Former Seattle Naval Supply Depot
Piers 90 and 91 – Port of Seattle
Seattle, WA

Formerly Used Defense Site
#F10WA012501

Remedial Investigation

Final Report

Contract No.: W9128F-10-D-0058
Delivery Order 04

September 2013

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Abbreviations and Acronyms

3D	Three Dimensional
AA	Anti Aircraft
AET	Apparent Effects Threshold
AFB	Air Force Base
AGL	Above Ground Level
AM	Action Memorandum
APE	Area of Potential Effect
AP-T	Armor Piercing-Tracer
ARAR	Applicable or Relevant and Appropriate Requirement
AT	Average Timing
ATc	Cancer Averaging Time
ATNC	Non-Cancer Averaging Time
AUF	Area Use Factor
BAF	Bioaccumulation Factor
BAZ	Biologically Active Zone
BCF	Bioconcentration Factor
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
BMDL	A lower, one-sided confidence limit on the Benchmark Dose
BTAG	Biological Technical Assistance Group
BW	Body Weight
c	Carcinogen
Cal-EPA	State of California Environmental Protection Agency
CAR	Corrective Action Report
CASRN	Chemical Abstracts Service Registry Number
CDC	Contained Detonation Chamber
CERCLA	Comprehensive Environmental Response Compensation, and Liability Act
cf	Cubic Foot/Feet
C_{FISH}	Fish or Shellfish Tissue Concentrations
CFR	Code of Federal Regulations
CHE	Chemical Warfare Materiel Hazard Evaluation
CHF	Contaminant Hazard Factor
cm	Centimeter
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSED	Concentration of Chemical in Sediment
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CWM	Chemical Warfare Materiel
d	Day
d/y	Days per Year

DA	Department of the Army
DAHP	Department of Archaeology and Historic Preservation
DAS	Data Acquisition Software
DDESB	Department of Defense Explosive Safety Board
DERP	Defense Environmental Restoration Program
DF	Detection Frequency
DGM	Digital Geophysical Mapping
DMM	Discarded Military Munitions
DMMO	Dredged Materials Management Office
DNT	Dinitrotoluene
DOD	Department of Defense
DPS	Distinct Population Segment
DQO	Data Quality Objective
DW	Dry Weight
EA	Exposure Area
E/W	East/West
ECBC	Edgewood Chemical and Biological Center
ED	Exposure Duration
EF	Exposure Frequency
EH	Reduction Potential
EHA	Explosive Hazard Assessment
EHE	Explosive Hazard Evaluation
ELAP	Environmental Laboratory Accreditation Program
EM	Electromagnetic
EOD	Explosive Ordnance Disposal
EPC	Exposure Point Concentration
EPCND	Exposure Point Concentration for Non-Detected Analytes
EqP	Equilibrium Partitioning
ERA	Ecological Risk Assessment
ESL	Ecological Screening Level
ESP	Explosive Site Plan
ESS	Explosives Safety Submission
ESU	Evolutionarily Significant Unit
ft	foot/feet
FIS	Fish Ingestion Rate
FOC	Fraction of Organic Compound in Soil/Sediment
FS	Feasibility Study
FSNSD	Former Seattle Naval Supply Depot
FUDS	Formerly Used Defense Sites
FUDSMIS	FUDS Management Information System
GA	Gauge
GIS	Geographical Information System
GPS	Global Positioning System
GSA	General Services Administration

H	High
HD	High Definition
HE	High Explosive
HEI	High Explosive Incendiary
HE-T	High Explosive Tracer
HHE	Health Hazard Evaluation
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	Hazard Quotient
hr.	Hour
IA	Institutional Analysis
IC	Institutional Controls
IR	Ingestion Rate
IRIS	Integrated Risk Information System
ISO	Industry Standard Object
IT	Information Technology
IVS	Instrument Verification Strip
J	Estimated
JBLM	Joint Base Lewis McChord
JHOC	Joint Harbor Operations Center
KD	Sediment to Water Partitioning Coefficient
kg	Kilogram
kHz	Kilohertz
Km	Kilometer
KOC	Soil/Sediment Organic Carbon to Water Partitioning Coefficient
Kow	Octanol Water Partitioning Coefficient
ksi	Kilogram per square inch
L	Low
LANL	Los Alamos National Laboratory
lb.	Pound
LED	Light-Emitting Diode
l/kg	Liters to Kilogram
LOAEL	Lowest Observed Adverse Effect Level
LOD	Limit of Detection
LOQ	Limit of Quantification
LO/TO	Lockout/tag out
LUCs	Land Use Controls
m	Meter
M	Medium
m/s	Meters per Second
MBES	Multibeam Echosounder
MC	Munitions Constituents
MD	Munitions Debris

MDC	Maximum Detected Concentration
MDL	Method Detection Limit
MEC	Munitions and Explosives of Concern
MFD	Maximum Fragment Distance
mg/kg	Milligram per Kilogram
mg/l	Milligram per Liter
MIDAS	Munitions Items Disposition Action System
MLLW	Mean Lower Low Water
mm	Millimeter
MMRP	Military Munitions Response Program
MPF	Migration Pathway Factor
MPPEH	Munitions Potentially Presenting and Explosive Hazard
MRA	Munitions Response Area
MRS	Munitions Response Site
MRSPP	Munitions Response Site Prioritization Protocol
MSL	Mean Sea Level
N/S	North/South
NA	Not Applicable
NAS	Network Attached Storage
NCP	National Contingency Plan
NDAI	No Department of Defense Action Indicated
NEW	Net Explosive Weight
NFS	Network File System
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEL	No Observed Effect Level
nT	nanoTeslas
OEHHA	Office of Environmental Health and Hazard Assessment
OSWER	Office of Solid Waste and Emergency Response
PD	Police Department
PETN	Pentaerythritol Tetranitrate
PHS	Priority Habitat and Species
PM	Project Manager
POS	Port of Seattle
PPRTV	Peer Provisional Reviewed Toxicity Value
PRP	Potentially Responsible Party
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QSM	Quality Systems Manual
RA	Risk Assessment
RAFLU	Reasonably Anticipated Future Land Use
RAGS	Risk Assessment Guidance for Superfund

RCHAS	Reproductive and Cancer Hazard Assessment Section
RCW	Regional Code of Washington
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RfD	Non-cancer Reference Dose
RHIB	Rigid Hull Inflatable Boat
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROC	Regional Operations Center
ROUMRS	Remotely Operated Underwater Munitions Recovery System
ROV	Remotely Operated Vehicle
RSL	Regional Screening Level
RTK	Real Time Kinematic
SAN	Storage Area Network
SBP	Sub-Bottom Profiler
SCUBA	Self Contained Underwater Breathing Apparatus
SD	Standard Deviation
SL	Screening Level
SLERA	Screening-Level Ecological Risk Assessment
SLERAP	Screening Level Ecological Risk Assessment Protocol
SOP	Standard Operating Procedure
SPAWAR	Space and Naval Warfare Systems Command
SQB	Sediment Quality Benchmark
SQuiRTs	Screening Quick References Tables
SSS	Sidescan Sonar
SUXOS	Senior Unexploded Ordnance Supervisor
SVOC	Semi-Volatile Organic Compound
T&E	Threatened and Endangered
TPP	Technical Project Planning
TCRA	Time Critical Removal Action
TDNT	Technical grade DNT
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TOC	Total Organic Carbon
TP	Technical Paper
TR	Target Risk (cancer)
UCL	Upper Confidence Limit
UFP-QAPP	Uniform Federal Policy-Quality Assurance Protection Plan
U.S.	United States
USACE	United States Army Corps of Engineers
USACE EM	United States Army Corps of Engineers Engineering Manual
USBL	Ultrashort Baseline
U.S.C.	United States Code
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency

USFWS	United States Fish and Wildlife Service
UXO	Unexploded Ordnance
UXOQCS	Unexploded Ordnance Quality Control Supervisor
WA	Washington
WAC	Washington Administrative Code
WADNR	Washington Department of Natural Resources
WDFW	Washington Department of Fish & Wildlife
WOE	Weight of Evidence
WP	Work Plan
WWII	Second World War
yr.	Year
%	Percent
ºF	Degrees Fahrenheit

1.0 EXECUTIVE SUMMARY

The Formerly Used Defense Site (FUDS) Former Seattle Naval Supply Depot (FSNSD) is located along Puget Sound in Seattle, Washington (WA) approximately 3 miles northwest of downtown at the site of the present day Terminal 91, operated by the Port of Seattle (POS). In 1942 and 1943, the United States (U.S.) Navy acquired the property through condemnation for use as bulk fuel and materiel storage, and as a marine terminal for naval vessels. During the Second World War (WWII), the FSNSD was used by U.S. Navy vessels including aircraft carriers, battleships, cruisers, and submarines. The FSNSD was not used as an ammunition resupply facility and there are no records of live fire actions ever occurring. This indicates that neither vast quantities of unfired munitions items dropped while loading, nor numerous fired but not detonated unexploded ordnance (UXO) items exist on the seafloor. Beginning in 1967, the U.S. Navy declared portions of the facility as excess to the General Services Administration (GSA). POS acquired 198.23 acres of the property in 1976 by quitclaim deed. The remainder of the property was acquired by the National Guard. Currently, POS uses the property as a marine terminal for cargo ships, factory trawlers, and more recently as the prime terminal for passenger cruise ships. In 2010, POS had 223 cruise ship visits and over 858,000 passengers, with an impact of over $400 million dollars to the local economy.

The POS Police Department (PD) Dive Team conducts regular underwater inspections of the facility and arriving cruise ships for explosive devices in accordance with POS and United States Coast Guard (USCG) security plans for Terminal 91. During a routine inspection on April 22, 2010, the PD divers encountered military munitions in sediments around piers 90 and 91. U.S. Navy Explosive Ordnance Disposal (EOD) personnel responded to the incident and determined the items to be discarded military munitions (DMM). The responding U.S. Navy EOD team took possession of the items and responsibility for final disposition. In 2010, U.S. Navy and U.S. Army EOD personnel responded to six other incidents after discovery of DMM in sediments on both sides of Pier 91.

In December of 2010, the U.S. Army Corps of Engineers (USACE) initiated the Piers 90 and 91 Remedial Investigation (RI). The overall objective of the RI was to characterize the nature and extent of DMM incidence in the munitions response area (MRA) to allow assessment of explosive hazard and risk associated with potential exposure to munitions constituents (MC) attributable to DMM for the reasonably anticipated future land use (RAFLU) with an acceptable degree of uncertainty to allow decision making on the need for remedial action to address the explosive hazard and chemical risk. The MRA totals 86.7 acres, which includes the 74.1 acres of marine open areas around piers 90 and 91, and 12.6 acres of accessible water areas under the piers. No Department of Defense Action Indicated (NDAI) would be recommended if no hazard was determined following the RI. A focused Feasibility Study (FS) including evaluation of Institutional Controls (IC) and Land Use Controls (LUCs) would be recommended if a low hazard was determined. A complete FS evaluation of removal actions would be recommended if hazard was determined to be unacceptably high, such as if caches of munitions were found.

The RI occurred between 2010 and 2012. The 2010 field season consisted of site characterization using acoustic technology, remotely operated vehicles (ROVs), and UXO divers. Several acoustic surveys were conducted with analysis of the data used to develop up-to-date and accurate models of bathymetry, sediment layering, and dispersal of seafloor debris. Geophysical data were collected and a system of high-pass filters were designed and tested on the data to remove effects of the pier structure from future geophysical surveys. UXO divers and ROVs were deployed to verify the acoustic and geophysical data and provide observations of the subsea conditions within the MRA.

On December 15, 2010, an Action Memorandum (AM) was signed which set forth the decision to conduct a Time Critical Removal Action (TCRA) at the FSNSD MRA. The AM concluded that due to the discovery of DMM by POS PD on the occasions cited above, there was a significant possibility that additional military munitions existed and that these munitions posed a potential explosive safety hazard to individuals, property and the environment if not addressed through the TCRA approved in the AM. The USCG issued a Captain of the Port Order establishing a safety zone around Terminal 91, and a munitions response was initiated. The TCRA occurred between January and March of 2011, in the immediate area surrounding Pier 91 used by cruise vessels during their annual spring through fall cruise season. The TCRA was primarily a 100% surface clearance of munitions and munitions related items from a 25.2 acre portion of the accessible seafloor under and surrounding Pier 91, referred to as Survey Area 1. The surface clearance was conducted by UXO divers utilizing a search method known as “Jackstay”. Jackstay searches involved zigzag swims along a cable secured on both ends of the search area. The UXO divers moved one end of the cable a set amount following each traverse of the search area, ensuring complete coverage. Quality Control (QC) of the surface clearance was completed by ROVs equipped with lights, sonar, and high definition (HD) video recorders, with questionable items verified by UXO Technicians trained in the discrimination of DMM from debris. During the course of the TCRA, additional acoustic and geophysical surveys occurred to further characterize site conditions and the nature of seafloor debris. This information was required by project stakeholders and was essential in planning the subsurface investigations necessary to establish the vertical extent of possible munitions and explosives of concern (MEC) present at the site. The TCRA concluded on schedule in March of 2011, with U.S. Army EOD from Joint Base Lewis McChord (JBLM) taking possession of 12 DMM items and 212 munitions debris (MD) items.

The Piers 90 and 91 RI included a second field season, which began in January of 2012, after the completion of the 2011 cruise season. The 2012 field season was designed to use all previously collected data regarding the physical nature of the site to implement an effective plan to clear seafloor metallic debris, conduct geophysical surveys to map subsurface anomalies potentially meeting the profile of the munitions item of concern, obtain and analyze sediment samples for possible MC contamination, and conduct surface and subsurface investigations for DMM. Debris clearance was not a policy driven objective for the site, but rather analogous to a terrestrial brush clearance in increasing the usefulness and assessment of digital geophysical mapping (DGM) in focusing diver-performed intrusive investigations. These operations occurred collectively over ten 4 meter (m) wide sections of the seafloor referred to as transects, similar to a munitions related RI at a terrestrial site. These transects ranged in length from approximately

400 m to 750 m and were placed throughout the MRA based on historical U.S. Navy use, current and projected future land use, and DMM discoveries made in 2010 and 2011. The 2012 field season concluded with the onsite demolition of 13 DMM items. MC were detected at multiple locations near or under DMM.

The efforts and results of the Piers 90 and 91 RI and TCRA are described in this report. Due to the location, use and importance of the site, increased data collection was necessary to satisfy stakeholder concerns beyond the base-level necessary to support a hazard analysis and risk assessment. A qualitative MEC hazard analysis and baseline risk assessment based on these data are presented in the report, as well as summarized below. Three figures are included at the conclusion of this Executive Summary. The first displays the type and location of all DMM items located during the RI and TCRA over a base-layer which displays sediment thickness levels (**Figure 1-1**). The second figure displays the area of potential MC contamination at the site based on the findings of the baseline risk assessment (**Figure 1-2**). The third displays the boundary of the recommended Munitions Response Site (MRS) following delineation based on the findings of the RI (**Figure 1-3**).

The largest DMM item recovered was a 5-inch projectile, thus the 5-inch projectile was used to determine the possible hazards posed by remaining DMM in the qualitative MEC hazard analysis performed for this report and an Explosive Hazard Assessment performed by elements of the U.S. Army and U.S. Navy for the USACE Seattle District. Although the 5-inch projectile was used to determine hazard, smaller munitions items such as 20 millimeter (mm) and 40mm projectiles may exist at the site and are subject to the same future response measures as the 5-inch projectile. In summary, the analysis found that munitions items most likely came to exist on the seafloor after infrequent and undocumented jettisoning from vessels while berthed at the facility. No significant concentrations were discovered on the seafloor or beneath the seafloor, and all munitions items recovered matched the historical armament of vessels known or suspected of having used the site. The analysis concluded that, to date, no record exists of an encounter with DMM resulting from vessel mooring and berthing operations at the facility, and that the probability of future encounters have been significantly reduced by the removal of the items recovered during investigative and response actions that have occurred at the site. All MEC items recovered at the site were DMM, and no records or findings indicate that UXO may be present, thus the likelihood of detonation of these items, even if disturbed or otherwise encountered during operations at Terminal 91, is extremely low. The qualitative MEC hazard analysis, presented in **Section 8.0** of this report, provided a level of hazard to each identified receptor based on the unlikely event of a detonation of a MEC item. Hazards to receptors were graded in a range that included None, Negligible, Low, Moderate, High, and Imminent. The qualitative MEC hazard analysis occurred for two scenarios: 1) a hazard analysis associated with regular use of the facility and 2) a hazard analysis associated with mechanical dredging activities at the site. For the normal use scenario, the Underwater Construction Worker and Terminal 91 Diver received rankings of Low. Hazards to all other receptors were considered None or Negligible. For the mechanical dredging scenario, the Construction Worker received a ranking of Moderate. Taken together, the Explosive Hazard Assessment and the qualitative MEC hazard analysis determined that:

- There is a low likelihood of an encounter with MEC at the FSNSD MRS during normal operations. There is a moderate to high likelihood of an encounter with MEC during mechanical dredging operations, when potentially MEC-laden sediments are brought to the surface and placed on a barge in the vicinity of the Construction Worker.
- Based on the nature of the munitions items as DMM, there is a low likelihood of an unintentional detonation.
- The hazard posed to potential human receptors and vessels during normal operations is low. The hazard posed to Construction Workers during mechanical dredging operations is Moderate.
- In the context of this qualitative MEC hazard analysis, “low” should mean sufficiently low hazard to allow current land use and RAFLU within an acceptable degree of uncertainty.
- An evaluation of the management of DMM items encountered in dredged materials will be included in the FS.

USCG rescinded Captain of the Port Order 99-10 on November 8, 2012 prior to the distribution of this report. USCG based the decision to rescind the order on a review of project data and initial recommendations presented in the Explosive Hazard Assessment provided by the USACE Seattle District.

The baseline human health risk assessment (HHRA) concluded that there are no excess lifetime cancer risks from seafood ingestion for either the Native American Subsistence Angler or the Recreational Angler. The screening-level ecological risk assessment (SLERA) concluded that there were no exceedances of sediment quality benchmarks for benthic invertebrates for any detected chemical.

The data collected from the FSNSD MRA were evaluated to determine the appropriate designation of MRSs. Based on this evaluation; the report recommends that the MRA be delineated into a single MRS matching the boundary of the MRA (shown in **Figure 1-3**). This MRS potentially possesses DMM and MC contamination and received a Munitions Response Site Prioritization Protocol (MRSPP) score of 5. The MRS is therefore recommended for further munitions response actions consisting of a focused FS and subsequent Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial response actions.

Figure 1-1 Discarded Military Munitions Items Found During Remedial Investigation and Time Critical Removal Action

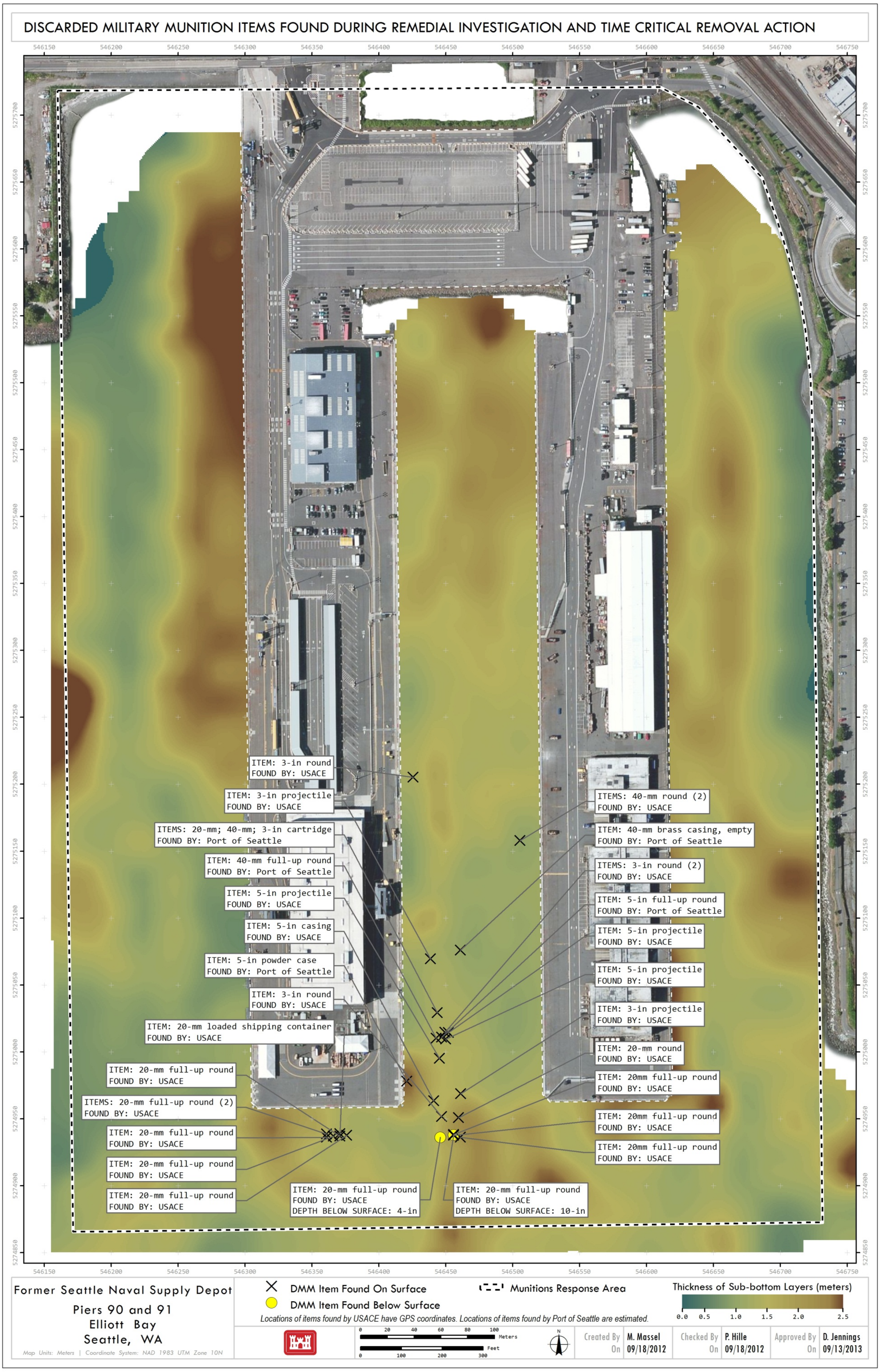

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Figure 1-2 Remedial Investigation Sediment Delineation Area

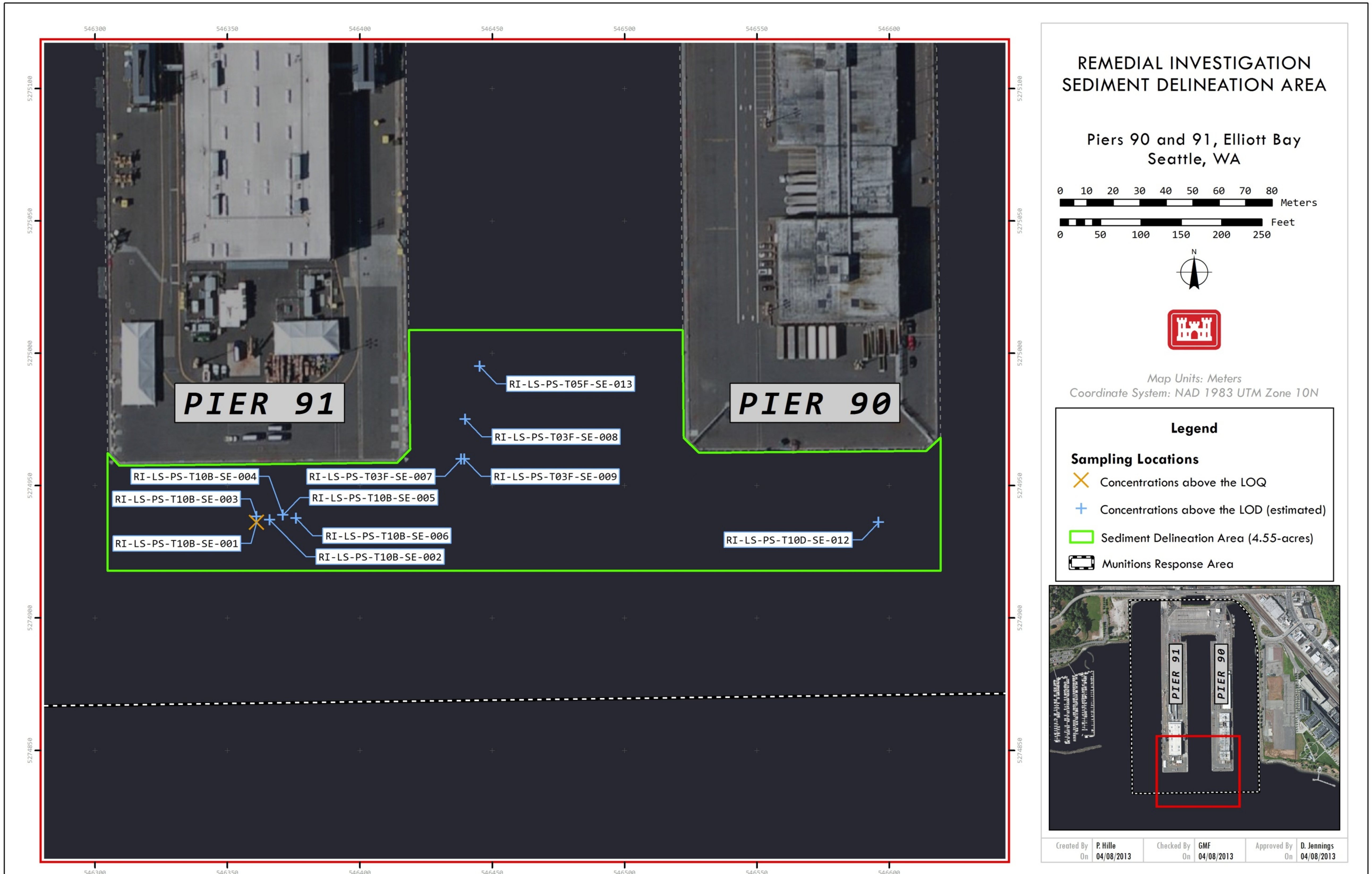

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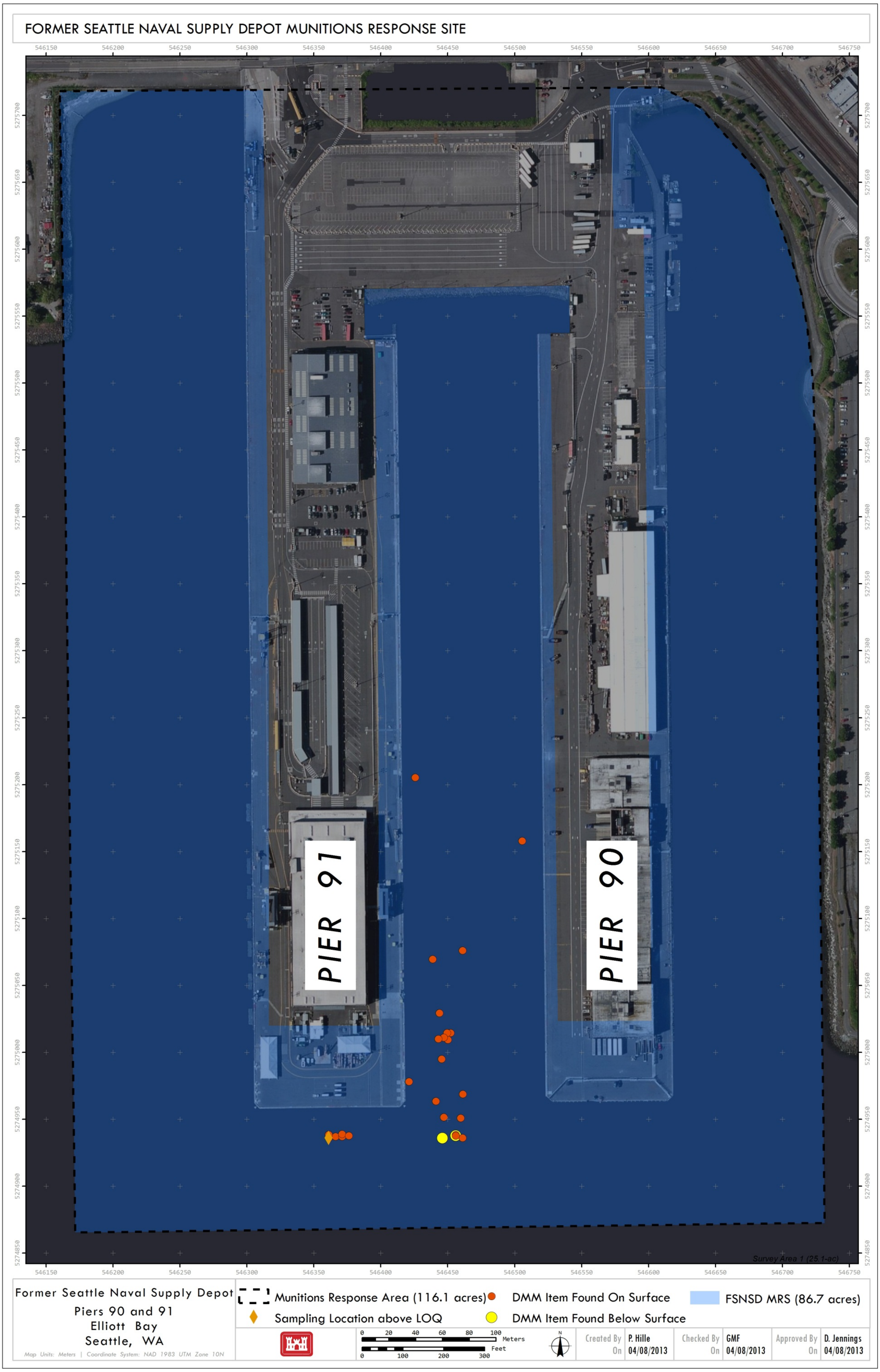
Figure 1-3 Former Seattle Naval Supply Depot Munitions Response Site



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2.0 INTRODUCTION

This section describes the purpose and authority of the FUDS RI at the FSNSD; presents a property description and history; depicts the property's physical and environmental setting; and provides information on prior munitions response actions at the site.

2.1 Purpose and Authority

This project consisted of performing RI activities at the FSNSD, which includes piers 90 and 91 (currently collectively identified as Terminal 91) at a property managed by POS under the FUDS Military Munitions Response Program (MMRP). The FSNSD is located in Elliott Bay, Seattle, Washington (**Figure 2-1**). The FSNSD MRA is depicted on **Figure 2-2**. Project activities were conducted under the Defense Environmental Restoration Program (DERP) and were subject to CERCLA and the National Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300 (USEPA, 2011c) implementing CERCLA. As a result, all response actions conducted on site or immediately adjacent to it met substantive requirements of permitting regulations but were exempt from administrative requirements.

2.2 Property Description and History

2.2.1 Project Location

The FSNSD is located along the Puget Sound in King County, WA, approximately 3 miles northwest of downtown Seattle, at the present day Terminal 91 site. The geodetic coordinates for the site location are at 47°37'57" North Latitude and 122°22'55.2" West Longitude, and include portions of Sections 23 and 26 of Township 25 North, Range 3 East of the Willamette Meridian. This site is located in the U.S. Environmental Protection Agency (USEPA) Region 10, and the Washington 7th Congressional District (SKY, 2012a).

2.2.2 Project Property Description

The FSNSD MRA is located on 86.7 acres of sub tidal lands in Elliott Bay in Seattle, WA. The survey area of interest 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 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 (SKY, 2012).

The MRA was divided into two Survey Areas prior to the TCRA to delineate the area requiring an immediate surface clearance. Survey Area 1 is a 25.2-acre section around the cruise berths of Pier 91. Survey Area 2 consists of the remaining 61.5 acres of the site (**Figure 2-2**).

2.2.3 Bathymetry

The bathymetry (**Figure 2-3**) of the FSNSD is diverse going from zero ft Mean Lower Low Water (MLLW) underneath the piers down to greater than 60 ft in the deepest sections of the site. Water depths average 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 (SKY, 2012). **Figure 2-3** outlines dredge prisms from dredging activities occurring within the MRA in 1992/1993 and 2006. Plans provided by POS indicate that the 1992/1993 maintenance dredging occurred in an approximately 1,000 ft long, 50 ft wide north/south (N/S) strip adjacent to the western side of Pier 91. The maximum allowable depth for this dredging activity was 40 ft below MLLW. The 2006 maintenance dredging occurred in four locations; three long N/S strips, each approximately 10 ft wide and located 10 ft west of the last 1,200 ft of the western side of Pier 91, and a fourth large irregular shape approximately 175 ft off the western side of Pier 91. The maximum allowable dredged depth for the 2006 activity was 35 ft below MLLW. Additional dredging is likely to have occurred at the project site before 1992 (SKY, 2012a).

The USACE Seattle District evaluated Suitability Determinations, provided by the Dredged Material Management Office (DMMO) in Seattle, WA, from prior dredging actions that occurred at Terminal 91. This evaluation determined that the material type dredged in 2006 contained, on average, 11-18% fines. This indicated a fairly coarse gradation of sediments near the facility, and that the area is not depositional due to the low fines content. Given the conceptual flow patterns described in (Ebbesmyer et al, 1998) the sediment load containing fine grained material is likely captured in two gyres on either side of Duwamish head in Elliot Bay. Additionally, given the hardened Seattle waterfront there is no appreciable sediment input into the nearshore system here which might be directed toward the site. This indicates that sediment deposition rates into Smith Cove (the portion of Elliot Bay where the site exists) are fairly negligible.

Figure 2-1 Former Seattle Naval Supply Depot Site Location

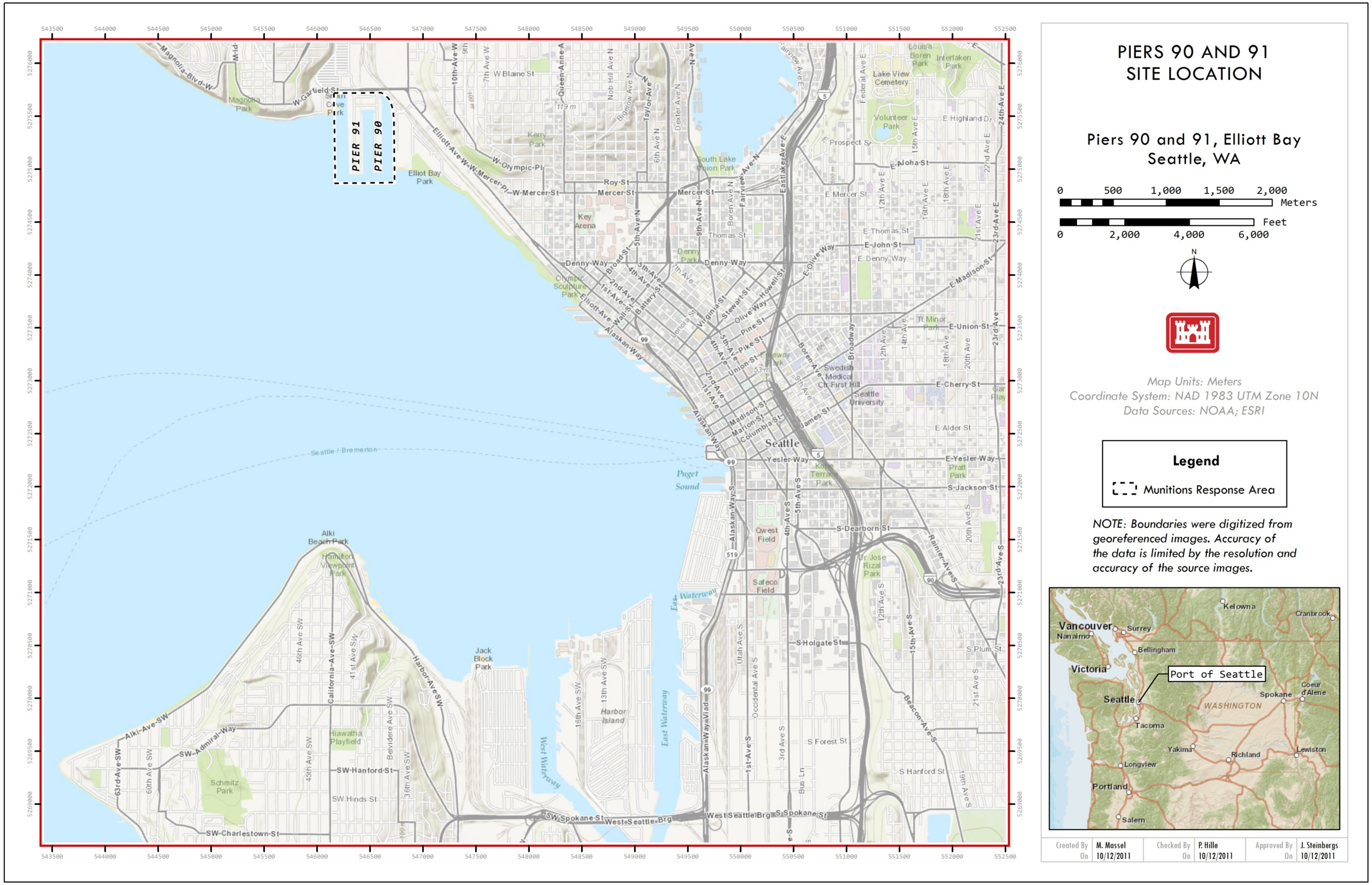

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Figure 2-2 Former Seattle Naval Supply Depot Munitions Response Area

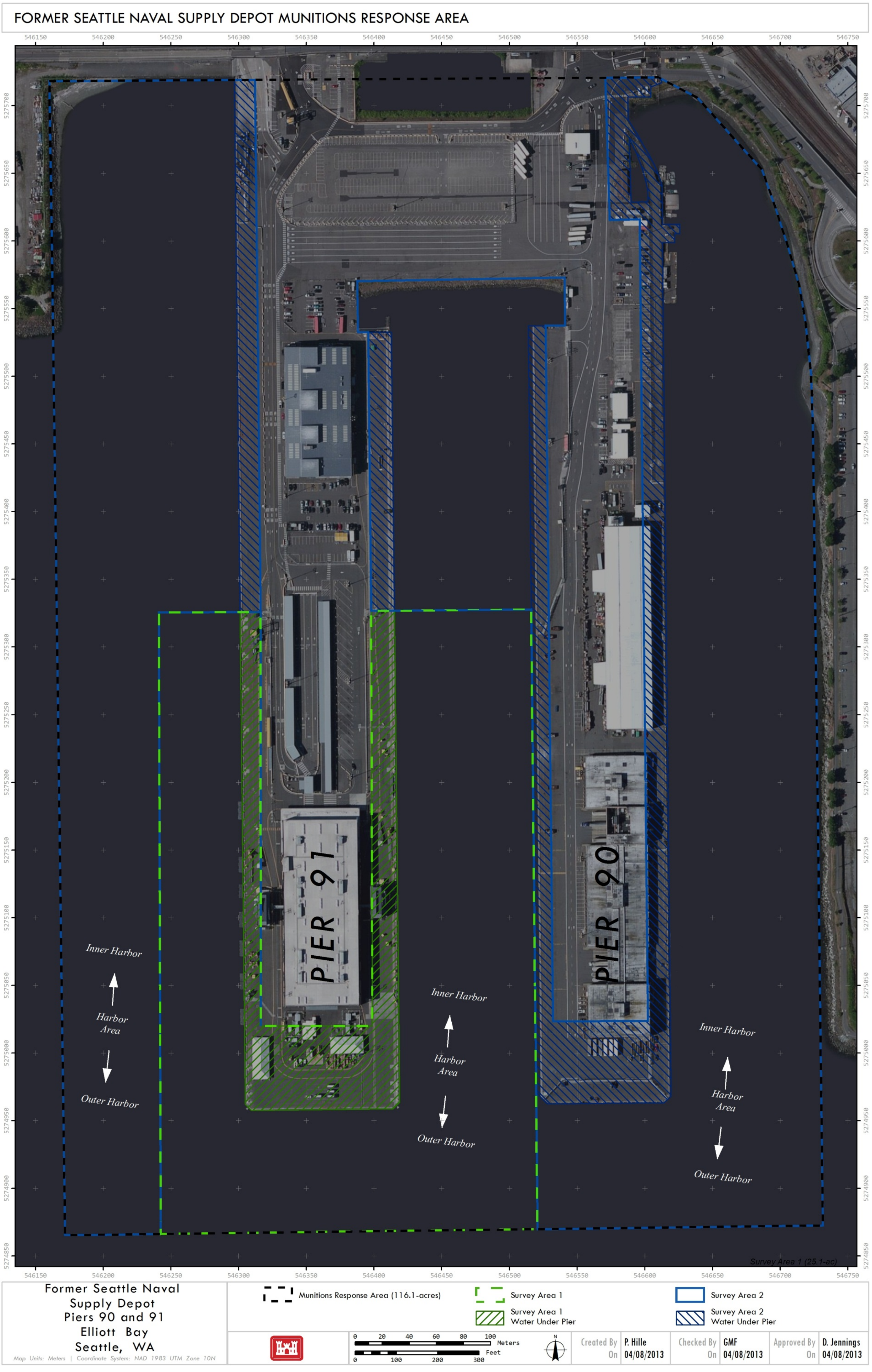

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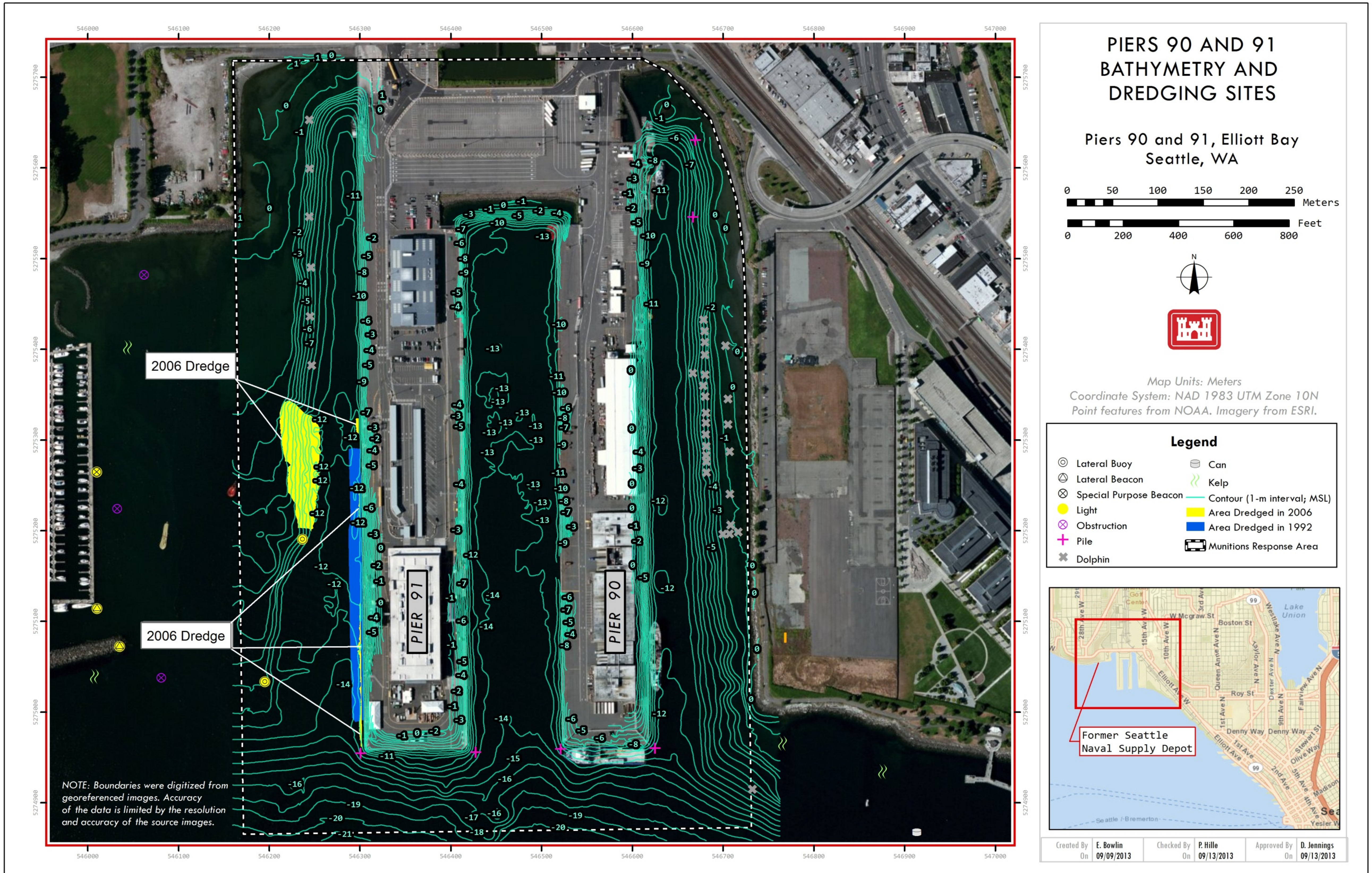
Figure 2-3 Former Seattle Naval Supply Depot Bathymetry



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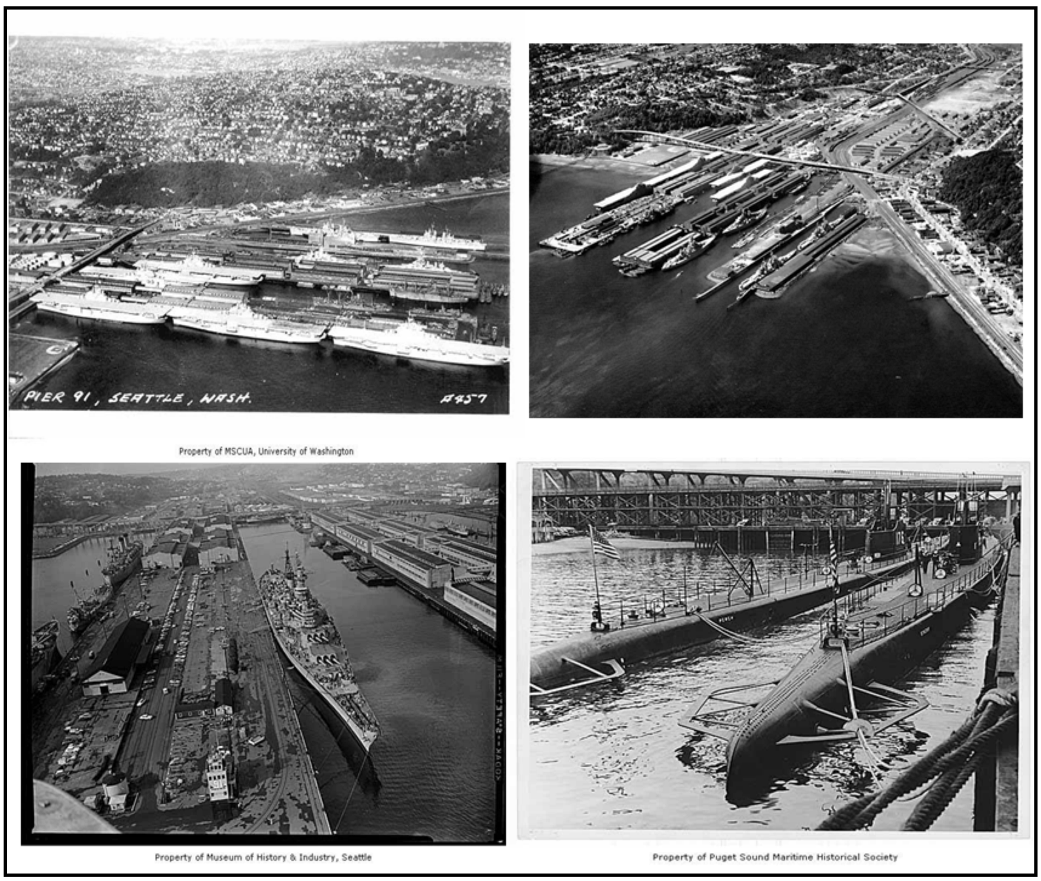
2.2.4 Facility Construction and Early History

Piers 40 and 41 (renamed piers 90 and 91 in 1941) were built in the early part of the twentieth century atop fill material at Smith Cove in Elliott Bay. At the time of its construction, Pier 41 was considered as possibly the largest commercial pier in the world. The facility was a hub for Seattle commerce and was used for loading and offloading lumber, coal and other materials (BOLA, 2005).

2.2.5 United States Navy Acquisition and Use

In 1942, and 1943, the U.S. 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 to support WWII**. Figure 2-4** is a set of aerial photographs of the facility while in use by the U.S. Navy. These photographs document the use of the facility by submarines, aircraft carriers, battleships, and cruisers. The property was already a partially developed commercial marine terminal with warehouses and fuel oil storage facilities. The U.S. Navy further expanded these facilities, and constructed approximately 100 buildings including general warehouses, maintenance shops, administration buildings, a heating plant, barracks, and cold storage facilities (SKY, 2012a).

Figure 2-4 Piers 90 and 91 U.S. Navy Use - World War II Era



It was during this period that DMM items from naval vessels were likely deposited on sub tidal areas surrounding the piers. POS PD divers recovered a sign labeled “Safety Orders for 3-Inch Guns” from the seafloor of the MRA in 2010. One section of the sign instructed sailors to throw potentially damaged or defective 3-inch rounds overboard. Based on these findings it was assumed that sailors jettisoned munitions and munitions-related items overboard as a housekeeping process and to speed the resupply process. No specific records of these events have been found, and it appears that this was an infrequent occurrence rather than a routine procedure. No evidence suggests that any live fire exercises occurred at the site, and all munitions found to date have been unfired and unarmed. (SKY, 2012a).

2.2.6 Post United States Naval Use

Beginning in 1967, the U.S. Navy declared portions of the facility as excess property to the GSA. POS acquired 198.23 acres of the former property in 1976 by quitclaim deed. The remainder of the property was acquired by the Army National Guard (24.75 acres) for their facility, and the North West Center (7.62 acres). The U.S. Navy retained 12.37 acres, identified as the Terminal 91 Annex (SKY, 2012). The facility was used to offload fishing vessels, to house cold storage facilities and as an imported automobile distribution center (BOLA, 2005).

2.3 Physical and Environmental Setting

2.3.1 Current and Projected Future Land Use

POS opened Smith Cove Cruise Terminal at Pier 91 in 2009. During May through September, the Cruise Terminal serves as Seattle’s Port of Call for a growing number of luxury cruises to Alaska. During the off-season, the cruise terminal itself is used for trade shows, concerts, and performances. 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.

The FSNSD site has been dredged multiple times in the past, and will be dredged in the future. Dredging projects at Terminal 91 will require permit approval from the USACE under provisions of Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act.

There are no known changes planned for land use at the project site (SKY, 2012a).

2.3.2 Site Physiography

The FSNSD FUDS site is located in the larger Terminal 91 complex, which encompasses approximately 216 acres, including adjacent water and upland areas. Terminal 91 lies at the southern end of a lowland area referred to as the Interbay Region, which was created by glacial and/or postglacial down cutting, followed by historical land filling. The Interbay Region is approximately 1.5 miles long and 1,000 to 2,000 ft wide and extends from the Lake Washington Ship Canal on the north to Elliott Bay in Puget Sound on the south. The Interbay Region lies within a larger physiographic region, known as the Puget Sound Lowland, a topographic and structural basin bordered by the Cascade Range on the east and the Olympic Mountains on the west. The Puget Sound Lowland is underlain by thousands of feet of unconsolidated glacial and non-glacial sediments (PES, 2009).

Both the upland areas and piers at Terminal 91 overlie a portion of the Smith Cove inlet that was initially modified by filling in the early 1900s. Surface water bodies include Elliott Bay and the Short Fill Impoundment, an isolated water body located just south of the Garfield Street Viaduct. The Short Fill Impoundment, which is approximately 30 ft deep, is a remnant of the former central slip between piers 90 and 91 that was isolated from Elliott Bay in 1988 during infilling of about 400 ft of the landward portion of the slip. Although permits authorized complete fill, the Short Fill Impoundment was left in place due to concerns that infilling could cause settlement and jeopardize the structural integrity of the West Garfield Street viaduct. Bulkheads of various types bound the seaward portions of the site and form the perimeter of the fill-cored piers. The east, center, and west slips adjacent to the piers have been maintained to dredged depths of about -35 ft MLLW. An exception to this is the landward ends of the east and west slips, where four intertidal habitat sites are located (two on the northeast corner of the east slip and two on the west margin of the west slip) (PES, 2009).

Four fish and wildlife habitat sites are present in the shallow sub-tidal and exposed intertidal aquatic areas of the FSNSD. The aquatic habitat sites were constructed by 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 restored as intertidal habitat. They were 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).

These improved and maintained habitat restoration areas are located within the MRA. RI and TCRA project activities were designed to avoid affecting these areas to the maximum extent possible. Further information on sensitive or important habitat located within or near the MRA is located in **Section 2.3.8** of this report, which covers threatened and endangered (T&E) species (SKY, 2012a).

2.3.3 Geology

The Puget Lowland is underlain at depth by Tertiary volcanic and sedimentary bedrock, and is filled to the present-day land surface with glacial and non-glacial sediments deposited during the Quaternary Period (within the last 2 million years). Only the late Quaternary deposits are exposed at land surface in the site area. The Quaternary geologic history of the Puget Sound region is dominated by a succession of at least six dated and named periods of continental glaciation. During these episodes of cooler mean global temperatures, continental ice sheets originating in Canada flowed south, covering much of low-lying northern North America with glacial ice, over a mile thick in places. In the Puget Lowland, the most recent continental glacier was present as a lobe of ice that reached its maximum extent just south of Olympia during the Vashon stage of the Fraser glaciation. Glacial ice was about 3,000 ft thick in the project area (PES, 2009).

As the glaciers advanced, glaciolacustrine silt and clay (known as transition beds) were deposited, followed by sand and gravel (advance outwash); silt, sand, and gravel compacted by glacial ice (till), and a succession of sand, gravel (recessional outwash), and silt (recessional lacustrine deposits) as the glaciers receded. Between glaciations (the non-glacial periods), erosion, and depositional processes worked much as they do today, with broad lowland rivers and streams filling the deep glacially modified channels, and erosion on the steep upland slopes forming ravines. Deposits from the non-glacial periods generally consisted of interbedded sand, silt, clay, and peat in an environment similar to the pre-development Green River and Duwamish River valleys. Geologic processes following the Vashon glaciation are dominated by erosion of the uplands and deposition of recent alluvium and lacustrine deposits in the valleys and water bodies of the Puget Lowland. Extensive filling of former wetlands and tidal flats in the Interbay area and grading for construction projects has further modified the land surface (PES, 2009).

2.3.4 Hydrology

The groundwater flow systems in western Washington can be grouped into regional and local flow systems. The regional flow systems are generally deep, long-flow path systems that are recharged via precipitation in the elevated foothills and plateaus, and discharge to the lower floodplains and to the marine waters of Puget Sound. These regional systems are of broad extent and generally involve aquifers comprised of thick glacial advance outwash deposits formed during the Vashon period or older glacial periods. Local groundwater flow systems overlap or overlie these regional systems, are of a smaller scale generally limited to lowlands between the elevated foothills and plateaus, and are controlled by local topographic and geologic conditions. These local flow systems generally include localized recessional glacial outwash, recent non-glacial alluvial and near shore marine deposits, fill placed on inland low areas, and filled areas adjoining Puget Sound. The aquifer systems of interest at the site are local groundwater flow systems within fill and near-shore marine deposits (PES, 2009).

2.3.5 Groundwater Use

No drinking water supply wells are present on or down gradient from the FSNSD site within Terminal 91. Two deepwater supply wells, neither of which is currently in use, have been identified within an approximately one-half-mile radius of Terminal 91. Both wells are within the larger Terminal 91 Complex owned by POS. Both wells are screened or perforated at depths of greater than about 250 ft below ground surface (bgs) in artesian aquifers, and one of the two wells is up-gradient from the site. In 2001, Roth Consulting (Roth Consulting, 2007) concluded that groundwater is non-potable according to criteria provided in the Model Toxic Controls Act [Washington Administrative Code (WAC) 173-340-720(2)] (WAC, 1991) (PES, 2009).

2.3.6 Climate and Vegetation

Air masses originating over the Pacific Ocean strongly affect the climate of the Puget Sound Lowland, with generally overcast, cool, damp, and mild weather during the autumn, winter, and spring, and warm and dry weather during the summer. The annual precipitation ranges from about 30 to 60 inches in the lowland. The average annual precipitation in the area is about 38 inches, with approximately 75% of the precipitation falling between October and March (PES, 2009).

Like most of the northwest coast of North America, prior to modern land alteration and the introduction of exotic species, the Puget Lowland was covered with extensive stands of coniferous forest belonging to the Tsuga heterophylla (western hemlock) vegetation zone. Western Hemlock, Western Red Cedar and Douglas Fir are typical components of that vegetation zone, with Douglas Fir being the dominant species. Old-growth forest understories are typically dense, consisting of shrubs and herbaceous plants dominated by sword fern, salal, Oregon Grape, Ocean Spray, Blackberry, Red Huckleberry and Red Elderberry. Big Leaf Maple and Red Alder are common in moist areas subject to disturbance, while stream courses and flood plains are dominated by Red Alder, Black Cottonwood, Big Leaf Maple and other riparian plants. Wetlands are common in river valleys and typically support willow, alder, cattail, reeds, Wapato, nettle and skunk cabbage (BOLA, 2005).

The region was thickly forested when the first Euro-American settlers arrived in Seattle in 1852. Dominant trees were Douglas Fir, Red Cedar and Western Hemlock, with Spruce much less common. The trees were large, often 6 to 8 ft in diameter, and reached heights of 300 ft. Red Alder and Cottonwood were the only abundant deciduous trees, with extent limited to river flood plains and disturbed lands (BOLA, 2005).

2.3.7 Fauna

Puget Sound is a rich marine ecosystem that has played an important role in prehistoric and contemporary cultures. The open waters of the Puget Sound environment support squid, shrimp, jellyfish, sea mammals, and over 200 species of fish indigenous to Puget Sound. Indigenous fish species include (but are not limited to) Coho (or Silver), Chinook (King), Sockeye (Red), Chum (Dog) Salmon, and Pink (Humpback) Salmon, and as well as Cutthroat, Steelhead and Bull Trout. The area also has numerous invertebrate species such as clams, sea cucumbers, crabs, starfish, and octopus. Intertidal zone invertebrates include crabs, shrimp, clams, oysters, mussels, sea anemones, sea stars, sponges, ribbon worms, round worms, chitons, barnacles, sea urchins, and sand dollars (BOLA, 2005).

Dungeness Crabs (*Metacarcinus magister*) are harvested in coastal areas in Puget Sound, primarily north of Seattle. This crab is managed as a priority species in the Priority Habitat and Species (PHS) list from Washington Department of Fish & Wildlife (WDFW). They are an important resource for recreational, commercial and tribal harvests (WDFW, 2008). There is a fairly large coastal area southeast of Smith Cove that supports local Dungeness Crab populations.

Fewer species of terrestrial mammals inhabit the western coastal forests due to the pervasive canopy cover and the dominance of the forest vegetation by coniferous species. In spite of this cover, and the degree of urbanization near the project site, terrestrial animals such as deer, fox, coyote, skunk, porcupine and raccoon may be present near the project area. Other species around the vicinity of the FSNSD include smaller mammals (e.g., rabbits, various small rodents), and many species of birds.

Small kettle lakes, the shorelines of the larger freshwater lakes, and the Puget Sound host several species of ducks, geese, and various shorebirds (BOLA, 2005). Purple Martin (*Progne subis*) habitat is also located in the vicinity and Peregrine Falcons (*Falco peregrinus*) have been observed (WDFW, 2008). Osprey (*Pandion haliaetus*) and Bald Eagle (*Haliaeetus leucocephalus*) were also observed during the munitions response at the FSNSD.

This site is in the Pacific Flyway, a major N/S route of travel for migratory birds in the Americas (SEPA, 2010).

2.3.8 Threatened or Endangered Species

Elliott Bay may be used by several federally listed T&E animal species including:

- The Georgia Basin/Puget Sound Distinct Population Segments (DPS) of Bocaccio (*Sebastes paucispinis*), Canary Rockfish (*S. pinneger*), and Yelloweye Rockfish (*S. ruberrimus*).
- The Puget Sound Evolutionarily Significant Unit (ESU) of Chinook Salmon (*Oncorhynchus tshawytscha*).
- The Puget Sound DPS of Steelhead (*O. mykiss*);
- The Coastal-Puget Sound DPS of Bull Trout (*Salvelinus confluentus*).

