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SEDIMENT DREDGING IN AREAS KNOWN OR SUSPECTED OF CONTAINING MUNITIONS AND EXPLOSIVES OF CONCERN AND/OR MATERIAL POTENTIALLY PRESENTING AN EXPLOSIVE HAZARD

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14. ABSTRACT This guidance was developed for Department of the Navy (DON) Environmental Restoration Remedial Project Managers (RPMs) who are managing and executing sediment dredging projects in areas known or suspected of containing munitions and explosives of concern (MEC) and/or material potentially presenting an explosive hazard (MPPEH). The topics covered include: an overview of the potential sources for MEC/MPPEH in the underwater environment; a summary of explosive safety policies and guidance; pre-design planning considerations; dredging and material transport options; dredged material processing and placement options; and additional considerations to ensure projects are executed in a manner that is protective of human health and the environment.						
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EXECUTIVE SUMMARY

This guidance was developed for Department of the Navy (DON) Environmental Restoration Remedial Project Managers (RPMs) who are managing and executing sediment dredging projects in areas known or suspected of containing munitions and explosives of concern (MEC) and/or material potentially presenting an explosive hazard (MPPEH). Properly accounting for MEC/MPPEH in areas where dredging will occur is an important aspect of managing restoration projects to ensure the safety of workers, the public, and dredging/process equipment. The topics covered in this guidance include: an overview of the potential sources for MEC/MPPEH in the underwater environment; a summary of explosive safety policies and guidance; pre-design planning considerations; dredging and material transport options; dredged material processing and placement options; and additional considerations to ensure projects are implemented in a manner that is protective of human health and the environment.

Sources of MEC/MPPEH in the Underwater Environment

MEC and MPPEH exist in ponds, lakes, marshes, streams, rivers, estuaries, harbors, canals, seas, and oceans. Some MEC/MPPEH sites have existed for decades and are well known, while at other sites, the presence of MEC/MPPEH is only evident after it unexpectedly appears in the dredging system or dredged material. Potential sources for MEC/MPPEH in the underwater environment are reviewed including current and historic military munitions-related activities.

Policies, Guidance, and Explosives Safety

Most sediment dredging projects are conducted in water bodies open to the public. In the U.S., tidelands and submerged land are usually owned by the state and therefore open to use by private, commercial and recreational vessels. The Navy must adhere to local, state, and federal applicable or relevant and appropriate requirements (ARARs) to perform dredging work in water bodies. RPMs should be aware of general dredging and environmental considerations, as well as applicable Department of Defense (DoD) and DON explosive safety policies and guidance which apply to all dredging projects where the potential exists to contact MEC/MPPEH. In accordance with these policies, requirements are reviewed for Explosives Safety Submissions (ESS) or Explosive Safety Submission Determination Requests (ESSDRs).

Pre-Design Planning Considerations for MEC/MPPEH Dredging Projects

Prudent management and planning for any dredging project should involve a robust due diligence effort to determine if the potential exists for MEC/MPPEH encounters at the site. The presence of MEC/MPPEH can have major impacts on cost, schedule, and implementation. This guidance supports pre-design planning efforts through a description of MEC/MPPEH types that may be encountered, along with a summary of archival resources and pre-design investigation methods that may reveal the potential for underwater MEC/MPPEH to be present.

If MEC/MPPEH is determined to be a hazard at the sediment site, additional key planning considerations are addressed. This includes decision-making related to leaving MEC/MPPEH in place under water, along with anticipating the significant impact that MEC/MPPEH can have on the selection of process options and the remedial cost. The lack of initial pre-design planning and judicious research of a given site can result in lengthy project delays and increased costs.

Evaluation of Dredging and Dredged Material Transport Options

Dredging is removal of sediment that is under water. Excavation is removal of sediment that is normally under water and exposed after lowering the water level. This document provides an overall introduction to dredging, excavation, and transport processes, followed by a discussion of the specific implications of dredging in the presence of MEC/MPPEH.

Mechanical dredging is effective for removal of sediment, debris and MEC/MPPEH under a variety of site conditions. The most economical method to dredge or excavate sediment with MEC/MPPEH is to use the same equipment and methods used for conventional dredging. This is the most common state-of-the-practice. Mechanical dredges cannot keep MEC/MPPEH out of the buckets, so it is not possible to remove sediment without also removing MEC/MPPEH and debris at the same time. On the other hand, because MEC/MPPEH and debris are removed simultaneously with sediment, there is less impact on dredge production compared to hydraulic dredging. Mechanical dredges can be equipped with blast shields on the operator cab and on the barge for personnel protection.

Hydraulic dredges are effective for removal of all types of sediment but have limited capacity to remove MEC/MPPEH and debris. The dredge operator and dredge crew cannot visually observe dredged material until it is discharged from the end of the pipeline, and, therefore, cannot know what types of materials are in the slurry. MEC/MPPEH and other large debris can cause significant issues for hydraulic dredging. To mitigate operational and safety issues, screens can be installed over the cutterheads to prevent MEC/MPPEH and debris larger than the screen opening size from entering the dredge. With this system, MEC/MPPEH and debris are pushed laterally by the dredgehead and remain at the dredge site.

Dredged material can be transported from the barge to land using either mechanical or hydraulic methods. In the majority of projects, sediment removed with mechanical equipment is transported with mechanical methods and sediment removed hydraulically is transported by hydraulic methods. If material is removed by mechanical dredging and must be transported via pipeline, additional water is needed to create a slurry that can be pumped. The sediment slurry dredged with hydraulic equipment behaves more like a liquid than solid material and it is typically not practical to transport slurries with most mechanical equipment; however, there are situations where hybrid systems have been used successfully. This guidance provides a general overview of equipment used to transport dredged material, along with a summary of how the presence of MEC/MPPEH impacts dredged material transport.

Evaluation of Dredged Material Processing and Material Placement Options

Dredged material produced during environmental dredging generally requires significant processing and treatment prior to disposal or reuse due to the presence of chemical contamination. If the dredged material also contains debris and MEC/MPPEH materials this will add to the processing needs prior to placement.

Processing of dredged sediment generally includes removal of water that initially separates from the sediment particles followed by one or more types of treatment prior to disposal. The type and degree of treatment are based on the types of MEC/MPPEH, debris and contaminants in the sediment, regulatory requirements, remedial goals, costs, and other site-specific considerations. Dredged material separation equipment and methods are reviewd including screens, magnetic separation, and manual removal. Treatment trains may include dewatering, separation, solidification, thermal desorption or incineration, and adding amendments to create various products for beneficial reuse (if applicable).

Disposal options for contaminated sediment include placement of sediment solids, residual items, and debris into a containment facility to reduce exposure of the material to humans and the environment. Placement options are reviewed including confined aquatic disposal (CAD), nearshore and offshore confined disposal facilities (CDFs), and upland CDFs (e.g., landfills). As an alternative to disposal, suitable dredged material can be processed, treated, and designated for beneficial reuse where applicable requirements are met.

