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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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
MLLW	mean lower low water

ABBREVIATIONS AND ACRONYMS (Continued)

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]
SVPS	sediment vertical profiling system
TCLP	toxicity characteristics leaching procedure

ABBREVIATIONS AND ACRONYMS (Continued)

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

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[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.

Figure 1-1 PSR Upland and Marine Sediments Unit Location Map

Figure 1-2 PSR Conceptual Site Model of Receptors and Exposure Pathways in the Marine Sediments Unit Post-upland Cleanup

Figure 1-3 ROD-Specified Capping Areas

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Figure 1-3 (Continued)

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

11 x 17, must start on odd-no. page, allow two pages

Figure 1-4 (Continued)

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 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.

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[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. A conventional split-hull barge can be opened slowly over a period of tens of

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

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.

Figure 2-1 PSR Remediation Areas

11 x 17, must start on odd-no. page, allow two pages

Figure 2-1 (Continued)

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

	Estimated Quantities (cy)			Dredging History		Future Dredging		
Project[a]	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.

Figure 3-1 Dredging Design Criteria

11 x 17, must start on odd-no. page, allow two pages

Figure 3-1 (Continued)

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 thinner deposits. The 2000 PSDDA monitoring data indicated that deposits at

[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.

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

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[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.

Figure 4-1 Cap Thickness Design Components

Figure 4-2 Modeled Cap Geometry in RA5

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

Figure 4-4 Estimated Extent of Offsite Cap Deposition

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Figure 4-4 Continued

Table 4-1 Summary of Cap Thickness Requirements by Area

Excel table

Table 4-2 Allowable Lift Heights for Cap Placement

Excel table

Table 4-3 Estimated Capping Volumes

Excel table

Table 4-4 Anticipated Extent of Offsite Cap Material Deposition

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)

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

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

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 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 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.

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

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Figure 11-1 (Continued)

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

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Figure 11-2 (continued)

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

Figure 11-3 (continued)

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