DRAFT FOR REGULATOR REVIEW FEASIBILITY STUDY

PIERS 90 AND 91
FORMER SEATTLE NAVAL SUPPLY DEPOT
FUDS PROJECT NO. F10WA012501

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May 2016

Contract No. W912F-10-D-48, Task Order 0002

Executive Summary

The former Seattle Naval Supply Depot (SNSD) is a Formerly Used Defense Sites (FUDS) #F10WA012501 facility that was used during the World War II-era as a loading and offloading facility for United States (US) Navy warships. It was not an ammunition depot, and no records exist of live firing ever occurring at the site. During this period, discarded military munitions (DMM) were infrequently jettisoned overboard without documentation while ships were in port.

The site is presently operated by the Port of Seattle (POS) as Terminal 91. Terminal 91 encompasses Pier 90 and Pier 91. Pier 91 is presently used during a portion of the year as the Smith Cove Cruise Terminal. The cruise terminal is a point of embarkation for cruise trips to Alaska. During routine security sweeps by POS Police Department (PD) divers on April 22, 2010, several DMM items were discovered. These discoveries led to a series of six subsequent active US Army and Navy Explosive Ordnance Disposal (EOD) responses to the facility. Prior to these events, there is no record of encounters with DMM at the facility.

Beginning in 2010, the United States Army Corps of Engineers (USACE) conducted a Remedial Investigation (RI) and Time Critical Removal Action (TCRA) at the FUDS munitions response site (MRS). These actions were completed in March 2012. The RI began in December of 2010 and concluded in March of 2012, and the TCRA occurred between January and March of 2011.The *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013) was issued in September 2013, and documents the results of these actions. DMM is potentially present on the seafloor and buried in surface sediments within the MRS.

A total of 25 DMM items were discovered and removed during the RI and TCRA. These DMM items were found in TCRA Survey Area #1. DMM ranged in size from 20 millimeter (mm) cartridges with projectiles to 5-inch projectiles. Based on the munitions discovered and removed, any potential remaining DMM is expected to range in sizes from 20 mm to 5-inch projectiles. A qualitative potential exposure analysis was conducted for defined human receptors and determined that during normal operations, the hazard posed to human receptors by the DMM remaining after the removal actions during the TCRA and RI is negligible to low. The analysis determined that during routine dredging operations, the hazard posed by DMM to Topside Construction Worker receptors is moderate, driven by an increased probability for an encounter when sediments potentially containing DMM are brought to the surface and placed on a barge in the vicinity of the receptor. A separate assessment performed by the USACE found that the likelihood of an encounter during routine dredging operations was “moderate to high”. The risk assessment concluded that munitions constituents (MC) are not present in sufficient quantities to pose a risk to human health or the environment.

This Feasibility Study (FS) serves as a mechanism for the development, screening, and detailed evaluation of alternative remedial actions to potentially be employed at the SNSD to reduce hazards associated with DMM. Remedial alternatives have been evaluated based on site characterization data obtained during the RI and all applicable or relevant and appropriate requirements (ARARs), and represent a list of remedial alternatives that may reduce the hazard posed by DMM at the site.

Based on the qualitative potential exposure analysis, the remedial action objective (RAO) for the SNSD MRA is to reduce or minimize the hazard to human receptors posed by DMM remaining exposed on the seafloor or buried in the shallow sediments of the MRA within a defined area

encompassing the area where DMM has been found during dive team inspections, the RI, and the TCRA. In order to meet this RAO, and additional requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a number of general response actions (GRAs) were considered. Technologies and process options necessary to complete the GRAs were evaluated, and led to the development of four unique alternatives for the site.

- Alternative 1 is No Further Action, and is a requirement of CERCLA.
- Alternative 2 manages potential explosive hazards associated with potential future dredging by the institution of administrative controls to prevent dredging in the area where DMM has been found in the past. In the event that future dredging was determined to be necessary in the area under administrative control, a process to properly design dredging operations to reduce risk to acceptable levels for receptors including the Topside Construction Worker, other sediment workers, and underwater security inspectors and divers.
- Alternative 3 would remove up to two feet of sediments within the area where DMM has previously been found, to a depth of -40 ft MLLW. Some additional incidental removal would occur in meeting this target. Alternative 3 would involve the dredging of approximately 16,000 cubic yards of material removed from approximately 4.6 acres of the site. Alternative 3 is expected to take approximately three months on-site to complete.
- Alternative 4 is similar to Alternative 3, but would remove up to the top two feet of sediments within the area where DMM has previously been found, to a depth of -50 ft MLLW. This alternative includes the removal of an estimated 53,200 cubic yards of material over approximately 12.4 acres. Alternative 4 is expected to take approximately 290 days on-site to complete, and would be completed over two field seasons, requiring two mobilizations.

This FS describes how, through a series of equipment modifications designed to ensure the safety of the Topside Construction Worker receptor, sediment workers, underwater divers and security inspectors, and the UXO support team, DMM encountered during dredging operations may be screened, inspected and stored until the dredging action is complete. This FS also evaluates the use of a Contained Detonation Chamber (CDC) to demilitarize and dispose of DMM on-site, in a similar fashion to the disposal action that occurred to conclude the RI. Off-site demilitarization and disposal of the DMM at a Resource Conservation and Recovery Act (RCRA) landfill has also been evaluated.

The remaining sediments may contain MC and other environmental contaminants, as well as significant surface debris. Under Alternatives 3 and 4, the debris would be sorted into recyclable and non-recyclable material, with the non-recyclable material being disposed to a local landfill. Sediments dredged under Alternatives 3 and 4 would be managed using one of three options—Option 1 involving the use of thermal treatment to treat sediment environmental contaminants prior to sediment disposition, Option 2 involving the dewatering and transport of the sediment to a non-hazardous landfill (Roosevelt Landfill) in Klicktat County, WA, and Option 3 involving the dewatering and disposal of the sediment to an open-water disposal location such as the Port Townsend site.

Alternatives underwent a detailed analysis based on seven evaluation criteria:

Threshold Criteria, including the following:

1. Overall Protection of Human Health and Environment; and
2. Compliance with ARARs;

Primary Balancing Criteria, including the following:

3. Long-Term Effectiveness and Permanence;
4. Reduction of Toxicity, Mobility, or Volume through Treatment (e.g. removal of DMM);
5. Short-Term Effectiveness;
6. Implementability; and
7. Cost.

These alternatives were then compared. The results of the detailed comparative analysis are presented in the table below.

Executive Summary Table - Results of Detailed and Comparative Analysis of Remedial Alternatives	**Alternative 1** No Further Action	**Alternative 2** **Administrative Controls**	**Alternative 3** **Dredging to -40 Ft MLLW**	**Alternative 4** **Dredging to -50 Ft MLLW**
Protective of Human Health and the Environment	No	Protective of human health and the environment in area under administrative controls	Protective of human health and the environment within dredged area shown on Figure 7.	Protective of human health and the environment within dredged area shown on Figure 9.
Compliance with ARARs	No	Compliant with ARARs	Compliant with ARARs	Compliant with ARARs.
Long-Term Effectiveness and Permanence	No	Exhibits long-term effectiveness and permanence in area under administrative controls	Provides long-term effectiveness and permanence over dredged area shown on Figure 7.	Provides long-term effectiveness and permanence over larger dredged area shown on Figure 9.
Reduction of Toxicity, Mobility, and Volume Through Treatment	No	No reduction of toxicity, mobility and volume with administrative controls alone. Reduction of toxicity, mobility, and volume would occur in the event that dredging of DMM-impacted sediments is conducted in the future in the area under administrative controls.	Reduction of toxicity, mobility, and volume through sediment dredging in area shown on Figure 7.	Greater reduction of toxicity, mobility, and volume of sediments than Alternative 3 due to removal of sediment in larger area shown on Figure 9.
Short Term Effectiveness	No	Few short-term impacts to establish administrative controls. If future dredging in area under administrative control is necessary, short-term impacts can be addressed through careful design.	Greater short-term impacts than Alternative 2, but can be minimized through proper design	Greater short-term impacts than Alternative 3 due to larger volumes and areas of dredged sediments. Period of implementation would be longer than Alternative 2.
Implementability	Very implementable since no further action would be undertaken	Highly implementable	Implementable, though will require additional equipment and time over Alternative 2.	Implementable, though will require additional time and over larger area than Alternative 3.
Estimated Total Net Present Value ($) **(30 years)**	$0.00	$660,000	$3,690,000 to $4,970,000	$9,726,500 to $13,556,500

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LIST OF ABBREVIATIONS AND ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirements
BHHRA	Baseline Human Health Risk Assessment
BT	Bioaccumulation Trigger
CDC	Contained Detonation Chamber
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
CWA	Clean Water Act
CWM	Chemical Warfare Material
DDESB	Department of Defense Explosives Safety Board
DERP	Defense Environmental Restoration Program
DGM	Digital Geophysical Mapping
DMM	Discarded Military Munitions
DMMO	Dredged Material Management Office
DMMP	Dredged Materials Management Program
DNT	Dinitrotoluene
DoD	Department of Defense
DPS	Distinct Population Segment
EM	Electromagnetic
EO	Executive Order
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ER	Engineering Report
ESA	Endangered Species Act
ESS/ESP	Explosive Safety Submission/Explosive Siting Plan
ESU	Evolutionary Significant Unit
ºF	Degrees Fahrenheit
FDEMI	Frequency Domain Electromagnetic Induction
FS	Feasibility Study

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

ft	Feet
FUDS	Formerly Used Defense Site
GPS	Global Positioning System
GRA	General Response Action
GSA	General Services Administration
HFD	Hazardous Fragment Distance
HQ	Hazard Quotient
JBLM	Joint Base Lewis-McChord
LDR	Land Disposal Restriction
LOQ	Level of Quantification
LUC	Land Use Control
m	Meter
MBES	Multibeam Echosounder
MC	Munitions Constituents
MD	Munitions Debris
MDAS	Material Documented as Safe
MEC	Munitions and Explosives of Concern
ML	Maximum Level
MLLW	Mean Lower Low Water
mm	Millimeter
MMPA	Marine Mammals Protection Act
MMRP	Military Munitions Response Program
MPPEH	Materials Potentially Presenting an Explosive Hazard
MRA	Munitions Response Area
MRS	Munitions Response Site
MSD	Minimum Separation Distance
N/A	Not Applicable
NCP	National Contingency Plan
NMRD	Non-Munitions Related Debris
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

OE	Ordnance and Explosives
O&M	Operation and Maintenance
PCB	Polychlorinated Biphenyl
PD	Police Department
POS	Port of Seattle
PVC	Polyvinyl Chloride
RAFLU	Reasonably Anticipated Future Land Use
RA	Remedial Action
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylene-trinitramine
RI	Remedial Investigation
ROV	Remotely Operated Vehicle
RRD	Range-related Debris
SBP	Sub-bottom Profiler
SL	Screening Level
SLERA	Screening Level Ecological Risk Assessment
SMS	Sediment Management Standards
SNSD	Seattle Naval Supply Depot
SQB	Sediment Quality Benchmark
SSS	Sidescan Sonar
SUXOS	Senior Unexploded Ordnance Supervisor
SVOC	Semi-Volatile Organic Compound
TBC	To Be Considered
TCRA	Time Critical Removal Action
TDEMI	Time Domain Electromagnetic Induction
T/E	Threatened or Endangered
TOC	Total Organic Carbon
TP	Technical Paper
TSDF	Treatment, Storage and Disposal Facilities
US	United States

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

USACE	United States Army Corps of Engineers
USC	United States Code
UU/UE	Unlimited Use/Unrestricted Exposure
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
WA	Washington
WQC	Water Quality Certification

GLOSSARY OF TERMS

Terminology is for terms used in this document and in the program, largely obtained from Engineer Manual (EM) 200-1-15, (USACE, 2015) *US Army Corps of Engineers, Environmental Quality, Engineer Manual, Technical Guidance for Military Munitions Response Actions*

Anomaly: Any item that is seen as a subsurface irregularity after geophysical investigation. This irregularity will deviate from the expected subsurface ferrous and non-ferrous material at a site (e.g., pipes, power lines, etc.).

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA): Congress enacted CERCLA, commonly known as Superfund, on 11 December 1980. This law created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Conceptual Site Model (CSM): A CSM is a description of a site and its environment that is based on existing knowledge. It describes sources and receptors, and the interactions that link these. It assists the team in planning, data interpretation, and communication.

Defense Environmental Restoration Program (DERP): Congressionally authorized in 1986, DERP promotes and coordinates efforts for the evaluation and cleanup of contamination at DoD installations and FUDS (10 United States Code [USC] 2701 et. seq.).

Discarded Military Munitions (DMM): Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance (UXO), military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of, consistent with applicable environmental laws and regulations. (10 USC 2710(e)(3)).

Explosive Ordnance Disposal (EOD) – The detection, identification, onsite evaluation, rendering safe, recovery, and final disposal of UXO and of other munitions that have become an imposing danger, for example by damage or deterioration.

Formerly Used Defense Site (FUDS): A FUDS is defined as a facility or site (property) that was under the jurisdiction of the Secretary of Defense and owned by, leased to, or otherwise possessed by the United States at the time of actions leading to contamination by hazardous substances. By the DERP policy, the FUDS program is limited to those real properties that were transferred from DoD control prior to 17 October 1986. FUDS properties can be located within the 50 states, District of Columbia, Territories, Commonwealths, and possessions of the United States.

Hazardous Fragment Distance (HFD) – Distance at which the areal number density of hazardous fragments or debris becomes one per 600 square feet $(ft)^2$ or 55.7 square meters $(m)^2$.

Intrusive Activity: An activity that involves or results in the penetration of the ground surface at an area known or suspected to contain munitions and explosives of concern (MEC). Intrusive activities can be of an investigative or removal action nature.

Land Use Controls (LUCs): Physical, legal, or administrative mechanisms that restrict the use of, or limit access to, contaminated property to reduce risk to human health and the environment.

Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and physical barrier to limit access to a property, such as fences or signs. The legal mechanisms are generally the same as those used for institutional controls (ICs) as discussed in the National Contingency Plan. ICs are a subset of LUCs and are primarily legal mechanisms imposed to ensure the continued effectiveness of land use restrictions imposed as part of a remedial action. Legal mechanisms include restrictive covenants, negative easements, equitable servitudes, and deed notices. Administrative mechanisms include notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions.

Material Potentially Presenting an Explosive Hazard (MPPEH): Material owned or controlled by the DoD that, prior to determination of its explosives safety status, potentially contains explosives or munitions (e.g., munitions containers and packaging material; munitions debris remaining after munitions use, demilitarization, or disposal; and range-related debris) or potentially contains a high enough concentration of explosives that the material presents an explosive hazard (e.g., equipment, drainage systems, holding tanks, piping, or ventilation ducts that were associated with the munitions.

Military Munitions: Military munitions means all ammunition products and components produced or used by or for the U.S. Department of Defense (DoD) or the U.S. Armed Services for national defense and security, including military munitions under the control of the Department of Defense, the U.S. Coast Guard, the U.S. Department of Energy (DOE), and National Guard personnel. The term military munitions includes: confined gaseous, liquid, and solid propellants, explosives, pyrotechnics, chemical and riot control agents, smokes, and incendiaries used by DoD components, including bulk explosives and chemical warfare agents, chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges, and devices and components thereof. Military munitions do not include wholly inert items, improvised explosive devices, and nuclear weapons, nuclear devices, and nuclear components thereof. However, the term does include non-nuclear components of nuclear devices, managed under DOE's nuclear weapons program after all required sanitization operations under the Atomic Energy Act of 1954, as amended, have been completed. (40 CFR 260.10).

Military Munitions Response Program (MMRP): The MMRP category is defined as response actions (i.e., the identification, investigation, and remedial actions, or a combination of removal and remedial actions) to address munitions and explosives of concern or munitions constituents. This includes the removal of foreign military munitions if it is incidental to the response addressing Department of Defense military munitions at a Formerly Used Defense Sites property. (ER 200-3-1).

Minimum Separation Distance (MSD): Minimum Separation Distance is the distance at which personnel in the open must be from an intentional or unintentional detonation.

Munitions and Explosives of Concern (MEC): This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks means: (A) UXO, as defined in 10 USC 101(e)(5) 10 USC 2710 (e) (9); (B) DMM, as defined in 10 USC 2710(e)(2); or (C) MC (e.g., TNT, cyclotrimethylene-trinitramine [RDX]), as defined in 10 USC 2710(e)(3), present in high enough concentrations to pose an explosive hazard.

Munitions Constituents (MC): Any materials originating from UXO, DMM, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 USC 2710(e)(3)).

Munitions Debris (MD): Remnants of munitions (e.g., fragments, penetrators, projectile, shell casing, links, fins) remaining after munitions use, demilitarization, or disposal.

Munitions Response: Response actions, including investigation, removal actions and RAs to address the explosives safety, human health, or environment risks presented by UXO, DMM, or MC.

Munitions Response Area (MRA): Any area on a defense site that is known or suspected to contain unexploded ordnance, discarded military munitions, or munitions constituents. Examples include former ranges and munitions burial areas. An MRA is comprised of one or more munitions response sites.

Munitions Response Site (MRS): A discrete location within a munitions response area that is known to require a munitions response.

National Oil and Hazardous Substance Pollution Contingency Plan (NCP): Revised in 1990, the NCP provides the regulatory framework for responses under CERCLA. The NCP designates the DoD as the removal response authority for ordnance and explosives (OE) hazards.

Remedial Action (RA): Those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health, welfare, or the environment. See CERCLA 106(24).

Remedial Investigation (RI):. The RI gathers necessary information to develop and evaluate remedial alternatives for the site. Per 40 CFR 300.430(d), the purpose of the RI is to “collect data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives”.

Resource Conservation and Recovery Act (RCRA): Enacted in 1976, RCRA promotes the protection of health and the environment. It regulates waste generation, treatment, storage, transportation, and disposal for facilities currently in operation.

Response Action: A CERCLA-authorized action involving either a short-term removal action or a long-term removal response. This may include, but is not limited to, removing hazardous materials, containing or treating the waste on-site, and identifying and removing the sources of ground water contamination and halting further migration of contaminants.

Technology-aided Surface Removal: A removal of UXO, DMM, or chemical warfare material (CWM) on the surface (i.e., the top of the soil layer) only, in which the detection process is primarily performed visually, but is augmented by technology aids (e.g., hand-held magnetometers or metal detectors) because vegetation, the weathering of UXO, DMM, or CWM, or other factors make visual detection difficult.

Time Critical Removal Action (TCRA): Removal actions where, based on the site evaluation, a determination is made that a removal is appropriate, and that less than six months exists before on-site removal activity must begin (40 CFR 300.5).

Unexploded Ordnance: Military munitions that (A) have been primed, fuzed, armed, or otherwise prepared for action; (B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (C) remain unexploded whether by malfunction, design, or any other cause.(U.S.C. 2710 (e) (9)).

UXO-Qualified Personnel: Personnel who have performed successfully in military EOD positions, or are qualified to perform in the following Department of Labor, Service Contract Act, Directory of Occupations, contractor positions: UXO Technician II, UXO Technician III, UXO Safety Officer, UXO Quality Control Specialist, or Senior UXO Supervisor (SUXOS).

1.0 INTRODUCTION

Under Executive Orders (EO) 12580 and 13016, the Department of Defense (DoD) was delegated the authority and responsibility for conducting responses under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at DoD facilities. To carry out these responses, the Defense Environmental Restoration Program (DERP) was formally established by Congress to identify, assess, and clean up or control hazardous waste contamination that originated from past DoD activities, operations, or spills. To specifically address munitions and explosives of concern (MEC), Congress established the Military Munitions Response Program (MMRP) under DERP to address unexploded ordnance (UXO), discarded military munitions (DMM), and munitions constituents (MC) located on current and former defense sites. This Feasibility Study (FS) is being conducted under the MMRP.

The Remedial Investigation (RI)/FS program was implemented as part of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) established in Title 40 Code of Federal Regulations (CFR) Part 300 (USEPA, 2011). The RI/FS represents the methodology that CERCLA established to assess site conditions and evaluate remedial alternatives at sites listed on the National Priority List (NPL). The RI and this FS are being conducted by the United States Army Corps of Engineers (USACE) in accordance with guidance and methodologies established under CERCLA and the NPL. The USACE Kansas City District is the Project Management district, the USACE Omaha District is the Military Munitions Design Center, and the site lies within the boundaries of the USACE Seattle District.

The RI, which was conducted at the Former Seattle Naval Supply Depot (SNSD) Munitions Response Site (MRS) between 2010 and 2012, served as a mechanism for collecting data to characterize the site and to determine if unacceptable risks and hazards exist, for the purpose of developing and evaluating effective remedial alternatives. Field investigations were conducted during this phase to characterize the site and determine the nature, extent, and threat of contamination posed by hazardous substances and munitions-related materials present at the site. A risk assessment and qualitative potential exposure analysis were conducted to evaluate risks and hazards to human health and the environment. Data collected during the RI were used to develop remedial alternatives evaluated in this FS.

The FS serves as a mechanism for the development, screening, and detailed evaluation of alternative remedial actions. Remedial alternatives have been evaluated based on overall protection to human health and the environment, as well as compliance with applicable or relevant and appropriate requirements (ARARs), and may represent a list of remedial alternatives which reduce the toxicity (or potential severity), mobility, or volume of the hazardous substances (i.e., DMM). Alternatives range from those that remove existing or potential DMM from the seafloor to the maximum extent possible, to those that involve little or no treatment but provide protection to human health and the environment by preventing or controlling exposure to the hazardous substances, to those that require no action. Alternatives in this FS have been evaluated based on seven of the nine standard evaluation criteria (two relating to state and community acceptance will be evaluated later in the process of selecting and designing a remedy). In general, the remediation goals for DMM focus on removing or limiting the exposure pathways to existing and/or future human receptors.

1.1 PROJECT PURPOSE

The purpose of this FS is to develop, screen, and evaluate remedial alternatives that address the risks and hazards associated with DMM at the SNSD MRA. The objective is to analyze the data collected during previous investigations and removal actions at the MRA, the findings of the Baseline Human Health Risk Assessment (BHHRA) and Screening Level Environmental Risk Assessment (SLERA), and the qualitative potential exposure analysis presented upon the conclusion of the RI to identify and screen alternatives for long-term remedial action.

1.2 FEASIBILITY STUDY ORGANIZATION

This FS has been developed in accordance with the United States Environmental Protection Agency's (USEPA) *Guidance for Conducting Remedial Investigations and Feasibilty Studies under CERCLA, Interim Final, October* (USEPA, 1988) and the USACE's *Final United States Army Military Munitions Response Program Munitions Response Program, Munitions Response, Remedial Investigation/Feasibility Study Guide* (USACE, 2009). The FS is organized into the following sections:

Section 1: Introduction - describes the project authorization, project purpose and scope, site location, setting, history and legal description, and current and future land uses, and presents a summary of the results of the RI.