Implementation Considerations for MEC/MPPEH Dredging Projects

Proper implementation for dredging operations in the presence of MEC/MPPEH should include site-specific procedures to address engineering controls (e.g., screens) and contingency actions to be taken in the event MEC/MPPEH gets trapped in the screen(s) or is deposited onto the land. This guidance covers basic considerations for handling onboard MEC/MPPEH dredge finds, MEC/MPPEH screening operations, underwater MEC/MPPEH recovery and disposal operations, along with additional factors to consider during project implementation.

Conclusions

RPMs should utilize this guide to support their efforts in determining the potential for MEC/MPPEH to be present in planned dredging areas. If MEC/MPPEH are known or suspected to be present, the explosive hazards must be effectively managed in compliance with DoD and DON policies to ensure the safety of workers, the public, and dredging/process equipment. The information provided in this guidance is meant to serve as a technical resource and summary of best practices for RPMs in the management of sediment dredging projects where the potential for MEC/MPPEH exists. It is not meant to replace existing DON explosives safety policies and guidance. RPMs should continue to rely on munitions-related subject matter experts (SMEs) on site and account for site-specific conditions when managing MEC/MPPEH during dredging operations.

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ABBREVIATIONS

A&E	ammunition and explosives
AAR	After Action Report
APP	Accident Prevention Plan
ARAR	applicable or relevant and appropriate requirement
ASR	Archive Search Report
ASTM	American Society of Testing Materials
AWOIS	Automated Wrecks and Obstructions Information System
BIP	blow in place
BRAC	Base Realignment and Closure
CA	chemical agent
CAD	Confined Aquatic Disposal
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNO	Chief of Naval Operations
CSE	Comprehensive Site Evaluation
CWM	chemical warfare materiel
DDESB	Department of Defense Explosive Safety Board
DERP	Defense Environmental Restoration Program
DESR	Defense Explosive Safety Regulation
DFW	definable feature of work
DMM	discarded military munitions
DoD	Department of Defense
DoDI	DoD Instruction
DON	Department of Navy
EC	engineering control
EM	Engineer Manual
EMM	earth moving machinery
EOD	explosive ordnance disposal
EPA	Environmental Protection Agency
ESS	Explosives Safety Submission
ESSDR	Explosives Safety Submission Determination Request
ESQD	explosive safety quantity distance
ESTCP	Environmental Security Technology Certification Program
EZ	Exclusion Zone
FEC	Field Engineering Command
FRTR	Federal Remediation Technology Roundtable
FS	Feasibility Study
FUDS	Formerly Used Defense Site

HASP	Health and Safety Plan
HE	high explosives
HFD	hazardous fragment distance
HOA	Historic Ordnance Assessment
HRR	Historical Records Review
IC	institutional control
ITRC	Interstate Technology & Regulatory Council
MAKE	Marine Ammunition Knowledge Enterprise
MARCORSYSCOM	Marine Corps Systems Command
MC	munitions constituent
MCAS	Marine Corps Air Station
MCO	Marine Corps Order
MDAS	material documented as safe
MDEH	material documented as an explosive hazard
MEC	munitions and explosives of concern
MFD	maximum fragment distance
MGFD	munition with the greatest fragmentation distance
MMRP	Military Munitions Response Program (Army, Air Force)
MOTCO	Military Ocean Terminal Concord
MPPEH	material potentially presenting an explosive hazard
MRP	Munitions Response Program (DON)
MRS	munitions response site
MURS	Magnetic UXO Recovery System
NAVFAC	Naval Facilities Engineering Command
NBSD	Naval Base San Diego
NDAA	National Defense Authorization Act
NEW	net explosive weight
NIRIS	Naval Installation Restoration Information Solution
NOAA	National Oceanic & Atmospheric Administration
NOSSA	Naval Ordnance Safety and Security Activity
NSWC	Naval Surface Warfare Center
OESS	Ordnance and Explosives Safety Specialist
PA	Preliminary Assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PPE	personal protective equipment
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control

QCP	Quality Control Plan
RI	remedial investigation
RPM	Remedial Project Manager
SAA	Small Arms Ammunition
SI	site inspection
SME	subject matter expert
SOP	standard operating procedure
SOW	statement of work
SUXOS	Senior UXO Supervisor
TP	Technical Paper
USACE	U.S. Army Corps of Engineers
UXO	Unexploded Ordnance
UXOSO	UXO Safety Officer
UXOQCS	UXO Quality Control Specialist
WAMS	Water Area Munitions Studies
WWI	World War I
WWII	World War II

GLOSSARY OF TERMS

Munitions-Related Terminology

Discarded Military Munitions (DMM) – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed consistent with applicable environmental laws and regulations (10 U.S.C. 2710(e)(2)).

Exclusion Zone (EZs) – A zone established around a munitions response work area where operations involving MEC/MPPEH or MPPEH recovery are being conducted. The EZ allows for site security and control with only essential personnel allowed within the EZ during intrusive operations in accordance with applicable safety policies.

Explosive Ordnance Disposal (EOD) Personnel – Military personnel who have graduated from the Naval School, Explosive Ordnance Disposal; are assigned to a military unit with a Service-defined EOD mission; and meet Service and assigned unit requirements to perform EOD duties. EOD personnel have received specialized training to address explosive and certain chemical agent (CA) hazards during both peacetime and wartime. EOD personnel are trained and equipped to perform Render Safe Procedures (RSPs) on nuclear, biological, chemical, and conventional munitions, and on improvised explosive devices (NAVSEA OP5).

Explosives Safety – The summation of all actions conducted at Department of the Navy (DON) activities, ashore and afloat, designed to manage and control the risks and hazards inherent with ammunition and explosives operations. Explosives safety is the process used to prevent premature unintentional, or unauthorized initiation of explosives and devices containing explosives; and with minimizing the effects of explosions, combustion, toxicity, and any other deleterious effects. Explosives safety includes all mechanical, chemical, biological, electrical, and environmental hazards associated with explosives, hazards of electromagnetic radiation to ordnance, and combinations of the foregoing. Equipment, systems, or procedures and processes whose malfunction would hazard the safe manufacturing, handling, maintenance, storage, transfer, release, testing, delivery, firing, or disposal of explosives are also included (NAVSEA OP5).

Explosive Safety Quantity Distance (ESQD) Arcs – The prescribed minimum (separation) distance between sites storing or handling hazard Class 1 explosive material and specified exposures to afford an acceptable degree of protection and safety to the specified exposure (e.g., inhabited buildings, public highways, public railways, ships, aircraft, and other facilities). The size of the ESQD is related to the types of munitions present and their net explosive weight (NAVSEA OP5).

Munition with the Greatest Fragmentation Distance (MGFD) – The munition with the greatest fragment distance that is reasonably expected (based on research or characterization) to be encountered in any particular area (NAVSEA OP5). The explosive force of a munition will act to break up the metallic casing into fragments. The distance the fragments have the potential to travel can be estimated based on the types of munitions and their net explosive weight.

Munitions and Explosives of Concern (MEC) – Distinguishes specific categories of military munitions that may pose unique explosives safety hazard/risks and means unexploded ordnance (UXO), DMM or munitions constituents (MCs) (e.g., trinitrotoluene [TNT], hexogen [RDX]) present in high enough concentrations to pose an explosive hazard (NAVSEA OP5).