Sockeye, Chum, and Coho salmon are Federal Threatened Species or Species of Concern where found along the West Coast. In addition, Pacific Cod (*Gadus macrocephalus*) is a Federal Species of Concern and a Washington State Candidate species. The Marbled Murrelet (*Brachyramphus marmoratus*) may also visit the project area. This small, pudgy, diving seabird is a member of the Auk family, and is listed as Federal Threatened in Washington State. The Southern Resident Killer Whale (*Orcinus orca*) and the Steller Sea Lion (*Eumetopias jubatus)* have been observed in Puget Sound. National Oceanic and Atmospheric Administration's (NOAA) Northwest Regional Office National Marine Fisheries Service (NMFS) have established critical habitat for the Southern Resident Killer Whale along the Washington coast and within Puget Sound. Critical habitat has also been established for Puget Sound Chinook Salmon and Bull Trout, which overlaps the project location. A complete listing of Washington State and Federal T&E, Species of Concern, and Washington State "monitor" species is included in **Appendix E** (SKY, 2012a).

Table 2-1 Federal Threatened and Endangered Wildlife Species of Concern

Animal Species	Listed Status
Bocaccio, DPS	Federal—Endangered
Canary Rockfish, DPS	Federal—Threatened
Yelloweye Rockfish, DPS	Federal—Threatened
Puget Sound Chinook Salmon, ESU	Federal—Threatened
Steelhead, DPS	Federal—Threatened
Coastal-Puget Sound Bull Trout, DPS*	Federal—Threatened
Chum Salmon	Federal—Threatened
Coho Salmon	Federal—Species of Concern
Pacific Cod	Federal—Species of Concern, State Candidate
Southern Resident Killer Whale, DPS	Federal—Endangered
Steller Sea Lion	Federal—Threatened
Marbled Murrelet	Federal—Threatened

Listed by: NOAA
*United States Fish and Wildlife Service (USFWS)

NMFS is currently monitoring the following Federal Threatened populations of Chum Salmon (*Oncorhynchus keta)*:

- All naturally spawned during the summer-run populations in Hood Canal and its tributaries and Olympic Peninsula Rivers between Hood Canal and Dungeness Bay. The potential exists that this species could migrate through the FSNSD MRA, although it is unlikely.
- All naturally spawned populations in the Columbia River and its tributaries.
- State of Washington, in which this population is known or believed to occur (WDFW, 2008).

The NMFS is also currently monitoring all naturally spawned populations of Sockeye Salmon (*Oncorhynchus nerka*, Federal-Threatened):

- State of Washington, in which this population is known to or is believed to occur (WDFW, 2008).

There are over 100 populations of salmon and steelhead that have been listed as T&E in Washington State under the federal Endangered Species Act (ESA) (Knight, 2009) (Good et.al., 2005), and at least seven salmon stocks are already extinct in Puget Sound (Brennan and Culverwell, 2004).

Puget Sound was once home to more populations of Chinook and other salmon with a greater diversity of traits than what exists today. Only 22 of at least 37 historic Chinook populations remain. The remaining Chinook Salmon are at only 10% of their historic numbers, with some down to lower than 1% of their historic numbers. The decline in salmon is closely associated with the decline in the health of Puget Sound, and therefore, requires a coordinated, ecosystem-wide restoration effort. Salmon recovery is guided by implementation of the Puget Sound Salmon Recovery Plan, adopted by NOAA in January of 2007. This recovery plan was developed by Shared Strategy, a grassroots collaborative effort to protect and restore salmon runs across Puget Sound (PSP, 2011)

There are a number of management plans for wildlife published by WDFW, which include, but are not limited to the following:

- Management Recommendations for Washington's Priority Species Volume I: Invertebrates (December 1995) (WDFW, 1995).
- Management Recommendations for Washington's Priority Species Volume III: Amphibians and Reptiles (November 1997) (WDFW, 1997).
- Management Recommendations for Washington's Priority Species – Volume IV: Birds (May 2004) (WDFW, 2004).
- Management Recommendations for Washington's Priority Species – Volume V: Mammals (Interim) (last updated 2004).
- Management Recommendations for Washington's PHS: Dungeness crab (*Metacarcinus magister*) (December 2008) (WDFW, 2008).
- PHS List (August 2008).

According to WDFW, the PHS list is a catalog of habitats and species considered as priorities for conservation and management. Priority species require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. Priority species include State T&E, Sensitive, and Candidate species; animal aggregations (e.g., heron colonies, bat colonies) considered vulnerable; and species of recreational, commercial, or tribal importance that are vulnerable. Priority habitats are habitat types or elements with unique or significant value to a diverse assemblage of species. A priority habitat may consist of a unique vegetation type (e.g., eelgrass) or dominant plant species (e.g., juniper savannah), a described succession stage (e.g., old-growth forest), or a specific habitat feature (e.g., cliffs) (WDFW, 2008).

2.3.8.1 Special or Sensitive Habitats

Puget Sound is technically a very large marine estuary or system of estuaries, which represent a diverse and extensive ecosystem. Estuaries are transition zones between land and sea. They are found in sheltered bays, inlets and lagoons where freshwater rivers and streams meet and mix with the seawater, forming a melting pot of organic and mineral nutrients (WA Department of Ecology, 2011).

As previously noted, there are four mitigation habitats associated with the Terminal 91 property owned by POS. Intertidal zone and near shore habitats are very limited, both in the vicinity of the Terminal 91 property and in many coastal areas of Puget Sound. The mitigation habitat consists only of intertidal habitat. Riprap constitutes 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 (SKY, 2012a).

There are many studies, restoration projects and management plans for the rehabilitation of Puget Sound, the ecosystem, and many of its fish species (especially salmonids). Documenting the extent of these efforts was beyond the scope of this investigation; however, some aspects of these sensitive habitats are provided below. Information contained in the appendices of this report provides life history and further detail on selected important aquatic species associated with the FSNSD MRA (SKY, 2012a).

2.3.9 Nearshore Habitat

Near shore habitat comprises the beach, the upland area adjacent to it, and the intertidal area. This habitat forms an essential link in the food web of Puget Sound and is an important fish and wildlife corridor. Shallow marine waters are home to sensitive young fish and shellfish, and provide an important feeding area for fish, birds and mammals. Muddy shores are best known as habitat for commercial and recreational shellfish such as oysters, geoducks and crabs. Eelgrass beds are among the most important sites where herring schools lay their roe. Small worms, mollusks, crustaceans and forage fish inhabiting muddy shores are prey for young salmon, sole and flounder, as well as resident and migrating shorebirds (PSP, 2002).

The most common type of shoreline along the Puget Sound contains a mixture of mud and sand along with coarser gravel and cobbles. This variety of bottom materials supports a great diversity of living creatures: seaweeds clinging to rocks; crab and shrimp scavenging the mud for food; clams burrowed between cobbles; and fish, birds and seals prowling for prey (PSP, 2002).

2.3.9.1 Intertidal Zone

The intertidal zone is the area where the land and sea meet. This habitat is covered with water at high tide, and is exposed to air at low tide. The land in this zone can be rocky, sandy, or covered in mudflats. The intertidal zone is divided into several subzones, starting near dry land with the splash zone, an area that is usually dry, and moving down to the littoral zone, which is usually underwater. Within the intertidal zone, tidepools are formed as puddles left in the rocks as water recedes when the tide goes out. The intertidal zone is home to a wide variety of organisms. Organisms in this zone have many adaptations that allow them to survive in this challenging, ever-changing environment.

There are many key features of the intertidal zone, which include but are not limited to the following:

- Moisture: There are usually two high tides and two low tides each day. Depending on the time of day, different areas of the intertidal zone may be wet or dry. Organisms in this habitat must be able to adapt if they are left “high and dry” when the tide goes out.
- Waves: In some areas, waves hit the intertidal zone with force, and marine animals and plants must be able to protect themselves. Kelp, a type of algae, has a root-like structure called a “holdfast” that it uses to attach to rocks or mussels, thus keeping it in place.
- Salinity: Depending on rainfall, the water in the intertidal zone may be more or less salty, and tidepool organisms must adapt to the increases or decreases in salt throughout the day.

- Temperature: As the tide goes out, tidepools and shallow areas in the intertidal zone will become more vulnerable to temperature changes that occur from increased sunlight or colder weather. Some tidepool animals hide under plants to find shelter from the sun (Kennedy, 2011).

2.3.9.2 Marine Life in the Intertidal Zone

The intertidal zone is home to many species of animals and plants. Many of the animals are invertebrates. Some examples of invertebrates found in tidepools are crabs, urchins, sea stars, sea anemones, barnacles, snails, mussels, and limpets. The intertidal zone is also home to marine vertebrates, some of whom prey on intertidal animals, such as fish, gulls and seals. (Kennedy, 2011).

By and large, the most important and sensitive species associated with Puget Sound and the project area are the salmonids, especially those that are listed as T&E or Species of Concern. Many government agencies and citizen groups are involved in the restoration of Puget Sound, especially its water and sediment quality and habitat that support these important fish species (SKY, 2012a).

2.3.9.3 Subtidal Zone

The subtidal zone lies below the intertidal zone and represents the area that remains submerged at low tide. This area is exposed briefly during extreme low tides around full and new moon events. Subtidal zones typically support a wide diversity of plant and animal species (Seattle Dept. of Transportation, 2012).

Since the late 19th century, the historic Smith Cove estuarine area has been filled with various materials to form the Interbay/Terminal 91 area (Seattle Dept. of Transportation, 2005). Little or no native sediment remains in the Terminal 91 vicinity due to construction, dredging, and other industrial and commercial activities. The subtidal zone at the MRA is limited to a small amount of shoreline and consists of riprap and some natural materials. The restoration areas are discussed in **Section 2.3.2** and include limited subtidal zone. Specific locations of strictly subtidal zone have not been identified nor has detailed information pertaining to tidal activity been obtained.

2.3.10 Cultural Resources

Consistent with Section 106 of the National Historic Preservation Act, The USACE Seattle District prepared a cultural resources report using information provided from diver reconnaissance and acoustic surveys that were conducted in the Area of Potential Effects (APE). The cultural resources report included a search of the Washington Department of Archaeology and Historic Preservation (DAHP) electronic historic sites inventory database, and other background and archival research. Due to safety concerns, monitoring the removal of any WWII-era munitions was not feasible. The USACE sent Tribal Knowledge and Concerns letters to the Muckleshoot and Suquamish tribes on November 22, 2010. The USACE sent a letter to the DAHP initiating consultation and a request for concurrence on the APE. On November 30, 2010, the USACE received concurrence from the DAHP on the APE.

Due to safety and environmental concerns, the DMM and MD recovered during the Piers 90 and 91 RI and TCRA at the FSNSD were recovered and properly disposed of. The DMM and MD date to when the piers were used by the U.S. Navy (1942 to 1976) and are munitions that are commonly used in military actions today. The USACE finds the material ineligible for listing in the National Register of Historic Places. No further cultural resource work is recommended. A cultural resources report was sent on August 25, 2011 to the DAHP, the Suquamish Tribe, and Muckleshoot Tribe, detailing the "No Historic Properties Affected" determination and requesting concurrence. The DAHP replied on August 29, 2011, concurring with the determination. No response was received from the Suquamish Tribe or the Muckleshoot Tribe.

2.4 Previous Munitions Response Actions

2.4.1 Port of Seattle Dive Team Findings

In accordance with POS and USCG security plans for the Smith Cove Cruise Terminal, the POS PD dive team conducts regular underwater inspections of arriving cruise ships and of the piers and seafloor. On April 22, 2010, during a routine dive sweep of the Terminal 91 area, the POS PD dive team encountered military munitions in sediments around Pier 91 (SKY, 2012b).

U.S. Navy EOD personnel responded to the incident and determined that the items were DMM and not UXO. U.S. Navy EOD took possession of these items and responsibility for their disposition. Since this initial discovery, U.S. Navy and U.S. Army EOD have responded to six more instances to recover and dispose of DMM (SKY, 2012b). **Table 2-2** displays the DMM and MD items recovered and disposed of by U.S. Army and U.S. Navy EOD personnel.

Table 2-2 Reportable Material Discovered by Port of Seattle Police Department Dive Team

Reportable Material Discovered by POS PD Dive Team			
Size	**Nomenclature**	**QTY DMM**	**QTY MD**
U.S. Casing, 20mm	Unknown*		1
U.S. Projectile, 40mm	MK Mod 1 Projectile	2	
U.S. Fuze	Mechanical, MK 18		1
U.S. Casing, 3-inch	Unknown*		1
U.S. Projectile, 3-inch	MK 29 Mod 2 AP Round	1	
U.S. Projectile, 3-Inch	MK 23 Series	1	
U.S. Casing, 5-inch	Unknown*		1
U.S. Casing, 5-inch	MK 5, 38Cal Shell Casing	1	
U.S. Projectile, 5-inch	MK 35 Mod 6 AA Round	1	
U.S. Projectile, 5-inch	5-inch MK 15 AP	1	
U.S. Projectile, 5-inch	Unknown Drill Rounds		3
	Total	**7**	**7**

Notes:
AA = anti-aircraft
AP = armor piercing

2.5 Summary of Institutional Analysis

The purpose of the Institutional Analysis (IA) (presented in **Appendix G** of this report) is to gather background information and document which stakeholder entities have jurisdiction over the FSNSD MRA, and to assess the capability and willingness of these entities to assert ICs that would protect the public from explosive hazards potentially present within the limits of the site. More specifically, this report:

- Identifies entities that have jurisdiction over the land within the FUDS MRA;
- Defines authority, responsibility, capability, resources, and the willingness of each entity to participate in ICs to protect the public from explosive hazards;
- Identifies potential IC strategies available to implement access controls and/ or public safety awareness actions for the property; and
- Defines and analyzes intergovernmental relationships, joint responsibilities, LUC functions, technical capabilities, and recommendations (USACE, 2009).

The IA identified four agencies with purview over activities at the FSNSD MRA, three of which have been actively involved in the project to date, and are expected to maintain involvement in both future actions and in the identification and implementation of ICs at the site.

The USACE is the executing agency of actions occurring under the FUDS MMRP. Additionally, the USACE retains regulatory purview of the site under Sections 9 and 10 of the Rivers and Harbors Act of 1899 (33 United States Code [U.S.C.] 401) and Section 404 of the Clean Water Act. The USACE has been, and will continue to be involved throughout all phases of the project.

POS, as landowner, is also the present manager of the Terminal 91 facility, responsible for upland maintenance and security measures, pier maintenance and repair, and dredging activities. POS also owns the subtidal lands inside the Inner Harbor Line. POS has been, and will continue to be involved throughout all phases of the project.

USCG Sector Puget Sound is responsible for on-water law enforcement and for approving the Terminal 91 security plan that led to the POS Police Dive Team sweeps that originally uncovered munitions at the site. USCG has been, and will continue to be involved throughout all phases of the project.

The Regional Code of Washington (RCW) 79.105.060 defines Harbor Areas as “the area of navigable waters determined as provided in Article XV, section 1 of the State Constitution, which shall be forever reserved for landings, wharves, streets, and other conveniences of navigation and commerce”. Washington State Department of Natural Resources (WADNR) has been charged with managing Harbor Areas (shown on **Figure 2-2**) on behalf of the citizens of the State. WADNR has been, and will continue to be involved throughout all phases of the project.

2.5.1 Existing Institutional Controls

The MRA is accessible by individuals from three vectors; entering the water from the tidelands adjacent to the MRA and diving to the seafloor; entering the water from the adjacent pier structures and diving to the seafloor, or diving from a boat.

- Access to the tidelands adjacent to the MRA is available from the public park and beach just east of Elliott Bay Marina. There are no restrictions in place to prevent access to the park.

- Access to Terminal 91 is restricted to approved personnel. Security is maintained through a system of 24-hour guards, gates and physical barriers, signage, video cameras and other standard security measures.
- Access to the surface waters of the MRA is not restricted, although vessel access not directly related to Terminal 91 business and authorized by POS is generally limited to recreational (fishing/yachting) vessels transiting through the southern extent of the MRA to enter or leave Elliott Bay Marina. Neither recreational fishing nor diving was observed within the MRA during any phase of the RI or TCRA field investigations.

POS Security was contacted in 2012 and provided the following guidance on individuals attempting to access the MRA: "Anyone attempting to dive down to the deep sediments from shore or arrive by boat would likely be contacted by POS, possibly detained and then referred to USCG for disposition. POS PD are not authorized to detain individuals for entering the waters of Terminal 91 and fishing or swimming since technically they are not considered trespassers. POS PD would be allowed to detain individuals based on unsafe boating practices, suspicion of intoxication, or illegal activities" (Port of Seattle, 2012).

POS does authorize both construction divers and PD divers to enter the waters of the MRA for maintenance and security purposes. These divers have been instructed by POS not to touch any MEC or MC items they encounter, but rather to report the location to USCG Puget Sound Joint Harbor Operations Center (JHOC) 24 hr. watch: 206-217-6002. The USCG JHOC will:

1. Call the Navy Regional Operations Center (ROC) Battle Watch, then
2. Call the USEPA's Emergency Spill line and National Response Center, & USACE.

The USCG Captain of the Port amended Order 99-10, which established a safety zone in the waters around Terminal 91 and use restrictions at the facility, on November 8, 2012, based on the preliminary findings of this RI field effort. The amendment rescinded the previous order, though required that any munitions items located at the site be immediately reported to USCG.

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3.0 REMEDIAL INVESTIGATION OBJECTIVES

3.1 Data Gap Analysis

Table 3-1 summarizes the data gaps and the investigation activities designed to address them during the RI.

Table 3-1 Data Gap Analysis

Data Gap Analysis		
Site Characterization		
Identified Data Gap	**Cause of Data Gap**	**To be Addressed by:**
Lack of up-to-date and reliable data to define site characteristics such as bathymetry, sediment layering, debris density and dispersal, underwater visibility and underwater currents.	Available site bathymetric data was outdated and not detailed enough to plan surveys. Data from acoustic seafloor surveys were not available. The project team had no direct experience in the subsea conditions specific to the FSNSD MRA.	Collection of multiple acoustic datasets including multibeam echosounder (MBES) to determine seafloor bathymetry, sub-bottom profiler (SBP) to determine sediment layering, and sidescan sonar (SSS) and stationary scanning sonar to determine seafloor debris density and dispersal. Dives by UXO divers and by video-equipped ROV to note subsea conditions and verify acoustic data.
Lack of geophysical data to assist primarily in the determination of vertical extent of munitions contamination, but also to establish the nature and extent of ferrous metallic content on and below the seafloor.	No pre-existing geophysical data from the FSNSD MRA. Potential for pier structures to adversely affect the geophysical data.	The design and implementation of a system of high-pass filters to remove pier affects from the geophysical data followed by DGM within the FSNSD MRA.
MEC Characterization		
Identified Data Gap	**Cause of Data Gap**	**To be Addressed by:**
The nature of the MEC contamination within the MRA.	Data on types of munitions potentially present was limited to a list of munitions recovered by the POS PD dive team in 2010.	Research to identify the types of U.S. Navy vessels which used the facility. Further research to determine a likely armament of those vessels. As the FSNSD was not an ammunition depot, MEC should be limited to the types of munitions present on vessels that used the facility, and should not be UXO.
The horizontal extent of MEC contamination.	No investigation to determine the horizontal extent of potential MEC contamination had occurred. In consultation with project stakeholders, it was determined additional data were necessary to resolve uncertainties with respect to factors relevant to decision making on the relative hazard posed by the MEC at the site.	Obtain global positioning system (GPS) coordinates on all located DMM items. Research historical berthing configurations and determine possible placement of sources of MEC prior to jettisoning. Conduct broad visual surveys using UXO divers and video-equipped ROVs. Conduct geophysical surveys. Conduct intrusive investigations based on DGM data and responses from UXO diver-carried all-metals detectors. Due to

Table 3-1 Data Gap Analysis

Data Gap Analysis		
Site Characterization		
		the location, use and importance of the site, increased data collection was necessary to satisfy stakeholder concerns beyond the base-level necessary to support a qualitative MEC hazard analysis and risk assessment.
The vertical extent of MEC contamination.	No investigation to determine the vertical extent of MEC contamination had occurred. In consultation with project stakeholders, it was determined additional data were necessary to resolve uncertainties with respect to factors relevant to decision making on the relative hazard posed by MEC at the site.	Conduct metallic debris clearance to the maximum extent practicable to increase the effectiveness of DGM, similar to a brush clearance at a terrestrial site. Conduct map and dig intrusive investigations on anomalies modeled on munitions potentially present at the site. Conduct "swim and dig" (mag and dig) intrusive investigations using all-metals detector equipped UXO-divers. Due to the location, use and importance of the site, increased data collection was necessary to satisfy stakeholder concerns beyond the base-level necessary to support a qualitative MEC hazard analysis and risk assessment.
MC Characterization		
Identified Data Gap	**Cause of Data Gap**	**To be Addressed by:**
The nature of potential MC contamination.	Analytical sampling for MC had not previously occurred at the site. In consultation with project stakeholders, it was determined additional data were necessary to resolve uncertainties with respect to factors relevant to decision making on the relative risk posed by MC at the site.	A MC-centered investigation and risk assessment would be conducted as part of the RI.
The extent of potential MC contamination in areas where contamination is above action levels.	Analytical sampling for MC had not previously occurred at the site. In consultation with project stakeholders, it was determined additional data were necessary to resolve uncertainties with respect to factors relevant to decision making on the relative risk posed by MC at the site.	A MC-centered investigation and risk assessment would be conducted as part of the RI.

3.1.1 Preliminary Conceptual Site Models

Preliminary conceptual site models (CSMs) and exposure pathway analyses were developed for access and exposure to MEC hazards for human receptors. In addition, preliminary CSMs for potential exposure to MC-related sediment contamination were developed for both human and ecological receptors during the work planning phase of the RI. Access and exposure to MEC was restricted to only human receptors for the explosive hazards posed by DMM.

A preliminary MEC CSM was developed for the RI work plan (WP) to address potential access and exposure to MEC hazards at the FSNSD MRA by identifying potential contaminant sources and receptors and evaluating the pathways linking them together. A CSM provides a means of communicating basic facts about the site, framing a risk or hazard assessment or analysis, and conducting data gap analysis. CSMs are used as planning tools to integrate information from a variety of resources, to evaluate the information in relation to project objectives and data needs, and to evolve through an iterative process including further data collection or other actions that enhance understanding of the site. Further detail regarding the development of the preliminary CSMs and the background pertaining thereto is provided in **Section 6.1**. The MEC access and exposure pathway analysis was further developed and refined after completion of the RI field activities (see **Section 6.2**, and the revised CSM in **Figure 6-1**). The CSM for exposure to MC was likewise further developed and refined following the field investigation (**Figure 6-2**).

3.1.2 Data Quality Objectives

Data Quality Objectives (DQOs) were developed for the RI during multiple Technical Project Planning (TPP) sessions and presented in the project WP. The DQO process as presented in USEPA's Guidance on Systematic Planning Using the Data Quality Objectives Process (USEPA, 2006) is iterative and is normally applied to operations requiring the application of data gathered as a result of the conduct of analytical sampling. The output from one-step may lead to the reconsideration of prior steps. This iteration leads to more efficient design of data collection operations.

Data users, relevant technical experts, and members of the QC staff participated in the DQO process planning to ensure that their specific needs were included prior to the data collection. DQOs provided the objective basis for quantitative definition of the RI project requirements.

DQOs were developed and used to ensure that the amount, type, and quality of data obtained during the project was adequate to support project decisions with a known level of confidence. The DQOs and analytical sampling DQOs (developed in accordance with the USEPA's Guidance for the project WP) are presented in tabular format below. Geophysical DQOs, which do not follow the USEPA Guidance, are also presented below.

Table 3-2 Munitions and Explosives of Concern Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Munitions and Explosives of Concern Data Quality Objectives for the Piers 90 and 91 Remedial Investigation	
Step	**Data Quality Objective**
1. State the problem	Do MEC items potentially remaining on or below the seafloor surrounding piers 90 and 91 pose an unacceptable explosive hazard or chemical risk to current and RAFLU at the site?
2. Identify the goal of the study	Determine if DMM incidence at the site poses an unacceptable explosive hazard for the RAFLU for the MRA. Supporting this decision will require collection of data on the nature and extent of DMM of sufficient quality to support decision making. Due to the location, use and importance of the site, increased data collection is necessary to satisfy stakeholder concerns beyond the base-level necessary to support a qualitative MEC hazard analysis and risk assessment.
3. Identify the Information Inputs	Information from previous investigations at the site represents key inputs. These include, but are not limited to acoustic data, bathymetric data, DGM, current and future land use information, ROV and diver data, the quantity and types of munitions removed to date, visual observations, historical records and photographs. Other information resources are being sought and evaluated to expand the project team's knowledge of the project site and its vicinity.
4. Define the boundaries of the study	The spatial boundaries of the study area are shown in **Figure 2-2**. The site is approximately 86.7 total acres. The potential human receptors include authorized port personnel, construction workers, and tourists; Native American tribal members are potentially present. Ecological receptors include aquatic vegetation, benthos, marine mammals, seabirds, and demersal fish. Tourists and residents are not considered to be receptors for sediment exposure at this site. The study boundary for marine sediment will be associated with digging boundaries and will be based on the presence of concentrations of MEC/MD in sediment. The temporal boundaries for the fieldwork are the timeframe for RI fieldwork. The MEC that may be present are not anticipated to migrate rapidly or at all, so samples collected during this timeframe will represent site conditions sufficiently to support decision-making.
5. Develop the analytic approach	Based on a conservative qualitative MEC hazard analysis that considers the likelihood of encounters with DMM items; the likelihood of an explosive event associated with a potential encounter, and; potential consequences of an explosive event, does an unacceptable explosive hazard exist for the RAFLU at the site?

Table 3-2 Munitions and Explosives of Concern Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Munitions and Explosives of Concern Data Quality Objectives for the Piers 90 and 91 Remedial Investigation	
Step	**Data Quality Objective**
6. Specify performance or acceptance criteria	The data will be of the quantity and quality necessary to provide technically sound and defensible assessments of potential risks and hazards to human health and the environment. The surface debris clearance, DGM, and intrusive investigations will meet the DQO's and QC procedures discussed in the WP. Every reasonable effort will be made to reduce or eliminate sources of error (e.g., sampling and measurement errors, errors in study design, data transcription and transmission errors, etc.). SOPs relevant to the WP contain methodology to address many of the potential error sources.
7. Develop the plan for obtaining data	The technical approach for the RI is documented in the RI WP. In summary, transects will be cleared of surface metallic debris and objects that may interfere with the deployment of the marine magnetometer array. Moveable debris items will be limited to what the dive team can see and remove from the transect by hand. DGM will occur over the transects. Data will be processed and analyzed to determine if anomaly mapping is possible. A target list will be generated following possible ROV-EM interrogation of the anomalies. UXO Divers will investigate targets to a depth capable of reaching by the diver by visual observation. If the diver cannot access the targets due to depth, another anomaly will be selected. The data collected are to be used to support a logic based qualitative MEC hazard analysis that uses data relevant to nature and extent (i.e., likelihood of encounter), likelihood of explosive event; and consequences of explosive event to determine the relative explosive hazard for the RAFLU. NDAI will be recommended if no hazard is determined. A focused FS evaluation of IC and LUCs will be recommended if a determination of Low hazard is determined. A complete FS evaluation of removal actions will be recommended if hazard is determined to be unacceptably high, such as if caches of munitions are found.

Table 3-3 Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation	
Step	**Data Quality Objective**
1. State the problem	Is there any evidence of DMM releasing MC to the environment? Are levels of MC present at concentrations that may present potential risks to human health or ecological receptors? If there is potential risk to human health and/or ecological receptors, to what extent has MC been released to the environment, and what risk does it pose to human health and the environment? If unacceptable risks are determined to be present, what MMRP response actions(s) is (are) necessary? ***<u>Field investigation is constrained by the following:</u>*** • Dive teams' dive time, depth, physical strain of underwater activities and equipment, and availability of UXO divers. • Timeframe (cruise season). • Site accessibility, especially to consolidated (i.e., subsurface) sediment. • Relocating and sampling of prior locations of DMM and MC from the surface.
2. Identify the goal of the study	The study objective is to determine the risk to public welfare, human health, and the environment attributable to MC at the FSNSD. Desired end state is to generate an RI that addresses both MEC and MC, and develops remedial designs, remedial actions, or no further actions.
3. Identify the Information Inputs	• Historical information, photographs, current and future land use information, results of previous dredging activities, industrial operations, current conditions, detailed history of information regarding past ordnance related activities, and site reconnaissance. • The TCRA conducted prior to the 2012 field season of the RI was also reviewed (SKY, 2012). • Other specific input data include, but are not limited to: acoustic sonar data; sediment topography; bathymetry data; locations of anomalies based on DGM, ROV and diver data, and the numbers and types of munitions removed to date based on the TCRA and 2010 RI field season (SKY, 2012). • Literature resources including human health and ecological media-specific screening levels, MC based on specific DMM extracted from the DoD MIDAS database.

Table 3-3 Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation	
Step	**Data Quality Objective**
4. Define the boundaries of the study	• ***Spatial Boundary:*** The physical boundaries of the Piers 90 and 91 project at the FSNSD MRA are based on historical DoD ownership, which represents the FUDS property (**Figure 2-2**) where munitions activities most likely occurred. The study area is a marine site on both sides and between piers 90 and 91 including areas where the piers overhang the water. • ***Temporal Boundary:*** For the MC investigation, the temporal boundary is the timeframe for RI fieldwork including horizontal and vertical extent sampling and modeling.
5. Develop the analytic approach	• The analytical approach follows the decision logic diagram presented in **Figure 3-1**. • Collect a sediment sample under any DMM discovered to evaluate whether MC has been released to the environment. • Sample and analyze for energetic and propellant compounds associated with types of munitions recovered and determine whether MC are present in sediments above protective screening levels. Biased sampling is planned based upon the condition, location, and density of DMM. Sediment quality benchmarks for energetic compounds are based upon protection of benthos; residential soil and fish consumption RSLs are based on human health. • If MC is present above screening levels in vicinity of recovered DMM, expand investigation to determine extent of MC contamination. A gridded approach and/or modeling will be used to determine extent of contamination. • If risk screen criteria are exceeded, quantify risk further using analytical data to develop exposure point concentrations (EPCs); develop exposure parameters from literature; review data for adequacy for risk assessment purposes, and perform screening-level risk assessments as appropriate. • In RI report, determine appropriate response. Compare to acceptable risk levels to determine whether further action is required.
6. Specify performance or acceptance criteria	• Biased sediment sampling for MC at the DMM location is most likely to determine if contamination is present. All DMM will be recorded per the MEC operations of the project. • The MC explosive analyte list and a cross reference to MC identification of DMM recovered assures the release of MC from DMM. • Analytical analysis will be conducted by a DoD-Environmental Laboratory Accreditation Program (ELAP) certified analytical laboratory and all results subject to verification and validation as describes in the Uniform Federal Policy-Quality Assurance Protection Plan (UFP-QAPP). A sufficient number of samples will be collected to

Table 3-3 Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Munitions Constituents Data Quality Objectives for the Piers 90 and 91 Remedial Investigation	
Step	**Data Quality Objective**
	develop EPCs based on 95% upper confidence levels (UCLs) or the maximum detected value to support the screening-level risk assessments. • The analytical data will meet all the requirements as set forth in the UFP-QAPP (presented in Appendix E in RI WP) and those contractual requirements with the analytical laboratory. These parameters include, among others: precision, accuracy, representativeness, reproducibility, and completeness.
7. Develop the plan for obtaining data	Sample location and the number of samples will be based on the MC sampling decision logic presented in **Figure 3-1**. The decision errors for the RI data collection at the FSNSD exist in two forms: sampling error, and measurement error. These will be controlled by following the project standard operating procedures (SOPs) (Appendix J in RI WP) and the UFP-QAPP (Appendix E of the RI WP). The results of quality assurance (QA)/QC efforts during sample collection and analysis will be used to evaluate the usability of chemical data for decision-making.

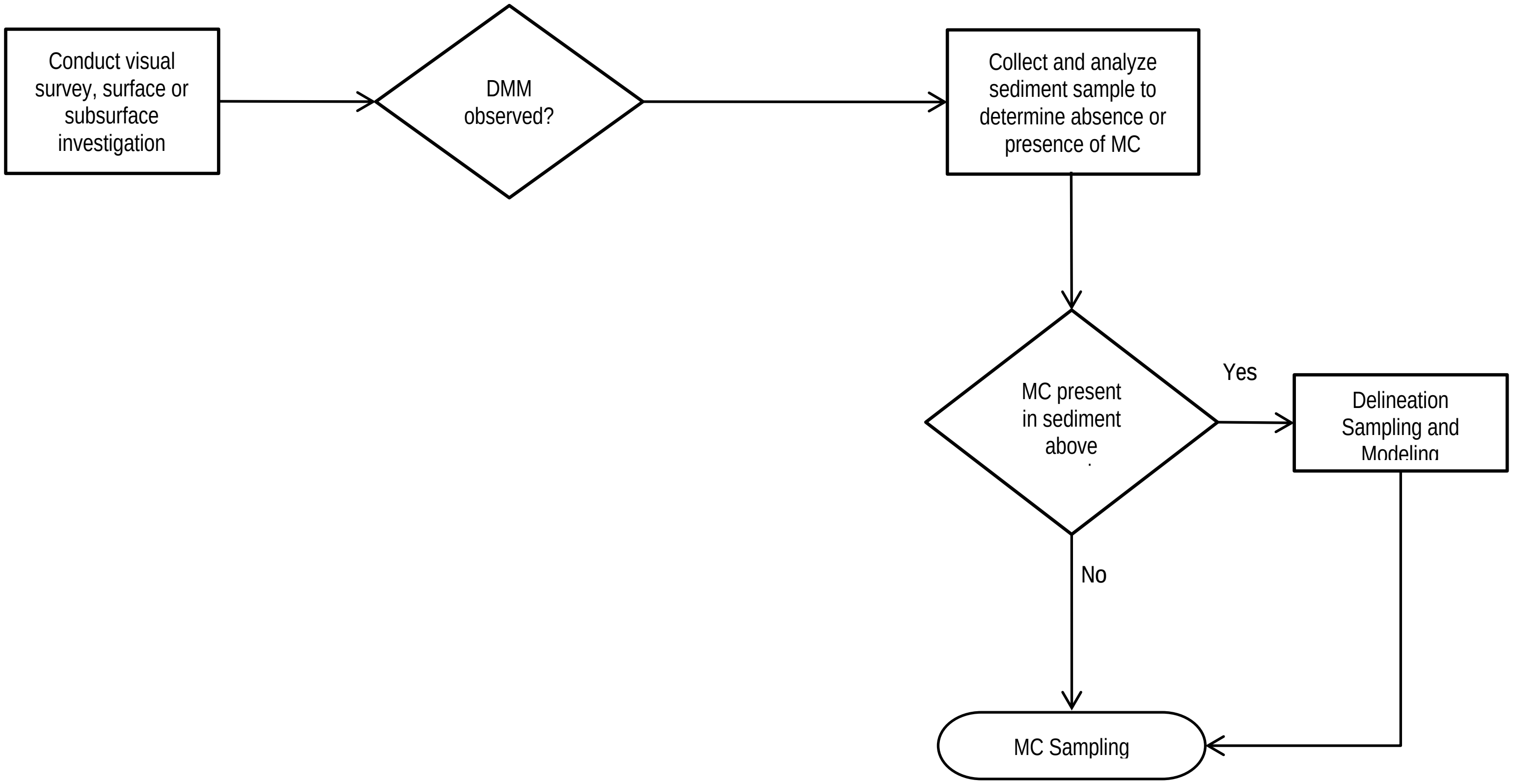
Table 3-4 Geophysical Data Quality Objectives for the Piers 90 and 91 Remedial Investigation

Geophysical Data Quality Objectives for the Piers 90 and 91 Remedial Investigation		
Data Quality Objective	**Test Method**	**DGM Measurement Performance Criteria**
1. Positioning of detected anomalies is accurate	Anomalies selected from validation surveys will be compared with known validation item locations to ensure compliance.	100% of detected validation lane anomalies lie within a 1.0 m radius.
2. Survey speed is appropriate for detection of MEC items	Results of DGM surveys will be evaluated to ensure compliance.	Point-to point speeds will not exceed 4 m per second (m/s).
3. Down-line data density is sufficient to detect MEC items.	Results of DGM surveys will be evaluated to ensure compliance.	98% of the down-line gaps will not exceed 0.20 m.
4. Across-track spacing is sufficient to detect MEC.	Results of DGM surveys will be evaluated to ensure compliance.	A survey days data will be evaluated for across-track gaps that will not exceed 3.0 m for distances >= 100 m for 100% coverage and 100 m for transect coverage surveys unless the gap is caused by obstacle avoidance. Gaps will also be evaluated between adjoining data.
5. Survey coverage is sufficient to meet project objectives.	Results of DGM surveys will be evaluated to ensure compliance.	For transect areas, transects will be complete and continuous for all accessible areas. Breaks in the line will occur where obstacles or other conditions prevent the completion of the line.
6. Appropriate latency corrections are being applied.	Results of Time Calibration and Point Position Tests will be evaluated to ensure compliance.	No visible chevron effects in the data or pseudo-color plots.

3.1.3 Decision Rules

During the TPP process, a decision logic was established to direct collection of MC samples for analysis during the Piers 90 and 91 RI. This decision logic is presented in **Figure 3-1**.

Figure 3-1 Sampling Decision Logic



4.0 DATA COLLECTION PROCEDURES

Section 4.0 documents all RI and TCRA actions at the site. The section is broken into four broader parts. The first part covers the objective, schedule, facilities, and personnel involved in the Piers 90 and 91 project. The remaining parts cover the efforts of each individual field season and TCRA (2010 through 2012) in chronological order.

4.1 Objective and Purpose of the Remedial Investigation

The overall objective of the RI was to define the nature and extent of DMM incidence in the MRA to allow assessment of explosive hazard and risk associated with potential exposure to MC attributable to DMM for the RAFLU with an acceptable degree of uncertainty to allow decision making on the need for remedial action to address the explosive hazard and chemical risk. NDAI would be recommended if no hazard was determined. A focused FS evaluation of IC and LUCs would be recommended if a Low hazard was determined. A complete FS evaluation of removal actions would be recommended if the hazard was determined to be unacceptably high, such as if caches of munitions were found. Data collection focused upon obtaining data necessary to complete a qualitative MEC hazard analysis based primarily on three considerations (source of potential explosive hazard, pathways for exposure to this hazard, and receptors and activities with potential exposure to hazard). Data necessary to perform ecological and human health risk assessments due to potential MC contamination at the MRA were also obtained.

4.2 Schedule of Response Actions and Investigation Field Seasons

Personnel, facilities, and equipment were initially mobilized to the site to begin the field portion of the Piers 90 and 91 RI in December of 2010. Based on reported munitions findings by the POS PD dive team earlier in the year, and the necessity to remove a potential hazard to the coming 2011 cruise season, a TCRA was initiated in mid-January 2011. The TCRA concluded on the last day of March of 2011, prior to the commencement of the cruise season. Information obtained during the 2010 RI field season and the TCRA was analyzed during the spring and summer of 2011. A project WP that was specific to the upcoming 2012 field season was written and procedures to complete the RI were put in place. The 2012 RI field season was initiated in late January 2012, upon the conclusion of the 2011 cruise season. The final day of field operations for the RI was April 11, 2012, with the final daily report covering demobilization filed on April 13, 2012 (SKY, 2012b).

4.3 Facilities

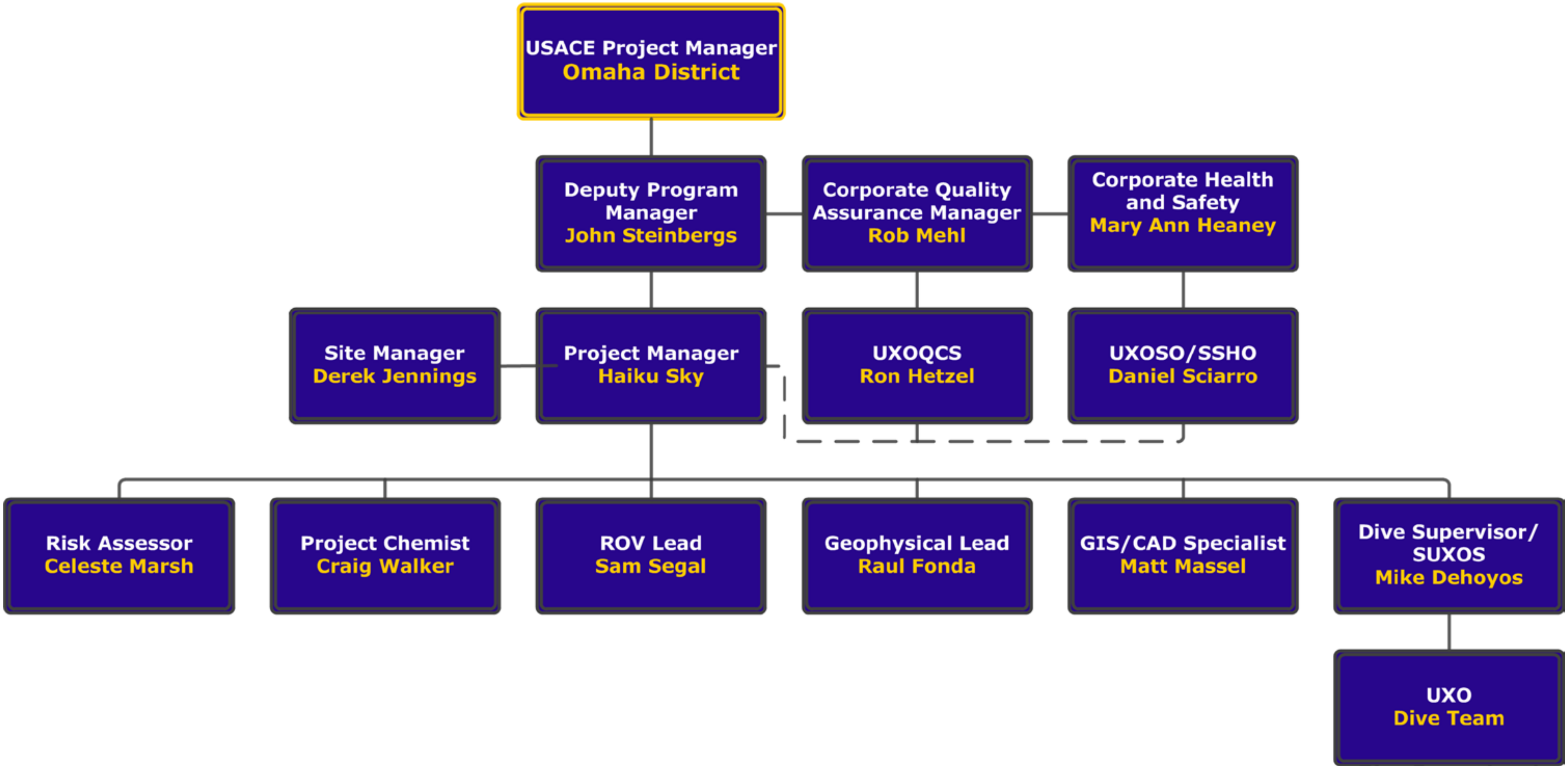
The RI command and control center for the 2010 field season and TCRA was located inside Building A-400 on Pier 90. For the 2012 field season, the RI command and control center was inside a 24 ft x 60 ft mobile office trailer installed on Pier 90 directly north of Building A-400 and the POS Operations building. The command and control center was a fully equipped office space with phone/fax lines, high-speed internet, and other information technology services allowing access to the POS-geographical information system (GIS). The office space also contained a conference room, which was used multiple times to host representatives from POS, USCG and the USACE Omaha, Seattle and Kansas City Districts (SKY, 2012b).

The dive staging area was located at the northeast corner of Pier 91 and encompassed a floating dock and gangway for vessel access, the Mobile Dive Locker for stowage, repair, and resupply of dive equipment, and three small POD storage containers. Two storage containers housed investigation equipment and supplies. The third storage container was powered and housed the real time kinematic (RTK)-GPS base station (SKY, 2012b). This configuration was used throughout all RI and TCRA efforts.

4.4 Personnel

Figure 4-1 provides an illustration of the project team (SKY, 2012b).

Figure 4-1 Remedial Investigation Project Organizational Chart



4.5 Equipment

The following equipment and supplies were used to complete the RI effort:

- A 36 ft Munson aluminum catamaran-hulled marine survey vessel used during the 2012 field season for transect installation, diving operations and as the platform for towing the marine magnetometer array.
- A 31 ft Kingfisher boat used for the entirety of the RI and TCRA. In 2010 and 2011, this vessel was used as the platform for towing the marine magnetometer array. In 2012, it was used primarily as the base of operations for Seabotix ROV activities with a secondary use as a standoff and safety vessel during poor weather conditions.
- An F470 Zodiac boat, an F580 Zodiac boat, and a rigid hull inflatable boat (RHIB) used for dive support and standoff support.
- Two Seabotix LBV300-5 suitcase sized ROVs equipped with a grappler arm, lights, low-light color, and black and white high definition video, sonar, altimeters, scaling lasers and ultrashort baseline (USBL) positioning.
- The U.S. Army's Remotely Operated Underwater Munitions Recover System (ROUMRS), a working class sized ROV equipped with lights, a scaling laser, high definition color video, USBL positioning and two arms with grappling hands manipulated by an operator in a surface control center.
- A marine magnetometer array consisting of five Geometrics G-882 cesium vapor magnetometers spaced on a high-density foam and fiberglass wing, custom A-frame, winch and data acquisition software (DAS) used for marine geophysical data collection.
- An RTK-GPS base station.
- Self-contained underwater breathing apparatus (SCUBA) diving equipment, underwater video cameras, hand tools, GPS units and Fisher and Minelab underwater all-metals detectors.
- Radios, safety equipment, sampling equipment, computer and office equipment, and other consumable supplies (SKY, 2012b).
- Various acoustic sensors including SSS, stationary scanning sonar, MBES and SBP. The specifications for these acoustic sensors are provided in subsections that document the data collection procedures and results for each acoustic sensor.

4.6 Geographical Information System

4.6.1 Data Management Plan

The technology suite deployed at the FSNSD generated a large amount of data, which needed to be analyzed and correlated on a near real-time basis. Therefore, all activities were supported through use of the comprehensive POS-GIS. The POS-GIS was established using standard ESRI tools in addition to a custom relational database and applications. Supporting data and materials were served to the project team via a secure, password-protected internet project portal. The POS-GIS was used to document and archive all relevant project information for the entirety of the Piers 90 and 91 RI and TCRA (SKY, 2012).

4.6.2 Generation of Data

Acoustic, geophysical, ROV and dive activities were conducted during this project, and generated the data in this report. Derivative datasets and associated tabular datasets were created within GIS allowing for presentation, analysis and archiving of all the field data. Assigned GIS specialists were responsible for obtaining all data generated over the life of the project and integrating it into the POS-GIS (SKY, 2012).

The POS-GIS provided full lifecycle tracking of all detected, investigated, characterized, and removed anomalies in a comprehensive database. Tracking included the capture, utilization, and documentation of anomaly information from: (1) detection of anomalies via acoustic surveys, ROV surveys, geophysical surveys, and dive activities; (2) identification of anomalies; to (3) removal of anomalies, including MEC, MD, and non-munitions related debris. The POS-GIS was used on-site daily as a logistics planning and tracking tool to monitor such activities as berthing schedules, survey activities, exclusion zones, status maps and interim reporting, in addition to storing, managing and analyzing spatial data (SKY, 2012).

4.6.3 Data Management, Storage and Security

All project data were uploaded and accessed through an information technology (IT) infrastructure. This infrastructure was comprised of both a storage area network (SAN) and network attached storage (NAS) running on hardware from Network Appliance. Due to the constant advance of operational activities, data needed to be replicated from the primary storage environment to the secondary storage environment every day, ensuring project data were frequently backed up. Additionally, data were replicated to tape twice per month and stored in a secure, offsite location to protect against data loss due to a major disaster. Furthermore, a mirrored server provided data redundancy and security (SKY, 2012).

Data were stored in an Oracle database as well as the common internet file system and network file system (NFS), and could be accessed by a variety of clients and applications. Project GIS data were stored on the Oracle database and accessed utilizing spatial indexing via the ESRI ArcSDE spatial database engine (SKY, 2012).

4.6.4 Data Reporting, Review and Evaluation

All acoustic, ROV, geophysical, pier-top and underwater diver generated data gathered during the project were reviewed for accuracy and completeness, and have been compiled into a deliverable package that accompanies this report. In-progress mapping and reporting was designed and conducted to ensure the completeness and accuracy of data collection. These maps assisted in planning changes when conditions occurred outside of the control of the project team, such as when unanticipated vessel movements or foul weather delays caused loss of access to specific investigation areas (SKY, 2012).

Internal data review occurred daily as part of the field data collection process. This consisted of a QC check by the field crew and quality assurance (QA) data validation from technical staff to ensure the QA/QC process was followed. The technical staff consisted of scientists, engineers, and geophysicists. The technical staff provided a final level of review as the material was sorted and organized for this report. QC evaluation regularly determined the following:

- Spatial integrity of primary and derivative datasets to project datum and coordinate systems.
- Versioning integrity of primary and derivative datasets.
- Data redundancy for project data to within a week of the current date (SKY, 2012).

4.6.5 On-line Data Tools

An online, password protected data portal was established to provide immediate and secure access to project data. This portal specifically:

- Established and maintained initial project information and data.
- Managed all acoustic, ROV, geophysical, pier-top and underwater diver data generated during the project.
- Supported data QC processes involving daily and weekly data logs.
- Stored and distributed all relevant data including maps, graphics, and deliverables.
- Stored and distributed raw and processed imagery.
- Identified features and associated classification results.
- Stored and distributed visual observations collected by the dive team, including dive locations, diver detections, feature identity, video, and pictures (SKY, 2012).

4.7 2010 Remedial Investigation Field Season

December of 2010 marked the initiation of the Piers 90 and 91 RI, which spanned two field seasons. The purpose and authority for the Piers 90 and 91 RI are noted in **Section 2.1**. After mobilizing to the site, the POS-GIS was created to store and manage data for the munitions response. During December of 2010, acoustic data were collected including SSS to map physical items proud of the surface, MBES data to determine bathymetry and bottom features, and SBP data to collect information on sediment layering. UXO divers conducted point-specific bounce dives, area searches and linear swims to report on site conditions and verify collected acoustic data. ROVs were deployed to conduct a visual sweep of portions of the MRA and to verify acoustic data. A marine magnetometer array was also deployed to assess the potential effects of the pier structure on further DGM (SKY, 2012b).

4.7.1 Multibeam Echosounder Data Collection

Geo-referenced MBES sonar data were collected over the FSNSD MRA during the 2010 field season (**Figure 4-3**) and provided a detailed bathymetric assessment of the MRA similar to a topographic survey on a terrestrial site. **Figure 4-2** presents a three dimensional (3D) rendering of the MBES data from the southern perspective at a 2-times vertical exaggeration. Possible scour markings are visible off the eastern side of Pier 91, and possible dredging effects from the 2006 maintenance dredging action may be seen west of Pier 91. To collect the MBES data, a

Kongsberg MBES EM3002 with an Applantix POS MV navigation system was deployed from a 26 ft aluminum jet drive survey vessel (SKY, 2012). MBES completeness was assured by collecting data over planned data collection lines. The line spacing was determined based on the acoustic coverage of the sensor. Data collected are summarized in **Table 4-1**.

Figure 4-2 3D Rendering of Multibeam Echosounder Data

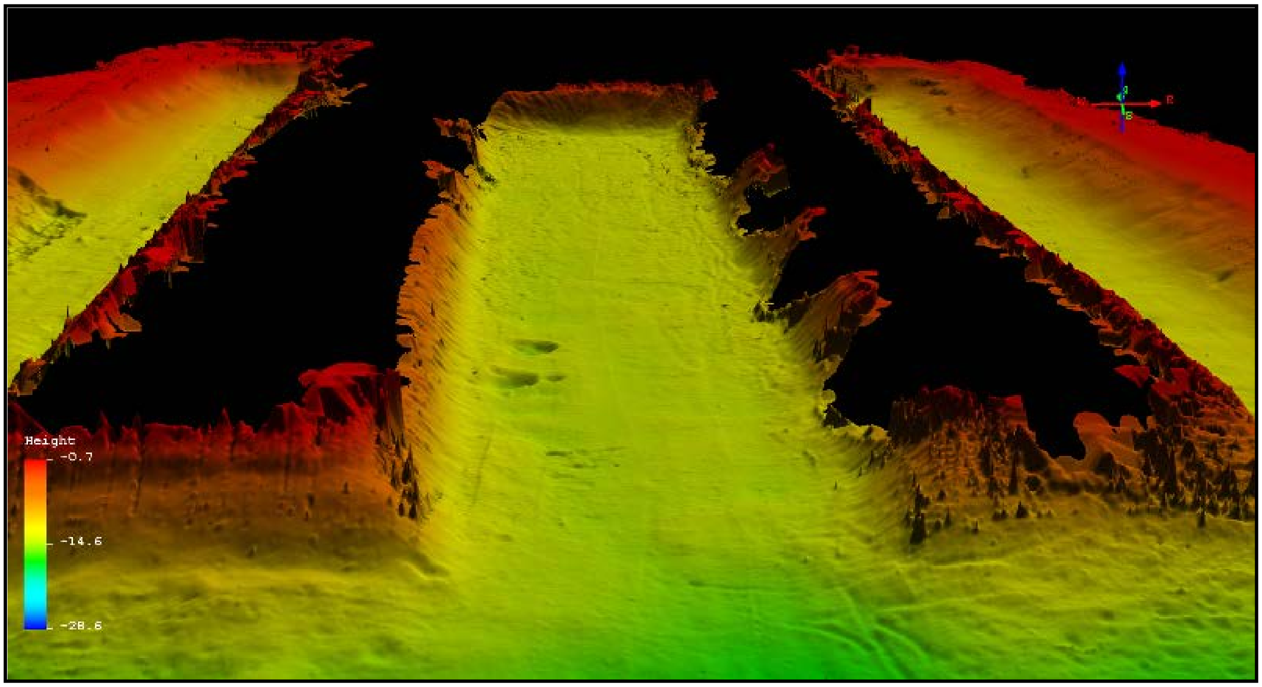


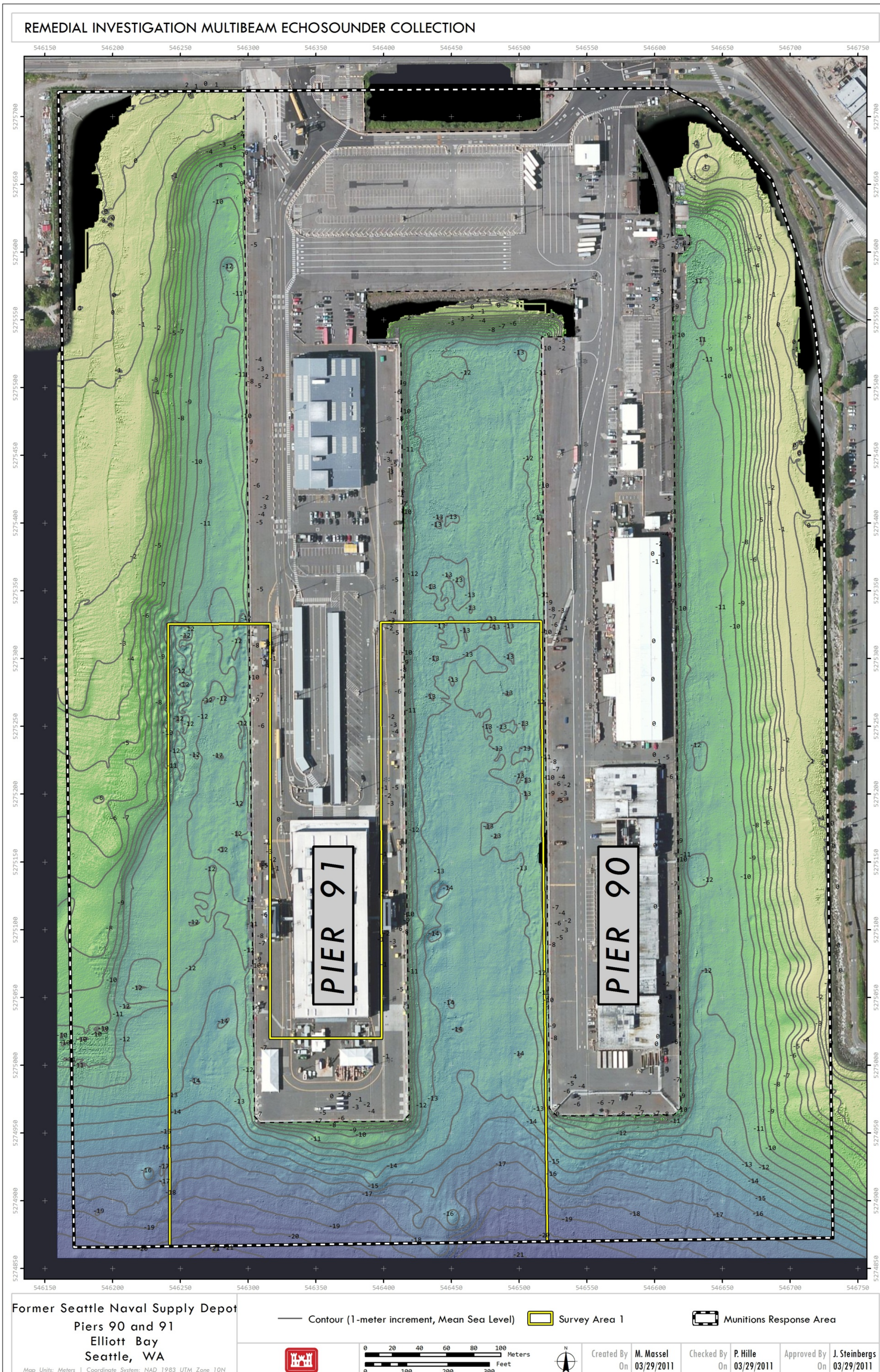
Table 4-1 Multibeam Echosounder Data Details

Multibeam Echosounder Data Details	
Parameters	**Data**
Total number of points processed	2,163,046
Resolution of surface bathymetry raster (all points)	25 centimeters (cm)
Contour interval of surface bathymetry	1 m
Maximum elevation of bathymetry in MRA	3m mean sea level (MSL)
Minimum elevation of bathymetry in MRA	-21.5m MSL
Mean elevation of bathymetry in MRA	-9.3m MSL

The data were processed and analyzed. Results included:

- Slope and bathymetry data.
- Identification of large debris proud of the surface, for subsequent avoidance.
- Characterization of the seafloor, including slope and roughness for support of UXO diver and ROV deployments (SKY, 2012) .

Figure 4-3 Remedial Investigation Multibeam Echosounder Collection



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4.7.2 Sidescan Sonar Data Collection

Geo-referenced SSS data were collected over the entire MRA during the 2010 field season and provided the location and characteristics of anomalies proud of the seafloor (**Figure 4-4**). An Edgetech 4100 600-kiloHertz (kHz) digital Towfish with an Applantix POS MV navigation system deployed from a 26 ft aluminum jet drive survey vessel was used to collect data (SKY, 2012). SSS completeness was assured by collecting data over planned data collection lines. The line spacing was determined based on the acoustic coverage of the sensor. Data collected are summarized in **Table 4-2**, below.

Table 4-2 Sidescan Sonar Feature List

Scan Classification	Quantity
Cable	1
Debris	3
Linear Feature	75
Log	89
Multiple Small Objects	15
Point Object	69
Tires	46
TOTAL	**298**

The resolution of acoustic sensors utilized at the site provides sufficient detail to differentiate logs and pilings from other linear features. Logs are simple to recognize by a data analyst; they are long, linear, and proud of the surface. Any smaller linear feature not clearly identified as a log/piling/etc. is termed a generic linear feature. A point object is a compact item that does not create a linear shadow in the data (SKY, 2012).

The data were processed and analyzed. Results included:

- A list of anomalies detected by SSS.
- A description of each anomaly which included length, width, height above seafloor, and a contact description (log, tire, possible MEC, etc.) (SKY, 2012).

This information was initially collected for three purposes: (1) as a list of possible MEC targets requiring evaluation, (2) for object avoidance during other response actions during the 2010 field season and thereafter, and (3) to attempt to quantify the density of various types of debris on the seafloor to support a determination of whether debris removal was feasible. Following analysis, it was determined that SSS surveys in large, very high clutter port environments are primarily useful as a site characterization tool and not for target locating and selection, though these data remain effective in lower debris density environments.

Geo-referenced SSS maps also served as a GIS layer used by ROV teams during the RI and TCRA at the FSNSD. Displaying the ROV positioning information on top of the SSS layer allowed the ROV operator navigate directly to an anomaly for verification (SKY, 2012).

All acoustic data are presented in the data package accompanying this report.