Section 2: Identification and Screening of Technologies - identifies the Remedial Action Objectives (RAOs), defines the ARARs, defines the General Response Actions (GRAs), and identifies and screens technologies and process options.

Section 3: Development and Screening of Alternatives – presents a range of alternatives for the SNSD MRA and screens these alternatives based on effectiveness, implementability and cost.

Section 4: Detailed Analysis of Alternatives – presents the results of a detailed analysis of the screened alternatives against the threshold and balancing criteria.

Section 5: References – identifies the references utilized in the preparation of the FS.

1.3 SITE LOCATION AND LEGAL DESCRIPTION

The SNSD (Formerly Used Defense Site [FUDS] property F10WA012501), is located along Puget Sound in Seattle, Washington (WA), approximately 3 miles northwest of downtown as shown on **Figure 1**. The site is currently owned by the Port of Seattle (POS) and operated as Terminal 91, consisting of Piers 90 and 91. The geodetic coordinates of the site location are 47° 37' 57" North Latitude and 122° 22' 55.2" West Longitude and includes portions of Sections 23 and 26 of Range 3 East, Township 25 North, of the Willamette Meridian. The site is located in the USEPA's Region 10 and the Washington 7th Congressional District (USACE, 2013).

The property itself consists of 198.23 acres. The MRA is comprised of 117 of these acres. The FUDS-eligible portion of the property that is the focus of this FS consists of 86.7 acres of sub-tidal lands in Elliott Bay in Seattle, WA, and comprises the "FS Study Area" **(Figure 2)**. The MRA is classified as being in open water surrounding each of the piers or under the overhang of a pier (an area approximately 60 feet [ft] wide). The piers are constructed on fill material connected to an upland area at the north end of each pier. The west, south, and east perimeter of each pier includes concrete and treated wood pilings and a supported dock area. They are fitted with a combined timber/steel pier fender piling system (USACE, 2012).

FS Study Area

Data Source: Esri, DeLorme, NAVTEQ, USGS, Intermap, et al.
http://goto.arcgisonline.com/maps/World_Street_Map
http://goto.arcgisonline.com/maps/NatGeo_World_Map
3/29/2016 D:\GIS\Projects\UX15-004 Port of Seattle\FS\Draft 2\Fig 1.mxd

FIGURE 1

LOCATION MAP
PIERS 90 AND 91
SEATTLE, WASHINGTON

Piers 90 and 91 Feasiblity Study - Seattle, Washington

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1.4 PHYSICAL DESCRIPTION

The FUDS MRS is a marine environment. Riprap covers the majority of the shoreline surrounding Terminal 91. Armoring of shoreline around Smith Cove and Elliott Bay is extensive and includes riprap, seawalls, bulkheads, barriers and pilings. The bathymetry of the SNSD MRA is extensive, ranging from zero feet (ft) Mean Lower Low Water (MLLW) underneath the piers down to greater than -60 ft MLLW in the deepest sections of the MRA. Water depths average greater than 30 ft between the piers and between Pier 90 and the land to the east. At the end of the piers, there is a steep drop off from 10 ft to greater than 60 ft. Water temperatures in the low to mid 40's degrees Fahrenheit (ºF) were recorded during previous phases of the project and can reach 50 ºF. Currents were nil during slack tide and increased to less than 0.5 knots during tidal shifts. Visibility underwater is highly dependent on current local conditions and can range from 1 foot to greater than 10 feet (USACE, 2013).

Sub-bottom profiler (SBP) data collected during the RI indicate that the seafloor is covered with between approximately 0 meters (m) and 2.5 m of sediment throughout the MRA. The USACE Seattle District evaluated sediments in Suitability Determinations, provided by the Dredged Material Management Office (DMMO) in Seattle, WA, from prior dredging at Terminal 91. This evaluation determined that the material type dredged in 2008 contained, on average, 11-18% fines. This indicated a fairly coarse gradation of sediments near the facility, and suggests that the area is not depositional due to the low fines content (USACE, 2013).

1.5 ENVIRONMENTAL INFORMATION

Several Threatened and Endangered (T/E) species have been identified within the vicinity of the project area, including Distinct Population Segments (DPS) of Boccaccio, Canary Rockfish, Yelloweye Rockfish, Coastal-Puget Sound Bull Trout and Southern Resident Killer Whales; and Evolutionary Significant Units (ESU) of Puget Sound Chinook Salmon, Chum Salmon, Coho Salmon, Pacific Cod, Stellar Sea Lions and Marbled Murrelet (USACE, 2013).

Four fish and wildlife habitat sites are present in the shallow sub-tidal and exposed intertidal aquatic areas of the SNSD. The aquatic habitat sites were constructed by the POS and are maintained as compensatory restoration areas linked with previous development actions at the site. Approximately 1.6 acres at the northwest margin of the west slip, northwest of Pier 91, were previously restored as intertidal habitat. The habitat was constructed by removing previously placed fill material. The water-ward portion of the confined dredged material disposal site in the center slip between Piers 90 and 91 includes approximately 0.8 acres of intertidal berm surface improved as habitat substrate. The east slip, east of Pier 90, includes two intertidal restoration areas: 1) a constructed intertidal mound, approximately 0.4 acres in size, consisting of habitat substrate placed in the sub-tidal aquatic area at the north end of the east slip, creating a habitat area subject to daily tidal exposure; and 2) approximately 0.75 acres of intertidal mud-sand substrate at the northeast margin of the east slip, restored by removing previously placed fill material and re-exposing low-slope aquatic habitat conditions (PES, 2009).

Detailed information regarding the physical and environmental setting of the MRA is presented in Section 2.3 of the *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013).

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FIGURE 2

FS STUDY AREA
PIERS 90 AND 91

Piers 90 and 91 Feasiblity Study - Seattle, Washington

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1.6 HISTORY OF THE FORMER SEATTLE NAVAL SUPPLY DEPOT

In 1942 and 1943, the US Navy acquired the property through condemnation, which in total consisted of 242.97 acres for use as bulk fuel and material storage, and as a marine terminal for naval vessels. The property was already a partially-developed commercial marine terminal with warehouses and fuel oil storage facilities. The US Navy further expanded facilities and constructed approximately 100 buildings including general warehouses, maintenance shops, administration buildings, a heating plant, barracks, and cold storage facilities (USACE, 2013).

Beginning in 1967, the US Navy declared portions of the facility as excess to the General Services Administration (GSA). The POS acquired 198.23 acres of the former property in 1976 by quitclaim deed. The remainder of the property was acquired by the National Guard (24.75 acres) for their facility (F10WA0398) and the Northwest Center (7.62 acres) (F10WA0572). The US Navy retained 12.37 acres, which is called the Terminal 91 Annex (F10WA0126) (USACE, 2012a).

1.7 CURRENT AND FUTURE LAND USE

The following sub-sections describe the current land use and projected future land use of the facility.

1.7.1 Current Uses

The POS opened Smith Cove Cruise Terminal on Pier 91 in 2009. During the cruise ship season, (from May through September, with preceding and following months utilized for setup and breakdown), the POS accommodates luxury cruises to Alaska. In 2010, the POS received more than 223 cruise ships and over 858,000 passengers. The local cruise ship industry creates $425 million in annual business revenue, along with approximately 4,500 jobs. The cruise industry is also responsible for approximately $18.9 million in annual State and local taxes. Each time a homeport ship docks in Seattle, it contributes an estimated $1.9 million into the local economy. During the off-season, the cruise terminal itself is used for trade shows, concerts, and other performances (USACE, 2013).

Terminal 91 also serves as a year-round loading and offloading station for commercial fishing fleets at both Piers 90 and 91, and allows large commercial, research, and military vessels to berth at the facility for repairs and shore leave. Additionally, the east side of Pier 90 is used for temporary berthing and crew transfers by both a tug company and a small marine environmental response company. The upland portion of the property contains buildings rented as office space, and a parking facility for buses serving the Seattle School District (USACE, 2013).

1.7.2 Future Site Use

Reasonably anticipated future land use (RAFLU) is expected to remain the same as current land use. The POS will continue to operate the Smith Cove Cruise Terminal on Pier 91. Piers 90 and 91 will continue to be used to moor, load and off-load fishing and other commercial vessels. **Figure 3**, provided by the POS, displays required depths for berths and access areas at Terminal 91. Construction and maintenance operations will continue on an as-needed basis (USACE, 2012a). Maintenance operations, though not considered a land use, is an ancillary activity that has historically occurred approximately once per decade in different areas around Pier 91 in order to ensure safe operational depths for large vessels. The most recent maintenance operations occurred during February 2016, involving the regrading of sediment in the berthing areas along the southeastern side of Pier 91 to deeper areas between Piers 90 and 91. **Figure 4** shows the area where regrading operations were conducted.

1.8 PREVIOUS MUNITIONS RESPONSE ACTIONS

Previous investigations and removal actions have been conducted at the SNSD to identify potential MEC and MC contamination and their extent, and remove immediate explosive hazards.

1.8.1 Port of Seattle Police Department Dive Team

On April 22, 2010, POS Police Department (PD) divers conducting routine security sweeps associated with the cruise terminal encountered potential military munitions in sediments around Terminals 90 and 91. The US Navy Explosive Ordnance Disposal (EOD) personnel responded to the incident and determined the items to be DMM. US Navy EOD took possession of the items and handled their disposition. US Army EOD personnel also responded on September 16, 2010 and November 11, 2010 to the discovery of DMM after the POS PD divers brought items onshore (USACE, 2012a).

1.8.2 Remedial Investigation and Time Critical Removal Action

FUDS Project Number F10WA012501 was approved on October 14, 2010 following the discovery of DMM in the sediments of the MRA by the POS PD divers. The FUDS project was approved to address concerns associated with military munitions at the SNSD. An RI began in December of 2010, transitioned to a Time Critical Removal Action (TCRA) between January and March 2011, and the RI was resumed and concluded in March of 2012. The TCRA included surface clearance of an approximately 25-acre underwater portion of the MRA during the January through March 2011 timeframe. DMM and munitions debris (MD) were located during each phase of the investigation. All munitions items located during the RI and TCRA were removed from the site. Munitions discovered during the TCRA were transferred to a Joint Base Lewis-McChord (JBLM) U.S. Army EOD Team during an emergency response for disposal, while all munitions discovered during the RI were removed from the water and disposed of within a CDC. The RI field efforts consisted of a number of integrated technologies and UXO divers performing surveys, excavations and sampling to characterize the physical nature of the site and the nature and extent of MEC and MC contamination. Specifically:

- Multibeam echosounder (MBES) data provided a bathymetric model used to direct deployment of marine geophysics and UXO divers, mapped seafloor scour from cruisevessel azipod thrusters, and identified dredged areas.
- Sidescan sonar (SSS)/stationary scanning sonar imagery was used to quantify and assess the distributions of seafloor objects. It identified MEC-like anomalies requiring further investigation, and data were integrated with remotely operated vehicles (ROVs) and marine geophysics for navigation and anomaly avoidance.
- Sub-bottom profiler surveys characterized sediment conditions and thickness of sediment layers above the hard pack. These data supported a determination of the maximum vertical extent of MEC contamination and allowed the team to evaluate the degree of difficulty for intrusive investigations in various areas of the site.
- Digital geophysical mapping (DGM) provided subsurface anomaly detection. DGM determined “map & dig” versus “mag & dig” areas, and located buried anomalies matching geophysical profiles of the munitions items of concern.

FIGURE 3

**BERTHING AND ACCESS AREAS
PIERS 90 AND 91**

Piers 90 and 91 Feasiblity Study - Seattle, Washington

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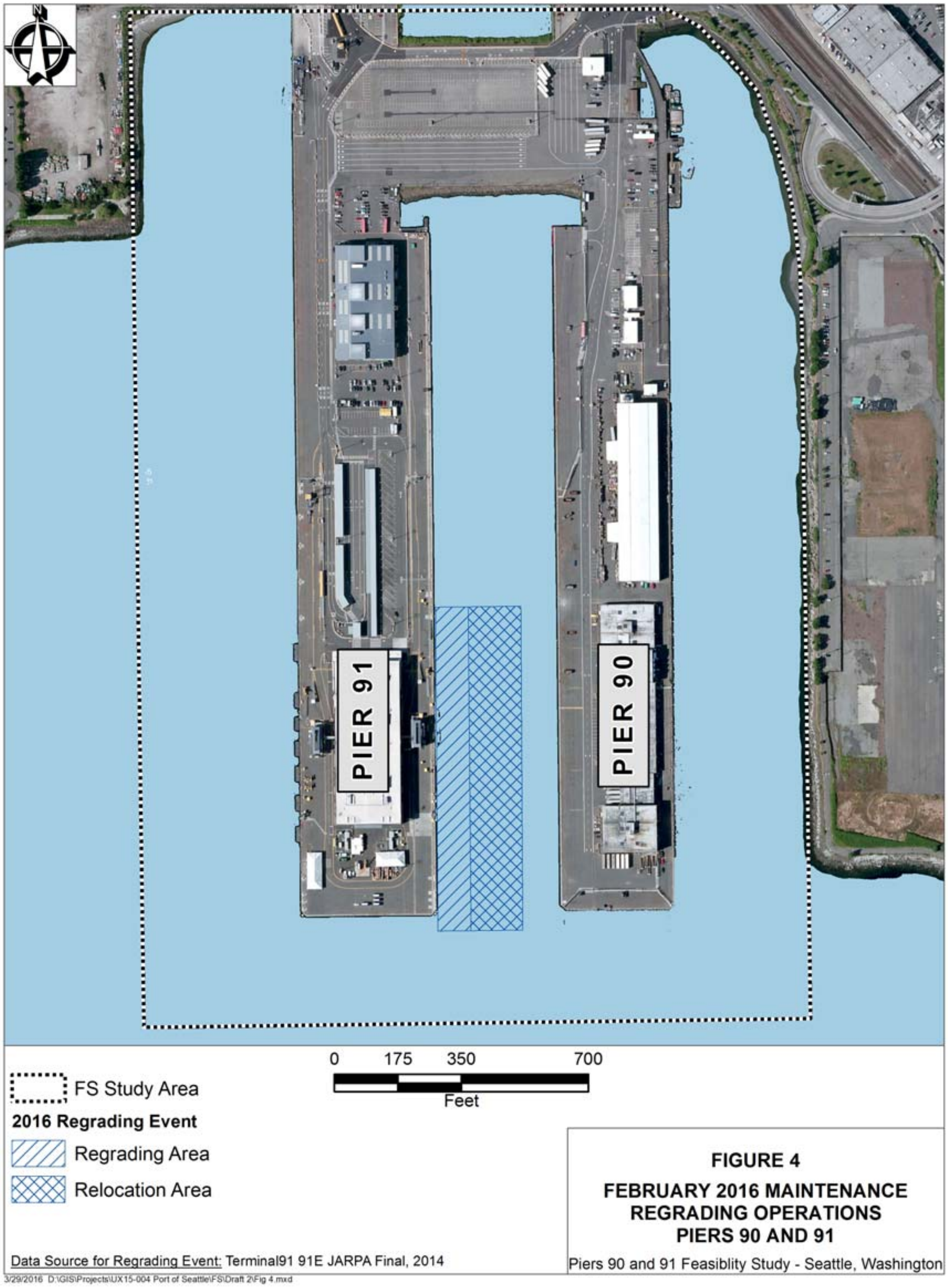

FIGURE 4
FEBRUARY 2016 MAINTENANCE REGRADING OPERATIONS PIERS 90 AND 91

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- Divers performed a "mag and dig" after underwater detector training over simulated MEC, reacquired and excavated geophysical anomalies during "mag and dig".
- Twelve sediment samples were collected during the RI and the analytical results of these samples were used to determine the absence or presence of MC and complete the assessments of potential risks to human health and the environment directly attributable to the munitions contamination at the site. Sediment samples were collected with an approximately 1-foot length and 3-inch diameter polyvinyl chloride (PVC) pipe deployed by divers. One end of the sample tube was cut at an angle and the opposing end was capped. The capped end had a small hole in the center, with a chain and plug attached. The UXO diver would thrust the sample tube into the sediment allowing water in the tube to escape. The plug was inserted into the hole to create suction when the sample tube was retracted. The open end was capped for transport to the surface.
- Samples were analyzed for the following parameters:
  - Energetics: Nitroaromatics and Nitramines (USEPA method 8330B), and Nitrophenols (picric acid, picramic acid, and 2,4-dinitrophenol) by liquid chromatography and tandem mass spectrometry.
  - Diphenylamine and N-Nitrosodiphenylamine (USEPA Method 8270D).
  - Dibutyl phthalate and Diethyl phthalate (USEPA Method 8270D) (to be analyzed only if positive results for energetics and/or stabilizers were observed).
  - Total Organic Carbon (TOC) (ASTM method D4129-05, modified for soil and sediment matrices (Puget Sound Estuary Program and Lloyd Kahn).
- All of the observed results for laboratory analyses for energetics (nitroaromatics, nitramines, nitrophenols), propellant stabilizers (diphenylamine and N-nitrosodiphenylamine), and propellant plasticizers (diethyl phthalate and di-n-butyl phthalate) were reported at trace levels.

A TCRA was conducted for an approximate 25-acre portion of the MRA immediately adjacent to the southern half of Pier 91 during the winter of 2011. The purpose of the TCRA was to reduce the immediate risk, to the extent possible, that military munitions on the seafloor within this 25-acre area posed to private and commercial vessel traffic and POS Terminal 91 operations. UXO divers conducted a surface and shallow subsurface clearance (to approximately one foot) of all MEC, MD and munitions potentially presenting an explosive hazard (MPPEH) within the TCRA area.

The *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013) documents the activities and findings of both the RI and TCRA, and presents conceptual site models (CSMs), human health and environmental risk assessments, and a qualitative potential exposure analysis. These risk and hazard analyses drive the development of the RAOs in this FS, and are summarized in the following sections.

1.8.3 Summary of the Qualitative Potential Exposure Analysis

A qualitative potential exposure analysis was performed during the RI utilizing historical knowledge, results of field investigations, and an Explosive Hazard Assessment prepared by the

USACE Seattle District. During normal operations, the likelihood of future encounters with DMM at the SNSD MRA is considered low, though the likelihood for Topside Construction Workers to potentially encounter DMM during mechanical dredging activities is considered moderate to high. Thirty-two total DMM items were located following surface and subsurface investigations biased to areas with the highest likelihood of concentrations, at the locations shown on **Figure 5**. Seven of these were located during POS Dive Team inspections, 12 were located during the TCRA, and 13 were located during the RI. The majority of these items were small 20 millimeter (mm) and 40mm projectiles, although larger projectiles up to five inches in length were also recovered. Prior to the initial discoveries made by the POS PD dive team, there are no records of encounters with DMM at the SNSD MRA, nor are there reports of vessels contacting seafloor DMM. The likelihood of future encounters has also been greatly reduced by the removal and disposition of all DMM items discovered during the POS PD dive sweeps, the RI and the TCRA.

The qualitative potential exposure analysis ranked the severity of the potential exposure posed to individual receptors on a scale of none through imminent. During normal operations, the highest level of hazard posed to any receptor evaluated was a low ranking assigned to Terminal 91 Divers and Underwater Construction Worker receptors. A moderate hazard ranking was determined for Topside Construction Worker receptors during mechanical dredging activities, due to the increased likelihood of an encounter with DMM in sediments brought to the surface during the dredging activity (USACE, 2013).

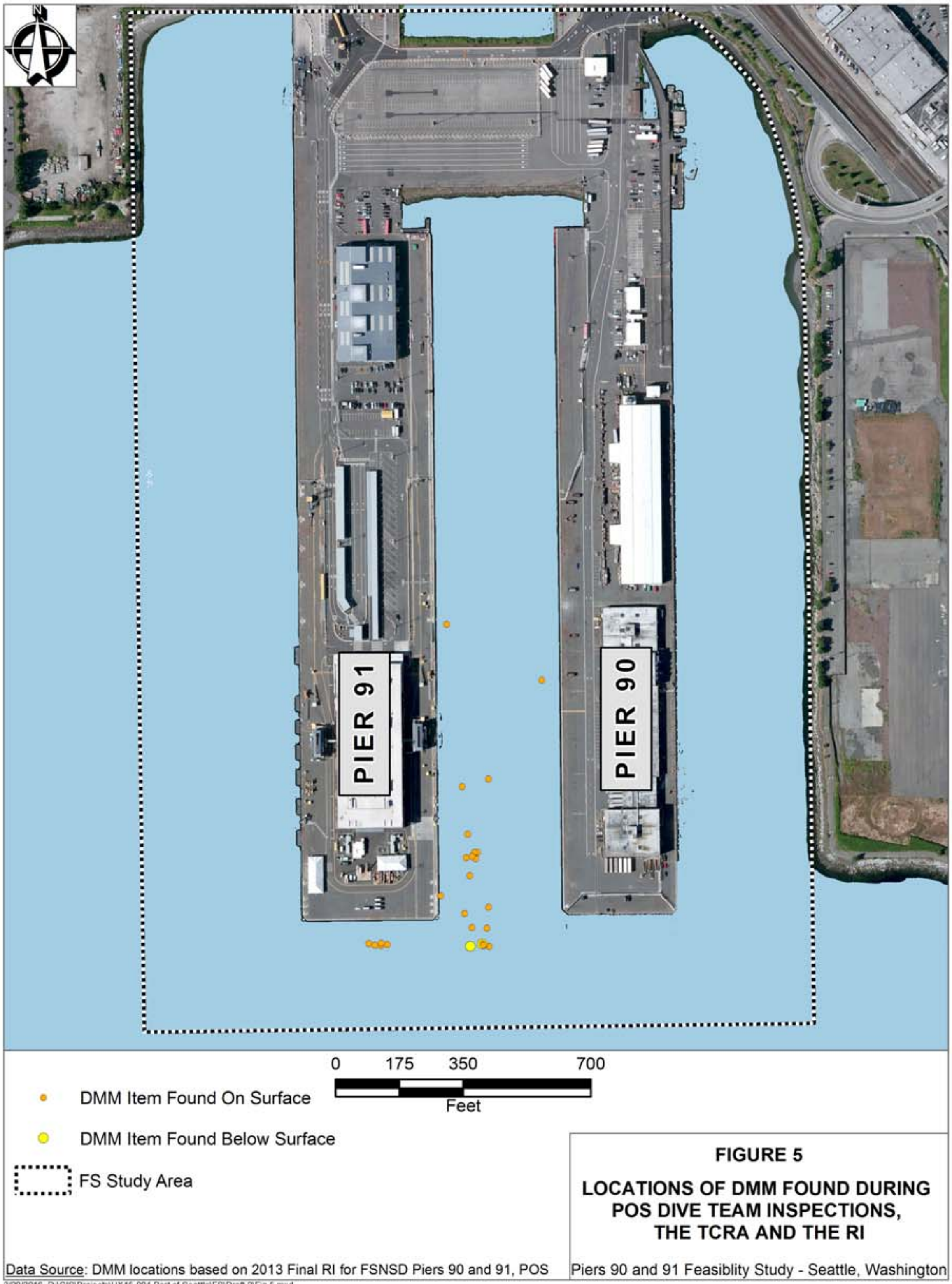
PIER 91
PIER 90
0 175 350 700
Feet
DMM Item Found On Surface
DMM Item Found Below Surface
FS Study Area
FIGURE 5
LOCATIONS OF DMM FOUND DURING
POS DIVE TEAM INSPECTIONS,
THE TCRA AND THE RI
Data Source: DMM locations based on 2013 Final RI for FSNSD Piers 90 and 91, POS
Piers 90 and 91 Feasiblity Study - Seattle, Washington
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Table 1 presents the findings of the qualitative potential exposure analysis for each defined receptor and pathway.

