of Engineers (Operations Division, Navigation Section), 4735 East Marginal Way South, Seattle, Washington. The Contractor may also encounter accumulations of forest trash, sunken logs, stumps, snags, whole trees with root systems, and miscellaneous debris. Bidders are expected to examine the site of work and decide for themselves the character of the materials.

6. RECORDS OF PREVIOUS DREDGING AND DETAILED CURRENT CONDITION SURVEYS

Records of previous dredging, including sediment sample analysis data, are available for inspection in Operations Division, Seattle District, Corps of Engineers, 4735 East Marginal Way South, Seattle, Washington. Government does not warrant accuracy of records of previous dredging. The drawings already prepared (SPECIAL CLAUSES, Paragraph CONTRACT DRAWINGS, MAPS, AND SPECIFICATIONS) present an estimated shoaled condition based on the previous dredge survey, but the depths shown thereon will be verified and corrected by soundings taken before dredging.

7. REPORTING REQUIREMENTS

Contractor shall prepare and maintain a daily report of operations and furnish two copies thereof to Contracting Officer daily. A copy of the Daily Report Form, which may be used for recording required information may be obtained from the Contracting Officer. Further instructions on preparation of report will be furnished at preconstruction conference. Contractor shall record times and durations of all shutdowns during the dredging day.

8. DISPOSAL OF DREDGED MATERIAL

8.1 Elliott Bay PSDDA Disposal Site

Where approved by the CO, dredged material shall be transported and bottom-dumped from barges at the Elliott Bay PSDDA Disposal Site, shown on the attached Elliott Bay Disposal Site map, Exhibit 2. The disposal area is a 600-foot radius circle with its center located as shown on attached Exhibit 2. When material is being disposed at the disposal area, barge position (inside the 600-foot radius) shall be verified by the Coast Guard Vessel Traffic System by radio before dumping begins and at the end of the dump. Both the Contractor and the Coast Guard will log each disposal operation. Disposal Site User Log forms will be provided to the Contractor at the preconstruction and safety meeting.

8.2 Disposal at PSR Capping Site

Where approved by the CO, dredged material shall be transported and bottom-dumped from barges at the PSR Capping Site, shown on the attached PSR Capping Site map, Exhibit 3. The two disposal areas measure approximately (800 feet by 1,600 feet) and (200 feet by 400 feet), respectively, and are located as shown on attached Exhibit 3. Within these two disposal areas, a series of target locations have been established. The target locations and coordinates to be used for this project are shown in Exhibit 3, along with the maximum amount of material to be placed at each target location. Locate center of barge within 100 feet of the designated target location and maintain static location during disposal, to the extent practical as conditions allow. When material is being disposed at the PSR Capping Site, barge position (inside the 50-foot radius of the designated target location) shall be verified by the Coast Guard Vessel Traffic System by radio before dumping begins and at the end of the dump. Both the Contractor and the Coast Guard will log each disposal operation. Disposal Site User Log forms will be provided to the Contractor at the preconstruction and safety meeting.

[Add automated data acquisition requirements.]

Coordinate with the CO and tribal fisheries departments to identify any conflicts with tribal fisheries.

8.3 Disposal in Unauthorized Areas

Payment will not be made for any material that is deposited elsewhere than in the disposal area shown, except as indicated below. Logs, snags, stumps, and miscellaneous debris shall not be disposed at the Elliott Bay disposal site. This debris shall be disposed in upland site(s) selected by the Contractor and approved by the Contracting Officer.

8.4 Contractor-Furnished Disposal Areas

If Contractor proposes to dispose of dredged material in other than disposal area shown on drawing, he shall submit with his offer a description of his proposed disposal areas and written permission of owners of property to use proposed areas for disposal. Written permission of owners shall be assigned to offeror and not a subcontractor. Description of disposal areas shall include location, size, and capacity of each area. Written permission of property owners involved in access to Contractor-furnished disposal areas shall also be submitted with Contractor's offer. Contractor shall coordinate his Contractor-furnished disposal areas with agencies listed in Paragraph Environmental Agencies and obtain all required permits. Written

approval of the agencies, together with copies of required permits, shall be submitted with his offer.

8.5 Areas Submitted After Award

If, after award of contract, a disposal area or areas other than shown on drawings is proposed by Contractor, acceptance thereof will be subject to approval of Contracting Officer and will be cause for contract modification in the best interest of the Government. Contractor shall obtain written consent of owners of substitute grounds and furnish evidence thereof to Contracting Officer. A proposal for an alternate disposal area shall be received in detail, and with supporting data, sufficiently in advance of required approval date to permit analysis to ensure that consideration has been given to interest of all affected parties. Contractor will be required to coordinate on use of his proposed disposal areas with Federal and State agencies as listed below in Paragraph Environmental Agencies and will be required to obtain written approval of all such agencies along with all permits and certifications required by law. Contract time will not be extended for obtaining approvals and permits. Suggested point of contact for known potential dredged material disposal sites is:

[provide contact]

8.6 Use of Any Contractor-Furnished Disposal Area

All expenses incurred in connection with providing and making available such disposal areas shall be borne by the Contractor, and all materials deposited thereon and all operations in connection therewith shall be at Contractor's risk. Method of containment of disposed material shall be as approved by the Contracting Officer. Offerors are cautioned that processing time for disposal-type permits is such that if permits have not already been obtained or initiated for the disposal site, it may be impossible to obtain them in enough time to meet the contract completion date.

8.7 Environmental Agencies

Except as otherwise specified hereinbefore, Contractor will be required to coordinate and furnish written approval on use of his proposed disposal areas and both natural and artificial wastewater channels, along with all required permits and certification, with following Federal and state agencies:

Pamela Erstad
Washington Department of Fish and Wildlife

333 E. Blackburn Rd.
Mt. Vernon, WA. 98273

Richard Vining
Washington Department of Ecology
P. O. Box 47600
Olympia, Washington 98504-7600

Lynn Childers
US Fish and Wildlife Service
510 Desmond Drive, Suite 102
Lacey, Washington 98503-1273

Justine Barton
Environmental Protection Agency
ECO-083
1200 Sixth Ave.
Seattle, WA. 98101-1128

Robert Grenner
Aquatic Resources
Washington Dept. of Natural Resources
111 Washington St. SE
P.O. Box 47027
Olympia, WA. 98504-7027

Hiram Arden, Operations Division
US Army Corps of Engineers
Seattle District
P.O. Box C-3755
Seattle, WA. 98124

[redacted]

ARCHIVE

EXHIBIT 3

[For the future contracts, USACE will provide the RA5 design drawings with the placement plan table modified to indicate only those target locations applicable to the specific disposal project]

ATTACHMENT F-3
RA5 DESIGN DRAWINGS

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

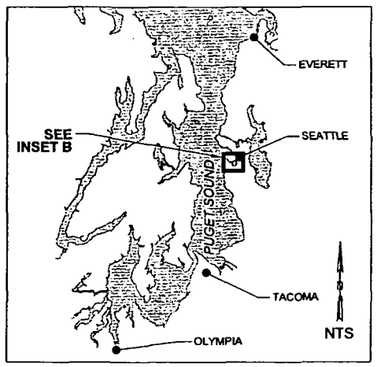
EPA REGION 10

PACIFIC SOUND RESOURCES MARINE SEDIMENT UNIT CAP CONSTRUCTION IN REMEDIATION AREA 5

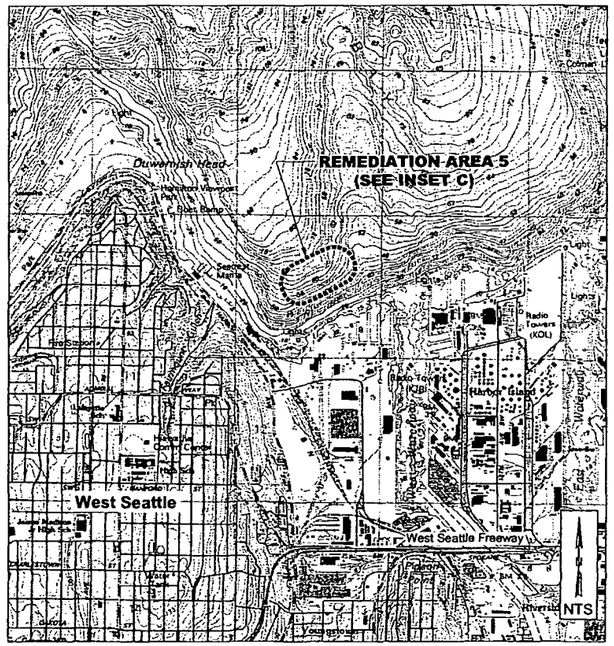
SEATTLE, WASHINGTON

DESIGN
URS
EPA Work Assignment No. 065-RD-RD-101-L
EPA Response Action Contract No. 68-W-98-228

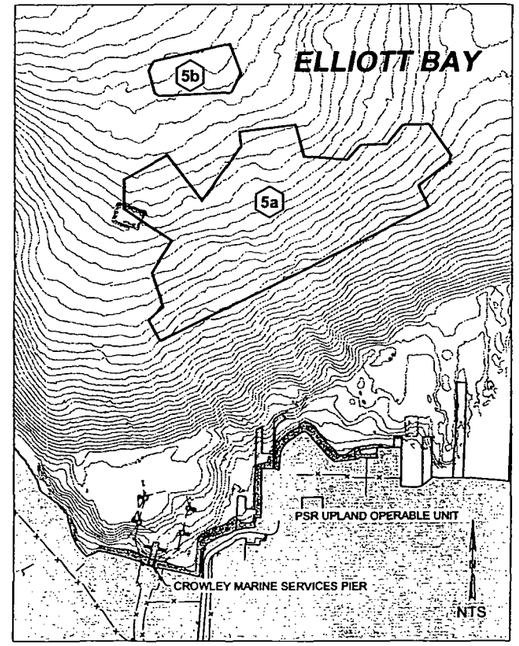
DRAWING INDEX		
SHEET NO.	PLATE NO.	TITLE
1	G-1	TITLE SHEET: VICINITY MAP, AREA MAP, AND DRAWING INDEX
2	C-1	RA5 CAPPING PLAN