Material Potentially Presenting an Explosive Hazard (MPPEH) – Material that potentially contains explosives or munitions or potentially contains a high enough concentration of explosives that the material presents an explosive hazard. Excluded from MPPEH are other hazardous items that may present explosion hazards (such as gasoline cans, compressed gas cylinders) that are not munitions and are not intended for use as munitions (NAVSEA OP5).

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

Unexploded Ordnance (UXO) – Military munitions that have been primed, fused, armed, or otherwise prepared for action; have been fired, dropped, launched, projected, or placed in such a manner as 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)).

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

Sediment-Related Terminology

Bathymetric Surveying – The process of surveying physical features under water via sensor or sounding systems in shallow water. Also referred to as hydrographic surveying.

Dredging – Removal of sediment that is under water.

Excavation – In this context, the term excavation refers to the removal of sediment that is normally under water and exposed after lowering the water level.

Hydraulic Dredge – Uses water added to sediment to create a slurry that can be pumped through a pipeline. There are several types of hydraulic dredges that use different methods to loosen sediment and guide the material into a suction pipe.

Mechanical Dredge – Uses digging buckets such as clamshells suspended by a cable from a crane, excavators on a fixed arm, or dragline buckets suspended by a cable from a crane.

1.0 INTRODUCTION

This guidance was developed for Department of the Navy (DON) Environmental Restoration Remedial Project Managers (RPMs) who are managing and executing sediment dredging projects in areas known or suspected of containing munitions and explosives of concern (MEC) and/or material potentially presenting an explosive hazard (MPPEH). The management approach presented is applicable to projects where dredging is intentionally used to address and remove MEC, as well as sites where there is a potential for incidental finds of MEC/MPPEH during sediment dredging activities.

Determining the potential for MEC/MPPEH to be present in areas where dredging will occur is an important aspect of managing restoration projects to ensure the safety of workers, the public, and dredging/process equipment. It is recommended that the presence of MEC/MPPEH (and other debris) be assessed for all dredging projects because of the major impacts on project cost, schedule, and implementation.

The topics covered include: an overview of the potential sources for MEC/MPPEH in the underwater environment; a summary of explosive safety policies and guidance; pre-design planning considerations; dredging and material transport options; dredged material processing and placement options; and additional considerations to ensure projects are implemented in a manner that is protective of human health and the environment.

1.1 Scope

The purpose of this document is to provide information that applies to the design and implementation of dredging and dredged material management in the presence of MEC/MPPEH. This document applies to sites where prior investigations have confirmed the presence of MEC hazards in sediment. This document also applies to sites where the presence of MEC/MPPEH is suspected prior to design and construction but has not been investigated. Information is provided that applies to the following stages of a dredging project:

- **Pre-Design Planning Considerations.** Effective management of dredging projects accounts for the potential for MEC/MPPEH to be encountered as soon as possible during the planning process. Naval Facilities Engineering Command's (NAVFAC's) *Munitions Response Remedial Investigation/Feasibility Study (RI/FS) Guidance* provides the decision-making involved in the selection of dredging as a remedy for underwater MEC/MPPEH (NAVFAC, 2019a). Sections 2 and 3 of this document expand on this existing guidance by providing policy and pre-design planning considerations where dredging has been selected and where the potential exists for the sediment to contain MEC/MPPEH.
- **Design Considerations.** Various types of dredging can be used in the presence of MEC/MPPEH, each of which have several process options. This stage includes developing the design for the dredging remedial action, along with evaluating material transport, processing, and placement options. The potential for MEC/MPPEH (and other debris) to impact each process should be accounted for in the design. See Sections 4 and 5 for an overview of technology/process options and design considerations in the presence of MEC/MPPEH.

- **Implementation Considerations.** Compliance must be maintained with applicable Department of Defense (DoD) and DON explosives safety requirements during dredging implementation. This stage covers dredging operations where MEC/MPPEH is known to be present, as well as situations where unexpected MEC/MPPEH materials are encountered. See Section 6 for implementation considerations for various MEC/MPPEH dredging project configurations.

This guidance is meant to serve as a technical resource and summary of best practices for RPMs in the management of sediment dredging projects where the potential for MEC/MPPEH exists. It is not meant to replace existing DON explosives safety policies and guidance and is not an extensive manual on MEC/MPPEH, dredging, dredged material processing or disposal. RPMs should continue to rely on munitions-related subject matter experts (SMEs) on site and account for site-specific conditions when managing potential MEC/MPPEH during dredging operations.

Additional resources in the appendices support MEC/MPPEH dredging project management. Appendix A provides a comprehensive flow chart that spans key decisions to be considered during the pre-design planning process. Appendix B summarizes key team members and their roles in safely implementing dredging projects in the presence of MEC/MPPEH. Appendix C summarizes planning documents including MEC-related safety submissions, work plans, standard operating procedures (SOPs) and their content. Appendix D describes the process for developing cost estimates for sediment dredging, along with an assessment of the impact of MEC/MPPEH on these costs. Appendix E includes key lessons learned from two Navy MEC/MPPEH-related sediment dredging projects. Appendix F contains links to relevant guidance documents and web sites for more information.

The information in this document applies to sites with MEC/MPPEH, as well as small arms ammunition (SAA). SAA seldom contain high explosives (HE). However, there are some exceptions.

1.2 Sources of MEC/MPPEH in the Underwater Environment

MEC and MPPEH exist in ponds, lakes, marshes, streams, rivers, estuaries, harbors, canals, seas, and oceans. Some MEC/MPPEH sites have existed for decades and are well known, while at other sites, the presence of MEC/MPPEH is only evident after it unexpectedly appears in the dredging system or dredged material. MEC/MPPEH (including chemical warfare materiel [CWM] munitions) have been recovered from dredged material, commercial fishing catches, at-sea clam harvesting, and beach replenishment operations.

There are a multitude of reasons why MEC/MPPEH exists in the underwater environment including current and previous military munitions-related activities and operations that have the potential for depositing munitions and related items in water bodies. Possible sources of MEC/MPPEH include, but are not limited to, the following:

- Historical coastal artillery batteries;
- Historical munitions sea disposal activities;
- Current and historical bombing and aerial gunnery ranges;
- Current and historical fixed ranges;

- Wrecks and obstructions including sunken military vessels;
- Past practices at wharfs, piers, harbors, berthing areas, and shipyards; and
- Acts of war.

These activities are described in more detail below including a summary of the general time period associated with each of these activities.