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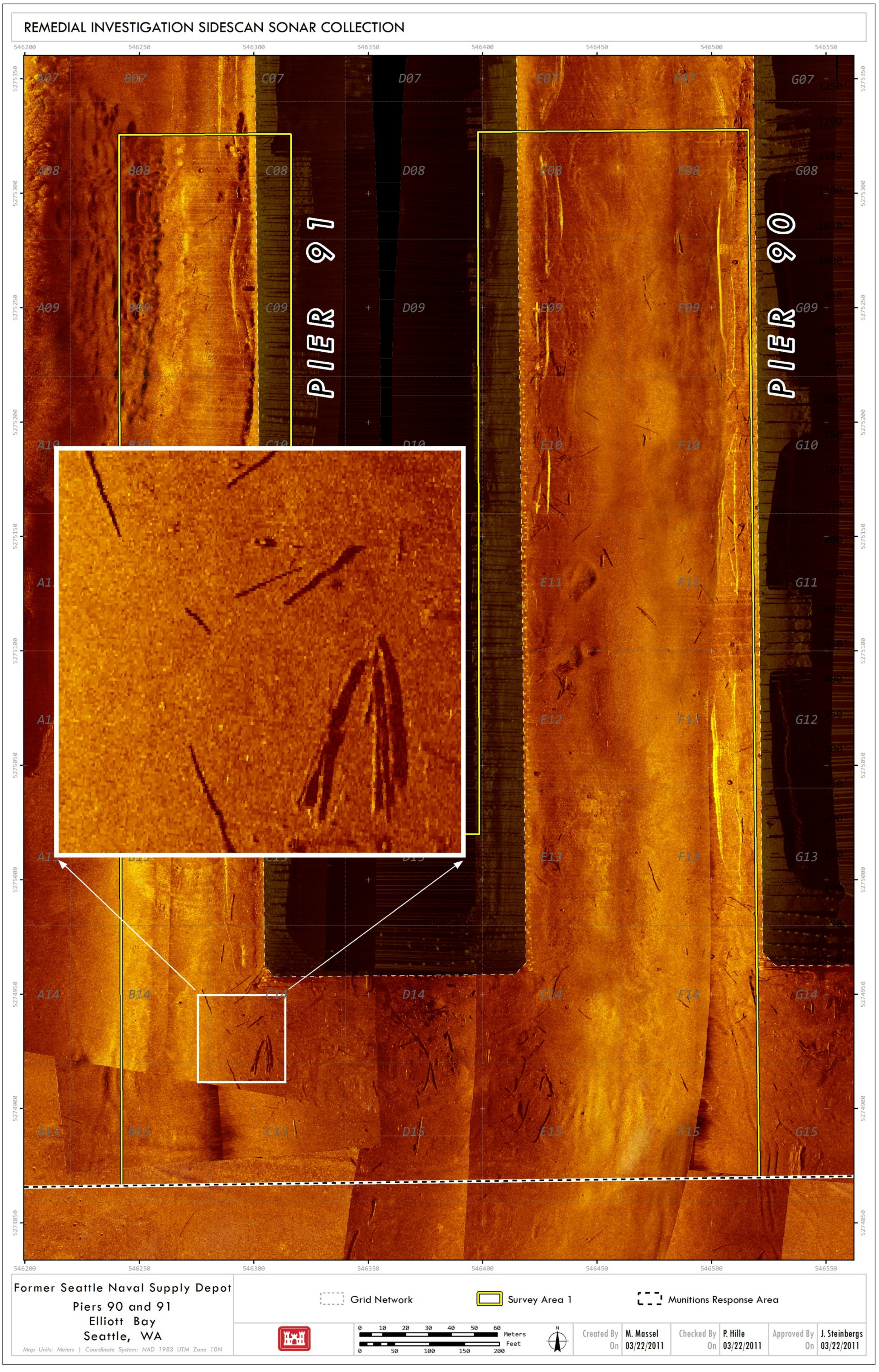
Figure 4-4 Remedial Investigation Sidescan Sonar Collection



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4.7.3 Sub-bottom Profiler Data Collection

Sub-bottom profiler sonar was deployed during the 2010 field season and used to characterize seafloor conditions and sediment layering in the MRA (**Figure 4-6**). SBP sonar transmits a low frequency acoustic wave capable of penetrating the seafloor, and receives the wave after its interaction with the different layers of the seafloor. An Edgetech SB-424 4-24 kHz digital Towfish with an Applantix POS MV navigation system deployed from a 26 ft aluminum jet drive survey vessel was used to collect data (SKY, 2012).

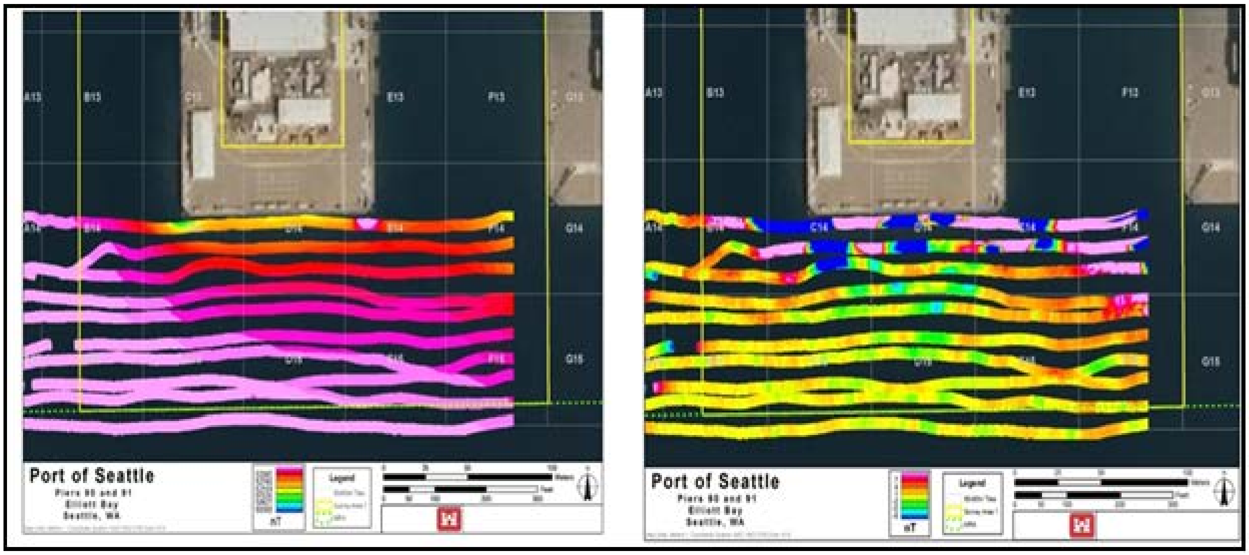
Initial analysis and comparison of these data (collected in December of 2010) occurred later, during the TCRA. This analysis estimated the thickness of soft materials above a hard-packed component layer below. This information was used primarily during the 2012 field season to support ROV and dive team deployments and intrusive investigations. Data were analyzed to determine the presence and location of sub-seafloor anomalies such as sediment layering, trenches filled in with silt, and large subsurface objects of interest. The sediment conditions across the MRA varies significantly, with areas of very shallow sediment less than 30 cm in thickness to areas containing 1-2 m of unconsolidated mud (**Figure 4-6**) (SKY, 2012).

4.7.4 2010 Field Season Geophysical Survey and Data Assessment

During the 2010 field season, a Marine Magnetics SeaSPY magnetometer with an Applantix POS MV navigation system was deployed from a 26 ft aluminum jet drive survey vessel to collect geophysical transect data at 10 m offsets from Pier 91. The sensor array was deployed at 2 m water depth. This depth was used to ensure that signatures from the sea-bottom or pier-top were not complicating the objective of assessing pier effects. As anticipated, the raw data showed heavy effects from the pier. A technique using high-pass filters and gradient measurements to quantify the magnetic signature of the piers was developed and mitigated the effects. The potential for signal degradation due to filter techniques was tested. Filtering techniques were used on the instrument verification strip (IVS) and total field amplitudes were compared. There was less than a 5% drop in amplitudes between standard filtering techniques and the more aggressive filtering used to reduce the pier effects. The effects were removed after filtering for offsets greater than 10 m from the piers (SKY, 2012).

Figure 4-5 displays DGM south of Pier 91, before and after filtering of pier effects from the geophysical data.

Figure 4-5 Pier Effects Filtering of Geophysical Data (Before and After)



4.7.5 Remotely Operated Vehicles

Two Seabotix-LBV300-5 ROVs (shown in **Figure 4-7**) were chosen for the RI and TCRA based on applicable characteristics to perform the assessment tasks, including their small-footprint, launch and recovery capabilities, ease of maneuverability, and integrated sensor package. This system allowed for safe and efficient launch and recovery from either boats or piers while still carrying all sensors required to perform the investigation and assessment activities. The ROVs were equipped with low-light color and black-and-white video, an external 4-head light-emitting diode (LED) multidirectional lighting system, a 120-degree imaging sonar, ground standoff altimeter, a USBL positioning system and a scaling laser. These visual and acoustic imaging tools provided a comprehensive and real-time picture of the seafloor in the area surveyed. The ROV was positioned to approximately 1 m accuracy with the TriTech MicronNAV USBL positioning system, which included multiple transceivers and transponders integrated with RTK-GPS (SKY, 2012).

Remotely operated vehicles were deployed in multiple areas of the MRA during the 2010 field season (**Figure 4-6**). The MRA was divided into an alphanumerical grid for ease of deployment, progress tracking, and later co-registration. The ROVs were initially used to provide visual assessments of bottom conditions in support the preliminary dive reconnaissance at the site. As the RI progressed, the ROVs played a larger role in anomaly investigation, subsurface anomaly marking, and QC activities. These additional ROV operations are covered in later sections of this report, chronologically based on each specific activity. The same ROVs were used for the entirety of the Piers 90 and 91 RI and TCRA activities at the FSNSD MRA.

Figure 4-6 Remedial Investigation Sub-bottom Profiler Collection

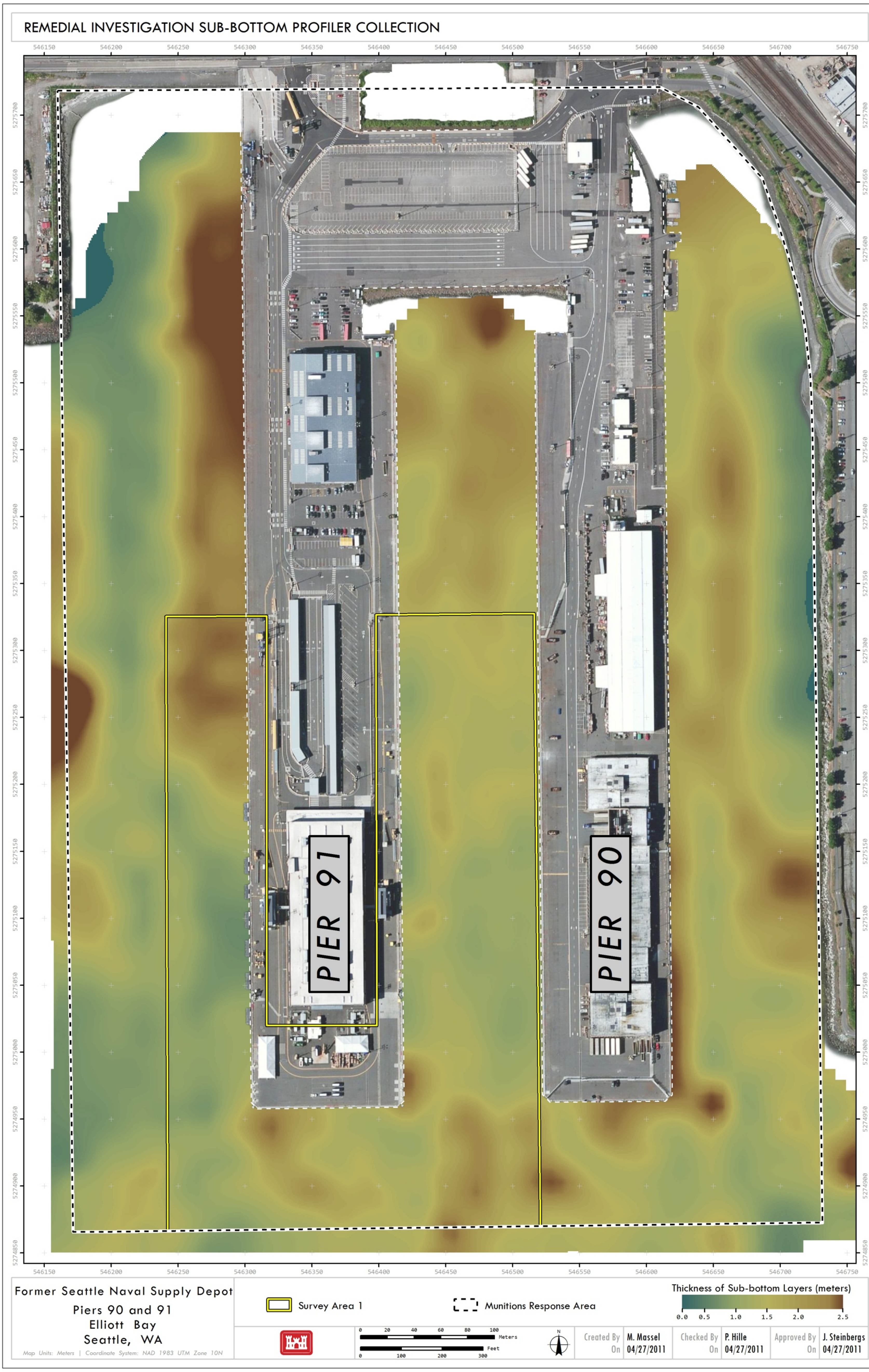


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Figure 4-7 Seabotix LBV300-5 Remotely Operated Vehicle

4.7.5.1 Remotely Operated Vehicle Quality Control Procedures

ROV launch positions were recorded and checked against standard known points on site throughout the TI and TCRA. The ROVs USBL positioning system was verified prior to each survey by utilizing known anomalies. Standard calibration anomalies were routinely imaged with the ROV systems to confirm accuracy of the scaling laser, video systems, and imaging sonar. Output data from the ROV was spot-checked on a daily basis to confirm accuracy of the timestamp and positioning information (SKY, 2012).

4.7.6 2010 Field Season Dive Reconnaissance

Diving operations began at the FSNSD in December of 2010 with a series of reconnaissance dives, using a small team of UXO divers. This team formed the core of all future diving operations within the MRA.

The initial diving reconnaissance at the FSNSD was limited in scope in comparison to follow-on efforts. The dive team completed point-specific bounce dives and area searches by descending to the seafloor in a specific area and conducting a limited reconnaissance of conditions in that area, before ascending to the surface. The dive team used long, linear swims in a transect format to determine conditions across a broad section of the MRA (though primarily in Survey Area 1). Locations of linear swims, area searches and bounce dives, along with recorded findings, are presented in **Figure 4-8**.

The following sections include information on qualifications of the typical dive team and the common team configuration used throughout the Piers 90 and 91 RI and TCRA at the FSNSD.

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Figure 4-8 2010 Field Season Diving and Remotely Operated Vehicles Activities and Results

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4.7.6.1 Unexploded Ordnance Dive Team Composition

All personnel that conducted underwater operations in the MRA successfully completed underwater Navy EOD training and graduated from U.S. Naval EOD School at Indian Head, Maryland, and/or U.S. Naval EOD School at Eglin Air Force Base (AFB), Florida.

A typical dive team operated off a vessel and consisted of:

- A UXO qualified Dive Supervisor.
- A UXO qualified standby diver.
- UXO qualified divers.
- A UXO qualified diver acting as a tender.
- A boat coxswain.

Divers shared dive team responsibilities as necessary to facilitate the dive plan and operational taskings. This approach balanced the diver safety, other project personnel safety, and maximized production rates to meet project schedules (SKY, 2012).

4.7.6.2 Dive Planning and Mobilization

The divers reported to work each morning at 0700 hours (hrs.) and attended a daily dive and safety briefing. The Dive Supervisor issued dive assignments and reviewed all relevant data obtained by the ROVs and other sensors with the dive team for situational awareness. Following these dive briefings, the entire dive team attended an operational briefing with all other site personnel to ensure all units were aware of all site operations and areas of activity. The Senior Unexploded Ordnance Supervisor (SUXOS) and Site Manager provided this briefing (SKY, 2012).

After the completion of all briefings, the dive team conducted pre-dive gear inspections, loaded onto the vessels and made ready for final Dive Supervisor checks. The dive vessel transported the dive team to the area of operation as planned during the dive briefing. The dive team dressed out in SCUBA and completed pre-dive checks (SKY, 2012).

4.7.6.3 Dive Procedures

All diving operations were performed in accordance with USACE Engineers Manual (USACE EM) 385-1-1 (USACE, 2010) and the U.S. Navy Diving and Salvage Manual Revision 6. All anticipated surface and underwater conditions, to include visibility, temperature, currents, etc., were considered:

Surface conditions: No diving was performed when the surface conditions did not permit the diver to maintain depth control. If the sea state was too energetic to transport an injured diver by boat, then dive operations were suspended.

Underwater conditions: Shallow dives are heavily influenced by the surface conditions. No dives were performed if conditions did not permit the diver to maintain depth control.

Temperature: Water temperatures in the low to mid 40's degrees Fahrenheit (ºF) were recorded over the life of the project. Thermal protection for the divers was provided by a 7 mm wetsuit or dry suit depending on diver preference.

Visibility: When poor visibility hampered diving operations, the dive team relocated to an area with increased visibility. In the event that poor visibility was reported throughout the site, diving operations ceased until conditions improved.

Currents: Currents were nil during slack tide and increased to less than .5 knot during tidal shifts. It was incumbent on the diver to report to the Dive Supervisor if he was having difficulty in maintaining position or depth control. Should either of these circumstances have existed the dive was aborted and not resumed until the conditions subsided.

The following list of additional dive details was pertinent to the dive operations:

- Diving operations were conducted in 84 ft of seawater or less.
- Diving was conducted from vessels.
- Maximum single dive bottom times were no greater than 60 minutes, dependent on air consumption, depth, and diver fatigue.
- Direct communications between the Dive Supervisor and the Site Manager and SUXOS were by marine radio and cell phone.
- The diving schedule was five, 10-hour days per week.

4.7.7 2010 Field Season Data Collection Summary

Without readily available data concerning the nature of this marine site (such as topographical maps or orthophotography used in terrestrial investigations), the first phase of the RI was the characterization of the site via collection of data useful in mapping the physical nature and characteristics of the MRA. The MBES survey provided detailed and current bathymetry of the MRA. The SSS provided a first glance at the debris conditions and clutter of the seafloor, while the SBP provided current information on the layers and thickness of sediment potentially containing buried munitions. Geophysical surveys and data assessments developed means for mitigating pier effects, which allowed further geophysical surveys at the site to occur. Seafloor reconnaissance, conducted by ROV or a diver, allowed for verification of the collected datasets and provided firsthand experience operating within the subsea conditions at the MRA. These efforts, which occurred in December of 2010, laid a foundation of site knowledge which allowed future activities to focus toward characterizing the nature and extent of MEC and MC contamination rather than the features of the site itself.

4.8 Time Critical Removal Action

The purpose of the TCRA was to reduce the risk, to the extent possible, that military munitions on the seafloor within Survey Area 1 posed to private and commercial vessel traffic and POS Terminal 91 operations. The TCRA needed to be completed prior to the commencement of the 2011 cruise season. An AM for a TCRA inside Survey Area 1 was approved on December 15, 2010. The TCRA was initiated in January of 2011 and terminated at the end of March of 2011. The TCRA followed the 2010 field season and concluded prior to the commencement of the 2011 POS cruise season. The primary objective of the TCRA was to conduct a 100% surface clearance of all MEC and MD within Survey Area 1, with a secondary objective of continuing to collect data leading to a determination of the nature and extent of MEC.

4.8.1 Scanning Sonar Collected During the Time Critical Removal Action

A Kongsberg MS-1000 scanning sonar mounted on a seafloor tripod and positioned by a Trimble RTK-GPS receiver was used for scanning sonar data collection. Initial deployments of the scanning sonar indicated that a scanning radius of 30 m provided acceptable resolution of objects on the seafloor. Therefore, subsequent scanning sonar data collection were spaced 60 m apart to provide full coverage of Survey Area 1. Since the sonar was stationary, it provided higher resolution data than a SSS, which was deployed from a Towfish behind a surface vessel. The scanning sonar provided object detection and characterization, especially in the channels between and alongside Pier 91 and between piers 90 and 91. Similar to the SSS data, geo-referenced scanning sonar maps and scanning sonar contact reports were generated and analyzed as part of the TCRA (SKY, 2012). Analysis results included a list of anomalies detected by the scanning sonar, which are summarized in **Table 4-3**. A description of each item detected by the scanning sonar was generated and included length, width, height above seafloor, and a contact description (log, tire, possible MEC, etc.). This information was used to quantify the density of various types of debris on the seafloor within Survey Area 1. Following data collection, completeness was assured through the creation of geo-registered maps of the MBES, SSS, and scanning sonar data. Following analysis it was determined that stationary scanning sonar in large, very high clutter port environments is primarily useful as a site characterization tool, and not as a target locating and selection device, though these data remain highly effective in lower debris density environments.

Scanning sonar was not deployed outside of Survey Area 1 during the TCRA, therefore preliminary debris assessments in Survey Area 2 were comprised of SSS and diver/ROV observations.

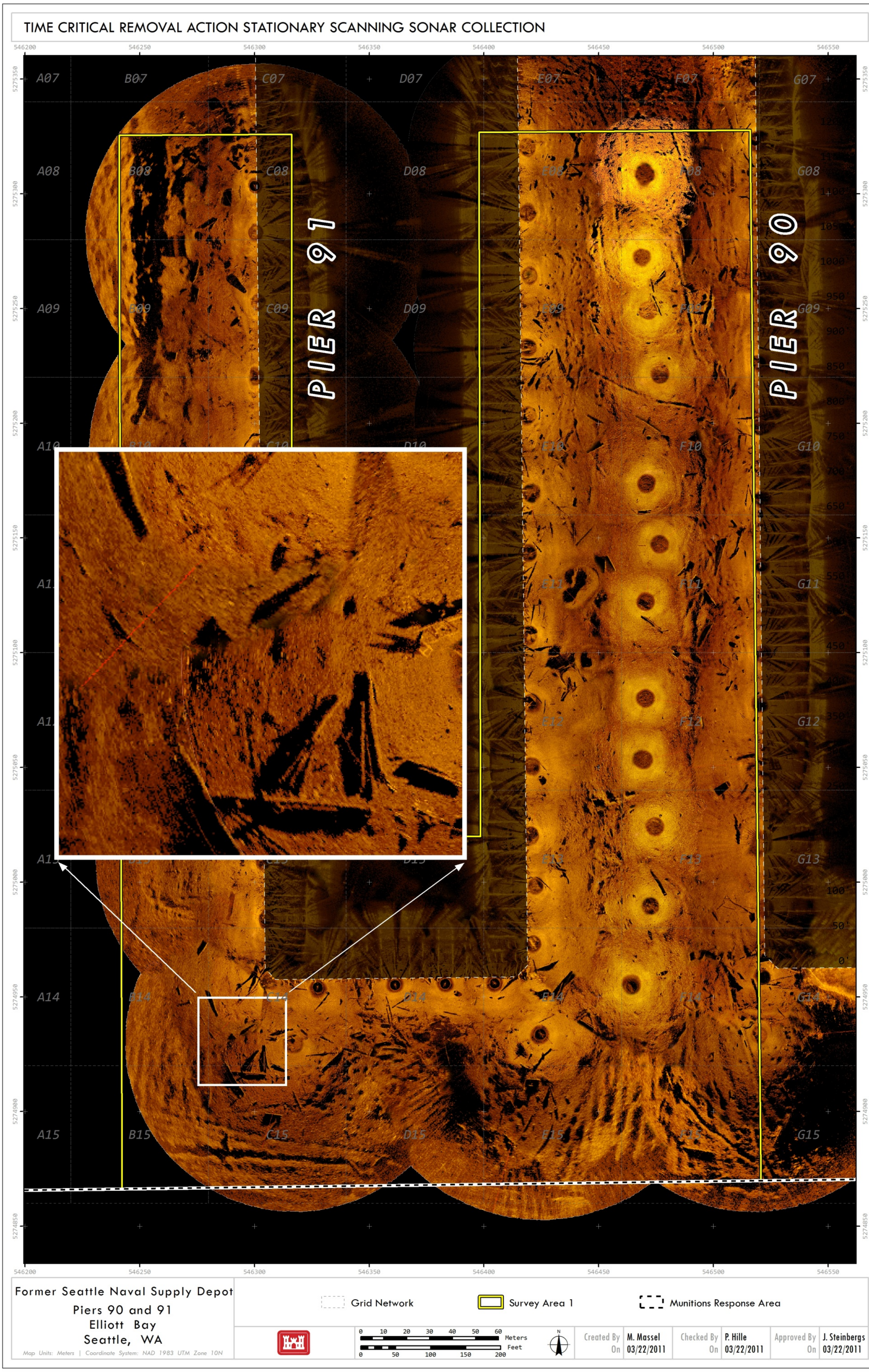
Table 4-3 Scanning Sonar Feature List

Scan Classification	Quantity
Linear Feature	461
Log	116
Point Object	871
Tire	125
TOTAL	**1,573**

Geo-referenced scanning sonar maps, as shown in **Figure 4-13**, also served as a GIS layer used by ROV teams during object reacquisition. Displaying the ROV positioning information on top of the scanning sonar layer allowed the ROV operator to go directly to an anomaly for verification. Since the scanning sonar was stationary, estimated object positions were more accurate than the object positions determined by the SSS. Therefore, the scanning sonar image and anomaly information was utilized wherever it was available (SKY, 2012).

All acoustic data are presented in the data package accompanying this report.

Figure 4-9 Time Critical Removal Action Stationary Scanning Sonar Collection



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4.8.2 Acoustic Quality Control

During the collection of the MBES, SSS and scanning sonar acoustic data, real-time displays were monitored to alert the data collection team to reductions in position and acoustic quality. Data were immediately recollected if errors occurred during a collection. The SSS, scanning sonar and MBES acoustic sensors were evaluated for quality, completeness, and accuracy through a daily review of all output data products and results. Positional accuracy was also evaluated for each acoustic sensor. The MBES sensor was attached to the hull of a survey vessel equipped with RTK-GPS. In contrast, the SSS sensor was towed behind the vessel at a variable length. Comparison of the MBES and SSS data indicated positional error of up to 3 m from the SSS data compared to the MBES data. When large errors were found, the SSS data position was adjusted to match the more accurate MBES or scanning sonar position data. The location of each scanning sonar deployment was determined using a surface GPS positioned above the scanning sonar on the seafloor, providing good positional accuracy of scanning sonar data. For scans that were close to the pier, the pier structure itself provided positional information to properly align the sonar image's position. Additionally, adjacent circular scans were reviewed to assure that large objects appeared at the same location in adjacent images. All scanning sonar data were reviewed for accuracy during the target picking process. Additional procedures included comparing the anomalies identified in both the SSS and scanning sonar data to confirm the positional accuracy of each data set. SSS and scanning sonar data were aligned by matching up similar targets across the two datasets. Once completed, a side-by-side comparison of SSS and scanning sonar data was performed. Results showed the scanning sonar detected all objects in the SSS and more. Additionally, large targets identified in the SSS and scanning sonar data which also had MBES signatures were used to confirm positional co-registration among all three acoustic data sets. A procedure was developed to test the accuracy of the MBES, SSS and scanning sonar against the ROVs USBL. This was accomplished by selecting proud anomalies detected in the acoustic datasets and then visiting the selected anomaly using the ROV. This test was conducted along the western, southern and eastern portions of Pier 91. Positional accuracy of scanning sonar was found to be within 1 m (SKY, 2012), or within the possible positional offset caused by the ROVs USBL positioning system.

4.8.3 Geophysical Survey During the Time Critical Removal Action

The purpose of the geophysical survey conducted during the TCRA at the FSNSD was to assess if geophysics could be effectively utilized for subsurface MEC detection. The main activities associated with this survey were installation of an IVS, collection of data with 100% coverage of Survey Area 1, and assessment of geophysical data (SKY, 2012).

4.8.3.1 Marine Magnetometer Array

A marine magnetometer array (shown in **Figure 4-10**), previously deployed with documented success at the USACE Omaha District's Comprehensive Site Evaluation Phase II at Eglin AFB, was utilized for the Piers 90 and 91 RI and TCRA. The marine magnetometer wing is constructed of high-density foam with a strong fiberglass exterior, making the sensor wing lightweight, durable, and non-magnetic. The platform is equipped with five Geometrics G-882 cesium vapor magnetometers that are spaced 1 m apart to detect the presence of ferrous metallic objects. A custom A-frame structure, weights and a high-speed winch are used to control the wing as it is towed behind a survey vessel. Dual Trimble MS750 GPS receivers provide positions and vessel heading, pitch, and yaw at a rate of ten times per second. A solid-state digital compass mounted to the survey vessel collects pitch and roll data. The system utilizes a state-of-the-art DAS that logs data at 400-Hertz frequency. The DAS has integrated operator guidance software that displays the platform and wing position, and depth information relative to the pre-determined survey lines (SKY, 2012b). The marine magnetometer array arrived at the site in January of 2011.

The marine magnetometer array went through several QC procedures prior to any data collection. The system went through a 15 minute warm-up followed by a sensor check to verify that all systems were operational. After launch, a one minute noise test was collected holding heading and speed with the wing 10 m away from the survey vessel. Four survey lines were then collected at 1.5 m above ground level (AGL) over the IVS lane, with two in each direction to test detection and positional accuracy. The results were compared to the prior IVS survey results. The marine magnetometer array passed all QC checks, and no data quality issues were noted.

Figure 4-10 Marine Magnetometer Array

4.8.3.2 Instrument Verification Strip

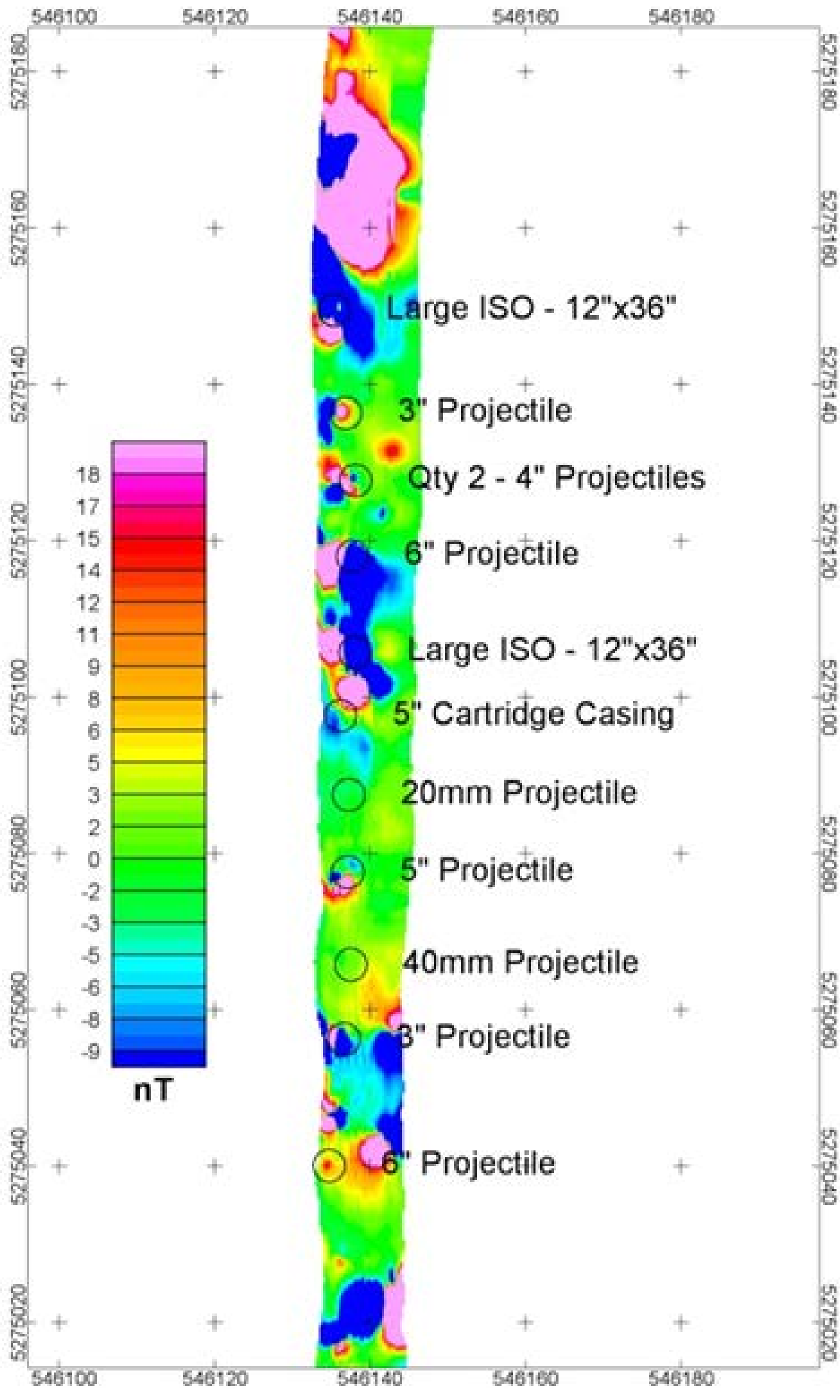
An IVS (shown in **Figure 4-12**) was installed near the site, west of the MRA. This site was selected as it contained the least amount of seafloor debris in the area. Eleven targets were emplaced for assessment, and RTK-GPS positioning was obtained on each target. Industry standard objects (ISOs) were used to simulate munitions targets. ISO selection was based on the range of munitions and munitions related items expected to be found during the survey. **Table 4-4** lists the quantity, placement, and type of simulant. Note that no munitions were emplaced, only items selected to simulate a munitions item.

Table 4-4 Instrument Verification Strip at the FSNSD MRA

Industry Standard Object	Quantity	Placement	Simulated
12-inch x 36-inch diameter metal pipe	2	Separately	Large 12-inch x 36-inch General Object
3-inch diameter metal pipe	2	Separately	3-inch projectile simulant
4-inch diameter metal pipe	2	Together	4-inch projectile simulant
6-inch diameter metal pipe	2	Separately	6-inch projectile simulant
5-inch diameter brass pipe	1	Single Item	5-inch cartridge casing simulant
20mm diameter rebar type metal bar	1	Single Item	20mm projectile simulant
5-inch diameter metal pipe	1	Single Item	5-inch projectile simulant
40mm diameter metal pipe	1	Single Item	40mm projectile

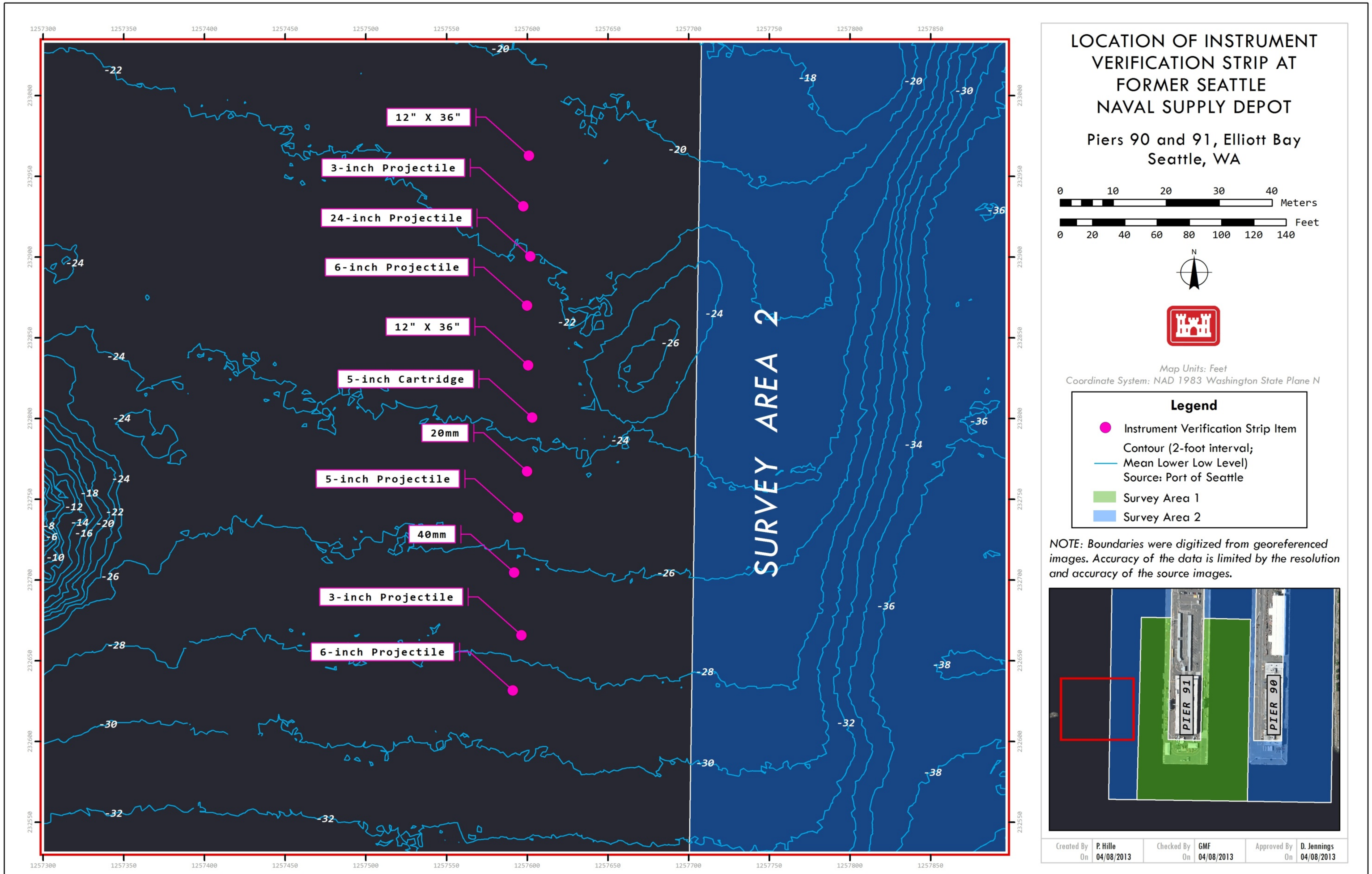
In addition to pre-emplacement background surveys, the marine magnetometer array completed 18 passes over the IVS during the TCRA. The 18 passes over the IVS were conducted to test direction and positional accuracy at different survey altitudes, based on the need for the marine magnetometer array to survey at a range of heights due to the quantity and estimated height of seafloor debris identified in the acoustic surveys. As shown in **Figure 4-11**, the IVS area contained a significant level of in-situ material causing noise in the geophysical data. On each pass, eight of the eleven items were detected. The three undetected items included the 5-inch brass cartridge casing, the 40mm projectile and the 20mm projectile. Non-ferrous items were included in the IVS based on the likelihood of later conducting future electromagnetic (EM) surveys at the FSNSD. Based on data from all passes, the average target detection positional accuracy was determined to be 57 cm (SKY, 2012).

Figure 4-11 Instrument Verification Strip in Digital Geophysical Mapping



The IVS remained in place and was used for multiple magnetometer and diver handheld all-metals detector surveys for the duration of the investigation through 2012. Uses of the IVS separate from TCRA geophysical data verification will be covered chronologically in sections of this report that are based on a specific activity.

Figure 4-12 Location Instrument Verification Strip at Piers 90 and 91



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4.8.3.3 Digital Geophysical Mapping

After execution of the IVS surveys, the marine magnetometer array was deployed to cover 100% of Survey Area 1. The following conclusions were reached upon analyzing the final data:

- Some subsurface items were masked by extensive surface debris signatures.
- DGM was ineffective for subsurface target detection in certain areas due to significant clutter and debris distributed across those areas.
- The effectiveness of geophysics for subsurface MEC target detection would remain unknown until debris clearance and a follow-on geophysical survey occurred.

Figure 4-13 shows the results of the initial magnetometer survey within Survey Area 1 collected during the TCRA. The data are displayed at a scale of +/- 10 nanoTeslas (nT), a range typically used for target detection. As evident from these data, the effects of the debris and clutter on the seafloor generated a strong, continuous, and overlapping magnetic signature across most of the area surveyed. This noise effect masked the possible signature of individual MEC items and made the geophysical mapping approach within Survey Area 1 ineffectual in certain areas without seafloor debris removal (SKY, 2012). This debris clearance would be analogous to a brush clearance and trash cleanup at a terrestrial site prior to DGM.

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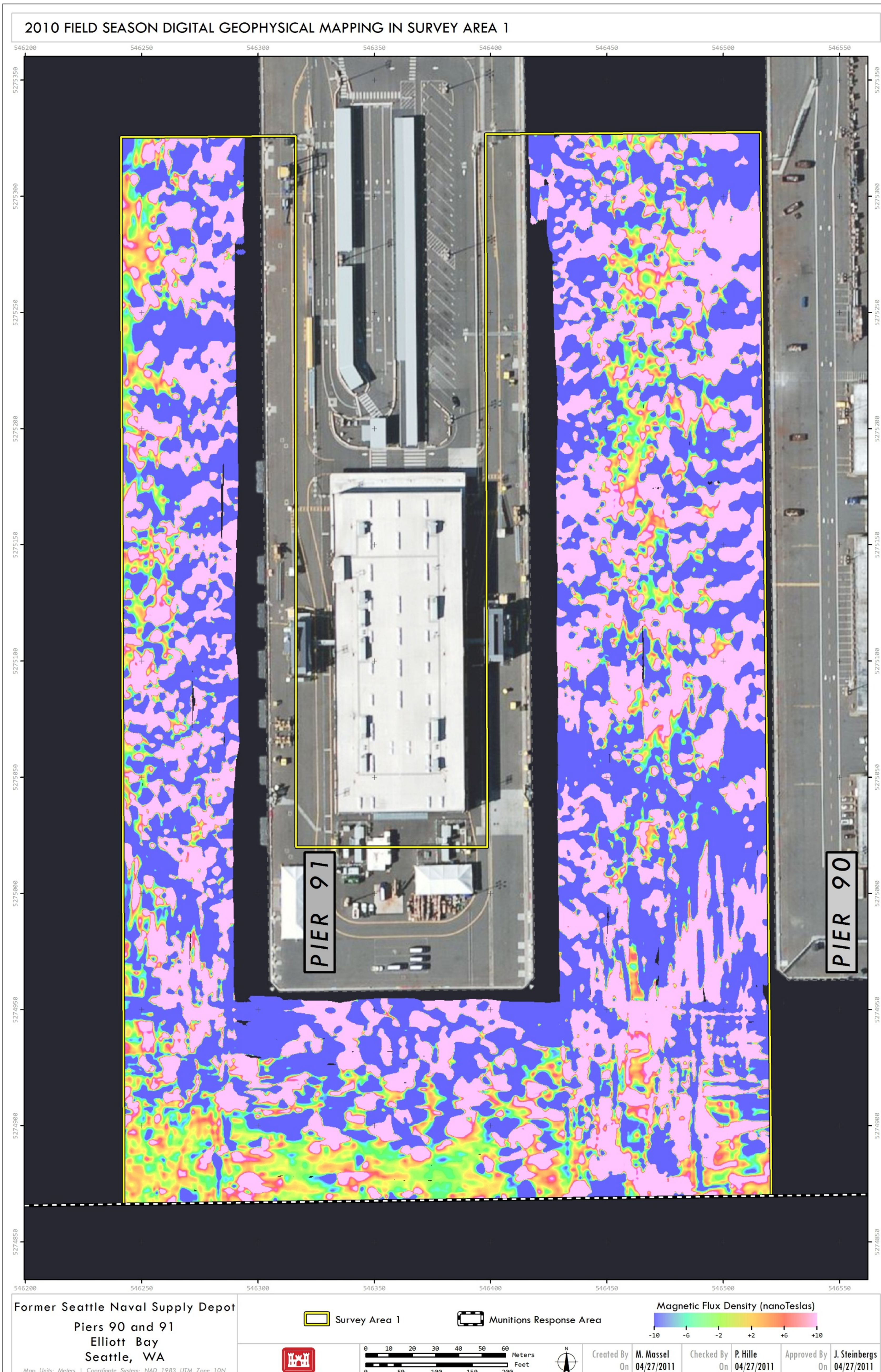
Figure 4-13 2010 Field Season Digital Geophysical Mapping in Survey Area 1



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4.8.4 Surface Clearance During the Time Critical Removal Action

UXO divers conducted a surface clearance of all MD, DMM, and munitions potentially presenting an explosive hazard (MPPEH) inside Survey Area 1. Items located and collected are listed in **Table 4-5**. Survey Area 1, totaling 25.2 acres, was divided into two fundamentally different sections for the diver surface clearance; open areas (21.4 acres) and under pier areas (3.8 acres). **Figure 2-2** delineates the boundaries of open water and under pier areas (SKY, 2012).

Open areas consisted of generally flat, sediment covered areas with heavy debris. Open areas were able to be surveyed by acoustic, DGM, and ROV technologies. Examples of open areas include the channel between piers 90 and 91, and the southern and western-most portions of Survey Area 1 (SKY, 2012).

Pier 91 sits atop an earth berm, slightly narrower than the pier itself. The highest point of this riprap covered berm is under Pier 91, and from this point slopes down to open water. There are gaps between pieces of riprap, and under pier areas are subject to wave action. Pier 91 has also undergone multiple modifications and construction projects over the last 70 years. These under pier areas within Survey Area 1 were surveyed by ROVs and divers (SKY, 2012).

The following sub-sections document the methods used during the surface clearance in both the open and under pier areas (SKY, 2012).

4.8.4.1 Under Pier Area Surface Clearance

The approximately four acres of Survey Area 1 under Pier 91 required a surface clearance of all DMM, munitions potentially presenting an explosive hazard (MPPEH), and MD items. This area slopes from inside the exterior edge of Pier 91 down to the edge of the open area, and is covered in riprap. The outside edges of the pier are supported by piling driven into the seafloor. The areas between these pilings were referred to as “bays”. UXO divers reported minimal debris in the under pier areas. In order to conduct a 100% surface clearance under the pier, UXO diver tandems swam long N/S transects under the eastern and western facing sides of Pier 91. Divers swam east/west (E/W) transects under the southern section of Pier 91. The quantity of individual transects required to completely clear an area was determined by the visibility conditions on the bottom, similar to the swaths divers would swim while performing the open area searches detailed below. During the surface clearance under the pier, divers thoroughly inspected the surface of the riprap and gaps in the riprap for potential DMM/MPPEH and MD. Zero DMM/MPPEH or MD items were located under the pier during the surface clearance. QC of these areas was accomplished by ROV, covered in **Section 4.8.12** (SKY, 2012).

4.8.4.2 Open Area Surface Clearance

UXO divers conducted a 100% surface clearance of DMM, MD and MPPEH in all open-water areas of Survey Area 1. The generally flat, sediment covered surface of the open area allowed the divers to utilize different surface clearance methods than during the clearance under the pier. The following subsections describe the open area surface clearance in detail. QC of these areas was accomplished by ROV, covered in **Section 4.8.12** (SKY, 2012).

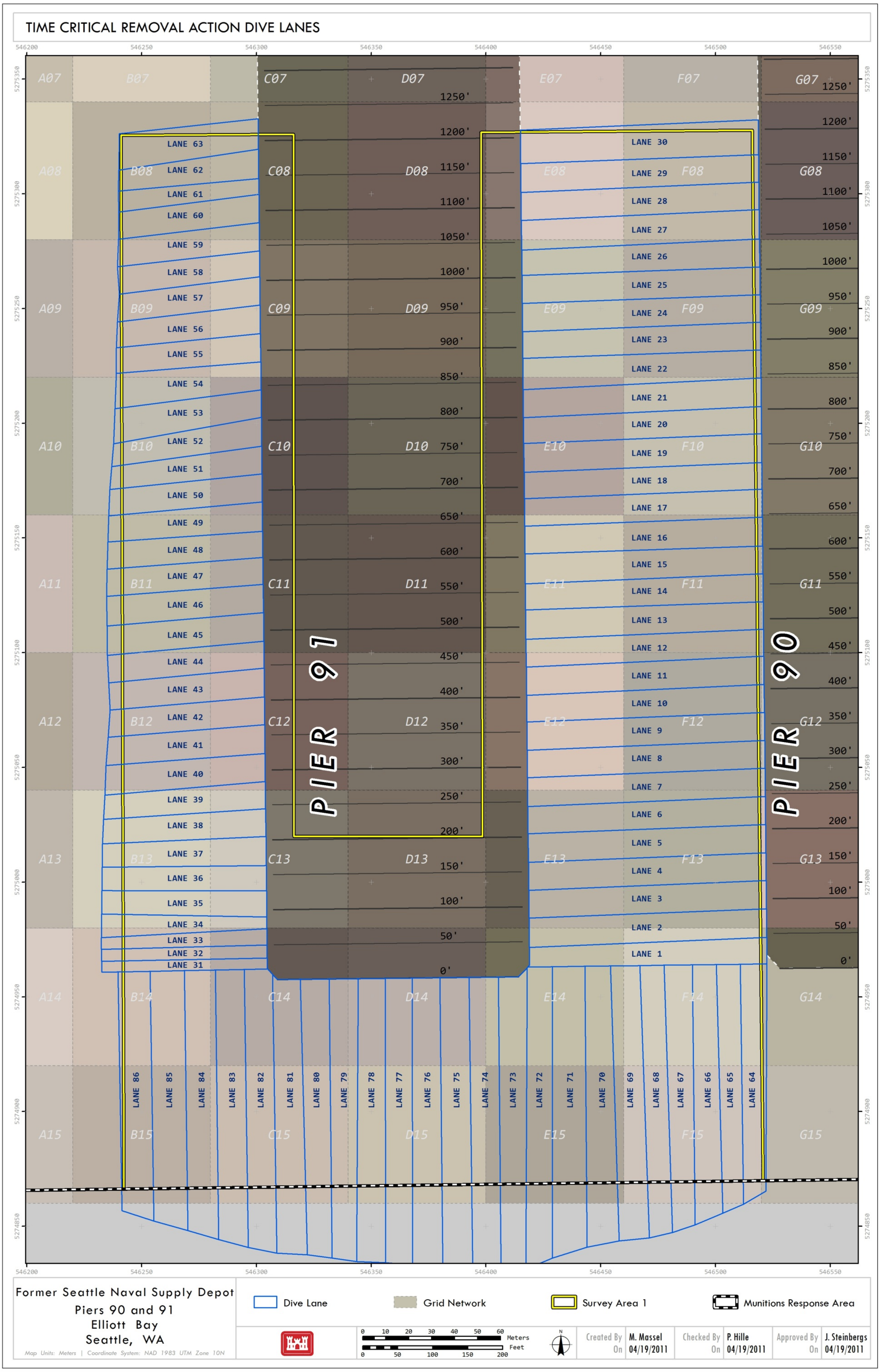
4.8.5 Dive Lane Installation

In order to ensure complete 100% coverage of Survey Area 1 during the surface clearance, divers employed the Jackstay search method. A physical grid system is required on the bottom in order to perform a Jackstay search. This section details the installation of that system, which provided smaller search areas referred to as “dive lanes” (SKY, 2012).

Dive lanes were created between piers 90 & 91 by securing Start/Finish cable lines to pier piling on the western side of Pier 90, and the eastern side of Pier 91. Lines were secured to the piling with chokers, and weighted as necessary to achieve a consistent separation from the seafloor. Start/Finish lines consisted of 12 gauge plastic-coated copper strands, and were installed beginning at the southern end of the channel and spaced every 40 ft north until lanes reached the northern border of Survey Area 1. Thirty lanes were installed in the area between piers 90 & 91, numbered #1 through #30. Thirty-three lanes were installed west of Pier 91, numbered #31 through #63. Lanes #31 through #34 were spaced approximately 20 ft N/S. The remaining lanes were spaced approximately 40 ft N/S. West of Pier 91, the eastern end of each Start/Finish line was secured to a pier piling under Pier 91 via choker. The western end of each line was secured to a ¼ inch steel Baseline cable located on the seafloor of the western-most boundary of Survey Area 1. This Baseline cable ran in a N/S direction from the northwestern-most point of Survey Area 1 to a point parallel with the southern edge of Pier 91. Lanes south of the piers were installed by securing Start/Finish lines to three east/west (E/W) Baselines and two N/S Baselines. One E/W Baseline was installed along the length of Survey Area 1’s southern boundary. The second E/W Baseline was installed from the southwestern most edge of Pier 91 to the western border of Survey Area 1. The third E/W Baseline was installed between the southern edges of piers 90 & 91. Two N/S Baselines were installed on either side of the search area. Start/Finish lines were then installed to create dive lanes every 40 ft across Survey Area 1, for a total of 23 more lanes numbered #64 through #86 (SKY, 2012).

At the end of this process, a complete grid system of dive lanes had been installed on the seafloor throughout the entirety of Survey Area 1. **Figure 4-14** shows dive lane layout (SKY, 2012).

Figure 4-14 Time Critical Removal Action Dive Lanes



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4.8.6 Jackstay Method

The Jackstay method was employed by UXO divers to conduct a 100% surface clearance of a dive lane. Jackstay procedures are defined as follows: Two divers swim together, one on each side of a 12ga. plastic-coated copper strand Highway line, thereby visually searching the area immediately to either side of the line (**Figure 4-15**). Each end of the Highway line is secured to a different Start/Finish line and stretched across a dive lane. Once divers have completed the sweep, they then reset that end of the Highway line a defined distance further into the search area, so that the line now runs at a slight angle to its original course. Divers then sweep back along the Highway line, visually searching much of the same ground over again. Once divers reach the start point they move that side of the Highway line a distance further into the search area, so that the line is once again parallel to its original course. Divers then repeat the pattern until they cover the entire dive lane. The Jackstay method provides a minimum of 100% search area coverage. Moving one end of the Highway line at a time means search areas overlap, resulting in overlapping coverage (SKY, 2012).

Figure 4-15 Jackstay Surface Clearance Methodology, First Pass

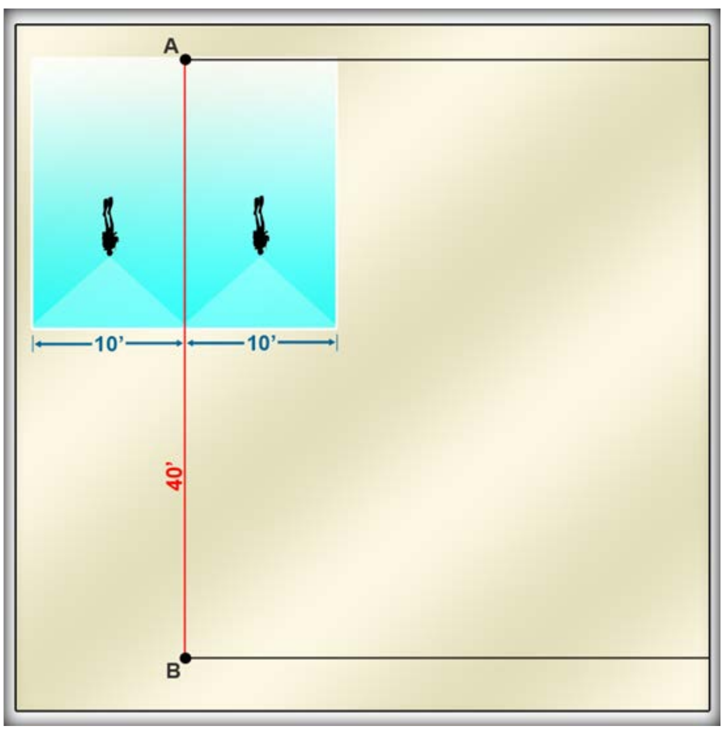


Figure 4-15 displays the first step in the Jackstay method. UXO divers swim in tandem (one on each side of the Highway line) from Point A to Point B (located on the Start/Finish lines). Their distance from the Highway line is determined by visibility conditions in the search area. In this diagram, each diver is able to sweep a swath 10 ft wide. The red line indicates the Highway line (SKY, 2012).

Figure 4-16 Jackstay Surface Clearance Methodology, Second Pass

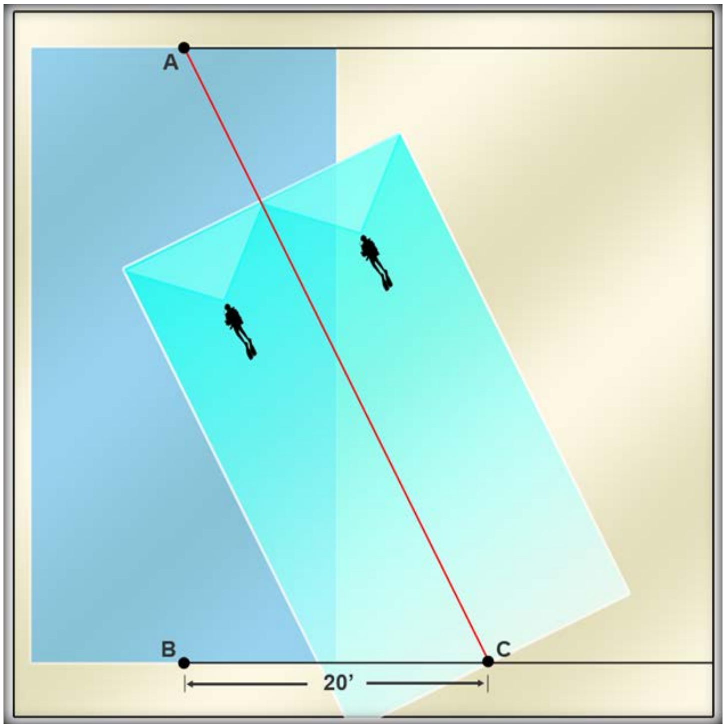


Figure 4-16 displays the second step in the Jackstay method. Once the divers reach Point B, they disconnect the Highway line and reconnect it at Point C, 20 ft east along the Start/Finish line. The distance between Points B and C is established by swath width. The divers then swim back to Point A along opposing sides of the Highway line, conducting a surface clearance along the way (SKY, 2012).

Figure 4-17 Jackstay Surface Clearance Methodology, Third Pass

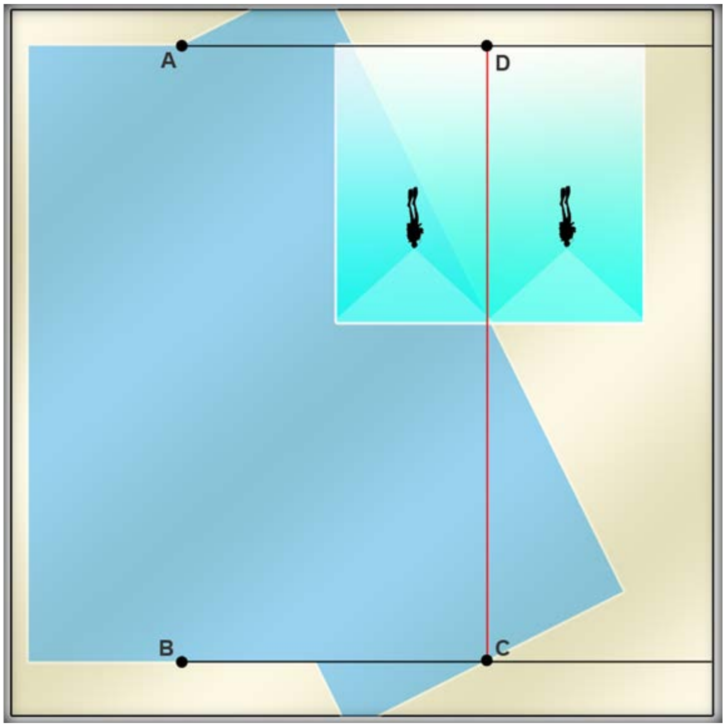


Figure 4-17 displays the third step of the Jackstay method. When the divers reach Point A, the Highway line is disconnected from the Start/Finish line and reconnected at Point D, 20 ft east of Point A. The divers then swim from Point D to Point C, surface clearing 10 ft swaths (SKY, 2012).

The Jackstay procedure is repeated until the UXO divers have completed a 100% surface clearance of their assigned dive lane. Visibility was the primary factor determining swath width. In periods of lower visibility, UXO divers reduced their swath to the maximum width they were able to effectively cover. Movement of the Highway line (from Point B to Point C and from Point A to Point D) was reduced to a distance proportionate with the swim swath (SKY, 2012).

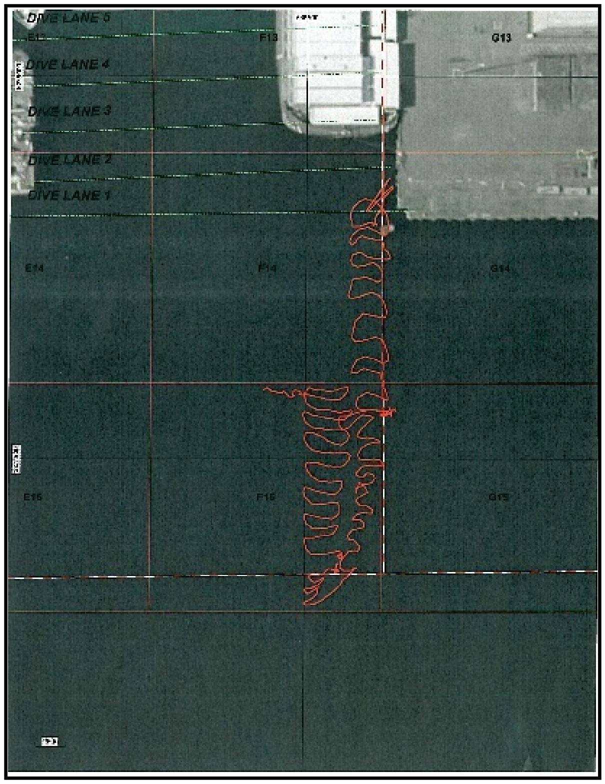
4.8.7 Dive Lane Global Positioning System Tracking

The UXO divers were tracked within each dive lane by GPS. GPS was attached to one member of the dive set (a pair of divers working together on the seafloor during one complete dive) by a line connecting a diver on the bottom to a self-plumbing buoy with GPS at the surface. At times, the line between buoy and diver exceeded 80 ft. The self-plumbing nature of the buoy provided an approximation of the dive sets' general location (SKY, 2012).