INSET A



INSET B



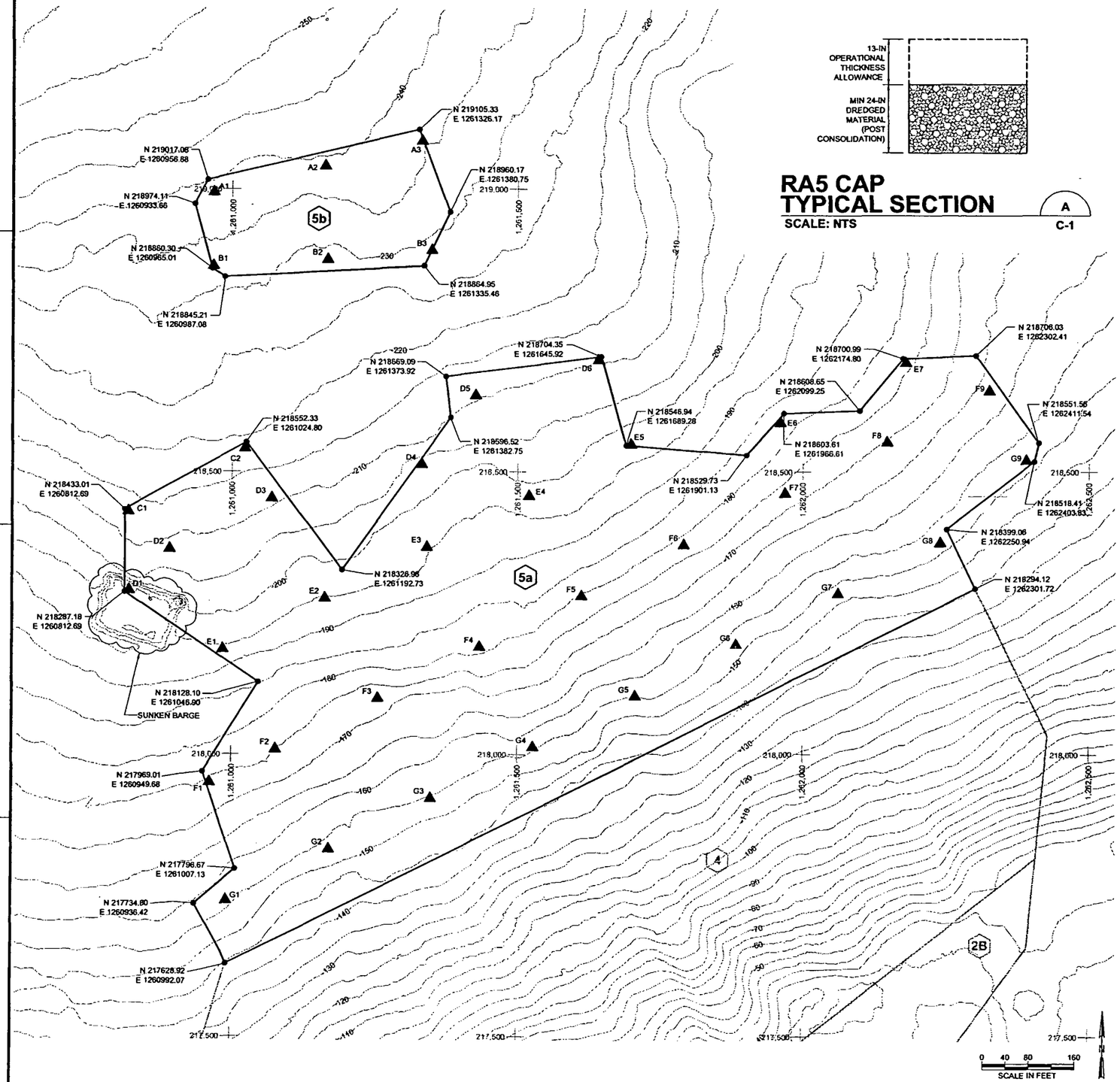
INSET C

SAFETY PAYS

URS	EPA REGION 10
PACIFIC SOUND RESOURCES SUPERFUND SITE MARINE SEDIMENT UNIT	
TITLE SHEET, VICINITY MAP, AREA MAP, AND DRAWING INDEX	
SEATTLE	WASHINGTON
SIZE F	DATE 2/3/03 PLATE G-1
DSGN DS/DG	CHK WLSO SHEET 1 OF 2

COE File No. E-13-1-1

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



RA5 CAP TYPICAL SECTION

SCALE: NTS

A C-1

NOTES

1. RA5 CAP MATERIAL SHALL CONFORM TO THE REQUIREMENTS FOR "DREDGED CAP MATERIAL" AS DEFINED IN THE FINAL DESIGN SUBMITTAL, APPENDIX F.
2. ALL DREDGED MATERIAL SHALL BE PLACED BY BOTTOM-DUMP BARGE.
3. CENTER OF BARGE SHALL BE WITHIN 100 FT OF TARGET COORDINATES AT TIME OF OPENING.
4. THE FIRST PLACEMENT EVENT AT EACH TARGET LOCATION SHALL NOT EXCEED 1,500 CY. SUBSEQUENT PLACEMENT EVENTS MAY EXCEED 1,500 CY AT A- THROUGH F-SERIES TARGET LOCATIONS. SUBSEQUENT PLACEMENT EVENTS SHALL NOT EXCEED 1,500 CY AT G-SERIES TARGET LOCATIONS.
5. HORIZONTAL DATUM: WASHINGTON COORDINATE SYSTEM NORTH ZONE, NAD 83. BASED UPON NGS CONTROL POINT AT DUWAMISH (PID SY4595).
6. VERTICAL DATUM: MLLW, US SURVEY, FEET.
7. TIDAL DATUM LOCATION: NOS STATION 9447130 ELLIOTT BAY SEATTLE, WA.
8. BASE MAPS HAVE BEEN DEVELOPED BASED ON BATHYMETRIC SURVEYS PERFORMED BY NOAA OFFICE OF COAST SURVEY IN MARCH 2001 AND PARAMETRIX IN SEPTEMBER 2001, AND ON A LAND SURVEY PERFORMED BY PARAMETRIX IN FALL 2001.
9. ALL QUANTITIES ARE EXPRESSED AS BARGE-MEASURE (BULK) VOLUME.
10. REFER TO PSRMP FOR CONSTRUCTION QUALITY CONTROL REQUIREMENTS.

RA5 PLACEMENT PLAN

COUNT	TARGET LOCATION	NORTHING	EASTING	REQUIRED QUANTITY (CY)	PLACEMENT SEQUENCE
1	A1	218994.34	1260967.82	5,500	Phase II
2	A2	219040.63	1261162.39	5,500	Phase II
3	A3	219084.75	1261331.99	5,500	Phase II
4	B1	218864.60	1260987.25	5,500	Phase II
5	B2	218875.88	1261166.93	5,500	Phase II
6	B3	218892.10	1261349.33	5,500	Phase II
7	C1	218429.68	1260819.29	5,500	Phase II
8	C2	218541.06	1261022.42	5,500	Phase II
9	D1	218290.10	1260820.40	5,500	Phase II
10	D2	218363.02	1260891.63	4,500	Phase II
11	D3	218453.60	1261069.96	5,500	Phase II
12	D4	218513.26	1261331.88	5,500	Phase II
13	D5	218634.76	1261426.62	5,500	Phase II
14	D6	218697.81	1261641.30	5,500	Phase II
15	E1	218185.84	1260984.44	5,500	Phase II
16	E2	218276.42	1261162.77	4,500	Phase II
17	E3	218367.00	1261341.10	4,500	Phase II
18	E4	218457.58	1261519.43	4,500	Phase II
19	E5	218548.16	1261697.77	5,500	Phase II
20	E6	218586.36	1261960.81	5,500	Phase II
21	E7	218693.04	1262179.59	5,500	Phase II
22	F1	217950.04	1260961.83	5,500	Phase I
23	F2	218008.67	1261077.26	4,500	Phase I
24	F3	218099.25	1261255.59	4,500	Phase I
25	F4	218189.82	1261433.92	4,500	Phase I
26	F5	218280.40	1261612.25	4,500	Phase I
27	F6	218370.98	1261790.58	4,500	Phase I
28	F7	218461.56	1261968.91	4,500	Phase I
29	F8	218552.14	1262147.24	4,500	Phase I
30	F9	218842.72	1262325.57	5,500	Phase I
31	G1	217740.91	1260991.75	5,500	Phase I
32	G2	217831.49	1261170.08	4,500	Phase I
33	G3	217922.07	1261348.41	4,500	Phase I
34	G4	218012.65	1261526.74	4,500	Phase I
35	G5	218102.46	1261705.47	4,500	Phase I
36	G6	218193.81	1261883.40	4,500	Phase I
37	G7	218284.39	1262061.73	4,500	Phase I
38	G8	218374.97	1262240.06	5,500	Phase I
39	G9	218518.77	1262389.99	5,500	Phase I
TOTAL				197,500	