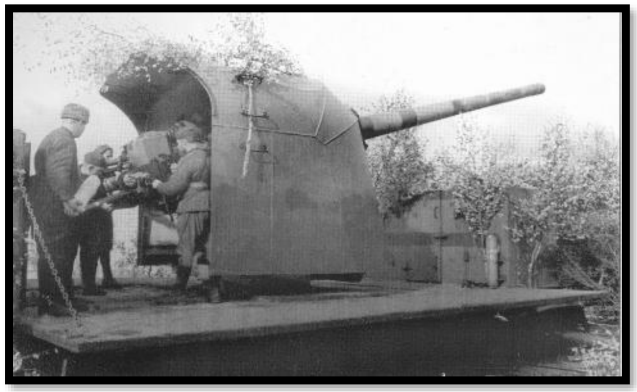

Figure 1-1. Coastal Artillery Gun Position (Source: National Archives Image)

Historical Coastal Artillery Batteries. The history of defense artillery and coastal protection gun emplacements in the U.S. dates back to the early 1800s. Coastal defense infrastructure grew to its peak during World War One (WWI). Coastal defense gun positions stretched along both coasts of the U.S. including the Atlantic coast from Maine to Florida (Figure 1-1). Heavy concentrations of guns were often positioned at military installations at approaches to bays and harbors. Examples of installations where coastal artillery gun batteries were installed include: Fort Popham, Maine; Fort Adams, Rhode Island; Fort Monroe, Virginia; and Fort Jefferson, Dry Tortugas, Florida. A wide variety of gun types and sizes were deployed at coastal artillery batteries including 3-inch, 6-inch, 155-mm, 12-inch, 14-inch and 16-inch guns. The larger guns had ranges in excess of 20 miles. Coastal artillery guns were generally phased out during the 1950s as more advanced weapon systems were developed. Depending upon the specific gun emplacement, historic records have indicated that gun positions conducted training exercises, including training with live HE filled rounds.

Historical Munitions Sea Disposal Activities. Past practices by the Navy and other services included the dumping of munitions at sea as an authorized means of disposal for unserviceable and obsolete items. Thousands of tons of munitions, including CWM munitions and bulk chemical agent (CA) containers were dumped at sea. Numerous historical policy and guidance documents outlined requirements for sea dumping activities as shown in the excerpt below from a Chief of Naval Operations (CNO) letter dated 24 April 1945 (National Archives).

> *"The area selected should be about 10 miles square and located outside regular steamer lanes… The dumping area must be in water over 150 fathoms deep and least 10 miles off shore."*

Large amounts of munitions were dumped at sea following WWI and WWII with the practice continuing until the early 1970s when sea dumping of munitions was banned. Past archival research efforts by the U.S. Army indicate that the majority of munitions-related sea disposal activities were conducted over 10 miles from shore, as noted above.

However, there have been documented incidents of shallow water dumping events in past years. Some of these historic munitions sea dumping activities have resulted in MEC encounters during dredging operations such as the case with Surf City, New Jersey (Figure 1-2) where approximately 3,000 WWI-era MEC items were unexpectedly deposited onto a 1.6-mile stretch of prime beachfront during a U.S. Army Corps of Engineers (USACE) beach replenishment project.

Figure 1-2. MEC Items Recovered from Surf City, New Jersey (Source: USACE)

Current and Historical Bombing and Aerial Gunnery Ranges. The military has a long history of using both land and water areas for bombing and gunnery practice to include the use of water ranges (e.g., Naval Surface Warfare Center [NSWC] Dahlgren, Marine Corps Air Station [MCAS] Cherry Point). During WWII there was a significant increase in the development and use of bombing and gunnery ranges to support war-related training.

Current and Historical Fixed Ranges. The U.S. military including the Navy has used fixed ranges to fire munitions for testing and training purposes either directly or indirectly (i.e., through overshoots) into the various waterways. All weapon sizes from small arms through large projectiles have been fired at DoD ranges over the years. RPMs should refer to site-specific historical research for range-specific details.

Wrecks and Obstructions Including Sunken Military Vessels. There are numerous historical instances of ordnance-laden military vessels that wrecked and/or sunk off U.S. coastal waters.

Past Practices at Wharfs, Piers, Harbors, Berthing Areas, and Shipyards. Areas used for short- and long-term berthing and loading/unloading of ships have been used in the past as dumping grounds. Although these practices have long since been abandoned, sites such as Philadelphia Navy Yard, Pennsylvania and Military Ocean Terminal Concord (MOTCO), California have a history of debris and ammunition disposals within the waters surrounding Naval vessels as a result of accidents or past practices. In addition, sites associated with explosive accidents or incidents have the potential of contributing to MEC/MPPEH within the area. For example, the Port Chicago Naval Magazine explosion that occurred in 1944 involved a massive detonation of nearly 3.5 million pounds of HE, resulting in tons of munitions scattered throughout MOTCO including within the tidal and offshore areas.

Acts of War. Historical maritime battle sites and military operational areas from the Revolutionary War (e.g., Baltimore Harbor/Fort McHenry, Maryland), the Civil War (e.g., Savannah Harbor, Georgia), WWI (e.g., German U-Boats off the North Carolina coast), and WWII (e.g., Pearl Harbor, Hawaii) are potential sources of MEC/MPPEH. It should be noted that the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Program specifically excludes sites contaminated as a result of "acts of war." However, to the extent these sites overlap areas impacted by dredging activities (i.e., dredging of borrow areas), the potential for MEC/MPPEH must be addressed as part of the project if the potential to encounter MEC/MPPEH is part of the site conditions.

Information on locations of records and key data sources for each of the areas noted above is described in more detail in Section 3.

1.3 Other Contaminants in Sediment

Sediment at dredge sites may contain chemical contaminants including metals (e.g., arsenic, chromium, copper, nickel, lead, mercury and tributyltin); polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), low-level radiation, and pesticides. These contaminants in sediment are due to releases from a wide variety of non-point sources such as urban and agricultural runoff and point sources such as industrial, power generation, port/harbor, anti-fouling painting and ship repair facilities. Chemical and possible biological testing of sediment is generally required during project planning, permitting, and/or design to determine the allowable reuse or disposal requirements. This testing should include those chemicals that may be present based on historical site use or required by regulatory agencies.

MEC has the potential to be a source of metals and munitions constituents (MCs). However, recent DoD research indicates that risks related to MC releases from MEC in aquatic environments is low. These DoD studies have shown that MC concentrations are often below criteria for protection of human health or ecological impact (Lotufo et al., 2017). However, sampling and analysis for metals and MCs may be needed to arrange for the proper disposal of dredged sediment after separation from munitions materials. RPMs should confirm MC concentrations by collecting analytical and supporting data and appropriately screening for human health and ecological impacts. More information on MC fate and transport in aquatic environments and sampling considerations is provided in NAVFAC's Munitions Response RI/FS Guidance (2019a).

RPMs should also be aware of other hazards including low-level radiological hazards and pressurized cylinders that can be commingled with debris under water. Best management practices include developing contingency plans for these hazards so adjustments can be made to the field operations in a timely manner if any of these items are found.

2.0 POLICIES, GUIDANCE, AND EXPLOSIVES SAFETY

RPMs should be aware of general dredging and environmental considerations, as well as applicable DoD and DON explosive safety policies and guidance which apply to all dredging projects where the potential exists to contact MEC/MPPEH. These topics are reviewed below, along with other related policies for situational awareness on how the USACE manages dredging projects with respect to MEC/MPPEH.

2.1 General Dredging and Environmental Considerations

Most sediment and dredging projects are in water bodies open to the public and there is typically a high level of public interest and use of the water bodies. In the U.S., tidelands and submerged land are usually owned by the state and, therefore, are open to use by private, commercial and recreational vessels.

The Navy must adhere to local, state, and federal applicable or relevant and appropriate requirements (ARARs) to perform dredging work in water bodies. For activities involving discharge of wastes off site from the CERCLA site, the need for permits should be evaluated. Key stakeholders are also given the opportunity to comment on any proposed actions at DON Environmental Restoration sites as part of the CERCLA process.