Table 1 Results of the Qualitative Potential Exposure Analysis

Receptor	Non-intrusive Activity Pathway	Intrusive Activity Pathway	Likelihood of Detonation	Qualitative Level of Hazard Posed to Receptor
During normal operations:				
Terminal 91 Diver	Complete	Complete	Low	Low
Underwater Construction Worker	Complete	Complete	Low	Low
Construction Worker (topside)	Incomplete*	Incomplete*	N/A	N/A
Recreational Angler	Potentially Complete though likely insignificant	Incomplete	Low	Negligible
Native American Subsistence Angler	Potentially Complete though likely insignificant	Incomplete	Low	Negligible
Tourist	Incomplete	Incomplete	N/A	None
Resident	Incomplete	Incomplete	N/A	None
During mechanical dredging operations:				
Construction Worker (topside)	Complete	Complete	Low	Moderate**

Note:
* = During normal operations, the Construction Worker (topside) has no contact with DMM on or beneath the surface of the seafloor; therefore the exposure pathways are incomplete.
** = During mechanical dredging operations, there is a moderate to high probability for the Topside Construction Worker (topside) to encounter DMM within sediments brought to the surface and placed on a barge by the dredging equipment.

1.8.4 Summary of the Baseline Human Health and Environmental Risk Assessments

There are complete but insignificant exposure pathways for incidental sediment ingestion and dermal contact for the Native American Subsistence Angler and Recreational Angler receptors. In addition, the seafood ingestion pathway is complete but likely insignificant for the Recreational Angler and Native American Subsistence Angler receptors. The sediment ingestion and direct sediment contact pathways for ecological receptors are complete but likely insignificant since there were no sediment quality benchmark (SQB) exceedances (USACE, 2013).

The BHHRA resulted in no excess lifetime cancer risks above 10^{-6} calculated for the fish ingestion pathway for the Native American Subsistence Angler or the Recreational Angler receptors. The cumulative carcinogenic and non-carcinogenic risks and hazards were within the acceptable risk range of 10^{-4} to 10^{-6} for 2,4- Dinitrotoluene (DNT), N-nitrosodiphenylamine, and cyclotrimethylene-trinitramine (RDX) for the Native American Subsistence Angler and Recreational Angler receptors. There were no non-cancer hazard quotients (HQs) exceeding one for any contaminant of potential concern (COPC). No MC chemicals were retained as contaminant of concern (COCs) for the BHHRA based on the fish ingestion pathway. The

SLERA did not result in any SQB exceedances (i.e., no hazard quotients >1) for the benthic community (USACE, 2013).

1.8.5 Conclusions from the Remedial Investigation

Based on the RI, the contaminant of concern (COC) at the site is DMM potentially remaining on, and in, sediments at the SNSD. The qualitative potential exposure analysis defined a low hazard as: “There is a low likelihood of detonation.” Receptors exist and the pathway between the DMM and the receptor is complete per the CSM, but an encounter is unlikely to occur.” Encounters are unlikely to occur during normal POS Terminal 91 operations, including cruise ship berthing. The qualitative potential exposure analysis further qualified a low hazard as: “Low should mean sufficiently low hazard to allow current land use and RAFLU within an acceptable degree of uncertainty”. A moderate hazard was defined as: “There is a low or moderate likelihood of detonation.” Receptors exist and the pathway between the MEC and the receptor is complete per the CSM, and an encounter has a moderate to high probability of occurring”. This FS focuses on mitigating the moderate hazard posed to the Topside Construction Worker receptor during dredging activities, where there is a moderate to high probability for the receptor to encounter DMM within sediments brought to the surface and placed on a barge by dredging equipment. The FS also addresses potential hazards to downstream sediment workers as well as future dive team inspectors.

The sampling, analysis and assessment of MC contamination during the RI found that MC is not found at levels that pose an unacceptable threat to human health or the environment; therefore, mitigation of MC is not a primary driver addressed in this FS. However, MC may be reduced during remedial activities.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The following sub-sections describe the RAOs for the FS, the ARARs, the GRAs, and identification and screening of technologies and process options.

2.1 REMEDIAL ACTION OBJECTIVES

Remedial action objectives identify the specific goals for protecting human health and the environment, based on the CSM, the human health and ecological risk assessments, and qualitative potential exposure analyses described in the RI. An RAO establishes the acceptable end state for the MRA. The likelihood of encounter is a factor of potential hazard and is a function of both the amount of DMM potentially present and the specific land use that presents the site-specific potential for encounter. Consideration has also been given to the severity of a potential unintentional detonation under the conditions of potential encounter. Finally, the sensitivity of the DMM to the energy of an encounter by specific land users is also considered. Remedial action objectives for the FSNSD MRA specify:

- The contaminant of concern.
  - For the MRA, the contaminant of concern is MEC, which has been categorized as DMM, potentially remaining on the seafloor in the areas discussed in Section 1.8.3 and shown on **Figure 5**.
- Accessibility.
  - Only DMM has been found within an area of the originally defined MRA as shown on **Figure 5**. Within that area, the DMM has only been found on the sediment surface, partially buried in sediment, and buried within the top ten inches of sediment. Based on a review of the RI findings and the processes by which the DMM has been distributed within the MRA, the DMM, if present, is likely within the top foot of sediment. Any activity that results in an encounter of the top foot of sediment from within the area shown in **Figure 5** has a potential to result in an encounter with DMM.
- The potential exposure pathway.
  - There are several potential exposure pathways; maintenance activities required to maintain a navigable depth for use by the Port of Seattle, underwater security dives and inspections, and an exposure to sediment by a secondary processing center (e.g. landfill with soil mixing or treatment) which may potentially contain DMM that has not been screened for removal of DMM. Underwater pier maintenance construction activities are not likely to result in an encounter as DMM has not been found within the immediate area of the individual pier supports.
- Sensitivity
  - The DMM found at the MRA has not been fired or primed and is considered reasonably stable with low likelihood of detonation under conditions associated with the methods of potential encounter anticipated. Of the potential exposure pathways, only the maintenance activities and secondary material processing are

considered as having enough potential for energy imparted to the DMM to cause detonation.

- Severity
    - The DMM of concern established during the RI is the 5-inch MK41. To present an explosive hazard, military munitions must detonate or explode. To initiate planned detonation, munitions items must be fuzed and the fusing mechanism must be armed. Fuzes for military munitions are specifically intended to prevent detonation of munitions unless conditions required to arm the fuze have been met (Dept. of the Army Seattle District, 2012);
    - The maximum fragment distance horizontal (MFD-H) for the 5-inch MK41 is 2,377 feet with an overpressure distance of 44 feet;
    - The depth of overlying water sufficient to stop all fragments from the munition of concern is 5.75 feet of water (USACE, 2012b); and
    - Within a short distance of the point of detonation, the overpressure and fragmentation generated by the detonation of the largest DMM item found to date at the Terminal 91 facility is unlikely to result in damage to vessels.
- The remediation goal(s) for each exposure route.
    - The remediation goal for the MRA is to reduce the explosive hazard to negligible.

Only the area as defined in **Figure 5** is considered for Remedial Action as the remaining area of the MRA is not known to contain DMM and is therefore already representative of a negligible explosive hazard. The RAO for the area defined by **Figure 5** is to reduce to negligible the explosive hazard to workers conducting sediment maintenance, workers processing sediments that have been removed from an in-water status, and potential future underwater dive team inspectors.

2.1.1 Applicable or Relevant and Appropriate Requirements

Section 121 of CERCLA requires that site cleanups comply with Federal and State laws that contain ARARs. Under CERCLA Section 121(d) (2), the Federal ARARs for an on-site remedial action could include requirements under any of the Federal environmental laws. This would include attainment of Federal standards, requirements, criteria, limitations, and more stringent State standards determined to be legally applicable or relevant and appropriate to the circumstances at a given site. State ARARs include promulgated requirements under State environmental or facility siting laws that are more stringent than Federal ARARs, and that have been identified in a timely manner, pursuant to 40 CFR Part 300.400(g)(4).

2.1.2 Definition of Applicable or Relevant and Appropriate Requirements

Section 121(d)(2) of CERCLA of 1980, 42 USC 9621(d)(2), requires that cleanup actions conducted under CERCLA achieve a level or standard of control which at least attains "any standard, requirement, criteria, or limitation under any Federal environmental law...or any (more stringent) promulgated standard, requirement, criteria or limitation under a State environment or facility siting law...(which) is legally applicable to the hazardous substance concerned or is relevant and appropriate under the circumstances of the release of such hazardous substance or pollutant, or contaminant...” The standards, requirements, criteria, or limitations identified pursuant to this section are commonly referred to as ARARs.

ARARs are either applicable or relevant and appropriate. To further define this distinction, applicable requirements are those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State environmental laws that specifically address a hazardous substance, pollutant, contaminant, cleanup action, location, or other circumstances found at a CERCLA site. Applicable requirements are those that a party or agency would have to comply with by law if the same action were being undertaken apart from CERCLA authorities. Relevant and appropriate requirements are those cleanup standards that address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site. They make sense given the circumstances at the site. Once a requirement has been determined to be relevant and appropriate, it has to be complied with to the same extent as if it were applicable.

To Be Considered Requirements (TBCs)

To Be Considered Requirements (TBCs), the final class of requirements considered by USEPA during the development of ARARs, are non-promulgated advisories or guidance documents issued by Federal or State governments..

2.1.3 Types of Applicable or Relevant and Appropriate Requirements

Applicable or relevant and appropriate requirements that govern actions at CERCLA sites fall into three broad categories based upon the chemical contamination present, site characteristics, and alternatives proposed for cleanup. These three categories (chemical-specific, location-specific, and action-specific) are described in the following subsections (USACE, 2010).

Chemical-Specific ARARs

Chemical-specific requirements govern the release of materials possessing certain chemical or physical characteristics or containing specific chemical compounds into the environment. Chemical-specific ARARs generally set human or environment risk-based criteria and protocol which, when applied to site-specific conditions, result in the establishment of numerical action values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

Location-Specific ARARs

Location-specific ARARs relate to the geographic or physical position of the site, rather than to the nature of the contaminants. These ARARs place restrictions on the concentration of hazardous substances or the conduct of cleanup activities due to their particular location and the proposed activity at the site.

Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or are limitations on actions taken with respect to hazardous substances. Action-specific ARARs indicate how the selected remedy must be achieved by setting performance, design, or other action-specific controls or restrictions on particular activities.

2.1.4 Application of Applicable or Relevant and Appropriate Requirements at the Former Seattle Naval Supply Depot

In determining whether a requirement is pertinent to DMM remedial actions at the SNSD MRA, potential ARARs were initially screened for applicability. If determined to be applicable, the requirement was then reviewed for both relevance and appropriateness. Requirements that are considered to be relevant and appropriate command the same importance as applicable requirements. Potential Federal ARARs and TBCs that may be pertinent to remedial actions at the SNSD are listed in **Table 2**. In accordance with 40 C.F.R. § 300.515(d)(1), two requests were provided to the Washington Department of Ecology (Ecology) for identification of potential State ARARs. Ecology provided no State ARARs for consideration.

2.2 GENERAL RESPONSE ACTIONS

General response actions are those actions that will achieve the RAOs and allow for the development of, at a minimum, the three alternatives required (no action, action to remediate the site to a condition that achieves unlimited use and unrestricted exposure [UU/UE] conditions, and action to remediate the site to a protective condition that requires land use restrictions (i.e., LUCs or exposure controls). The following general remedial actions were considered at the SNSD MRA:

- No Action: The No Action alternative was evaluated to satisfy the NCP requirement of 40 CFR 300.430(e)(6), which requires consideration of this alternative as a baseline against which other alternatives may be compared.
- DMM Removal and Disposal: DMM can be detected and removed from on and below the seafloor surface. Alternatives for DMM removal will include technologies for DMM detection, DMM removal, and DMM disposal.
- Institutional Controls/Engineering Controls: Institutional or administrative controls include proprietary and governmental components, plus informational devices such as access and usage restrictions, public education and outreach, and procedure modifications enacted to limit the potential for human or mechanical encounters with DMM while maintaining the current and RAFLU of the site. Engineering controls include signage, capping, fencing, etc.
    - Proprietary controls are generally created pursuant to state and tribal law to prohibit activities that may compromise the effectiveness of the response action or restrict activities or future resource use that may result in unacceptable risk to human health or the environment (USEPA, 2012).

2.3 TECHNOLOGIES

Various remedial technologies were identified to develop alternatives that meet the RAOs for the SNSD MRA. The RAO for the SNSD is to reduce to negligible the explosive hazard to workers conducting sediment maintenance, workers processing sediments that have been removed from an in-water status, and potential future underwater dive team inspectors.

Table 2 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered

ARAR/TBC		Citation	Description	Comments
Location specific				
Federal				
ARAR	Endangered Species Act (ESA)	16 USC 1538(a)(1)(B);	The taking of endangered species is prohibited.	This ARAR is applicable to Alternatives 2, 3 and 4. Critical habitat has been established for the Puget Sound Chinook Salmon and Bull Trout and overlaps the project site. A previous Biological Evaluation prepared by POS for maintenance dredging found that the project had the potential to impact listed species, but that impacts were unlikely to be adverse or significant (USACE, 2013b).
ARAR	The Migratory Bird Treaty Act	16 USC 703(a)	This Act makes it unlawful to (or attempt to) pursue, hunt, take, capture, or kill any migratory bird, part, nest, egg, or product. All but a few bird species naturally occurring in the US are protected under this Act.	Applicable to any on-site detonation of DMM.
ARAR	Marine Mammal Protection Act (MMPA)	16 USC 1372(a)	The taking of marine mammals is prohibited.	Applicable to Alternatives 2, 3 and 4 as these activities will be conducted in marine waters, coastal zones, and aquatic areas where marine mammals or their habitat is present. The Southern Resident Killer Whale (*Orcinus orca*) and the Stellar Sea Lion (*Eumetopias jubatus*) have been observed in Puget Sound and have the potential to be present at the site during remediation.
Chemical-specific				
Federal				
ARAR			None	
Action-Specific				
Federal				
ARAR	Miscellaneous Units	40 CFR 264.601	Section 264.601 pertains to environmental performance standards	Alternatives 2, 3, and 4 may be subject to this ARAR in the event that DMM is handled with an on-site CDC unit. Section 264.601 provides performance standards for miscellaneous treatment, storage, or disposal facilities for hazardous waste, which would include the CDC.

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An initial preliminary screening of remedial technologies was performed to refine the list of available technologies to be considered for the development of alternatives. This screening followed the process and format discussed in *Munitions Response RI/ FS Guidance* (USACE, 2009) and *Guidance for Conducting RIs and FSs Conducted under CERCLA* (USEPA, 1988).

The screening was conducted on the basis of the following three factors:

1. Effectiveness,
2. Implementability, and
3. Cost.

Effectiveness is the demonstrated ability of a technology to perform both short and long-term. Effectiveness was evaluated by considering system rankings, industry standards and familiarization, demonstrated capability, reliability and success, productivity, limitations, ability to address the size of the site, and the potential impacts to human health and the environment.

Implementability was evaluated by considering factors such as logistics; portability; discrimination capabilities; production rates; field proven techniques; training; safety; applicability, permitting, need for treatability studies, and constructability; regulatory and public support; compatibility with planned land uses; and availability of material, equipment, and technical expertise (USACE, 2010).

Costs of each technology were compared by order-of-magnitude and included immediate and long-term costs. Costs were evaluated by considering capital and operating costs rather than detailed estimates. The costs for various types of technologies were assessed based on engineering judgment and experience and are identified as low, medium, or high as compared to other process options. The technologies identified are summarized in **Table 3** below. For each technology the table includes a description; an evaluation of its effectiveness, implementability and cost; a list of representative systems; notes; and a screening decision (retained or removed from further consideration via Yes or No). Technologies considered effective, implementable, and cost-effective were carried through to the development and screening of alternatives presented in **Section 3.1**.

2.3.1 Identification and Screening of Technology Types and Process Options

Various technologies were identified and evaluated to remediate DMM at the SNSD MRA. There are three categories of technologies required for a remedial action for DMM: detection, recovery (removal and demilitarization), and disposal. In addition, LUCs were evaluated as risk mitigation measures (engineering and institutional/administrative). As shown in **Table 3**, the following technologies and process options were evaluated:

- **DMM Detection**
    - Towed magnetometer arrays
        - Fluxgate magnetometer arrays
        - Cesium vapor magnetometer arrays
    - Time-domain electromagnetic induction (TDEMI) metal detector arrays

  - UXO diver deployed frequency-domain electromagnetic induction (FDEMI) metal detectors
  - Acoustic sensors
    - SSS
    - Stationary scanning sonar
- **DMM Removal**
  - Hand excavation via UXO divers
  - Mechanized removal
  - Remotely operated equipment
  - Mass excavation via mechanical dredging and surface sifting
  - Mass excavation via hydraulic dredging and ordnance exclusion
- **Storage, Handling, Transportation, and Disposal of DMM**
  - Off-site disposal at RCRA Subtitle C Treatment, Storage and Disposal Facilities (TSDF)
  - Contained detonation chambers (CDC) – mobile
  - Scrap metal recycling
- **Sediment and Non-Munitions Related Debris (NMRD) Management**
  - Dewatering of Sediment
  - Thermal Treatment of Sediment
  - Transportation to Open-Water Disposal Site
  - Transportation and Disposal at RCRA Landfill
  - Recyclable NMRD disposal
  - Non-recyclable NMRD disposal
- **Land Use Controls**
  - Engineering controls: signage
  - Engineering controls: fencing
  - Engineering controls: capping
  - Institutional/Administrative controls (proprietary): dredging restrictions
  - Institutional/Administrative controls (governmental): waterway use restrictions
  - Institutional/Administrative controls (informational devices): targeted advisories

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options		Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Detection	Towed Magnetometer Arrays	Fluxgate magnetometer arrays	Fluxgate magnetometer arrays utilize a number of fluxgate magnetometers deployed in an array towed beneath the water surface by a tow vessel. Fluxgate magnetometers utilize a two-coil system to monitor the direction and strength of magnetic fields. Arrays are positioned using several methods including a system of tow-cable length and angle encoders and ultrashort baseline acoustic positioning.	**Low:** Fluxgate magnetometer arrays are typically reliable, rugged, have low energy consumption, and are less susceptible to errors. These systems can detect small and large ferrous items [1]. The DGM surveys conducted during the RI indicate that large portions of the site, including the majority of the areas defined as cruise berths by the POS, have a significant amount of ferrous metallic material present. Material is present on the seafloor surface, and may be present in significant quantities buried in sediments. This material reduces the effectiveness of DGM in these areas by masking potential targets within the non-DMM metallic material.	**Medium-High:** Towed fluxgate magnetometer arrays are readily available. These systems have relatively equal detection capabilities compared to each other, thus primary consideration needs to be given to selecting a system with the highest positional accuracy. Towed magnetometer arrays are able to collect useable data at higher survey altitudes (e,g., the distance between the seafloor and the sensor array) than electromagnetic (EM) systems, thus they can conduct surveys in more areas at higher production rates.	**Low-Medium:** Fluxgate magnetometers have a relatively low cost compared to other DMM detection technologies. Costs associated with deployment arrays and positioning capabilities vary, with more robust and accurate systems costing more.	Foerster FEREX 4.032, Ebinger MAGNEX 120 LW, Kokkola Dredging Co. mag array, Vallon EL1303D2 [1]	The increased detection range available with Cesium vapor systems is more suited to the debris–laden environment of the MRA.	No
		Cesium vapor magnetometer arrays	Cesium vapor magnetometer arrays utilize a number of cesium vapor magnetometers deployed in an array towed beneath the water surface by a tow vessel. Cesium vapor magnetometers monitor the energy level in electrons, which are affected by the magnetic field. Arrays are positioned using several methods including a system of tow-cable length and angle encoders and ultrashort baseline acoustic positioning.	**Low:** High level of industry familiarization for optically pumped magnetometers (a magnetometer that measures total magnetic field intensity by observation of the precession frequency of magnetic atoms) with off-the-shelf and specialized underwater units are available. Can detect small and large items. Higher sensitivity (versus fluxgate) - 40% increase in detection range for given size magnetic target [1], though Cesium vapor magnetometer arrays utilized at the site during the RI were unable to reliably detect 20mm projectiles, the smallest DMM item known to be at the site. The DGM surveys conducted during the RI indicate that large portions of the site, including the majority of the areas defined as cruise berths by the POS, have a significant amount of ferrous metallic material present. Material is present on the seafloor surface, and may be present in significant quantities buried in sediments. This material reduces the effectiveness of DGM in these areas by masking potential targets within the non-DMM metallic material.	**High:** Towed Cesium vapor magnetometer arrays are readily available. These systems have superior detection ranges compared to fluxgate systems. Cesium vapor systems have relatively equal detection capabilities compared to each other, thus primary consideration needs to be given to selecting a system with the highest positional accuracy. Towed magnetometer arrays are able to collect useable data at higher survey altitudes than EM systems, thus they can conduct surveys in more areas at higher production rates.	**Low-Medium:** Cesium vapor magnetometers have a relatively low cost compared to other DMM detection technologies. Costs associated with deployment arrays and positioning capabilities vary, with more robust and accurate systems costing more.	GTK UW mag array, G 880 Cesium Marine Deep Tow Magnetometer, HDR MarineMag array [1]	A Cesium vapor system collected useable data to detect 5 inch projectiles with a high degree of accuracy during the RI at the SNSD MRA, within areas relatively free of debris. The increased detection range allowed for these systems compared to fluxgate magnetometer arrays makes these systems more suited for DGM in the SNSD MRA environment, though the inability to reliably detect 20mm projectiles and detect/position individual anomalies within metallic debris-laden areas of the site severely reduces its ability to meet the RAO of the FS.	No