LEGEND

ABBREVIATIONS

CY	CUBIC YARDS
MLLW	MEAN LOWER LOW WATER
IN	INCHES
NTS	NOT TO SCALE
PSRMP	PACIFIC SOUND RESOURCES MANAGEMENT PLAN

-20- ELEVATIONS IN FEET MLLW

REMEDIATION AREA BOUNDARIES FOR RA5

RA BOUNDARIES FOR OTHER CAP AREAS

(5) REMEDIATION AREA

BOTTOM-DUMP TARGET LOCATION

DREDGED MATERIAL

URS | EPA REGION 10

PACIFIC SOUND RESOURCES SUPERFUND SITE
MARINE SEDIMENT UNIT

RA5 CAPPING PLAN

SEATTLE WASHINGTON

SIZE			DATE	PLATE
F			2/3/03	C-1
DSN. DS/DG	CHK. WLSO		SHEET	2 OF 2

W. MARTIN NELSON — STATE OF WASHINGTON — 20489 — REGISTERED PROFESSIONAL ENGINEER — EXPIRES: 3/18/03

DAVID K. SCHUCHMAN — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER — 21-02-03 — EXPIRES: 09/18/03

COE File No. E-13-1-1

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EDIT DATE: 01/30/03 AZ: RL30

Appendix G

APPENDIX G

USACE DREDGE MODEL OUTPUT AND CALCULATIONS

APPENDIX G

USACE DREDGE MODEL OUTPUT AND CALCULATIONS

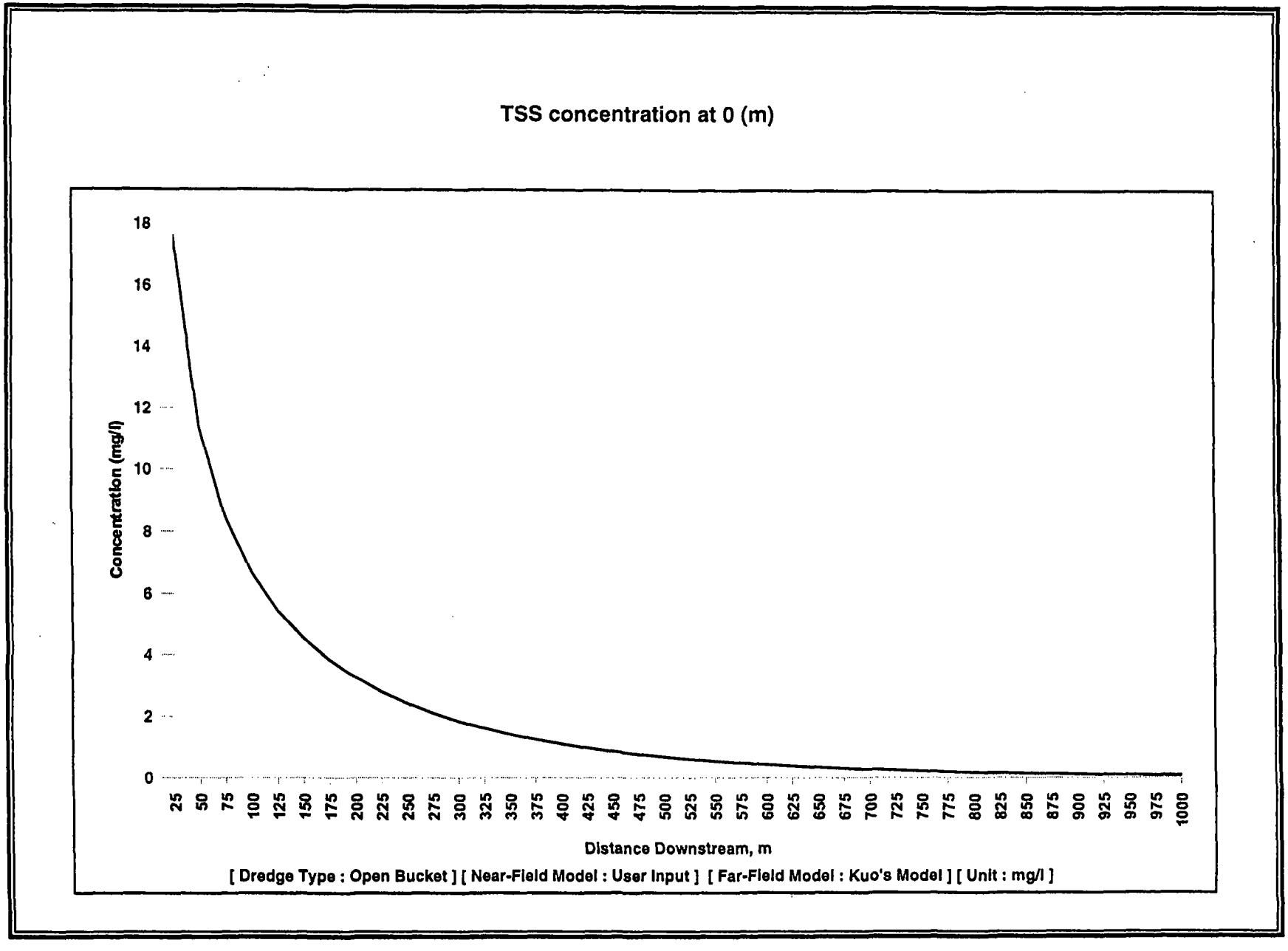
This appendix presents USACE DREDGE model input, output, and associated calculations for the evaluation of short-term turbidity impacts associated with dredging. The results are discussed in Section 5 of the basis of design report.

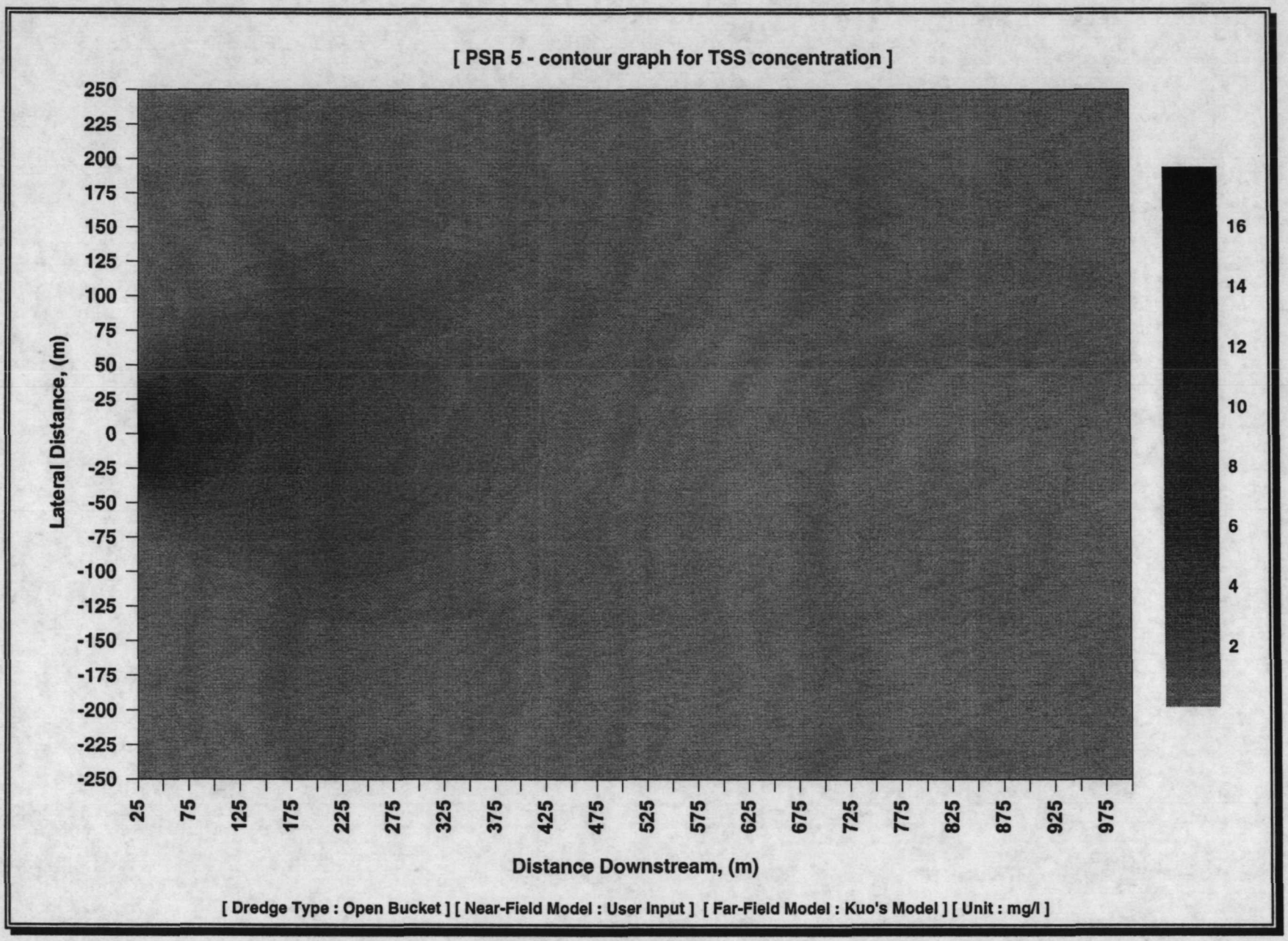
DREDGE MODULE OUTPUT

Dredge Type : Open Clamshell
Near-Field Model : User Input
Far-Field Model : Kuo's Model
Resuspended Material Selected : TSS, mg/L