Figure 4-18 is a track of a dive set performing the Jackstay method in dive lane #64 and the southern half of dive lane #65. The GPS tracks provided an additional verification/QC method that the surface clearance had been performed appropriately. Formal QC of the diver surface clearance was performed by ROV (SKY, 2012). Multiple methods of diver positioning were evaluated for the Piers 90 and 91 RI including GPS, USBL, and CobraTAC. It was determined that in high-clutter port environments, difficulty existed in accurately positioning a UXO diver with the same degree of certainty equal to the cm level of accuracy provided by the marine magnetometer array or the approximately 1 m level accuracy provided by the ROV.

When finding a potential DMM/MPPEH item, divers would hover over the item to obtain a general GPS position. Divers would also physically tie the item into the grid system to ease reacquisition.

Figure 4-18 Time Critical Removal Action Diver Tracking



4.8.8 Dive Reporting

UXO divers had direct communication with the Dive Supervisor. Visibility, currents, bottom conditions and munitions-related finds were reported in real-time and logged in the vessel. Upon reaching the surface after completing a dive, the dive set members would board the vessel and doff their dive gear. They would then immediately provide a complete log of the dive, including bottom conditions such as currents and visibility, to verify previously recorded information. Divers would also verify information relating to potential DMM/MPPEH and MD type and quantity located. At the end of each dive day during the TCRA, the Dive Supervisor would compile all written dive logs into one complete Dive Report of the days' activities, and turn that report into the SUXOS. The SUXOS and Site Manager would then review the report with the Dive Supervisor. The SUXOS would also check the Dive Reports against the GPS tracks shown in **Figure 4-18** obtained by the self-plumbing GPS buoy (SKY, 2012).

4.8.9 Time Critical Removal Action Reportable Material Discovered

Table 4-5 lists items discovered during the surface clearance and removed from Survey Area 1 during the TCRA (SKY, 2012).

Table 4-5 Time Critical Removal Action Reportable Materials Discovered

Size	Nomenclature	QTY DMM	QTY MD
Small Arms	.30 Caliber (Cal)	-	4
Small Arms	9mm	-	2
Small Arms	.45 Cal	-	1
Small Arms	.50 Cal	-	20
Small Arms	12 Ga.	-	2
Small Arms	30.06	-	6
U.S. Casing, 20mm	Unknown*	0	147
U.S. Projectile, 20mm	Unknown*	1	0
U.S. Casing, 30mm	Unknown*	0	5
U.S. Casing, 40mm	Unknown*	0	7
U.S. Projectile, 40mm	Unknown*	2	0
U.S. Casing, 3-inch	Unknown*	0	5
U.S. Projectile, 3-inch	Unknown*	6	0
U.S. Casing, 5-inch	Unknown*	0	6
U.S. Projectile, 5-inch	Unknown*	3	0
Various sizes**	Pyro./munitions related	0	7
	TOTAL	**12**	**212**

Notes:
* = Nomenclature was not obtained from U.S. Army EOD prior to disposition.
** = Includes flares
- = Small Arms ammunition do not qualify for DMM status

4.8.9.1 Locations of Materials Found During the Time Critical Removal Action

Twelve DMM items were located at 10 separate locations within Survey Area 1. Information regarding the disposition of these items is located in **Appendix A**. **Figure 4-19** shows DMM type, date found, and location. **Figure 4-20** shows location and quantity of MD items found in Survey Area 1, and displays quantities in concentrations found per dive within a specific area (SKY, 2012).

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Figure 4-19 Time Critical Removal Action Location of Discarded Military Munitions

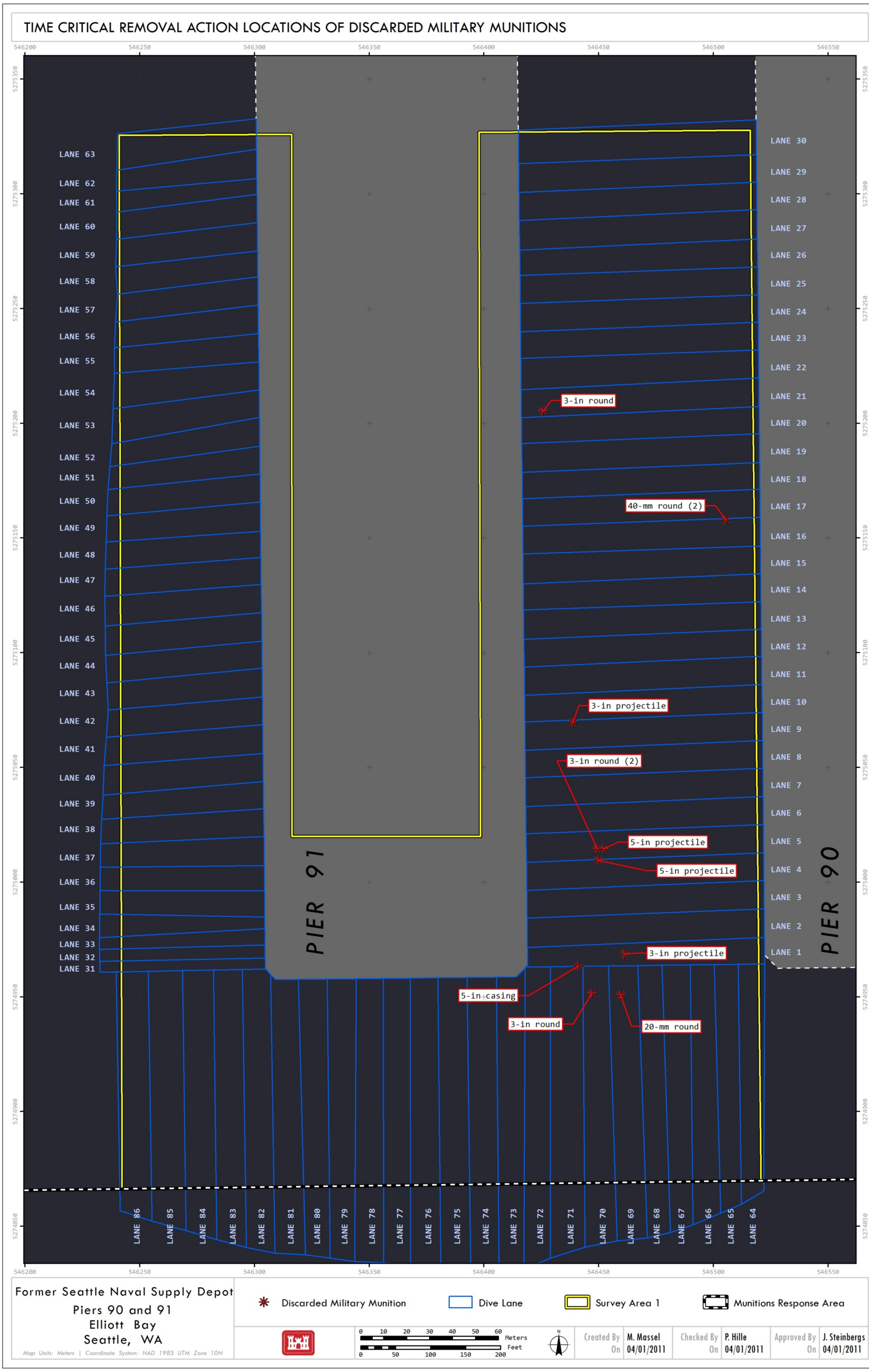

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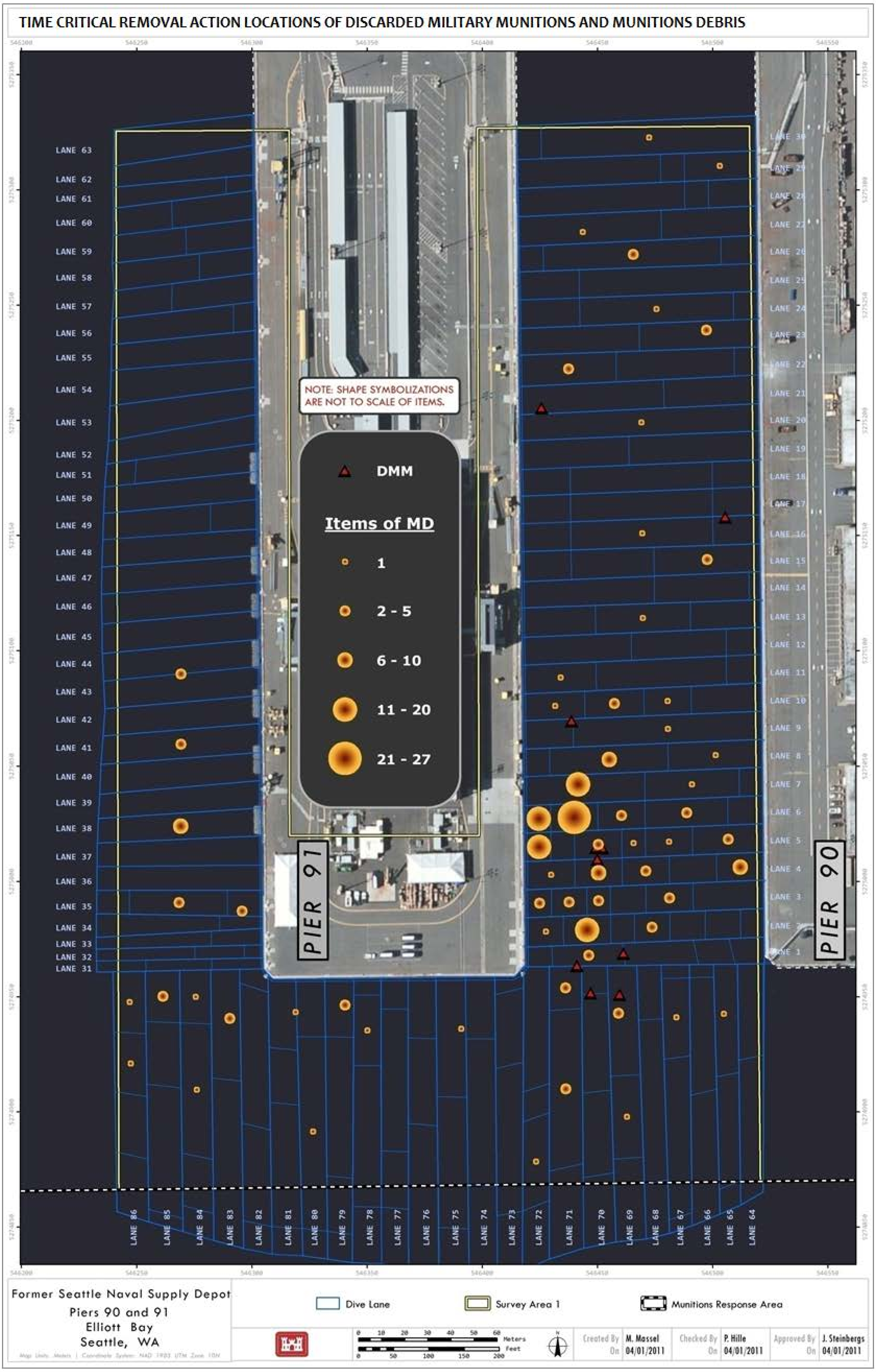
Figure 4-20 Time Critical Removal Action Location of Discarded Military Munitions and Munitions Debris



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4.8.10 Time Critical Removal Action Munitions Disposition

U.S. Army EOD personnel from JBLM took possession of all DMM and some MD items on March 30, 2011. Along with the 12 DMM items discovered, EOD took possession of 53 items classified as MD, for a total of 65 items. The remaining MD items were turned over to a qualified MD recycler on March 31, 2011. Department of Defense (DoD) Form 1348 Issue Release/Receipt Documents were completed for all MEC/MD items. Following final disposition, EOD from JBLM completed Department of the Army (DA) Form 3265 Explosive Ordnance Incident Report. Copies of these forms are located in **Appendix A** of this report.

4.8.11 Time Critical Removal Action Remotely Operated Vehicle Surveys

Remotely operated vehicle visual surveys were performed in Survey Area 1. The purpose of the ROV visual surveys was to investigate sonar anomalies (beginning with SSS then transitioning to higher frequency stationary scanning sonar anomalies as the data became available), to conduct visual reconnaissance of bottom conditions, and to execute QC of dive lane and bay surface clearances. On a grid-by-grid basis (using the previously described alphanumeric grids), a comprehensive assessment of bottom conditions was provided to the UXO divers to supplement the divers understanding of the sea bottom to support and improve the surface clearance (SKY, 2012). This method of providing situational awareness to the divers by dual-use of other survey datasets was significantly refined over the course of the RI, and reached its peak during the 2012 field season by providing the dive teams with a useable version of the site data model, covered in **Section 4.9.2**.

4.8.11.1 Remotely Operated Vehicle Survey Procedures

Remotely operated vehicles were used to perform visual surveys underwater and provided dive teams with a rapid and effective capability to assess a site from the safety of the surface prior to diving on the site. This capability allowed the dive teams to be more focused on where they dove, and helped ensure they had a level of situational awareness prior to commencing diving operations (SKY, 2012).

Before ROVs investigated sonar features, the anomaly lists were filtered into categories to remove obvious non-munitions related debris features such as logs, tires, and anchors (although noting and verifying these debris occurred in tandem with anomaly reacquisition). These anomaly lists were loaded by alphanumeric grid system into the ROV positioning software. ROV teams surveyed a grid, anomaly by anomaly, using the USBL positioning system to reacquire positioned anomalies. The ROVs made note of, and surveyed, any additional anomalies discovered along the way. A custom graphical user interface and Access database software was developed to allow the ROV team to enter and store observations for random ROV search paths and ROV investigation of acoustic features. Over 600 hrs. of video, still images, as well as acoustic imaging data of anomalies and video of dive lane QC were recorded during the TCRA ROV surveys. Positions of reacquired anomalies were verified and recorded. To ensure the anomalies that were passed on to divers for subsequent investigation fit the items of interest profile, the ROV operator was provided with a commonly-found ordnance item “picture book” to reference what they were investigating compared to known munitions items at the site. At the end of each day, data were downloaded to the project database. Field notes, site photographs, videos, and positioning data were consolidated for all survey groups following the field action, and the information was reviewed and QC checked (SKY, 2012).

4.8.12 Time Critical Removal Action Surface Clearance Quality Control

Quality control monitoring for the surface clearance focused on the following four main phases of work:

1. Work Preparation:
    a. Ensured the work site was correctly identified, surveyed, and marked.
    b. Ensured there was an adequate, approved WP.
    c. Ensured the correct equipment was selected and used.
    d. Ensured that qualified personnel were used and that personnel were properly trained.
    e. Ensured all necessary permits were obtained and that notifications were made.
2. The Unexploded Ordnance Quality Control Supervisor (UXOQCS) monitored the work-in-progress and ensured that work was in compliance with the WP.
3. The UXOQCS inspected the finished product and ensured conformance with the finished product requirements. ROV QC accomplished this requirement for the TCRA surface clearance.
4. Inspection of surface clearance documentation occurred and ensured it was in compliance with the WP (SKY, 2012).

4.8.12.1 Quality Control Measures

The UXOQCS ensured UXO divers and ROV personnel were supervised by a competent supervisor, and that they were observed daily by an onsite QC specialist. The QC specialist conducted verification sampling by inspecting a random portion of each dive lane. For the TCRA surface clearance, this was accomplished by utilizing the ROVs. The UXOQCS monitored the recording of dive line data as required by the WP for accuracy and completeness. All items that were removed from the MRA during the surface clearance activities were inspected and disposed of in accordance with the Explosives Safety Submission (ESS), TCRA WP, and SOPs.

Surveillance Logs and QC Reports are included with the project data deliverable (SKY, 2012).

4.8.12.2 Verification Sampling Preparation

The ROV QC teams consisted of a minimum of three personnel: an ROV operator, a person to watch the monitor and take notes in the graphical user interface, and a person to manage the ROV tether connecting the ROV with the control station. Personnel involved in ROV QC procedures attended a training class conducted by the UXOQCS which ensured complete understanding of the process and expectations of the QC process. This class included information on how to utilize all the tools at their disposal when investigating an anomaly. The ROV QC teams were provided with all pertinent data relating to the anomaly or dive lane they were investigating (i.e. DMM/MPPEH/MD found, dive team logs and any geophysical and/or acoustic data which may have been previously collected). The ROV QC teams were provided with a commonly found ordnance item “picture book” and a chart showing the dimensions of commonly found MEC items. They were also provided with a copy of the ROV QC procedures (SKY, 2012).

4.8.12.3 Verification Sampling

The ROV QC teams were provided with a daily list of dive lanes to be QC checked by the SUXOS. Lanes were chosen in such a way that the QC process would not interrupt ongoing underwater surface clearance or survey activities. Lanes were selected for QC after divers had finished the surface clearance. Upon arriving at the work site, the ROV QC personnel set up, calibrated and checked out the ROVs and the USBL positioning systems as per the direction of the technical lead, using the procedures previously detailed in this report. The generally 40 ft wide dive lanes were then QC checked with a minimum of 10% coverage. The ROV operator chose a heading that enabled the ROV to transit from one end of the dive lane to another, along its length. This initial transit followed the emplaced dive lane lines because this was an area where lane drift was most likely to cause gaps to occur (not in the center of lanes due to the overlapping nature of the Jackstay method following the Highway lines). Subsequent transects, when required, were chosen in a random fashion. It was determined via testing that, on average, the ROV could sweep a QC transit approximately 1.5 m wide at an altitude of between 1 and 1.5 m, with a -25 degree camera tilt. Therefore, one transit pass could QC the required 10% of the lane. Due to varying visibility, current and debris, teams occasionally determined that an additional transit was necessary to ensure 10% coverage. For example, if the ROV could only sweep a 3 ft wide lane on that particular day, they would choose another transit through the dive lane to ensure the required coverage percentage was met (SKY, 2012).

The ROV QC team completed two transits (equaling approximately 20% coverage) in lanes where DMM items were found during the diver surface clearance. The team videotaped all QC operations, and the UXOQCS periodically viewed the tapes to verify that proper procedures were followed. The tapes also provided tangible evidence of the success of the QC procedures. The ROV QC team kept a daily electronic field log of all QC activities, which included transits/lanes completed, items of interest that required a revisit, information on visibility and turbidity, and any problems encountered with equipment and/or data.

The ROV teams QC checked at least 10% of the bays (the areas underneath the pier between the pilings) under Pier 91. These bays were associated with the corresponding dive lanes emplaced by the divers (SKY, 2012). Bays were not of a consistent size or shape due to the varied spacing between the pilings and variations in the riprap under the pier. The QC efforts covered 25% of the available area of each bay investigated. Bay QC surveys were recorded in the electronic field log in the same manner as the dive lane QC transits (SKY, 2012).

There were 72 bays associated with Pier 91 within Survey Area 1. Dive lane 1-21 bays were QC checked, as these bays were most likely to contain DMM and MD based on the results of the diver surface clearance operations in this area. Thirty-nine of the remaining bays were QC checked. These bays were picked in a random fashion by the UXOQCS (SKY, 2012).

4.8.12.4 Items of Interest

When the ROV team identified an anomaly during QC operations, they utilized the ROV to identify its composition, shape, color, and approximate dimensions. This was conducted by maneuvering the ROV so that the UXO technician could get a clear view of both ends and/or both sides of the item. The laser scale measured the item (length and diameter). The item was also viewed in both black/white and in color video. If the anomaly could not be eliminated as a potential DMM/MPPEH or MD item by the UXO technician, the SUXOS was notified immediately, who made the final determination as to whether the item was classified as an item of interest and therefore required a revisit. If the item needed a revisit, the team entered all information regarding the item into the POS-GIS (SKY, 2012).

4.8.12.5 Verification Dives and Lane Failures

If it was determined that an item of interest must be revisited, verification dives by UXO divers were coordinated through the SUXOS and the Dive Supervisor. Quality control was not considered complete until all verification dives were completed. If a verified DMM/MPPEH or MD item was encountered, either by the ROV QC team or by the UXO divers during a verification dive, the UXOQCS was to file a Corrective Action Report (CAR). The CAR was to be included in the Daily Quality Control Reports. The dive team would then need to re-clear the entire lane in which the item was found. The UXOQCS was to determine the root cause of the lane failure and any necessary procedural changes in coordination with the Project Manager (PM), Site Manager, SUXOS and Dive Supervisor. Upon completion of the second clearance, the lane would be investigated again by a ROV QC Team (SKY, 2012). No munitions related items were discovered during verification dives following ROV QC.

4.8.12.6 Lane Resolution

The UXOQCS would periodically monitor all QC activities and ensured that QC procedures were being followed. The UXOQCS checked all daily QC logs for accuracy and completeness at the end of each workday. Any deficiencies found in procedures, performance or recordkeeping was noted in a non-conformance report and a corrective action was initiated by the UXOQCS (SKY, 2012).

4.8.12.7 Dive Lanes Quality Control Results

All 86 dive lanes were QC checked by the ROVs, and all lanes received at least 10% coverage. All bays were QC checked. All bays received at least 25% coverage. Seven separate verification dives were conducted to investigate ten items following ROV QC of dive lanes and bays. Six lanes and 2 bays required diver revisits (**Table 4-6**) following the initial ROV QC. No additional munitions related items were located during revisits, and all lanes subsequently passed QA/QC inspection. **Figure 4-21** represents the ROVs USBL tracks through the QC of dive lanes #16 through #20, as a representation of the transit an ROV took during QC operations (SKY, 2012). **Figure 4-22** displays the dates and acreage covered for each dive lane QC performed by the ROVs.

Table 4-6 Time Critical Removal Action Surface Clearance Quality Control Revisits

Quality Control Revisits	
Dive Lane	**Item Located**
Lane 3	Metallic cylinder, non-munitions
Lane 39	Pipe
Lane 73	Bottle
Lane 74	Jar
Lane 75	Thin pipe
Lane 75	2-inch x 6-inch metal pipe
Lane 86	1.5-inch x 8-inch metal pipe
Bay 1	Cylindrical object, non-munitions
Bay 1	Cylindrical object, non-munitions
Bay 4	Pipe

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Figure 4-21 Time Critical Removal Action Ultrashort Baseline Quality Control Tracks

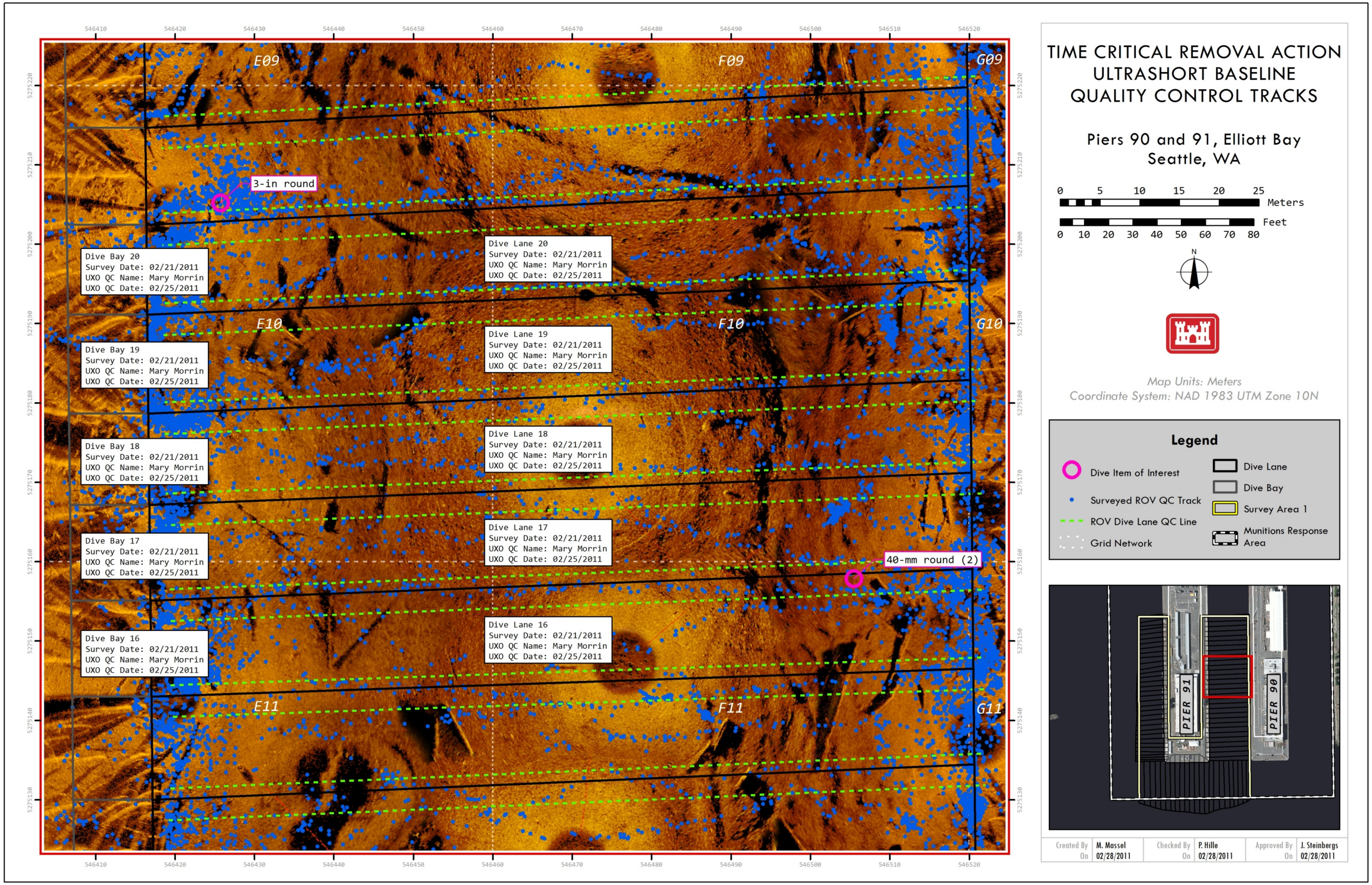

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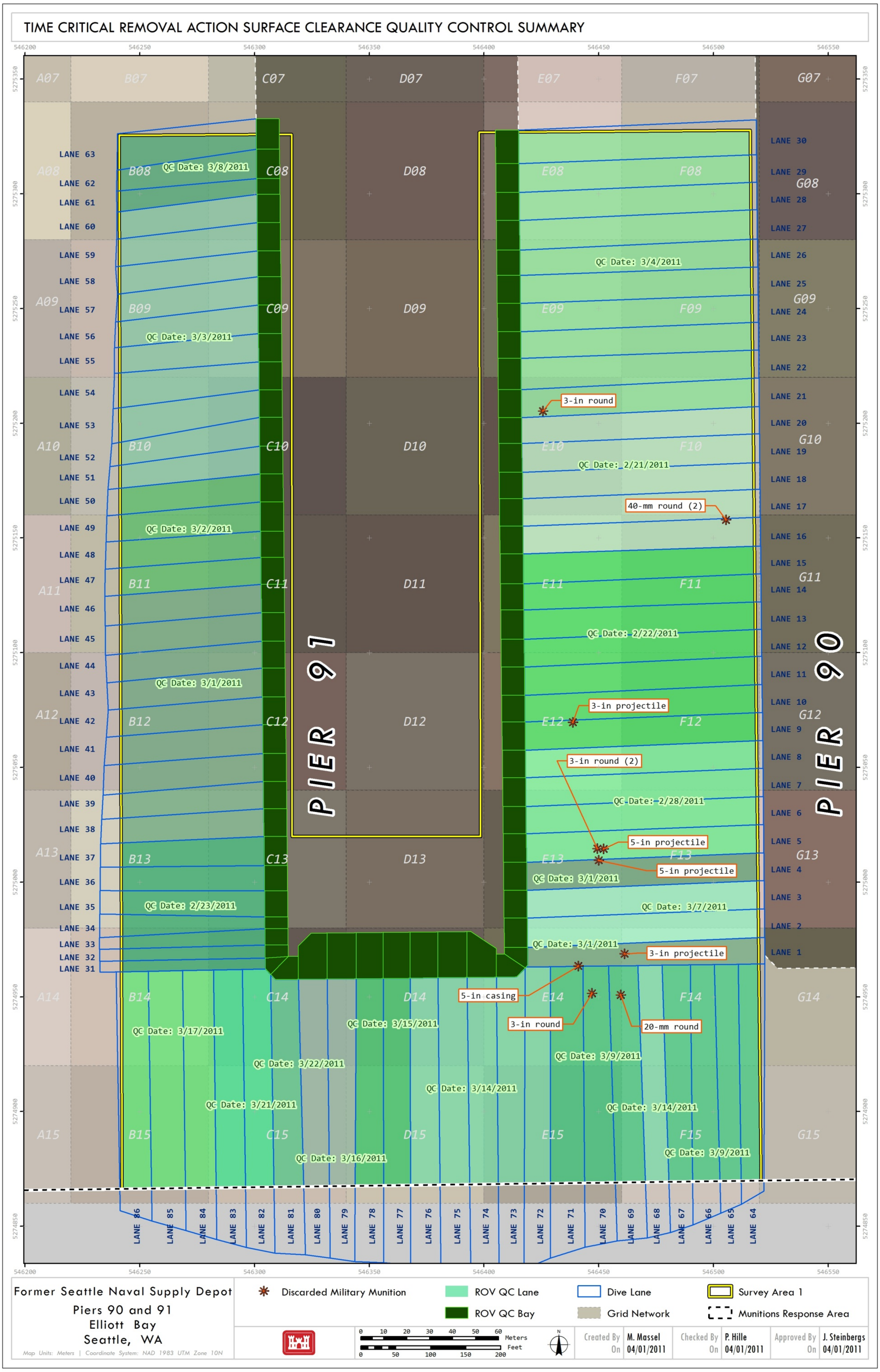
Figure 4-22 Time Critical Removal Action Surface Clearance Quality Control Summary



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4.8.13 Time Critical Removal Action Data Collection Summary

The TCRA, which occurred between January and March of 2011, added to the site data collected during the 2010 field season of the Piers 90 and 91 RI, and began providing information on the nature and extent of potential MEC contamination. General knowledge of site characteristics was also increased. A complete DGM survey of Survey Area 1, utilizing the pier effect filters developed during the 2010 field season, provided an assessment of the content and dispersal of metallic debris on the seafloor. Scanning sonar was deployed over the entirety of Survey Area 1, and the higher frequency scan supplemented the SSS assessment of physical debris conditions while also providing a method to QC previously collected acoustic datasets. ROV observations and video in each of Survey Area 1's alphanumeric grids continued to shed light (i.e. "seeing through the looking glass") on the seafloor of the MRA. In addition to providing an assessment of bottom conditions, the dive team also began to gather information useful in determining the nature and horizontal extent of munitions contamination (vertical extent would be investigation during the 2012 field season). With well over 200 munitions related items located, an assessment of the likely munitions to be found inside the entire MRA was possible. The successful completion of the TCRA inside Survey Area 1 also led the USCG Captain of the Port to lift the restriction on large vessels berthing at Pier 91, allowing following cruise seasons to occur generally unaffected.

4.9 2012 Remedial Investigation Field Season

The 2012 field season was designed to address the remaining data gaps documented in **Section 3.1.** All previous data collected at the site were analyzed together in order to generate a plan to define the nature and extent of MEC and MC at the FSNSD MRA. The approach used for the investigation relied on multiple lines of evidence, most importantly the results of surface and subsurface interrogation of anomalies to determine the likelihood of an encounter with DMM. Other lines of evidence (i.e., geophysical and sonar imaging data, sediment sampling, etc.) would support decision making by characterizing the site, planning operations and most importantly helping to confirm that large accumulations of debris were not related to deliberate disposal of munitions.

4.9.1 Historic Records Review, Interviews, Aerial Photo Analysis

To obtain broad, yet focused investigation coverage and maintain consistency with a common RI approach, the investigation areas for the 2012 field season at the FSNSD MRA were designed similarly to terrestrial RI projects. Archival information, including decades-old aerial photographs (such as the historical photo of the FSNSD displayed in **Figure 4-23**) and operational histories of the site are commonly used to develop CSMs, define MRA boundaries and plan visual survey transects for terrestrial investigations. Commonly, features such as backstops, firing points and range buildings are visual snapshots of past munitions related activity and are supplemented with documented findings of munitions and related items (SKY, 2012b).

Figure 4-23 Aerial Photograph of Naval Use During World War II Era

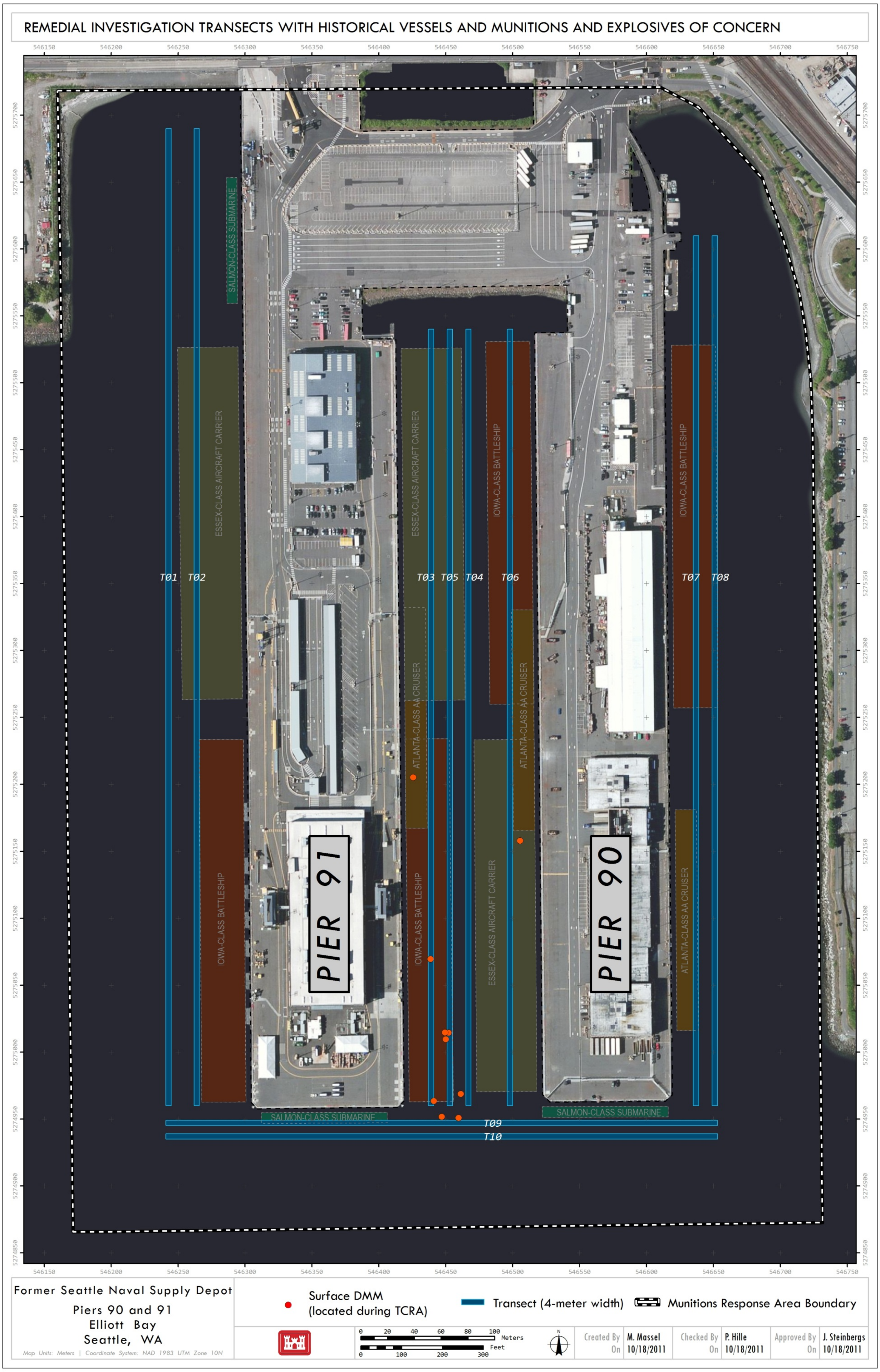
Aerial photographs of U.S. Navy vessels berthed at the FSNSD during the 1940s were obtained. Research was conducted to determine the classes of vessels (if names were visible and/or recorded) or to make a class estimation based on size, shape, and vessel configuration (if no names were available). From this research, a list of vessel classes was compiled. Vessel information such as length, width (beam) and armament were tabulated and loaded into the POS-GIS to generate visual representations of past U.S. Navy use within the investigation areas. Current land use and RAFLU at the facility (visualized in **Figure 4-24**, which displays current use as Smith Cove Cruise Terminal) were taken into account and ensured appropriate coverage was obtained in areas of greatest current use. An overlay of the GPS coordinates for DMM items recovered during the TCRA was developed as part of the refinement of the CSM, covered in **Section 6.0**. This overlay supported the assumption that U.S. Navy munitions items were discarded overboard from naval vessels, in that the preponderance of DMM items discovered were in areas aligned with the outboard perimeter of naval vessels that had been moored at the facility (see **Figure 4-25** and **Table 4-7**) (SKY, 2012b).

Table 4-7 U.S. Naval Use of the FSNSD by Vessel and Class

Class	Name	Length (m)	Beam (m)	Listed Armament	Location seen in photographs
Salmon class Submarine	*Stingray*	94	7.96	50 Cal/3-inch Deck Gun (+ torpedoes)	Northwest corner of Pier 91, south of piers, rafted
Porpoise class Submarine	*Perch* (SS176)	91	7.9	50 Cal/4-inch Deck Gun (+ torpedoes)	Northwest corner of Pier 91, south of piers rafted
Atlanta class AA Cruiser (possible identification based on size/shape)	Multiple, unknown	165	16.1	1.1-inch, 20mm, 27mm, 40mm, 5-inch/38 Cal, Torpedoes	Filled area east of Pier 90. Possibly visible on the eastern sides of Pier 90 and Pier 91.
Iowa class Battleship	Multiple, *USS Missouri* and unknown	271	33	20mm, 40mm, 5-inch/38 Cal, 16-inch/50 Cal	Eastern side of Pier 91, Eastern of Pier 90
Colorado class Battleship	Multiple, *USS Colorado* and *USS Maryland*	190	29.7	3-inch/50 Cal, 5-inch/25 Cal, 5-inch/38 Cal, 5-inch/51 Cal, 16-inch/45 Cal, Torpedoes	Between piers 90 and 91
South Dakota class Battleship	*USS Alabama*	210	33	20mm, 40mm, 5-inch/38 Cal, 16-inch/50 Cal Aircraft: .30 Cal, 100 pound (lb.) bombs, 325 lb. depth charges	Between piers 90 and 91
Essex class Aircraft Carrier	Multiple, *USS Bunker Hill* and unknown	250-263	28-45	Naval: 20mm, 40mm, 5-inch/38 Cal Aircraft: .30 Cal, .50 Cal,12.7mm, 20mm, 127mm High Velocity Aircraft Rockets, 500 lb. bombs, 1,000 lb. bombs, Torpedoes	Western side of Pier 91. Eastern side of Pier 91. Western side of Pier 90.

Figure 4-24 Smith Cove Cruise Terminal at Pier 91

Figure 4-25 Remedial Investigation Transects with Historical Vessels and Munitions and Explosives of Concern



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The refined CSM was used in support of the development of the 2012 field season investigation plan by focusing investigative efforts on those areas believed to be most likely to contain DMM items. The 2012 field season investigation areas (**Figure 4-26**) were broken into ten 4 m wide transects ranging in length between +/- 400 m to 750 m, in total accounting for approximately six acres and 7% of the MRA (SKY, 2012b).

- Two transects were placed in a N/S orientation west of Pier 91 (transects T01 and T02).
- Four transect were placed in a N/S orientation between the two piers (T03 through T06).
- Two transects were placed in a N/S orientation east of Pier 90 (T07 and T08).
- Two transects were placed in an E/W orientation south of the two piers (T09 and T10).

Transects were divided into smaller 4 m wide x 100 m long boxes referred to as segments (**Figure 4-26**). These segments were labeled “A” through “D”, “A” through “G”; “A” through “I” etc. north to south for transects T01 through T08 and west to east for transects T09 and T10 (SKY, 2012b).

4.9.2 Site Data Model

Acoustic surveys, DGM, visual surveys and a surface clearance were previously completed within the portions of the MRA. A key element of the 2012 field season was the leveraging of data collected from prior investigations and munitions response actions within the MRA to maximize the potential to collect useable information during the constrained field phase of the 2012 season (SKY, 2012b).

As discovered during the 2010 field season and the TCA, the seafloor of the MRA is heavily cluttered with miscellaneous metallic debris (anchors, sinks, batteries, cables, and chains, etc.) and non-metallic debris (pilings, logs, ropes, tires, etc.) of various sizes. In certain areas, this debris interferes with the ability to use DGM to conduct subsurface anomaly investigations using geophysics, either through the metallic content of the debris or its nature as a physical impediment to the survey platform. Removal of all debris to support the investigation was not practical. Based on an evaluation of pre-existing investigative data, limited debris clearance would need to be executed to maximize the potential for DGM to identify anomalies, similar to clearing brush and removing trash prior to a terrestrial DGM effort. To support planning for this effort, a site data model was developed for the purpose of identifying:

- Transect segments that could be efficiently cleared of debris.
- Segments that would require an unreasonably excessive effort to clear of debris.
- Areas too shallow for the marine magnetometer array to operate in (SKY, 2012b).

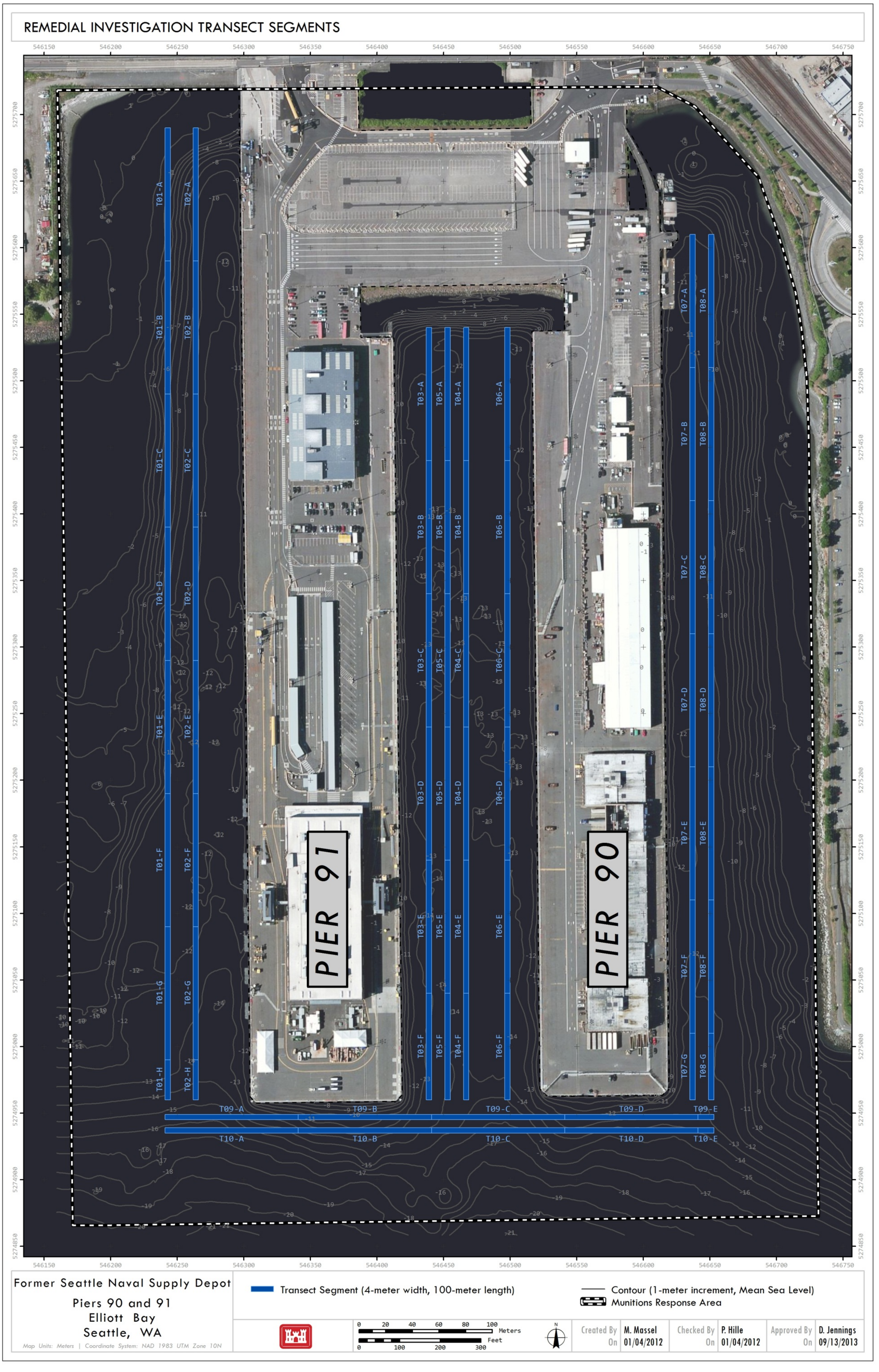
Previously collected data including marine magnetometer, SSS data, scanning sonar data, MBES data and SBP data were used to develop this site data model. MBES bathymetric contours were used to develop a simple “go/no go” for the marine magnetometer array based on water depth and accessibility for the towed array. To determine a “go/no go” for debris clearance within a specific transect segment, all of the anomaly features that were noted by the acoustic and magnetometer surveys were input into the model and weighted based on size. Small “point” type acoustic features (small chunks, blocks, and boxes, etc.) were weighted differently than large items (ship anchors, tires, etc.) and long, linear features (logs, pier piling, etc.) due to the assumed difficulty of debris clearance within the constraints of the investigation. It was assumed that if the divers were unable to move ship anchors, naval anchor chain, massive tires, pilings and other obstructions rising above the seafloor in those segments, the marine magnetometer array would not be able to fly at the necessary height of approximately 1.5 m AGL and/or collect any data useable in individual anomaly selections due to the presence of exceptionally large metallic debris (SKY, 2012b).

In addition to MBES, acoustic, and magnetometer anomalies, the model evaluated the sediment thickness information from the SBP survey results. The difficulty of excavation per transect segment was assessed based on the sediment thickness and the level of effort needed to remove subsurface items. This difficulty of excavation had no affect on determining whether segments were “go” or “no go”. The model provided UXO divers with sufficient information to project daily production rates and plan dive operations in conjunction with the bathymetry derived from MBES, which was useful to ascertain maximum dive depths and safe allowable bottom times (SKY, 2012b).

Transect segments where the site model results suggested that divers could clear surface debris and were also assumed accessible to the marine magnetometer array were listed as “go” segments, while those areas either too shallow or presented too many obstructions or contained large debris items were considered “no go” segments. The model suggested 42 transect segments should move forward for debris clearance while 22 segments should proceed directly into intrusive investigations by divers equipped with handheld all-metals detectors. The 42 “go” segments were queued for debris clearance, DGM, anomaly reacquisition and diver intrusive investigations. These areas were defined as “map and dig” segments and colored green on the project status maps provided to the project Action Officers on a weekly basis. The 22 “no go” segments were defined as “swim and dig” segments and colored red on the project status maps (SKY, 2012b).

Prior to beginning any diver or ROUMRS (shown in **Figure 4-27**) operations, an ROV was deployed over each transect segment to provide visual validation of the site data model. This ROV preliminary survey and findings are covered in a later section of this report (SKY, 2012b).

Figure 4-26 Remedial Investigation Transect Segments



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4.9.3 Remedial Investigation Transect Construction

Sequencing multiple underwater operations along 4 m x 100 m segments of the seafloor represented a technological and logistical challenge. Survey equipment and platform positional accuracies, along with a logistical solution in the form of seafloor transect lines, are covered in the following paragraphs (SKY, 2012b).

Positioning capabilities differed among the suite of technologies required to perform the RI. The Seabotix ROVs employed a USBL positioning system accurate to approximately 1-2 m. The marine magnetometer array employed surface RTK-GPS with line length and angle management encoders accurate to 25 cm to 1 m. Diver GPS positioning ranged from 1 m to 5 m based on depth and site conditions. At the time of this field effort, ROUMRS's USBL positioning system was accurate to no greater than 5 m (SKY, 2012b).

In order to minimize the potential for wasted effort during sequential operations (ROV preliminary survey to diver/ROUMRS debris clearance to DGM to diver intrusive investigations) it was necessary to ensure that all tasks occurred over the same 4 m wide investigation area. To meet this imperative, a fixed line system was positioned on the seafloor to mark the center of each of the 4 m wide transects (SKY, 2012b).

Transect lines were created out of 5/16-inch diameter sinking line and secured to the seafloor every 100 m by 0.5 cubic foot (cf) sandbags wrapped in bright orange bags with bright contrasting patches of duct tape. The fixed line system was installed from the Munson marine survey vessel using its RTK-GPS and navigation systems. Each bag was marked alphanumerically indicating which transect it was part of and its position within each transect. Placed at 100 m intervals, the sandbags marked the break points between the transect segments evaluated in the site data model. The 5/16-inch sinking line was also marked alphanumerically at 5 m intervals on a 6-inch long tab of bright duct tape. Twenty-five 12-inch x 24-inch square metal tubes, striped with bright pink paint, were placed in a N/S orientation directly adjacent to selected sandbags in the map and dig model segments. These metal tubes acted as fiducials which were visible in the geophysical data. The metal tube fiducials were lowered to the seafloor and placed adjacent to the selected sandbags by UXO divers. By locating an alphanumerically marked tab, divers and ROV operators were able to position themselves to a specific (and common) 5 m length within the investigation area. (SKY, 2012b).

4.9.4 2012 Field Season Remotely Operated Vehicle Preliminary Survey

The Seabotix ROVs were deployed to visually survey the investigation areas after fixed line installation. The ROV preliminary survey with 100% video collection had multiple purposes:

- Verified that the 5/16-inch line was installed in a straight and tight manner, with 5 m marking tabs visible.
- Verified that 0.5 cf sandbags were installed correctly and markings were visible.
- Obtained seafloor positioning on sandbags and metal tube fiducials.
- Obtained seafloor positioning on large, potentially unmovable debris.

- Compared actual seafloor debris conditions within each segment to the site data model to ensure its accuracy.
- Added to the percentage of the site on which visual surveys for munitions occurred, providing additional information on the potential nature and horizontal extent of MEC.

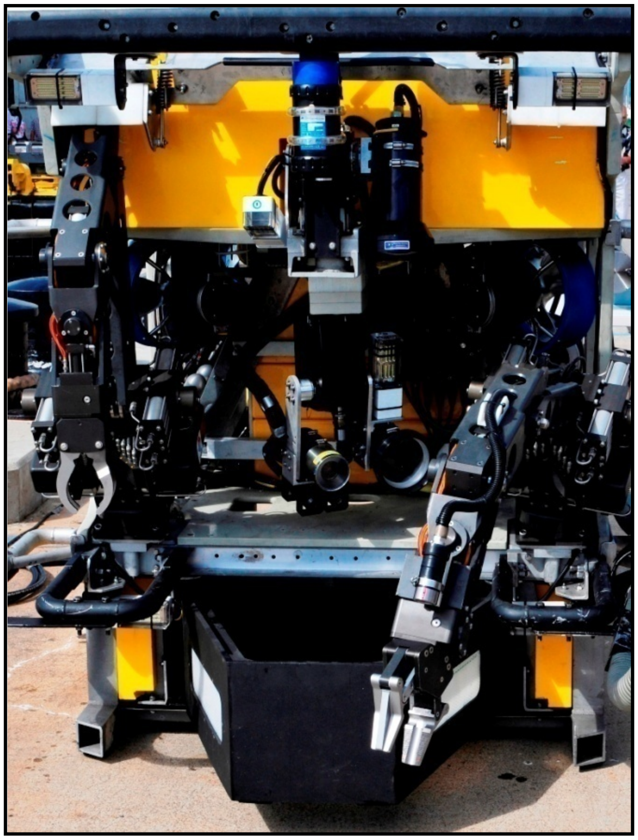
The initial results of the site data model were reevaluated using current information from the ROV pre-survey. The number of transect segments that were reclassified as swim and dig was increased by 6 to total 28. The number of segments suitable for debris clearance, subsequent DGM and map and dig were reduced by 6 to total 34. **Figure 4-28** presents a visual representation of swim and dig and map and dig segments (SKY, 2012b).

4.9.5 Debris Clearance

Metallic debris and obstruction clearance occurred within the selected transect segments to maximize the potential to deploy the marine magnetometer array for the collection of useful geophysical data. Clearance was performed either by UXO divers or by the ROUMRS ROV and occurred in all segments queued for map and dig as shown in **Figure 4-28** (SKY, 2012b).

The debris clearance was not a policy driven objective. Rather, the debris clearance was analogous to a brush clearance on a terrestrial project. The debris clearance, coupled with the second round of DGM that occurred in the 2012 field effort, served two purposes. Together, they reduced both wasted time and wasted effort in subsurface investigations occurring in the less densely cluttered areas of the site (as desired by project stakeholders to investigate vertical extent of potential contamination at the MRA) and they provided defensible data on the usefulness of DGM-aided intrusive investigations. If RI results indicated a necessity for a complete removal action following the RI, the data regarding the efficiency of DGM to select targets in certain areas of the site would be available for evaluation. This evaluation would be based on extrapolating the effectiveness of the debris clearance and 2012 field season transect DGM data over to other areas of the site deemed to be similar based on the site data model (which incorporates results from all remote sensing technologies and is discussed in **Section 4.9.2**).

Figure 4-27 Remotely Operated Underwater Munitions Recovery System



All located metallic items larger than approximately 4 inches diameter but small enough to be moved by a diver/ROUMRS were moved a distance outside each segment so as to not present or create edge effects in the geophysical data. Metallic items too large to move were left in place. Type, size and location both in GPS coordinates and relative to the nearest 5 m marking on the fixed line (henceforth referred to as a “tab location”) were documented on daily logs. Large metallic items outside the segment, though close enough to potentially mask nearby anomalies, were also documented with tab locations. GPS coordinates and tab locations were collected for non-metallic objects greater than 1 m proud of the seafloor. This information was used to avoid obstructions in the flight path of marine magnetometer array (SKY, 2012b).

Approximately 41% of the debris clearance was completed by ROUMRS and captured in color video, allowing UXO divers to focus on intrusive investigations earlier in the constrained fieldwork season. The grappling hands and arm seen in **Figure 4-27** were successfully able to manipulate both small and large debris items. As a mechanical system, its lifting capacity exceeded that of a human. A hydraulic system fitted to the grappling hand on the right arm provided measured resistance, allowing the operator to “feel” what the ROV had picked up. A qualified UXO technician located on the surface viewed all objects through the video feed in real time to determine whether they were munitions related (SKY, 2012b).

These activities increased the amount of data and the knowledge level in debris-clearance investigation areas over the previously conducted ROV preliminary survey. In addition to visually surveying these areas, divers and ROUMRS were able to put "hands" on small surface items. This "hands-on" enhanced visual survey of portions of the investigation area added to the knowledge of MEC at the site, and assisted in making a determination of the nature and extent of MEC at the FSNSD.

4.9.6 Swim and Dig

Swim and dig segments, deemed unsuitable for geophysics and map and dig, were queued for intrusive investigations by UXO divers equipped with an all-metals detector. The purpose of intrusive investigations was to obtain data necessary to support a determination of the vertical extent of munitions contamination at the FSNSD. Segments at the northern end of the investigation area were too shallow to access with a vessel towing the marine magnetometer array. Large pilings, tires and other debris cluttered all of T09, T10, and many segments between the two piers to a point that flying the marine magnetometer array at 1.5 m AGL was unfeasible. Segment "E" of T07 was queued for swim and dig due to the presence of the F/V *Highland Light*, a derelict fishing vessel moored at Pier 90 during the project waiting for a tow to the scrap yard (SKY, 2012b).

Prior to conducting swim and dig operations, the dive team deployed and tested their all-metals detectors over the IVS lane containing simulated munitions items. Divers swam at various heights and angles, using their all-metals detectors to reacquire the ISO's, thus familiarizing themselves with the pitch and tone of each of the potential munitions items. Diver positioning during these IVS training sessions was not recorded for two reasons; 1) ISO's were located on the surface and visible to divers, and 2) diver positioning at depth in this environment is only 1-5 m. Thus divers could see the item (meaning they did not have to find it exclusively with the detector) and even then their reported position while directly on top of it could be meters off the point surveyed in by marine magnetometer array or the ROVs based entirely on the limitations of diver positioning technology. The inability to accurately position divers to centimeter accuracy was identified prior to the 2012 field season, and was among the primary drivers for installing the transect lines. By installing the marked transect system (including the square tube fiducials surveyed in by the marine magnetometer array and the 100 m clumps surveyed in by the ROVs using approximately 1 m accurate USBL), the need to position divers using technology was removed entirely. Rather, divers were required to report their positions (distance and direction to nearest tab location) within a marked "grid" which had been surveyed in with superior technology, such as the marine magnetometer array and the ROV USBL. Detectors were also function-checked prior to each day's use at a land-based test lane containing buried metallic objects (SKY, 2012b) located adjacent to the dive staging area.

Divers began swim and dig operations in each segment with a detector-aided sweep of the seafloor surface and near-surface metallic debris. Near surface is defined as being covered with a thin layer of sediment, thus not visible, but easily located with a detector and cleaned off with minimal effort. The purpose of this initial sweep was to locate and collect any surface/near-surface munitions-related items before initiating subsurface intrusive investigations on diver-selected anomalies. Once excavations began, diver visibility within the investigation area dropped dramatically and could remain affected for a substantial portion of time (5 minutes of reduced visibility accounts for greater than 10 percent of a 45 minute dive). The majority of munitions items located were in the near-surface zone during these initial sweep operations (SKY, 2012b).

Swim and dig was performed by UXO divers in all red segments depicted in **Figure 4-28**. Approximately 18 intrusive investigations occurred within every 4 m x 100 m segment. Divers completed logs and photographed every item they excavated. Divers also video recorded at least one complete investigation from anomaly selection through to excavation per dive set (defined as one total dive from descent to resurfacing and generally lasting 45 minutes). In total, the divers conducted 432 intrusive investigations during the swim and dig phase. The exact number of investigations per segment is shown in **Table 4-8**. Excavation results are listed in **Table 4-9** along with map and dig results, to give a complete accounting of all subsurface intrusive investigations. (SKY, 2012b).

A total of 15 munitions related items were excavated during the swim and dig phase. Two of these items (20mm rounds consisting of a cartridge casing and projectile) were DMM. The remaining items were MD and consisted of .30-06 casings, 20mm empty casings, a 3-inch empty casing, a 5-inch empty casing, and a 5-inch shipping cap.