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Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Detection	Towed TDEMI metal detector arrays	TDEMI is a technology used to induce a pulsed magnetic field beneath the Earth's surface with a transmitter coil, which in turn causes a secondary magnetic field to emanate from nearby objects that have conductive properties. When the pulsed primary field is off, the secondary magnetic field decays and is measured by a receiver coil. Marine systems are towed behind a vessel, mounted to an ROV, or carried by divers.	**Low:** Typical off-the-shelf TDEM systems are well suited for use in shallow underwater environments. Array platforms may be hard to control. Depth of detection can be increased minimally by increasing power output of system. Can detect small and large metal items [1]. The DGM surveys conducted during the RI indicate that large portions of the site, including the majority of the areas defined as cruise berths by the POS, have a significant amount of ferrous metallic material present. Material is present on the seafloor surface, and may be present in significant quantities buried in sediments. This material reduces the effectiveness of DGM in these areas by masking potential targets within the non-DMM metallic material.	**Medium:** Fewer TDEMI off-the-shelf options are available for underwater geophysical mapping. Classification capabilities of TDEMI systems exceed those of magnetometer systems, and positioning accuracy ranges are consistent with magnetometer systems. TDEMI surveys are performed at lower speeds and require a lower survey altitude than magnetometer systems.	**Medium-High:** TDEMI sensors have a relatively high cost compared to other DMM detection technologies. Additionally, lower production rates inherent with underwater EM systems compared to magnetometer systems increase cost. Costs associated with deployment arrays and positioning capabilities vary, with more robust and accurate systems costing more.	Geonics EM61S MK2, Ebinger UWEX 700 series [1]	The capability of TDEMI systems to energize buried objects from different orientations and digitally capture sensor data is a distinct advantage in that signature responses of various DMM types can be further evaluated to provide valuable information pertinent to discrimination efforts. Detection depths are highly dependent on coil size and power, but typically TDEMI units are better suited to detect small objects in the shallow subsurface [1]. Based on the debris (i.e. obstructions such as clusters of discarded wooden piles) present in many areas of the SNSD MRA environment, TDEMI systems would not be able to operate in ideal conditions, thus they are less suited than magnetometer arrays for DGM at the MRA. Additionally, the reduced detection range of TDEMI arrays compared to magnetometer arrays indicates that TDEMI sensors would very likely not be able to detect DMM (especially small DMM) buried in sediments beyond the detection range of the sensor in areas where the SBP data collected during the RI indicate the sediment layer is thickest.	No

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Detection	FDEMI metal detectors	FDEMI sensors generate one or more defined frequencies in a continuous mode of operation. Depending upon the transmitter and receiver separation, geometry, and frequencies used, the units can be used to obtain information about the variations in conductivity (or resistivity), as well as infer the presence, material properties, and shape of metal objects. Marine systems are most commonly carried by divers but may be mounted to an ROV or towed.	**Low:** Effectiveness of these units is highly dependent upon the UXO diver conducting real-time discrimination, and the environment within which they are being deployed. Effectiveness can be increased by training the UXO Technician to recognize the signals of potential DMM by conducting practice surveys over simulants placed underwater. Mapping capabilities are extremely limited. FDEMI metal detectors would likely be ineffective at meeting the RAO of the FS at the site due to two factors: 1) Target selection is based on real-time UXO Technician discrimination, and in areas with a large quantity of metallic debris; there would be no way to achieve certainty that all DMM was detected by the FDEMI sensor. 2) Small DMM may be buried beyond the detection range of the sensor, though still within the prism of sediments defined by the RAO. Without removing these sediments, there would be no way to achieve certainty that all DMM was detected by the FDEMI sensor.	**High:** These sensors are readily available and have been used at the site during the RI to successfully detect subsurface DMM. UXO divers are trained in operating procedures.	**High:** Higher costs are associated with the primary deployment method for this sensor; UXO divers. UXO diver costs are inherently high and require substantial support.	Fisher Pulse 8X, Fisher 1280-X Underwater, Minelab Excalibur 1000, Garret Infinium LS, Garrett Sea Hunter Mark II, DetectorPro Headhunter Diver [1]	These sensors were utilized at the SNSD MRA during the RI, and were able to successfully detect DMM in both areas cluttered and clear of metallic debris, leading to the excavation of DMM buried in sediments shallower than 18 inches. Although these sensors are valuable tools for surface clearance operations and during an RI, as very fine layers of sediment (i.e. millimeters [mm's]) can visually obscure DMM on the seafloor, these sensors possess very low effectiveness when considering the RAO of the FS.	No

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category		Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Detection	Acoustic Sensors	Sidescan Sonar	SSS (Sidescan Sonar) surveys involve towing an acoustic sensor behind a survey vessel. The sensor pings at a designated frequency, and the sensor collects information related to these pings as they return after bouncing off seafloor objects.	**Low:** SSS is effective for creating images of large areas of the sea floor, but munitions must be on the surface or proud, and uncluttered by nearby environmental factors such as coral, rocks, and vegetation [1]. SSS will not detect buried DMM.	**High:** These sensors are readily available and have been deployed successfully during prior stages of the munitions response at the SNSD MRA.	**Medium-High:** Sensor costs are generally high compared to other DMM detection technologies, but deployment and collection costs are lower.	Fishers SSS-100k/600K, Klein 3000 Series, SportScan, Tritech SeaKing Towfish, Edgetech 4100 [1]	SSS possesses DMM detection capabilities for large DMM items proud of the seafloor in relatively debris-free environments. This technology has been deployed at the SNSD MRA during the RI and provided useable data to map debris and rule-out potential dumping points for clusters of DMM. SSS data have been collected over the entirety of the site and are available for future use, such as when planning dredging operations in areas with large non-DMM debris (such as wooden piling) present.	No
		Stationary Scanning Sonar	Stationary scanning sonar operates on the same acoustic principles as SSS, but rather than being towed, the sensor is lowered to the seafloor on a tripod and conducts a fixed 360° scan of an area generally 15 meters (m) to 90 m in diameter.	**Low:** Stationary scanning sonar is effective for creating high resolution images of small areas of the seafloor. Munitions must be on the surface or proud, and uncluttered by nearby environmental factors such as coral, rocks, and vegetation [1]. Stationary scanning sonar will not detect buried DMM.	**High:** These sensors are readily available and have been deployed successfully during prior stages of the munitions response at the SNSD MRA.	**Medium-High:** Sensor costs are generally high compared to other DMM detection technologies, but deployment and collection costs are lower.	Kongsberg MS-1000, Tritech SeaKing Hammerhead	Stationary scanning sonar is suitable for detecting larger DMM items, but only those proud of the seafloor surface. This technology has been deployed at the SNSD MRA during the RI and provided useable data to map debris, define individual surface anomalies requiring further investigation, and to rule-out potential dumping points for clusters of DMM. Stationary scanning sonar data have been collected over the approximately 25 acres of the site most likely to contain DMM based on RI and TCRA findings, and are available for future use.	No

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Removal	Hand excavation	Hand excavation consists of UXO divers digging individual anomalies using commonly available hand tools. It can be very thorough and provides good data on items collected.	**Low:** This is the industry standard method for performing underwater DMM removals and investigations. It is highly effective for removing DMM after DMM items are located, but its effectiveness is dependent upon accurate DGM and/or anomaly selection by UXO divers. These technologies (towed magnetometer arrays, TDEMI arrays, FDEMI sensors, etc.) have been determined to a have a low effectiveness The focus of hand excavations is on recovering each item/anomaly one at a time. The underwater excavations can be video recorded. In many cases, results can be verified in real time, though in many cases munitions-related items require cleaning and an inspection after removing the item from the water to determine exact nomenclature.	**High:** Hand excavations have successfully occurred at the SNSD MRA. It is limited only by the number of people available, as personnel authorized to conduct these excavations are limited by Department of Defense Explosive Safety Board (DDESB) Technical Paper (TP)-18 (DDESB, 2004) to graduates of military EOD dive schools, which represent only a portion of the total UXO Technician labor pool. There are a small number of firms in the DMM industry qualified to perform hand excavations at underwater sites.	**High:** The cost for manual excavations can vary greatly depending on a number of factors that affect diving operations including maximum depth, visibility, and sediment conditions. Additional factors include the amount and types of DMM to be excavated, spacing between investigations and whether UXO divers are selecting anomalies based on FDEMI detectors or transiting to pre-identified anomalies selected using DGM. Based on the results of the RI, single teams of UXO divers can be reasonably expected to detect, select and conduct between 20 and 40 excavations per day, depending on which areas of the site are being investigated. UXO divers can be reasonably expected to complete 10 excavations per day when diving on pre-selected DGM anomalies. Necessary diver support including stand-off safety vessels and diver emergency transport vessels are also cost factors that are not seen when conducting terrestrial investigations.	Shovels, picks, trowels, knives, etc.	Hand excavation, both on pre-selected anomalies detected by DGM and on anomalies detected by UXO divers using FDEMI detectors has proven to be an effective method for detecting and removing DMM from this project site. Hand excavation via UXO divers is the only viable technology for removal of individual DMM that does not include the removal of sediments from the MRA. However, it is both time- and cost-intensive and increases the risk to divers that encounter DMM.	No

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Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Removal	Mechanized removal	This underwater method of removing single anomalies (comparable to mechanized removal on a terrestrial site) uses commonly available mechanical excavating equipment, such as small clamshell dredges, to assist in the excavation of anomalies. It is considered an assist because for safety reasons the equipment can only be used to dig to within one ft (vertically or horizontally) of any targeted anomaly. The equipment is used to dig a hole beside the anomaly, with UXO divers manually finishing the excavation and removal by approaching from the side of the anomaly.	**Low-Medium:** Mechanized removal at underwater sites is substantially different from mechanized removal on terrestrial sites. Due to the water barrier and the inability of the equipment operator to monitor the excavation, using clamshell equipment (similar to a backhoe) to assist UXO divers or remotely operated equipment in performing excavations is not implementable; therefore, it is not feasible or effective. Vacuum dredges with ordnance exclusion screens deployed by divers have a degree of utility greater than clamshell style removal.	**Low-Medium:** Although the equipment to conduct mechanized removal with clamshell dredges is readily available, hindrances to positioning equipment and monitoring excavations would require that a UXO diver assist in positioning the equipment and monitor the removal. This presents a substantial safety hazard to the diver, and causes this technology to not be readily implementable. Vacuum dredges with ordnance exclusion screens are safely deployable by divers, though inserting an exclusion screen small enough to prohibit small DMM and MD from transferring up the line would slow progress and cause a substantial increase to sediment in the water column.	**High:** Cost factors include barges, tugs, construction crews and time lost due to reduced visibility for divers following vacuum dredging operations.	Crane-deployed small clamshell dredges, Vacuum dredges such as the Vortex 4-inch dredge system, with custom fabricated ordnance exclusion screens.	Mechanical excavation methods are designed for bulk removal rather than detailed work. The equipment generally lacks the precision required for working closely with DMM. For this reason, mechanical excavations are typically restricted to no closer than one ft (horizontally and/or vertically) from any anomaly, which would provide little assistance if excavations were limited to 18 inches as occurred during the RI.	No
	Remotely operated equipment (innovative)	Underwater remotely operated equipment consists of excavating equipment (shovels, sucker/blower combinations, etc.) mounted to an ROV, which allows the equipment to be operated remotely. The work is monitored by video cameras that are attached to the ROV.	**Low:** Recent advancements in the field of DMM investigations using remotely operated equipment led to the inclusion of this technology, though the technology is not yet on par with remotely operated equipment used on a terrestrial site.	**Low:** ROVs able to manipulate tools and sensors underwater are generally large and metal-framed, significantly reducing the effectiveness of mounted all-metals detectors. This represents a significant hindrance in detecting anomalies in areas where DGM is ineffective. Large ROVs are also unable to freely maneuver and conduct excavations in areas with substantial debris.	**Medium:** Although the rate of both anomaly acquisition and investigation is lower than that of a UXO diver, the ROV is also capable of operating in subsea conditions nearly continuously with a smaller support team.	Remotely Operated Underwater Munitions Recovery System, Other specially modified working class remotely operated vehicles	The U.S Army's Remotely Operated Underwater Munitions Recovery System was deployed at the project site for a short period during the RI. Following the conclusion of its planned operations, the system attempted to locate and excavate two submerged "test" anomalies, (whose locations were derived through DGM) through the use of a sucker/blower system and hydraulically-powered arms. The system was not successful.	No
DMM Removal	Mass excavation via hydraulic dredging with ordnance exclusion screening meeting a rejection threshold of	Mass excavation can be performed by hydraulic dredges equipped with ordnance exclusion screens to remove sediment and uncover DMM, which is later recovered by UXO divers.	**High:** This technology is highly effective for the removal of DMM, as it removes and screens the entire medium where DMM may be contained.	**Low:** For hydraulic dredging, UXO divers would need to re-enter the MRA following dredging to retrieve DMM exposed on the seafloor. Furthermore, large amounts of NMRD are present in	**High:** Cost factors include barges, tugs, construction crews, and site preparatory work and fabrication	Hydraulic-style dredges Custom fabricated ordnance	See Mechanical Dredging in box below.	No.

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Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Removal	anything equal to or larger in size than a 20mm projectile, and seafloor recovery.			areas of the site and would make hydraulic dredging difficult to implement at best.	costs for ordnance exclusion screens	exclusion screens, and other raw materials.		
DMM Removal	Mass excavation via mechanical dredging and surface sifting.	Mass excavation is performed by mechanical dredging equipment operated from a surface barge. Sediments are brought to the surface and sifted to identify and collect DMM.	**High:** This technology is highly effective for the removal of DMM, as it removes and screens the entire medium where DMM may be contained.	**Low-Medium:** Dredging equipment is readily available; however, certain steps additional to a normal dredging project would be required. UXO support would be necessary on the barge to inspect and separate any DMM that was brought to the surface. The dredging operation would occur after facility hours, with all non-dredging personnel removed from the site. Operator shielding and other physical safety measures would be installed on the construction barge to protect personnel from explosive hazards during placement and inspection of dredged materials on the barge deck. Calculations conducted in accordance with DDESB TP-16 indicate that sufficient shielding and standoff distances must be maintained for non-UXO technicians performing work on the dredging barge. Shielding would consist of 1.45 inches of hard steel or 6.32 inches of bulletproof glass, and would be placed a minimum of 44 ft from where the dredged materials are deposited.	**High:** Cost factors include barges, tugs, construction crews, and site preparatory work and fabrication costs for ordnance exclusion screens.	Common crane-barges, clamshell dredges,	Mechanical dredging has occurred at the site numerous times. There is no record of an encounter with DMM, though it is possible that it has occurred. The USACE Omaha District performed a hazard assessment (USACE, 2013a), which found the probability for an encounter with MEC during dredging at the site to be moderate to high. There is a high degree of likelihood that dredging will occur at the site in the future, and methods should be implemented to reduce the potential hazard posed by DMM during these operations.	Yes.

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Demilitarization	Off-site demilitarization and disposal at a RCRA facility	Consists of coordinating the pre-acceptance paperwork with the TSDF, and shipping the DMM to the facility for Open Burn/Open Detonation operations.	**High:** The use an off-site USEPA permitted RCRA facility for DMM disposal is not a routine procedure during CERCLA munitions response actions. It is a USEPA approved procedure; however, once a DMM item leaves the MRA as it loses its classification as Solid Waste (conditional exemption under CERCLA) and becomes RCRA Hazardous Waste [2]. (USEPA, 1988). This technology is highly effective for the removal of DMM, as it removes DMM from the site.	**Low:** There are a limited number of facilities performing DMM demilitarization, and it takes a substantial amount of time to coordinate acceptance. Transport permits can take approximately a year to obtain, and facilities often have a substantial backlog processing explosives from other Army projects [2].	**Medium:** Cost varies depending on distance from site to a suitable facility, difficulty in obtaining permits, and quantity of materials delivered.	General Dynamics – Ordnance and Tactical Systems Munitions Services in Joplin, Missouri [2], Other qualified facilities	Based on the DMM Disposal Options Study (USACE, 2012a) and the methods used to complete the RI and TCRA at the site, a limited number of options to demilitarize DMM exist. These options include utilizing active military EOD personnel and ranges from Naval Station Whidbey Island or Joint Base Lewis-McChord, identifying a RCRA facility, or conducting on-site demolitions. The project phase and other considerations eliminated demilitarization by active EOD as a viable option during the 2012 field season of the RI (it was the method used during the 2011 TCRA).	Yes
DMM Demilitarization	CDC – mobile	CDCs involve destruction in a mobile chamber, vessel, or facility designed and constructed specifically for the purpose of containing blast and fragments from DMM and release of MC. CDCs can only be employed for munitions that are acceptable to move.	**High:** CDCs successfully contain hazardous components, safeguard the public during onsite demolitions, and eliminate explosive hazards from material that has been processed.	**Medium-High:** CDCs are designed to be deployed at project sites, and have been used at this site with prior success. This technology requires temporary evacuation while DMM is being prepared for demolition. The chamber may produce additional hazardous waste streams such as metallic scrap, and gravel contaminated with MC.	**High:** Costs include travel distance, setup/ material costs for consumables purchased near the project site, and staffing.	U.S. Army Edgewood Chemical and Biological Center T30 CDC, Donovan Blast Chamber, Kobe Blast Chamber	The T30 CDC was used successfully during the RI at the SNSD. Metallic scrap resulting from demolitions was determined to be material documented as safe (MDAS). Analytical sampling of gravel indicated it was non-hazardous.	Yes
	Scrap metal recycling	Consists of transporting all MDAS to a qualified scrap metal recycler for final disposition.	**High:** This method requires the inspection of all MD and scrap, and subsequent determination of the material as MDAS before shipping to a recycler. The process is simple and effective for removing MDAS from the project site.	**High:** MDAS is placed in locked containers, labeled, and shipped to authorized disposal facilities.	**Low:** Shipping and disposal costs are based on net weight.	DEMIL Metals, Inc. in Glencoe, Illinois, Timberline Environmental Services in Cold Springs, California, Other qualified	This process was implemented for all MDAS upon the conclusion of the RI at the site. It is a simple, quick and inexpensive method for disposing of MDAS.	Yes

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Technology Category	Process Options	Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
DMM Demilitarization						facilities		
Sediment and NMRD Management	Thermal Treatment	The Vapor Energy Generator (VEG) thermal treatment system is a mobile in-situ and ex-situ technology used to remediate soils for unrestricted reuse. A vapor generator, the ex-situ component of the technology, thermally treats soils within a fully-enclosed chamber, while eliminating emissions through the use of a filter system. The ex-situ technology is also fully sustainable, relying on vapors generated through thermal treatment of soils to serve as fuel for operation of the system; this significantly reduces operational costs relative to other thermal treatment options. The in-situ component of the VEG technology relies on an efficient vapor generator to change the physical properties of soil contaminants, allowing for subsequent recovery/recycling. Other types of thermal treatment exist and are well-known for treating contaminated soils and sediments.	**High:** The VEG system and other thermal treatment systems have been effective to remediate soils laden with PCBs/PAHs. The vapor energy generator, which initially utilizes recycled water and propane to generate steam at 1300°F, provides the thermal energy for both in-situ and ex-situ applications of the VEG technology. An enclosed rotational renewal/treatment chamber containing a 20-inch auger and a hollow 6- inch shaft, the VEG soil remediation system rotates via a variable speed hydraulic system, thermally treating soil moving down the auger. Soil contaminants are entirely desorbed at specified temperatures and residence times, and are passed as vapors into the box head space within the enclosed chamber. Induced vapors in the head space are then sent through patented filters for capture and/or treatment of NOx, SOx, HCl, and CO2 components, with the remaining vapors subsequently sent back to the vapor generator to replace the propane as the fuel to operate the system.	**High:** The VEG treatment system maybe an effective way to remediate PCB-contaminated sediment so that it can pass the DMMP screening criteria and be disposed at a disposal site or used locally as clean fill. Should this option be selected, further testing will be necessary to confirm performance criteria and optimize operating parameters to address potential concerns with PCBs, dioxins, and other contaminants.	**High:** The cost is based on the volume of sediment (cubic yards) that will be treated.	Endpoint Environmental Services and other vendors	Sediment can be 50% solids and still be thermally treated.	Yes
Sediment and NMRD Management	Dewatering of Sediment	Consists of removing the water from sediment so that it can be disposed of either at a landfill, Open-Water Disposal Site, or treated thermally. There are several primary methods to dewater sediments passively; Settling Ponds with Impermeable Liners or Geotextile Tubes. Settling ponds with impermeable liners allow the material to settle over time. Water is then drained from the top using a weir box and pumped into a water treatment facility. Geotextile tubes are effective in reducing the surface area required for dewatering. In this process, slurry is pumped directly into the geotextile bag where the surface acts as a filter, allowing water to flow through the micro-	**High:** Passive and active systems are effective in dewatering sediment.	High: Depending on the sediment characteristics settling ponds can be one of the most cost effective, but also requires the most area. Because the containment facility uses gravity to separate out the materials, a large surface area is required. The use of settling ponds at POS is not implementable due to the large area and time that would be needed for the sediments to dewater. Although geotextile tubes would take up less space, they also will require a storage area and may take months to dewater prior to disposal. Active dewatering using filter presses will take a much	**Medium to High:** The cost is based on the volume of sediment (cubic yards) that will be dewatered.	Genesis Water Rapid Dewatering System, other belt and filter press vendors	Passive dewatering systems should be screened out due to the lack of space at the POS site and the time required for the sediment to be dewatered. Similarly, geotextile bags would not be implementable at the site. Active dewatering methods may be effective and will be considered further.	Yes