Downstream Distance, m

Lateral Distance From Dredge, m	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000
-250	0	0	0	0	0	0.001	0.002	0.004	0.007	0.011	0.016	0.021	0.026	0.031	0.035	0.039	0.042	0.044	0.046	0.047	0.048	0.048	0.048	0.047	0.046	0.044	0.043	0.041	0.04	0.038	0.036	0.034	0.032	0.03	0.028	0.027	0.025	0.023	0.022	0.02
-225	0	0	0	0	0.001	0.003	0.008	0.014	0.023	0.032	0.041	0.05	0.058	0.064	0.07	0.074	0.077	0.078	0.079	0.079	0.078	0.076	0.074	0.071	0.069	0.066	0.063	0.059	0.056	0.053	0.05	0.047	0.044	0.041	0.038	0.035	0.033	0.031	0.028	0.026
-200	0	0	0	0.001	0.006	0.015	0.029	0.045	0.062	0.079	0.094	0.106	0.116	0.123	0.128	0.13	0.131	0.13	0.127	0.124	0.12	0.115	0.11	0.104	0.099	0.093	0.088	0.082	0.077	0.072	0.067	0.062	0.058	0.053	0.049	0.046	0.042	0.039	0.036	0.033
-175	0	0	0.001	0.009	0.029	0.057	0.09	0.123	0.152	0.177	0.195	0.208	0.216	0.219	0.219	0.215	0.21	0.203	0.195	0.185	0.176	0.166	0.156	0.146	0.136	0.127	0.118	0.11	0.101	0.094	0.087	0.08	0.074	0.068	0.062	0.057	0.052	0.048	0.044	0.04
-150	0	0.001	0.014	0.054	0.115	0.182	0.244	0.294	0.33	0.354	0.367	0.371	0.368	0.36	0.348	0.333	0.316	0.299	0.281	0.263	0.245	0.228	0.211	0.195	0.18	0.166	0.153	0.14	0.129	0.118	0.108	0.099	0.091	0.083	0.076	0.069	0.063	0.058	0.053	0.048
-125	0	0.014	0.097	0.235	0.374	0.487	0.566	0.614	0.636	0.638	0.627	0.607	0.579	0.548	0.515	0.481	0.447	0.415	0.383	0.353	0.324	0.297	0.273	0.249	0.228	0.208	0.19	0.173	0.158	0.144	0.131	0.119	0.109	0.099	0.09	0.082	0.074	0.067	0.061	0.056
-100	0.003	0.156	0.485	0.783	0.981	1.088	1.127	1.121	1.086	1.034	0.972	0.907	0.84	0.774	0.711	0.65	0.594	0.542	0.493	0.449	0.408	0.37	0.336	0.305	0.277	0.251	0.227	0.206	0.187	0.169	0.153	0.139	0.126	0.114	0.103	0.093	0.085	0.077	0.069	0.063
-75	0.142	1.018	1.694	2.001	2.078	2.032	1.926	1.791	1.648	1.505	1.368	1.239	1.12	1.011	0.912	0.822	0.741	0.667	0.601	0.541	0.488	0.439	0.396	0.357	0.321	0.29	0.261	0.235	0.212	0.192	0.173	0.156	0.141	0.127	0.115	0.104	0.094	0.085	0.076	0.069
-50	2.063	3.886	4.137	3.908	3.55	3.176	2.823	2.503	2.219	1.967	1.745	1.549	1.377	1.225	1.091	0.972	0.867	0.774	0.692	0.619	0.554	0.496	0.445	0.399	0.358	0.321	0.288	0.259	0.233	0.209	0.188	0.17	0.153	0.137	0.124	0.112	0.101	0.091	0.082	0.074
-25	10.29	8.678	7.069	5.841	4.896	4.151	3.552	3.06	2.652	2.31	2.019	1.771	1.558	1.374	1.214	1.075	0.953	0.847	0.753	0.671	0.598	0.534	0.477	0.426	0.381	0.342	0.306	0.274	0.246	0.221	0.198	0.178	0.16	0.144	0.13	0.117	0.105	0.095	0.085	0.077
0	17.583	11.344	8.451	6.678	5.45	4.539	3.834	3.272	2.815	2.437	2.12	1.852	1.623	1.427	1.258	1.111	0.984	0.872	0.775	0.689	0.613	0.547	0.488	0.436	0.39	0.349	0.312	0.28	0.251	0.225	0.202	0.181	0.163	0.146	0.132	0.118	0.107	0.096	0.086	0.078
25	10.29	8.678	7.069	5.841	4.896	4.151	3.552	3.06	2.652	2.31	2.019	1.771	1.558	1.374	1.214	1.075	0.953	0.847	0.753	0.671	0.598	0.534	0.477	0.426	0.381	0.342	0.306	0.274	0.246	0.221	0.198	0.178	0.16	0.144	0.13	0.117	0.105	0.095	0.085	0.077
50	2.063	3.886	4.137	3.908	3.55	3.176	2.823	2.503	2.219	1.967	1.745	1.549	1.377	1.225	1.091	0.972	0.867	0.774	0.692	0.619	0.554	0.496	0.445	0.399	0.358	0.321	0.288	0.259	0.233	0.209	0.188	0.17	0.153	0.137	0.124	0.112	0.101	0.091	0.082	0.074
75	0.142	1.018	1.694	2.001	2.078	2.032	1.926	1.791	1.648	1.505	1.368	1.239	1.12	1.011	0.912	0.822	0.741	0.667	0.601	0.541	0.488	0.439	0.396	0.357	0.321	0.29	0.261	0.235	0.212	0.192	0.173	0.156	0.141	0.127	0.115	0.104	0.094	0.085	0.076	0.069
100	0.003	0.156	0.485	0.783	0.981	1.088	1.127	1.121	1.086	1.034	0.972	0.907	0.84	0.774	0.71	0.65	0.594	0.542	0.493	0.449	0.408	0.37	0.336	0.305	0.277	0.251	0.227	0.206	0.187	0.169	0.153	0.139	0.126	0.114	0.103	0.093	0.085	0.077	0.069	0.063
125	0	0.014	0.097	0.235	0.374	0.487	0.566	0.614	0.636	0.638	0.627	0.607	0.579	0.548	0.515	0.481	0.447	0.415	0.383	0.353	0.324	0.297	0.273	0.249	0.228	0.208	0.19	0.173	0.158	0.144	0.131	0.119	0.109	0.099	0.09	0.082	0.074	0.067	0.061	0.056
150	0	0.001	0.014	0.054	0.115	0.182	0.244	0.294	0.33	0.354	0.367	0.371	0.368	0.36	0.348	0.333	0.316	0.299	0.281	0.263	0.245	0.228	0.211	0.195	0.18	0.166	0.153	0.14	0.129	0.118	0.108	0.099	0.091	0.083	0.076	0.069	0.063	0.058	0.053	0.048
175	0	0	0.001	0.009	0.029	0.057	0.09	0.123	0.152	0.177	0.195	0.208	0.216	0.219	0.219	0.215	0.21	0.203	0.195	0.185	0.176	0.166	0.156	0.146	0.136	0.127	0.118	0.11	0.101	0.094	0.087	0.08	0.074	0.068	0.062	0.057	0.052	0.048	0.044	0.04
200	0	0	0	0.001	0.006	0.015	0.029	0.045	0.062	0.079	0.094	0.106	0.116	0.123	0.128	0.13	0.131	0.13	0.127	0.124	0.12	0.115	0.11	0.104	0.099	0.093	0.088	0.082	0.077	0.072	0.067	0.062	0.058	0.053	0.049	0.046	0.042	0.039	0.036	0.033
225	0	0	0	0	0.001	0.003	0.008	0.014	0.023	0.032	0.041	0.05	0.058	0.064	0.07	0.074	0.077	0.078	0.079	0.079	0.078	0.076	0.074	0.071	0.069	0.066	0.063	0.059	0.056	0.053	0.05	0.047	0.044	0.041	0.038	0.035	0.033	0.031	0.028	0.026
250	0	0	0	0	0	0.001	0.002	0.004	0.007	0.011	0.016	0.021	0.026	0.031	0.035	0.039	0.042	0.044	0.046	0.047	0.048	0.048	0.048	0.047	0.046	0.044	0.043	0.041	0.04	0.038	0.036	0.034	0.032	0.03	0.028	0.027	0.025	0.023	0.022	0.02


TSS concentration at 0 (m)
Concentration (mg/l)
18
16
14
12
10
8
6
4
2
0
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675 700 725 750 775 800 825 850 875 900 925 950 975 1000
Distance Downstream, m
[Dredge Type : Open Bucket] [Near-Field Model : User Input] [Far-Field Model : Kuo's Model] [Unit : mg/l]


[PSR 5 - contour graph for TSS concentration]
Lateral Distance, (m)
250
225
200
175
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
-225
-250
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725
775
825
875
925
975
Distance Downstream, (m)
16
14
12
10
8
6
4
2
[Dredge Type : Open Bucket] [Near-Field Model : User Input] [Far-Field Model : Kuo's Model] [Unit : mg/l]

<< Input Data Summary >>

<< Input Data File >> = C:\ADDAMS\DREDGE\PSR5.DAT

<< Dredge Type >> = Open Bucket

<< Open-Bucket Dredge Data >>

Bucket size	= 5 (m^3)
Cycle time	= 60 (sec)
Settling velocity	= 0.00066 (m/sec)
In-situ dry density	= 1387 (kg/m^3)