Dredging may be performed for a variety of reasons. The most common is navigational dredging, which is done to increase the depth of water to allow safe vessel navigation. Dredging may also be performed for the following reasons:

- Provide deeper water to increase flood flow capacity;
- Improve the environment by removing physical or chemical hazards;
- Mine sediment materials for use in upland construction (i.e., sand or gravel mining);
- Mine sediment that contains ore with minerals.

To protect human health and the environment, RPMs must consider measures to mitigate the 5Rs of dredging in the presence of MEC/MPPEH which are removal accuracy and precision, resuspension, releases, residuals, and risk/hazard (NAVFAC, 2019a as adapted from Bridges et al., 2008).

The disturbance created during dredging activities can result in resuspension of the sediment material and increased turbidity of the water column. Chemicals in the resuspended sediment can further impact the environment (such as metals from anti-fouling paint). Silt curtains can be used to contain suspended sediments within the work area, minimizing adverse effects of these releases on the surrounding environment. There is also an impact to the local benthic community in the immediate area of dredging where sediments are removed. In some locations, construction work within water bodies is prohibited during certain times of the year to protect fish reproduction or benthic community health. In these locations, in-water work, including dredging and backfill placement, can only be performed within allowed time periods, referred to as "dredge windows" (Interstate Technology and Regulatory Council [ITRC], 2014).

Dredging sediment results in changes to the sediment condition, which include:

- Exposing sediment and debris to air above the water changes conditions from anerobic to aerobic;
- Exposing sediment and debris to air changes the temperature;
- Sediment and debris will start to dry when exposed to air;
- Removal causes physical disturbance to the sediment and debris materials.

These changes in conditions from dredging also have the potential to result in important changes to the stability of MEC/MPPEH. Materials that have been stable in anerobic sediment may become unstable when removed. As outlined below, RPMs must consider measures to mitigate these hazards from MEC/MPPEH during dredging activities in accordance with the DoD and DON requirements.

2.2 DON Explosive Safety Related Policies and Guidance

Key DON explosive safety and guidance documents that apply to dredging projects with the potential to encounter MEC/MPPEH are briefly summarized below:

NAVSEA OP5 – Ammunition and Explosive Ashore: Safety regulations for handling, storage, production, renovation and shipping. It is the policy of the DON to maintain an effective and aggressive ordnance safety program throughout the Department. Adherence to the instructions and regulations contained in NAVSEA OP5 will provide a continuing, aggressive accident prevention program throughout all commands where military or civilian personnel are stationed or employed and ordnance equipment, ammunition, and explosives are used.

OPNAV Instruction 8020.14 Series – DON Explosives Safety Policy (latest version): Requires that all DON commands establish an explosive safety program as described in the DON Explosive Safety Policy Manual.

SECNAVINST 5100.10 Series – Department of the Navy Policy for Safety, Mishap, Prevention: Policy for DON safety, mishap prevention, and occupational health and fire protection programs afloat and ashore.

NOSSAINST 8020.15 Series – Explosives Safety Review (for Navy installations) or *Marine Corps Order (MCO) 8020.10* (for Marine Corps Installations) – Covers the Explosives Safety Submission (ESS) and Explosive Safety Submission Determination Request (ESSDR) process including formats and submittal requirements. In addition, an After Action Report (AAR) for completed munitions responses is also a required feature of all Department of Defense Explosive Safety Board (DDESB)-approved ESSs. RPMs shall submit AARs within six months after completion of the munitions response action authorized by the ESS.

RPMs can obtain Navy documents on explosives safety by contacting the Naval Ordnance Safety and Security Activity (NOSAA) at https://intranet.nossa.navsea.navy.mil//default.asp. Navy Directives, including OPNAV Instructions, are available at http://neds.nebt.daps.mil/.

2.2.1 Explosive Safety Submissions

Depending upon the probability of encountering MEC/MPPEH during the dredging and/or navigational support project, an ESS may be required before any intrusive operations commence. A general overview of ESS requirements is provided here, while Appendix C provides more information on MEC-related safety submissions, work plans, SOPs, and their content for dredging-related projects. The guidance for performing RI/FS at sites with munitions (NAVFAC 2019a) describes the requirements for ESS submittal for the RI/FS stage of a project.

For construction/dredging projects where the probability of encountering MEC/MPPEH is considered low, the RPM shall obtain a determination that an ESS is not required from NOSSA for Navy installations or Marine Corps Systems Command (MARCORSYSCOM) for Marine Corps installations. The RPM must complete and submit the ESSDR according to NOSSAINST 8020.15 (Series)/MCO 8020.10 Enclosure (2), *Explosives Safety Submission Determination Request*. Information provided in the ESSDR will allow NOSSA or MARCORSYSCOM to evaluate the site-specific conditions and the risk/hazard assessment and provide their findings in writing. In order to meet operational time constraints, this concurrence/non-concurrence may take the form of a fax or e-mail. In addition, SAA sites may also require an ESSDR. More information can be found in NOSSAINST 8020.15 (series), Enclosure (2B) *Small Arms Range No Further Action Explosives Safety Submission Determination Request* or MCO 8020.10. The RPM shall contact NOSSA or MARCORSYSCOM if there is any uncertainty on whether an ESS is required.

If the probability of encountering MEC/MPPEH is determined to be moderate or high, an ESS will be required to be approved by the DDESB prior to the initiation of any intrusive or dredging activities. An ESS is a document that details how explosives safety standards in OP5 are applied to munitions responses. Additionally, it addresses how the project will comply with applicable environmental requirements related to the management of MEC/MPPEH. The ESS shall be completed in accordance with NOSSAINST 8020.15 (Series)/MCO 8020.10, Enclosure (3)/MCO 8020.10 Appendix A *Guide for Preparing an Explosives Safety Submission*. For the Navy, all ESS requests shall be submitted after appropriate reviews to NOSSA via the NOSSA WebESS tool or to MARCORSYSCOM via the Marine Ammunition Knowledge Enterprise (MAKE) portal.

The ESS is a complex document; therefore, RPMs must ensure their project schedules include adequate time for ESS preparation, review, endorsement, and approval. Note that draft ESSs that do not conform with NOSSA guidance will require revision and resubmission resulting in project delays. This schedule needs to be clearly articulated with the entire project team, including regulatory agencies and other stakeholders. In addition to reviewing and endorsing ESSs, NOSSA and MARCORSYSCOM should also be considered valuable resources to the project team. RPMs are encouraged to engage them early in the project planning process so that operational options, new technologies, and all aspects of explosives safety are considered.

As discussed below, the ESS will identify the explosive safety quantity distance (ESQD) arcs and exclusion zones (EZs) required based upon project-specific information, including the munition with greatest fragmentation distance (MGFD) and blast overpressure as determined by the types of MEC/MPPEH present. The ESS is independent of the site Accident Prevention Plan

(APP)/Health and Safety Plan (HASP) and addresses only those hazards posed by MEC/MPPEH.