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Sediment and NMRD Management		mesh. This process requires a refined slurry-thickening agent, but can be a cost-effective way to rapidly dewater contaminated sediments. Once the tube is filled, it is allowed to dry for several days, and then the sediments can be loaded out on trucks or rail for disposal. An active dewatering method is the use of Belt or filter presses. This method is the process in which water is separated from the slurry with the use of mechanical equipment that can press and filter water from subaqueous sediments.		smaller area and can be set up on an adjacent barge. A large volume of sediment can be dewatered daily and transported to the disposal area. In addition, the treatment of the water through polymers may allow for the water to be discharged back into the harbor.				
Sediment and NMRD Management	Transportation and Disposal of Sediment at Open-Water Disposal Site	Consists of transporting via a hopper barge dewatered sediment to an open-water disposal site such as the Port Townsend Disposal area located approximately 60 miles from the POS.	**High:** This method is a highly effective means of sediment disposal with the locations of several sites listed in the Dredged Material Management Program Users Manual (USACE, 2014). For disposal to be allowed, sediment must be sampled and pass DMMP screening criteria.	**Low:** Sediments in some of the areas to be dredged are known to contain PCBs greater than the DMMP Screening Criteria. In addition, the washing of sediment during the screening process for DMM may make the sediment unsuitable for disposal at sea. The sediment must be dewatered, and pass DMMP screening criteria for open water disposal	**Low:** Transportation and disposal cost is based on volume of sediment (cubic yards).	Port Townsend Open-Water Disposal Site	This process is the least expensive and most effective means of disposing sediment that have been characterized as passing the DMMP screening criteria.	Yes
Sediment and NMRD Management	Transportation and Disposal of Sediment at Non-hazardous Landfill	Consists of transporting via a barge dewatered sediment to a local facility where the sediment will be loaded onto rail cars and transported to a non-hazardous landfill such as the Roosevelt Regional Landfill in Klickitat County, WA.	**High:** Sediment that does not maintain the physical and chemical characteristics for open water disposal at sea will need to be disposed of upland at a Class D landfill. This method was effectively implemented during the recent remedial action that was performed at the Lower Duwamish Waterway.	**High:** Once dewatered, the sediment would be loaded onto a barge and transported to a local facility where it would be offloaded from the barge, reloaded into rail cars and then transported to a local landfill for final disposition.	**High:** The cost is based on the volume of sediment (cubic yards).	Roosevelt Class D Regional Landfill	This process may be the most effective means of disposing sediment that fail to pass the DMMP screening criteria.	Yes
Sediment and NMRD Management	Recyclable NMRD Disposal	Consists of transporting all recyclable NMRD to a qualified recycler.	**High:** This method requires the segregation of all recyclable NMRD such as metal, tires etc... into rolloff containers for transportation to a recycler	**High:** Recyclable NMRD is placed in rolloff containers, and shipped to authorized recycling facilities.	**Low:** Shipping and disposal costs are based on net weight	South Recycling and Disposal Station Seattle, Washington Other qualified facilities	This process is a simple, quick and inexpensive method for disposing of recyclable NMRD.	Yes
Sediment and NMRD Management	Non-recyclable NMRD Disposal	Consists of transporting all Non-recyclable NMRD to a permitted landfill.	**High:** This method requires the segregation of all non-recyclable NMRD into rolloff containers for transportation to a local disposal facility	**High:** Non-recyclable NMRD is placed into rolloff containers, and shipped to authorized disposal facilities.	**Low:** Shipping and disposal costs are based on net weight.	King County Solid Waste Division, Washington Other qualified facilities	This process is a simple, quick and inexpensive method for disposing of non-recyclable NMRD	Yes

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options		Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
Land Use Controls		Engineering controls: signage	Consists of installing signage warning of potential hazards and risks for trespassers and site users.	**Low:** Signage placed throughout the facility would be generally ineffective for warning transitory, barge-based Topside Construction Worker receptors of the moderate hazards present while performing dredging operations.	**Low-Medium:** Although relatively easy to create and emplace, installation of signage may be difficult to implement and may cause elevated levels of concern to non-impacted receptors.	**Low:** Capital cost is low but it requires indefinite maintenance.	Numerous companies create unique signage.	Signage would need to be placed at multiple vantage points to be seen by the necessary receptors. There are signs at the facility that warn of the risks of catching and eating fish and shellfish. These signs are placed on the pier but near the water, but the expansiveness of the facility renders them generally ineffective.	No
Land Use Controls	Engineering Controls	Engineering controls: capping	Consists of constructing a cover over the contaminated area. Reduces the potential for contact with and migration of DMM or environmental contaminants.	**High:** Depending on the material used, this method can eliminate the potential for contact with DMM or environmental contaminants with a high degree of permanence.	**Medium to High:** Placing a cap over the existing bathymetry at the site would reduce the level of clearance between ship keels and the bottom, and over time could reduce the usability of the facility, depending on depth.	**Low to High:** Costs for material and installation necessary to cover the 86 acre site would be very high. A derivative high cost associated with the potential for long-term loss of use exists. However, capping of areas that exceed sediment criteria in the DMMP Users Manual (USACE, 2014) could be cost-effective, depending on the area to be capped.	Regular marine construction equipment including barges, clamshell dredges and barrier material such as gravel or rip-rap.	Highly effective for installing a barrier that eliminates the potential for interaction with DMM or environmental contaminants.	Yes
Land Use Controls		Engineering controls: fencing	Consists of placing fencing around the MRA to limit receptor access.	**Low:** Fencing, placed in any location, would not have any discernible effect on receptor access to the MRA.	**Low:** Fencing would obstruct daily operations at the Terminal 91 facility, and would prevent access to public areas northwest of the MRA.	**Low:** Costs for material and installation would be low compared to other process options.	Standard fencing supplies.	Fencing, a common engineering control, is not practical or feasible for this site.	No

Table 3 Identification and Screening of Technology Types and Process Options

Technology Category	Process Options			Descriptions	Effectiveness	Implementability	Cost	Representative Systems	Notes	Retained Yes / No
Land Use Controls	Institutional Controls	Administrative Proprietary Controls	Dredging Restriction	Includes restricting future POS maintenance operations until an effective design can be completed that addresses potential receptors and Post-completion, POS maintenance operations would be allowed within prisms previously dredged or cleared of DMM during the implementation of an alternative.	**High:** The effectiveness of this restriction is high. By limiting future dredging to previously dredged areas or areas cleared of DMM, and by preventing maintenance operations in areas that may contain DMM until an alternative design is approved that addresses potential hazards, POS eliminates the activity that leads to a moderate hazard of a potential encounter with DMM.	**Medium:** This restriction can be implemented at the site with minimal impact to current and RAFLU. Medium difficulty is assumed with regard to negotiating and administering the formal restriction, as the POS would have to implement any restriction on themselves.	**Low:** Costs for implementing restrictions, compared to costs for DMM detection and removal, are low.	LUCs are an industry standard method for reducing hazards posed by DMM.	This dredging restriction has short-term and long-term effectiveness. Short-term, the restriction eliminates the only identified activity occurring at the facility that presents a moderate hazard to receptors. Long-term effectiveness is dependent upon the alternative selected. The POS would have to impose these restrictions on themselves.	Yes
Land Use Controls	Institutional Controls	Governmental Controls	Waterway use restriction	Includes restricting harvesting of shellfish and other marine organisms using pots and other harvesting or fishing equipment that interacts with the seafloor within the MRA until a remedial alternative allowing for unrestricted use and unlimited exposure is completed.	**Medium:** The effectiveness of this restriction is medium. By restricting bottom-impacting and harvesting within the MRA, the exposure pathway leading to an existing, though negligible, hazard is eliminated. Constant enforcement of any such restrictions is difficult, and lowers effectiveness.	**Low:** This restriction can be implemented at the site with minimal impact to current and RAFLU. A high degree of difficulty is assumed with regard to negotiating and administering the formal restriction, and with enforcing any restrictions.	**Low:** Costs for implementing restrictions, compared to costs for DMM detection and removal, are low.	LUCs are an industry standard method for reducing hazards posed by DMM.	This short-term process option would be considered for recommendation if the desired end-state of the selected remedial alternative is to reach unrestricted use and unlimited exposure and the hazard posed to these receptors was above negligible. Fishing and harvesting within the MRA was not documented during any prior response action, and although possible, the likelihood of an encounter between applicable receptors and DMM is very low, and currently considered acceptable.	No
Land Use Controls	Institutional Controls	Informational Devices	Targeted advisories	Includes receptor outreach and education designed to modify the behavior of potential receptors to avoid encounters with DMM, and the appropriate steps to take to avoid hazards in the event of an encounter.	**High:** Education and outreach is highly effective in training receptors not typically exposed to DMM to recognize and avoid potential hazards.	**High:** DMM training is readily available, and could be conducted rapidly for receptors found to possess a hazard from DMM prior to conducting dredging operations at the facility.	**Low:** Costs include a day of training and the creation of a small number or reference pamphlets for potential receptors.	Awareness training is common throughout the industry.	Effectiveness increases when used in conjunction with other LUCs. May not be necessary if dredging restrictions are in place.	No

[1] = Information obtained from *An Overview of Underwater Technologies for Operations Involving Underwater Munitions*, by Andrew Schwartz and Erika Brandenburg, published in the Marine Technology Society Journal, Volume 43, Number 4 (Schwartz and Brandenburg, 2009)
[2] = Information obtained from the *MEC Disposal Options Study for the Former Seattle Naval Supply Depot*, by USACE Omaha District, March 2012. (USACE, 2012a)

2.3.2 Retained Technologies

The technologies that are considered to be potentially implementable and effective for DMM remediation at the SNSD MRA were retained as indicated in **Table 3**. The remaining technologies were dropped from further consideration because of low effectiveness and/or difficulties associated with implementation or cost. Specific reasons for eliminating a technology or process option are also noted in **Table 3**. As a general rule, only the technologies or process options that are applicable and address the RAOs stated in **Section 2.1** are retained for further evaluation. As shown in **Table 3**, the following technologies and process options were retained for further analysis:

- **DMM Removal**
  - Mass excavation via mechanical dredging and surface sifting
- **Storage, Handling, Transportation, and Disposal of DMM**
  - CDC – mobile
  - Off-site disposal at RCRA Subtitle C TSDF
  - Scrap metal recycling
- **Sediment and Non-Munitions Related Debris (NMRD) Management**
  - Dewatering of Sediment
  - Thermal Treatment of Sediment
  - Transportation to Open-Water Disposal Site
  - Transportation and Disposal at Non-Hazardous Landfill
  - Recyclable NMRD disposal
  - Non-recyclable NMRD disposal
- **Land Use Controls**
  - Sediment Capping
  - Institutional/Administrative controls (proprietary): dredging restrictions

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3.0 DEVELOPMENT OF ALTERNATIVES

The evaluation of historical information, site conditions, RAFLU, and suitable technologies has resulted in the development of several remedial alternatives for the SNSD MRA. The purpose of this section is to present a summary of these alternatives, which incorporate the technologies screened and retained in the previous section of this document.

3.1 SUMMARY OF ALTERNATIVES

At least three alternatives must be considered in the FS: no action, action to remediate the site to a condition that allows for a UU/UE condition, and action to remediate the SNSD MRA to a protective condition that requires land use restrictions (i.e., LUCs or exposure controls) (DERP, 2012). The four alternatives presented below cover this range of remedial alternatives.

3.1.1 Alternative 1: No Further Action

This alternative is required by CERCLA and the NCP to establish a baseline set of conditions against which other remedial actions may be compared. This no additional action and cost alternative allows the SNSD MRA to remain in its current state with no additional remedial actions being implemented. This no further action alternative recognizes the removal efforts that have occurred at the site to date, including the removal of all DMM discovered during the RI, and the TCRA that were completed at the SNSD in 2012.

3.1.2 Alternative 2: Administrative Controls

The POS has conducted several routine maintenance operations within the MRA in the past, with the most recent maintenance operation conducted east of Pier 91 during February 2016.. Dates and dredging prisms of maintenance operations prior to that time are presented in Section 2.2.3 of the *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013). Additional maintenance operations will be necessary in the future to maintain a sufficient navigable depth for cruise ships and other vessels that routinely berth at the site. These future maintenance operations may result in exposure of Topside Construction Workers to DMM that is brought to the surface as a result of dredging. Other sediment workers who handle dredged sediment may also be exposed to DMM. Future dive teams conducting underwater inspections may also potentially be exposed to DMM. The qualitative potential exposure analysis presented in the *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013) found that there is a moderate level of hazard during dredging operations posed to Topside Construction Workers due to the moderate to high probability for an encounter with DMM after it is raised to the surface and placed on the construction/dredging barge. If the material is not properly and effectively screened, the potential for exposure of workers processing sediment that has been removed also exists.

Alternative 2 would use administrative controls to prevent unacceptable hazards to Topside Construction Workers and workers processing sediments by preventing sediments from being removed during future maintenance activities in areas where DMM has previously been found. These administrative controls would require the concurrence of the current owner, the Port of Seattle, and would place restrictions on bringing material to the surface unless provisions were in place to effectively screen the material to remove any DMM that is present. These controls could take the form of deed restrictions or other restrictive covenants. It is estimated that these administrative controls could be developed and implemented within several months. Future underwater maintenance operations that would maintain a sufficient navigable depth for future ship berthing and other activities could still be conducted. Areas where past dredging has been completed and DMM removed could be eliminated from future restrictions. The area that would be subject to the administrative controls under this alternative is shown on **Figure 6**.

The estimated present worth cost to implement Alternative 2 is $660,000. This cost includes an annual review to ensure that the administrative controls are still in effect and being effective. Five-year CERCLA reviews are also included in the cost estimate.

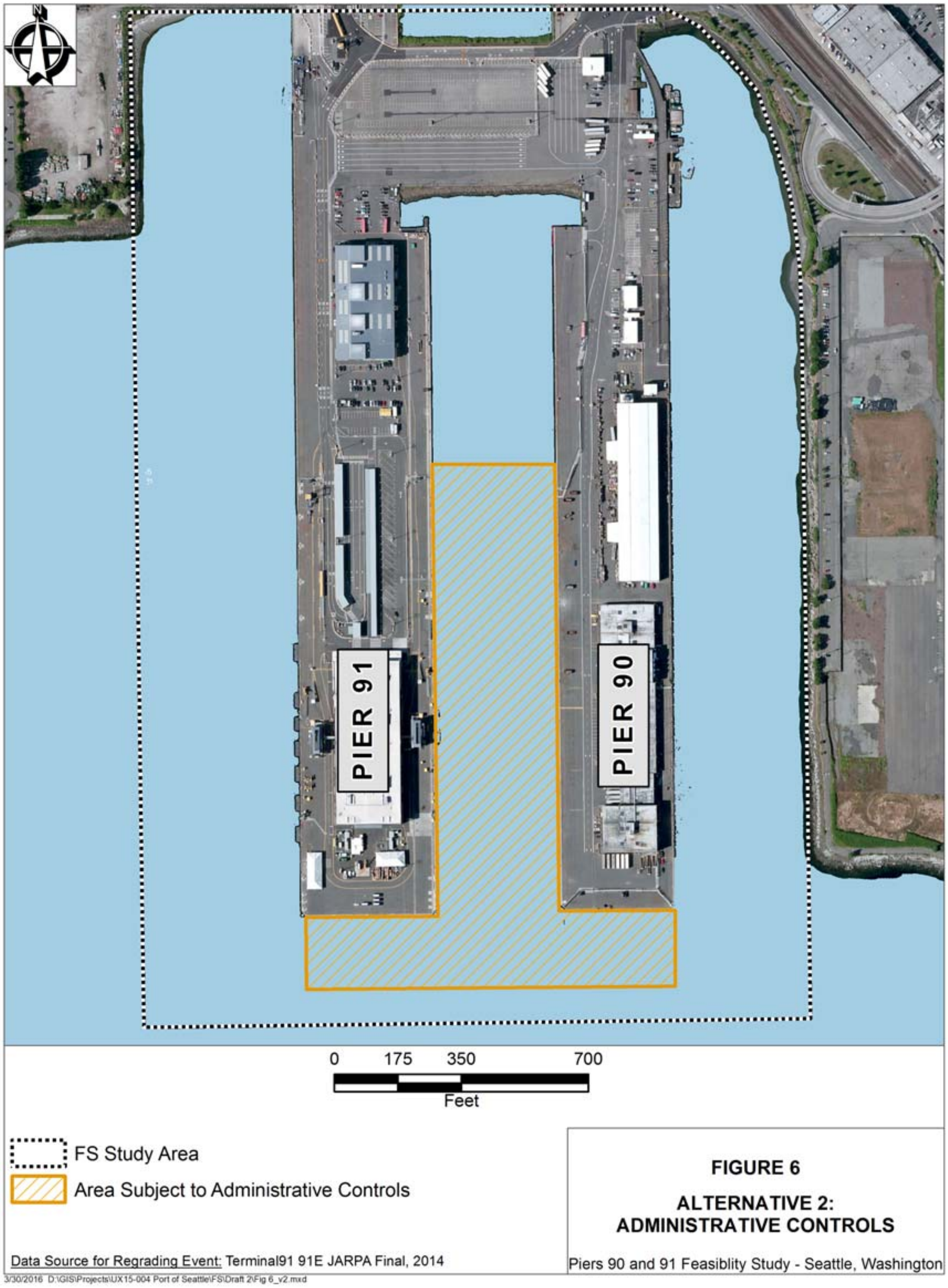

FIGURE 6

ALTERNATIVE 2: ADMINISTRATIVE CONTROLS

Piers 90 and 91 Feasiblity Study - Seattle, Washington

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3.1.3 Alternative 3: Sediment Removal to -40 Foot MLLW

Alternative 3 would involve the removal of sediment by dredging of up to the top two feet of sediments in the area in which DMM has been previously found (**Figure 5**) based on POS diver findings and DMM discoveries during the TCRA and RI, down to a depth of -40 feet MLLW. The area to be dredged is constrained by the area shown on **Figure 7** that encompasses and is slightly larger than the area of previous DMM discoveries. A target removal of two feet of sediment would be dredged in this area down to -40 feet MLLW to remove any remaining DMM with a reasonable degree of certainty. A two-foot depth was selected based on the following factors:

- Available information indicates that local sediment deposition rates are expected to be minimal based on flow patterns in Elliott Bay (Ebbesmyer et al, 1998).
- Given the hardened Seattle waterfront, there is no appreciable sediment input into the nearshore system that might be directed toward the site. This also indicates that sediment deposition rates into Smith Cove (the portion of Elliot Bay where the site exists) are fairly negligible (USACE, 2013).
- Both the CSM and text in Section 4.9.7 *Former Seattle Naval Supply Depot Terminal 91-Port of Seattle, Seattle, Washington, Remedial Investigation Final Report* (USACE, 2013) indicate that DMM items dropped from naval vessels should sit within sediments above the hard pack layer.
- During the TCRA, subsurface DMM was located in only two areas, at a maximum depth of ten inches within the soft sediment above the hard pack layer (USACE, 2013).

Based on these data, it is not anticipated that DMM will be found at depths of more than approximately one foot at the site. A targeted dredging depth of two feet was determined to provide a sufficient safety factor to ensure that any remaining DMM would be removed from the historical area of DMM occurrence to a reasonable degree of certainty.

Alternative 3 would involve targeted sediment removal down to a depth of -40 feet MLLW. The total volume of sediment removed under this alternative would be approximately 16,000 cubic yards over 4.6 acres. While targeted removal would go down to -40 Ft MLLW, there would be some incidental removal below this depth, as discussed in Appendix B, in achieving this targeted depth. Dredged materials would be placed on a construction/dredging barge, where the sediments would be screened for DMM. The process of separating DMM and NMRD from the sediment, and managing all three components, is described below. Further information on conducting dredging in DMM-laden sediments is available in the August 2008 USACE Engineer Research and Development Center paper titled *Dredging in Sediments Containing MEC* (USACE, 2008).

Sediment Screening

There are several potentially feasible methods for screening dredged materials after placement on the construction/dredging barge. Using one method, UXO technicians (qualified in compliance with DDESB TP-18 [DDESB, 2004] requirements) would physically inspect each bucket load of dredged material with FDEMI detectors. Using another method, dredged materials would be placed on an ordnance exclusion screen on the construction/dredging barge. The screen would be sized to exclude the DMM determined to be present on the site. Each bucket load of dredged material would be washed through the screen with water, leaving DMM and non-munitions related debris (NMRD) on the screen.

Once screened for DMM and NMRD, the sediment and water used to wash the sediment would pass through a de-sanding unit that would separate the sand from the sediment by size and weight. The coarse sand would be dewatered by gravity and stockpiled on a barge prior to being sent offsite for use as clean fill or for other use. The water used to wash the sediments would be discharged back to Elliott Bay, along with any water from gravity settling of the coarse sand.

DMM and NMRD Management

Prior to initiation of dredging activities, an exclusion zone based on the MGFD from the approved Explosive Safety Submission/Explosive Siting Plan (ESS/ESP) would be established. Any DMM items reaching the construction/dredging barge with the dredged material would be cordoned off in an exclusion zone based on the type of DMM, with all non-essential personnel evacuated to the shielded areas. Non-essential personnel necessary for the dredging project would be subject to permanent exclusion zones while working on the barge. The UXO technicians would place the discovered DMM items into a lockable containment box in an area to be specified in the ESS/ESP and marked with a sub-surface buoy, and lower the lockable containment box to the seafloor in a previously dredged or non-dredged area, thereby using the water as a barrier to potential detonation impacts. For the purposes of this FS, it is anticipated that all DMM lockable containment boxes would be collected and staged underwater at the northeast corner of Pier 91 awaiting final disposition. This is considered more practical operationally than storing DMM on a barge-based magazine, or placing a magazine on-shore for the duration of the project, which could prove a hindrance to daily POS operations. All MEC items discovered to date at the SNSD MRA have been classified as DMM and were considered safe to move. It is anticipated that any future DMM items will be similar in nature to those previously found.

The NMRD recovered during the screening process would be removed and segregated into roll-off containers for the recycling or disposal of recyclable and non-recyclable items, as appropriate. There is extensive debris prevalent at the site, including large items such as logs and tires, as well as small items such as pieces of sheet metal, boxes, cables, abandoned fishing equipment, etc. **Figure 8** shows typical small debris that is present at the site and would become part of the NMRD recovered during the implementation of this alternative. Digital geophysical mapping, sidescan sonar (SSS) and stationary scanning sonar data collected during the TCRA and RI help position and characterize this debris, and would be provided to the dredging contractor to increase the efficiency of the dredging effort.

Munitions and explosives of concern would be removed from the site following the dredging operation via one of two methods; onsite demolition within a CDC, or via transport to a RCRA Subtitle C TSDF that is permitted to perform demilitarization of DMM. A CDC was effectively employed during the DMM removal that concluded the 2012 field season of the RI, and is the ideal process option for DMM demilitarization. The identified CDC would be placed within the parking lot at the north end of the facility, or another suitable location, and safe demolition operations would occur after business hours on a pre-scheduled date following the dredging operation. All procedures successfully implemented during the RI would be repeated (e.g. offsite donor charge storage and transportation, evacuation and exclusion zones, timing, public relations, etc.) and MDAS would be shipped to an authorized facility for recycling.