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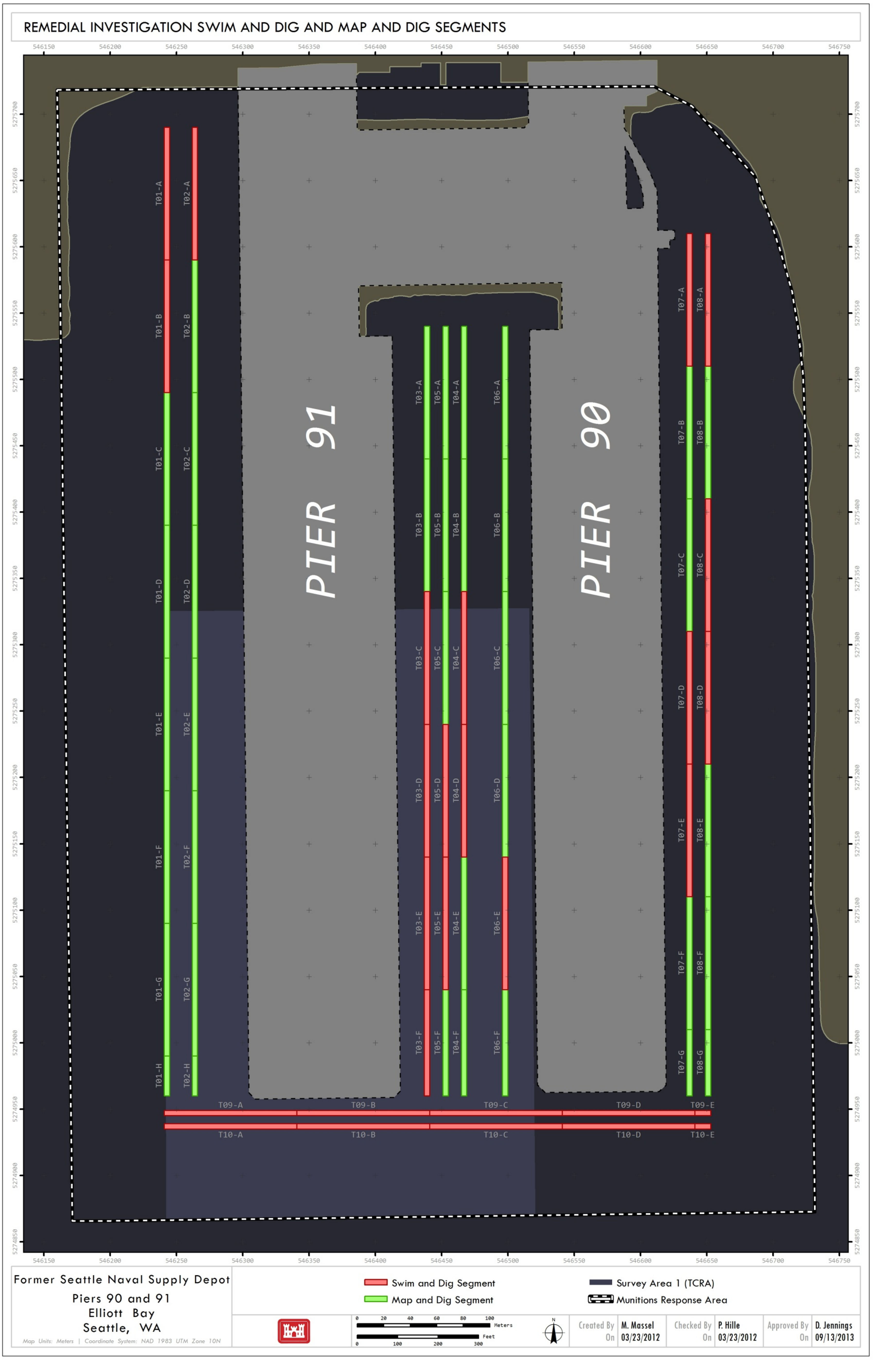
Figure 4-28 Remedial investigation Swim and Dig and Map and Dig Segments



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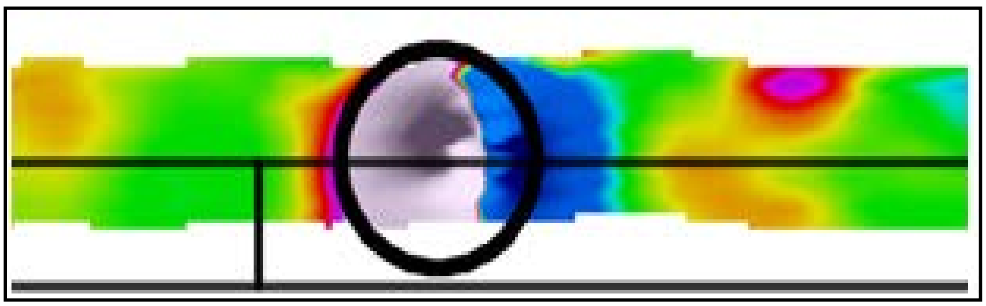
4.9.7 2012 Field Season Marine Geophysics

The purpose of the 2012 field season marine geophysical survey was to locate and identify individual subsurface ferrous anomalies in the investigation areas that were cleared of metallic debris, in order to support effective intrusive investigations and to gather data to support a determination of the nature and extent of MEC at the FSNSD. The survey was conducted using the same marine magnetometer array utilized during the TCRA (SKY, 2012a).

All segments queued for map and dig were geophysically surveyed. All previously collected data were used to plan the geophysical surveys. MBES generated bathymetric contours for bottom following, while previous acoustic surveys, ROV preliminary surveys and debris clearance observations were used to map and avoid potential obstructions. The marine magnetometer array was flown as close to 1.5 m AGL as possible to detect 5-inch projectiles in the survey areas. Multiple, overlapping passes occurred over each segment and were linked together to ensure 100% coverage of transects. The 12-inch x 24-inch square tube fiducials were used to verify data collection over the correct survey areas (**Figure 4-29**). Surveys occurred over the IVS before and after all survey operations. The IVS, installed outside of the MRA during the TCRA, was composed of simulants of munitions likely to be found at the site and has been detailed previously in this report (SKY, 2012b).

Figure 4-29 Fiducials as Seen in Digital Geophysical Mapping



Data collected by the marine magnetometer array were used to generate a list of subsurface ferrous anomalies. The following techniques were employed to cull the total count of anomalies to a list of subsurface anomalies most likely matching the geophysical profile of a 5-inch projectile. The list of individual subsurface anomalies was:

- Selected using analytical signal and refined using total magnetic field.
- Total magnetic field was used to verify anomalies automatically selected by the Geosoft target picking routine using the analytical signal grid. In some instances, high frequency noise was amplified by the analytic signal calculation and the total magnetic field data was used to verify potential anomalies.
- Selected anomalies down to the noise floor.
- Refined anomaly list based on known SSS and stationary scanning sonar anomalies.
- Refined anomaly list based on diver, ROUMRS and ROV-marked unmovable debris locations.

- Refined anomaly list using sediment thickness raster from SBP to mask anomalies exceeding sediment thickness. Estimated anomaly depths were compared to the sediment thickness raster generated by the SBP then ranked from best to worst within each transect segment. Dipole modeling indicating that an anomaly was found deeper than the sediment layer and in the hard pack below the softer layer indicated 1) it was not dropped, 2) that it was deeper than the 18" depth established for excavations, and 3) would require excavation tools beyond the capabilities of a hand-tool equipped diver to access.
- The top 3-4 anomalies per transect segment were moved into the diver investigation phase. The post-filter target list included more anomalies than the 3 to 4 anomalies that were investigated. This screening method prioritized the list of targets but had no bearing on the total number of targets investigated.
- Performed dipole modeling and classification based on a 5-inch projectile. Although smaller items such as 20mm and 40mm projectiles were present and recovered at the site previously, the potential explosive hazard associated with these items was deemed to be low. Therefore, in consultation with project stakeholders, the determination was made that the munition of concern at the site was the 5-inch projectile, the largest DMM item found at the site and believed to be largest likely to occur based on historic records and process knowledge. DGM efforts including height flown AGL and dipole modeling were thus planned around this item and not detection of 20mm and 40mm rounds.

Each selected anomaly was given a unique three-digit numerical identifier and GPS coordinates allowing for subsequent reacquisition and investigation (SKY, 2012b).

4.9.8 Map and Dig

Map and dig investigations on DGM anomalies gathered information necessary to support a determination of the extent of MEC. Reacquisition of DGM anomalies was accomplished with Seabotix ROVs and UXO divers. The ROV navigated to each anomaly's GPS coordinates on the seafloor, carrying a marked buoy in its grappling arm. Marked buoys consisted of a 3 lb. dive weight and a small peanut-style buoy attached with +/- 1 m of floating line. A tab marked with the anomaly's numerical identifier was attached to the line and visible to ROV cameras and divers. When properly positioned at the GPS coordinates, the ROV released the marker buoy atop the subsurface anomaly and noted position and nearest tab location. Anomaly locations are shown in **Figure 4-30**, with the number of investigations per segment previously detailed in **Table 4-8** (SKY, 2012b).

Divers, equipped with all-metals detectors, cameras and excavation tools reacquired each marked buoy. Divers then performed a 2 m radius circle search around the buoy. The circle search was performed to negate the potential positional offset of the ROVs USBL positioning system. Using the all-metals detectors, the UXO diver located the peak response inside the zone and began intrusive investigations (SKY, 2012b).

The maximum depth investigated during map and dig excavations was 18 inches. The 18 inches maximum depth was established based on multiple factors. In hard pack areas with minimal sediment, munitions were less likely to be below 18 inches. In soft sediment areas, holes deeper than 18 inches required considerable effort to excavate due to sloughing. Anomalies found to be deeper than 18 inches after excavation over the peak response were listed as "depth exceeded 18 inches". UXO divers were instructed to proceed to a secondary anomaly if the peak anomaly proved non-ferrous. Once the anomaly excavation was complete, the diver moved the marked buoy to the center point of the excavation and transmitted findings to the surface via radio. Investigations yielding no peak response around the marked buoy were reported as "No Finds". Divers completed map and dig logs, and provided video of anomaly investigations including acquisition of the marked buoy, excavation, and placement of the buoy for ROV retrieval. (SKY, 2012b).

After divers cleared the area, the ROV returned to the marked buoy to obtain and record a position, then retrieve it. These data were used as a QC device and ensured that divers investigated the selected anomalies and did not investigate peak responses outside the DGM anomaly zones. Marked buoy drop-off and retrieval by ROV were video-recorded (SKY, 2012b).

Diver notes and video were reviewed nightly by the project geophysicist, SUXOS and Site Manager. Excavation results and anomaly responses were compared to provide a QC check that the correct anomaly was reacquired and excavated. If non-ferrous and/or non-metallic source objects were excavated and the diver could not detect another anomaly within the 2 m search area, an additional anomaly was added to the excavation list (SKY, 2012b). In total, the divers investigated 122 map and dig anomalies. Excavation results are listed in **Table 4-8** with the swim and dig results, to give a complete accounting of all subsurface intrusive investigations.

One 20mm empty casing was recovered from 4 inches beneath the seafloor during an excavation down to a metal bar located 8 inches beneath the seafloor.

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Figure 4-30 Remedial Investigation Locations of Map and Dig Geophysical Anomalies

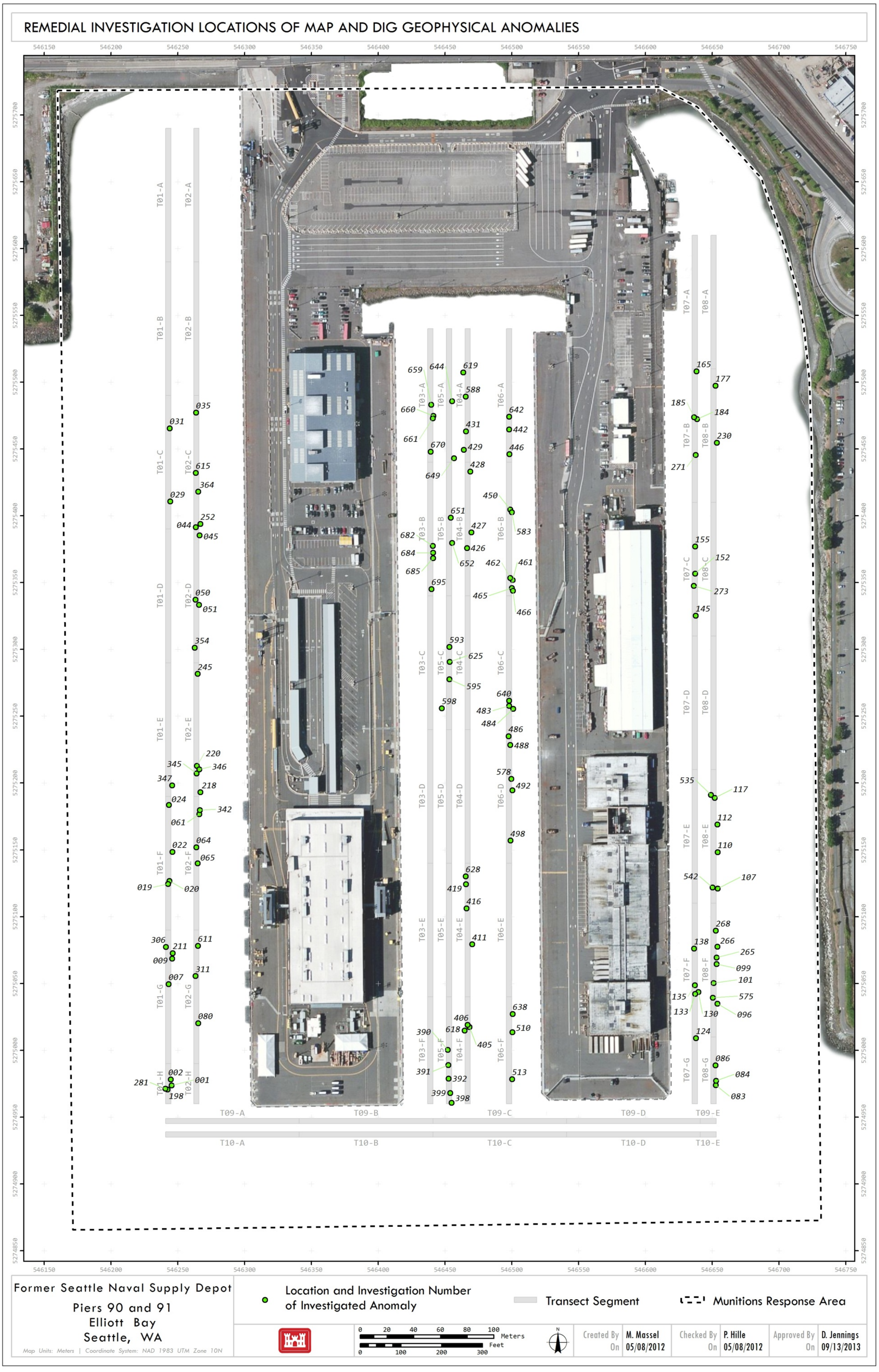

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Table 4-8 Intrusive Investigations per Segment

Transect	Number of Digs	Transect	Number of Digs
T01	**22**	T05E	18
T01A	3	T05F	5
T01B	4	***T06***	**38**
T01C	2	T06A	3
T01D	0	T06B	6
T01E	1	T06C	3
T01F	4	T06D	5
T01G	4	T06E	18
T01H	4	T06F	3
T02	**25**	***T07***	**65**
T02A	4	T07A	19
T02B	0	T07B	4
T02C	5	T07C	4
T02D	4	T07D	16
T02E	5	T07E	17
T02F	4	T07F	4
T02G	3	T07G	1
T02H	0	***T08***	**72**
T03	**78**	T08A	18
T03A	4	T08B	2
T03B	4	T08C	18
T03C	16	T08D	18
T03D	18	T08E	6
T03E	18	T08F	7
T03F	18	T08G	3
T04	**50**	***T09***	**83**
T04A	4	T09A	18
T04B	3	T09B	18
T04C	18	T09C	29
T04D	18	*T09D**	18
T04E	4	*T09E**	N/A*
T04F	3	***T10***	**72**
T05	**49**	T10A	18
T05A	2	T10B	18
T05B	2	T10C	18
T05C	4	*T10D**	18
T05D	18	*T10E**	N/A*

= Red cells indicate “swim and dig” segments. = Green cells indicate “map and dig” segments.

* = T09E and T10E segments were approximately 10m in length and were investigated with adjacent “D” segments.

\- = These segments had no anomalies matching the potential MEC profiles.

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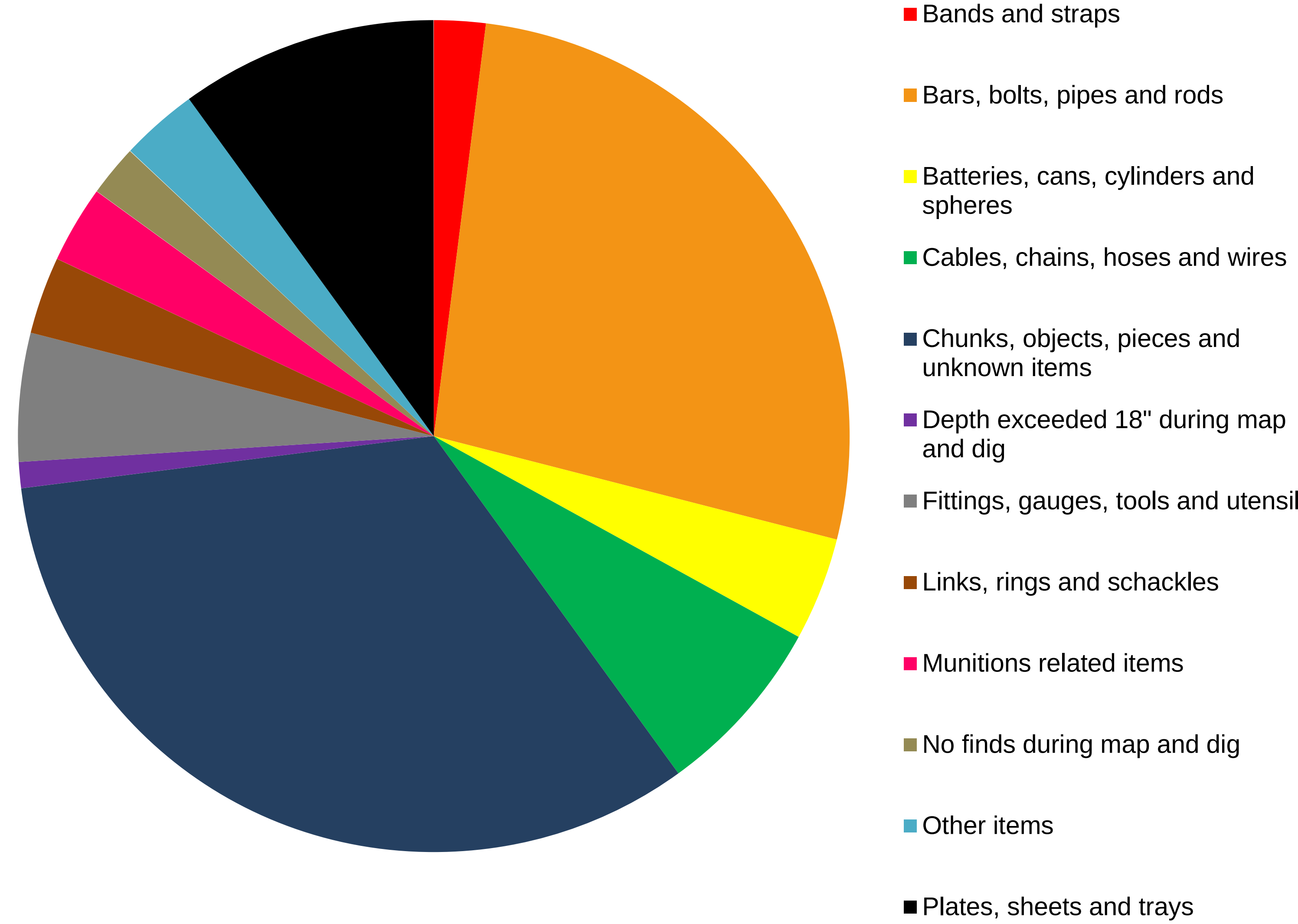
Table 4-9 Results of All Intrusive Investigations

Item Category	Category Percentage [1,2]
Description of item provided by dive team [3]	
Bands and straps	**2%**
Aluminum banding, large metal band, metal band, metal strap.	
Bars, bolts, pipes and rods	**27%**
Aluminum bar, angle iron, bar stock, bolt, channel iron, crowbar, flange, flat metal bar, I-beam, large metal bar, large metal pipe, large metal rod, large nail, L-shaped metal, metal bar, metal bolt, metal pipe, metal rebar, metal rod, metal spike, metal triangle, metal tube, repeating flange, round stock, single iron, steel bar, steel bolt, steel pipe, steel rod, steel stock, U-bolt, welding rods.	
Batteries, cans, cylinders and spheres	**4%**
Aluminum cans battery, can, large metal cylinder, metal ball, metal cylinder, and tin can.	
Cables, chains, hoses and wires	**7%**
Cable, chain, large hose, large metal cable, metal cable, metal wire, power cable, several links die lock, steel cable.	
Chunks, objects, pieces and unknown items	**33%**
Aluminum piece, debris pile, large metal object[4], metal chunk[4], metal object[4], metal scrap, scrap metal, several small pieces, slag metal, steel object[4], unknown metal item[4].	
Depth exceeded 18" during map and dig	**1%** (7% of total map and dig investigations)
Fittings, gauges, tools and utensils	**5%**
Brass hose coupling, brass padlock, coupling, crock pot, electrical harness, fire-fighting nozzle, fishing lure, grappling hook and chain, handheld radio antenna, hose fitting, metal grinding wheel, metal nipple, nozzle, paint roller handle, pipe fitting, pocket knife, screwdriver, spoon, steel cotter pin, steel nut, toothpaste container, valve, welding gauge, wrench.	
Links, rings and shackles	**3%**
Chain link, copper ring, large metal ring, large metal staple, metal ring, metal, shackle, steel shackle, u-shaped metal.	
Munitions related items	**3%**
.30-06 casing, .30-06 round, 20mm casing, 20mm plugged casing[5], 20mm full up round[6], 3-inch casing, 5-inch plugged casing[5], 5-inch shipping cap.	
No finds during map and dig	**2%** (11% of total map and dig investigations)
Other items	**3%**
5" steel bollard section, board with nails, deck fitting, large metal box, light gauge train rail, metal box, metal joint assembly, motor axle, piece of tin, reinforced concrete, section of piling, zinc anode.	
Plates, sheets and trays	**10%**

Percentage of Investigation Results



Notes:
1 = The total number of items recovered is greater than the total number of investigations due to cases of multiple items being recovered and reported during single excavations.
2 = Percentages have been rounded.
3 = Some formatting of diver descriptors on the original written reports has occurred to lower redundancy, i.e. two divers listing slightly different names for the same type of item.
4 = Although positively unidentifiable, these items were determined not to be munitions or munitions debris.
5 = The term "plugged" was included by the diver in the original description of nomenclature to differentiate between empty cases and cases where the diver was unable to determine content of the casing due to a dirt plug.
6 = The term full up round indicates a cartridge case with a projectile, as opposed to just a casing or a just a projectile.

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4.9.9 Munitions Constituents in Sediment

Sediment samples were collected during the 2012 field season. 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. Sample collection, handling, and analysis occurred in accordance with procedures established in the RI WP. Multiple TPP sessions and stakeholder meetings were necessary to obtain agreement on sediment sampling and analytical procedures. Sediment samples were collected directly below assumed DMM and MPPEH immediately after discovery.

Thirteen sediment samples were collected and twelve samples were sent to the laboratory for analysis (see **Figure 4-32** and **Table 4-10**). Eight of the thirteen samples were collected under munitions items located on the surface of the seafloor. Three samples were collected below excavated munitions items. One sediment sample was collected under an item believed at the time to be a 5-inch projectile. After additional inspection, the item was determined to be non-munitions related debris and this sample was not analyzed.

Sediment samples were collected with the hand-held coring device deployed by divers shown in **Figure 4-31**. The coring device, designed and fabricated for the RI effort, consisted of an approximately 1 ft length of 3-inch diameter polyvinyl chloride (PVC) pipe. Each pipe (referred to as a “sample tube”) was marked with a numerical identifier used to differentiate samples after completion of a dive set. One end of the sample tube was cut at an angle to assist the diver in driving it into the sediment. 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. UXO divers radioed collection information to the surface and proceeded to the next dive task.

Figure 4-31 Sediment Sampling Device Used During the Piers 90 and 91 RI

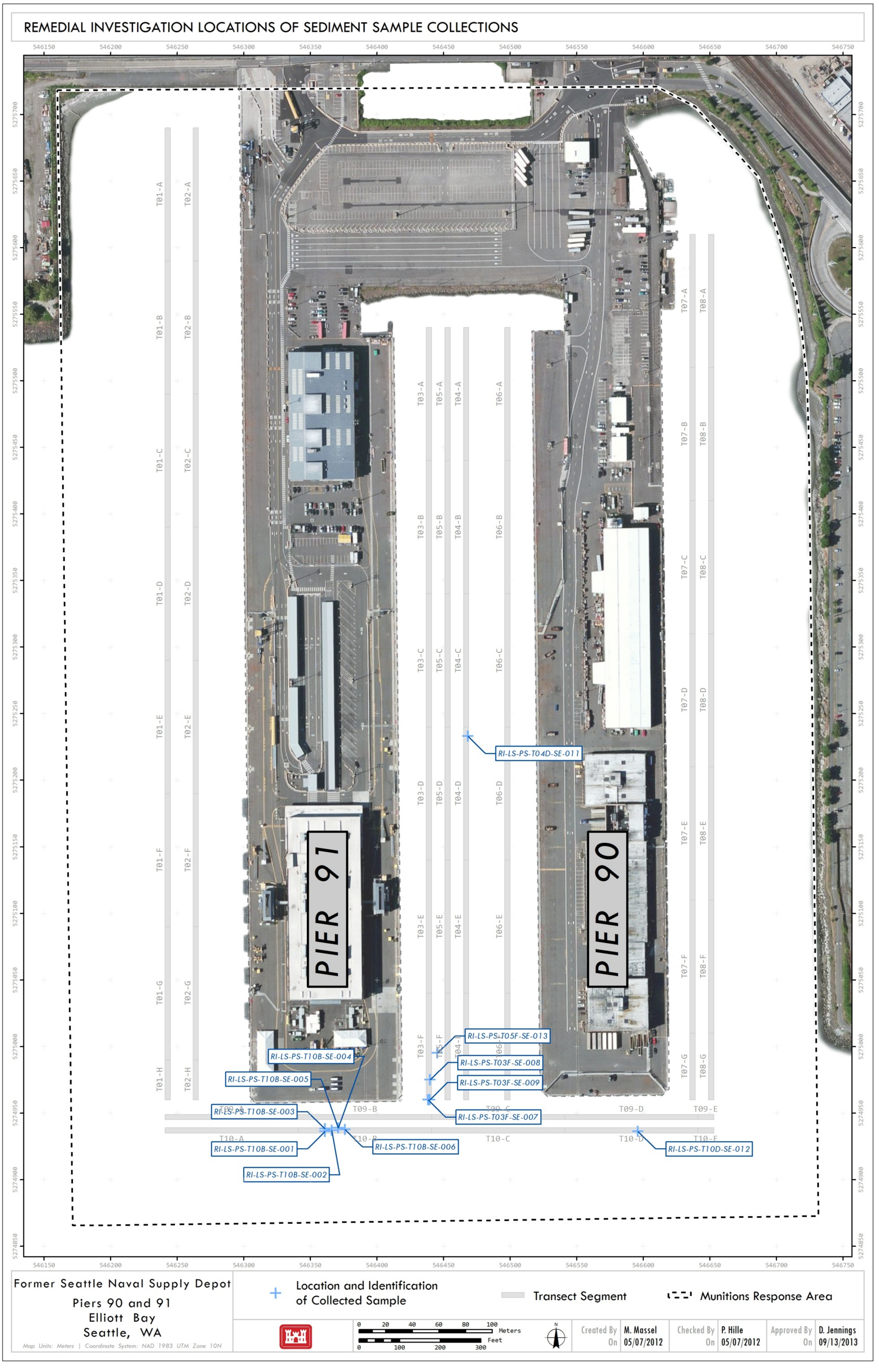
Once surfaced, dive logs were completed and the sediment was transferred to 8-ounce glass jars, which were labeled, packaged, and shipped in accordance with the SOPs and laboratory requirements. Sample tubes were decontaminated in accordance with the SOPs and returned to the divers for future use.

Table 4-10 Sediment Sample Information

Sample ID	Date Collected	Location	Sample Collected	Depth of Sample* (Inches)
RI-LS-PS-T10B-SE-001	21Feb12	T10, B20	20mm on surface/near-surface	0 to 6
RI-LS-PS-T10B-SE-002	21Feb12	T10, B25	20mm on surface/near-surface	0 to 6
RI-LS-PS-T10B-SE-003	22Feb12	T10, B20	20mm on surface/near-surface	0 to 6
RI-LS-PS-T10B-SE-004	22Feb12	T10, B30	20mm loaded shipping container on surface	0 to 6
RI-LS-PS-T10B-SE-005	22Feb12	T10, B30	20mm loaded shipping container on surface	0 to 6
RI-LS-PS-T10B-SE-006	22Feb12	T10, B35	20mm on surface/near-surface	0 to 6
RI-LS-PS-T03F-SE-007	27Feb12	T03, F95	20mm on surface/near-surface	0 to 6
RI-LS-PS-T03F-SE-008	27Feb12	T03, F65	20mm on surface/near-surface	0 to 6
RI-LS-PS-T03F-SE-009	27Feb12	T03, F80	5-inch casing excavated at 2 inches	2 to 8
RI-LS-PS-T06E-SE-010	1Mar12	T06, E05	Debris[1] excavated at 18 inches	18 to 24
RI-LS-PS-T04D-SE-011	5Mar12	T04, D10	20mm excavated at 6 inches	6 to 12
RI-LS-PS-T10D-SE-012	21Mar12	T10, D55	20mm excavated at 8 inches	8 to 14
RI-LS-PS-T05F-SE-013	22Mar12	T05, F45	5-inch projectile[2] on surface	0 to 6

Notes:
* = 0" indicates the seafloor surface.
[1] = This item was considered to be a 5" projectile covered in sea growth upon initial discovery. After further inspection, the item was determined to be non-munitions related debris. Analysis was not conducted on this sample.
[2] = This item was located 25ft west of the transect segment and was located during a swim from one transect segment to another during anomaly reacquisition.

Figure 4-32 Remedial Investigation Locations of Sediment Sample Collections



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4.9.10 2012 Field Season Munitions Disposal

The U.S. Army's Edgewood Chemical and Biological Center (ECBC) mobilized a T30 Contained Detonation Chamber (CDC) (shown in **Figure 4-33**) to the FSNSD MRA to conduct disposal operations. The CDC and associated facilities provided a method to safely dispose of all munitions-related items recovered during the 2012 field season. The chamber arrived at Terminal 91 on April 2, 2012, and took one week to assemble and become operational (SKY, 2012b).

In accordance with the Explosive Site Plan (ESP), and based on the explosive load-out required to complete all disposal operations and the maximum allowable weight of donor charges able to be stored inside the temporary magazine, it was determined that disposal operations would take two to three days. At the request of POS, detonation operations occurred after normal business hours on the evenings of April 9 through April 11, 2012 (SKY, 2012b).

Following establishment of an exclusion zone enforced by POS police and security, munitions items were raised to the surface at the dive staging area by UXO technicians and transported to the CDC facility. Items were then handed off to ECBC personnel, who operated the CDC facility. Items were photographed and documented (as shown in **Figure 4-34**, a photograph provided by ECBC documenting demolition Shot #4 of six 40mm empty casing MD items), wrapped in datasheet donor charges, hung inside the chamber and detonated. All munitions scrap remaining after safe disposition by controlled demolition of the DMM/MD recovered (scrap is shown in **Figure 4-35**) was collected, inspected, documented as material deemed as safe, and shipped to a munitions scrap metal recycler (RI-ISR). Documentation of the T30 CDC operations and final disposition of all munitions scrap is provided in **Appendix A**.

Figure 4-33 T30 Controlled Detonation Center

Figure 4-34 T30 Photo Documentation Prior to Controlled Demolition of 40mm Empty Casing Munitions Debris Items

Figure 4-35 T30 Munitions Scrap Collected after Controlled Demolition of All Munitions Items Recovered During the 2012 Field Season

5.0 NATURE AND EXTENT OF CONTAMINATION

5.1 Munitions and Explosives of Concern Delineation

The following sections provide a complete listing of the MEC items recovered from the FSNSD MRA during the Piers 90 and 91 RI and TCRA, a brief description of their condition and sensitivity, and an analysis of the extent of munitions contamination at the FSNSD MRA.

5.1.1 Type, Condition, and Sensitivity of Munitions and Explosives of Concern

There are three categories of MEC. UXO (which was not found at the site) is defined as military munitions that have been primed, fuzed, armed or otherwise prepared for action, fired, dropped, launched, projected, or placed in such a manner to constitute a hazard to operations, installations, personnel, or material and remain unexploded either by malfunction, design, or any other cause (10 U.S.C. 101(e)(5)) (DoD, 2010). DMM is defined as 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 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 U.S.C 2710(e)(2)) (DoD, 2010). The final category of MEC is MC present in high enough concentrations to pose an explosive hazard. All 32 MEC items recovered at the FSNSD MRA were DMM. No UXO or concentrations of MC large enough to constitute MEC were located. A complete listing is detailed in **Table 5-1**. The majority of the DMM items are 20mm projectiles, shown in **Figure 5-1**. The largest item recovered was a 5-inch projectile. A 5-inch projectile is shown before and after cleanup in **Figure 5-2**. These photographs accurately document the general condition of DMM items on the seafloor of the MRA. As seen in these photographs, these items remain intact but have become heavily encrusted with sea growth.

Table 5-1 Total Discarded Military Munitions Found to Date at the FSNSD MRA

Size / Type	Nomenclature	Quantity
U.S. Cartridge, 20mm, with projectile	Unknown*	12
U.S. 20mm Loaded Shipping Container	Unknown*	1
U,S, Projectile, 40mm	Unknown*	2
U,S, Projectile, 40mm	MK Mod 1	2
U.S. Projectile, 3-inch	Unknown*	6
U.S. Projectile, 3-inch	MK 23 Series	1
U.S. Projectile, 3-inch High Explosive (HE)	MK 29 Mod 2	1
U.S Projectile, 5-inch	Unknown*	4
U.S. Cartridge, 5-inch/38	MK 5 Shell Casing	1
U.S. Projectile, 5-inch	MK35 Mod 6 AA	1
U.S Projectile, 5-inch	MK15 AP	1
	Total	**32**

Notes:
* = Specific nomenclature was not provided by U.S. Army EOD at JBLM and the U.S. Army's ECBC due to excessive sea growth.

Figure 5-1 20mm Discarded Military Munition Item and 20mm Empty Casing Held by Diver Upon Discovery

Figure 5-2 Condition of 5-Inch Projectile Upon Discovery and After Cleaning Prior to Disposition

Photograph of a 5in Projectile encrusted with growth on the seafloor

Photograph of the item on the surface after removal of sea growth

None of the DMM items found to date at the FSNSD have been fuzed and armed. The operational history of the site indicates that none of the munitions items that may have been present on naval vessels were fired or used for their intended purpose, which could have resulted in arming of fuzing mechanisms present on munitions used for this purpose. Therefore, the only possible means of arming fuzes that might be present on DMM items that may remain within the MRA is as a result of disturbance of the items during vessel mooring operations or mechanical dredging activities (USACE, 2012b).

5.1.2 Aerial Extent, Depth, and Distribution of Munitions and Explosives of Concern

Figure 5-3 is a map of where each individual DMM item has been recovered in the FSNSD MRA. GPS coordinates were collected at all DMM recovery locations during the Piers 90 and 91 RI and TCRA, but were not collected by POS PD divers during munitions recoveries in 2010. Therefore, the DMM positions of POS PD diver collected items are estimates provided by the POS PD dive team based on available information, and should not be considered conclusive. The GIS base layer of **Figure 5-3** is composed of the SBP acoustic data, which displays the thickness of the sediment layers above hard-pack layers below. Combining the DMM GPS coordinates and depth of discovery data with a map of the facility and the SBP acoustic data describing sediment layers is sufficient information to make a determination on the lateral and vertical extent of DMM contamination. Data collected support the CSM that munitions items were infrequently jettisoned overboard by sailors while onboard U.S. Navy vessels at berth without documentation (USACE, 2012b). The RI and TCRA investigations, biased to areas with the highest likelihood of containing MEC, discovered a low number (32 total items) of DMM, the majority of which were small 20mm and 40mm items.

Figure 5-4 displays all areas of the MRA which have undergone visual surveys by UXO diver, ROV or UXO Tech III's during areas of low tide. Although subsurface intrusive investigations were limited to inside transect segments during the 2012 RI field season, and silt levels on the seafloor of the FSNSD are constantly changing due to environmental and man-made factors such as prop wash; the majority of the DMM and MD items located during the Piers 90 and 91 RI and TCRA were located on the seafloor surface (only two DMM items were recovered during intrusive investigations). As shown in **Figure 5-4**, a large percentage of the site has undergone visual survey. The lack of 100% subsurface investigations and shifting silt patterns removes the ability to state that visual survey areas are free of DMM, but it does strongly indicate that DMM is limited to near-pier areas and supports the CSM assumption that munitions items were jettisoned overboard while at berth at the FSNSD.

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Figure 5-3 Discarded Military Munition Items Found During Remedial Investigation and Time Critical Removal Action

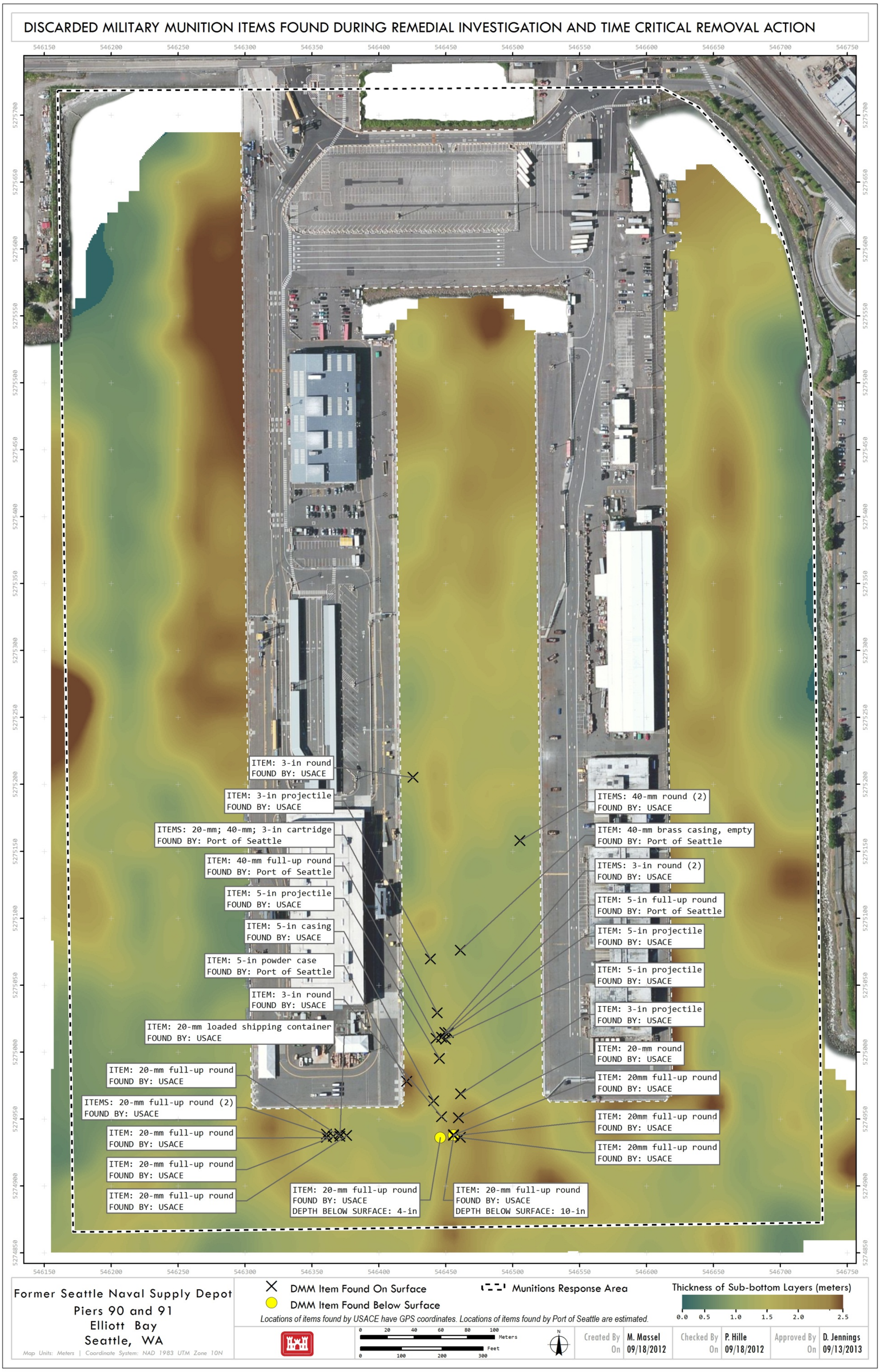

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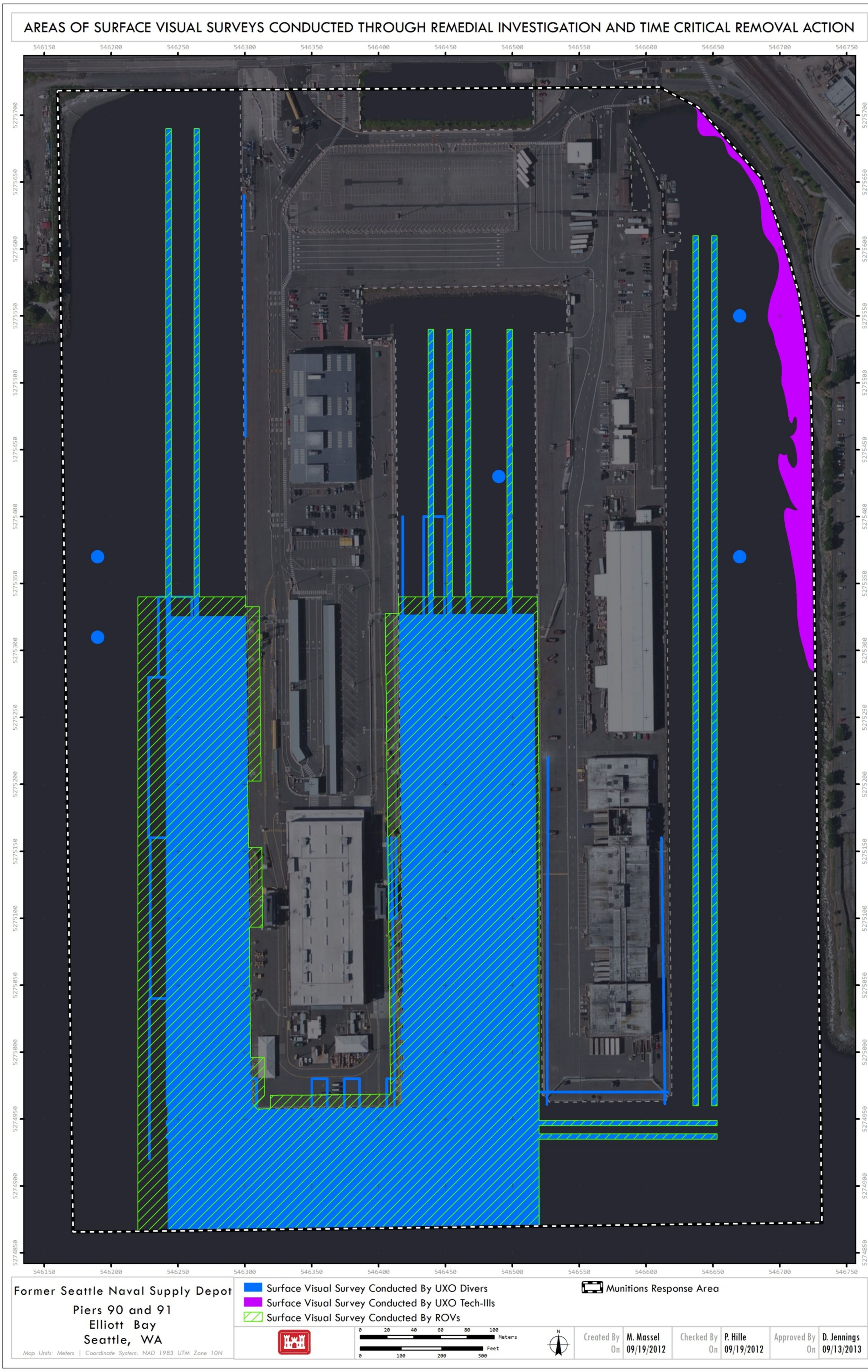
Figure 5-4 Areas of Surface Visual Surveys Conducted Through Remedial Investigation and the Time Critical Removal Action



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5.2 Munitions Constituents Delineation

The nature and extent of MC contamination was assessed through sediment sampling and laboratory analysis. **Figure 4-32** presents sample locations during the 2012 field season. **Table 5-2** provides a summary of various MC associated with various the DMM items recovered during the munitions responses at the FSNSD MRA. Multiple munitions items of different nomenclatures are listed in **Table 5-2**, including specific nomenclatures not confirmed as discovered at the FSNSD MRA. This inclusion is due to the inability of JBLM EOD and/or ECBC personnel to define a specific nomenclature for a DMM item. For example, several DMM items were recovered in good enough condition to classify them as 20mm, but due to sea growth there was an inability to identify a specific nomenclature. Metals typically associated with the MC items listed in **Table 5-2** include iron, copper, and zinc. However, due to the ubiquitous nature of metals from a variety of anthropogenic sources, any detection of metals from analytical analyses could not be conclusively tied to any specific MC item. Metals sampling was not conducted.

Table 5-2 Munitions Constituents for Discarded Military Munitions Recovered from the Former Seattle Naval Supply Depot

Size/Type	Nomenclature	Net Explosive Weight	Munitions Constituent(s)	Chemical for Laboratory Analysis
U.S. Cartridge, 5-inch/38 HE	MK 5	7.25 lb.	Explosive D/A3 Explosive D = Ammonium Picrate A3 = 91% RDX and 9% desensitizing wax	Ammonium Picrate as Picric Acid RDX
		Unknown	Red Pyrotechnic burning mixture in Tracer Element	
U.S. Cartridge, 5-inch/38 HE	MK 35 Mod 6	7.25 lb.	Explosive D / Comp A Explosive D = Ammonium Picrate A3 = RDX and plasticizing wax	Ammonium Picrate as Picric Acid RDX
		Unknown	Red Pyrotechnic burning mixture in Tracer Element	
U.S. Cartridge 40mm, High Explosive Tracer (HE-T)	MK-II AA	2.72 lb.	TNT	2,4,6-TNT
U.S. Cartridge, 20mm, High Explosive Incendiary (HEI)	M97A2	120 grains	RDX	RDX
		Unknown	Incendiary Pellet	
		470 grains	Smokeless Powder in M12 propellant	
		< 1 gram	Potassium Chlorate and Lead Sulfocyanate Electric Primer	
U.S. Cartridge, 20mm, HEI	M56A3	165 grains	H761 Propellant Class Comp A3 - 91% RDX and 9% desensitizing wax	RDX Dinitrotoluene
		20 grains	I136 Incendiary Pellet	

Table 5-2 Munitions Constituents for Discarded Military Munitions Recovered from the Former Seattle Naval Supply Depot

Size/Type	Nomenclature	Net Explosive Weight	Munitions Constituent(s)	Chemical for Laboratory Analysis
		585 grains	WC870 Propellant 80% Nitrocellulose 9% Nitroglycerine 5% Dibutyl Phthalate 1% Dinitrotoluene 1% Diphenylamine 4% Oxidizers (potassium nitrate, etc.)	Nitroglycerine Dibutyl-Phthalate Dinitrotoluene Diphenylamine
		< 1 gram	Potassium Chlorate and Lead Sulfocyanate Electric M52A3B1 Primer	
U.S. Cartridge, 20mm, Armor Piercing-Tracer (AP-T)	M95	470 grains	Smokeless Powder in M12 propellant M12 Propellant contains no explosives and is 98% nitrocellulose	NA
		< 1 gram	Potassium Chlorate and Lead Sulfocyanate Percussion or Electric Primer	
		< 1 gram	Red Pyrotechnic burning mixture in Tracer Element	
U.S. Cartridge, 20mm, Target Practice	M99A1	500 grains	Smokeless Powder Propelling Charge	NA
		< 1 gram	Potassium Chlorate and Lead Sulfocyanate Electric Primer	
U.S. Cartridge, 20mm, AA, HE-T	MK 4	0.01 lb.	Tetryl or PETN	Tetryl PETN
		< 1 gram	Lead Azide and Tetryl Detonator	
		< 1 gram	Lead Azide in Percussion Primer	
		500 grains	Smokeless Powder Propellant	
		< 1 gram	Pyrotechnic Tracer Composition	
U.S. Fuze, Nose, Impact	K 18	<1 gram	Primer mixture	NA
		3 gram	Black Powder	
U.S. projectile, 3-inch HE	MK 29 Mod 2	0.14 lb.	Explosive D (ammonium picrate)	Tetryl PETN Ammonium Picrate as Picric Acid
		4.4 grams	Tetryl or PETN	
		Unknown	Red Pyrotechnic burning mixture in Tracer Element	
U.S. Cartridge, 3-inch, AA, HE-T	MK 23	0.74 lb.	TNT	2,4,6-TNT (Source: MK 22 Series, MK 30 Series, or MK 51 Series)
		Unknown	MK 14 Percussion Primer and Igniter Tube	
		Unknown	Mercury Fulminate, Antimony Sulfide, and Potassium Chlorate in Percussion Cap	
		3.8 lbs.	Propellant	
		Unknown	Pyrotechnic Composition in MK 4 Tracer	
U.S. Cartridge, 3-inch, HE	M42 Series	0.86 lb.	TNT	2,4,6-TNT (Source: TM-9-1901 and M48)
		4.87 lbs.	NH Propelling Charge	
		300 grains	Smokeless Powder in M28 Percussion Primer	

Notes:
Chemicals found in primers are in such low quantities that analysis for them is infeasible by dilution in site marine conditions.
N/A – Not applicable.
NA – No analytical method or concentration is negligible such that the source is DMM.

5.2.1 Munitions Constituents Sampling Quality Assurance/Quality Control

The UFP-QAPP was developed as part of the Piers 90 and 91 RI WP. It was implemented through the integration of well-defined QC elements for activities associated with the task assignment. The QC criteria defined for sampling and analysis activities were developed in accordance with specifications contained in the USACE EM 200-1-3, Requirements for the Preparation of Sampling and Analysis Plans (USACE, 2001), USEPA Systematic Planning: A Case Study for Hazardous Waste Site Investigation, QA/CS-1, February 2006 (USEPA, 2006), and the DoD Quality Systems Manual (QSM) for Environmental Laboratories, Final Version 4.2 (DoD, 2010a). The Piers 90 and 91 Port of Seattle RI UFP-QAPP was prepared in accordance with the Uniform Federal Policy for Quality Assurance Project Plans (USEPA, 2005).

Documentation required for this project was reviewed and deficiencies, if any, were identified. Required project documentation included the following:

- **Field Forms**: Field forms were used to log daily activities and data collected during the course of field activities.
- **Chain-of-Custody**: Samples were collected and relinquished under stringent protocols as specified in the project QAPP. A review of Chain-of-Custody forms indicates that all sample collection, identification, and project information was correctly supplied.
- **Document Control:** Documents generated by or provided for the project team in support of project activities were input into the project database.

Sampling activities were performed by a qualified person in compliance with SOPs as presented in the RI WP (SKY, 2012a), and each individual performing sampling was aware of the requisite protocols for collection of environmental samples. Each sample technician was experienced or trained in the sampling techniques for the media collected. Personnel were provided with copies of the associated WP, which included the Field Sampling Plan, QAPP, and the Accident Prevention Plan/Site Safety and Health Plan.

5.2.2 Sample Methodology and Identification

Sampling collection devices and methodology are described in prior sections, including **Section 4.7.9** discussing coring tubes and UXO diver deployment, and **Figure 3-1** covering the sampling decision logic prepared during the TPP process.

Each sample was assigned a unique sequential number at the time of sampling, written on the sample label, and permanently affixed to the sample container. The sample identification number consisted of an alphanumeric designation related to the event, screening sample (as appropriate), location, media type, and QC sample (as appropriate), according to the following convention:

Event:	RI	=	RI sample
Laboratory Sample:	LS	=	Sample for laboratory analysis
Installation:	PS	=	POS

Transect/Segment:	T10B	=	Segment B of Transect 10
Media Type:	SE	=	Sediment sample
Sample #:	###	=	Number the samples in sequential #'s (001, 002, etc.)

An example name for the third sample is RI-LS-PS-T10B-SE-003. An example name for the tenth sample and duplicate is RI-LS-PS-T10B-SE-010 & RI-LS-PS- T10B-SE-010.

QC Sample:	=	Duplicate sample. The sample container was assigned an ID number in the field that cannot be identified (blind duplicate) as a duplicate sample by laboratory personnel.
MS/MSD	=	Matrix spike/ duplicate was added to the chain-of-custody in the special instructions column by the selected sample, which have additional sample volume.

Sampling QC included submitting MS/MSD samples along with the original sample for analytical analysis.

5.2.3 Munitions Constituents Analytical Methodology

The analytical services for the sampling effort were provided by Columbia Analytical Services located in Kelso, WA, a National Environmental Laboratory Accreditation Conference, and DoD-Environmental Laboratory Accreditation Program (ELAP) accredited laboratory. The analytical procedures adhered to the DoD Quality Systems Manual for Environmental Laboratories, Version 4.2 (DoD, 2010). The sediment samples were analyzed according to USEPA Office of Solid Waste and Emergency Response (OSWER) Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846), Update IVB (USEPA, 2008), as well as laboratory SOPs for this project.

Sediment samples were shipped to the Columbia Analytical Services with instructions to analyze for the following:

- 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).

5.2.4 Total Organic Carbon Sediment Sampling

The analysis for TOC in sediment was included to evaluate the applicability of sediment screening values, which are often derived using an equilibrium partitioning (EqP) approach, which includes the TOC value in the calculations. Sediment screening values are often based on a range of %TOC values from which to select based on the chemical of interest. In addition, the TOC result was used to model fish tissue concentrations from water using bioconcentration factors and soil organic carbon to water partitioning coefficients.

5.2.5 Data Validation

Laboratory data were electronically downloaded into the project databases and validated by chemists against project specific criteria, DoD QSM 4.2 (DoD, 2010a), method-specific criteria following USEPA *Office of Solid Waste and Emergency Response* (OSWER) *Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846), Update IVB* (USEPA, 2008) and the subcontract laboratory SOPs. Data validation was conducted in accordance with the *National Functional Guidelines for Inorganic Superfund Data Review* (USEPA, 2010) and *National Functional Guidelines for Superfund Organic Methods Data Review* (USEPA, 2008a). Data validation reports are included in **Appendix B**. In conjunction with the data validation guidelines, project specific DQOs, the DoD QSM, method-specific criteria, and the laboratory SOPs were examined to determine the overall usability of the analytical results.

All analytical data packages were validated and the analytical results were found to be usable per the projects DQO's, and no data were rejected. Validation was completed to ensure compliance with specified analytical QA/QC requirements, data reduction procedures, data reporting requirements and required accuracy, precision, and completeness criteria.

The following parameters were evaluated during the data validation process:

- Analyte identification.
- Sample Preservation and Technical Holding Times.
- Blank Analysis.
- Instrument Performance Check.
- Initial and Continuing Calibrations.
- Laboratory Control Sample.
- Matrix Spike/Matrix Spike Duplicate.
- Laboratory and Field Duplicates.
- Quantification Verification.

If these parameters for the site-specific analyses did not meet the USEPA criteria, a discussion of the implications about the guidelines appears in the data validation report narratives found in **Appendix B**. Parameters outside guidelines do not necessarily indicate that the result is invalid. The decision of validity is made by the professional validator based on the USEPA guidelines referenced herein. Complete validation report narratives for all the analytical results, as well as a glossary of QA/QC terms and data qualifier codes, can be found in **Appendix B**.

5.2.6 Munitions Constituents Sediment Sampling Results

Twelve sediment samples were collected and submitted for analytical quantification for explosive energetics (Nitroaromatics, Nitramines, and Nitrophenols), and munitions related propellant stabilizers (Diphenylamine, N-Nitrosodiphenylamine). Munitions related propellant plasticizers (Di-n-butyl phthalate, diethyl phthalate) were analyzed if positive detections for energetics and/or propellant stabilizers were observed in the sample. Sediment samples were collected within the 0-10 cm (3.94 inch) biologically active zone (BAZ) with the exceptions of samples RI-LS-PS-T06E-SE-010 and RI-LS-PS-T06E-SE-012 (18 inches and 8 inches respectively) (depth of samples is detailed in **Table 4-10**). The 0-10 cm BAZ interval is for regulatory purposes; however, the effective BAZ is known to extend down to at least 100 cm (MacDonald and Ingersoll, 2003).

5.2.6.1 Energetics (Nitroaromatics, Nitramines, and Nitrophenols)

Four sediment samples (RI-LS-PS-T10B-SE-001, RI-LS-PS-T10B-SE-004, RI-LS-PS-T03F-SE-009, and RI-LS-PS-T05F-SE-013) had results for energetics above the laboratory's Limit of Detection (LOD). Sample RI-LS-PS-T10B-SE-001 had detections of 2,4-DNT, 2,6-DNT, and tetryl at 0.97J, 0.12J, and 0.23J milligrams per kilogram (mg/kg) respectively. Sample RI-LS-PS-T10B-SE-004 had one detection of 2,4-DNT at 0.16J mg/kg. Sample RI-LS-PS-T03F-SE-009 also had a detect of 2,4-DNT at 0.20J mg/kg. Sample RI-LS-PS-T05F-SE-013 had a detect of RDX at 0.058J mg/kg.

5.2.6.2 Nitrophenols

Sediment sample RI-LS-PS-T10B-SE-001 had a reported result of 0.0028J mg/kg for Picric Acid.

5.2.6.3 Propellant Stabilizers

All the sediment samples were analyzed for diphenylamine and N-nitrosodiphenylamine. Diphenylamine was detected in samples RI-LS-PS-T10B-SE-001, RI-LS-PS-T10B-SE-004, RI-LS-PS-T03F-SE-008, and RI-LS-PS-T03F-SE-009 at 0.67J, 0.16J, 0.064J, and 0.033J mg/kg respectively. N-nitrosodiphenylamine was detected in samples RI-LS-PS-T10B-SE-001, RI-LS-PS-T10B-SE-004, and RI-LS-PS-T03F-SE-008 at 0.87J, 0.19J, and 0.071J mg/kg respectively.

5.2.6.4 Propellant Plasticizers

Sediment samples RI-LS-PS-T10B-SE-001, RI-LS-PS-T10B-SE-004, RI-LS-PS-T03F-SE-008, RI-LS-PS-T03F-SE-009, and RI-LS-PS-T05F-SE-013 were analyzed for diethyl phthalate and di-n-butyl phthalate after confirmation that energetics and/or propellant stabilizers were observed in the sample. Di-n-butyl phthalate was detected in samples RI-LS-PS-T10B-SE-001, RI-LS-PS-T10B-SE-004, RI-LS-PS-T03F-SE-008, and RI-LS-PS-T03F-SE-009 at 0.040J, 0.050J, 0.090J, and 0.14J mg/kg respectively. Diethyl phthalate was detected in samples RI-LS-PS-T03F-SE-008 and RI-LS-PS-T05F-SE-013 at 0.062J and 0.020J mg/kg respectively.

Table 5-3 Sediment Sample Analytical Results - Former Seattle Naval Supply Depot Munitions Response Area

Location: Field ID: Lab ID: Collection Date: DMM found		T10,B20 RI-LS-PS-T10B-SE-001 K1201784-001 2/21/2012 20mm				T10,B25 RI-LS-PS-T10B-SE-002 K1201784-002 2/21/2012 20mm				T10,B20 RI-LS-PS-T10B-SE-003 K1201784-003 2/21/2012 20mm				T10,B30 RI-LS-PS-T10B-SE-004 K1201784-004 2/21/2012 20mm/Container				T10,B30 RI-LS-PS-T10B-SE-005 K1201784-005 2/21/2012 20mm/Container			
Energetics - Nitroaromatics, Nitramines, and Nitrophenols (mg/kg)	Abbreviation	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual
1,3,5-trinitrobenzene	1,3,5-TNB	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
1,3-dinitrobenzene	1,3-DNB	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
2,4,6-trinitrotoluene	2,4,6-TNT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
2,4-dinitrotoluene	2,4-DNT	0.97	0.40	0.060		< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	0.16	0.40	0.060	J	< 0.40	0.40	0.060	U
2,6-dinitrotoluene	2,6-DNT	0.12	0.40	0.060	J	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
2-amino-4,6-dinitrotoluene	2-Am-DNT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
2-nitrotoluene	2-NT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
3,5-dinitroaniline	3,5-DNA	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
3-nitrotoluene	3-NT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
4-amino-2,6-dinitrotoluene	4-Am-DNT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
4-nitrotoluene	4-NT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
Nitrobenzene	NB	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
Nitroglycerin	NG	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	HMX	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U
Pentaerythritol tetranitrate	PETN	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U
Trinitrophenylmethyl-nitramine	Tetryl	0.23	0.40	0.060	J	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U
2-Amino-4,6-dinitrophenol (Picramic Acid)		< 0.0075	0.0075	0.00045	U	< 0.0082	0.0082	0.00049	U	< 0.0065	0.0065	0.00039	U	< 0.0060	0.0060	0.00036	U	< 0.0064	0.0064	0.00038	U
2,4,6 Trinitrophenol (Picric Acid)		0.0028	0.0075	0.0015	J	< 0.0082	0.0082	0.0016	U	< 0.0065	0.0065	0.0013	U	< 0.0060	0.0060	0.0012	U	< 0.0064	0.0064	0.0013	U
2,4-Dinitrophenol		< 0.0075	0.0075	0.00068	U	< 0.0082	0.0082	0.00074	U	< 0.0065	0.0065	0.00058	U	< 0.0060	0.0060	0.00054	U	< 0.0064	0.0064	0.00057	U
Propellant Stabilizers (mg/kg)																					
Diphenylamine	DPA	0.67	0.99	0.036	J	< 0.99	0.99	0.036	U	< 0.10	1.0	0.036	U	0.16	1.0	0.036	J	< 0.99	0.99	0.036	U
N-Nitrosodiphenylamine	NDPA	0.84	0.98	0.059	J	< 0.98	0.98	0.060	U	< 0.99	0.99	0.060	U	0.19	0.99	0.060	J	< 0.98	0.98	0.060	U
Propellant Plasticizers (mg/kg)																					
Di-n-butyl phthalate		0.040	0.99	0.051	J	NA				NA				0.050	1.0	0.051	J	NA			
Diethyl phthalate		< 0.98	0.98	0.051	U	NA				NA				< 0.99	0.99	0.051	U	NA			
Other (%)																					
Total Organic Carbon	TOC	1.35	0.05	0.02		0.507	0.05	0.02		1.61	0.05	0.02		1.62	0.05	0.02		0.772	0.05	0.02	

Notes:
All results highlighted in table are reported detections, all non detect values listed in results column are < LOQ, all values between the LOQ and MDL are reported and J qualified per the DoD QSM 4.2.
J = Estimated
U = Non-detect
NA = Not Analyzed
NR=Not Reported

Table 5-3 Sediment Sample Analytical Results - Former Seattle Naval Supply Depot Munitions Response Area (Cont.)