<< Far-Field Model >>

Lateral diff. coeff.	= 3500 (cm^2/sec)
Vertical diff. coeff.	= 5 (cm^2/sec)
Settling velocity	= .00066 (m/sec)
Downstream locations	= 1000 (m)
X-step	= 25 (m)
Lateral locations	= 250 (m)
Y-step	= 25 (m)
Desired water depth	= 6 (m)

<< Site Characteristics >>

Water depth	= 6 (m)
Ambient water velocity	= 0.03 (m/sec)
Mean particle size	= 31 (um)
Specific gravity of sediment	= 2.65
R74	= 0.278
Ro	= 0.17

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	*Lateral Position(m)*						*Unit:(mg/l)*
	-250	-225	-200	-175	-150	-125	-100
25	.000	.000	.000	.000	.000	.000	.003
50	.000	.000	.000	.000	.001	.014	.156
75	.000	.000	.000	.001	.014	.097	.485
100	.000	.000	.001	.009	.054	.235	.783
125	.000	.001	.006	.029	.115	.374	.981
150	.001	.003	.015	.057	.182	.487	1.088
175	.002	.008	.029	.090	.244	.566	1.127
200	.004	.014	.045	.123	.294	.614	1.121
225	.007	.023	.062	.152	.330	.636	1.086
250	.011	.032	.079	.177	.354	.638	1.034
275	.016	.041	.094	.195	.367	.627	.972
300	.021	.050	.106	.208	.371	.607	.907
325	.026	.058	.116	.216	.368	.579	.840
350	.031	.064	.123	.219	.360	.548	.774
375	.035	.070	.128	.219	.348	.515	.710
400	.039	.074	.130	.215	.333	.481	.650
425	.042	.077	.131	.210	.316	.447	.594
450	.044	.078	.130	.203	.299	.415	.542
475	.046	.079	.127	.195	.281	.383	.493
500	.047	.079	.124	.185	.263	.353	.449
525	.048	.078	.120	.176	.245	.324	.408
550	.048	.076	.115	.166	.228	.297	.370
575	.048	.074	.110	.156	.211	.273	.336
600	.047	.071	.104	.146	.195	.249	.305
625	.046	.069	.099	.136	.180	.228	.277
650	.044	.066	.093	.127	.166	.208	.251
675	.043	.063	.088	.118	.153	.190	.227
700	.041	.059	.082	.110	.140	.173	.206
725	.040	.056	.077	.101	.129	.158	.187
750	.038	.053	.072	.094	.118	.144	.169
775	.036	.050	.067	.087	.108	.131	.153
800	.034	.047	.062	.080	.099	.119	.139
825	.032	.044	.058	.074	.091	.109	.126
850	.030	.041	.053	.068	.083	.099	.114
875	.028	.038	.049	.062	.076	.090	.103
900	.027	.035	.046	.057	.069	.082	.093
925	.025	.033	.042	.052	.063	.074	.085
950	.023	.031	.039	.048	.058	.067	.077
975	.022	.028	.036	.044	.053	.061	.069
1000	.020	.026	.033	.040	.048	.056	.063

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	Lateral Position(m)						Unit:(mg/l)
	-75	-50	-25	0	25	50	75
25	.142	2.063	10.290	17.583	10.290	2.063	.142
50	1.018	3.886	8.678	11.344	8.678	3.886	1.018
75	1.694	4.137	7.069	8.451	7.069	4.137	1.694
100	2.001	3.908	5.841	6.678	5.841	3.908	2.001
125	2.078	3.550	4.896	5.450	4.896	3.550	2.078
150	2.032	3.176	4.151	4.539	4.151	3.176	2.032
175	1.926	2.823	3.552	3.834	3.552	2.823	1.926
200	1.791	2.503	3.060	3.272	3.060	2.503	1.791
225	1.648	2.219	2.652	2.815	2.652	2.219	1.648
250	1.505	1.967	2.310	2.437	2.310	1.967	1.505
275	1.368	1.745	2.019	2.120	2.019	1.745	1.368
300	1.239	1.549	1.771	1.852	1.771	1.549	1.239
325	1.120	1.377	1.558	1.623	1.558	1.377	1.120
350	1.011	1.225	1.374	1.427	1.374	1.225	1.011
375	.912	1.091	1.214	1.258	1.214	1.091	.912
400	.822	.972	1.075	1.111	1.075	.972	.822
425	.741	.867	.953	.984	.953	.867	.741
450	.667	.774	.847	.872	.847	.774	.667
475	.601	.692	.753	.775	.753	.692	.601
500	.541	.619	.671	.689	.671	.619	.541
525	.488	.554	.598	.613	.598	.554	.488
550	.439	.496	.534	.547	.534	.496	.439
575	.396	.445	.477	.488	.477	.445	.396
600	.357	.399	.426	.436	.426	.399	.357
625	.321	.358	.381	.390	.381	.358	.321
650	.290	.321	.342	.349	.342	.321	.290
675	.261	.288	.306	.312	.306	.288	.261
700	.235	.259	.274	.280	.274	.259	.235
725	.212	.233	.246	.251	.246	.233	.212
750	.192	.209	.221	.225	.221	.209	.192
775	.173	.188	.198	.202	.198	.188	.173
800	.156	.170	.178	.181	.178	.170	.156
825	.141	.153	.160	.163	.160	.153	.141
850	.127	.137	.144	.146	.144	.137	.127
875	.115	.124	.130	.132	.130	.124	.115
900	.104	.112	.117	.118	.117	.112	.104
925	.094	.101	.105	.107	.105	.101	.094
950	.085	.091	.095	.096	.095	.091	.085
975	.076	.082	.085	.086	.085	.082	.076
1000	.069	.074	.077	.078	.077	.074	.069

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	Lateral Position(m)						Unit:(mg/l)
	100	125	150	175	200	225	250
25	.003	.000	.000	.000	.000	.000	.000
50	.156	.014	.001	.000	.000	.000	.000
75	.485	.097	.014	.001	.000	.000	.000
100	.783	.235	.054	.009	.001	.000	.000

125	.981	.374	.115	.029	.006	.001	.000
150	1.088	.487	.182	.057	.015	.003	.001
175	1.127	.566	.244	.090	.029	.008	.002
200	1.121	.614	.294	.123	.045	.014	.004
225	1.086	.636	.330	.152	.062	.023	.007
250	1.034	.638	.354	.177	.079	.032	.011
275	.972	.627	.367	.195	.094	.041	.016
00	.907	.607	.371	.208	.106	.050	.021
325	.840	.579	.368	.216	.116	.058	.026
350	.774	.548	.360	.219	.123	.064	.031
375	.710	.515	.348	.219	.128	.070	.035
400	.650	.481	.333	.215	.130	.074	.039
425	.594	.447	.316	.210	.131	.077	.042
450	.542	.415	.299	.203	.130	.078	.044
475	.493	.383	.281	.195	.127	.079	.046
500	.449	.353	.263	.185	.124	.079	.047
525	.408	.324	.245	.176	.120	.078	.048
550	.370	.297	.228	.166	.115	.076	.048
575	.336	.273	.211	.156	.110	.074	.048
600	.305	.249	.195	.146	.104	.071	.047
625	.277	.228	.180	.136	.099	.069	.046
650	.251	.208	.166	.127	.093	.066	.044
675	.227	.190	.153	.118	.088	.063	.043
700	.206	.173	.140	.110	.082	.059	.041
725	.187	.158	.129	.101	.077	.056	.040
750	.169	.144	.118	.094	.072	.053	.038
775	.153	.131	.108	.087	.067	.050	.036
800	.139	.119	.099	.080	.062	.047	.034
825	.126	.109	.091	.074	.058	.044	.032
850	.114	.099	.083	.068	.053	.041	.030
875	.103	.090	.076	.062	.049	.038	.028
900	.093	.082	.069	.057	.046	.035	.027
925	.085	.074	.063	.052	.042	.033	.025
50	.077	.067	.058	.048	.039	.031	.023
975	.069	.061	.053	.044	.036	.028	.022
1000	.063	.056	.048	.040	.033	.026	.020

URS Greiner Woodward Clyde

Page 1 of 1

Job PSR Superfund Site | Project No. 52-F4006500 | Sheet ___ of ___

Description Settling Velocity Calc | Computed by MTM | Date 4/15/02

Checked by DS | Date 4/18/02

Reference

Find: Settling velocity for median particle size less than 74 μm in area of proposed dredge cuts ($D_{50_{Fines}}$)

Given: $D_{50_{Fines}}$ = 31 μm from grain size distribution report for sample from station 207 comp.