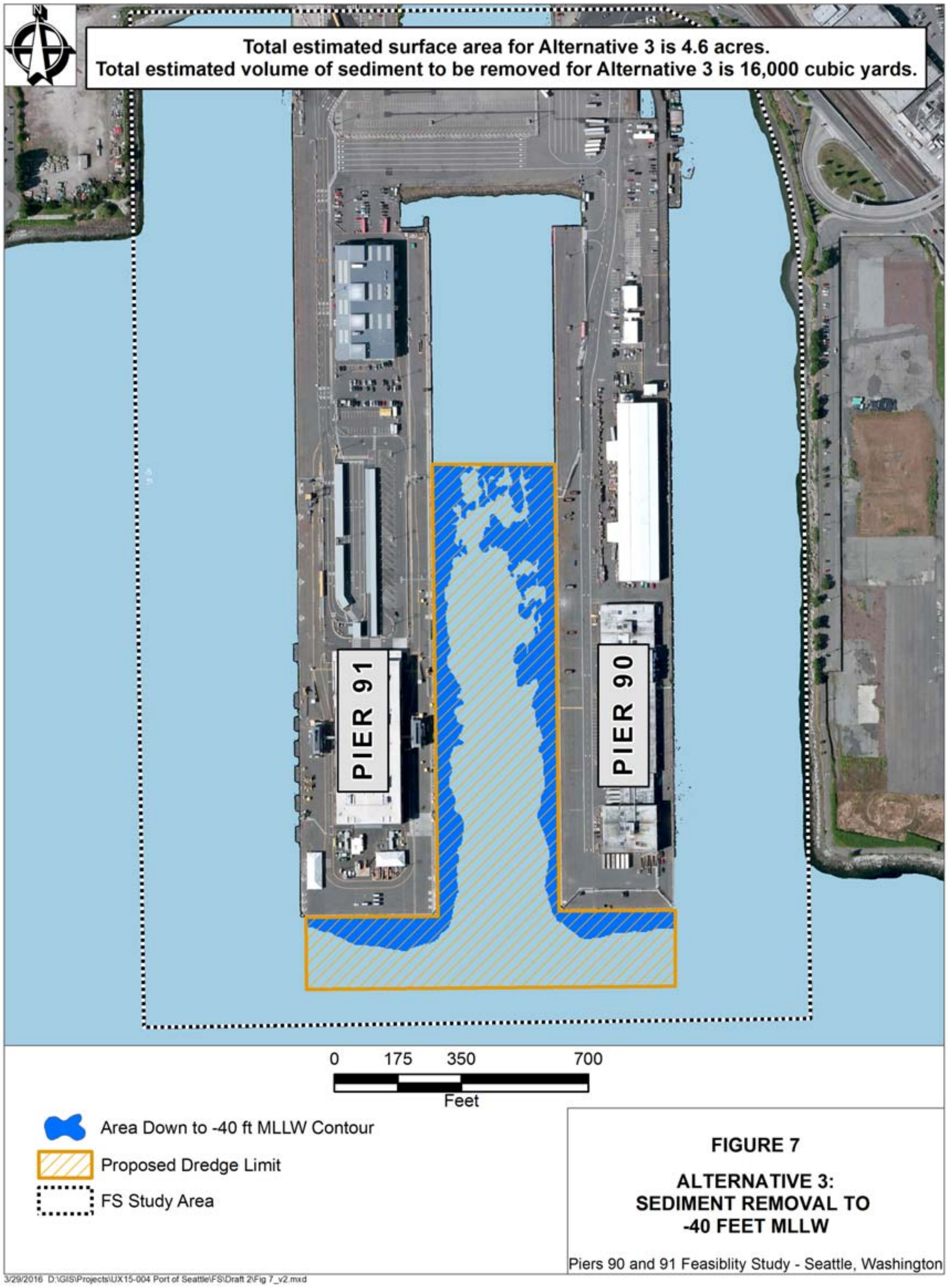

FIGURE 7

ALTERNATIVE 3:
SEDIMENT REMOVAL TO
-40 FEET MLLW

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Figure 8 Typical Small Non-Munitions Debris Items

Utilizing a RCRA Subtitle C TSDF facility for demilitarization and disposal is also possible, but presents a unique set of challenges that must be overcome prior to implementation. These challenges, described in the DMM Disposal Options Study (USACE, 2012a), include; a limited number of facilities performing DMM demilitarization, a substantial lead time to coordinate acceptance, the lengthy time period to obtain transport permits (which can take approximately a year to obtain), and the likelihood of a substantial backlog at the facility due to processing explosives from other Army projects. Although possible, and likely preferable to facility managers and stakeholders, as well as less expensive, these operational constraints severely limit the suitability of a RCRA Subtitle C TSDF as a viable process option for DMM demilitarization.

Post-Dredging Sampling

Following the implementation of Alternative 3, a visual survey of the dredged area would be conducted by divers to ensure that there is no remaining DMM evident in the dredged area. The dredging operation may leave contaminants in the exposed sediments remaining on the seafloor at levels that exceed environmental criteria contained in the *Dredged Materials Management Program (DMMP) Users Manual* (USACE, 2014). Post-dredging sampling would be conducted to establish residual sediment contaminant concentrations at the sediment/water interface in dredged areas. Where these concentrations exceed applicable criteria in the DMMP , the area could be covered with a sand cap or an armored sand cap (as appropriate) of approximately one-foot thickness. The need for a sand cap would be determined as part of the detailed design efforts. The cost estimate for Alternative 3 includes a contingency cost for such a cap.

Sediment Management

There are three basic options for managing the volume of sediments anticipated under Alternative 3: thermal treatment, dewatering and upland disposal, and disposal to an open-water marine open-water disposal site such as the one near Port Townsend, WA. Each of these options are described below.

Option 1: Thermal Treatment

Under this option, the sediment would be dewatered and treated using an on-site thermal treatment process to remove PCBs and other organic constituents from the sediment. Pre-dredging testing would be conducted to optimize the operating parameters for the thermal treatment unit. The effluent from dewatering would be tested and treated as needed, prior to discharge back to Elliott Bay. This could involve solids removal and possible treatment with carbon to adsorb organic constituents, if needed. Specific requirements would be determined during the design process, in conjunction with any discharge conditions necessary to meet Department of Ecology requirements.

The dewatered sediment would be treated in a mobile thermal treatment unit specifically transported to the site for this purpose. This treatment process involves temperatures less than those required for incineration, but sufficient to remove organic contaminants such as PCBs, VOCs, and SVOCs. The treated sediment would be sampled and if determined to be clean it could be used as clean fill locally transported by barge to an open-water disposal location for final disposition.

The thermal treatment equipment could be located either on a barge, or on land adjacent to the pier, where it would not interfere with normal POS operations.

Option 2: Dewatering and Upland Disposal

Under this option, the sediment remaining after screening would be transported to a nearby facility located on the Duwamish River where the sediment would be dewatered, loaded onto railcars, and transported to a Class D Solid Waste Landfill such as the Roosevelt Regional Landfill, operated by Republic Services in Klickitat County, Washington. The water from the dewatering process would be handled at the dewatering facility as appropriate, in accordance with the facility's existing discharge permit, prior to discharge to the receiving water at that location.

Option 3: Disposal to Port Townsend Open-Water Disposal Site

Under this option, the sediment remaining after screening would be sampled and tested, and if suitable, would be transported for disposal to an open-water sediment disposal area such as the one at Port Townsend, WA. The sediment would likely require both physical and chemical testing, as well as possible ecological testing, to ensure that it was suitable for disposal at that location.

If Alternative 3 is selected, regardless of which sediment management option is selected, additional engineering services would be required in the design phase to define the areas impacted by dredging, to perform a stability analysis on the pier piling and pier structure in the vicinity of the dredged area, and to design any ancillary treatment facilities (or arrange for their use) needed to meet environmental criteria for dredged sediments and/or water. Post-dredging characterization would also be needed to ensure that sediments remaining in the dredging area meet environmental criteria specified in the DMMP Users Manual (USACE, 2014). If these criteria are not met, installation of a sand cap may be needed to provide a clean substrate for benthic organisms.

Following implementation of Alternative 3, annual long-term monitoring and a CERCLA review conducted every five years would ensure that the remedy is continuing to be effective over time.

Implementation of this alternative would take approximately three months at the site to complete. Based on an estimated production rate of 200 cubic yards per day, the dredging activity would take an estimated 80 days. Sampling and disposing of dredged materials would take an estimated 5 days. Based on site-specific UXO diver production rates for detector aided surface clearances recorded during the TCRA and RI, the post-dredge clearance and sampling would take another 5 days. Safe demolition and disposal of the DMM would take an estimated 2 days. Additional days are necessary for mobilization and demobilization of project equipment.

The estimated present worth cost for implementing Alternative 3 would be $4,970,000 for Option 1, $4,810,000 for Option 2, and $3,690,000 for Option 3.

3.1.4 Alternative 4: Sediment Removal to -50 Foot MLLW

Alternative 4 would be very similar to Alternative 3, with the exception that the targeted removal would be up to two feet, to a depth of -50 ft MLLW instead of -40 ft MLLW. This would encompass a larger area of removal—covering an estimated 12.4 acres—and an estimated removal volume of 53,0200 CY. The area impacted by the implementation of Alternative 4 is shown on **Figure 9**.

Dredging methodology, UXO support and screening, DMM handling and disposal, NMRD handling and disposal, sediment handling and disposal, and post-dredging sampling would occur as described for Alternative 3.

Following implementation of Alternative 4, annual long-term monitoring and a CERCLA review conducted every five years would ensure that the remedy is continuing to be effective over time.

Implementation of this alternative would take approximately 290 days at the site to complete, and would be accomplished over a two calendar year period. This would require two mobilizations to the site. Based on an estimated production rate of 200 cubic yards per day, the dredging activity would take an estimated 265 days. Sampling and disposing of dredged materials would take an estimated 10 days. Based on site-specific UXO diver production rates for detector aided surface clearances recorded during the TCRA and RI, the post-dredge clearance and sampling would take an estimated 10 days. Safe demolition and disposal would take an estimated 3 days. Additional days are necessary for mobilization and demobilization of project equipment.

The estimated present worth cost for implementing Alternative 4 would be $13,556,500 for Option 1, $13,436,500 for Option 2, and $9,726.500 for Option 3.

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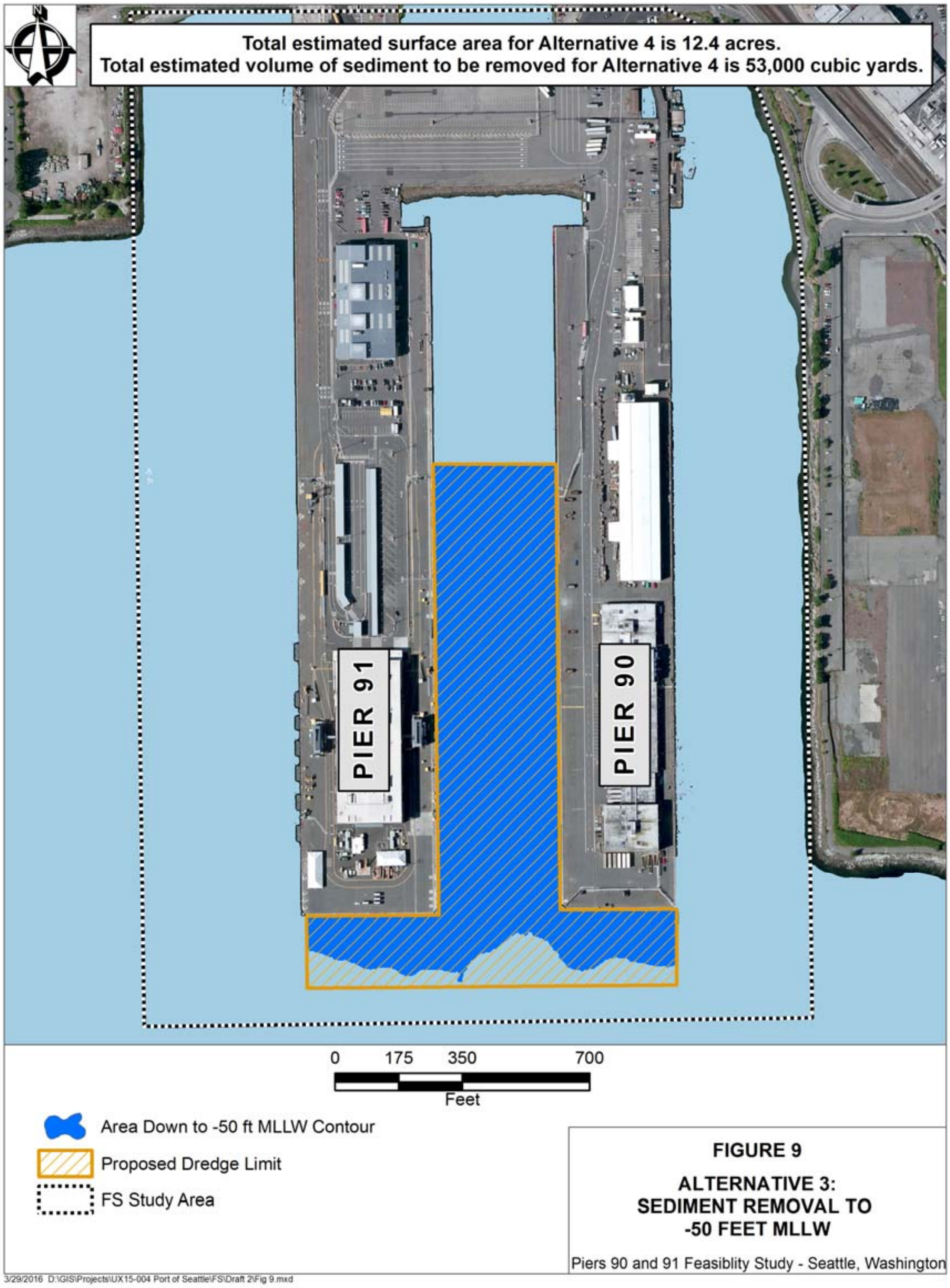

FIGURE 9

ALTERNATIVE 3:
SEDIMENT REMOVAL TO
-50 FEET MLLW

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4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section describes the detailed alternatives analysis process and presents the results of the detailed analysis of remedial alternatives that passed the preliminary screening for the MRA. The detailed analysis of alternatives applies seven evaluation criteria to each remedial action considered. These criteria are grouped into two categories as follows:

Threshold Criteria, including the following:

1. Overall Protection of Human Health and Environment; and,
2. Compliance with ARARs;

Primary Balancing Criteria, including the following:

3. Long-Term Effectiveness and Permanence;
4. Reduction of Toxicity, Mobility, or Volume through Treatment;
5. Short-Term Effectiveness;
6. Implementability; and,
7. Cost.

A third category, Modifying Criteria, includes State Acceptance, and Community Acceptance criteria. The Modifying Criteria evaluation will be finalized after completion of the public comment period on the Proposed Plan, the next step following this FS.

The evaluation criteria utilized in the detailed alternatives analysis are summarized in **Table 4**, on the following page.

Table 4 Detailed Analysis Evaluation Criteria

Criterion Type	Evaluation Criterion	Definition
Threshold	Protective of human health and the environment	Protects human health and the environment through the elimination, reduction, or control of contaminated media. All migration pathways must be addressed.
	Compliance with ARARs	Complies with ARARs, state and local regulations and codes, and TBC guidelines.
Balancing	Long-term effectiveness and permanence	Long-term protection of human health and the environment after the remedial objectives have been met, and the permanence of the remedy.
	Reduction of Toxicity, Mobility, or Volume through Treatment	Reduction of the toxicity, mobility, and/or volume of contaminants through treatment. For the purpose of this evaluation, dredging is considered a treatment process for sediment.
	Short-term effectiveness	Protects human health and the environment during construction and implementation. Degree of risk, short-term impacts of implementation, and the time period to achieve remedial action objectives are also considered.
	Implementability	Refers to both the technical and administrative feasibility of implementing a remedial action alternative. It also takes into account legal considerations, regulatory issues, and community acceptance. Factors of particular consideration include construction and operational feasibility; availability of equipment, personnel, and treatment capacity; the availability of materials and personnel, site features such as available space and topography, and impacts upon ongoing operations are considered. The technical status of alternatives is also considered; theoretical technologies with only limited bench-scale evaluation are considered less implementable than fully proven processes.
	Cost	Costs include design, construction, start up, monitoring, and maintenance. Accuracy to within -30% and +50%.

A more detailed discussion of each threshold and primary balancing criterion is presented in this section. The two modifying criteria (state acceptance and community acceptance), have not been evaluated at this stage of the FS process. These criteria will be considered after receipt of stakeholder and public comments on the proposed remedy for the MRA, as will be described in the Proposed Plan.

Threshold Criteria

Two threshold criteria relate directly to the statutory compliance of the alternatives in question: (1) Overall Protection of Human Health and the Environment, and (2) Compliance with ARARs. A given alternative must meet these criteria to be considered as a remedy.

Overall Protection of Human Health and Environment

Under this criterion, the adequacy of the protection afforded by a remedial action must be addressed. The means by which human health and the environment would be protected must be considered. This includes how specific site remedial actions achieve protection over time, how site risks are reduced, and how sources of contamination are to be eliminated, reduced, or controlled.

Compliance with ARARs

Under this criterion, the means by which a given remedial alternative would meet the ARARs identified in **Section 2.1.4** must be established. Compliance with the chemical, action-specific, and location-specific ARARs must be achieved by the alternative to be considered as a remedy.

Primary Balancing Criteria

Five primary balancing criteria address the technical and cost criteria for each alternative: (1) Long-Term Effectiveness and Permanence; (2) Reduction of Toxicity, Mobility, or Volume through Treatment; (3) Short-Term Effectiveness; (4) Implementability; and (5) Cost.

Long-Term Effectiveness and Permanence

Under this criterion, the effectiveness and permanence of the remedial action is established in terms of risk remaining at the site after the RAOs have been met. The effectiveness of the controls that would be applied to manage the risks posed by the residuals of the remedial activities and/or unaddressed impacted material remaining at the site is of particular concern.

Reduction of Toxicity, Mobility, or Volume through Treatment

Under this criterion, each DMM remedial alternative is assessed by evaluating the degree to which the toxicity, mobility, or volume of DMM is reduced through treatment. For the purposes of this evaluation, sediment dredging followed by recovery of the DMM and demilitarization of the accumulated DMM is considered treatment of sediment.

Short-Term Effectiveness

Under this criterion, impacts during the construction and implementation phase of the remedial action are evaluated, including potential adverse impacts to site workers and the environment. The time required to implement the proposed alternative is also considered.

Implementability

Under this criterion, the technical and administrative feasibility of implementing the proposed alternative is evaluated. The availability of needed materials and services is also considered. The technical feasibility considerations include the technical difficulties anticipated in construction, reliability of the selected technology, and ease of implementing the remedy. Administrative feasibility considers coordination of interested parties, as well as any required permits (e.g., for off-site transport and disposal).

Cost

Under this criterion, estimates are made of capital costs, engineering expenses, and the present value of future operations and maintenance (O&M) and periodic costs. Cost estimates have been developed according to *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA, 2000). Present value analysis allows remedial actions to be compared on the basis of a single cost representing an amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life. The present value analysis uses constant dollars, also called "real dollars", which are not affected by general price inflation, and uses a January 2015 discount factor.

The project scope and duration must be defined in order to provide a present value cost estimate. As a result, a number of assumptions must be made to provide cost estimates for the various remedial alternatives. In the present value analysis, all capital costs are assumed to be incurred within the first year of implementation. Future O&M and periodic costs are included and reduced by the appropriate discount factor, calculated based on a discount rate of 3.4 percent, in accordance with the *2015 Discount Rates for OMB Circular No. A-94*, January 15, 2015 (OMB, 2015).

4.1 INDIVIDUAL ANALYSIS OF ALTERNATIVES

The four remedial alternatives considered at the SNSD MRA are:

- Alternative 1: No Further Action
- Alternative 2: Administrative Controls
- Alternative 3: Sediment Removal to -40 Ft MLLW
- Alternative 4: Sediment Removal to -50 Ft MLLW

Each alternative has been compared to the seven evaluation criteria as discussed in detail below. Criteria findings for each component of each alternative are also summarized in **Table 5**.

4.1.1 Alternative 1: No Further Action

The No Further Action alternative is required as it serves as a baseline for comparison with other remedial technologies. Under the No Further Action alternative, no new administrative, engineering, or institutional LUCs will be instituted, and no additional DMM clearance will be performed.

4.1.1.1 Threshold Criteria

<u>Protection of Human Health and the Environment</u>

This alternative is not protective of human health and the environment, since DMM which is categorized as DMM potentially remains in the top foot of sediment on the seafloor in the area shown on **Figure 5**, and may pose a risk to Topside Construction Workers and other workers processing sediment should sediment be brought to the surface in the future during maintenance operations. Future dive team inspections could also potentially encounter DMM.

<u>Compliance with ARARs</u>

Since no additional action is anticipated, the alternative is compliant with the ARARs shown on Table 2. There will be no impact to endangered or threatened species, migratory birds, or marine mammals from actions undertaken under this alternative, and no triggering of performance standards for miscellaneous treatment units.

4.1.1.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

The no further action alternative would not provide for long-term effectiveness and permanence, since potential DMM would remain in sediments within the MRA that could be uncovered during future dredging activities and pose a future risk to the Topside Construction Worker receptor or other sediment workers during future maintenance operations within the area shown on **Figure 5**. The sediment could also pose a potential risk to future dive team inspections of the area.

Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no treatment, and no reduction of toxicity, mobility, or volume of DMM should this alternative be implemented.

Short-term Effectiveness

The short term risk to human health and the environment from implementing Alternative 1 would not increase and there would be no short term disturbance to the community or environment from remedial action since no further remedial action would be undertaken under this alternative.

Implementability

This alternative is implementable, since no further action is anticipated. There are no technical or administrative barriers to no further action.

Cost

There are no costs associated with this alternative, since no further action would be undertaken at the MRA.

4.1.2 Alternative 2: Administrative Controls

This alternative meets the RAO to prevent unacceptable hazards to the Topside Construction Worker receptor, sediment workers, and potential dive team inspectors posed by DMM items potentially remaining on the seafloor surface and buried in shallow sediments that may be brought to the surface during future maintenance operations at the facility. Alternative 2 would use administrative controls to prevent unacceptable hazards by preventing sediments from being removed during future maintenance activities in areas where DMM has previously been found. These administrative controls would require the concurrence of the current owner, the Port of Seattle, and would place restrictions on bringing material to the surface unless provisions were in place to properly and effectively screen the material to remove any DMM that is present. These controls could also limit potential dive team inspections to certain areas where DMM has not been historically found. These controls could take the form of deed restrictions or other restrictive covenants. Underwater maintenance operations that would maintain a sufficient navigable depth for future ship berthing and other activities could still be conducted. The area that would be subject to the administrative controls under this alternative is shown on **Figure 6**.

4.1.2.1 Threshold Criteria

Overall Protection of Human Health and Environment

Alternative 2 would be protective of human health and the environment by reducing the hazard posed by DMM to the Topside Construction Worker receptor and other sediment workers during future maintenance operations in the area shown on **Figure 6**. This would be accomplished through administrative controls over future maintenance operations, ensuring that any such operations in areas where DMM was potentially present were conducted under provisions to effectively screen and recover any DMM from recovered sediment and manage any recovered DMM in a manner that would ensure potential receptors were protected. These controls could also extend to future dive team inspections to limit the extent of these inspections to areas where no DMM has been found or is anticipated.