Until approved by the DDESB, an ESS is a working document and is not authorized for release outside of the DON and its contractors. After DDESB approval, distribution is authorized to U.S. Government agencies and their contractors for administrative and operational use only as an ESS contains information obtained from sources which, while unclassified, are sensitive. The ESS should carry the appropriate distribution statement, warning, and destruction notice. The Final ESS should be a standalone document and it must be maintained and followed at the dredging site. Restricted material must be redacted from any documents if they are provided to any personnel (e.g., state regulators) who do not meet the distribution requirements.

2.2.2 ESQD Arcs and Essential Personnel

The ESS will identify the ESQD arcs and EZs for dredging and material sorting/separation operations at sites known or suspected to contain MEC/MPPEH.

RPMs should keep in mind that the ESQDs are driven by the types of MEC/MPPEH known or suspected at the site including the MGFD. ESQD arcs are established for the primary and contingency MGFDs from among the MEC/MPPEH known to be present which have the greatest fragmentation distance. In developing the EZ, there are two fragmentation distances to be considered: maximum and hazardous. If one known munition item has a larger hazardous fragment distance, while another munition item has a larger maximum fragment distance (MFD), both must be identified as primary MGFDs (Primary-1 and Primary-2). This (these) will be the primary MGFD(s) for the site. A minimum of one contingency MGFD shall also be identified to reduce the potential for work stoppage. Selection of the contingency MGFD may be based on anecdotal evidence suggesting that a MEC and/or MPPEH item with a larger MFD may be present at the site (NAVFAC, 2019a).

For blast overpressure, protection is afforded by distance from the blast as calculated using a function of K-values and the net explosive weight (NEW) from any source. Using this information, the levels of protection afforded essential and non-essential personnel against both blast overpressure and fragmentation hazards are estimated. NOSSAINST 8020.15 (Series)/MCO 8020.10 Enclosure (3), *Guide for Preparing an Explosives Safety Submission*, provides a hierarchal list of sources of information for developing MGFDs. Fragmentation Data Review Forms contain data on both the blast overpressure and fragmentation distances for some common munitions and are available by contacting NOSSA. As discussed below, DDESB Technical Paper (TP)-16 (2009) also provides methodologies for calculating primary fragment characteristics (NAVFAC, 2019a). Consideration must be given to both terrestrial and underwater blast overpressure distances, since underwater distances can be quite extreme.

The ESQD arcs and EZs are intended to protect essential and non-essential personnel. In accordance with DoD and DON explosive safety policy, only essential personnel are allowed within the identified EZs during intrusive operations. Essential personnel are those whose duties require them to remain within an ESQD arc to ensure the safe and efficient completion of the munitions response action. Examples of essential personnel include the contactor’s UXO Safety Officer (UXOSO), Senior UXO Supervisor (SUXOS), and other work team members.

Non-essential personnel are all others. In general, access to EZs is limited to personnel essential to the operation being conducted. NOSSAINST 8020.15 (Series)/MCO 8020.10 specifies the protocol to use to request and authorize entry to the EZ by non-essential personnel in the performance of their duties. Without this authorization, all hazardous work must stop if unauthorized personnel enter the EZ (NAVFAC, 2019a).

ESQD distances can exceed several hundred feet for terrestrial and several thousand feet for underwater in all directions, which can be extremely challenging in tight quarters such as wharfs and harbors. For example, dredging operations at Naval Base San Diego (NBSD) would have essentially halted all operations in and around the pier being dredged. A waiver, per DDESB and OP5, had to be obtained to allow operations at nearby piers to continue during intrusive activities. More information on the CNO event waiver for NBSD is provided in Section 6 and Appendix E.

ESQD impacts should be thoroughly evaluated during the planning process to include strategies to maintain and manage potential encroachment issues and impacts to the installation/facility where explosive operations are being performed. RPMs must account for ESQD arcs during all aspects of munitions response operations including establishing EZs at the dredging location, in-water material off-loading stations, material discharge locations, locations for inspecting and/or shifting materials for MEC/MPPEH processing areas or collection points, explosive storage magazines, and areas where demolition operations will occur if on-site disposal of MEC/MPPEH is required and authorized in the approved ESS.

It should also be noted that ESS amendments are required when a change to an approved ESS increases explosives safety risks, identifies requirements for additional or increased explosives safety controls, or changes an ESQD arc. These types of amendments require NOSSA/MARCORSYSCOM and DDESB approval (NAVFAC, 2019a).

2.3 Other DoD-Related Policy and Guidance

Other DoD policy and guidance related to MEC/MPPEH at sediment dredging sites is listed below along with a brief description of how the specific policy impacts MEC/MPPEH dredging operations.

DDESB TP-16, *Methodologies for Calculating Primary Fragment Characteristics* (2009), and associated Fragmentation Data Review Forms are referenced in the ESS. The fragmentation data forms define the hazardous fragmentation distance; MFDs both horizontal and vertical, respectively; specifications for sandbag and water-based blast mitigation options; overpressure distances; and minimum thicknesses to prevent perforations. The fragmentation data form for the MGFD and contingency munitions are referenced and included in the ESS. These forms provide details on the minimum thickness of shielding required (based upon shielding material type) in order to protect dredging/equipment operators within the EZs. Section 6 of this guidance document provides more information on shielding requirements for dredging operations.

DDESB TP-18, *Minimum Qualifications for Personnel Conducting Munitions and Explosives of Concern-Related Activities* (2016) is used by personnel conducting munitions response operations to meet the requirements and qualifications outlined in TP-18. Several Unexploded ordnance (UXO)-qualified personnel should be part of the team for a MEC dredging project including the UXOSO, UXO Quality Control Specialist (UXOQCS), and others as defined in Appendix B.

DoD Instruction (DoDI) 4145.26, *DoD Contractor's Safety Requirements for Ammunition and Explosives* (April 2005 incorporating Change 1, August 2018) provides uniform baseline safety standards for DoD contractors performing contractual work involving ammunition and explosives (A&E). It also authorizes the Military Departments when contractual work is to be performed at DoD-owned facilities to apply their own selected A&E and other safety standards and procedures to DoD contractors by inclusion within contracts. Applicable safety standards and procedures must be adhered to during dredging projects involving MEC/MPPEH.

Defense Explosive Safety Regulation (DESR) 6055.09 (edition 1, January 2019) establishes uniform safety standards applicable to quantity distance modeling; explosive safety standards for the identification and control of areas known or suspected to contain MEC/MPPEH; and the transportation, handling, and storage of explosives. RPMs must adhere to the requirements in DESR 6055.09 when establishing an ESQD arc for explosive-related operations, including MEC/MPPEH dredging-related projects.

DoD communications and directives are available at http://www.dtic.mil/whs/directives/. The website also provides an explanation of the different types of directives, instructions and publications including an explanation of each.

2.4 USACE Explosive Safety Policies Related to Dredging

Other than Engineer Manual (EM) 385-1-1, *Safety and Health Requirements Manual* (USACE, 2014), DON RPMs are not "required" to follow USACE policy with respect to explosive safety and dredging operations. However, it is prudent to have a basic understanding of USACE policy and guidance related to MEC/MPPEH and dredging as the same regulators and stakeholders involved in USACE projects may work on DON projects within the same state. In addition, at times, NAVFAC works directly with USACE on coordination of dredging activities where operational and environmental dredging needs may coincide.