$\rho_s \approx 2.65\ Mg/m^3$ – typical value for sand

$\rho = 1.01\ g/cm^3$

$g = 9.81\ m/s^2$

$\mu = 1.31 \times 10^{-2}\ g/cm \cdot s$

Governing equation:

Stoke's Law

$$\omega = \frac{g D^2}{18 \mu} (\rho_s - \rho)$$

ω = settling velocity (m/s)

g = acceleration of gravity (m/s^2)

D = particle diameter (m)

μ = viscosity of water ($g/m \cdot s$)

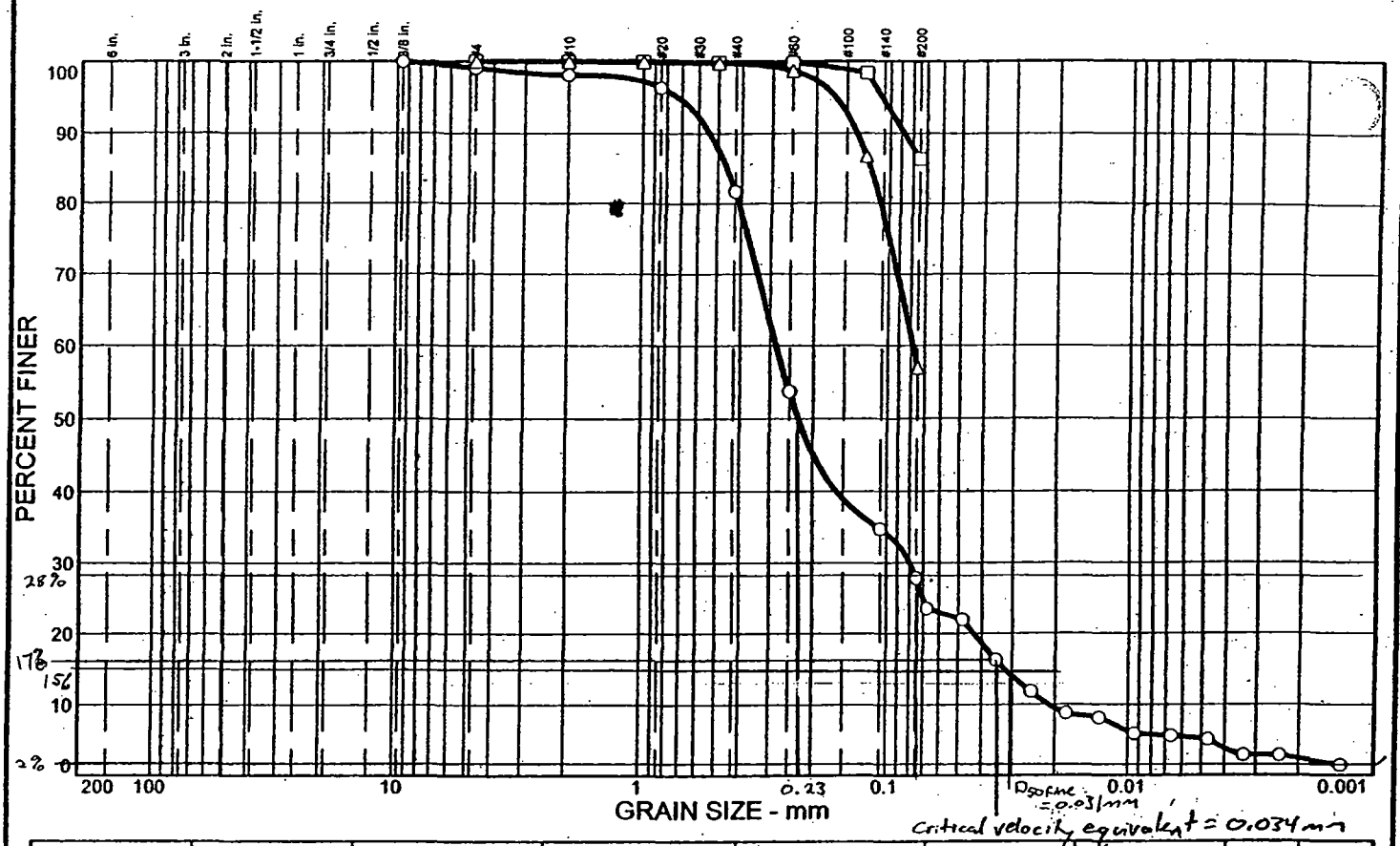
ρ_s = particle density (g/m^3)

ρ = density of water (g/m^3)

$$\omega = \frac{(9.81\ m/s^2)(0.000031\ m)^2(2.65 \times 10^6\ g/m^3 - 1.01 \times 10^6\ g/m^3)}{18(1.31 \times 10^{-2}\ g/m \cdot s)}$$

$$\omega = 0.00066\ m/s$$

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		0.9	71.3	22.6	5.2	SM		GNP	C
□			13.7	86.3		ML		29	32
△			43.0	57.0		ML			

SIEVE inches size	PERCENT FINER ○	□	△
.375	100.0		
	GRAIN SIZE		
D_{60}	0.283		0.0785
D_{30}	0.0798		
D_{10}	0.0212		
	COEFFICIENTS		
C_c	1.06		
C_u	13.35		

SIEVE number size	PERCENT FINER ○	□	△
#4	99.1	100.0	100.0
#10	98.1	100.0	100.0
#18		100.0	99.9
#20	96.4		
#35		99.9	99.8
#40	81.7		
#60	53.7	99.8	98.7
#120		98.4	86.7
#140	34.8		
#200	27.8	86.3	57.0

SOIL DESCRIPTION

○ Silty sand

□ Silt

△ Sandy silt

REMARKS:

○ CLASSIFICATION BASED ON GRAINSIZE ONLY

□

△ classification based on grainsize only

○ Source: Sample No.: 207 COMP. Elev./Depth: 1-3

□ Source: B-1 Sample No.: S-1 Elev./Depth: 1.7-2.3

△ Source: B-1 Sample No.: S-2 Elev./Depth: 3.8-4.2

SOIL TECHNOLOGY, INC.

Client: URS #53-F4006500

Project: PSR Superfund Site,Marine Sediment Unit EPA United States Environmental Protection Agency

Project No.: J-1426 Plate 1

URS Greiner Woodward Clyde

Page 1 of 1

Job PSR Superfund Site | Project No. 53-F4006500 | Sheet ___ of ___

Description Dry density calculation | Computed by MTM | Date 4/16/02

Checked by DG | Date 4/18/02

Reference

Find: Dry density of sediments in dredge area

Given: Measured sediment density = 110 pcf = 1,762 kg/m³

Assumed this is a saturated density (ρ_{sat}) and is equal to total density, ρ

Measured water content = 27%

Governing Equation:

$$\rho_d = \frac{\rho}{1+w}$$

ρ_d = Dry density

ρ = Total density

w = water content

Solution

$$\rho_d = \frac{1,762 \text{ kg/m}^3}{1+0.27} = 1,387 \text{ kg/m}^3$$

Appendix H

APPENDIX H

VEGETATIVE PLANTING SPECIFICATIONS

Summary of Vegetative Planting Specifications
Pacific Sound Resources Superfund Site

Section No.	Section Title
Division 2 - Site Work	
02923	Sprigging
02930	Exterior Planting

SECTION 02923

SPRIGGING

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only. The most recent version of the reference applies.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 4972	(1995a) pH of Soils
ASTM D 5268	(1992; R 1996) Topsoil Used for Landscaping Purposes

1.2 DESCRIPTION OF WORK

This scope of work consists of furnishing all labor, equipment, and materials to establish shrubs as noted on the Drawings and in the plant list. Any substantive variance to this specification due to unforeseen conditions encountered on the Site, weather conditions, plant availability, other construction activities, etc. shall be approved by the Contracting Officer (CO).

1.3 SUBMITTALS

Government approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES.

SD-01 Data

Delivery; FIO

Delivery schedule.

Quantity Check; FIO

Bag count or bulk weight measurements of material used compared with area covered to determine the application rate and quantity installed. The quantity of sprigs used shall be compared against the total area installed.

Sprig Establishment Period; GA

Calendar time period for the sprig establishment period.

Maintenance Record; FIO

Maintenance work performed, photographic documentation of planted areas, the quantity of plant losses, diagnosis of the plant loss, and the quantity of replacements made on each site visit. This maintenance record shall also include documentation of the maintenance work performed for exterior planting in accordance with Section 02930 EXTERIOR PLANTING.

Goose Exclosure Installation Plan; GA

The Contractor shall submit a goose exclosure installation plan as part of the Planting Work Plan in accordance with Section 02930 EXTERIOR PLANTING. This plan shall include the proposed design of each goose exclosure structure, including proposed spacing, materials, and procedure. Drawings shall be included that show plan and profile views of each proposed exclosure.

SD-13 Certificates

Sprigs; GA

Prior to the delivery of materials, certificates of compliance attesting that materials meet the specified requirements. Certified copies of the material certificates shall include the following:

a. Sprigs. Cultivar name, genetic purity and field location.

1.4 SOURCE INSPECTION

The sources of sprig material shall be subject to inspection.

1.5 DELIVERY, INSPECTION, STORAGE, AND HANDLING

1.5.1 Delivery

A delivery schedule shall be provided at least 10 calendar days prior to the first day of delivery.

1.5.2 Sprigs

Sprigs shall be protected during delivery to prevent desiccation, internal heat buildup, or contamination.

1.5.3 Inspection

Sprigs shall be inspected upon arrival at the jobsite for conformity to cultivar and genetic purity. Sprigs that have been exposed to heat or excessive drying shall be rejected. Other

materials shall be inspected for compliance. Unacceptable materials shall be removed from the job site.

1.5.4 Storage

1.5.4.1 Sprigs

Sprigs shall be stored in designated areas and covered with moist burlap, straw, or other covering. Covering shall allow air to circulate preventing internal heat from building up. Sprigs shall be protected from exposure to wind, and direct sunlight until installed.

1.5.4.2 Other Material Storage

Materials shall be stored in designated areas.

1.5.5 Handling

Sprigs shall not be damaged during handling. Except for bulk deliveries, materials shall not be dropped or dumped from vehicles.

1.5.6 Time Limitation

Time limitation between harvesting and installing sprigs shall be a maximum 24 hours. If nursery-grown sprigs are used, time limitation between delivery and installation shall be 24 hours.

PART 2 PRODUCTS

2.1 SPRIGS

2.1.1 Sprig Cultivar

The sprigs, as shown in Table 02923-1, shall be healthy living stems, stolons, or rhizomes.