Compliance with ARARs

Alternative 2 would be compliant with ARARs that have been identified for the project, by ensuring that administrative controls are in place to require appropriate design and execution conditions were placed on any future maintenance operations in areas where DMM is potentially present. Should these maintenance operations be conducted in the future, they can be designed to protect endangered and threatened species, migratory birds, and marine mammals covered under the Endangered Species Act, Migratory Bird Treaty Act, and Marine Mammal Protection Act, which were identified as location-specific ARARs. Should DMM be handled in the future by a CDC following dredging of sediments containing DMM, performance standards would be incorporated into the management process to meet this ARAR.

4.1.2.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Alternative 2 is protective of human health and the environment, and would substantially reduce the hazard posed by DMM to the Topside Construction Worker receptor, other sediment workers, and potential future dive team inspectors. The effectiveness would be permanent as long as the administrative controls were in place within the footprint of the potential future maintenance operations covered by this alternative, as shown on **Figure 6**.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 would not reduce the toxicity, mobility, and volume of DMM through treatment. If future maintenance operations involved dredging in the area shown in **Figure 6**, the toxicity, mobility, and volume of DMM would be reduced through treatment of the sediments via dredging, screening, and handling of the DMM.

Short-Term Effectiveness

Under typical site operations, when sediments potentially containing MEC remain undisturbed, the hazard posed by the remaining DMM is considered negligible to low, and acceptable. If future maintenance operations do not occur within the area covered by this alternative, and shown on **Figure 6**, there would be no short-term risks, and the alternative would be effective in the short term. However, if maintenance operations involving dredging were conducted in the future, implementation of Alternative 2 would incur some short-term risk to Topside Construction Workers and other workers potentially exposed to DMM in sediments removed from the area. The level of risk would depend on the area to be dredged and could be mitigated through the use of various protective measures as discussed for Alternative 3 in Section 3.1.3.

DMM identified and recovered during maintenance operations would require handling and demilitarization with an approved method, likely either through the use of a CDC or through a permitted RCRA landfill. The former would present short-term impacts due to the transport of the CDC to the site, the staging of the CDC at the pier, and the operation of the unit. All of these impacts can easily be dealt with as they were during the RI and TCRA, when the unit was previously used at the site. Should the DMM be sent to a permitted landfill for demilitarization, short-term impacts such as on-site storage prior to transport can be dealt with, and would be considered during design.

The dredging and handling of sediments would create various short-term impacts during implementation of Alternative 2, depending on the option employed. These impacts can be dealt with effectively and would be part of the detailed design process conducted prior to any maintenance operations in the area shown on **Figure 6** that would be subject to administrative controls.

Implementability

Alternative 2 is implementable. Administrative controls on the dredging of sediments possibly containing DMM, in the area defined by **Figure 6**, would require action by the Port of Seattle, but should be implementable. Should future maintenance operations be needed in this area, an effective design process would be implemented to take into consideration handling of any DMM that was recoverable.

Cost

The total estimated net present value over 30 years for the implementation of Alternative 2 is estimated to be $660,000. **Appendix B** presents detailed cost information for this Alternative.

4.1.3 Alternative 3: Sediment Removal to -40 Ft MLLW

This alternative includes dredging of up to two feet of sediment in the area shown on **Figure 7**, down to a depth of -40 feet MLLW, plus additional incidental removal in achieving this target depth. This depth is greater than the current depth necessary to support the berthing of cruise ships and other vessels that use the piers. This alternative meets the RAOs and would prevent unacceptable hazards to the Topside Construction Worker receptor and other sediment workers posed by DMM items remaining on the seafloor surface and buried in the top two feet of sediments brought to the surface during future maintenance operations at the facility, as well as future potential dive team inspectors. Under Alternative 3, a total of approximately 16,000 cubic yards would be removed from an estimated 4.6 acres in the area shown on **Figure 7**.

Under Alternative 3, DMM recovered during the dredging operation would be separated from the sediment and from other NMRD. The DMM would be handled through the use of a CDC, or by sending the material to a permitted RCRA landfill for demilitarization and disposal. Recovered NMRD would be separated into material that is either recyclable and non-recyclable. The recyclable material would be recycled at local recycling facilities, and the non-recyclable material would be disposed to a local non-hazardous landfill.

Dredged sediment would be managed through one of three options, to be determined during the detailed design of the alternative. Under Option 1, the sediment would be dewatered and treated thermally. Treated sediment would be tested and, if acceptable, the sediment would be transported to an open-water disposal site such as the Port Townsend site, or reused locally for clean fill.

Under Option 2, the sediment would be transported to a local facility located on the Duwamish River, dewatered, loaded onto railcars, and sent to a non-hazardous landfill such as the Roosevelt Regional Landfill in Klickitat County, WA for final disposal. Water from the sediment dewatering process would be treated and discharged to the Duwamish River under the existing treatment permit for the facility.

Under Option 3, if testing indicates the sediment would be acceptable for disposal to an open-water site, it would be transported by barge to the Port Townsend site or an acceptable alternative site for final disposal.

Following removal of the sediment in the dredged areas, the areas would be visually examined by divers to ensure that no remaining DMM was present on the seafloor. The dredging operation may leave contaminants in the exposed sediments remaining on the seafloor at levels that exceed environmental criteria contained in the *Dredged Materials Management Program (DMMP) Users Manual* (USACE, 2014). Post-dredging sampling would be conducted to establish residual sediment contaminant concentrations at the sediment/water interface in dredged areas. Where these concentrations exceed applicable criteria in the DMMP Users Manual, the area could be covered with a sand cap or an armored sand cap (as appropriate) of approximately one-foot thickness. Specific measures for addressing the remaining sediment would be determined during the detailed design process should this alternative be selected.

4.1.3.1 Threshold Criteria

Overall Protection of Human Health and Environment

Alternative 3 would achieve overall protection of human health and the environment by eliminating the unacceptable hazard posed by DMM to the Topside Construction Worker receptor, other sediment workers, during future maintenance operations, by removing DMM in areas where DMM was observed on the surface and in the shallow subsurface during the RI and TCRA (**Figure 7**). This alternative would also protect future dive team inspectors in the dredged area.

Compliance with ARARs

Alternative 3 would be compliant with ARARs that have been identified for the project, by placing the appropriate design and execution conditions on the project during implementation, and by removing sediment that could be encountered during future dive team inspections. For example, the project could be scheduled to occur during periods that would not negatively impact endangered or threatened species, migratory birds, or marine mammals. DMM separated from the dredged material would be demilitarized through the use of a CDC or at a permitted RCRA landfill. If a CDC was used, performance standards would be incorporated into the design in accordance with 40 CFR Part 264.601.

4.1.3.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Alternative 3 is protective of human health and the environment after the alternative has been implemented and the remedial action objectives have been achieved. This alternative substantially reduces the future risk to the Topside Construction Worker, other sediment workers, and future dive team inspectors in areas where DMM was observed during the RI and TCRA, increasing the long-term effectiveness of the actions.

Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 3 would reduce the toxicity, mobility, and volume of DMM through dredging of the sediment and the separation and management of the recovered DMM. If a CDC was utilized, treatment of the DMM through the use of a CDC would directly reduce the toxicity, mobility, and volume of the DMM. If the DMM was transported to a RCRA landfill, demilitarization at and disposal in a RCRA landfill would accomplish a similar reduction.

For the remaining sediments, dewatering and thermal treatment under Option 1 would reduce the toxicity, mobility, and volume of contaminated sediments by treating the sediment thermally. Dewatering and landfill disposal of the sediments under Option 2 would reduce the future mobility of contaminants in the sediments. Dewatering and disposal to an open-water disposal site such as the Port Townsend site under Option 3 could occur only if sediments meet disposal criteria for the location and would reduce the overall toxicity, mobility, or volume of contaminated sediments remaining at the site.

Short-Term Effectiveness

Under normal facility operations, the hazard posed by DMM in the sediment is considered negligible to low, and acceptable.

During dredging activities, the implementation of Alternative 3 poses a short-term risk to Topside Construction Workers and other sediment workers. This would be mitigated through the establishment of an exclusion zone based on the MGFD from the approved ESS/ESP developed for the site, the installation of equipment modifications including screens and shielding, and implementing a minimum of 44 feet of stand-off between sediments potentially containing DMM and the shielding for Topside Construction Workers until such a time that UXO Technicians determine the sediments to be free of DMM would provide additional protection to this receptor. Any DMM encountered would be removed and disposed of by UXO technicians.

The dredging process is estimated to take approximately three months working on-site, and could disrupt normal operations during this period. During the dredging phase, there would be short-term impacts due to the presence of construction/dredging barges, and short-term impacts to benthic biota until the sediment was removed. The exposed sediments remaining after dredging would require post-dredging sampling to ensure that environmental contaminant concentrations were below threshold concentrations, and capping may be necessary to isolate remaining environmental contaminants in the event that residual concentrations exceeded these thresholds. These activities can be accomplished with minimal short-term impacts through careful process design.

DMM identified during the dredging operation would require handling and demilitarization through the use of a CDC or demilitarization at and disposal to a permitted RCRA landfill. The former would present short-term impacts due to the transport of the CDC to the site, the staging of the CDC at the pier, and the operation of the unit. All of these impacts can easily be dealt with as they were during the RI and TCRA. Should the DMM be sent to a permitted RCRA landfill, short-term impacts such as on-site storage prior to transport, and a minor short-term increase in truck traffic can be dealt with, and would have to be considered during design, based on possible long wait times for disposal capacity due to other users.

The dredging and handling of sediments would create various short-term impacts during implementation of Alternative 3, depending on the option employed for dredged sediment handling. All of the options would involve dredging of the proposed area. For thermal treatment of the dredged material (Option 1), short-term impacts would include the transport of the thermal treatment unit to the site, set-up and staging of the equipment, pre-dredging testing and shakedown, dewatering and treatment, system demobilization, and treated sediment disposal. These will create short-term impacts for the duration of the site activities (estimated to take approximately three months). All of these short-term impacts can be minimized through careful process planning during the design stage of the project.

Short-term impacts for the dewatering and landfill disposal option (Option 2) would include sediment transport to the dewatering site, increased traffic due to loading of the sediment onto trucks, consumption of landfill space at the landfill disposal facility, and use of water treatment capacity for treatment of the water from the dewatered sediment. These short-term impacts can be minimized through careful process planning during the design stage of the project.

Short-term impacts for sediment disposal at an open-water sediment disposal site such as the Port Townsend site (Option 3) include use of barge capacity and increased barge traffic, as well as consumption of site sediment capacity. All of these short-term impacts can be mitigated through careful process planning during the design stage of the project.

Implementability

Alternative 3 is implementable. Dredging equipment and protective equipment for the dredging operation is readily available or can readily be fabricated. UXO support and dredged sediment inspection is readily available. Unexploded ordnance divers for post-dredge surface sweeps and DMM collection are readily available. There are a number of CDC options suitable to the site to demilitarize and dispose of DMM. RCRA landfill space may be limited for DMM demilitarization and disposal, although this can be evaluated in more detail as part of the detailed design process, as availability of capacity is subject to change over time.

Thermal treatment equipment is available for use at the site. A local dewatering option is available through existing contractors with facilities located on the Duwamish River. Railcar capacity should be available for transporting dewatered sediments to the Roosevelt Regional Landfill in Klickitat County for disposal. Landfill capacity at that location is available at present and would be confirmed during the detailed design phase.

Cost

The total estimated net present value over 30 years for the implementation of Alternative 3 is estimated to be approximately $4,970,000 for Option 1, $4,810,000 for Option 2, and $3,690,000 for Option 3. **Appendix B** presents detailed cost information for this Alternative.

4.1.4 Alternative 4: Sediment Removal to -50 Ft MLLW

Execution of Alternative 4 would be similar to Alternative 3 and would remove up to two feet of sediment down to a depth of -50 ft MLLW, plus additional incidental removal in achieving this target depth. . This alternative meets the RAOs to prevent unacceptable hazards to the Topside Construction Worker receptor, other sediment workers, and potential future dive team inspectors posed by DMM items remaining on the seafloor surface and buried in sediments being brought to the surface during potential future dredging operations at the facility, within the area identified by **Figure 9**. Approximately 53,000 cubic yards of material would be dredged from approximately 12.4 acres of the site under Alternative 4.

4.1.4.1 Threshold Criteria

Overall Protection of Human Health and Environment

Alternative 4 would achieve overall protection of human health and the environment and would eliminate the hazard posed by DMM to the Topside Construction Worker receptor and other sediment workers during future maintenance operations within the area where DMM has previously been identified. This alternative would also protect future dive team inspectors in the dredged area.

Compliance with ARARs

Implementation of Alternative 4 would be fully compliant with ARARs that have been identified for the project, by placing the appropriate design and execution conditions on the project during implementation. For example, the project would be scheduled to occur during periods that would not negatively impact endangered or threatened species, migratory birds, or marine mammals. Careful design and planning of the remedy would take into account and would achieve ARARs associated with the Endangered Species Act, Migratory Bird Act, and Marine Mammal Protection Act. If a CDC was used for demilitarization of the DMM separated from the dredged sediment, performance standards would be incorporated into the design in accordance with 40 CFR Part 264.601, and this ARAR would also be achieved.

4.1.4.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Alternative 4 is protective of human health and the environment after the alternative has been implemented and the remedial action objectives achieved. This alternative substantially reduces the future risk to the Topside Construction Worker, other sediment workers, and potential future dive team inspectors in the area shown on **Figure 9**.

Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 4 would reduce the toxicity, mobility, and volume of DMM through sediment dredging and the separation and management of the recovered DMM. DMM would be treated to reduce its toxicity, mobility, and volume through the use of a CDC for demilitarization, or alternately, DMM toxicity, mobility, and volume would be reduced through demilitarization at and disposal to a RCRA landfill.

Short-Term Effectiveness

During the implementation of Alternative 4, there are a number of short-term impacts and risks to the Topside Construction Worker receptor and other sediment workers. These risks could be mitigated by the establishment of an exclusion zone based on the MGFD from the approved ESS/ESP developed for the site, by installing equipment modifications including screens and shielding, and implementing a minimum or 44 feet of stand-off between sediments potentially containing DMM and the shielding for Topside Construction Workers before UXO technicians determine the sediment to be free of DMM. Any DMM encountered would be removed and disposed by UXO technicians.

The implementation of Alternative 4 would take approximately 290 days working on site, and would occur during two calendar years, requiring two mobilizations. During this time period, there would be some disruption to normal site operations. A post-dredging visual survey would be conducted to ensure that no visible DMM was present in the dredged area, and post-dredging sampling would be conducted to ensure the remaining sediment/water interface met environmental criteria.

During the dredging phase, there would be short-term impacts due to the presence of construction/dredging barges, and short-term impacts to benthic biota until the sediment was removed. There would also be short-term impacts due to handling of DMM in a CDC, and increased truck traffic during transport for disposal of DMM in a RCRA landfill, if that option for DMM disposal was implemented. Recyclable material handling capacity would be used for recyclable materials recovered during dredging, and landfill capacity for non-recyclable material disposal would be consumed. If Option 1 were implemented for sediment management, there would be short-term impacts for the dewatering and rail transport for the landfill disposal of sediments. The disposed sediment would consume a portion of available landfill space, which would then be unavailable for other disposal. If Option 2 were utilized, barge capacity would be necessary for the transport and disposal of sediment to the Port Townsend disposal site.

DMM identified during the dredging operation would require handling and demilitarization through the use of a CDC or demilitarization at and disposal to a permitted RCRA landfill. The former would present short-term impacts due to the transport of the CDC to the site, the staging of the CDC at the pier, and the operation of the unit. All of these impacts can easily be dealt with as they were during the RI and TCRA. Should the DMM be sent to a permitted RCRA landfill, short-term impacts such as on-site storage prior to transport, and a minor short-term increase in truck traffic can be dealt with, and would have to be considered during design, based on possible long wait times for disposal capacity due to other users.

The dredging and handling of sediments would create various short-term impacts during implementation of Alternative 4, depending on the option employed for dredged sediment handling. All of the options would involve dredging of the proposed area. For thermal treatment of the dredged material (Option 1), short-term impacts would include the transport of the thermal treatment unit to the site, set-up and staging of the equipment, pre-dredging testing and shakedown, dewatering and treatment, system demobilization, and treated sediment disposal. These will create short-term impacts for the duration of the site activities (an estimated 290 days over two construction seasons). All of these short-term impacts can be minimized through careful process planning during the design stage of the project.

Short-term impacts for the dewatering and landfill disposal option (Option 2) would include transport to the dewatering site, increased traffic due to loading of the sediment onto trucks, consumption of landfill space at the landfill disposal facility, and use of water treatment capacity for treatment of the water from the dewatered sediment. These short-term impacts can be minimized through careful process planning during the design stage of the project.

Short-term impacts for sediment disposal at an open-water sediment disposal site such as the Port Townsend site (Option 3) include use of barge capacity and increased barge traffic, as well as consumption of site sediment capacity. All of these short-term impacts can be mitigated through careful process planning during the design stage of the project.

Implementability

Alternative 4 is implementable, and all equipment and supplies needed to fully implement the alternative are available. Dredging equipment and protective equipment for the dredging operation is readily available or can readily be fabricated. UXO support and dredged sediment inspection is readily available. Unexploded ordnance divers for post-dredge surface sweeps and DMM collection are readily available. There are a number of CDC options suitable to the site to demilitarize and dispose of DMM. RCRA landfill space may be limited for DMM demilitarization and disposal, although this can be evaluated in more detail as part of the detailed design process, as availability of capacity is subject to change over time.

Thermal treatment equipment is available for use at the site. A local dewatering option is available through existing contractors with facilities located on the Duwamish River. Railcar capacity should be available for transporting dewatered sediments to the Roosevelt Regional Landfill in Klickitat County for disposal. Landfill capacity at that location is available at present and would be confirmed during the detailed design phase.

Cost

The total estimated net present value over 30 years for the implementation of Alternative 4 is estimated to be $13,556,500 for Option 1, $13,456,500 for Option 2, and $9,726,500 for Option 3. **Appendix B** presents detailed cost information for this Alternative.

4.2 COMPARATIVE ANALYSIS

A comparative analysis of the four alternatives is presented in this section to evaluate the relative performance of each of the alternatives at the FSNDS MRA in relation to the two threshold evaluation criteria and the five balancing criteria. The modifying criteria of community and regulatory acceptance will be evaluated in detail during the formal state and public comment period through the Proposed Plan. The relative merits of the alternatives provide the rationale for selecting a preferred alternative and provide a transition between the RI and the Proposed Plan and Decision Document.

Table 5 presents a comparative analysis of Alternatives 1, 2, 3, and 4 against the Detailed Analysis evaluation criteria.

Table 5 Comparative Analysis of Alternatives

Remedial Alternative	Alternative 1 No Further Action	Alternative 2	Alternative 3	Alternative 4 Dredging the MRA
Protective of Human Health and the Environment	No	Protective of human health and the environment in area under administrative controls	Protective of human health and the environment within dredged area shown on Figure 7.	Protective of human health and the environment within dredged area shown on Figure 9.
Compliance with ARARs	No	Compliant with ARARs	Compliant with ARARs	Compliant with ARARs.
Long-Term Effectiveness and Permanence	No	Exhibits long-term effectiveness and permanence in area under administrative controls	Provides long-term effectiveness and permanence over dredged area shown on Figure 7.	Provides long-term effectiveness and permanence over larger dredged area shown on Figure 9.
Reduction of Toxicity, Mobility, and Volume Through Treatment	No	No reduction of toxicity, mobility and volume with administrative controls alone. Reduction of toxicity, mobility, and volume would occur in the event that dredging of DMM-impacted sediments is conducted in future in area under administrative controls.	Reduction of toxicity, mobility, and volume through sediment dredging in area shown on Figure 7.	Greater reduction of toxicity, mobility, and volume of sediments than Alternative 3 due to removal of sediment in larger area shown on Figure 9.
Short Term Effectiveness	No	Few short-term impacts to establish institutional controls. If future dredging in area under administrative control is necessary, short-term impacts can all be addressed through careful design.	Greater short-term impacts than Alternative 2, but can be minimized through proper design	Greater short-term impacts than Alternative 3 due to larger volumes and areas of dredged sediments. Period of implementation would be longer than Alternative 3 and would extend over two years..
Implementability	Very implementable since no further action would be undertaken	Highly implementable	Implementable, though will require additional equipment and time over Alternative 2.	Implementable, though will require additional time and over larger area than Alternative 3.
Estimated Total Net Present Value ($) **(30 years)**	$0.00	$660,000	$3,690,000 to $4,970,000	$9,726,500 to $13,556,500

4.2.1 Threshold Criteria

Protection of Human Health and the Environment

Alternative 1 is not protective of human health and the environment, since no further action would be undertaken. Alternative 2 is protective of human health and the environment since it would place administrative controls on the area shown on Figure 6 where DMM has been identified in the past, preventing risks due to contact of the Topside Construction Worker, other sediment workers who may contact DMM, and future potential dive team inspectors. Should dredging be necessary in the future in this area, careful design of the dredging process would protect these receptors, achieve the RAOs, and ensure protection of human health and the environment. Alternative 3 would also be protective by removing any DMM within the top two feet of sediment down to -40 feet MLLS in the area where DMM was observed on the surface or in the shallow subsurface during the RI and TCRA (as shown on **Figure 7**). Alternative 4 would provide a similar level of protection, but over a larger area down to -50 feet MLLW (**Figure 9**).

Compliance with ARARs

Alternative 1 would not comply with ARARs, since no further action would be undertaken under this alternative. Alternatives 2, 3, and 4 would all comply with ARARs, with the difference between Alternatives 3 and 4 primarily in the area and volume of sediments addressed under those alternatives, compared to the reliance on administrative controls for Alternative 2.

4.2.2 Primary Balancing Criteria

Long-term Effectiveness and Permanence

Alternative 1 would not be effective in the long term, since it would potentially leave DMM in areas that may be subject to future dredging and pose an unacceptable risk to the Topside Construction Worker, other sediment worker receptors, and future dive team inspectors. Alternative 2 would be both effective and permanent as it would remove the potential for removal of DMM-impacted sediments from areas where DMM has previously been found (**Figure 6**) through administrative controls unless the removal was conducted in such a way as to eliminate the risk to the Topside Construction Worker Receptor and other sediment workers. Alternative 3 would exhibit effectiveness and permanence as it would remove up to two feet of sediments (potentially containing DMM) in areas where DMM was found during the RI and TCRA. Alternative 4 would provide a similar level of effectiveness and permanence, but over a larger area and to a target depth of -50 feet MLLW.

Reduction of Toxicity, Mobility, and Volume Through Treatment

Since Alternative 1 involves no further action, there would be no reduction of toxicity, mobility, or volume of DMM through treatment.