	Location	T10,B35				T03, F95				T03, F65				T03, F80				T04, D10			
	Field ID:	RI-LS-PS-T10B-SE-006				RI-LS-PS-T03F-SE-007				RI-LS-PS-T03F-SE-008				RI-LS-PS-T03F-SE-009				RI-LS-PS-TO4D-SE-011			
	Lab ID:	K1201784-006				K1201882-001				K1201882-002				K1201882-003				K1202188-001			
	Collection Date:	2/21/2012				2/27/2012				2/27/2012				2/27/2012				3/5/2012			
	DMM found	20mm				20mm				20mm				5 Inch				20mm			
Energetics - Nitroaromatics, Nitramines, and Nitrophenols (mg/kg)	Abbreviation	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual
1,3,5-trinitrobenzene	1,3,5-TNB	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
1,3-dinitrobenzene	1,3-DNB	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
2,4,6-trinitrotoluene	2,4,6-TNT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2,4-dinitrotoluene	2,4-DNT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	0.20	0.40	0.060	J	< 0.39	0.39	0.060	U
2,6-dinitrotoluene	2,6-DNT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2-amino-4,6-dinitrotoluene	2-Am-DNT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
2-nitrotoluene	2-NT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
3,5-dinitroaniline	3,5-DNA	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
3-nitrotoluene	3-NT	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
4-amino-2,6-dinitrotoluene	4-Am-DNT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
4-nitrotoluene	4-NT	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
Nitrobenzene	NB	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Nitroglycerin	NG	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	HMX	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Pentaerythritol tetranitrate	PETN	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.40	0.40	0.40	U	< 0.39	0.39	0.40	U
Trinitrophenylmethyl-nitramine	Tetryl	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2-Amino-4,6-dinitrophenol (Picramic Acid)		< 0.0091	0.0091	0.00055	U	< 0.0088	0.0088	0.00053	U	< 0.0096	0.0096	0.00058	U	< 0.0082	0.0082	0.00049	U	< 0.0084	0.0084	NR	U
2,4,6 Trinitrophenol (Picric Acid)		< 0.0091	0.0091	0.0018	U	< 0.0088	0.0088	0.0018	U	< 0.0096	0.0096	0.0019	U	< 0.0082	0.0082	0.0016	U	< 0.0084	0.0084	NR	U
2,4-Dinitrophenol		< 0.0091	0.0091	0.00082	U	< 0.0088	0.0088	0.00079	U	< 0.0096	0.0096	0.00086	U	< 0.0082	0.0082	0.00074	U	< 0.0084	0.0084	NR	U
Propellant Stabilizers (mg/kg)																					
Diphenylamine	DPA	< 0.10	1.0	0.036	U	< 0.10	1.0	0.036	U	0.064	1.0	0.036	J	0.033	0.99	0.036	J	< 0.10	1.0	0.036	U
N-Nitrosodiphenylamine	NDPA	< 0.99	0.99	0.060	U	< 0.99	0.99	0.06	U	0.071	0.99	0.06	J	< 0.98	0.98	0.06	U	< 0.99	0.99	0.06	U
Propellant Plasticizers (mg/kg)																					
Di-n-butyl phthalate		NA				NA				0.090	1.0	0.051	J	0.14	0.98	0.051	J	NA			
Diethyl phthalate		NA				NA				0.062	0.99	0.051	J	< 0.99	0.99	0.036	J	NA			
Other (%)																					
Total Organic Carbon	TOC	1.77	0.05	0.02		0.837	0.05	0.02		0.898	0.05	0.02		2.01	0.05	0.02		0.805	0.05	0.02	

Notes:
All results highlighted in table are reported detections, all non detect values listed in results column are < LOQ, all values between the LOQ and MDL are reported and J qualified per the DoD QSM 4.2.
J = Estimated
U = Non-detect
NA = Not Analyzed
NR = Not Reported

Table 5-3 Sediment Sample Analytical Results – Former Seattle Naval Supply Depot Munitions Response Area (Cont.)

	Location Field ID: Lab ID: Collection Date: DMM found	T10, D55 RI-LS-PS-T10B-SE-012 K1202691-001 3/21/2012 20mm				T05, F45 RI-LS-PS-T05F-SE-013 K1202691-002 3/21/2012 5-inch			
Energetics - Nitroaromatics, Nitramines, and Nitrophenols (mg/kg)	Abbreviation	Result	LOQ	LOD	Qual	Result	LOQ	LOD	Qual
1,3,5-trinitrobenzene	1,3,5-TNB	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
1,3-dinitrobenzene	1,3-DNB	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
2,4,6-trinitrotoluene	2,4,6-TNT	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2,4-dinitrotoluene	2,4-DNT	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2,6-dinitrotoluene	2,6-DNT	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2-amino-4,6-dinitrotoluene	2-Am-DNT	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
2-nitrotoluene	2-NT	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
3,5-dinitroaniline	3,5-DNA	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
3-nitrotoluene	3-NT	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
4-amino-2,6-dinitrotoluene	4-Am-DNT	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
4-nitrotoluene	4-NT	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	< 0.40	0.40	0.060	U	0.058	0.39	0.060	J
Nitrobenzene	NB	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Nitroglycerin	NG	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	HMX	< 0.40	0.40	0.16	U	< 0.39	0.39	0.16	U
Pentaerythritol tetranitrate	PETN	< 0.40	0.40	0.40	U	< 0.39	0.40	0.40	U
Trinitrophenylmethyl-nitramine	Tetryl	< 0.40	0.40	0.060	U	< 0.39	0.39	0.060	U
2-Amino-4,6-dinitrophenol (Picramic Acid)		< 0.0097	0.0097	0.00058	U	< 0.0010	0.0010	0.00060	U
2,4,6 Trinitrophenol (Picric Acid)		< 0.0097	0.0097	0.0019	U	< 0.0010	0.0010	0.0020	U
2,4-Dinitrophenol		< 0.0097	0.0097	0.00087	U	< 0.0010	0.0010	0.00090	U
Propellant Stabilizers (mg/kg)									
Diphenylamine	DPA	< 0.34	0.34	0.0120	U	< 0.34	0.34	0.0120	U
N-Nitrosodiphenylamine	NDPA	<0.33	0.33	0.0200	U	<0.33	0.33	0.0200	U
Propellant Plasticizers (mg/kg)									
Di-n-butyl phthalate		NA				< 0.33	0.33	0.017	U
Diethyl phthalate		NA				0.020	0.33	0.017	J
Other (%)									
Total Organic Carbon	TOC	1.13	0.05	0.02		1.09	0.05	0.02	

Notes:
All results highlighted in table are reported detections, all non detect values listed in results column are < LOQ, all values between the LOQ and MDL are reported and J qualified per the DoD QSM 4.2.
J = Estimated
U = Non-detect
NA = Not Analyzed
NR = Not Reported

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5.2.6.4.1 Delineation of Sediment Contamination

For the purposes of defining an exposure area for the risk assessments (presented in **Section 7.0**), the locations of the sediment samples were evaluated on an area basis and frequency of detection. The sediment samples represent a localized area of very low levels of MC contamination, and this area represents a very small portion of the entire MRA. **Figure 5-5** shows the approximate exposure area based on the sediment samples collected where DMM was investigated and removed. The delineation area does not include the area under the piers, as the foundations are solid construction and rip rap, retain little or no sediment, and no DMM was found under them. The isolated sample location RI-LS-PS-T04D-SE-011 (shown in **Figure 4-32**) had no detections and was not included in defining the approximate exposure area. The selection of the exposure area was used to establish the area for calculating area use factors (AUFs) for evaluating seafood ingestion (**Section 7.1.3.5.1**) and to develop the EPCs for the risk assessment (**Section 7.1**).

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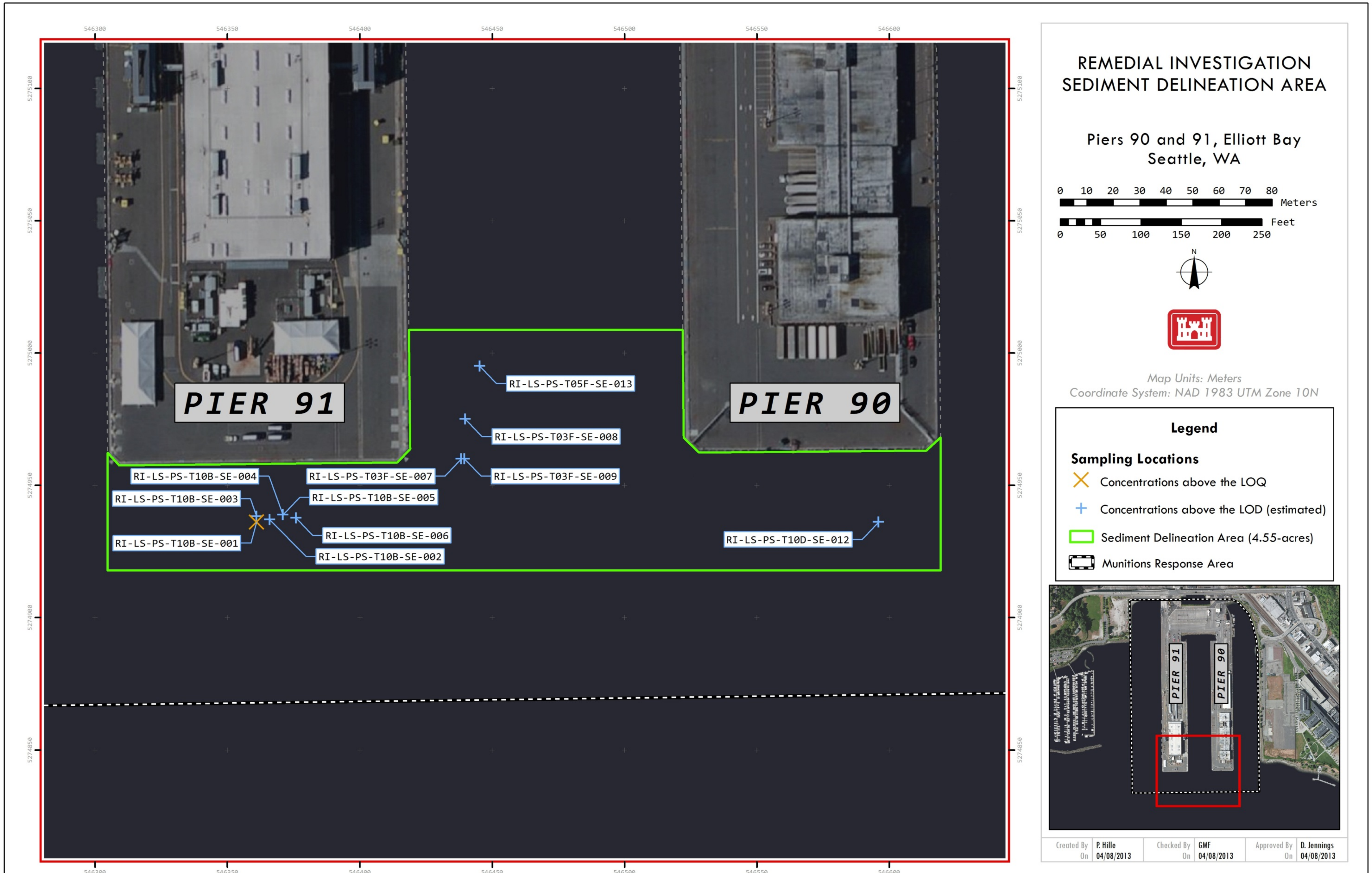
Figure 5-5 Delineation of Sediment Contamination at the FSNSD Munitions Response Area



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5.3 Additional Munitions Response Site Designations

According to the *USACE Handbook on Realignment, Delineations, and MRS Prioritization Protocol Implementation, Version 1.0.2, (October 2011)* (USACE, 2011), delineation of a FUDS MMRP project should be performed for a number of reasons. The number and configuration of MRSs on an MRA should maximize the District's flexibility to plan, manage, and execute response actions and achieve FUDS Program goals. As more information becomes available, the PM District may consider delineating MRSs into manageable segments of work that are executable within anticipated funding and required time frames (USACE, 2011).

The following criteria may be used during any phase of work to support MMRP project/MRS delineation decisions based on project specific parameters:

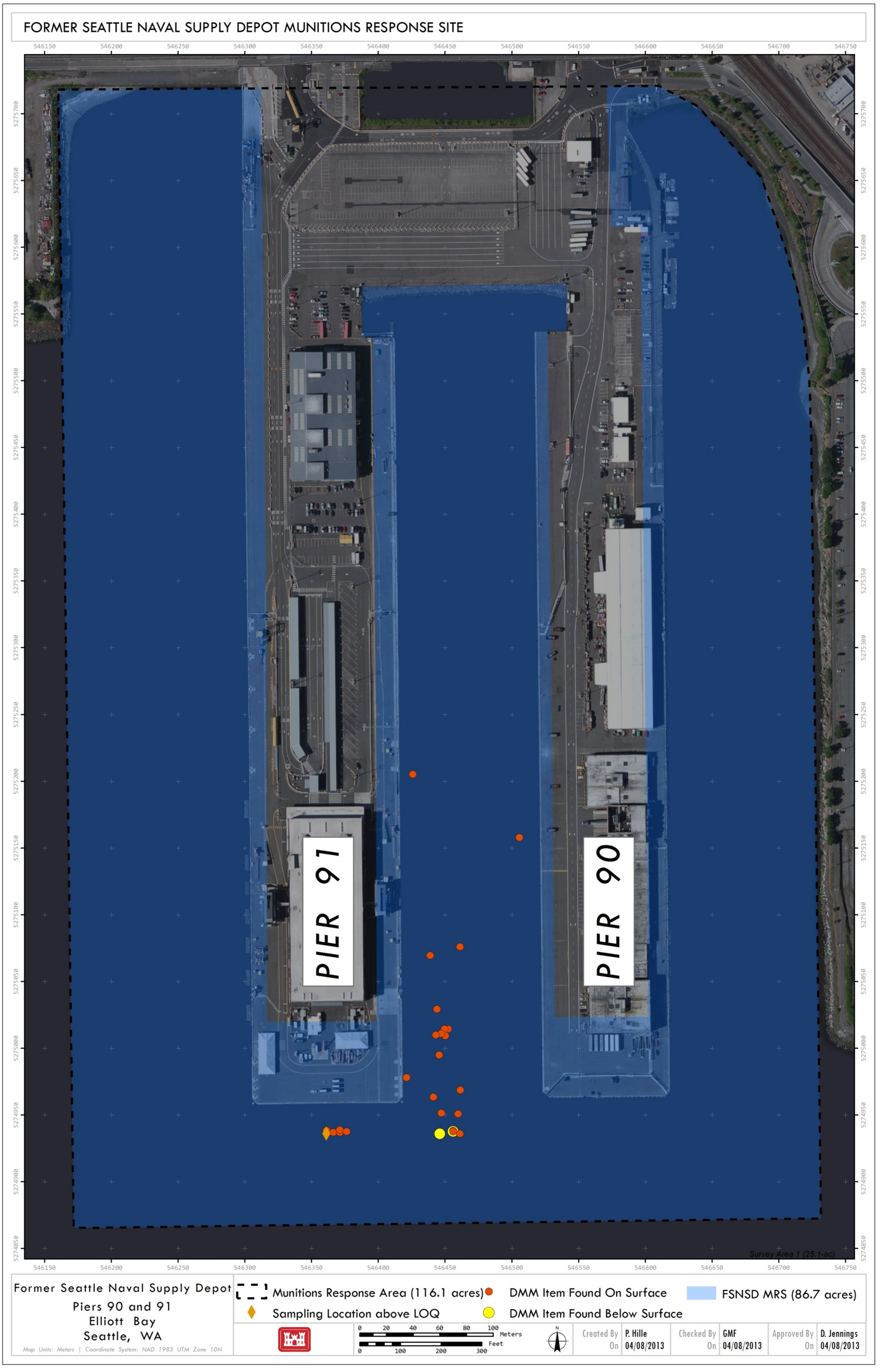
- Geographic Setting: Site-specific conditions related to geography, topography, bodies of water, terrain and vegetation types, significant natural features, and other physical barriers.
- Anticipated Response: Site-specific conditions related to the anticipated future response actions, such as investigative approaches, types of removal or remedial actions proposed, and common technological application.
- Management Efficiency: Practical considerations related to project management efficiencies such as the number of MRAs and MMRP projects at a FUDS property.
- Land Use: Site-specific conditions related to current and future land use, such as the number of property owners, the type of owners (private vs. government agency), existing infrastructure, and planned development.
- Right-of-Entry: The ability, or inability, to obtain right-of-entry to access the MRS or portion of the MRS.
- Stakeholder Input: The interest and input from the lead regulatory agency, property owners, or other stakeholders; congressional interest; regulatory orders; community interest; and public involvement issues.
- Risk Management: Site-specific conditions related to risk management to include the CSM; accident history for the site; types, sources, and locations of MEC; surface and subsurface exposure scenarios; types and concentrations of MC; public access issues; and risk screening or risk assessment data.
- Performance Goals: Practical considerations related to meeting FUDS, USACE, DA, and DoD performance metrics, such as the FUDS Program Management Plan, MMRP phase completion goals, project milestones, and achievement of NDAI or regulatory closeout.
- Project Complexity: Practical considerations related to project complexity, such as the size of the MRAs; the type, sources, or location of munitions; making progress within constrained funding for MMRP projects with a high cost-to-complete estimate; and the cost and timeframe to implement response action.
- Potentially Responsible Party (PRP) Issues: Separation of portions of projects with PRP implications. This prevents the expenditure of FUDS funding on portions of the original project with PRP considerations (USACE, 2011).

Based on the combined findings of the RI and TCRA field efforts, the FSNSD MRA is recommended to be delineated as a single MRS matching the boundary of the MRA (shown on **Figure 5-6**):

<u>FSNSD MRS (86.7 acres)</u>

- All DMM found at the site, and all MC samples collected at the site to date are within the boundary of this MRS. The sediment delineation area shown in **Figure 5-5** is completely within this area.

Figure 5-6 Former Seattle Naval Supply Depot Munitions Response Site



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6.0 CONCEPTUAL SITE MODELS AND CONTAMINANT FATE AND TRANSPORT

This section discusses the fate and transport, including exposure pathway analysis for MEC and MC found on and beneath the seafloor at the FSNSD MRS. MEC was limited to DMM. The fate of MC is located in **Section 6.2.8***.* The development of the preliminary CSMs for the RI WP and subsequent refinement of those CSMs follows.

6.1 Development of Preliminary Conceptual Site Models

The preliminary CSMs for the WP were developed as a means to identify the potential access and exposure pathways, receptors, exposure media, release and transport mechanisms, and exposure routes based on information from the TCRA and other historical information. The preliminary CSMs provided a starting point for the RI, especially for defining the presence or absence of MEC and the nature and extent of MC contamination. This in turn directed the underwater investigations and sampling for MC in sediment. These preliminary CSMs were modified to reflect the understanding of site-specific conditions following the data collection and evaluation.

6.1.1 Potential Exposure to Human and Ecological Receptors

Based on the knowledge gained prior to the actual site investigations, human and ecological receptors were evaluated for their potential to access the MRS and contact contaminated environmental media. Persons could enter the waters adjacent to the FSNSD MRS from the Elliott Bay Marina and from the eastern boundary of Terminal 91. There is a small park area and bike/running path adjacent to the far perimeter fence, and this fence is not contiguous on the eastern boundary. There is limited shoreline at Terminal 91, most of which is covered with riprap. The shoreline is quite steep and drops off rapidly. Terminal 91 itself is fenced and security-controlled to prevent vehicles and persons entering without proper authorization (SKY, 2012a).

Potential human receptors that could incidentally ingest sediments ingest marine life contaminated by uptake from sediments, or come into dermal contact with MC-contaminated sediments at the FSNSD included the following:

Current and Future Underwater Site Worker—This receptor represents POS PD dive team divers performing periodic pier inspections, security, and other activities. Divers and other underwater site workers could potentially be exposed to contaminated sediments. Security personnel are not expected to contact sediment in their daily routines. It is documented that divers enter the area at least one day per week during the seven-month cruise ship season, and that divers are underwater for 30 to 60 minutes (SKY, 2012). Divers are encapsulated in a dry suit due to water temperatures. Only a small portion of the face is exposed to sediment or water. Divers do not remove gloves or clear their masks underwater. Their suits and gear are partially rinsed in seawater on the way up. Divers also rinse off with water either on the dive platform, on the embarkation pier or both locations. Divers may make up to four dives per day (SKY, 2012a).

Current and Future Underwater Construction Worker—This receptor represents the construction worker-diver performing normal intrusive activities on an infrequent basis, such as structural repairs. Divers and other site workers could potentially be exposed to contaminated sediments. Divers are encapsulated in a dry suit due to water temperatures. Only a small portion of the face is exposed to sediment or water. Divers do not remove gloves or clear their masks underwater, and partially rinse off on the way up in seawater. Divers may make up to four dives per day. Handling of sediment-contaminated pier materials during normal repairs and renovations could pose similar potential exposures. Used wooden pier timbers may have been discarded in place upon replacement and not brought to the surface (SKY, 2012a); however, the current practice is to remove the piers and have them disposed of in an approved facility. The underwater construction worker also includes a topside construction worker while performing dredging operations at Terminal 91. The topside construction worker is not expected to contact contaminated sediments in the normal performance of job duties.

Current and Future Commercial Worker—Commercial fishermen and longshoremen could potentially be exposed via incidental ingestion of contaminated sediment and dermal contact while handling their anchors and fishing equipment, although such exposure is likely minimal and insignificant compared to underwater workers. Commercial fishing vessels utilizing Terminal 91 are typically very large and use automated equipment for heavy operations, and water hoses for cleaning anchors, decks, and fishing tackle. Therefore, exposure by the commercial worker is expected to be addressed by evaluating the underwater site worker or underwater construction worker. Longshoremen are not expected to contact sediment in typical cargo handling activities. Exposures for this receptor category will be discussed qualitatively (SKY, 2012a).

Current and Future Native American—Tribal members might harvest fish, crabs, shrimp, kelp, and shellfish from areas near the MRS. The FSNSD MRS is within Native American tribal "usual and accustomed" harvesting areas. However, all kelp beds are outside the MRS. No clam, oyster, or similar bivalve harvesting by digging or dredging into sediments is included in this exposure scenario since there is little shoreline habitat and the area is partially fenced. The habitat for bivalves at the FSNSD site is limited and access to the sediments is deep. Native Americans could not be prohibited from catching some Dungeness Crab and bottom-dwelling fish (e.g., English Sole, Starry Flounder), and anadromous salmonids from within the MRS. Elliott Bay is closed for shell fishing due to pollution (DOH, 2012). Fish and shellfish consumption advisories are in place in the vicinity of the FSNSD site and Elliott Bay due to pollution, and therefore fishing or harvesting of shellfish within the MRA is highly unlikely (SKY, 2012a).

Current and Future Recreational Angler—Divers, snorkelers and swimmers exploring around the pier are unlikely receptors due to the cold water, lack of visibility, and shipping traffic. Recreational anglers may utilize the area. The potential for greatest exposure would be the possible ingestion of contaminated fish and shellfish by recreational anglers, and incidental ingestion and dermal contact with sediments while handling fishing equipment. The same seafood items (i.e., finfish and shellfish) for the Native American are assumed to apply for the recreational angler. The ratio of finfish to shellfish in the diet was assumed 50:50.

Current and Future Tourist—Cruise ship passengers embarking and debarking cruise vessels may be present but are unlikely to contact contaminated sediments. A remote potential exists that tourists might consume contaminated fish from this locale but their presence at Terminal 91 is of very short duration and on a seasonal basis. Considering the fish advisories in place, exposures for this receptor will be discussed qualitatively (SKY, 2012a). The potential exists for seawater splash on tourists; however, this exposure pathway was deemed insignificant and not addressed in the RI.

Current and Future Resident—There are no permanent residents within the MRS boundary or in close proximity to the FSNSD site. Any exposure is unlikely; however, the potential for exposure could hypothetically include the ingestion of contaminated fish caught from the FSNSD MRS. This is unlikely due to the extensive fish advisories in place, secure access, and fencing. Residents are therefore not addressed.

Ecological Receptors—Potential ecological receptors that may incidentally ingest sediments, ingest prey, forage in contaminated sediments, or come into direct contact with MC-contaminated sediments at the FSNSD MRS include the following:

- Benthic marine invertebrates (e.g., infauna and epifauna)—may be exposed by direct contact and ingestion (e.g., Dungeness Crab [*Metacarcinus magister]*). This receptor category includes mollusks and crustaceans.
- Marine plants—rooted or floating plants may be exposed by direct contact to contaminated sediment.
- Marine mammals—mammals may be exposed by direct contact, incidental sediment ingestion, and ingestion of marine vegetation and prey contaminated by uptake from sediments. Examples include Harbor (common) seal (*Phoca vitulina*), California Sea Lion (*Zalophus californianus*), and Federal Threatened Steller Sea Lion (*Eumetopias jubatus*) (USFWS, 2012).
- Marine birds—birds may be exposed by direct contact with sediment (diving birds), incidental sediment ingestion, and ingestion of marine vegetation and prey contaminated by uptake from sediments. Examples include Spotted Sandpiper (*Actitis macularius*), pelicans, seagulls, ospreys, and other raptors.
- Demersal salt-water fish—fish may be exposed by incidental sediment ingestion on suspended sediments, ingestion of marine vegetation/prey contaminated by uptake from sediments, and possible inhalation of suspended sediments particles through gills. Examples include Starry Flounder (*Platichthys stellatus*) and English Sole (*Parophrys vetulus*); both bottom feeders (SKY, 2012a).

Salmonids may be present in the MRS but only on an infrequent basis during migration, during which time they could potentially ingest contaminated invertebrates. Risks to demersal fish species were considered protective of potential risks to salmonids. Future ecological receptors are expected to be the same as those currently present (SKY, 2012a).

6.1.2 Exposure Pathway Analysis

Each exposure pathway includes a source (e.g., explosives released to the environment), an exposure medium (i.e., sediment), a release mechanism (e.g., leaking through cracked casings), an exposure route (e.g., ingestion) and a receptor (e.g., Terminal 91 Diver). The potential for exposure to MEC was realized when POS divers conducted routine pier inspections prior to the TCRA and located DMM. Since MEC was found, the presence of MC contamination was considered a possibility. The RI and TCRA confirmed the MEC present was DMM and not UXO.

Surface water is not expected to contain detectable levels of MC at the FSNSD, and potential source areas for DMM and MC are currently limited by access and activity.

Ingestion of MC from sediment (primarily surface, and to a far lesser extent, subsurface) was deemed possible (though highly unlikely) for persons engaged in any underwater intrusive or sediment disturbing activity, such as excavation, removal, or construction. It was thought that incidental sediment ingestion might occur through a leaking facemask or around the regulator mouthpiece. Likewise, subsurface MC-contaminated sediment could pose exposure to human receptors through intrusive and non-intrusive (unintentional) activities. During normal site operations, human receptors were thought more likely to be exposed through ingestion of contaminated seafood and to a far lesser degree by dermal contact with sediments on lines, anchors, cables, fishing tackle, nets, and crabbing pots. The likelihood of any such actual seafood ingestion, fishing or crabbing within the MRS is essentially non-existent.

Ecological exposures from MC-contaminated sediment can occur via root uptake in marine plants, and via direct contact. Ingestion of sediment particles by diving birds, marine mammals, fish, and marine invertebrates is possible. Explosives (nitroaromatics and nitramines) are not included as bioaccumulative compounds in aquatic systems according to the USEPA Great Lakes Initiative (USEPA, 2011a), and bioaccumulation is considered to be likely minimal. However, because it is possible, bioaccumulation was modeled as a complete exposure pathway.

Other animal receptors can be exposed through ingestion of contaminated prey such as piscivorous mammals, fish, and birds. Herbivorous receptors can ingest contaminated marine vegetation. Marine species can ingest benthic or water column invertebrates and vegetation (e.g., algae, kelp) which may contain contaminated sediment or dissolved, absorbed, and adsorbed contaminants.

Ecological receptors are also potentially exposed through direct contact with surface and subsurface sediments. The RI investigation was focused on the top 10 cm of the surface sediment (the BAZ). Although some marine life can burrow to greater depths during various life stages (e.g., Geoduck [*Panopea generosa*]), the unconsolidated surface layer is most relevant. The preliminary sediment pathways to ecological receptors at the FSNSD MRS were identified as potentially complete, incomplete, and insignificant.

Available site characteristics were used to predict whether preliminary exposure pathways to MEC for human receptors were incomplete, potentially complete, or complete. The definitions for each pathway are listed below:

- **Incomplete Pathway:** Based on the available munitions information collected during the TCRA and during the RI field investigation, there is no evidence that receptors would be exposed to MEC through the indicated exposure route. Therefore, the pathway is incomplete.
- **Potentially Complete Pathway**: Insufficient data are available to determine if receptors may be exposed to MEC through the indicated pathway.
- **Complete Pathway:** Data collected during the TCRA and the RI may indicate that MEC as DMM are present within the indicated exposure media and that receptors exist at the site that may have access to the MEC through the environmental media.

In addition, a pathway may exist or be potentially complete but may represent an insignificant exposure route (e.g., tourists potentially disturbing sediments in the MRS).

6.1.2.1 Munitions and Explosives of Concern Exposure Pathways Analysis

During normal facility operations, potential interaction with human receptors is expected to occur only at the source areas where DMM are encountered. The primary exposure medium for human receptors at the MRS is assumed to be marine sediment. It is possible that sediment could be brought up from below to the surface and piers on fishing and other commercial equipment (e.g., anchors, propellers, ropes, Dredge Heads) although this exposure pathway is likely insignificant. The potential for recreational persons or Native Americans to access DMM or MC-contaminated sediment from the scant shoreline at the MRS is essentially non-existent. POS maintains a degree of oversight in the vicinity of Terminal 91. Anyone attempting to dive down to the deep sediments from shore or arrive by boat would likely be contacted by the POS, possibly detained and then referred to the USCG for disposition. POS harbor police are not authorized to detain individuals for entering the waters of Terminal 91, fishing, or swimming since technically they are not considered trespassers. They would be allowed to detain individuals based on unsafe boating practices, suspicion of intoxication, or illegal activities. POS harbor police are not authorized to enforce federal laws, and the waters of the MRS fall under jurisdiction of the USCG (Port of Seattle, 2012).

Terminal 91 is a very busy commercial port and the danger posed to persons attempting to swim, fish, or dive in the MRS waters is extremely high. There are other more desirable and safer areas designated for recreational diving in Elliott Bay (e.g., Seacrest Park). Elliott Bay and Puget Sound have many designated recreational fishing and shell fishing locations.

Recreational or Native American anglers would be deterred from fishing from the shore or in boats in Terminal 91 waters due to the fish advisories in place. Existing signage on the piers advises anglers that it is unsafe to eat bottom-feeding fish, crab, or other shellfish from the area due to pollution.

6.1.2.2 Munitions Constituents Exposure Pathways Analysis

Each exposure pathway includes a source (e.g., explosives released to the environment), an exposure medium (i.e., sediment, seawater), a release mechanism (e.g., leaking), an exposure route (e.g., ingestion, biouptake) and a receptor (e.g., angler) (SKY, 2012a).

6.1.2.2.1 Munitions Constituents Release Mechanisms

The potential for MC release at the MRS results from weathering, degradation, leaking, or structural damage to MEC. Subsequent physical disturbance of MEC could potentially release MC into sediments if the physical force was sufficient and/or the item was substantially compromised (SKY, 2012a).

Human activities including construction such as dredging, diving, underwater exploration, or vessels contacting the surface and subsurface sediments could potentially contact MC. Such activities could cause movement of MEC and release MC within the marine environment (SKY, 2012a). It is very unlikely that any unauthorized diving or underwater exploration would take place at the MRS due to the commercial nature of Terminal 91 and security measures in place. However, as a conservative measure in scoping the baseline HHRA, such activities were considered.

Release to seawater may occur. However, due to the size of the water body, tidal influences (dilution) and the limited numbers of DMM found, the quantitation of MC in seawater would likely result in non-detected values. Release to seawater, therefore, is not a mechanism of concern for MC (SKY, 2012a).

6.1.2.2.2 Transport Processes

Physical disturbance can provide significant transport mechanisms. Natural physical processes, including saltwater corrosion, currents, tides and storm surges, might cause MC to migrate within the marine environment following a primary release. A form of biological disturbance, bioturbation, is the disturbance of sediment particles by flora and fauna. In addition, disturbance caused by marine animals (e.g., seals, diving seabirds, and fishes) at the site could possibly release and move contaminants into the environment (SKY, 2012a). Because of the small numbers of DMM found, release and transport due to bioturbation is not expected to result in significant levels of contamination. MC is expected to remain localized adjacent or under DMM objects.

Explosives may migrate and may or may not biodegrade or adsorb (bind) to organic matter. The degree to which adsorption occurs depends in part on the TOC in the sediment. The particle sizes and TOC content of the sediment materials contribute significantly to mobilization potential. Marine water salinity levels, pH, reduction potential (eH), and many other factors contribute to various contaminant transport mechanisms (DiToro, 1992) (SKY, 2012a).

Aquatic life, especially demersal fish and benthic invertebrates, can stir up and potentially uptake unconsolidated sediment through ingestion and direct contact. This represents a potential transport pathway to humans or marine receptors. Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) tend to be low for the explosive MC (U.S. Navy, 2011, **Table 5-3**) (SKY, 2012a).

Some dispersal of unconsolidated surface sediment may be possible through sediment-to-seawater partitioning and physical disturbance. Transport of MC suspended sediments may occur. However, quantitation of MC in suspended sediment particles would prove very difficult and outside the scope of this RI. Although there is some potential for MC to dissolve in seawater based on chemical-specific solubilities, this is considered an insignificant pathway due to the extensive dilution and unconfined nature of the FSNSD MRS (SKY, 2012a).

6.1.2.3 Exposure Media

Exposure media for MC at the FSNSD potentially include sediment and aquatic life if a release has occurred. This RI was limited to sediment chemical analysis for energetics (nitroaromatics, nitramines, and nitrophenols), propellant stabilizers, and certain phthalates (propellant plasticizers) if explosives were detected. Seawater exposure was considered an incomplete or insignificant exposure medium since the project area is unconfined, and subject to tides, currents, and dilution (SKY, 2012a).

6.1.2.3.1 Sediment

For the purposes of the screening-level and baseline HHRA and the SLERA, the sediment exposure medium was effectively limited to unconsolidated surface sediment in the BAZ of 0-10 cm (WA Dept of Ecology, 2011). Underlying subsurface or consolidated sediment is not easily accessible and exposure to that medium is unlikely without intentional intrusive activities. Deeper sediments are typically anoxic and less biologically active. The FSNSD MRS marine environment is cold and murky with limited visibility and hence, less desirable. Normal access to sediment requires diving down to the seafloor at depths ranging from an average of 30 ft MLLW between piers to drop-offs greater than 60 ft (SKY, 2012a).

6.1.2.3.2 Aquatic Life

Marine plants were not considered an exposure medium because the FSNSD MRS has been dredged several times and the substrate has been disturbed and/or removed. There are no kelp beds in within the MRS boundary. Benthic-dwelling (demersal) fish such as flatfish and benthic invertebrates such as crustaceans or echinoderms may bioaccumulate MC from sediments, and may then serve as indirect exposure media for human and ecological receptors. Pelagic fish and invertebrates are not expected to bioaccumulate MC from sediments. Uptake from sediments is typically evaluated by application of chemical-specific BCFs, which were developed based on the results of the initial investigations (SKY, 2012a).

6.2 Updated Conceptual Site Models for Munitions and Explosives of Concern and Munitions Constituents

The DMM found at the FSNSD MRS are itemized in **Section 5.1**. Based on the RI field investigations, the MEC CSM from the RI WP was revised and is presented as **Figure 6-1**.

Figure 6-2 and **Figure 6-4** present updated CSMs for exposure to MC based on the RI fieldwork and analytical data.

6.2.1 Sources of Munitions and Explosives of Concern

The source of DMM at the FSNSD MRS is the historical jettisoning of munitions into the marine waters of the facility. DMM was found exposed in surface sediments (0-6 inches). DMM was also found in subsurface sediments (greater than 6 inches to 18 inches). Subsurface burial in sediment can vary considerably due to wave action, currents, tides, and storms. DMM was also covered by debris through the same actions.

6.2.2 Access to Munitions and Explosives of Concern

The DMM located at the FSNSD MRS lie in approximately 40 to 60 ft of water. The seabed is littered with debris (e.g., tires, pylons, metal scrap, cables, trash, etc.). The Terminal 91 Diver and the Underwater Construction Worker have access to the DMM. These receptors are inclusive of other underwater workers such as the RI team and others who would be down at such depths conducting authorized work or investigations. In addition, a topside construction worker performing mechanical dredging operations at Terminal 91 could be exposed to MEC contained in dredged spoils brought to the surface and placed on a barge; although typically these operations take place using remotely handled mechanical Dredge Heads such as clamshell buckets.

Access to MEC is gained by diving to the seafloor of the MRS. It is conceivable that DMM could also be brought up during dredging operations. The FSNSD site has been dredged on several occasions.

Normal accessibility is limited to those persons authorized to perform underwater pier inspections, maintenance, or construction. Both the Underwater Construction Worker and the Terminal 91 Diver could conduct intrusive activities during inspection or construction, thereby accessing DMM on the seafloor or below the seafloor in subsurface sediments. It is possible that much deeper subsurface sediments could be accessed with machinery (e.g., pile drivers) or during mechanical dredging activities. The topside construction worker could potentially come in contact with MEC in dredge spoils brought to the surface in mechanical Dredge Head equipment, such as clamshell buckets.

It is possible, but not realistic, for an unauthorized, untrained person to dive down to the seafloor and access the sediments, and thereby, potentially be exposed to DMM. Such unauthorized persons might be treasure hunters, archaeologists, etc., but would likely be detained by POS security personnel for unauthorized access and safety concerns. The area is dangerous due to the large ocean-going vessels entering and leaving the Terminal. The water is cold and murky, and prior coordination with POS Operations staff is required prior to diving to ensure that moored vessels do not activate engines or pumps and cause life-threatening situations for nearby divers.

It is also possible, although very unlikely, that the Recreational Angler or Native American Subsistence Angler could contact DMM by bringing up crab pots or fishing nets, which snare DMM.

By virtue of the depth of the located DMM (some at 60 ft or more), the DMM is inaccessible to all but adequately-equipped and trained, authorized professional divers prepared to encounter very cold and murky waters, and potentially dangerous site conditions. Dredging operations could potentially access DMM in deeper waters.

6.2.2.1 Activities with Potential for Contacting Munitions and Explosives of Concern

Both non-intrusive and intrusive activities can bring human receptors into contact with DMM items which may potentially exist in the MRS. Terminal 91 pier, pylon, or deep-foundation pile replacement would constitute activities where such contact could occur, as well as routine pier inspections. Dredging could bring up or move DMM from one location to another, or remove it outside of the MRS completely.

6.2.3 Munitions and Explosives of Concern – Locations and Transport Mechanisms

Figure 5-3 shows the location and quantity of the DMM items found. As previously described, the DMM was likely jettisoned while vessels were in port. During the ensuing 60-plus years, some DMM may have migrated from their original locations; however, depending on the weight and shape of the items, such migration may have been limited. DMM may have been transported from original locations by marine currents or wave action, or through physical disturbances from previous dredging.

6.2.4 Munitions and Explosives of Concern – Release Mechanisms

DMM originally jettisoned more than 60 years ago have undergone some degree of degradation through saltwater “weathering” processes. It is possible, although unlikely, that other physical damage may have occurred from disturbance through waves and current action or dredging. DMM items retrieved during the RI were generally intact, but partially covered in sea growth as shown in **Figure 5-2**, suggesting that MC releases from compromised MEC are low and focused in the areas sampled.

6.2.5 Migration of Munitions and Explosives of Concern

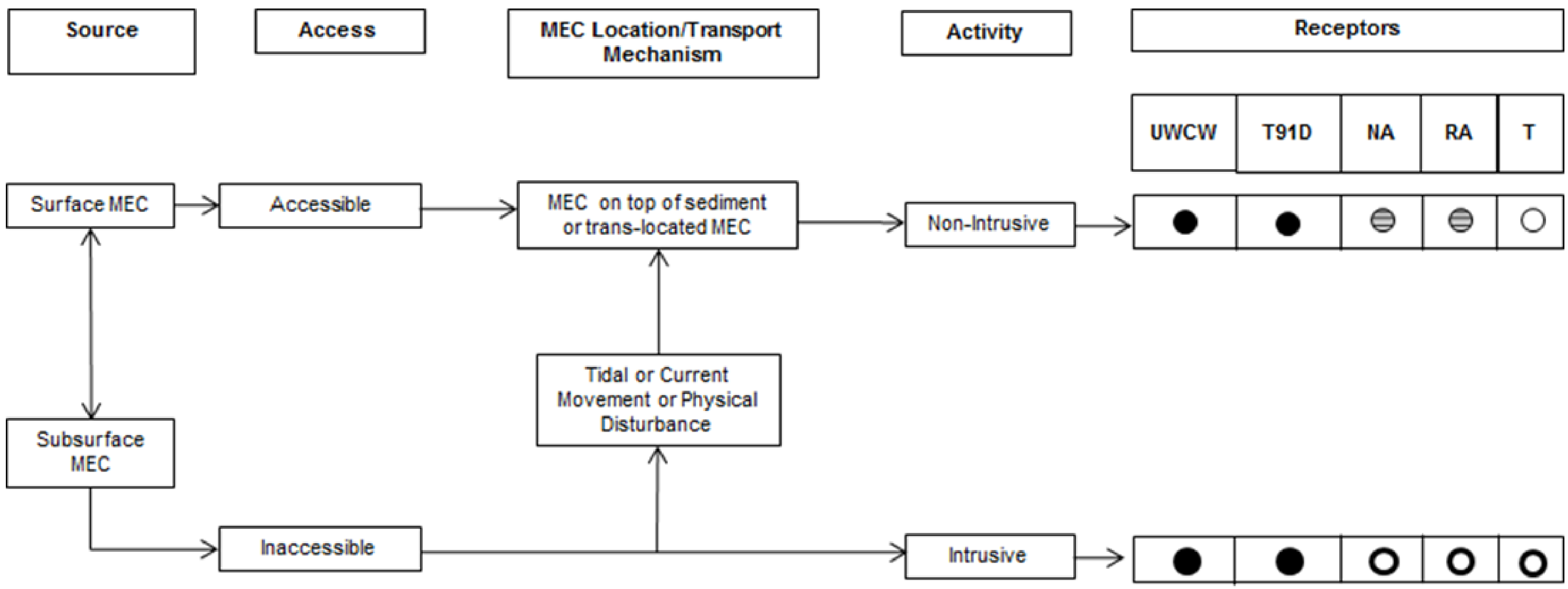
Whether or not DMM have migrated substantially or insignificantly from the likely original deposition points is uncertain. Most of the MD and DMM were located at the southern end of Pier 90 and between piers 90 and 91. Based on the model of infrequent and undocumented jettisoning from vessels in port, it appears from the locations shown in **Figure 5-3** that migration from original deposition locations has been limited.

6.2.6 Human Receptors Potentially-Exposed to Munitions and Explosives of Concern

The receptors that can contact DMM under current and reasonable site conditions would be the Terminal 91 Diver, the Underwater Construction Worker, and the topside construction worker performing mechanical dredging operations.

The Native American Subsistence Angler and Recreational Angler could potentially be exposed to DMM if they brought up crabbing pots or fishing nets/tackle that contained MEC. This is a very unlikely to implausible scenario.

Figure 6-1 Conceptual Site Model for Access to Munitions and Explosives of Concern at the Former Seattle Naval Supply Depot Munitions Response Site



MEC	-	Munitions and Explosives of Concern
T91D	-	Terminal 91 Diver
UWCW	-	Underwater Construction Worker (includes the topside construction worker performing dredging operations
RA	-	Recreational Angler
T	-	Tourist (cruise ship vacationers boarding and de-boarding at cruise terminal)
NA	-	Native American Subsistence Angler
CW	-	Construction Worker (dredging operations)

○ Incomplete Pathway

● Complete Pathway

⊜ Potentially complete though likely insignificant pathway

6.2.7 Ecological Receptors Potentially-Exposed to Munitions and Explosives of Concern

Ecological receptors (i.e., animals and plants) are not typically addressed in relation to MEC explosive hazards unless there are T&E species present at the MRS. Risks to ecological receptors (with the exception of T&E species) are addressed on a population level, not the individual. If an individual T&E specie was harmed or killed by a MEC explosion, then the situation would be viewed as an unauthorized "taking" in which case the issue would be taken up by the USFWS under the ESA (16 U.S.C. §1531 et seq. (1973). There are no known T&E species living in or on the FSNSD MRS sediments. Migratory or occasional marine life (including T&E species) could pass through the area, but exposure to such DMM would be negligible or more likely, non-existent.

6.2.8 Exposure Pathway Analysis for Munitions Constituents

Chemicals from MC were detected in sediment at low concentrations. The MC were comprised of explosives/energetics, propellant stabilizers, and propellant plasticizers. **Figure 6-2** presents the CSM for human exposure to MC detected in sediment at the FSNSD MRS.

6.2.8.1 Sources of Munitions Constituents

The source of the MC is likely the chemicals released from compromised DMM found in the surface and subsurface sediments on the seafloor at the FSNSD MRS. Some of the chemicals are energetics/explosives, while others are used as propellant stabilizers and propellant plasticizers. A list of DMM and MC associated with those items is detailed in **Table 5-1**.

6.2.8.2 Primary Release Mechanism for Munitions Constituents

Leakage of MC from compromised (leaking or broken) DMM is the likely primary release mechanism. Physical damage or chemical degradation of DMM under saltwater conditions could release MC to the marine environment. These mechanisms would have provided the means by which MC escaped from its container.

6.2.8.3 Exposure Media for Munitions Constituents

Low levels of MC were released to both seawater and sediment. Due to the large dilution associated with the MRS waters and likelihood of MC non-detections, seawater was not included as a medium for exposure evaluation. Sediment (both surface and subsurface) is the primary exposure medium for MC.

6.2.8.4 Transport Mechanisms for Munitions Constituents

Munitions constituents, once released, could have migrated by current action or physical disturbance and attenuated by dilution or sequestration within sediments. Dredging over the years may have moved some of the contaminants from their original location.

Biological receptors can transport MC through a variety of means such as ingestion, translocation, burrowing, and biouptake. Biological transformation and chemical degradation can also transport contamination at the sediment-water interface and at the pore water level. There are many such complex processes, which can also result in complex degradation products and subsequent chemical and biological transformations.

6.2.8.5 Human Receptors Potentially-Exposed to Munitions Constituents

The human receptors potentially exposed to MC in sediments include the following:

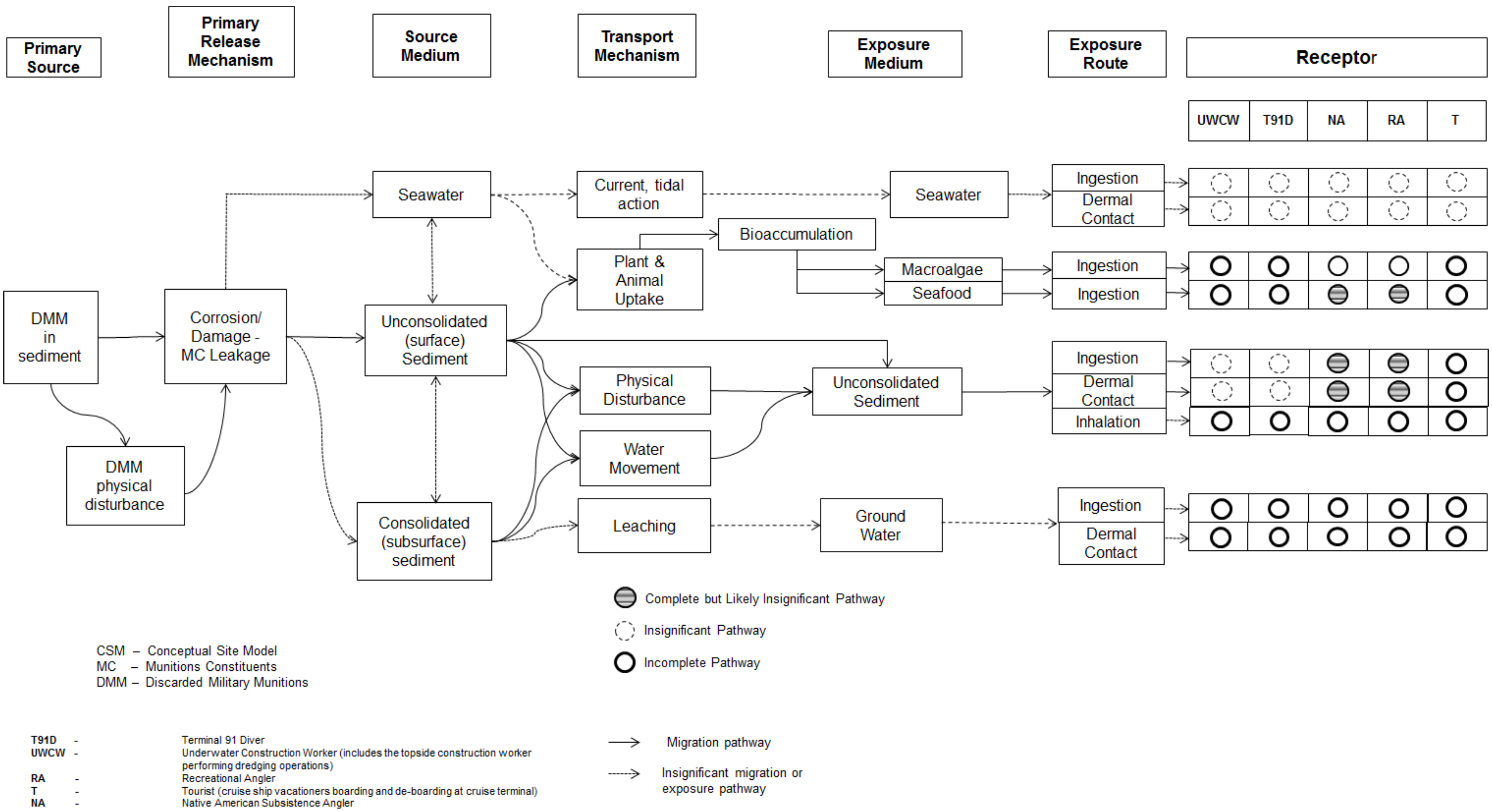
- Terminal 91 Diver (adult)
- Underwater Construction Worker (adult)
- Native American Subsistence Angler (adult and juvenile)
- Recreational Angler (adult and juvenile)
- Tourists were considered for purposes of the CSM and potential exposure pathways. The tourists boarding and de-boarding the cruise vessels do not contact sediment while present at Terminal 91 in the FSNSD MRS.
- Residents were not evaluated. Residents do not contact sediment while present at the FSNSD MRS in Terminal 91, nor are there residents living on the MRS.

6.2.8.6 Potential Exposure Pathways for Munitions Constituents

Several exposure pathways were evaluated for the RI and are depicted in **Figure 6-2**. Inhalation of chemicals was not addressed due to the aquatic nature of the site, and since the MC are not generally considered volatile chemicals. Ingestion of groundwater was also not evaluated since groundwater is very deep in the area and not used for drinking water. The following receptors and exposure pathways were evaluated or considered in the HHRA (**Section 7.1**):

- Terminal 91 Diver (adult)
  - o Incidental sediment ingestion and dermal contact with sediment.
- Underwater Construction Worker (adult)
  - o Incidental sediment ingestion and dermal contact with sediment.
- Native American Subsistence Angler (adult and juvenile)
  - o Incidental sediment ingestion, dermal contact with sediment, and ingestion of potentially contaminated seafood.
- Recreational Angler (adult and juvenile)
  - o Incidental sediment ingestion, dermal contact with sediment, and ingestion of potentially contaminated seafood.

Figure 6-2 Conceptual Site Model for Potential Munitions Constituents Exposure to Human Receptors, Former Seattle Naval Supply Depot Munitions Response Site



6.2.8.7 Ecological Receptors Potentially-Exposed to MC and Potential Exposure Pathways

The FSNSD MRS ecological receptors include both marine and marine-dependent plants and animals. The CSM from the Piers 90 and 91 RI WP (SKY, 2012) was updated based on the results of the field investigations and laboratory samples. Ecological receptors exposed to MC in sediment, prey, or forage items, or potential biouptake through the food chain are presented in **Section 6.1.1**, above. The SLERA is presented in **Section 7.2**.

6.3 Fate of Munitions Constituents in Marine Environments

In 1972, Congress enacted the Marine Protection, Research, and Sanctuaries Act (Public Law 92-532) that generally prohibits sea disposal of contaminants (Davis, 2009) (Lotufo et al., 2012). Prior to 1970, military munitions disposal in freshwater and marine environments was routinely conducted. The fate of MC in aquatic environments has not been well studied and represents a source of uncertainty; however, most MC are solids at room temperature and are insoluble in water. In aquatic systems, most MC is extensively transformed through biological or chemical processes as well as through photo degradation (Sunahara, 2009).

Secondary explosives (i.e., trinitrotoluene [TNT], RDX, and Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine [HMX]) tend to be more prevalent at MEC sites than primary explosives (e.g., lead styphnate and lead azide (Lotufo et al, 2012). Most explosives used by the DoD can be classified into three categories: nitroaromatics, nitramines, or nitrate esters.

Trinitrotoluene and dinitrotoluene (DNT) are both nitroaromatics. TNT was widely used as an explosive, and 2,4-DNT was used as a component of propellants. RDX and HMX are cyclic nitramines. Nitroglycerin and nitrocellulose are nitrate esters that were used in gun and rocket propellants. In addition to the explosives, there were many types of fillers used in munitions. Fillers included composition explosives, (i.e., two or more explosive compounds mixed to produce an explosive with more suitable characteristics for a particular application). Older munitions contained compounds such as tetryl or ammonium picrate

After the 60 plus years following the jettisoning of WWII-era munitions at Terminal 91, the RI results suggest that what DMM are present or have been removed have only resulted in very low concentrations of some MC in environmental media. **Table 7-1** presents the summary statistics for the detected MC. Of all the MC analyzed for the RI, most chemicals were not detected or were detected at low frequency. The chemicals listed below were not detected in any of the 12 sediment samples collected within the MRS:

1. HMX,
2. 1,3,5-trinitrobenzene,
3. 1,3-dinitrobenzene,
4. nitrobenzene,
5. 2,4,6-trinitrotoluene,
6. 4-amino-2,6-dinitrotoluene,
7. 2-amino-4,6-dinitrotoluene,

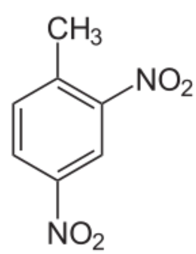
8. 2-nitrotoluene, 3-nitrotoluene,
9. 4-nitrotoluene,
10. nitroglycerine,
11. 3,5-dinitroaniline,
12. PETN, or
13. 2,4-dinitrophenol.

Photolysis and photo-oxidation are examples of chemical-physical processes that can cause nitroaromatic breakdown in the marine environment. MC may partition to sediments depending on their chemical properties and the organic carbon content of the substrate. The higher the sediment-to water partitioning coefficient (Kd) value, the greater the adsorption to sediment. Some bacterial mineralization can also occur, although this is not a primary transformation process for most nitroaromatic MC due to the stability of the benzene ring (Sunahara et al, 2009).

The fate of MC in the marine environment may also be influenced by chemical and physical properties including solubility, density, and partitioning coefficients, as well as environmental conditions (Lotufo et al., 2012). Environmental fate is influenced by temperature, pH, salinity, dissolved oxygen, and the ionic strength of seawater. Reactions in the aquatic environment include hydrolysis, photolysis, thermolysis, and oxidation. A review of the properties that affect fate and transport of major explosives is provided in Noblis, (2011). Singh et al., (2012) summarized biodegradation and biotransformation information for major explosives.

2,4-Dinitrotoluene (CAS Registry No. 121-14-2) represented the highest detected concentration (0.97 mg/kg) of any MC. The remaining detected analytes had values that were J-qualified and were essentially at the detection limit. For these reasons, only information pertaining to this MC is provided.

Figure 6-3 2,4-Dinitrotoluene (CASRN: 121-14-2)

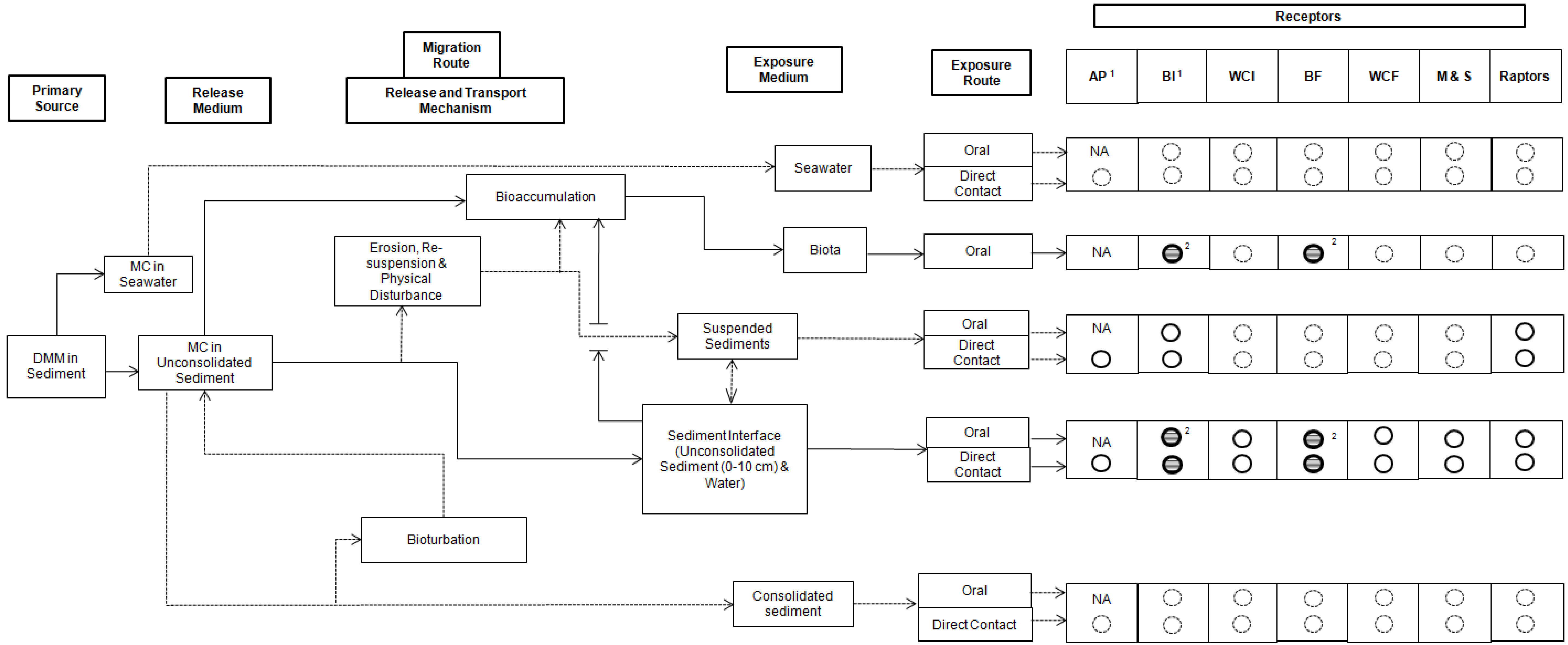


The molecular formula for 2,4-DNT is $C_7H_6N_2O_4$ (**Figure 6-3**). The molecular weight is 182.2 grams (g) mol-1. 2,4-DNT is a yellow crystalline solid at room temperature. The water solubility of 2,4-DNT is 270 milligrams per liter (mg/L) at 25° centigrade (C). Dissolved 2,4-DNT will diffuse and disperse with the water it is dissolved in (Lotufo et al., 2012).