USACE policy related to dredging is evolving and lessons learned from past projects (such as the Surf City, New Jersey example described earlier) have significantly influenced policies and protocols followed by USACE to reduce the potential to deposit MEC/MPPEH on beach fill and shoreline protection areas.

One major difference with the USACE approach is that they typically only develop an ESS if the UXO contractor is conducting on-site demolition and/or commercial explosives are being stored on site, as per the DDESB policy. For dredging projects where military explosive ordnance disposal (EOD) personnel handle MEC/MPPEH and material documented as an explosive hazard (MDEH) disposals, the USACE does not develop an ESS. The USACE also does not have an ESSDR process. However, an Ordnance and Explosives Safety Specialist (OESS), who serves either on site and/or acts in a supervisory role over the UXO contractor hired by the dredging company, is typically assigned to each dredging project.

Changes to EM 385-1-97 issued in 2013 include the following requirements for dredge projects:

Dredging projects. Planning for dredging projects must also consider the possibility of encountering MEC during operations (see paragraph III.B.01 above for conducting a probability assessment). Plans shall include equipment (maintenance), material screening, and disposal procedures. The selected Military Munitions Design Center should be contacted to determine requirements on a case-by-case basis. General considerations include:

a. If a hydraulic dredge is used, it shall be equipped with a screen on the suction/intake end to prevent unwanted objects from reaching the removed sediment. The screen shall be capable of removing the smallest MEC item expected to be encountered. Additionally, screening mechanism of the same or smaller size is recommended at the outfall point of the dredge material.

b. If a mechanical dredge is used in a moderate to high probability dredging area, a plan to screen the oversize material shall be developed and approved.

c. Blast protection and shielding of equipment and personnel may be required.

The USACE also issues an Engineer Construction Bulletin recommending UXO contractor support for all dredging contracts with the USACE/OESS shifting over to a quality assurance (QA) role.

USACE dredging contracts that have the potential to encounter MEC/MPPEH typically include requirements for a Work Plan, which includes the following:

a) Drawings and detailed descriptions of the required screening devices on the dredge intake and at the discharge end of the pipeline, and includes the materials, equipment, procedures and personnel to be used in the construction, operations and oversight of such devices;
b) Personnel, equipment, and procedures to be used to perform visual inspections at the discharge end of the pipeline on the beach;
c) The measures to be followed if oversized material is discovered in the screening devices;
d) The measures to be followed if oversized material is identified as deposited on the beach;
e) The measures to be followed if MEC/MPPEH is discovered in the screening devices; and
f) The measures to follow if MEC/MPPEH is identified as deposited on the beach.

Additional requirements on USACE dredging contracts with the potential to encounter MEC/MPPEH typically include: worker training, and screening devices (on dredge intake and MEC/MPPEH beach baskets), land-based UXO technicians (a minimum of one UXO technician per beach discharge point providing 24-hour, 7-days per week), and two UXO technicians per hopper dredge (to provide 24-hour, 7-days per week, MEC/MPPEH support, aboard the dredge on a rotating watch basis). Typically, the on-dredge support is included as an option with the number and types of MEC/MPPEH finds determining when on-dredge support is added.

3.0 PRE-DESIGN PLANNING CONSIDERATIONS FOR MEC/MPPEH DREDGING PROJECTS

Prudent management and planning for any dredging project should involve a robust due diligence effort to determine if the potential exists for MEC/MPPEH encounters at the site. This section supports pre-design planning efforts through a description of the types of MEC/MPPEH that may be encountered, along with a summary of archival resources and pre-design investigation methods that may reveal the potential for underwater MEC/MPPEH to be present. If MEC/MPPEH is determined to be a hazard at the sediment site, additional key planning considerations are addressed. This includes decision-making related to leaving MEC/MPPEH in place under water, along with anticipating the significant impact that MEC/MPPEH can have on the selection of process options and remedial cost. The lack of initial pre-design planning and judicious research of a given site can result in lengthy project delays and increased costs.

Additional information to support the pre-design planning of MEC/MPPEH dredging projects is provided in the appendices. Appendix A provides a comprehensive flow chart that spans key decisions to be considered during the pre-design planning process. Appendix B notes the key personnel that will be involved in MEC/MPPEH sediment dredging projects with specialized roles for each team member to ensure safety and sound project execution. Appendix C outlines MEC-related safety submissions and planning documents. Appendix D covers MEC/MPPEH dredging project cost considerations.

3.1 MEC/MPPEH Type and the Implications for Dredging, Screening, Disposal, and Placement

It is recommended that a SME in MEC/MPPEH and military historical research assist with the due diligence effort to ensure that all potential record sources are thoroughly searched for MEC/MPPEH-related operations. Although this is typically accomplished during the Preliminary Assessment/ Site Inspection (PA/SI) phase, not all potential dredging sites are located in areas where a munitions-related PA/SI or RI/FS has already been conducted or required. For example, the dredging area may be located outside of a known DON Munitions Response Program (MRP) site.

Over the past century, ordnance of all shapes and sizes has been utilized by the military for weapons testing and military training. Ordnance ranges in size from small arms and submunitions approximately the size of a golf ball to bombs weighing in excess of 4,000 lbs. The military EOD program divides ordnance into three top level categories including ground, air and underwater ordnance. Ordnance are further divided into families or types including, but not limited to:

- Bombs
- Projectiles
- Mortars
- Rockets
- Guided Missiles

- Grenades
- Submunitions
- Underwater ordnance (torpedoes, sea mines, and limpet mines)
- Note that landmines are not typically associated with dredging sites and SAA is not typically considered as MEC/MPPEH (unless it contains HE).

Bombs are air dropped munitions ranging in weight from 1 to 3,000 lbs and in length from 2 to 10 feet. There are hundreds of specific bomb configurations, but generally all bombs have similar components including a container or body, a fuze or fuzes, a booster and a stabilizing device. Bombs are categorized according to the ratio of explosive weight to total weight. Categories include general purpose, demolition, fragmentation, and penetration. There are also two other common categories of bombs including cluster or dispenser bombs and incendiary or firebombs.

Projectiles are typically deployed from ground gun platforms, but in certain configurations the guns can be mounted on an aircraft. Projectiles range from 20 mm to 406 mm in diameter and from 83 mm to just over 1 meter in length. Typical projectile configurations consist of a bullet-shaped metal body, a fuze and a stabilizing assembly. Fillers include antipersonnel submunitions, HEs, illumination, smoke, white phosphorus, riot control agent or a chemical filler. Fuzing may be located in the nose or base. Fuze types include proximity, impact and time delay depending upon the mission and intended target. Stabilization is achieved by either a fin assembly attached to the base or the body or are spin stabilized.

Mortars range from 1 to 11 inches in diameter and resemble projectiles, although they usually contain a thinner body casing. Mortars can be filled with explosives, chemicals, white phosphorus or illumination flares. Mortars are launched from gun tubes where the propellant charges are usually loaded separately from the mortar round. Typical U.S. sizes include 60-mm, 81-mm and 4.2-inch mortars.