Table 02923-1
PLANT LIST

Common Name	Scientific Name	Form
Seashore saltgrass	*Distichlis spicata*	1 gallon pot
Gumweed	*Grindelia integrifolia*	1 gallon pot
American dunegrass	*Leymus mollis*	1 gallon pot

2.1.2 Quality

Sprigs shall be cultivated from plant origin native to the Pacific Northwest. Sprigs shall be grown under climatic conditions similar to those in the locality of the project. Sprigs shall be free from material detrimental to a healthy stand of grass plants. Sprigs that have been exposed to heat or excessive drying will be rejected.

2.2 SEED (NOT USED)

2.3 SUBSTITUTIONS

Substitutions will not be allowed without written request and approval from the CO.

2.4 PLANTING SOIL

Planting soil shall be a 50%:50% by weight mixture of beach sand and topsoil. Beach sand shall conform to the requirements in Section 02483 SEDIMENT CAP. Topsoil shall conform to the requirements in Section 02930 EXTERIOR PLANTING.

2.5 SOIL AMENDMENTS (NOT USED)

2.6 MULCH (NOT USED)

2.7 WATER

Unless otherwise noted, water shall be the responsibility of the Contractor. Water shall not contain elements toxic to plant life, nor salinity greater than 1 part per thousand (ppt).

2.8 PESTICIDE (NOT USED)

PART 3 EXECUTION

3.1 INSTALLING SPRIGS TIME AND CONDITIONS

3.1.1 Sprigging Time

Sprigs shall be installed from October to November for spring establishment.

3.1.2 Sprigging Conditions

Sprigging operations shall be performed only during periods when beneficial results can be obtained. When drought, excessive moisture, or other unsatisfactory conditions prevail, the work shall be stopped when directed. When special conditions warrant a variance to the sprigging operations, proposed alternate times shall be submitted for approval.

3.2 SITE PREPARATION

The prepared surface shall be smooth and completed with a light raking to remove debris. Debris and stones over 3 inches in any dimension shall be removed from the surface.

3.3 INSTALLATION

Prior to installing sprigs, any previously prepared surface compacted or damaged shall be reworked to meet the requirements of paragraph 3.2 SITE PREPARATION. Areas shall be sprigged as indicated.

3.3.1 Installing Sprigs

The sprigging method shall be Row Sprigging described below.

3.3.1.1 Row Sprigging

Sprigs shall be planted according to the spacing and elevations shown on the Drawings. In general, seashore saltgrass shall be planted at the lowest elevations (12 to 13 feet MLLW), with American dunegrass and gumweed shall be interspersed above 13 feet MLLW. Plantings shall appear random and not in traditional rows.

3.3.2 Finishing

All installed sprigs shall extend above the ground surface upon completion of the sprigging operation.

3.3.3 Watering Sprigs

Watering shall be started immediately after completing each day of sprigging. Water shall be applied at a rate sufficient to ensure moist soil conditions to a minimum 1-inch depth. Run-off, puddling, and wilting shall be prevented.

3.4 TEMPORARY SEEDING (NOT USED)

3.5 QUANTITY CHECK

The quantity of sprigs used shall be as shown on the Drawings.

3.6 APPLICATION OF PESTICIDE (NOT USED)

3.7 RESTORATION AND CLEAN UP

3.7.1 Restoration

Existing facilities that have been damaged from the sprigging operation shall be restored to original condition at Contractor's expense.

3.7.2 Clean Up

Excess and waste material shall be removed from the sprigged areas and shall be disposed offsite. Adjacent paved areas shall be cleaned.

3.8 PROTECTION OF INSTALLED AREAS FROM GEESE

Goose exclosure structures shall be installed to protect the two sprigging areas from geese. The exclosures shall consist of posts with twine strung from nails between the posts or alternate equivalent design if approved by the CO. The following are performance requirements of each exclosure:

a. Posts: The posts shall be securely buried at least 2-feet below ground surface. The top of each post shall be at least +15 feet MLLW. Each post shall have nails hammered halfway into the post every 10 inches of its length. Perimeter posts shall border the sprigging area at least 1 foot outside of the planting zone. Additional interior posts shall be installed within the planting zone to create the required coverage of twine.

b. Twine: The twine shall be strung from each perimeter post, from one nail to another nail of equal height on the next post. Twine shall be strung from the top nail on each post to the top nail on surrounding posts. Proposed twine materials shall not be stretchable under wetting/drying cycles.

c. Spacing of Posts: Perimeter and interior posts shall be spaced such that twine strung on the tops of the posts covers the top of the planting area. No open space created by absence of string shall be greater than 10 feet in any direction.

d. The temporary goose exclosure structures shall be installed to withstand the tidal flux throughout the sprig establishment period in accordance with paragraph 3.9 SPRIG ESTABLISHMENT PERIOD.

e. The Contractor shall maintain the temporary goose exclosure structures in good and effective operating condition throughout the sprig establishment period, in accordance with paragraph 3.9 SPRIG ESTABLISHMENT PERIOD, by performing routine inspections to determine condition and effectiveness. The Contractor shall make repairs immediately. Repairs to the temporary goose exclosures shall be reported to the CO in the maintenance record in accordance with paragraph 3.9.2.1 Maintenance Record.

f. The Contractor shall inspect the temporary goose exclosure structures at least once every 7 calendar days and within 24 hours of the end of any storm event that produces 0.5 inches or more rainfall at the Site.

3.9 SPRIG ESTABLISHMENT PERIOD

3.9.1 Commencement

The sprig establishment period to obtain a healthy stand of plants shall commence on the first day of sprigging work under this Contract and shall continue through the remaining life of the Contract and end 12 months after the last day of sprigging operations required by this Contract. The sprig establishment period shall be coordinated with Section 02930 EXTERIOR PLANTING. The sprig establishment period shall be modified for separate completion dates of areas.

3.9.2 Maintenance During Establishment Period

Maintenance of the planted areas shall include eradicating weeds, insects, and diseases; maintaining temporary goose exclosure structures; and watering. Use of pesticides or herbicides is not permitted. Following completion of sprigging, watering shall continue twice a week for 4 weeks, unless otherwise directed by the CO. After 4 weeks, watering shall continue for the establishment period at a minimum once per week and adjusted accordingly to natural precipitation, unless otherwise directed by the CO.

At least 60 percent of the original plant material shall be in vigorous growing condition during the entire sprig establishment period. The 60 percent survival criterion shall apply to each species of plant, unless otherwise approved by the CO. The Contractor shall provide and install replacement plants, in accordance with PART 2 PRODUCTS, as necessary to maintain the minimum 60 percent requirement throughout the sprig establishment period.

Should particular areas of the initial sprig installation show continued excessive mortality, the Contractor may propose more intensive planting in the healthier areas. Any such proposal must be approved by the CO. The overall 60 percent plant survival criterion shall remain in effect unless otherwise approved by the CO.

3.9.2.1 Maintenance Record

A record of each site visit shall be submitted to the CO describing the maintenance work performed, photographic documentation of planted areas, the quantity of plant losses, diagnosis of the plant loss, and the quantity of replacements made on each site visit. One maintenance record shall be submitted that incorporates maintenance for sprigging and exterior planting. Coordinate with the requirements of Section 02930 EXTERIOR PLANTING.

END OF SECTION

SECTION 02930

EXTERIOR PLANTING

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only. The most recent version of the reference applies.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI A300	(1995) Tree Care Operations - Trees, Shrubs and Other Woody Plant Maintenance

AMERICAN NURSERY AND LANDSCAPE ASSOCIATION (ANLA)

ANLA Z60.1	(1996) Nursery Stock

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 422	(1963; R 1998) Particle-Size Analysis of Soils
ASTM D 4972	(1995a) pH of Soils
ASTM D 5268	(1992; R 1996) Topsoil Used for Landscaping Purposes

1.2 DESCRIPTION OF WORK

This scope of work consists of furnishing all labor, equipment, and materials to establish shrubs as noted on the Drawings and in the plant list. Any substantive variance to this specification due to unforeseen conditions encountered on the Site, weather conditions, plant availability, other construction activities, etc. shall be approved by the Contracting Officer (CO).

1.3 SUBMITTALS

Government approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES.

SD-01 Data

Delivery; FIO

Delivery schedule

Plant Establishment Period; GA

Calendar time period for the plant establishment period.

Maintenance Record; FIO

Maintenance work performed, photographic documentation of planted areas, quantity of plant losses, and replacements; and diagnosis of unhealthy plant material.

Planting Work Plan; GA

The Contractor shall submit a Planting Work Plan, including planting procedures and plant material replacement procedures; suppliers; goose exclosure installation plan; and a detailed maintenance schedule for plants, shrubs, and goose exclosures during the plant establishment period. The Planting Work Plan shall coordinate with the requirements of Section 02923 SPRIGGING.

SD-04 Drawings

Drawings; FIO

Scale drawings defining areas to receive plant materials.

SD-14 Samples

Delivered Topsoil; FIO

Samples taken from several locations at the source.

SD-13 Certificates

Plant Material; GA
Topsoil; GA

Prior to delivery of materials, certificates of compliance attesting that materials meet the specified requirements. Certified copies of the material certificates shall include the following.

a. Plant Material: Classification, botanical name, common name, size, quantity by species, and location where grown.

b. Topsoil: Particle size, pH, organic matter content, textural class, soluble salts, chemical and mechanical analyses.

1.4 SOURCE INSPECTIONS

The nursery or source of plant material and the source of delivered topsoil shall be subject to inspection.

1.5 DELIVERY, INSPECTION, STORAGE, AND HANDLING

1.5.1 Delivery

A delivery schedule shall be provided at least 10 calendar days prior to the first day of delivery.