Alternative 2 would exhibit no reduction of toxicity, mobility, or volume of sediments through administrative controls. However, the controls would require that in the event of future sediment removal in the area where DMM has previously been detected, careful planning would protect identified receptors. Future removal of DMM under these administrative controls would reduce the toxicity, mobility, and volume of any DMM-containing sediments.

Alternative 3 would remove sediments potentially impacted by DMM within the area identified as containing DMM in the past, and would reduce the toxicity, mobility, and volume of DMM in the top two feet sediments down to -40 feet MLLW by removing them from the site.

Demilitarization of any recovered DMM with a CDC would further reduce the toxicity, mobility, and volume of DMM. Should the DMM optionally be sent to a RCRA landfill for demilitarization and disposal, the future toxicity, mobility, and volume of the DMM would be reduced.

Sediment environmental contaminant toxicity, mobility, and volume would be reduced through thermal treatment, if Option 1 were employed. Should the sediments be dewatered and sent to a permitted landfill under Option 2, future mobility of sediment environmental contaminants would be reduced, and the toxicity of sediments at the site would be reduced. Dewatering and disposal to an open-water disposal site such as the Port Townsend site under Option 3 (which would occur only is the sediments met disposal criteria) would reduce the overall toxicity, mobility, and volume of the contaminated sediments remaining at MRA.

Alternative 4 would exhibit a similar reduction of toxicity, mobility, and volume as Alternative 3, although the magnitude would be greater since a greater volume of sediments would be removed over a larger surface area.

Short-term Effectiveness

Alternative 1 would not be effective in the short-term, but would have no short-term impacts since no additional activities are proposed for the site.

Alternative 2 would have limited short-term impacts during the period of establishing administrative controls, limited to the time and expense (including regulatory review) of the proposed controls. It is estimated that these controls could be established within several months. In the event that dredging became necessary in the future in the area under administrative control, there would be short-term impacts and risks to the Topside Construction Worker receptor and other sediment workers. These risks can be mitigated through careful process design at the time the dredging need is identified.

Alternative 3 poses short-term risks to Topside Construction Workers and other sediment workers, over an estimated three months period of implementation. These would include potential impacts to workers during the dredging process, as well as potential impacts during the transport of dredged material to the dewatering site under Option 2 or to an open-water disposal site under Option 3. There would be a short-term increase in rail traffic should the dewatered sediments be sent to a permitted landfill under Option 2, or truck traffic if the thermally-treated sediments be sent to a permitted landfill or used as clean fill under Option 1. Should exposed sediments exceed environmental criteria for sediments, there would be short-term impacts to exposed biota potentially followed by capping efforts to isolate impacted areas with a sand cap.

Alternative 4 is expected to have similar short-term impacts as Alternative 3, but these impacts will be spread over the larger estimated time period of approximately 290 days over a two-year period for implementation. Due to the larger surface area of dredging, the larger volumes to be dredged, and the duration of the alternative implementation, all short-term impacts described for Alternative 3 are anticipated to be somewhat greater, in rough proportion to the scope of the respective remedial efforts.

Implementability.

Alternative 1 is readily implementable, since no additional actions would be undertaken at the site.

Alternative 2 is also readily implementable, as administrative controls are widely used and can be readily developed for the site. Implementation of Alternative 2 would depend on the Port of Seattle to establish appropriate administrative controls for the MRA.

Alternatives 3 and 4 are also readily implementable, as the technologies for dredging, DMM screening, material separation, dewatering, thermal treatment, CDC destruction of DMM, capping, sediment transport by barge, rail, or truck, recycling, landfill disposal, and other technologies are well-established. Capacity is expected to be available for the sediment and DMM volumes anticipated under this alternative, though demilitarization and RCRA disposal of DMM may experience some delay due to scheduling issues involving available capacity.

Cost

The estimated costs of the four alternatives range from $0 for Alternative 1 to a range of $9,726,500 to $13,556,500 for Alternative 4. Estimated alternative costs increase for each alternative from 1 to 4.

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Appendix A
Fragmentation Data Review Form

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Fragmentation Data Review Form

Database Revision Date 3/7/2016

Category:	Surface-Launched HE Rounds
Munition:	5 in Mk 41
Case Material:	Steel, Mild
Fragmentation Method:	Naturally Fragmenting
Secondary Database Category:	Projectile
Munition Case Classification:	Robust

DODIC:	D320
Date Record Created:	9/21/2004
Record Created By:	MC
Last Date Record Updated:	9/14/2011
Individual Last Updated Record:	SDH
Date Record Retired:	

Munition Information and Fragmentation Characteristics

Explosive Type:	Explosive D
Explosive Weight (lb):	7.38
Diameter (in):	5.0000
Cylindrical Case Weight (lb):	51.30473
Maximum Fragment Weight (Intentional) (lb):	0.6726
Design Fragment Weight (95%) (Unintentional) (lb):	0.1367
Critical Fragment Velocity (fps):	2538

Sandbag and Water Mitigation Options

TNT Equivalent (Impulse):	0.81
TNT Equivalent Weight - Impulse (lbs):	5.978
Kinetic Energy 10^6 (lb-ft²/s²):	2.4521

Single Sandbag Mitigation

Required Wall & Roof Thickness (in)	36
Expected Max. Throw Distance (ft):	220
Minimum Separation Distance (ft):	220

Double Sandbag Mitigation

Required Wall & Roof Thickness (in)	Not Permitted
Expected Max. Throw Distance (ft):	Not Permitted
Minimum Separation Distance (ft):	Not Permitted

Water Mitigation

Minimum Separation Distance (ft):	275
Water Containment System:	1100 gal tank

Note: Use Sandbag and Water Mitigation in accordance with all applicable documents and guidance. If a donor charge larger than 32 grams is utilized, the above mitigation options are no longer applicable. Subject matter experts may be contacted to develop site specific mitigation options.

Theoretical Calculated Fragment Distances

HFD [Hazardous Fragment Distance: distance to no more than 1 hazardous fragment per 600 square feet] (ft):	359
MFD-H [Maximum Fragment Distance, Horizontal] (ft):	2377
MFD-V [Maximum Fragment Distance, Vertical] (ft):	1748

Overpressure Distances

TNT Equivalent (Pressure):	0.85
TNT Equivalent Weight - Pressure (lbs):	6.273
Unbarricaded Intraline Distance (3.5 psi), K18 Distance:	33
Public Traffic Route Distance (2.3 psi); K24 Distance:	44
Inhabited Building Distance (1.2 psi), K40 Distance:	74
Intentional MSD (0.0655 psi), K328 Distance:	605

Note: Per V5.E3.2.2.1 of DoD 6055.09-M the minimum sited K328 distance may be no smaller than 200 ft.

Minimum Thickness to Prevent Perforation

	Intentional	Unintentional
4000 psi Concrete (Prevent Spall):	9.17	4.80
Mild Steel:	1.77	0.92
Hard Steel:	1.45	0.75
Aluminum:	3.43	1.86
LEXAN:	8.58	5.73
Plexi-glass:	7.05	4.13
Bullet Resist Glass:	6.32	3.49

Item Notes

Distribution authorized to the Department of Defense and U.S. DoD contractors only for Administrative-Operational Use (17 October 2002). Other requests shall be referred to the Chairman, Department of Defense Explosives Safety Board, Room 856C, Hoffman Building I, 2461 Eisenhower Avenue, Alexandria, VA 22331-0600.

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Appendix B
Detailed Cost Analysis for Alternatives

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Detailed Cost Analysis

Alternative 2 - Administrative Controls

- Use administrative controls to prevent unacceptable hazards to Topside Construction Workers and workers processing sediments by preventing sediments from being removed during future maintenance activities in areas where DMM has previously been found.
- Place restrictions on bringing material to the surface unless provisions were in place to properly and effectively screen the material to remove any DMM that is present.
- These controls could take the form of deed restrictions or other restrictive covenants.
- Underwater maintenance operations that would maintain a sufficient navigable depth for future ship berthing and other activities could still be conducted.
- Informational flyers distributed to affected receptors warning of the potential MEC hazards.
- Long term monitoring and CERCLA 5-Year Review.

Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		
Year 0	$ 25,000.00	1.00	$ 25,000.00		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.
Long Term Monitoring (LTM)					
Year 1	$ 25,000.00	0.97	$ 24,250.00		
Year 2	25,000.00	0.94	23,500.00		
Year 3	25,000.00	0.90	22,500.00		
Year 4	25,000.00	0.87	21,750.00		
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00		
Year 6	25,000.00	0.82	20,500.00		
Year 7	25,000.00	0.79	19,750.00		
Year 8	25,000.00	0.77	19,250.00		
Year 9	25,000.00	0.74	18,500.00		
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00		
Year 11	25,000.00	0.69	17,250.00		
Year 12	25,000.00	0.67	16,750.00		
Year 13	25,000.00	0.65	16,250.00		
Year 14	25,000.00	0.63	15,750.00		
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00		
Year 16	25,000.00	0.59	14,750.00		
Year 17	25,000.00	0.57	14,250.00		
Year 18	25,000.00	0.55	13,750.00		
Year 19	25,000.00	0.53	13,250.00		
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00		
Year 21	25,000.00	0.50	12,500.00		
Year 22	25,000.00	0.48	12,000.00		
Year 23	25,000.00	0.46	11,500.00		
Year 24	25,000.00	0.45	11,250.00		
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00		
Year 26	25,000.00	0.42	10,500.00		
Year 28	25,000.00	0.41	10,250.00		
Year 25	25,000.00	0.39	9,750.00		
Year 29	25,000.00	0.38	9,500.00		
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00		
TOTALS	**$ 1,075,000.00**		**$ 666,000.00**		

Notes:
DF = Discount Factor at 3.4 percent rate (OMB Circular No. A-94, Appendix C, revised January 2015).
1- UXO estimate based on contractor experience and includes a 2.5 multiplier. The UXO team consists of SUXOS, UXOSO/QC, UXO Tech III, two UXO Tech II and two UXO Tech !.
2- Assumes materials, fabricating labor (welding labor with 2.5 multiplier plus materials) and engineering services to construct crew and crane operator and ordnance exclusion screening. Based on vendor quotes.
3- It is not anticipated that MEC will be found at depths of more than approximately one foot at the site. A targeted dredging depth of two feet was determined to provide a sufficient safety factor to ensure that all MEC would be removed from the historical area of MEC occurrence. Therefore, this alternative also includes the removal of the top two feet of sediments, with incidental overdepth removal of approximately 75% of the next foot, and 15% removal of the three- to six-foot sediment depth
4- Contingency costs include post-dredging MEC removal verification utilizing UXO divers;assumes mob/demob, equipment, analytical costs and labor to perform post-dredging sampling and analysis of newly-exposed seabed and the installation of a one-foot cap if concentrations exceed regualtory criteria. Based on vendor quotes.and contractor experience.

Detailed Cost Analysis

Alternative 3 - Sediment Removal to -40 Foot MLLW - Option 1 Thermal Treatment

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 24,250 cubic yards in a 5.2 acre area of the site. Alternative 3 will generally consist of the following:

• Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.

• During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.

• Land use restrictions to restrict dredging.

• Informational flyers distributed to affected receptors warning of the potential MEC hazards.

.• Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	80	Day	$ 8500.00	$ 680,000.00	Eighty days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	16,000	Unit	$ 50.00	$ 800,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	16,000	Unit	$ 40.00	$ 640,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	2
Thermal Treatment of Sediment	16,000	Unit	$ 80.00	$ 1,280,000.00	Unit rate based on $80 per c/y.	2
Contingency Costs	1	Unit	$ 385,000.00	$ 385,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Transportation and disposal of sediment to Open Water Disposal Site	16,000	Unit	$ 5.00	$ 80,000.00	Unit rate based on $5 per c/y.	2
Disposal of non-recyclable debris	15	Unit	$ 800.00	$ 12,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	2
CDC Safe Demolition	1	Unit	$ 350,000.00	$ 350,000.00		
RCRA disposal of the MEC	1	Unit	$ 85,000.00	$ 85,000.00	This option, not included in the subtotal cost, could be used in lieu of the CDC.	
SUBTOTAL				**$ 4,329,000.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 4,329,000.00	1.00	$ 4,329,000.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
Year 11	25,000.00	0.69	17,250.00			
Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
Year 26	25,000.00	0.42	10,500.00			
Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 5,379,000.00**		**$ 4,970,000.00**			

Detailed Cost Analysis

Alternative 3 - Sediment Removal to -40 Foot MLLW - Option 2 Dewatering and Upland Disposal

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 24,250 cubic yards in a 5.2 acre area of the site. Alternative 3 will generally consist of the following:

• Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.
• During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.
• Land use restrictions to restrict dredging.
• Informational flyers distributed to affected receptors warning of the potential MEC hazards.
.• Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	80	Day	$ 8500.00	$ 680,000.00	Eighty days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	16,000	Unit	$ 50.00	$ 800,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	16,000	Unit	$ 40.00	$ 640,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	2
Transportation and disposal of sediment to upland landfill.	16,000	Unit	$ 75.00	$ 1,200,000.00	Unit rate based on $75 per c/y.	2
Contingency Costs	1	Unit	$ 385,000.00	$ 385,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Disposal of non-recyclable debris	15	Unit	$ 800.00	$ 12,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	2
CDC Safe Demolition	1	Unit	$ 350,000.00	$ 350,000.00		
RCRA disposal of the MEC	1	Unit	$ 85,000.00	$ 85,000.00	This option, not included in the subtotal cost, could be used in lieu of the	
SUBTOTAL				**$ 4,169,000.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 4,169,000.00	1.00	$ 4,169,000.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
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Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
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Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 5,219,000.00**		**$ 4,810,000.00**			

Detailed Cost Analysis

Alternative 3 - Sediment Removal to -40 Foot MLLW - Option 3 Disposal to Port Townsend Dispersive Site

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 24,250 cubic yards in a 5.2 acre area of the site. Alternative 3 will generally consist of the following:

- Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.
- During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.
- Land use restrictions to restrict dredging.
- Informational flyers distributed to affected receptors warning of the potential MEC hazards.

.• Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	80	Day	$ 8500.00	$ 680,000.00	Eighty days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	16,000	Unit	$ 50.00	$ 800,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	16,000	Unit	$ 40.00	$ 640,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	2
Transportation and disposal of sediment to Open Water Disposal Site	16,000	Unit	$ 5.00	$ 80,000.00	Unit rate based on $5 per c/y.	2
Contingency Costs	1	Unit	$ 385,000.00	$ 385,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Disposal of non-recyclable debris	15	Unit	$ 800.00	$ 12,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	2
CDC Safe Demolition	1	Unit	$ 350,000.00	$ 350,000.00		
RCRA disposal of the MEC	1	Unit	$ 85,000.00	$ 85,000.00	This option, not included in the subtotal cost, could be used in lieu of the CDC.	
SUBTOTAL				**$ 3,049,000.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 3,049,000.00	1.00	$ 3,049,000.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
Year 11	25,000.00	0.69	17,250.00			
Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
Year 26	25,000.00	0.42	10,500.00			
Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 4,099,000.00**		**$ 3,690,000.00**			

Detailed Cost Analysis

Alternative 4 - Sediment Removal to -50 Foot MLLW - Option 1 Thermal Treatment

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 53,000 cubic yards in a 12.4 acre area of the site. Alternative 4 will generally consist of the following:

- Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.
- During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.
- Land use restrictions to restrict dredging.
- Informational flyers distributed to affected receptors warning of the potential MEC hazards.

.• Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	265	Day	$ 8500.00	$ 2,252,500.00	265 days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	53,000	Unit	$ 50.00	$ 2,650,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	53,000	Unit	$ 40.00	$ 2,120,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	2
Thermal Treatment of Sediment	53,000	Unit	$ 80.00	$ 4,240,000.00	Unit rate based on $80 per c/y.	2
Contingency Costs	1	Unit	$ 924,000.00	$ 924,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Transportation and disposal of sediment to Open Water Disposal Site	53,000	Unit	$ 5.00	$ 265,000.00	Unit rate based on $5 per c/y.	2
Disposal of non-recyclable debris	15	Unit	$ 800.00	$ 12,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	2
CDC Safe Demolition	1	Unit	$ 350,000.00	$ 350,000.00	Assumes 2 mobilizations of the CDC Unit	
RCRA disposal of the MEC	1	Unit	$ 85,000.00	$ 85,000.00	This option, not included in the subtotal cost, could be used in lieu of the CDC.	
SUBTOTAL				**$ 12,915,500.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 12,915,500.00	1.00	$ 12,915,500.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
Year 11	25,000.00	0.69	17,250.00			
Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
Year 26	25,000.00	0.42	10,500.00			
Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 13,965,500.00**		**$ 13,556,500.00**			

Detailed Cost Analysis

Alternative 4 - Sediment Removal to -50 Foot MLLW - Option 2 Dewatering and Upland Disposal

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 53,000 cubic yards in a 12.4 acre area of the site. Alternative 4 will generally consist of the following:
- Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.
- During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.
- Land use restrictions to restrict dredging.
- Informational flyers distributed to affected receptors warning of the potential MEC hazards.
- Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	265	Day	$ 8500.00	$ 2,252,500.00	265 days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	53,000	Unit	$ 50.00	$ 2,650,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	53,000	Unit	$ 40.00	$ 2,120,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	2
Transportation and disposal of sediment to upland landfill.	53,000	Unit	$ 75.00	$ 3,975,000.00	Unit rate based on $75 per c/y.	2
Contingency Costs	1	Unit	$ 924,000.00	$ 924,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Disposal of non-recyclable debris	90	Unit	$ 800.00	$ 72,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	2
CDC Safe Demolition	2	Unit	$ 350,000.00	$ 700,000.00	Assumes 2 mobilizations of the CDC Unit	
RCRA disposal of the MEC	2	Unit	$ 85,000.00	$ 170,000.00	This option, not included in the subtotal cost, could be used in lieu of the CDC.	
SUBTOTAL				**$ $12,795,500.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 12,795,500.00	1.00	$ 12,795,500.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
Year 11	25,000.00	0.69	17,250.00			
Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
Year 26	25,000.00	0.42	10,500.00			
Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 13,845,500.00**		**$ 13,436,500.00**			

Detailed Cost Analysis

Alternative 4 - Sediment Removal to -50 Foot MLLW - Option 3 Disposal to Port Townsend Dispersive Site

Perform enhanced maintenance dredging operations with targeted MEC removals of approximately 53,000 cubic yards in a 12.4 acre area of the site. Alternative 4 will generally consist of the following:

- Providing a SUXOS, UXOSO/QC, one UXO Tech III, two UXO Technician II's and two UXO Tech I's to inspect dredged sediments and maintain UXO safety and quality control, and one dive team to sweep dredged areas for remaining MEC.
- During mechanical dredging, the fabrication of two shields in the form of 1.45 inch thick hard steel. One shield would be required to protect the crane operator and would include 6.32 inch thick bulletproof glass for visibility, and another would be required a minimum of 44 ft from the area where dredged sediments are inspected by UXO Technicians to protect other Topside Construction Worker receptors.
- Land use restrictions to restrict dredging.
- Informational flyers distributed to affected receptors warning of the potential MEC hazards.
- Long term monitoring and CERCLA 5-Year Review.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES	NOTES
UXO Personnel (Inspection)	265	Day	$ 8500.00	$ 2,252,500.00	265 days at 10-hour days assumed.	1
Equipment Modifications (Mechanical)	1	Unit	$ 52,000.00	$ 52,000.00		2
Dredging Engineering Services	1	Unit	$ 50,000.00	$ 50,000.00		2
Dredging	53,000	Unit	$ 50.00	$ 2,650,000.00	Unit rate based on $50 per c/y.	3
Dewatering of sediment	53,000	Unit	$ 40.00	$ 2,120,000.00	Unit rate based on $40 per c/y and includes cost for Suitability Testing of dewatered sediment.	3
Contingency Costs	1	Unit	$ 924,000.00	$ 924,000.00	Post Dredging UXO dive operations, sediment sample and analysis, and capping as necessary.	4
Transportation and disposal of sediment to Open Water Disposal Site	53,000	Unit	$ 5.00	$ 265,000.00	Unit rate based on $5 per c/y.	3
Disposal of non-recyclable debris	90	Unit	$ 800.00	$ 72,000.00	Unit rate based on cost for transportation and disposal of one 20-cubic yard rolloff.	3
CDC Safe Demolition	2	Unit	$ 350,000.00	$ 700,000.00	Assumes 2 mobilizations of the CDC Unit	
RCRA disposal of the MEC	2	Unit	$ 85000.00	$ 170,000.00	This option, not included in the subtotal cost, could be used in lieu of the CDC.	
SUBTOTAL				**$ $9,085,500.00**		
Periodic Costs:	**COST**	**DF**	**PRESENT VALUE**		Assumes no further dredging activities within the 30-year cycle. CERCLA 5-Year Review cost of $50,000 for for each of the review years 5, 10, 15, 20, 25 and 30. Long term monitoring includes annual monitoring, data collection and analysis, reviewing POS PD diver MEC findings, reviewing LUC effectiveness should capping be needed, management and reporting. The initial review will develop the procedures and format for following reviews.	
Year 0	$ 9,085,500.00	1.00	$ 9,085,500.00			
Long Term Monitoring (LTM)						
Year 1	$ 25,000.00	0.97	$ 24,250.00			
Year 2	25,000.00	0.94	23,500.00			
Year 3	25,000.00	0.90	22,500.00			
Year 4	25,000.00	0.87	21,750.00			
Year 5 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.85	$ 63,750.00			
Year 6	25,000.00	0.82	20,500.00			
Year 7	25,000.00	0.79	19,750.00			
Year 8	25,000.00	0.77	19,250.00			
Year 9	25,000.00	0.74	18,500.00			
Year 10 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.72	$ 54,000.00			
Year 11	25,000.00	0.69	17,250.00			
Year 12	25,000.00	0.67	16,750.00			
Year 13	25,000.00	0.65	16,250.00			
Year 14	25,000.00	0.63	15,750.00			
Year 15 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.61	$ 45,750.00			
Year 16	25,000.00	0.59	14,750.00			
Year 17	25,000.00	0.57	14,250.00			
Year 18	25,000.00	0.55	13,750.00			
Year 19	25,000.00	0.53	13,250.00			
Year 20 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.51	$ 38,250.00			
Year 21	25,000.00	0.50	12,500.00			
Year 22	25,000.00	0.48	12,000.00			
Year 23	25,000.00	0.46	11,500.00			
Year 24	25,000.00	0.45	11,250.00			
Year 25 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.43	$ 32,250.00			
Year 26	25,000.00	0.42	10,500.00			
Year 28	25,000.00	0.41	10,250.00			
Year 25	25,000.00	0.39	9,750.00			
Year 29	25,000.00	0.38	9,500.00			
Year 30 (LTM & CERCLA 5 Year Review)	$ 75,000.00	0.37	$ 27,750.00			
TOTALS	**$ 10,135,500.00**		**$ 9,726,500.00**			

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