Dinitrotoluenes may degrade to the corresponding mono or diamino derivatives. Strong sorption of 2,4-DNT to soil organic matter has been reported. 2,4 dinitrotoluene is the most common of the DNT isomers. Technical grade DNT (TDNT) is composed of approximately 75% 2,4-DNT, 20% 2,6-DNT, and 5% other isomers.

Dinitrotoluene is not as soluble in seawater as freshwater (Craig and Taylor, 2011); solubility of TDNTs is 10-20% lower in seawater (Phelan and Barnett, 2001). More information regarding the fate of MC in aquatic systems may be found in Sunahara, (2009), Singh et al., (2012), Lotufo et al., (2012), and other literature.

Figure 6-4 Conceptual Site Model and Munitions Constituents Exposure Pathway Analysis for Ecological Receptors at the Former Seattle Naval Supply Depot Munitions Response Site



AP —Aquatic Plants
BI —Benthic Invertebrates
WCI —Water Column Invertebrates
BF —Benthic Fish
WCF —Water Column Fish
M & S —Mammals and Seabirds
R —Raptors

DMM —Discarded Military Munitions
CSM —Conceptual Site Model
MC —Munitions Constituents
NA —Not Applicable
MRA —Munitions Response Area
cm —centimeter

● - Potentially Complete
○ - Potentially Incomplete
◌ - Potentially Insignificant - not evaluated quantitatively
----- - Insignificant Pathway - not evaluated quantitatively

[1] Little or no vegetation is present within the MRA
[2] Although potentially complete, ingestion exposure by benthic invertebrates and fish can not be quantified due to lack of information on ingestion rates or toxicity information for this pathway. Risk is quantified for direct contact pathways.

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7.0 RISK CHARACTERIZATION AND ANALYSIS

The presentations of the baseline HHRA and the SLERA are provided in the following sections. The baseline HHRA consists initially of a screening-level evaluation for contaminants of potential concern (COPCs), followed by an in-depth evaluation of risk for analytes and exposure scenarios that exceeded conservative screening levels. The SLERA is a conservative comparison of the data to established ecological screening levels, where contaminants of potential ecological concern (COPECs) for a baseline ecological risk assessment are identified.

7.1 Baseline Human Health Risk Assessment

The quantitative HHRA was prepared in accordance with the USEPA Risk Assessment Guidance for Superfund (RAGS); Volume I: Human Health Risk Assessment, Parts A, D, E, and F (USEPA, 1989-2010), as appropriate.

The quantitative HHRA consisted of the following steps:

- Data Evaluation.
- Screening for COPCs.
- Exposure Assessment.
- Toxicity Assessment.
- Risk Characterization and Uncertainty Analysis.

These steps are discussed in detail in the following subsections.

7.1.1 Data Evaluation

The 2012 RI sediment analytical laboratory data for the FSNSD MRS were initially evaluated to determine if quantitative risk assessment was necessary. There were detections of MC (i.e., explosives, propellant stabilizers, and propellant plasticizers) in some of the sediment samples. Therefore, a quantitative HHRA was performed on the FSNSD MRS sediment data.

Laboratory chemical sediment data were reviewed according to USEPA's QA/QC requirements and evaluated for analytical detection limits. Data were summarized with respect to minimum and maximum concentrations, frequency of detection, and range of detection limits. There were no rejected data. **Section 5.2** presents the analytical results and a discussion of data usability, while **Appendix B** presents the data validation reports.

7.1.2 Screening for Contaminants of Potential Concern

An initial screening-level HHRA was performed. This was a conservative evaluation of the maximum detected concentrations (MDCs) relative to protective health-based environmental media concentrations from USEPA termed "regional screening levels" (RSLs). The RSLs are medium and receptor-specific. RSLs for sediment exposure pathways were lacking. Therefore, RSLs for residential and occupational exposure for soils were selected to screen sediment data to identify COPCs. These RSLs are considered conservative because humans are unlikely to contact sediments as frequently as soils, and there are no residents on the MRS so contact by site-specific receptors will be lower.

Fish ingestion is not an exposure pathway included in the soil RSLs. Following a TPP meeting in February of 2012 (SKY, 2012c) between the project team, USEPA Region 10 and WADNR, USEPA Region 10 recommended that the USEPA RSLs for fish tissue be used for HHRA screening for the fish ingestion pathway. Because no fish tissue data were collected, fish tissue concentrations had to be modeled.

The following steps were taken with respect to COPC screening:

1) Chemicals that were not detected in sediment were removed from further consideration. There were no other environmental media sampled. There were no detections of HMX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, nitrobenzene, 2,4,6-trinitrotoluene, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, nitroglycerine, 3,5-dinitroaniline, PETN, or 2,4-dinitrophenol.

2) Summary statistics were generated for the detected chemicals and the detection frequency (DF) evaluated. No detected chemical was removed from further evaluation since the DF was greater than 5% for all detected chemicals (see **Table 7-1**).

3) An initial COPC screening was performed by comparing MDCs for each detected chemical result in sediment (i.e., explosives, propellant stabilizers, and propellant plasticizers) to the pathway-specific soil screening levels provided by the USEPA Region 9 RSL calculator as described in the following paragraphs. Screening levels represent media concentrations that correspond to a target *de minimus* cancer risk of 1E-06 or a hazard quotient (HQ) of 1.

Table 7-1 Summary Statistics for Detected Munitions Constituents in Sediment, Munitions Response Site

Chemical	Minimum Detected Result	Maximum Detected Result	Arithmetic Mean of Detected Results	Number of Detects	Number of Samples	Standard Deviation of Detected Results	Detection Frequency
2,4,6-Trinitrophenol (Picric Acid)	0.0028	0.0028	NA	1	12	NA	8.3%
2,4-Dinitrotoluene [c]	0.16	0.97	0.44	3	12	0.46	25%
2,6-Dinitrotoluene	0.12	0.12	NA	1	12	NA	8.3 %
Diethyl phthalate	0.020	0.062	0.04	3	5	0.02	60%
Di-n-butyl phthalate	0.04	0.14	0.08	4	5	0.05	80%
Diphenylamine	0.033	0.67	0.23	4	12	0.30	33%
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) [c]	0.058	0.058	NA	1	12	NA	8.3%
N-Nitrosodiphenylamine [c]	0.071	0.84	0.37	3	12	0.41	25%
Trinitrophenylmethylnitramine (Tetryl)	0.23	0.23	NA	1	12	NA	8.3%

Notes:
All results are in milligram per kilogram, mg/kg, dry weight.
No distribution fitting was performed on these data. Data were assumed to follow a normal distribution for calculation of mean and standard deviation.
NA = not applicable due to low detection frequency.
c = carcinogen

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In the absence of any other methods or relevant scenarios with which to perform a traditional COPC screening, USEPA's risk calculator at: http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search was used to calculate soil RSLs for comparison to receptors most likely to occur at the site, as follows:

- **Terminal 91 Diver** or underwater site worker—evaluated in the initial COPC screening since MC were detected in sediment and this represented a conservative receptor scenario. Terminal 91 Dive Team divers perform pier inspections on a regular basis during the cruise season. This receptor may be exposed to incidental sediment ingestion and dermal contact with sediment.
  - There were no exceedances of soil RSLs for: 1) incidental sediment ingestion and 2) dermal contact with sediment.
  - All other POS workers were evaluated qualitatively as their potential for exposure to contaminated sediment was assumed negligible. Any risks to the Terminal 91 Diver were considered protective of exposure to other POS workers.
  - The Terminal 91 Diver was represented by the USEPA soil RSLs for the "Outdoor Construction Worker" using standard default exposure parameters (**Table 7-2** and **Table 7-3**). This evaluated sediment ingestion and dermal contact exposure pathways.
- **Underwater Construction Worker—** selected as the only worker that would reasonably contact sediments as part of their job activities. This receptor engages in pier maintenance or upgrades, and was evaluated since MC (i.e., explosives, propellant stabilizers, and propellant plasticizers) were detected in sediment. This receptor may be exposed to incidental sediment ingestion and dermal contact with sediment.
  - The Underwater Construction Worker was represented by the USEPA soil RSL for the "Outdoor Construction Worker" using standard default exposure parameters (**Table 7-3**). This evaluation included the sediment ingestion and dermal contact exposure pathways.
  - There were no exceedances of soil RSLs for: 1) incidental sediment ingestion and 2) dermal contact with sediment.
- **Commercial Worker**—This category includes workers not directly employed by POS, including commercial fishermen, longshoremen, and construction workers involved with commercial fishing activities, cargo handling, or building and repairs who may be exposed to incidental sediment ingestion and dermal contact with sediment. These receptors may have presence at Terminal but very limited or no contact with sediments. Commercial anglers are primarily fishing outside the MRS; however, they do come into port to unload their catch, re-provision, conduct repairs, and then depart. Commercial construction workers, as a rule, are not typically performing underwater dive operations; rather, they are working outdoors or indoors, on the piers, or in the cruise terminal; however, it was conservatively assumed that a few construction workers do engage in underwater activities periodically and that receptor category is addressed above in the

Underwater Construction Worker. Exposure to the Underwater Construction Worker is considered protective of other commercial workers, as their potential for exposure to contaminated sediment was assumed negligible.

- The **Native American Subsistence Angler**— this receptor was evaluated with USEPA soil RSLs for residential use, while substituting a limited number of site-specific exposure parameters (**Table 7-4** and **Table 7-5**). The soil RSL was used to evaluate the Native American Subsistence Angler for:
  - Incidental ingestion of sediment and
  - Dermal contact with sediment.
- The **Recreational Angler**— this receptor was evaluated with the USEPA RSLs for residential use. The following exposure pathways were evaluated:
  - Incidental ingestion of sediment and
  - Dermal contact with sediment (**Table 7-6** and **Table 7-7**).

The MDC for each MC in sediment was compared to:

1) The “Resident” soil RSLs for: 1) the soil ingestion exposure pathway, and 2) the dermal contact with soil exposure pathway.

2) The “Outdoor Worker” soil RSLs for: 1) the soil ingestion exposure pathway, and 2) the dermal contact with soil exposure pathway.

For this preliminary screening, there were no exceedances of the soil RSLs when comparing to the sediment data; however, the fish ingestion pathway is not addressed in the calculator.

No analytes exceeded RSLs for sediment ingestion or dermal contact for any receptor. These pathways were not evaluated further.

Table 7-2 Outdoor Worker Soil RSLs for Underwater Construction Worker and Terminal 91 Diver for Incidental Sediment Ingestion and Dermal Contact Exposure Pathways (USEPA Default Exposure Parameters)

Chemical	CASRN	Ingestion SL (Cancer) TR=1.0E-6 (mg/kg)	Dermal SL (Cancer) TR=1.0E-6 (mg/kg)	Ingestion SL (Non-cancer) HQ=1 (mg/kg)	Dermal SL (Non-cancer) HQ=1 (mg/kg)	EPC (mg/kg)	EPC Exceeds Ingestion SL (Cancer)?	EPC Exceeds Dermal Contact SL (Cancer)?	EPC Exceeds Ingestion SL (Non-cancer)?	EPC Exceeds Dermal Contact SL (Non-cancer)?	COPC?
Dibutyl Phthalate	84-74-2	-	-	114,000	172,000	0.14	NA	NA	No	No	No
Diethyl Phthalate	84-66-2	-	-	908,000	1,380,000	0.062	NA	NA	No	No	No
2,4-Dinitrotoluene c	121-14-2	1.03E+01	1.52E+01	2,270	3,370	0.97	No	No	No	No	No
2,6-Dinitrotoluene	606-20-2	-	-	1,140	1,740	0.12	NA	NA	No	No	No
Diphenylamine	122-39-4	-	-	28,400	43,000	0.67	NA	NA	No	No	No
N-Nitrosodiphenylamine c	86-30-6	6.49E+02	9.83E+02	-	-	0.84	No	No	NA	NA	No
Picramic Acid (2-Amino-4,6-dinitrophenol)	96-91-3	-	-	114	172	0.0028	NA	NA	No	No	No
Picric Acid (2,4,6-Trinitrophenol)*	88-89-1	-	-	-	-	0.0028	NA	NA	NA	NA	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	0.015	2.89E+01	292	3,410	0.058	No	No	No	No	No
Tetryl (Trinitrophenylmethyl nitramine)	479-45-8	-	-	4,540	6,880	0.23	NA	NA	No	No	No

Note: the default values for soils (USEPA, 2012) were considered to be applicable to sediments and highly conservative and were applied in the initial screening-level evaluation.
The EPC for the screening-level evaluation is the maximum detected value.
c = carcinogen
SL = screening level (i.e., sediment)
EPC = exposure point concentration
NA = Not applicable
RSL = Regional Screening Level
HQ - hazard quotient
TR - target risk (cancer)
- not available
COPC = contaminant of potential concern
CASRN = Chemical Abstracts Service Registry Number
mg/kg-day = milligram per kilogram (of body weight) per day.
* - there are no toxicity data or screening values for picric acid; consequently, picramic acid was selected as a surrogate compound.

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Table 7-3 Outdoor Worker Exposure Parameters for Sediment Ingestion and Dermal Contact RSLs (USEPA Default Exposure Parameters)

Variable	Value
TR (target cancer risk) unitless	1E-06
THQ (target hazard quotient) unitless	1
ATow (averaging time)	365
EFow (exposure frequency) d/yr.	225
EDow (exposure duration) yr.	25
ETow (exposure time) hr.	8
LT (lifetime) yr.	70
BWow (body weight)	70
IRow (soil ingestion rate) mg/day	100
SAow (surface area) cm^2/day	3300
AFow (skin adherence factor) mg/cm^2	0.2

Notes:
The default values for soils (USEPA, 2012b) were considered applicable to sediments and highly conservative, and were applied in the initial screening-level evaluation.
RSL = regional screening level. (USEPA, 2012b)
d = day
yr. = year
mg = milligram
cm^2 = square centimeter
hr. = hour
OW = outdoor worker

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Table 7-4 Resident Soil RSLs Used to Represent the Native American Subsistence Angler for the Incidental Sediment Ingestion and Dermal Contact Exposure Pathways

Chemical	CASRN	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Ingestion SL HQ=1 (mg/kg)	Dermal SL HQ=1 (mg/kg)	EPC, Maximum Sediment Concentration (mg/kg)	EPC Exceeds Ingestion SL (Cancer)?	EPC Exceeds Dermal Contact SL (Cancer)?	EPC Exceeds Ingestion SL (Non-cancer)?	EPC Exceeds Dermal Contact SL (Non-cancer)?	COPC?
Dibutyl Phthalate	84-74-2	-	-	19,200	68,500	0.14	NA	NA	No	No	No
Diethyl Phthalate	84-66-2	-	-	154,000	548,000	0.062	NA	NA	No	No	No
2,4-Dinitrotoluene [c]	121-14-2	1.64E+00	4.85E+00	384	1,340	0.97	No	No	No	No	No
2,6-Dinitrotoluene	606-20-2	-	-	192	692	0.12	NA	NA	No	No	No
Diphenylamine	122-39-4	-	-	4,800	17,100	0.67	NA	NA	No	No	No
N-Nitrosodiphenylamine [c]	86-30-6	1.04E+02	3.13E+02	-	-	0.84	No	No	NA	NA	No
Picramic Acid (2-Amino-4,6-dinitrophenol)	96-91-3	-	-	19.2	68.5	0.0028	NA	NA	No	No	No
Picric Acid (2,4,6-Trinitrophenol) *	88-89-1	-	-	-	-	0.0028	NA	NA	NA	NA	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) [c]	121-82-4	6.74E+01	1.36E+03	8,400	200,000	0.058	No	No	No	No	No
Tetryl (Trinitrophenylmethyl nitramine)	479-45-8	-	-	768	2,740	0.23	NA	NA	No	No	No

Note: The default values for residents exposed to soils (USEPA, 2012b) were considered to be applicable to sediments and highly conservative and were applied in the initial screening-level evaluation.
The EPC for the screening-level evaluation is the maximum detected value.
Refer to Table 7-5, below for site-specific values used in RSL calculations.
c = carcinogen
SL = screening level (i.e., for sediment)
EPC = Exposure point concentration
NA = Value is not available or could not be calculated
RSL = Regional Screening Level
COPC = contaminant of potential concern
CASRN = Chemical Abstracts Service Registry Number
HQ = hazard quotient
TR = target risk (cancer)
- = not available
mg/kg-day = milligram per kilogram (of body weight) per day
* - there are no toxicity data or screening values for picric acid; consequently, picramic acid was selected as a surrogate compound.

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Table 7-5 Resident Exposure Parameters for Native American Subsistence Angler for Sediment Ingestion and Dermal Contact RSLs (Site-Specific Exposure Parameters)

Variable	Value
TR (target cancer risk) unitless	1E-06
ED_r (exposure duration - resident) year	64
ET_r (exposure time - resident) hour	24
ED_c (exposure duration - child) year	15 [1]
ED_a (exposure duration - adult) year	49 [2]
BW_a (body weight - adult) kg	79 [3]
BW_c (body weight - child) kg	36.8 [4]
SA_a (skin surface area - adult) cm^2/day	5700
SA_c (skin surface area - child) cm^2/day	2800
THQ (target hazard quotient) unitless	1
LT (lifetime - resident) year	70
EF_r (exposure frequency) day/year	350
IRSa (sediment intake rate - adult) mg/day	100
IRSc (sediment intake rate - child) mg/day	200
AF_a (skin adherence factor - adult) mg/cm^2	0.07
AF_c (skin adherence factor - child) mg/cm^2	0.2
IFSadj (age-adjusted sediment ingestion factor) mg-year/kg-day	144
DFSadj (age-adjusted sediment dermal factor) mg-year/kg-day	476
IFSMadj (mutagenic age-adjusted sediment ingestion factor) mg-year/kg-day	230 (not applicable)
DFSMadj (mutagenic age-adjusted sediment dermal factor) mg-year/kg-day	709 (not applicable)

Notes:
The default values for soils (USEPA, 2012b) were considered applicable to sediments and highly conservative, and were applied in the initial screening-level evaluation.
RSL = regional screening level.
USEPA = United States Environmental Protection Agency
Values in shaded cells represent site-specific exposure parameters obtained from:
[1] ED for children – Child Table 1-3, EFH (USEPA, 2011b) sum of 3 age groups
[2] ED for adults – Table 1-3, EFH ≥ 21 years to 70 years (6< 11 years, 11 to < 16 years, 16 to < 21 years) (USEPA, 2011b)
[3] The Suquamish Tribe, 2000; value is average body weight.
[4] Value is the average of 3 mean body weights for child/juvenile (i.e., 6 < 11 years, 11 to < 16 years, 16 to < 21 years); Exposure Factors Handbook Table ES-1 (USEPA, 2011b).
yr. = year
mg = milligram
cm^2 = square centimeter
kg = kilogram
hr. = hour

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Table 7-6 Resident Soil RSLs Used to Represent the Recreational Angler Incidental Sediment Ingestion and Dermal Contact Exposure Pathways

Chemical	CASRN	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Ingestion SL HQ=1 (mg/kg)	Dermal SL HQ=1 (mg/kg)	EPC, Maximum Sediment Concentration (mg/kg)	EPC Exceeds Ingestion SL (Cancer)?	EPC Exceeds Dermal Contact SL (Cancer)?	EPC Exceeds Ingestion SL (Non-cancer)?	EPC Exceeds Dermal Contact SL (Non-cancer)?	COPC?
Dibutyl Phthalate	84-74-2	-	-	7,820	27,900	0.14	NA	NA	No	No	No
Diethyl Phthalate	84-66-2	-	-	62,600	223,000	0.062	NA	NA	No	No	No
2,4-Dinitrotoluene [c]	121-14-2	2.07E+00	6.40E+00	156	548	0.97	No	No	No	No	No
2,6-Dinitrotoluene	606-20-2	-	-	78.2	282	0.12	NA	NA	No	No	No
Diphenylamine	122-39-4	-	-	1,960	6,980	0.67	NA	NA	No	No	No
N-Nitrosodiphenylamine [c]	86-30-6	1.31E+02	4.13E+02	-	-	0.84	No	No	NA	NA	No
Picramic Acid (2-Amino-4,6-dinitrophenol)	96-91-3	-	-	7.82	27.9	0.0028	NA	NA	No	No	No
Picric Acid (2,4,6-Trinitrophenol) *	88-89-1	-	-	-	-	0.0028	NA	NA	NA	NA	No (based on Picramic acid)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	5.82E+00	1.23E+02	235	5,590	0.058	No	No	No	No	No
Tetryl (Trinitrophenylmethylnitramine)	479-45-8	-	-	313	1,120	0.23	NA	NA	No	No	No

Note: the default values for soils (USEPA, 2012b) were considered to be applicable to sediments and highly conservative and were applied in the initial screening-level evaluation.
The EPC for the screening-level evaluation is the maximum detected value.
c = carcinogen
SL = Screening level (i.e., for sediment)
EPC = Exposure point concentration
NA = Value is not available or could not be calculated.
RSL = Regional Screening Level
EPC = Exposure point concentration
COPC = contaminant of potential concern
CASRN = Chemical Abstracts Service Registry Number
HQ = hazard quotient
TR = target risk (cancer)
\- = not available
mg/kg-day = milligram per kilogram (of body weight) per day.
USEPA = United States Environmental Protection Agency
* - there are no toxicity data or screening values for picric acid; consequently, picramic acid was selected as a surrogate compound.

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Table 7-7 Resident Exposure Parameters for "Recreational Angler" for Sediment Ingestion and Dermal Contact RSLs (USEPA Default Exposure Parameters)

Variable	Value
TR (target cancer risk) unitless	1E-06
ED_r (exposure duration - resident) year	30
ET_r (exposure time - resident) hour	24
ED_c (exposure duration - child) year	6
ED_a (exposure duration - adult) year	24
BW_a (body weight - adult) kg	70
BW_c (body weight - child) kg	15
SA_a (skin surface area - adult) cm^2/day	5,700
SA_c (skin surface area - child) cm^2/day	2,800
THQ (target hazard quotient) unitless	1
LT (lifetime - resident) year	70
EF_r (exposure frequency) day/year	350
IRSa (sediment intake rate - adult) mg/day	100
IRSc (sediment intake rate - child) mg/day	200
AF_a (skin adherence factor - adult) mg/cm^2	0.07
AF_c (skin adherence factor - child) mg/cm^2	0.2
IFSadj (age-adjusted sediment ingestion factor) mg-year/kg-day	114
DFSadj (age-adjusted sediment dermal factor) mg-year/kg-day	361

Notes: the default values for soils (USEPA, 2012b) were considered applicable to sediments and highly conservative, and were applied in the initial screening-level evaluation
RSL = regional screening level. (USEPA, 2012b)
USEPA = United States Environmental Protection Agency
mg = milligram
cm^2 = square centimeter
kg = kilogram

7.1.2.1 Modeling of Seafood Tissue Concentrations and Comparison to Fish Tissue Regional Screening Levels

Bioaccumulation modeling was performed to estimate fish or shellfish tissue concentrations (Cfish) due to uptake from contaminated sediment. The modeled fish tissue concentrations based on uptake from sediment were compared to the USEPA 2012 fish tissue RSLs to evaluate potential cancer and non-cancer risks. The RSLs are available at:

http://www.epa.gov/reg3hwmd/risk/human/pdf/MAY_2012_FISH.pdf (USEPA, 2012a).

Fish RSLs are acceptable tissue concentrations in fish for human consumption. The fish tissue RSLs were compared to modeled fish tissue levels to represent seafood ingestion exposures to the Native American Subsistence Angler and the Recreational Angler from fish theoretically taken within the MRS. The diet of these receptors is composed of finfish and shellfish. The finfish and shellfish tissue concentrations were modeled as follows:

Concentrations of MC in finfish or shellfish were estimated separately with the following equation:

Equation 7-1 Concentration of Chemical in Fish/Shellfish Tissue

Cfish = (BCF Csed * AUF)/(Koc * foc)*

Where:

Cfish = concentration of chemical in demersal fish and shellfish tissue, in units of milligram per kilogram (mg/kg), wet or fresh weight

BCF= bioconcentration factor from water to fish, or shellfish liter/kilogram (L/kg), unitless (wet weight) (SLERAP, USEPA, 1999, Appendix C, page C-5).

Csed = concentration of chemical in sediment, mg/kg, dry weight (dw)

AUF = area use factor for shellfish or finfish, unitless

foc = fraction of organic carbon in soil/sediment (kg organic carbon/kg soil/sediment)

The term foc was estimated from the TOC measured at the site as TOC/100 where TOC equals total organic carbon (in mg/kg, dw)

Koc = soil/sediment organic carbon to water partitioning coefficient (L soil/sediment pore water / kg organic carbon);

Bioconcentration factors were obtained primarily from the USEPA Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (SLERAP) (USEPA, 1999). These are regression equations based on log octanol water partition coefficient (Kow) values for each organic chemical or measured fixed value BCFs, depending on the analyte. The equations used to estimate BCFs are detailed in **Table 7-8**.

7.1.2.1.1 Derivation of Area Use Factors

An exposure area of 4.55 acres was previously defined and displayed in **Figure 5-5**. This is the area within the MRS where the DMM were discovered and retrieved, and where sediment sampling was conducted.

English sole and Dungeness crab are mobile species. English sole are known to have a home range of 9 square kilometers (km^2) (Stern et al, 2001). Dungeness crabs have a small home range, where females move 3.75 km^2 and males move 0.4 km^2 (Stone and O'Clair, 2001). The home range values for males and females were averaged to obtain an overall home range of 2.075 km^2. Home range movements are important because mobile animals are not rooted to one point, but move in and out of the exposure area. The movement effectively reduces total bioaccumulation potential because the animals are not constantly exposed to contaminants within the exposure area. To account for this, an AUF was calculated for the English sole and Dungeness crab. The AUF is the ratio of the exposure area (4.55 acres) by the species home range, estimated as follows:

Equation 7-2 Area Use Factor for English Sole

$$AUF = \frac{4.55\ ac * 0.00404686\ km2/ac}{9\ km2} = 0.00205$$

Equation 7-3 Area Use Factor for Dungeness Crab

$$AUF = \frac{4.55\ ac * 0.00404686\ km2/ac}{2.075\ km2} = 0.0089$$

The AUFs as defined above were used to adjust the BCF to reflect exposure within the exposure area.

There were only 3 MCs that exceeded the fish tissue RSL based on a cancer endpoint (**Table 7-9**). These were:

1) 2,4-DNT,
2) RDX, and
3) N-nitrosodiphenylamine.

The non-cancer fish tissue RSLs were not exceeded for any chemical. Only the three detected analytes that exceeded fish tissue cancer RSLs were retained for further evaluation as COPCs for the quantitative risk assessment.

Table 7-8 Bioconcentration Factors Used in the Human Health Risk Assessment – Former Seattle Naval Supply Depot Munitions Response Site

Chemical	CASRN	Medium	BCF Description	Type	BCFs	Taxa	Log Kow	Equation
2,4-Dinitrotoluene	121-14-2	Surface Water	BCFf	Regression equation	10.4	Fish	1.98	BCF=10^(0.91*log Kow-1.975*log (6.8E-7*10^Kow+1)-0.789
2,6-Dinitrotoluene	606-20-2	Surface Water	BCFf	Same as above	11.3	Fish	2.02	same as above
Tetryl	479-45-8	Surface Water	BCFf	Same as above	11.8	Fish	2.04	same as above
Picric Acid	88-89-1	Surface Water	BCFf	Same as above	4.7	Fish	1.6	same as above
Picramic Acid	96-91-3	Surface Water	BCFf	Same as above	1.2	Fish	0.93	same as above
Dibutyl phthalate	84-74-2	Surface Water	BCFf	Same as above	4.245	Fish	4.9	same as above
Diethyl phthalate	84-66-2	Surface Water	BCFf	Same as above	28.9	Fish	2.47	same as above
Diphenylamine	122-39-4	Surface Water	BCFf	Same as above	2.11	Fish	3.42	same as above
N-Nitrosodiphenylamine	86-30-6	Surface Water	BCFf	EpiSuite equation	3.76	Fish	3.13	Log BCF = 0.6598 * log Kow – 0.33 + correction Average of 3 estimated BCFs (54, 37.2, 21.3) L/kg, wet weight basis (EpiSuite, V4.1)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	Surface Water	BCFf	EpiSuite equation	2.54	Fish	NA	Log 0.5 with no correction. Average of 3 estimated BCFs (3.16,1.3,2) L/kg wet weight basis (EpiSuite, V4.1)

Notes:
Source: USEPA, 1999, Appendix C, Equation C-1-8.
BCF = bioconcentration factor
Kow = octanol-water partition coefficient; Kow values obtained from USEPA Region 9 Regional Screening Tables (USEPA, 2012a)
SLERAP = *Screening-Level Ecological Risk Assessment Protocol for Combustion Facilities*, USEPA, 1999
* BCF information came from Epi Suite™ V 4.10 available at: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm
CASRN = Chemical Abstracts Service Registry Number; BCFf = bioconcentration factor, fish, L/kg or unitless.

Table 7-9 Comparison of USEPA Fish Tissue RSLs to Modeled Fish Tissue Concentrations for Uptake From Sediment

Chemical	CASRN	EPC, Sediment (mg/kg)	Fish Tissue RSL, Cancer (mg/kg)	Fish Tissue RSL, Non-cancer (mg/kg)	Demersal Finfish Tissue Concentration, Modeled – Uptake From Sediment (mg/kg)	BCF	Shellfish Tissue Concentration, Modeled – Uptake From Sediment (mg/kg)	Fish Tissue RSL for Target Cancer Risk Exceeded?	Fish Tissue RSL for Non-cancer Hazard Quotient Exceeded?	COPC?
Dibutyl phthalate	84-74-2	0.14	NA	140	40.4	4245	40.4	NA	No	No
Diethyl phthalate	84-66-2	0.062	NA	1100	1.35	28.9	1.35	NA	No	No
2,4-Dinitrotoluene [c]	121-14-2	0.97	0.01	2.7	1.38	10.4	1.38	Yes	No	Yes
2,6-Dinitrotoluene	606-20-2	0.12	NA	1.4	0.18	11.3	0.18	NA	No	No
Diphenylamine	122-39-4	0.67	NA	34	13.5	211	13.5	NA	No	No
N-Nitrosodiphenylamine [c]	86-30-6	0.84	0.65	NA	0.945	37.5	0.945	Yes	NA	Yes
Picramic Acid *	96-91-3	0.0028	NA	0.14	0.00112	1.15	0.00112	NA	No	No
Picric Acid	88-89-1	0.0028	NA	0.14	0.0079	4.68	0.0079	NA	No	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) [c]	121-82-4	0.058	0.029	4.1	0.13	2.54	0.13	Yes	No	Yes
Tetryl (Trinitrophenylmethylnitra-mine)	479-45-8	0.23	NA	5.4	0.046	11.8	0.046	NA	No	No

Source: Regional Screening Level (RSL) Fish Ingestion Table, April 2012 (USEPA, 2012a)
NA = not available or not applicable
c = carcinogen
mg/kg = milligram per kilogram
USEPA = U.S. Environmental Protection Agency
CASRN = Chemical Abstracts Service Registry Number
EPC = exposure point concentration, sediment, maximum detected value.
COPC = contaminant of potential concern
* - proxy compound for picric acid which was actually detected.

7.1.3 Exposure Assessment

The objectives of the exposure assessment were to:

- Characterize the exposure setting.
- Identify populations (receptors) potentially exposed to the MC COPCs.
- Identify and evaluate the complete pathways by which exposure occurs by updating the preliminary CSMs for complete exposure pathways.
- Calculate EPCs for each of the COPCs.
- Develop exposure parameters for each exposed receptor, which were used to estimate a chronic daily intake, also, referred to simply as an intake.

7.1.3.1 Exposure Setting

Conceptual site models were developed as discussed in **Section 6.2** and shown in **Figure 6-1** (MEC) and **Figure 6-2** (MC). The CSM process is iterative; consequently, the preliminary CSMs from the RI WP were revised as a result of RI field investigations. Exposure to potentially contaminated sediment was evaluated as a potentially complete pathway. Surface water was not included in the HHRA due to extensive dilution associated with the MRS waters, and in accordance with the WP approach. Only sediment samples were collected; as such, no other environmental media were sampled.

Under the current and future land use scenarios, the receptors evaluated in the quantitative HHRA included the Native American Subsistence Angler (adult/juvenile) and the Recreational Angler.

Native American Tribal members may potentially be exposed to contaminants through ingestion of sediment, dermal contact with sediment, and ingestion of potentially contaminated seafood from fishing, crabbing, and net harvesting from boats. Native Americans have no restrictions regarding seasonal access to the fishing areas near Terminal 91. Terminal 91 is a very busy port and smaller watercraft are at risk from the high traffic and wakes caused by larger marine vessels.

1. The Native American Subsistence Angler (both adult and juvenile) were evaluated quantitatively since MC (i.e., explosives, propellant stabilizers, and propellant plasticizers) were detected in sediment, even though there were no exceedances of soil RSLs for: 1) incidental sediment ingestion and 2) dermal contact with sediment. A key component of the exposure analysis for the Native American Subsistence Angler is seafood ingestion, which comprises a very large portion of their diet. Because COPCs were identified for fish tissue, seafood ingestion was further evaluated.

   The Native American Subsistence Angler adult and juvenile represent the receptors with the greatest exposure potential both from incidental sediment ingestion and dermal contact while fishing. The Suquamish and other Tribal members have “Usual and Accustomed” fishing rights which extend to Terminal 91. They are also most likely to be subsistence anglers and consume the greatest quantities of fish and shellfish.

The Native American Subsistence Angler juvenile was assumed to represent individuals from 6 years of age to 20 years. Younger children are at a higher risk from drowning and were assumed not present in boats during fishing activities especially in such a busy and congested commercial terminal as Terminal 91. The Native American Subsistence Angler was assumed to limit activities to daylight hours in Terminal 91 waters.

2. Recreational Angler (adult/juvenile)—This receptor category is potentially exposed to contaminants through incidental sediment ingestion and dermal contact with sediment when fishing and boating (e.g., anchoring, oars, handling tackle, lines, and crab pots). Recreational anglers also ingest the seafood they catch. These receptors were assumed occasionally present on the Terminal 91 waters and only during daylight hours. Terminal 91 is a very busy port and smaller watercraft are at risk from the high traffic and wakes caused by larger ocean-going vessels. There is a very low probability that recreational anglers could ingest fish and shellfish caught from the FSNSD MRS. The juvenile recreational angler is assumed to represent males and females from 6 to 20 years of age. Younger children are at much higher risk from drowning and assumed not to be present in boats while fishing, especially in such a busy and congested commercial terminal as Terminal 91. The Recreational Angler would limit activities to daylight hours.

   The Recreational Angler (both adult and juvenile) was evaluated quantitatively since several MCs were detected in sediment, even though there were no exceedances of soil RSLs for: 1) incidental sediment ingestion and 2) dermal contact with sediment. A key component of the exposure analysis for the Recreational Angler is seafood ingestion, which could theoretically comprise a significant portion of their diet. The seafood ingestion pathway is not addressed with the soil RSLs, and the presence of 3 MCs for which modeled concentrations exceeded the fish tissue RSLs indicates additional evaluation is necessary.

   Other recreational users such as swimmers, snorkelers, and divers were not assessed because these uses are not expected to occur within the MRS boundaries due to safety concerns, very cold-water temperatures, and busy commercial marine traffic. Risks to the recreational angler are expected to be protective of all other recreational users.

Tourist—there is insignificant potential for exposure. Therefore, this receptor is considered protected by evaluation of the recreational angler and evaluated qualitatively.

Resident—residents are not expected to be exposed to sediments from the site unless engaged in fishing, which is described above for the Recreational Angler. Therefore, this receptor is considered protected by the evaluation of the recreational angler, and evaluated qualitatively.

7.1.3.1.1 Current and Future Use

The future use of the FSNSD MRS is anticipated to be the same or very similar to the current use. It is expected that the FSNSD MRS will continue to serve as a major marine terminal for cruise ships, cargo handling, and commercial fishing. Use of the MRS waters by recreational anglers or Native American Subsistence Anglers remains a remote possibility.

7.1.3.2 Exposure Assumptions

There are several exposure assumptions associated with the baseline HHRA. These are as follows:

- The only site-specific receptors that could have significant exposure to COPCs from the MRS are the Recreational Angler and Native American Subsistence Angler (adult and juvenile) that fish or crab within FSNSD MRS waters.
- It was assumed that no shellfish collection would be conducted in the MRS.
- It was assumed from a site visit and a review of the area topography that there is no wading on the steep, limited shoreline, and any fishing or crabbing is done from boats.
- The childhood portion of the receptors lifetime is represented by the juvenile from 6 to 20 years of age.
- Children younger than 6 years would not be expected to be in a boat in Terminal 91 waters due to cold water, drowning hazard, possible hypothermia, and age.

7.1.3.3 Exposure Point Concentrations

The EPC represents the average exposure contracted by a receptor within an exposure area (EA) over a long period of time, consistent with the chronic nature of the toxicity values. Therefore, the EPC is most accurately estimated by an average value (e.g., the UCL95) and not by the maximum observed concentration or MDC. Typically, the UCL95 suggested by ProUCL V. 4.1 will be less than the MDC (USEPA, 2010a).

However, often a UCL95 cannot be estimated due to a low number of detected values, which makes determination of the underlying sample distribution uncertain. This can occur at sites that are relatively free of contaminants overall or where contamination occurs in discrete, limited, locations.

For the initial screening level HHRA, the MDCs were used as the EPCs as a conservative estimate of exposure. The MDC is considered conservative because it is likely to overestimate the true mean concentration to which receptors are exposed. EPCs for those analytes that exceeded screening values were then re-evaluated. Because data were limited in numbers and the detection frequency was low, UCL95's could not be calculated with statistical confidence using ProUCL V. 4.1 (USEPA, 2010a).

The quantitative risk estimates were therefore estimated using either the median value or MDC, whichever was lower, to represent the EPC in accordance with ProUCL V. 4.1 guidance (USEPA, 2010a; USEPA, 2010b). The median is a robust measure of central tendency recommended by USEPA (2010a) for data sets with low detection frequencies. The median was preferred over the MDC because the median uses all of the data, and not just one data point, as does the MDC. Therefore, it is more representative of the true EPC.

If the median exceeded the MDC due to elevated reporting limits, the MDC was selected for use as the EPC, because of the uncertainty associated with nondetected data. Because a biased sampling plan was implemented for MC (i.e., samples were collected from areas only where DMM was observed), the results are also biased high. Any estimate of an average will also be biased high regardless of the statistic used to represent the EPC.

Table 7-10 presents the measured and modeled EPCs used in the quantitation of cancer risks and non-cancer HQs in the quantitative HHRA. The same approach as described in **Equation 7-4**, in **Section 7.1.2.1** was used for calculating finfish and shellfish EPCs.

Table 7-10 Measured and Modeled Exposure Point Concentrations Used in the Baseline Human Health Risk Assessment

Chemical	CASRN	EPC for Sediment (mg/kg)	EPC for Modeled Fish Tissue (mg/kg) [1]	EPC for Modeled Shellfish Tissue (mg/kg) [1]
Energetics				
2,4-Dinitrotoluene	121-14-2	0.4	0.00116	0.00503
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	0.058	0.000267	0.00116
Propellant Stabilizers				
N-Nitrosodiphenylamine	86-30-6	0.84	0.00193	0.00836

Notes:
CASRN = Chemical Abstracts Service Registry Number
mg/kg = milligram per kilogram
EPC = exposure point concentration represented by the median or maximum detected concentration in sediment whichever was lower. The tissue EPCs represent the tissue concentrations calculated from sediment uptake.
The fraction of organic carbon (foc) used in the calculation of fish tissue concentrations was = 0.0127 (unitless) and based on site total organic carbon data).
[1] see Section 7.1.2.1 for derivation of fish tissue concentrations.

7.1.3.4 Exposure Parameters Used in the Quantitative Human Health Risk Assessment

Fish ingestion rates for the Suquamish Tribe are provided in **Table 7-13**. Exposure parameters were used to develop estimates of cancer risks or non-cancer HQs in the baseline risk assessment (**Table 7-14**). A description of the human health exposure parameters (**Table 7-14**) that were used to develop the intakes are described in the following subsections. The Native American Suquamish Tribe fish ingestion rates were also evaluated during development of the exposure parameters, shown in **Table 7-14**, according to the USEPA guidance (USEPA, 2007).

Table 7-11 Exposure Durations Used in the HHRA for the Native American Subsistence Angler and Recreational Angler – FSNSD MRS

Default RME		Site RME	
Age (year)	**Exposure Duration (year)**	**Age (year)**	**Exposure Duration (year)**
Child: 0 to 6	6	No child	NA
Juvenile	varies	Juvenile: 6 to <21	**15**
Adult Resident: 6 to 30	24	Adult: > 21 to 30	**9**
Totaled	30		9 + 15 = **24**

Notes: Defaults based on a default of a resident being 30 years in one place (USEPA, 2012a, RSL tables). There is no child from 0 to < 6 years at FSNSD MRS.
RME = reasonable maximum exposure
NA = not applicable

Averaging Time

The variable "averaging time" is expressed in days to calculate average daily intake. For non-carcinogenic chemicals, intakes were calculated by averaging the total cumulative dose over the period of exposure to yield an average daily intake. For carcinogens, intakes are calculated by averaging the intake dose over a 70-year lifetime, yielding lifetime average daily dose.

By definition, the cancer averaging time (ATc) is the typical lifetime (i.e., 70 years * 365 days per year [d/y] = 25,550 days). The non-cancer averaging time (ATnc) is the exposure duration in years multiplied by 365 days per year. *Source*: (USEPA, 2011b).

Body Weight

Body weight (BW) is receptor-specific and expressed in kg. A body weight of 36.8 kg was used to represent the RME BW for the juvenile recreational angler (6 to <21 years) represented by an average of three (3) age categories (6 to <11 y, 11 to <16 y, and 16 to <21 y). Body weight was calculated as the average of 21.3, 37.2, and 52.0 kg (USEPA, 2011b).

There were no body weights provided for Native American juveniles in the Suquamish seafood ingestion survey (The Suquamish Tribe, 2000) or in the USEPA "Framework" document (USEPA, 2007). Consequently, the same body weight values were used for the juvenile Native American Subsistence Angler (≥ 6 to <21 yrs.).

Adult body weight for the recreational angler was 70 kg (USEPA, 2011b). Adult body weight for the Native American was slightly higher at 79 kg (The Suquamish Tribe, 2000).

Exposure Duration

An exposure duration (ED) of 15 years (i.e., 6 y through 20 y) was used for the juvenile Recreational Angler and Native American Subsistence Angler, and nine (9) years (i.e., 24 y – 15 y) for the adult Recreational Angler. The Native American Subsistence Angler adult ED was 49 years (i.e., 70 y- 15 y – 6 y). Carcinogenic effects for all receptors were evaluated over the course of a lifetime (i.e., 70 years or 25,550 days).

The adult was assumed to represent both males and females 21 years of age and older, while the juvenile was assumed to be from 6 to 20 years of age (USEPA, 2011b) (see **Table 7-11**).

Exposure Frequency

The exposure frequency (EF) is the number of d/y that the receptors are predicted to be exposed. This parameter is very uncertain since it is likely that none of the receptors will be exposed because of the fishing advisories and shell fishing bans in place for the area. EF is further limited by the nature of MC contamination, which is highly localized. Fish ingestion is averaged across yearly values because of the way the fish ingestion rate is derived; thus, the EF for sediment differs from the EF for fish. The EF for fish was set to 350 days/year because the fish ingestion rate is averaged across this period.

7.1.3.5 Derivation of Seafood Ingestion Rates

Seafood ingestion rates were derived for the Recreational Angler and the Native American Subsistence Angler. The 95th percentile fish ingestion rate for the Pacific area Recreational Angler used to represent the RME was 6.8 g/day for adults over 18 (USEPA, 2011b). The juvenile Recreational Angler RME fish ingestion rate (95th percentile) was the average of 95th percentiles for four age groups: (6-<11, 11 to <16, 16 to 18, and > 18 years of age) **Table 7-12**.

The fish ingestion rates for the Native American Subsistence Angler were obtained from the Suquamish tribal seafood consumption survey (The Suquamish Tribe, 2000). Native American Subsistence Angler juveniles were presumed to have an ingestion rate equal to 40% that of the adults (USEPA, 2007). Native American Subsistence Angler juveniles were presumed to have a fish and shellfish ingestion rate equal to 40% that of the adults (USEPA, 2007) **Table 7-13**.

Table 7-12 Recreational Angler Fish Ingestion Rates

Age Group, years	95th Percentile Fish Ingestion Rate, fresh weight (mg/d)
6 to < 11	3,200
11 to < 16	4,800
16 to < 18	2,500
> 18	6,800
Average (mg/d)	4,325

Source: (USEPA, 2011b), Table 10-50, and Table ES-1, Pacific marine fish (NCHS, 1993).
Assumed ½ finfish & ½ shellfish for exposure modeling, so the fish ingestion rate (FIR) is 2,163 mg/d each for shellfish & finfish for 95th percentile to represent the RME.

Table 7-13 Native American Subsistence Angler Seafood Ingestion Rates

Seafood Group	95th Percentile Seafood Ingestion Rate, g/kg/d, fresh weight	BW_{adult}, kg	Seafood Ingestion Rate, 95th percentile (RME), g/d, fresh weight
D (demersal finfish) *	0.475	79	37.5
Seafood Group	**75th Percentile Seafood Ingestion Rate, g/kg/d**	**BW_{adult}, kg**	**Seafood Ingestion Rate, 75th percentile (RME), g/d**
E (shellfish & invertebrates) **	0.121	79	9.56

Source: Table C-2, (The Suquamish Tribe, 2000).
Per (USEPA, 2007) assume juvenile ingestion rate is 40% of adult ingestion rate.
Notes:
g/kg/d = gram per kilogram (of body weight) per day
RME = reasonable maximum exposure
BW = body weight, adult, in kilograms, kg
Inclusion of selected seafood items is based on MRS habitat.
* Group D: Value represents average ingestion rates of Rockfish, Halibut, Sole, and Flounder.
**Group E: Value represents average of Dungeness crab, sea urchin, and sea cucumber seafood ingestion rates based on MRS habitat; only 75th percentile values were provided (Table C-2, Appendix C-D, (The Suquamish Tribe, 2000).

7.1.3.5.1 Concentrations of Munitions Constituents in Seafood Tissue

MC concentrations in bottom dwelling or demersal finfish and crabs were estimated by application of BCFs from the available literature. BCFs are presented in **Section 7.1.2.1** and **Table 7-8**.

7.1.3.6 Exposure Equations

Exposure is assessed by considering the various exposure pathways, and using equations to quantify an estimated exposure for each pathway. The exposure pathways for the baseline HHRA were ingestion of seafood contaminated by MC in sediments, sediment ingestion, and sediment dermal contact. Exposure equations consistent with the USEPA RSL User's Guide (USEPA, 2012d) were applied to quantify the complete exposure pathways shown in **Figure 6-2**. With carcinogens (2,4-DNT, RDX, and N-nitrosodiphenylamine), appropriate age adjustments as detailed in USEPA RSL User's Guide (USEPA, 2012d) were used. These equations were rearranged to solve for potential cancer risks and non-cancer hazards. There were no mutagenic COPCs.

The Native American Subsistence Angler parameters differ from standard parameters. There is a higher exposure rate for adults than juveniles based on a higher exposure duration and higher fish or shellfish ingestion rate. Therefore, age-specific parameters for adults were applied for the Native American Subsistence Angler only for the non-cancer fish and shellfish ingestion equations.

7.1.3.7 Estimation of Chemical Intakes

Chemical intake is the daily chronic chemical intake estimated as the chemical concentration in the exposure medium multiplied by pathway specific intake factor(s).

Intakes are expressed in units of mg/kg-d normalized for body weight. Intake equations were calculated separately for each receptor and exposure pathway. Numerous assumptions were necessary to derive the intake equations. The assumed exposure parameters for the seafood ingestion exposure scenario, including EF, ED, BW, AT, seafood ingestion rates (IR), toxicity values, and others are summarized in **Table 7-14**. The seafood intake equation is presented below.

Exposures were age-adjusted for cancer risks consistent with USEPA (2011b) to address sensitive growth stages of early childhood and adolescence.

Equation 7-4 Recreational Angler, Fish/Shellfish Ingestion, Cancer, Adult and Juvenile

$$Intake = \frac{Cfish * EF * EDj * IRfishj * CF}{(ATc * BWj)}$$

Where:

Cfish = (Csed * BCF)/(Koc * foc)
EF = exposure frequency, recreational angler, days/year
EDj = exposure duration, juvenile, year
IRfishj = ingestion rate, fish/shellfish, juvenile, milligrams/day
CF = conversion factor, 1E+06 milligram to kilogram or 1E-06 kilogram to milligram
ATc = averaging time, cancer = 70 years (y) or 25,550 days
BWj = body weight, juvenile, kilograms

Table 7-14 Human Health Risk Assessment Exposure Parameters - FSNSD MRS

Exposure Parameter	Variable	Units	Recreational Angler		Ref	Native American Subsistence Angler		Ref
			Juvenile (6-20 yrs.)	Adult	*	Juvenile (6-20 yrs.)	Adult	*
Averaging Time - Cancer	(ATc)	d	25,550	25,550	a,d	25,550	25,550	a,d
Averaging Time - Noncancer	(ATnc)	d	5,475	3,285	a	5,475	17,885	a,d
Body Weight	(BW_i)	kg	36.8	70	a	36.8	79	c,b
Conversion Factor, mass	(CFm)	kg/mg	1E-06	1E-06		1E-06	1E-06	a,d
Exposure Duration - Fish	(EDi)	yr	15	9	a,e	15	49	b
Exposure Frequency - Fish	(EFfish)	d/yr.	350	350	e	350	350	e
Finfish Ingestion Rate	(IRfish)	mg/d	2,163	3,400	e	15,010	37,525	e
Finfish Ingestion Rate, Age Adjusted	($IRfish_{adj}$)	mg-y/kg-d	1,318	NA	e	29,388	NA	a,e
Shellfish Ingestion Rate	(IRfish)	mg/d	2,163	3,400	e	3,824	9,559	e
Shellfish Ingestion Rate, Age Adjusted	($IRfish_{adj}$)	mg-y/kg-d	1,318	NA	e	7,486	NA	a,e
Fraction of Fish Ingested from Contaminated Source	(FCfish)	Unitless	1	1	c	1	1	e
Fraction of Sediment Ingested from Contaminated Source	(FCsed)	Unitless	1	1	c	1	1	e

Notes:
a - (USEPA, 2012d). Regional Screening Table - Equations and User's Guide (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm)
b - (USEPA, 2007). Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. Revision 00. Region 10. Seattle WA. August 2007.
c - (USEPA, 2011b). Exposure Factors Handbook. Final.
d - (USEPA, 1989-2010). Risk Assessment Guidance for Superfund, Volume 1.
e - Site-specific based on professional judgment (Table references below refer to (USEPA, 2011b), Exposure Factors Handbook).
For residents: Assume there is no contact with sediments within the munitions response area (MRS).
For juvenile Recreational Angler: Assume only juveniles >=6 years but less than 21 years of age are engaged in angling although younger individuals may eat fish caught from the site. A frequency of 24 d/y [1 day every other week] was used as the EF for the RME.
For adult Recreational Angler: The duration of 24 years (i.e., = 30 years - 6 years as no angling) at a frequency of 24 d/y [1 day every other week] was used for the RME.
For juvenile Native American: Assume only juveniles >=6 years but less than 21 years of age are engaged in angling although younger may eat fish caught from the site. A frequency of 24 d/y [1 day every other week] was used as the EF for the RME.
For adult Native American: The exposure duration of 49 years (70 years – 15 (juvenile 6-20 yr.) - 6 yr. as non-angler) at a frequency of 24 d/y [1 day every other week] was used for the RME.

7.1.4 Toxicity Assessment

The toxicity assessment followed the methodology recommended by USEPA (2012a) for classifying health effects from exposure to chemicals. The health effects analysis considers chronic (long-term) exposures. Using the following hierarchy, the chronic toxicity criteria were obtained from:

1. Tier 1 – Integrated Risk Information System (IRIS) (USEPA, 2012c).
2. Tier 2 – Provisional Peer Reviewed Toxicity Values (PPRTVs) — as developed on a chemical-specific basis by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center. These values were obtained directly from the USEPA PPRTV web site (USEPA, 2003).
3. Tier 3 – Other Toxicity Values — including additional USEPA and non-USEPA sources of toxicity information, such as the Agency for Toxic Substances and Disease Registry Method Reporting Limits, California Environmental Protection Agency (Cal-EPA), and the Health Effects Assessment Summary Tables (USEPA, 1997).

Toxicity values based on cancer and non-cancer endpoints were applied in the cancer risk and non-cancer HQ calculations, respectively. The toxicity information pertinent to this baseline HHRA includes the non-cancer reference dose (RfD) and the cancer slope factor (CSF).

USEPA sources (USEPA, 2012a) were used to assess potential health risks resulting from the estimated chemical intakes. Toxicity factors were expressed either as an Rfd or a CSF for evaluating oral exposure (USEPA, 2009). 2,4-DNT is evaluated as a carcinogen for purposes of the HHRA; however, USEPA's IRIS provides no information as to carcinogenicity. Instead, the CSF is provided by the Cal-EPA.

The RfD was used to predict the non-cancer risks due to oral exposure. The RfD is the daily dose for oral exposure that is unlikely to result in non-carcinogenic toxic effects to humans over a lifetime of exposure.

Cancer slope factors were used to estimate potential carcinogenic risks for oral exposures. The CSF is an estimate of the upper-bound probability of an individual developing cancer as a result of exposure to a potential carcinogen.

Toxicity values for carcinogens and non-carcinogenic explosives were evaluated. Chemical-specific toxicity profiles are provided for contaminants that were carried forward to the quantitative risk assessment following COPC screening. **Table 7-15** presents the toxicity data used to assess carcinogenic risks and non-carcinogenic HQs through seafood ingestion only.

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Table 7-15 Toxicity Values for the Human Health Risk Assessment – FSNSD MRS

Chemical of Potential Concern	Toxicity Value	Source	Species	Endpoint	Experimental Doses (mg/kg)	WOE	Category
Oral Cancer Slope Factor (CSFo)(1) (mg/kg-day)-1							
2,4-Dinitrotoluene [c]	0.31	USEPA RSLs, 2012; Cal-EPA	--	--	--	--	Explosive
N-Nitrosodiphenylamine [c]	0.0049	USEPA RSLs, 2012; Cal-EPA	Female Fisher 344 Rats (OEHHA, Appendix H RCHAS-S -Standard Proposition 65 document and IRIS)	Transitional cell carcinoma of bladder (IRIS)	Dietary gavage with drinking water (OEHHA, Appendix H); mixed studies	B2 (probable human carcinogen) (IRIS)	SVOC
RDX [c]	0.11	USEPA RSLs, 2012; IRIS	--	--	--	--	Explosive
Chronic Non-Cancer Oral Reference Dose (RfDo) (mg/kg-day)							
2,4-Dinitrotoluene	0.002	USEPA RSLs, 2011, IRIS	2-Year Dog Feeding Study	Neurotoxicity, Heinz bodies and biliary tract hyperplasia	NOEL: 0.2 LOAEL:1.5	Not assessed under IRIS Program	Explosive
N-Nitrosodiphenylamine	NA	--	--	--	--	--	SVOC
RDX	0.003	USEPA RSLs, 2011; IRIS	2-Year Rat Feeding Study	Inflammation of prostate	NOEL: 0.3 LOAEL:1.5	C (possible human carcinogen)	Explosive

Notes:
(1) Oral slope factors and oral references doses are also used to assess toxicity, hazard, and cancer risk for dermal exposure pathways.
-- = Information is not available.
USEPA RSLs - U.S. Environmental Protection Agency Regional Screening Levels, available at: http://www.epa.gov/region9/superfund/prg/ May 2012
c = carcinogen
Most if not all values are also found in the Integrated Risk Information System (IRIS) (USEPA, 2012c) at www.epa.gov/iris.
mg/kg-day = milligram per kilogram (of body weight) per day
RfD = reference dose
CSF = cancer slope factor
WOE = weight of evidence
NOEL = no observed effect level; LOAEL = lowest observed adverse effect level
BMDL = A lower one-sided confidence limit on the Benchmark Dose
SD = standard deviation
Cal-EPA=State of California Environmental Protection Agency formally referred to as California OEHHA California Office of Environmental Health and Hazard Assessment (OEHHA) Reproductive and Cancer Hazard Assessment Section (RCHAS)
PPRTV = Peer Provisional Reviewed Toxicity Value
SVOC = semi-volatile organic compound

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7.1.5 Risk Characterization and Uncertainty Analysis

Risk characterization combines the outputs of the exposure and toxicity assessments to develop quantitative estimates of risks associated with exposures to COPCs. The risk characterization presents the risk estimates and explains the uncertainties associated with the calculation of the risk estimates. In this portion of the risk evaluation, potential health risks are estimated individually for each COPC as well as summed across all COPCs for each exposure pathway, and for all pathways combined. Cancer risk and non-cancer hazard estimates were calculated using the exposure parameters discussed above and standard USEPA equations outlined in USEPA (1989-2010), USEPA (2002), and USEPA (2012d). RME cancer risks and non-cancer HQs were calculated for each receptor.

Cumulative cancer risks and cumulative non-cancer hazard indices were calculated using the intakes and toxicity values obtained from the previous steps. For each receptor, the cumulative risk and hazard indices for all COPCs at the MRS and complete routes of exposure were compared to USEPA's risk management range of 1 x 10^{-6} to 1 x 10^{-4} and a hazard index (HI) of 1.

7.1.5.1 Calculation of Non-Cancer Risks

The potential for non-carcinogenic risks expressed as HQs is characterized by comparing estimated chemical intakes with chemical specific RfDs. Chemical intake is the daily chronic chemical intake estimated as the chemical concentration in the exposure medium multiplied by the pathway specific intake factor. The ratio of the estimated intake to the RfD is called an HQ, which is calculated as follows:

Equation 7-5 Calculation on Non-Cancer Hazard Quotients

$$Noncancer\ \ Hazard\ \ Quotient\ \ (HQ) = \frac{Chemical\ \ \ Intake\ \ \ (mg/kg - day)}{RfD\ \ \ (mg/kg - day)}$$

For each receptor category (i.e., the Recreational Angler, and Native American Subsistence Angler), HQs were summed as appropriate for all COPCs and their relevant exposure pathways to yield a total HI. An HI less than or equal to one (≤ 1) indicates that no adverse non-carcinogenic health effects are expected to occur even to sensitive individuals over a lifetime of exposure. An HI above one indicates a potential cause for concern for non-carcinogenic health effects and the need for further evaluation of assumptions about exposure and toxicity.

Regarding non-cancer HQ calculations, it is standard practice to model only the most sensitive receptor (i.e., the juvenile) and not both adult and juvenile since if there are HQ exceedances for the juvenile, then the adult is also at risk.

7.1.5.2 Calculation of Cancer Risks

Potential carcinogenic effects were characterized in terms of the excess probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. The target cancer risk management range applied by USEPA (1989) is $1x10^{-6}$ to $1x10^{-4}$. Excess lifetime cancer risk for the ingestion and dermal contact pathways was calculated by multiplying the average daily chemical intake by the CSF, which is expressed as a risk per unit chemical intake:

Equation 7-6 Calculation of Cancer Risks

$$Cancer\ Risk\ = Chemical\ \ Intake\ (mg/kg\text{ - }d)\ x\ SF\ \ (mg/kg\text{ - }d)^{-1}$$

For each receptor category, cancer risks were calculated separately for each carcinogen and each exposure pathway. The resulting cancer risks were summed to yield a cumulative or total estimate of cancer risk due to multiple exposures.

In March of 2005, the USEPA published the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposures to Carcinogens ("Supplemental Guidance") (USEPA, 2005a) (USEPA, 2005a) to provide additional focus on childhood exposures to carcinogens, as recommended in the Guidelines for Carcinogen Risk Assessment (USEPA, 2005b). The Supplemental Guidance document evaluated cancer risks from early-life exposure and compared them to cancer risks associated with exposures occurring later in life. The Supplemental Guidance recommended that in some cases, when carcinogens have a mutagenic mode of action, it may be appropriate to apply an age adjustment safety factor to risk calculations when evaluating cancer risk associated with exposure for children ages 0 to 16 years. No COPCs were categorized as mutagens.

7.1.5.3 Summary of Cancer Risks and Non-Cancer Hazard Quotients

Cancer risks and non-cancer HQs are presented by receptor in the following subsections.