1.5.1.1.1 Plant Material Identification

Plant material shall be identified with attached, durable, waterproof labels and weather-resistant ink, stating the correct botanical plant name and size.

1.5.1.1.2 Protection During Delivery

Plant material shall be protected during delivery to prevent desiccation and damage.

1.5.1.1.3 Delivered Topsoil

Prior to the delivery of any topsoil, the availability of topsoil shall be verified in paragraph 2.2 TOPSOIL. A soil test shall be provided for delivered topsoil.

1.5.2 Inspection

Plant material shall be well shaped, vigorous and healthy, free from disease, harmful insects and insect eggs, sun-scald injury, disfigurement or abrasion. Plant material shall be checked for unauthorized substitution and to establish nursery grown status. Plant material showing desiccation, abrasion, sun-scald injury, disfigurement, or unauthorized substitution shall be rejected. The plant material shall meet the caliper and height measurements specified. Plant material that measures less than specified, or has been poled, topped off or headed back, shall be rejected. Other materials shall be inspected for compliance with PART 2 PRODUCTS. Topsoil that contains slag, cinders, stones, lumps of soil, sticks, roots, trash or other material larger than 1-1/2 inch diameter shall be rejected. Topsoil that contains viable plant material and plant parts shall be rejected. Unacceptable material shall be removed from the Site.

1.5.3 Storage

1.5.3.1 Plant Material Storage

Plant material not installed on the day of arrival at the Site shall be stored and protected in areas designated by the CO. Plant material shall not be stored longer than 30 calendar days. Plant material shall be protected from direct exposure to wind and sun.

1.5.3.2 Other Material Storage

Storage of other material shall be in areas designated by the CO.

1.5.4 Handling

Plant material shall not be injured in handling. Plant material shall not be handled by the trunk or stems. Materials shall not be dropped from vehicles.

1.5.5 Time Limitation

The time limitation from digging to installing plant material shall be a maximum 7 calendar days.

PART 2 PRODUCTS

2.1 PLANT MATERIAL

2.1.1 Plant Material Classification

The plant material shall be nursery grown stock conforming to ANLA Z60.1 and shall be the species specified.

2.1.2 Plant Schedule

The plant materials shall be as shown in Table 02930-1.

Table 02930-1
PLANT LIST

Common Name	Scientific Name	Form
Hooker willow	*Salix hookeriana*	Cutting (stake)
Scouler willow	*Salix scouleriana*	Cutting (stake)

2.1.3 Substitutions

Substitutions will not be permitted without written request and approval from the Contracting Officer (CO).

2.1.4 Quality

Plant materials shall be cultivated from plant origin native to the Pacific Northwest. Well shaped, well grown, vigorous plant material in accordance with ANLA Z60.1 shall be provided. Plant material shall be provided free from disease, harmful insects and insect eggs, sun-scald injury, disfigurement and abrasion. Plant material shall be free of shock or damage to branches, trunk, or root systems, which may occur from the digging and preparation for shipment, method of shipment, or shipment. Plant quality is determined by the growing conditions; method of shipment to maintain health of the root system; and growth of the trunk and crown as follows.

2.1.5 Cuttings (Stakes)

Cuttings (stakes) shall be nursery grown stock. They shall be 2.5 to 3 feet in length and over 0.5 inch in diameter. Cuttings (stakes) shall be protected from sun, wind, freezing, drying, or injury before and during planting.

2.2 TOPSOIL

Imported material shall meet the acceptance criteria for cap materials in accordance with Section 02483 SEDIMENT CAP.

Topsoil shall be as defined in ASTM D 5268. Topsoil shall be free from slag, cinders, stones, lumps of soil, sticks, roots, trash or other material over a minimum 1-1/2 inch diameter. Topsoil shall be free from viable plants and plant parts.

Topsoil shall be imported two-way mix, screened, friable, fertile, sandy, natural top loam consisting of 2/3 soil and 1/3 organic matter with no admixture of refuse or any material toxic to plant growth and it shall be reasonably free from subsoil and stumps, roots, brush, stones (2 inches or more in diameter), clay lumps or similar objects. Brush and other vegetation which will not be incorporated with the soil during handling operations shall be cut and removed. The topsoil or soil mixture, unless otherwise specified or approved, shall have a pH range of approximately 5.5 pH to 7.6 pH, when tested in accordance with the ASTM D 4972. The organic content shall not be less than 3 percent nor greater than 20 percent, as determined by the wet-combustion method (chromic acid reduction). There shall be not less than 20 percent nor more than 80 percent of the material passing the No. 200 (0.074 mm) sieve as determined in accordance with ASTM D 422.

Natural topsoil may be amended by the Contractor with approved materials and methods to meet the above requirements.

2.3 WATER

Unless otherwise directed, water shall be the responsibility of the Contractor. Water shall not contain elements toxic to plant life nor salinity greater than 1 part per thousand (ppt).

PART 3 EXECUTION

3.1 INSTALLING PLANT MATERIAL TIME AND CONDITIONS

3.1.1 Deciduous Plant Material Time

Deciduous plant material shall be installed from October to November.

3.1.2 Plant Material Conditions

Planting operations shall be performed only during periods when beneficial results can be obtained. When drought, excessive moisture, frozen ground or other unsatisfactory conditions prevail, the work shall be stopped when directed. When special conditions warrant a variance to the planting operations, proposed planting times shall be submitted for approval.

3.2 SITE PREPARATION

3.2.1 Layout

Plant material locations may be adjusted to meet field conditions.

3.2.2 Protecting Existing Vegetation

Existing trees, shrubs, and plant beds shall be protected during planting operations.

3.3 EXCAVATION (NOT USED)

3.4 INSTALLATION

3.4.1 Setting Plant Material

Plant material shall be installed opportunistically and in a random fashion, in existing voids in the riprap. Plant in locations and elevations shown on the Drawings. Plant material shall be set plumb and held in position until sufficient soil has been firmly placed around root system or ball. In relation to the surrounding grade, the plant material shall be set even with the grade at which it was grown.

3.4.1.1 Bare-Root Plant Material

Bare-root plant material shall be placed in water a minimum 30 minutes prior to setting.

3.4.2 Backfill Soil Mixture

The backfill soil mixture shall be topsoil.

3.4.3 Watering

Plant pits and plant beds shall be watered immediately after backfilling, until completely saturated.

3.5 FINISHING (NOT USED)

3.6 MAINTENANCE DURING PLANTING OPERATION

Installed plant material shall be maintained in a healthy growing condition. Maintenance operations shall begin immediately after each plant is installed to prevent desiccation. Installed areas shall be kept free of weeds, grass, and other undesired vegetation. Watering shall be done twice a week for 4 weeks following completion of planting, unless otherwise directed by the CO.

3.7 APPLICATION OF PESTICIDE (NOT USED)

3.8 RESTORATION AND CLEAN UP

3.8.1 Restoration

Turf areas, pavements and facilities that have been damaged from the planting operation shall be restored to original condition at the Contractor's expense.

3.8.2 Clean Up

Excess and waste material shall be removed from the installed area and shall be disposed offsite. Adjacent paved areas shall be cleared.

3.9 PLANT ESTABLISHMENT PERIOD

3.9.1 Commencement

The plant establishment period for maintaining exterior plantings in a healthy growing condition shall commence on the first day of exterior planting work under this Contract and shall continue through the remaining life of the Contract and end 12 months after the last day of exterior planting required by this Contract. Written calendar time period shall be submitted to the CO for the plant establishment period. The plant establishment period shall be coordinated with Section 02923 SPRIGGING. The plant establishment period shall be modified for separate completion dates for areas.

3.9.2 Maintenance During Establishment Period

Maintenance of the planted areas shall include eradicating weeds, insects, and diseases; maintaining temporary goose exclosure structures; and watering. Use of pesticides or herbicides is not permitted. Following completion of planting, watering shall continue twice

a week for 4 weeks, unless otherwise directed by the CO. After 4 weeks, watering shall continue for the establishment period at a minimum once per week and adjusted accordingly to natural precipitation, unless otherwise directed by the CO.

At least 60 percent of the original plant material shall be in vigorous growing condition during the entire establishment period. The 60 percent survival criterion shall apply to each species of plant, unless otherwise approved by the CO. The Contractor shall provide and install replacement plants, in accordance with PART 2 PRODUCTS, as necessary to maintain the minimum 60 percent requirement throughout the plant establishment period.

The Contractor shall remove invasive species including butterfly bush and Himalayan blackberry from shrub planting areas.

Should particular areas of the initial shrub installation show continued excessive mortality, the Contractor may propose more intensive planting in the healthier areas. Any such proposal must be approved by the CO. The overall 60 percent plant survival criterion shall remain in effect unless otherwise approved by the CO.

3.9.2.2 Maintenance Record

A record of each site visit shall be submitted to the CO describing the maintenance work performed, photographic documentation of planted areas, the quantity of plant losses, diagnosis of the plant loss, and the quantity of replacements made on each site visit. One maintenance record shall be submitted that incorporates maintenance for sprigging and exterior planting. Coordinate with the requirements of Section 02923 SPRIGGING.

3.9.3 Unhealthy Plant Material

A shrub shall be considered unhealthy or dead when up to a maximum 25 percent of the plant has died. This condition shall be determined by scraping on a branch an area of 1/16 inch square, maximum, to determine if there is a green cambium layer below the bark. The Contractor shall determine the cause for unhealthy plant material and shall provide recommendations for replacement if 40 percent or more of the plant material is determined to be unhealthy. Unhealthy or dead plant material requiring replacement (over 40 percent of total plants installed) shall be removed immediately and shall be replaced as soon as seasonal conditions permit.

END OF SECTION