For the Native American Subsistence Angler and the Recreational Angler, cancer risks are age-adjusted to address exposure as both an adult and a juvenile (refer to intake equations in **Section 7.1.3.7**, above).

For the non-cancer HQs, it is standard practice to evaluate for the most sensitive receptor (i.e., the juvenile), and not both adult and juvenile.

7.1.5.3.1 Native American Subsistence Angler

The RME cancer risks and non-cancer HQs for the Native American Subsistence Angler are presented in **Table 7-16**.

There were no excess lifetime cancer risks for the seafood ingestion pathway for any COPC.

There were no non-cancer HQs greater than 1 for any COPC. Therefore, there are no non-cancer hazards. There are no contaminants of concern (COCs) identified as a result of the risk assessment, and therefore, further evaluation to determine impacts to human health is not necessary.

Table 7-16 Native American Subsistence Angler RME Cancer Risks and Non-Cancer Hazard Quotients

Chemical	CAS No.	Cancer Risks			Non-Cancer Hazard Quotients		
		Finfish Ingestion	Shellfish Ingestion	Total Cancer Risk	Fish Ingestion	Shellfish Ingestion	Total HQ
Energetics							
2,4-Dinitrotoluene	121-14-2	1.4E-07	1.6E-07	3.0E-07	0.00002	0.00001	0.0003
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	1.2E-08	1.3E-08	2.5E-08	0.000002	0.0000002	0.00004
Propellant Stabilizers							
N-Nitrosodiphenylamine	86-30-6	3.8E-09	4.2E-09	8.0E-09	No RFD	No RFD	0
Cumulative Risk		1.6E-07	1.8E-07	3.4E-07	0.00002	0.00001	0.0003

Notes:
Bold italics - cancer risk > 1E-6 or hazard quotient >1
Cancer risks and hazard quotients are unitless.
CASRN = Chemical Abstracts Service Registry Number
No CSF—Cancer slope factor not available; risk cannot be calculated.
No RfD—Non-cancer RfD value not available; non-cancer hazard cannot be estimated.
Total = sum of all pathways
c = carcinogen

7.1.5.3.2 Recreational Angler

The cancer risks and non-cancer HQs for the Recreational Angler are presented in **Table 7-17**. There were no excess lifetime cancer risks for the seafood ingestion pathway for any COPC. There were no non-cancer HQs greater than 1 for any COPC. Therefore, there are no non-cancer hazards. No MC were identified as COCs for the HHRA.

Table 7-17 Recreational Angler RME Cancer Risks and Non-Cancer Hazard Quotients

Chemical	CASRN	Cancer Risks			Noncancer Hazard Quotients		
		Finfish Ingestion	Shellfish Ingestion	Total Cancer Risk	Fish Ingestion	Shellfish Ingestion	Total HQ
Energetics							
2,4-Dinitrotoluene	121-14-2	6.5E-09	2.8E-08	3.5E-08	0.00003	0.0001	0.0002
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	5.3E-10	2.3E-09	2.8E-09	0.000005	0.00002	0.00003
Propellant Stabilizers							
N-Nitrosodiphenylamine	86-30-6	1.7E-10	7.4E-10	9.1E-10	No RFD	No RFD	0
Cumulative Risk		7.2E-09	3.1E-08	3.8E-08	0.00004	0.0002	0.0002

Notes:
Bold italics - cancer risk > 1E-6 or hazard quotient >1.
Cancer risks and hazard quotients are unitless.
No CSF - Cancer slope factor not available; risk cannot be calculated.
No RfD - Noncancer RfD value not available; non-cancer hazard cannot be estimated.
CASRN = Chemical Abstracts Service Registry Number
Total = sum of all pathways
c = carcinogen

7.1.5.4 Uncertainty Analysis

Uncertainties associated with the HHRA process have been qualitatively assessed and potential impacts on the HHRA results are discussed herein. Specifically, the uncertainty analysis addresses uncertainties associated with data collection and evaluation, exposure assessment, and the toxicity assessment.

7.1.5.4.1 Data Collection and Evaluation

The sampling data were collected following visual surveys and intrusive investigations. This sampling design intentionally biased the data to represent worst-case conditions. It is expected that most DMM were found and removed, but this is not certain. Remaining DMM do not bias the risk results because the DMM that were found were removed, thus removing the source. If anything, the data are biased high. In addition, the sediments directly under the DMM were the fraction sampled; this is a worst-case sampling design that would bias EPCs high.

Analysis was performed with standard laboratory protocols. This is not expected to bias the results of the risk assessment. J-flagged values were retained; these may slightly bias results high or low. Furthermore, all of the detected MC results in sediment, with the single exception of the 0.97 mg/kg MDC, were qualified as “J-estimated”. The details of the required laboratory reporting under the DoD program Quality Systems Manual for Environmental Laboratories, Version 4.2 (DoD, 2010a) are provided in **Section 5.2.5**. In fact, if the samples had been analyzed under the USEPA Contract Laboratory Program, all results except the 2,4-DNT value of 0.97 mg/kg would have been flagged as non-detected results.

7.1.5.4.2 Exposure Assessment

The uncertainties in the exposure assessment are due to the determination of the EPC as well as uncertainties inherent in the exposure assumptions. The EPC was considered highly conservative, which is likely to bias risk results high. This is because the maximum detected value was applied as the concentration to represent the entire exposure area. In reality, the DMM are scattered intermittently within the exposure area, and MC are limited to sediment underneath the DMM.

Other parameters used in the exposure assessment include estimates of bioaccumulation, fish ingestion rates, exposure frequency, and exposure duration. MC is not expected to bioaccumulate to a great degree. Fish and shellfish are also not considered to be in direct contact with the sediment that was directly under the DMM, but only to the side. Even with application of the home range and AUF to adjust biouptake to a more realistic level, uptake by fish is expected to be overestimated because bioaccumulation models assume constant contact with the EPC; the predicted tissue concentrations are, therefore, those that would occur if the fish was “attached” to the place where the maximum EPC occurred. As fish move in and out of the exposure area, depuration will counter uptake and decrease tissue concentrations. Therefore, bioaccumulation is expected to be over-estimated and fish concentrations are expected to be biased high.

Ingestion of fish or shellfish from within the exposure area of the MRS is expected to be intermittent and sporadic because not every fish or crab caught would have been within the exposure area long enough to have accumulated MC. There are warnings against fishing near the MRS, which further reduces the likelihood that any fish or crab caught would have been from within the exposure area of the MRS. There are fish advisories in place to prevent fish ingestion from this area of Elliott Bay. In addition, the C_{fish} used as the EPC is over-estimated because the fraction of contaminated sediments is low relative to the total area of the site. Therefore, while a high fish ingestion rate and a high exposure frequency were applied in the exposure modeling for the Baseline Human Health Risk Assessment (BHHRA), the fish concentration in the intake equation would be biased high, thereby biasing intake estimates due to fish ingestion high.

Discarded military munitions are highly discrete and most MC is not highly mobile in marine sediments due to low aqueous solubility (Lotufo et al., 2012); however, MC are extensively biologically or chemically transformed in the aquatic environment (Sunahara, 2009). Each DMM covered approximately 1 ft^2. This would suggest total contaminated sediment to cover an area approximately 32 ft^2. Therefore, the estimate of the EPC as covering a total of 4.55 acres is likely biased high.

7.1.5.4.3 Toxicity Assessment

Potential toxicity of MC was evaluated by comparing the sediment concentrations to RSLs for soil and fish. The RSLs developed for use at Superfund sites are conservative risk-based soil and fish tissue concentrations, derived from standardized equations. They are considered by the USEPA to be protective for humans (including sensitive groups) over a lifetime. Humans are unlikely to contact sediments at the same rate as they would soils, and therefore, the soil RSLs provide a conservative starting point for COPC evaluation. Analytes that are below the soil RSLs are not expected to adversely affect humans exposed to sediments by incidental ingestion, dermal contact, or particulate inhalation.

The fish RSLs are also considered conservative even though they are not based on a Native American Subsistence Angler fish ingestion rate because of the low likelihood of fish or crabs being collected by anglers or crabbers from within the MRS. The RSLs used for human health screening in the initial evaluation are generic; that is, for the most part, they are calculated without any site-specific information. For this reason, they were used for a very preliminary review of the sediment data.

The use of picramic acid toxicity values for ingestion and dermal exposure to represent picric acid, which was actually detected, represents a source of uncertainty. It is unknown if this would bias risks high or low, or introduce no bias.

Where CSFs were unavailable for carcinogens, cancer risks cannot be estimated. Risks from carcinogens, if they were present, would therefore be underestimated. However, not all chemicals produce a cancer effect. N-nitrosodiphenylamine and 2,4-DNT were the only COPCs identified as having carcinogenic effects. Alternatively, if RfDs are unavailable, non-cancer hazards cannot be estimated and also underestimated. The only COPC which could not be quantitatively assessed for non-cancer hazard, was n-nitrosodiphenylamine.

7.1.6 Conclusions

The BHHRA evaluated the data, characterized potential risk, and considered uncertainties. The uncertainty analysis above indicates that risk results should be biased high. Considering that the cancer risks were less than $1x10^{-6}$, and the noncancer HQs were below 1, there are likely no human health risks due to MC from DMM at the MRS. There were no risks or hazards for Underwater Divers or Underwater Construction Workers at the site for direct contact with sediment or incidental sediment ingestion. The conclusions can be summarized as follows:

- All relevant receptors were evaluated.
- Fish and shellfish from within the MRS are not actually consumed.
- Fish are likely not contaminated.
- All HQs were <1.
- No cancer risks were above $1x10^{-6}$ for the fish ingestion pathway.

The FSNSD MRS has no human health risks if realistic exposure assumptions like the AUFs are applied (**Section 7.1.3.5.1**).

7.2 Screening Level Ecological Risk Assessment

This ecological risk assessment (ERA) was conducted in accordance with the guidelines set forth in the Tri-Service Ecological Risk Assessment Working Group—A Guide to Screening Level Ecological Risk Assessment (TSERAWG, 2008); Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA, 1997); Guidelines for Ecological Risk Assessment (USEPA, 1998); Risk Assessment Handbook, Volume II: Environmental Evaluation (USACE, 2010); and the Tri-Service Procedural Guidelines for Ecological Risk Assessment (U.S. Army Environmental Center [U.S. Army, 2000]). The first two steps of the ERA process include the screening-level ERA known as a SLERA. This includes a Problem Formulation, Exposure Assessment, Ecological Effects Analysis, and Risk Characterization. An Uncertainty Analysis is included in the Risk Characterization. Where no adverse effects are predicted on the basis of a SLERA, a baseline ERA is not performed.

7.2.1 Problem Formulation

The Problem Formulation describes the overall ecological setting in and around the project area, the species of special concern that may occur within the project area, and the types of contaminants within the project area. The Problem Formulation culminates with the CSM and assessment and measurement endpoints.

7.2.1.1 Ecological Setting

This information is presented in **Section 2.3**.

7.2.1.2 Threatened and Endangered Species and Species of Concern

This information is presented in **Section 2.3.8**.

7.2.1.3 Sensitive Habitats

This information is presented in **Section 2.3.8.1**.

7.2.1.4 Stressors of Interest

The stressors of interest at the site are the DMM that were discarded during the WWII era. These munitions may leak MC (e.g., explosives, propellant stabilizers, or propellant plasticizers) into surrounding sediments.

7.2.1.5 Conceptual Site Model

The CSM defines the potentially complete exposure pathways at the FSNSD. It describes the way that DMM in sediment could be released to other media, and the exposure routes that could lead to ecological receptors contacting MC. The source of MC at the MRS is DMM which rest on the seafloor and may or may not be covered with sediments. These DMM can rupture and leak MC to seawater, where dilution and wave action are expected to reduce any MC concentrations to well below detection. MC may adsorb to sediment solids, whereby physical disturbance, bioturbation, or other transport mechanisms could lead to MC occurring at the sediment-water interface or in suspended sediments (**Figure 6-4**). These MC-contaminated sediments in the top 10 cm (or BAZ) could be contacted by animals feeding or living on the substrate (i.e., benthic life or demersal fish). Although the BAZ can extend as far down as 100 cm (MacDonald and Ingersoll, 2003), Washington Sediment Management Standards consider the BAZ to represent the 0-10 cm interval (WA Dept of Ecology, 2011). While other receptors may occur at the FSNSD, these species are expected to be the most highly exposed, and thus, protective of other species that occur.

Receptors of concern are those animals and plants at the FSNSD MRS that have the greatest likelihood of contact with MC-contaminated sediment (**Figure 6-4**). Of all the potential ecological receptors at the site, there were only two identified receptors of concern:

- Benthic Invertebrates (e.g., Dungeness crab)
- Benthic Fish (e.g., Starry flounder and English sole)

These ROCs were considered the most likely exposed receptors, and it was assumed that risks to these receptors would be protective of risk to other, lesser-exposed receptors. The benthic invertebrate community includes invertebrates such as the Dungeness crab, sea cucumbers, and others living on the substrate.

Benthic invertebrates were evaluated by comparing maximum detected explosive concentrations to applicable sediment quality benchmarks (SQBs).

Dungeness Crab (*Metacarcinus magister*)—a sediment-dwelling crustacean (macroinvertebrate) of local commercial importance that inhabits the seafloor and eelgrass beds. Crabs were selected as a receptor of concern to represent higher trophic level benthic invertebrate species present at the FSNSD MRS. Adult crabs prey on clams, crustaceans, and fish. Crabs eat bivalves their first year, shrimp their second year, and teleost fish in their third year. Juvenile crabs are preyed upon by various demersal (bottom-dwelling) fish in the nearshore area, including flatfish, such as starry flounder and English sole (*Pleuronectes vetulus*). Adult and juvenile crabs are preyed upon by sea otters, fish, and octopuses. Cannibalism is also common among crabs (U.S. Navy, 2011).

Dungeness crabs are harvested in coastal areas in Puget Sound primarily north of Seattle. This crab is managed as a priority species in the PHS list from WDFW. They are an important resource for recreational, commercial, and tribal harvests (WDFW, 2008). There is a fairly large coastal area southeast of Smith Cove that supports local Dungeness crab populations.

The benthic fish community includes flatfish such as the English sole and Starry flounder, which are important commercial fish species.

Starry flounder (*Platichthys stellatus*)—a vertebrate flatfish of local commercial importance that lives both inshore in estuarine habitat and at saltwater depths up to 375 m. This receptor is likely to feed on tubeworms, bi-valves, amphipods, and mollusks while also ingesting some amount of sediment (based on information for the English Sole, another bottom feeder) (Fresh, 1979). An incidental sediment ingestion rate of 10% based on the stomach contents of the English Sole and other bottom-feeding fish was estimated from a study at the Lower Duwamish Waterway RI (Johnson, 2006).

English sole (*Pleuronectes vetulus*)—a vertebrate flatfish of moderate commercial importance that relies on tidal currents to move into and out of estuaries. It is the most abundant flatfish in Puget Sound and feeds on amphipods, mollusks, crustaceans, and polychaetes. Piscivorous birds are among the English sole's main predators. Adults are found in near-shore coastal waters and make only limited migrations (PSMFC, 1996). Much of the research on contaminant accumulation in fish in Puget Sound has focused on the English sole (WDFW, 2012).

It was assumed that if there are no impacts to the benthic invertebrate community as indicated by the comparison of MC concentrations in sediments to the SQBs, then there would be no impact to the English sole, Starry flounder, or Dungeness Crab as they are more mobile than benthic invertebrates and would not be as highly exposed to isolated, discrete occurrences of MC.

7.2.1.6 Assessment and Measurement Endpoints

The following assessment endpoints were considered appropriate for the FSNSD MRS SLERA:

- Long-term survival and reproductive capabilities for populations of benthic marine invertebrates;
- Long-term survival and reproductive capabilities for populations of demersal marine fish.

Long-term survival and reproductive capabilities for individual special status species (i.e., Federally-listed T&E or State species of concern) is also a typical assessment endpoint for an ERA; however, with the exception of the Bald eagle (*Haliaeetus leucocephalus*), no special status species have been observed within the MRS. In addition, habitat within the MRS is very disturbed and there is a high level of human activity. This decreases the potential for special status species to occur.

There is little to no vegetation present, and therefore plants were not identified as receptors of concern, and there are no assessment endpoints specifically for plants. Exposure to pelagic fish, seabirds, raptors, and marine mammals is expected to be minimal due to the limited areal extent of MC and DMM. Therefore, these categories of receptors were not addressed in the SLERA. However, evaluation of exposure of the benthic community is expected to be protective of these other categories since benthos are in constant direct contact with any MC occurring in sediments.

The measurement endpoints relevant to the two assessment endpoints identified above are the measurement of sediment concentrations from under and adjacent to DMM. This is a measure of exposure. The data were compared to SQB for benthic communities in order to determine if a risk to the environment was present.

7.2.2 Exposure Assessment

The screening-level exposure assessment describes the data and how they were used to develop EPCs.

7.2.2.1 Exposure Parameters

There were no exposure parameters developed for the SLERA. SQBs are concentrations in bulk sediment that correlate to No Effects concentrations. Intakes were not calculated, and parameters were not required. Dietary ingestion rates for fish and benthic invertebrates were not available to assess sediment consumption rates.

7.2.2.2 Bioaccumulation of Munitions Constituents

There are few relevant studies with explosives data in marine tissues to apply in food web modeling. The U.S. Navy (U.S. Navy, 2011) did not detect munitions in fish tissue or in clams analyzed as a primary food item for the Starry flounder. The munitions compound 1,3,5-trinitrobenzene (TNB) was detected in only 1 of 6, and picramic acid and picric acid were detected in 2 of six 6 total crab tissue samples at low part per billion levels (U.S. Navy, 2011). This suggests that widespread bioaccumulation of MC is unlikely at the FSNSD.

7.2.3 Ecological Effects Analysis

The SQBs were derived from various marine and freshwater sources (**Table 7-18**). Marine SQBs were preferred over freshwater; however, if there were no marine values, values from USEPA were applied. Comparison of sediment data to SQBs is meant to address potential adverse effects to benthic invertebrates from ingestion and direct contact or dermal exposure to sediment contaminants.

7.2.4 Screening Level Ecological Risk Characterization and Uncertainty Analysis

This Risk Characterization includes a Risk Estimation, where HQs are calculated, and a Risk Description, where the impact or significance of the HQs is qualitatively discussed. There is also an Uncertainty Analysis, where the major uncertainties within the SLERA are presented.

7.2.4.1 Risk Estimation

The initial step in the SLERA process is screening for COPECs. Detections of MC as COPECs in sediment were compared to SQB. Exceedances of benchmarks indicate that a chemical could pose unacceptable risk to benthos and further evaluation may be warranted. The HQ is calculated as follows:

Equation 7-7 Hazard Quotient Estimation

HQ = EPC (mg/kg)/SQB (mg/kg)

The potential for MC to pose unacceptable risks to marine life was assessed by comparing detected sediment concentrations to appropriate SQBs. If a chemical exceeded the SQB (i.e., an HQ >1), there is a potential for adverse effects to ecological receptors. Risk estimates in the form of HQs are presented in **Table 7-20**. There were no HQs that exceeded one.

7.2.4.2 Risk Description

The HQs were well below the target threshold of 1, indicating that adverse effects on the benthic community are unlikely. In addition, the number of detections is low across all samples collected, indicating that widespread exposure is not expected. Furthermore, the number of DMM found within the MRS was also low, further reinforcing the conclusion that widespread exposure is not occurring. Because there are no suggested impacts to the benthic invertebrates, there is unlikely to be any adverse effects to other ecological receptors that may occur in the MRS.

7.2.4.3 Uncertainty Analysis

This section discusses the major sources of uncertainty associated with the risk assessment, and how these uncertainties are likely to affect the predicted hazard estimates.

7.2.4.3.1 Data Evaluation

The data are considered to be biased high and represent the worst-case scenario because they were collected under and adjacent to any DMM that were found. All sediment data, with the exception of two samples, were collected on the seafloor surface and within the BAZ of unconsolidated sediment (detailed in **Table 4-4)**. The data collectively represent the exposure medium.

An extensive intrusive investigation resulted in the recovery of two DMM items. Although there is the potential for remaining DMM, it would appear that the remainder of the MRS has very little or does not have DMM in sediments. The use of the data bias the risk results high; if additional DMM (and MC) remain in sediments, it is expected that risks would be no higher than those estimated to date.

7.2.4.3.2 Exposure Assessment

Exposure was evaluated by utilizing the maximum detected value as the EPC. This is expected to bias the risk results high (i.e., make HQs higher than they would be if data were collected randomly).

Table 7-18 Sediment Screening Values for Ecological Receptors – Former Seattle Naval Supply Depot Munitions Response Site

Analyte	Washington State Sediment Management Standard (Marine) mg/kg	NOAA SQuiRTs (Saltwater) mg/kg	Preliminary Sediment Screening Criteria for Marine Benthic Invertebrates (Pascoe et al. 2010) mg/kg (based on TOC)	Freshwater Sediments (Talmage et al. 1999) mg/kg	USEPA Sediment Screening Values (Freshwater) mg/kg	LANL Eco Risk Database Rel. 3.0, Ecological Sediment Screening Value (Freshwater) mg/kg	Selected Benthic Invertebrate Screening Value mg/kg
Explosives							
1,3,5-Trinitrobenzene	NA	NA	0.16	0.24	NA	1,300	0.16
1,3-Dinitrobenzene	NA	NA	0.5	0.67	NA	1.2	0.5
3,5-Dinitroaniline	NA	NA	4.3	NA	NA	NA	4.3
2,4,6-Trinitrotoluene	NA	NA	1.1	9.2	0.092 (USEPA R3 BTAG Screening Benchmark)	420	1.1
2,4-Dinitrotoluene	NA	NA	210	NA	0.0144 (USEPA R5 ESL) 0.0416 (USEPA R3 BTAG Screening Benchmark)	0.29	210
2,6-Dinitrotoluene	NA	NA	210	NA	0.0398 (USEPA R5 ESL)	1.9	210
2-Amino-4,6-dinitrotoluene	NA	NA	1.3	NA	NA	7	1.3
4-Amino-2,6-dinitrotoluene	NA	NA	3.5	NA	NA	1.9	3.5
2-Nitrotoluene	NA	NA	620	NA	NA	5.6	620
3-Nitrotoluene	NA	NA	190	NA	0.086 (USEPA R5 ESL)	4.9	190
4-Nitrotoluene	NA	NA	68	NA	4.06 (USEPA R3 BTAG Screening Benchmark)	10	68
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	NA	0.021 AET N‡	0.38	0.47	NA	27,000	0.38
Nitrobenzene	NA	NA	180	NA	0.145 (USEPA R5 ESL)	32	180
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	NA	NA	1.2	1.3	0.013 (USEPA R3 BTAG Screening Benchmark)	45	1.2
Trinitrophenylmethyl-nitramine (Tetryl)	NA	NA	0.6	NA	NA	100	0.6
Pentaerythritol tetranitrate (PETN)	NA	NA	32,533	NA	NA	120,000	32,533
Nitroglycerin	NA	NA	127	NA	NA	1,700	127
Picrates							
2,4,6 Trinitrophenol (Picric Acid)	NA	NA	340	NA	NA	NA	340
2-Amino-4,6-dinitrophenol (Picramic Acid)	NA	NA	57	NA	NA	NA	57
2,4-Dinitrophenol	NA	NA	1.4	NA	0.00621 (USEPA R5 ESL)	NA	1.4
Propellant Stabilizers							
N-Nitrosodiphenylamine	NA	0.028 AET (only value - infaunal community impact)	11	NA	2.68 (USEPA R3 BTAG Screening Benchmark)	NA	11
Diphenylamine	NA	NA	280	NA	0.0346 (USEPA R5 ESL)	13 - No Effect Level ESL (Violet-green swallow, aerial avian insectivore)	280

Table 7-18 Sediment Screening Values for Ecological Receptors – Former Seattle Naval Supply Depot Munitions Response Site

Analyte	Washington State Sediment Management Standard (Marine) mg/kg	NOAA SQuiRTs (Saltwater) mg/kg	Preliminary Sediment Screening Criteria for Marine Benthic Invertebrates (Pascoe et al. 2010) mg/kg (based on TOC)	Freshwater Sediments (Talmage et al. 1999) mg/kg	USEPA Sediment Screening Values (Freshwater) mg/kg	LANL Eco Risk Database Rel. 3.0, Ecological Sediment Screening Value (Freshwater) mg/kg	Selected Benthic Invertebrate Screening Value mg/kg
Propellant Plasticizers							
Di-n-butyl phthalate	220	NA	NA	NA	6.47 (USEPA R3 BTAG Screening Benchmark) 1.114 (USEPA R5 Freshwater ESL)	0.014 - No Effect ESL (Violet-green swallow, aerial avian insectivore) 11 - No Effect Level ESL (Aquatic community organisms)	220
Diethyl phthalate	61	0.006 AET (lowest value -larval$_{max}$ bivalve)	NA	NA	0.603 (USEPA R3 BTAG Screening Benchmark) 0.295 (USEPA R5 ESL)	4,500 - No Effect Level ESL (Little Brown Myotis bat, aerial mammalian insectivore	61

Notes:
mg/kg = milligram per kilogram = parts per million
NA - Value not available.
AET – apparent effects threshold
†Screening values for this analyte have not been established. Picric acid values used.
‡Value is lowest among Apparent Effects Thresholds (AET) tests - *Neanthes* bioassay
Sources:
State of Washington Marine Sediment Quality Standard – Chemical Criteria/Puget Sound Marine Sediment Cleanup Screening Levels & Minimum Cleanup Levels-Chemical Criteria, dry weight basis
NOAA SQuiRTs – National Oceanic and Atmospheric Administration Screening Quick References Tables; official citation: Buchman, M.F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, 34 pages. (Buchman, 2008)
(Pascoe et al, 2010). *Munition constituents: Preliminary sediment screening criteria for the protection of marine benthic invertebrates*. Chemosphere, 81 (2010) 807-816. Values were based on the equilibrium partitioning (EqP) approach using chronic water screening benchmarks (from Talmage et al, 1999 and Nipper et al, 2001 for freshwater) and based on organic carbon (OC) content and the lower of marine or freshwater toxicity data. Sediments collected from Ostrich Bay, Puget Sound. Screening value represents lowest value presented in journal article.
(Talmage, Opresko, Maxwell, & al., 1999). Nitroaromatic munition compounds: environmental effects and screening values, Rev. Environ. Contam. Toxicol. 161, 1-156.
(USEPA, 2003) Region 5 (R5) Biological Technical Assistance Group (BTAG), 2003. Ecological Screening Levels (ESLs). Accessed 10/19/11. http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm#hierarchy
USEPA Region 3 (R3). Freshwater Sediment Screening Benchmarks http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm#hierarchy (USEPA, 2006a)
Los Alamos National Laboratory (LANL), New Mexico, Eco Risk Database, Release3.0, November 2011. (LANL, 2011)

Table 7-19 Hazard Quotients for Benthic Invertebrates at the FSNSD MRS

Chemical	Sediment Data								
	Minimum Detected Value (mg/kg)	Maximum Detected Value (mg/kg)	Arithmetic Mean Detected Values (mg/kg)	Number of Detected Values	Number of Samples	Standard Deviation (mg/kg)	Detection Frequency (%)	Sediment Quality Benchmark (mg/kg)	Maximum HQ
2,4,6 Trinitrophenol (Picric Acid)	0.0028	0.0028	NA	1	12	NA	8.3	340	0.000008
2,4-Dinitrotoluene	0.16	0.97	0.44	3	12	0.46	25	210	0.005
2,6-Dinitrotoluene	0.12	0.12	NA	1	12	NA	8.3	210	0.0006
Diethyl phthalate	0.020	0.062	0.04	3	5	0.02	60	61	0.001
Di-n-butyl phthalate	0.04	0.14	0.08	4	5	0.05	80	220	0.0006
Diphenylamine	0.033	0.67	0.23	4	12	0.30	33	280	0.002
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.058	0.058	NA	1	12	NA	8.3	1.2	0.05
N-Nitrosodiphenylamine	0.071	0.84	0.37	3	12	0.41	25	11	0.08
Trinitrophenylmethylnitra-mine (Tetryl)	0.23	0.23	NA	1	12	NA	8.3	0.6	0.4

Notes:

No distribution fitting was performed on these data. Data were assumed to follow a normal distribution for calculation of mean and standard deviation.

NA - Number of detected values is too low to estimate a standard deviation.

Not Detected: HMX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, nitrobenzene, 2,4,6-trinitrotoluene, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, nitroglycerine, 3,5-dinitroaniline, pentaerythritol tetranitrate (PETN), or 2,4-dinitrophenol.

7.2.5 Toxicity Assessment

The evaluation of the SQBs was based on both USEPA values and other peer-reviewed sources. Preference was given to marine sediment screening values where available.

7.2.6 Risk Characterization

The SLERA risk characterization utilizes the site data and the SQBs to derive HQs. Only detected values were used in the analysis. The reporting limits were examined (**Table 7-20**) for adequacy to use to evaluate potential ecological risk. If the reporting limits are too high, there may be risks for nondetected analytes. Since, by definition, analytes that are not detected are below their reporting limit, a proxy value of ½ the maximum Limit of Quantification (LOQ) was applied as the EPC for non-detected analytes (EPCND). All EPCND values were at or below the SQB used in the analysis. Given the limited number of detections across a relatively large area, no adverse effects to populations of ecological receptors are anticipated for nondetected analytes.

7.2.7 Conclusions

The concentrations of MC were low and there were infrequent detections. The most sensitive receptors are the benthic invertebrate community. There were no HQs for detected analytes that produced HQs greater than 1.

Table 7-20 Reporting Limit Evaluation for the FSNSD MRS SLERA

Chemical	Maximum Reporting Limit/ Maximum LOQ (mg/kg)	EPC (mg/kg)	Sediment Quality Benchmark (mg/kg)	Maximum HQ for Non-detected MC
Energetics - Nitroaromatics, Nitramines, and Picrates				
1,3,5-Trinitrobenzene	0.4	0.2	0.16	1
1,3-Dinitrobenzene	0.4	0.2	0.5	0.4
2,4,6-Trinitrotoluene	0.4	0.2	1.1	0.2
2,4-Dinitrotoluene	0.4	0.2	210	NA
2,6-Dinitrotoluene	0.4	0.2	210	NA
2-Amino-4,6-dinitrotoluene	0.4	0.2	1.3	0.2
2-Nitrotoluene	0.4	0.2	620	0.0003
3,5-Dinitroaniline	0.4	0.2	4.3	0.05
3-Nitrotoluene	0.4	0.2	190	0.001
4-Amino-2,6-dinitrotoluene	0.4	0.2	3.5	0.06
4-Nitrotoluene	0.4	0.2	68	0.003
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.4	0.2	1.2	NA
Nitrobenzene	0.4	0.2	180	0.001
Nitroglycerin	0.4	0.2	127	0.002
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0.4	0.2	0.38	0.5
Pentaerythritol tetranitrate (PETN)	0.4	0.2	32,533	0.000006
Trinitrophenylmethyl-nitramine (Tetryl)	0.4	0.2	0.6	NA
2-Amino-4,6-dinitrophenol (picramic acid) (surrogate for picric acid)	0.0097	0.0048	57	0.00009
2,4,6 Trinitrophenol (Picric Acid)	0.0097	0.0048	340	NA
2,4-Dinitrophenol	0.0097	0.0048	1.4	0.003
Propellant Stabilizers				
Diphenylamine	1	0.5	280	NA
N-Nitrosodiphenylamine	0.99	0.5	11	NA
Propellant Plasticizers				
Di-n-butyl phthalate	1	0.5	220	NA
Diethyl phthalate	0.99	0.5	61	NA

Notes:
The maximum level of quantitation (LOQ) is shown as the maximum reporting limit. The LOQ was divided by 2 to estimate the exposure point concentration.
NA - Not applicable because analyte was detected
HQ - Hazard quotient
DMM - discarded military munitions
mg/kg - milligram per kilogram

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8.0 MUNITIONS AND EXPLOSIVES OF CONCERN HAZARD ANALYSIS

A qualitative MEC hazard analysis has been conducted in conjunction with the risk assessment to evaluate baseline hazards associated with MEC within the FSNSD MRS based primarily on three considerations; the source of potential explosive hazard, pathways for exposure to this hazard, and receptors and activities with potential exposure to hazard. The analysis builds off all the data collected within the MRS, the CSM for hazards relating to MEC, and incorporates information from several sources within the U.S. Army and U.S. Navy regarding the effects of underwater detonations.

8.1 Sources for Potential Explosive Hazards

The source of potential explosive hazards within the FSNSD MRS is MEC on the seafloor and buried in sediments from U.S. Navy use of the FSNSD complex during the WWII era. A component of the 2012 field season survey design involved the placement of transects in areas likely to contain MEC based on the beam width of U.S. Navy vessels documented as having used the facilities. Research conducted on vessels seen in aerial photos provided a list of vessel classes that used the facility. Once a vessel class was established, further research provided a standard armament for each of these types of vessels. This information is present in **Table 8-1**. Comparing the likely armament of the WWII-era vessels that berthed at the facility with actual MEC and MD items located during munitions response activities logically confines the nature of MEC potentially present within the MRS.

Table 8-1 Comparison of Munitions Recovered and Historical Armament

Listed Armament	MEC and MD Recovered
.50 Cal	Yes
20mm	Yes
30mm	Yes
40mm	Yes
3in	Yes
4in	No [1]
5in	Yes [2]
16in	No [3]
Torpedoes	No [3]
Additional items recovered include flares and commercially available small arms ammunition.	

[1] = No 4 inch items were recovered, but the maximum fragmentation distance (MFD) calculations provide a distance less than that of a 5 inch MK41.

[2] = The majority of armaments list the 5 inch as the 38Cal, which has a smaller MFD than the MK41 5 inch Projectile.

[3]= It is unlikely that 16 inch items weighing over 2,100lbs and similar sized torpedoes were jettisoned overboard by forklift or other mechanical device while berthed at FSNSD.

The nature and extent of potential DMM at the site was determined during the course of the RI and TCRA by hundreds of hours of bottom time by UXO divers, ROV surveys, extensive marine magnetometer and acoustic surveys, and intrusive investigations. A small number of DMM (32 total items) were located on the seafloor in areas consistent with ships at berth. The data collected support the model that munitions were infrequently jettisoned from vessels in port, without documentation. No significant accumulations or other evidence was found that would indicate deliberate disposal of DMM as a normal practice.

A low number (32 total) of DMM items were located following surface and subsurface investigations biased to areas with the highest likelihood of concentrations. All munitions items located after the initial discoveries by the POS PD dive team in 2010 have been found due to the response efforts of the RI and TCRA. Prior to the initial discoveries made by the POS PD dive team, there are no records of encounters with DMM at the FSNSD, 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 low number of munitions items taken in conjunction with the removal and disposition of all MEC located during the response activities, and the limited access of human receptors to MEC potentially remaining on the seafloor of the MRS indicates that the likelihood of future encounters during normal operations at the facility is low. Infrequent mechanical dredging activities, where potentially MEC-laden sediments are brought to a surface barge in a clamshell bucket, removes water as an access barrier to MEC and increases the probability of an encounter with humans during these activities.

The 2011 ESS and 2012 ESP presented the munition of concern as the 5-inch MK41 projectile. This assumption, made during the 2010 field season, was a conservative projection based on initial discoveries of the POS PD dive team. Although smaller items, such as 20mm and 40mm projectiles were present and recovered at the site, the potential explosive hazard associated with these items was deemed to be low. Therefore, in consultation with project stakeholders the determination was made that the munition of concern at the site was the 5-inch projectile. Although multiple 5-inch projectiles have been recovered within the FSNSD MRS, none have been larger than the 5-inch MK41. Furthermore, research into armament loads of WWII-era vessels does not indicate larger 5-inch MEC items may be present. This qualitative MEC hazard analysis thus will focus on the potential hazards from the MEC item of concern (the 5-inch projectile) and not smaller MEC items such as 3-inch or 40mm projectiles, though smaller items are still subject to the IC summarized in **Section 2.5.1** and the Institutional Analysis in **Appendix G**.

8.2 Likelihood of Potential Explosions

To date, the only MEC items recovered during all munitions response activities at the FSNSD MRS are categorized as DMM. There is no record or evidence of live firing exercises taking place within the MRS, nor did analytical sampling conducted during RI discover MC in significant enough quantities to be classified as MEC. Based on these factors it is highly probable that all MEC located within the FSNSD MRS are DMM.

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).

Arming fusing mechanism for munitions items typically requires application of specific forces to the munitions item. The typical arming process for fuzes installed in a 5-inch munitions item is initiated by a "set-back" force of six to seven times gravitational force that occurs when the munitions item is fired downrange. Once the projectile has experienced this set back force, the fuze must then experience a rotational force of 3,000-4,500 revolutions per minute to allow the detonator to align itself to arm the fuze. This rotational force occurs as the projectile spins while moving down the barrel of the gun toward the muzzle. This final arming process occurs approximately 20-30 ft downrange of the muzzle of the gun firing the projectile. These set back and rotational forces are extremely unlikely to occur in any circumstances other than deliberate firing of the munitions item for its intended purpose (Dept. of the Army Seattle District, 2012).

None of the DMM items found to date at the FSNSD have been fuzed and armed. The operational history of the site as a supply depot and not an ammunition depot or firing range also supports a conclusion that that the DMM present at the FSNSD were not fired or used for their intended purpose, which have led to the lack of fuzing mechanisms being present on these munitions. Therefore, direct disturbance of DMM items during either vessel mooring operations or mechanical dredging activities present only a low probability of causing an unintentional detonation of DMM items potentially remaining at the FSNSD.

The most likely scenarios for a potential encounter with a DMM item remaining at the FSNSD are infrequent mechanical dredging and the scouring and moving of an item from the bottom as a result of hydraulic forces related to vessel propulsion systems. It is very unlikely that the forces required to cause an unintentional detonation of DMM resting on or below the seafloor could occur as the result of disturbing the item with thrusters, azipods, other vessel propulsion methods or mechanical dredging. Therefore the probability of detonating a DMM item is extremely low.

8.3 Summary of Explosive Hazard Assessment for Former Seattle Naval Supply Depot, Terminal 91 – Discarded Military Munitions

Following the RI field effort, the USACE Seattle District collected information from the U.S. Army and U.S. Navy to assist in the determination of potential explosive hazards from subsea munitions remaining in the FSNSD MRS. This information was compiled into a document titled "Final Draft Summary of Explosive Hazard Assessment, Terminal 91 (T-91) – Discarded Military Munitions" (EHA), and the document was presented to the USCG. A summary of the information presented in the EHA is presented below.

8.3.1 Navy Surface Warfare Center Ship Damage Assessment Summary

The Navy Surface Warfare Center Ship Damage Assessment Summary was based on U.S. Navy damage rules and ship damage experience, which is undisclosed information. The assessment made the following assumptions:

- Assumed a net explosive weight (NEW) for a 5-inch projectile at 6.45 pounds of TNT
- Assumed a hull strength of 60 kilo pound per square inch (ks) mild steel
- Assumed standoff distance of 5 ft from detonation

The assessment concluded that there was a "…very low probability of hull rupture or holing at standoff distances 5 ft or greater", that such an explosion was "…not sufficient to be a threat to propulsion equipment mounted inside (the ship's hull)" and it was "…unlikely that the small charge could disable a large distributed system such as ship's propulsion" (NSWC, 2011).

8.3.2 Department of Army Huntsville Center of Expertise Fragment Burial in Water Calculation Assessment Summary

The DA Huntsville Center of Expertise conducted a Fragment Burial in Water Calculation Assessment Summary based Department of Defense Explosive Safety (DDESB) Technical Paper 16 (TP16) (DDESB, 2010), Buried Explosion Module modeling software and the DDESB Fragmentation Database. The assessment assumed a standard NEW for a 5-inch projectile and calculated the depth of overlying water sufficient to stop all fragments from the munition of concern. The assessment concluded that "…5.75 ft of water (above the bottom location of the munitions item detonation) is sufficient to stop all fragments from a 5-inch Caliber Mk35" (USACE, 2012b).

8.3.3 Test Data from U.S. Navy Space and Naval Warfare Systems Command

Mr. William Wild, Principle Investigator at the U.S. Navy's Space and Naval Warfare Systems Command (SPAWAR), System Center Pacific, provided a summary of 5-inch - 54 Cal Naval Artillery Shell Peak Pressures and Energies. This data was derived from field-testing to determine the peak pressures and energies at various distances from underwater detonations of an array of munitions items. The relevant test data set was from underwater detonations of a 5-inch 54 Cal Navy artillery shell, which has a greater NEW than any of the 5-inch projectiles recovered within the MRS. The conclusion was that data "…indicated peak pressures from a detonation of a munitions item of concern decreases to levels well below expected hull strengths (60ksi) within short standoff distances from detonation" (SPAWAR, 2012).

8.3.4 Explosive Hazard Assessment Conclusion

The following conclusion was presented in the EHA:

In summary, the conclusion of both of these site specific explosive hazard evaluations is that 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. These conclusions are further supported by data collected by independent research conducted to evaluate the magnitude of blast overpressure from underwater detonation of munitions similar to the largest DMM items found at Terminal 91 as well as detonation of non-munitions explosives in underwater environments (see references [c] and [d] of the EHA). This research indicates that blast overpressure from underwater detonations of munitions comparable in terms of NEW to the largest DMM item found at Terminal 91 decays to levels far below pressures that would threaten hull damage within a short distance of the underwater detonation (USACE, 2012b).

Underwater detonation of explosives could result in localized fish kills as a result of an associated pressure wave. Based on the nature of DMM and the exposure scenarios documented in **Section 8.2**, the likelihood of such a detonation is low and is not believed to pose an unacceptable hazard to ecological receptors.

8.4 Qualitative Hazard Analysis

This qualitative MEC hazard analysis combines all project data, including field observation results, MEC discoveries, CSMs developed for the project, and information pertaining to the effects of a detonation presented in the EHA. With these data, the level of hazard posed to receptors by potential MEC items remaining on and beneath the seafloor at the FSNSD site are analyzed (summarized in **Table 8-2**). The level of hazard posed to receptors by potential MEC items brought to the surface during mechanical dredging is also analyzed. The method for analyzing the hazard involved linking a series of four questions in succession together with a hazard analysis ranking system, from Very Low to Very High. The questions were:

Is there a receptor? → Is there a pathway between the hazard source (MEC) and the receptor? → What is the likelihood of a MEC item detonating? → What is the level of hazard posed to the receptor if a MEC item detonates?

Each question was answered with information available in this report. In order for a hazard to be ranked, every link in the chain must have remained unbroken. If any of the first three questions resulted in a “no” or “none” answer, then no hazard existed and no hazard ranking was necessary.

Is there a receptor? The CSM listed displayed in **Figure 6-1** provides a list of receptors for MEC at the FSNSD MRS. Those receptors, briefly summarized are:

- ***Terminal 91 Diver***: These receptors perform pier inspections on a regular basis during the cruise season, and conduct sweeps and recoveries as needed throughout the year, especially during the cruise season.
- ***Construction Worker.*** These topside receptors are primarily involved in infrequent dredging operations at the Terminal 91 facility.
- ***Underwater Construction Worker***: These receptors engage in pier maintenance or upgrades on an infrequent basis.
- ***Recreational Angler***: These receptors were assumed occasionally present in the FSNSD MRS, and only during daylight hours; however, fishing rarely if ever occurs within the MRS waters.
- ***Native American Subsistence Angler***: These receptors were assumed occasionally present in the FSNSD MRS due to Usual and Accustomed Fishing Grounds Treaty Rights, and only during daylight hours. Fishing rarely if ever occurs in the MRS.
- ***Tourist***: These receptors are present in Smith Cove Cruise Terminal for planned events, and to embark/disembark cruise vessels.
- ***Resident***: These receptors were assumed occasionally present within the FSNSD MRS to fish, which was not observed during the Piers 90 and 91 RI and TCRA. There are no permanent residents at the MRS.

- ***Ecological Receptors***: Ecological receptors in relation to MEC are covered in detail in **Section 6.2.7** of this report. There are no known T&E species living in or on the FSNSD MRS sediments. Migratory or occasional marine life (including T&E species) could pass through the area, but exposure to such DMM would be negligible or more likely, non-existent, and would not result in a significant impact at the population level. Therefore, there are no identified ecological receptors upon which to conduct an analysis.

Is there a pathway? The CSM listed in **Figure 6-1** provides a pathway analysis for potential receptors for MEC. The CSM assessed intrusive and non-intrusive activities. Three complete or potentially complete pathways (based on intrusive and non-intrusive activities) existed for certain receptors, while both pathways remained incomplete for others. If a receptor had multiple pathways, i.e. complete and potentially complete though likely insignificant, the complete pathway was considered for the analysis.

- ***Incomplete pathway***: The CSM included incomplete pathways (intrusive and non-intrusive activities) for Tourists and Residents. As there is no pathway from the receptor to the MEC source, there is no hazard posed to Tourists and Residents even if a detonation were to occur. The CSM determined that Native American Subsistence Anglers and Recreational Anglers would not conduct intrusive activities on the seafloor of the FSNSD MRS; therefore, those pathways are incomplete.
- ***Potentially complete though likely insignificant pathway:*** The Native American Subsistence Angler and Recreational Angler could potentially be exposed to DMM (through non-intrusive activities) if they were to bring up crabbing pots or fishing nets/tackle that contained MEC. This is a very unlikely or implausible scenario, but the hazard was analyzed and ranked. Based on the level of commercial activity between the two piers and directly south of Pier 91, it is very improbable that anglers would fish from vessels in these areas. Fishing was never observed in the FSNSD MRS during the Piers 90 & 91 RI or TCRA. Data are available to analyze the affect of a detonation on an angler's vessel if present in the MRS. The report from U.S. Army Huntsville Center of Expertise (summarized in **Section 8.3.2**), noted that 5.75 ft of water was sufficient to stop all fragments from an exploding 5-inch MEC item. The average water depth at the FSNSD MRS ranges from 30 ft to 60 ft. Commercial deep draft fishing vessels do not fish while moored at berth. The hulls of private fishing vessels belonging to Native American Subsistence Anglers and Recreational Anglers would not extend down to less than 5.75 ft from the seafloor in areas with MEC contamination. Hazards posed to anglers in vessels due to seafloor detonations will not be ranked, as there is no direct hazard.
- ***Complete Pathway:*** The CSM determined that complete pathways (intrusive and non-intrusive activities) existed for the Terminal 91 Diver, Underwater Construction Worker and Construction Worker. The majority of Terminal 91 Diver and Underwater Construction Worker activities occur in two areas. The first area is under or directly adjacent to the piers for security sweeps/investigations and inspections/repairs to the pier structure. As shown in **Figure 5-4** and stated in this report, UXO divers and ROVs conducted visual surveys in many of these areas of and reported no surface MEC, a

finding consistent with the CSM. The riprap in many of these areas also greatly reduces the possibility of (and precludes access by a diver to) any MEC below the riprap. Heavy equipment activities such as drilling or pile driving may occur, but due to safety concerns, it is highly unlikely that a diver would be in the direct vicinity of the heavy equipment activity while these operations were active. The second likely scenario is the underwater inspection or repair of vessel hulls. In either of these probable scenarios (security or construction), it is important to point out standard safety procedures for divers. A diver will not enter the water when a vessel is moving in the vicinity. Additionally, lockout/tag out (LO/TO) procedures are enforced on vessels at berth to prevent divers from suffering catastrophic injuries from props or pumps. The LO/TO procedures temporarily remove the most likely cause of an unintentional detonation of MEC while a diver is in the water; impact with a vessel or vessel's propulsion system. The POS PD dive team is trained in identification of munitions and response procedures, as noted in **Section 2.4.1** detailing 2010 POS PD dive team munitions discoveries. Due to this training and experience, the hazard to Terminal 91 Divers posed by detonation of MEC located during a security sweep is minimal.

A complete pathway exists for the Construction Worker (topside) performing infrequent mechanical dredging operations at the Terminal 91 facility. Mechanical dredging operations could cause potentially MEC-laden sediments to be brought to the surface in a clamshell bucket and placed on a barge in the vicinity of the Construction Worker. Although the number of DMM items found at the site is low and all DMM items located during the response activities have been removed, the likelihood for an encounter with DMM within the complete pathway for a construction worker performing dredging is higher than the likelihood of an encounter within the completed pathways of Terminal 91 Divers and Underwater Construction Workers.

<u>What is the likelihood of a Detonation</u>? All DMM found to date near Piers 90 and 91 are in an unfired and unarmed condition, and there is a low likelihood of detonation, even if disturbed by vessel thrusters of other forces. Therefore, as none of the receptors directly impacts MEC items on purpose, there is no reason to assess increasing or decreasing likelihoods of detonations based on a cause of the receptor. Receptors may accidentally contact MEC, but as that is an unlikely event as discussed in **Section 6.2.6**, the likelihood of a detonation will remain consistent as Low all receptors.

<u>What is the hazard posed by a detonation to the receptor</u>? In order to qualitatively analyze the hazard posed by a complete "link" to from the source MEC to individual receptors, a ranking system ranging from None to Imminent was developed. A definition of each ranking is provided below.

- ***None*** = There are no receptors per the CSM. If there are receptors, there are no pathways per the CSM, or there are receptors and pathways but no chance of a detonation.
- ***Negligible*** = There is a low likelihood of detonation. Receptors exist and the pathway between the MEC and the receptor is only potentially complete and likely insignificant per the CSM.

- ***Low*** = There is a low likelihood of detonation. Receptors exist and the pathway between the MEC and the receptor is complete per the CSM, but an encounter is unlikely to occur.
- ***Moderate*** = 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.
- ***High*** = There is a moderate to high likelihood of detonation. Receptors exist and the pathway between the MEC and the receptor is complete per the CSM, and an encounter has a high probability of occurring.
- ***Imminent*** = There is a high likelihood of detonation or detonation is imminent. Receptors exist and the pathway between the MEC and the receptor is complete per the CSM, and encounters are occurring.

Table 8-2 presents the findings of the qualitative MEC hazard analysis.

Table 8-2 Results of Qualitative Munitions and Explosives of Concern Hazard 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	Complete	Complete	Low	Moderate**

* = During normal operations, the Construction Worker (topside) has no contact with MEC 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 Construction Worker (topside) to encounter MEC within sediments brought to the surface and placed on a barge by the clamshell bucket.

In the context of this qualitative MEC hazard analysis, "low" should be mean sufficiently low hazard to allow current land use and RAFLU within an acceptable degree of uncertainty.

An evaluation of the management of DMM items encountered in dredged materials will be included in the FS.

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9.0 MUNITIONS RESPONSE SITE PRIORITIZATION

The DoD proposed the MRSPP (32 CFR Part 179) (DoD, 2009) to assign a relative risk priority to each defense site in the MMRP Inventory for response activities. These response activities are based on the overall conditions at each MRA or MRS and consider various factors related to explosive safety and environmental hazards (68 FR 50900) (DoD, 2003). The application of the MRSPP applies to all locations:

- That are or were owned, leased to, or otherwise possessed or used by the DoD.
- Those that are known to or are suspected of containing MEC or MC.
- That are included in the MMRP Inventory.

In assigning a relative priority for response activities, the DoD generally considers MRAs and MRSs posing the greatest hazard as being the highest priority. The MRSPP priority will be one factor in determining the sequence in which munitions response actions are funded.

Based on the results of the RI, the MRSPP has been updated to include scoring for the recommended MRS (refer to **Section 5.3**). The MRSPP worksheets are provided in **Appendix F**.

9.1 Explosive Hazard Evaluation Module

The Explosive Hazard Evaluation (EHE) module assesses the presence of known or suspected explosive hazards. The EHE module is composed of three factors, each of which has two to four data elements that are intended to assess the specific conditions at an MRS. These factors are as follows:

- Explosive Hazard: which has the data elements Munitions Type and Source of Hazard
- Accessibility: which has the data elements Location of Munitions, Ease of Access, and Status of Property
- Receptors: which has the data elements Population Density, Population Near Hazard, Types of Activities/Structures, and Ecological and/or Cultural Resources

Based on site-specific information, each data element is assigned a numeric value, and the sum of these values is the EHE module score. The EHE module score results in a MRS receiving a rating of D. The MRSPP tables for the MRS are presented as **Appendix F**.

9.2 Chemical Warfare Materiel Hazard Evaluation Module

The Chemical Warfare Materiel (CWM) Hazard Evaluation (CHE) module provides an evaluation of the chemical hazards associated with the physiological effects of CWM. The CHE module is used only when CWM in the form of MEC or MC are known or suspected of being present at a MRS. There is no confirmed evidence of CWM use at the FSNSD. Therefore, the CHE module does not apply to this site and the MRS receives the alternative module rating of “No Known or Suspected CWM Hazard”.

9.3 Health Hazard Evaluation Module

The Health Hazard Evaluation (HHE) module provides a consistent department-wide approach for evaluating the relative risk to human health and the environment posed by contaminants (i.e., MCs) present at an MRS. The module has three factors, as follows:

1. Contamination Hazard Factor (CHF): which indicates contaminants present. This factor contributes a level of High (H), Middle (M), or Low (L) based on Significant, Moderate, or Minimal contaminants present, respectively.
2. Migration Pathway Factor (MPF): which indicates environmental migration pathways, and contributes a level of H, M, or L based on Evident, Potential or Confined pathways, respectively.
3. Receptor Factor (RF): which indicate the receptors. This factor contributes a level of H, M, or L based on Identified, Potential, or Limited receptors, respectively.

9.4 Summary of Munitions Response Site Prioritization Protocol Update Scoring

The following table summarizes the MRSPP worksheets presented in **Appendix F**.

Table 9-1 Summary of Munitions Response Site Prioritization Protocol

MRS Name	EHE Module Total	EHE Module Rating
FSNSD	67	D
MRS Name	**CHE Module Total**	**CHE Module Rating**
FSNSD	0	No Known or Suspected CWM Hazard
MRS Name	**HHE Module Total**	**HHE Module Rating**
FSNSD	MML	E

Based on the information summarized above, the FSNSD MRS received a total MRS Priority rating of 5.

10.0 SUMMARY OF RESULTS

This summary describes the Piers 90 and 91 RI and provides a review of the nature and extent of contamination delineated during the RI and TCRA, a review of contaminant fate and transport, and a review of the risk assessment and qualitative MEC hazard analysis performed. It also presents conclusions derived from the results of the Piers 90 and 91 RI.

10.1 Summary

The RI field activities at the FSNSD MRA in Seattle, WA were conducted between December 2010 and March 2012. Field activities included acoustic surveys and site characterization, DGM, ROV surveys, MC sampling, an underwater surface clearance of munitions related items in a portion of the MRA, a surface debris clearance in selected areas, and intrusive investigations. DMM, MD, and MC at concentrations below levels of concern were identified during the RI. The effective site characterization melding technology and UXO divers met the objectives of the RI to characterize the presence, nature and extent of MEC/MD/MC contamination and the results provide sufficient information to make a recommendation for delineation of the MRA into an MRS and recommend a future action.

Sediment samples were collected directly below the location of any DMM item found during the intrusive investigations. 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 and fell below the laboratories 95% confidence LOQ except for one sample with a detection of 2,4-DNT. The analytical results that are below the LOQ are considered to be estimated J and all non-detects are estimated UJ. The extent of any contamination is most likely to be localized directly beneath any DMM item and at such low concentrations, as is observed in the sediment samples collected, that overall human health risk would be minimal. It would depend on the condition of the item(s) and not necessarily the quantity. During the RI, all DMM items observed were collected and disposed of helping to eliminate any further source for contamination in the future.

MEC contamination appears limited to DMM, and of the type assumed prior to the RI based on the historic use of the facility. There is no indication of UXO or any increased or focused areas of dumping, and all investigative data points toward munitions being jettisoned while in port.

10.1.1 Fate and Transport and Conceptual Site Model Update

The MEC and MC exposure analyses for human and ecological receptors were updated from the 2012 RI WP and presented in **Section 6.2** (**Figure 6-1, Figure 6-2** and **Figure 6-4**,).

There are complete but insignificant exposure pathways for incidental sediment ingestion and dermal contact for the Native American Subsistence Angler and Recreational Angler. In addition, the seafood ingestion pathway is complete but likely insignificant for the Recreational Angler and Native American Subsistence Angler.

The sediment ingestion and direct sediment contact pathways for ecological receptors are complete but likely insignificant since there were no SQB exceedances.

A discussion of chemical fate and transport is presented in **Section 6.0**. Most of the MC from DMM deposited over 60 years ago has been diluted, transported from initial deposition locations, or has undergone chemical and/or biological degradation over time. Some residual MC remains located near or under the DMM, which suggests slow but long-term leakage from weathered or damaged munitions. Based on the extensive investigations to date, it would appear that most of the DMM has been recovered.

10.1.2 Risk Assessment

The HHRA resulted in no excess lifetime cancer risks for the fish ingestion pathway for the Native American Subsistence Angler or the Recreational Angler. The cumulative cancer risks were *de minimus* for 2,4-DNT, N-nitrosodiphenylamine, and RDX for the Native American Subsistence Angler (**Table 7-16**) and for the Recreational Angler (**Table 7-17**). There were no non-cancer HQs exceeding one for any COPC. No MC chemicals were retained as COCs for the HHRA based on the fish ingestion pathway.

The SLERA did not result in any SQB exceedances (i.e., no HQs >1) for the benthic community (**Table 7-19**).

10.1.3 Hazard Analysis

A qualitative MEC hazard analysis was performed for this RI utilizing historical knowledge, results of field investigations, and the EHA prepared by the USACE Seattle District. During normal operations, the likelihood of future encounters with DMM at the FSNSD MRS is low, though the likelihood for Construction Workers to potentially encounter MEC during mechanical dredging activities is moderate to high. Thirty-two total DMM items were located following surface and subsurface investigations biased to areas with the highest likelihood of concentrations. The majority of these items were small 20mm and 40mm projectiles. Prior to the initial discoveries made by the POS PD dive team, there are no records of encounters with DMM at the FSNSD 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 (USACE, 2012b). The qualitative MEC hazard analysis ranked the severity of the MEC hazard 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 to Terminal 91 Divers and Underwater Construction Workers. A Moderate hazard ranking was determined for Construction Workers during mechanical dredging activities, due to the increased likelihood of an encounter with MEC in sediments brought to the surface.

10.2 Conclusions

The Piers 90 and 91 RI results indicate that sufficient data were collected to complete the RI and meet the objective to determine whether further action is required under CERCLA. The MRA is recommended to be delineated into a single MRS matching the boundary of the MRA.

The FSNSD MRS (see **Figure 5-6**) is recommended for a focused Feasibility Study based on finding of low explosive hazard. Applicable or Relevant or Appropriate Requirements (ARARs), and remedial alternatives will be presented in a FS.

10.2.1 Data Limitations, Baseline Risk Assessment Analysis of Uncertainty, and Recommendations for Future Work

Data limitations exist regarding the area and quantity of MEC investigations at the FSNSD. Visual surveys, although covering a large portion of the site, were not complete over the entirety of the MRS. Additionally, heavy surface debris may have obscured the detection of surface (located on the seafloor) munitions items. Intrusive investigations were limited to transect investigation areas during the 2012 field season. Although these segments were placed in the areas most likely to contain MEC, and common RI practice is to investigate only a portion of the site, the majority of the site did not undergo intrusive investigations. Not every anomaly detected, either through DGM or all-metals detector equipped UXO divers was investigated. Conducting a removal action of all anomalies would have provided an absolute determination on the nature and extent of MEC contamination.

The RI analytical data did not include seafood tissue results, which would have allowed for a direct comparison to USEPA fish tissue RSLs. This comparison would have reduced the amount of uncertainty associated with modeling fish tissue concentrations using literature-based BCFs and regression equations. Due to the large number of non-detected values, EPCs were limited to the MDCs for detected chemicals. A larger data set may have provided a better delineation of nature and extent of contamination and reduced the uncertainty of the EPC. **Section 7.1.5.4** presents the uncertainty for the HHRA and **Section 7.2.4.3** addresses the uncertainty in the SLERA.

Table 10-1 presents the recommendations for the FSNSD stemming from the findings of this RI.

Table 10-1 Potential Future Response Actions

MRS	RI Conclusions	Recommended Future Actions
Former Seattle Naval Supply Depot (FSNSD)	**MEC Results:** 32 MEC items identified and removed. **MC Results:** One sample collected returned a detection for 2,4-DNT. **Human Health Risk Screening Results:** The FSNSD MRS has no human health risks if realistic exposure assumptions such as AUFs are applied. **Ecological Risk Screening Results:** Given the limited number of detections across a relatively large area, no adverse effects to populations of ecological receptors are anticipated for nondetected analytes. **MRSPP Priority Score: 5**	Focused Feasibility Study and subsequent CERCLA remedial response actions.

10.2.2 Formerly Used Defense Site Management Information System Update

The FUDS Management Information System (FUDSMIS) is used to track and report FUDS property, project, and phase data. It also supports planning, programming, and budgeting for FUDS sites. Upon final approval of the MRS designation based on the results of the Piers 90 and 91 RI, changes to the MRS designation in the FUDSMIS will be updated by the USACE and used to support scheduling/estimating of future projects, studies, and any cleanup actions determined necessary.

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