Rockets are self-propelled ordnance ranging from 37 mm to more than 380 mm in diameter and measure from 1 foot to 9 feet in length. Rockets are ordnance that use gas pressure from rapidly burning propellant to transport a payload (warhead) to a desired target. Rockets consist of a warhead, a motor, fuze and a stabilizing mechanism. Rockets are unguided after launch and are stabilized by canted nozzles at the base of the motor or fins attached to the motor. Rockets are put together in sections; it is not uncommon to find rocket motors, warheads and fuzes on a range by themselves.

Guided missiles resemble rockets; however, they are guided to their target by various guidance systems. Guidance systems use internal or external radar, video, laser or wire guides, depending upon the particular configuration of the missile. Guided missiles have features such as fins and mini-propellant motors that guide the missile to the target.

Grenades are classified according to their type, use and function. There are three major types of grenades including hand grenades, rifle grenades and projected grenades.

Submunitions are ordnance that are payloads to larger ordnance such as cluster bombs, dispensers, 155-mm projectiles and some rockets that scatter the submunitions across an area when deployed. Submunitions include bomblets, grenades and mines.

Underwater ordnance includes torpedoes and mines including sea mines and limpet mines. Torpedoes are self-propelling ordnance that are launched into the water against ships, submarines, or other water targets. Sea mines are mines that are deployed in the sea for use on water targets such as ships and submarines. A limpet mine is a type of mine that can be attached to a ship or target via a magnet.

Depending upon the environmental conditions at the dredge site, the types of ordnance, and their location (e.g., how deep they are buried in the sediment), underwater MEC/MPPEH can vary from pristine to highly corroded conditions. For example, MEC/MPPEH items recovered from Ostrich Bay were encased in the hardened sediment and found in near pristine condition. At other sites, ordnance-related finds may consist of components or pieces of ordnance corroded by saltwater as shown in Figure 3-1. UXO technicians on site must be cognizant and vigilant in inspections of dredge materials to identify and recover all munitions-related materials. Ordnance-related finds should be managed as either MEC or MPPEH until they can be further inspected and verified.

Figure 3-1. Ordnance-Related Finds from Dredging Operations (Source: OHI)

EM 385-1-97, *Explosives Safety and Health Requirements Manual* (USACE, 2013) is a good resource for basic information on ordnance types. RPMs and on-site UXO technicians need to be concerned with the size of the ordnance known or suspected to be at the dredge site such that screens and other engineering controls can be properly designed or sized to screen out the ordnance. More information on screening operations is provided in Section 5. As discussed previously in Section 2, the NEW, MFD, and hazardous fragment distance (HFD) (as provided in the DDESB Fragmentation Database) are needed for the site as these values will drive the ESQD arcs, EZs, and shielding requirements.

3.2 Records of Sites with MEC/MPPEH

As summarized in the flow chart in Appendix A, a key step in the pre-design planning process includes evaluating the dredge site for the potential existence of MEC/MPPEH. Various records can be reviewed to obtain an understanding of the history of the dredge site with respect to munitions-related activities and the types of munitions potentially at the site. There is no one centralized database or data repository providing a comprehensive summary of all known and/or suspected underwater munitions sites. Therefore, RPMs should consult multiple resources to determine if the potential exists for MEC/MPPEH encounters at the site.

3.2.1 Past Dredging Sites Known or Suspected of Containing MEC/MPPEH

DON defines underwater munitions response sites (MRSs) as shallow water areas where munitions releases are known or suspected to have occurred, where Navy actions are responsible for the release, and where munitions are covered by water no deeper than 120 feet. Note that MRSs located in waters between high and low tides will be considered terrestrial sites. Sites meeting the above criteria will follow DON's underwater MRP site policy, with the following exceptions:

- A site that is part of, or associated with, a designated operational range (terrestrial or water range);
- A designated water disposal site;
- A Formerly Used Defense Site (FUDS);
- A result solely of combat operations;
- A maritime wreck; and
- An artificial reef (NAVFAC, 2019a).

Sites that can be "reasonably" dewatered (e.g., a test pond) can be considered a terrestrial site, when it is feasible and cost effective to conduct dewatering operations to support the MRP. Wetland areas, rivers, creeks, streams or other areas where water intrusion cannot be controlled, or would complicate access to study, identify or remediate munitions should be considered a water site. Cleanup at identified underwater MRSs is based on risk and hazard determinations. Existing risk assessment guidance is applicable for MCs identified at an underwater MRS. Explosive hazards must be assessed on a site-specific basis; there is no standard model for assessing underwater explosive hazards (NAVFAC, 2019a).

Although inventories of DON MRP and operational ranges exist, there is no single comprehensive inventory of all areas known or suspected to contain MEC/MPPEH. To provide examples of sites with MEC/MPPEH, Table 3-1 provides a list of DON installations and sites that have maritime areas known or suspected to contain MEC/MPPEH. Sites where dredging has occurred in the past are presented in bold text. *The list is not considered to be comprehensive as sources of MEC/MPPEH have not been compiled into a single database or plotted on nautical charts*. It should also be noted that MEC/MPPEH concentrations within each installation listed vary dramatically. Whether or not your project site is located on one of the installations below, best management practices should be followed, and due diligence conducted to determine if the potential exists for MEC/MPPEH before dredging commences.

Table 3-1. Example DON Installations and BRAC Sites with Maritime Areas or Water Bodies Known or Suspected to Contain MEC/MPPEH

State	DON Installation or BRAC Site Name
Alaska	Former Naval Air Facility Adak Attu Island
California	Former Mare Island Naval Shipyard Naval Weapons Station Seal Beach **Naval Base Coronado** **Naval Base San Diego**
Hawaii	**Joint Base Pearl Harbor-Hickman** Naval Magazine Pearl Harbor
Illinois	Naval Training Center Great Lakes
Indiana	Naval Surface Warfare Center Crane
Maine	Naval Air Station Brunswick Naval Ammunition Depot Bangor
Maryland	Naval Surface Warfare Center Indian Head
North Carolina	Marine Corps Air Station Cherry Point
Pennsylvania	**Philadelphia Navy Yard**
Rhode Island	Naval Station Newport
Texas	Naval Air Station Corpus Christi
Virginia	**Joint Expeditionary Base Little Creek/Fort Story** **Naval Air Station Oceana** Naval Surface Warfare Center Dahlgren
Washington	**Former Naval Ammunition Depot (Ostrich Bay)**

Note: Bold indicates sites where dredging has previously occurred.

3.2.2 Key Data Sources and Data Repositories

The following is a list of key data sources and data repositories that can be consulted for information on underwater munitions sites.

MRP PAs. In the early to mid-2000s, a Navy-wide effort was conducted to develop PAs for all MRP sites. The purpose of the PAs was to summarize the history of each site with respect to military use and to document any known or suspected MEC/MPPEH.

MRP Water Area Munitions Studies (WAMS). During the Navy-wide MRP PA effort, water ranges were documented separately from land-based MRP sites per guidance provided by NAVFAC as the policy of the eligibility of water ranges was still in discussion. Water ranges were documented in reports known as "Water Area Munitions Study (WAMS)" reports that provided a historical summary of the area with respect to military munitions-related activities. In June 2005, the Navy issued guidance on the eligibility of water ranges in the MRP (CNO SER N456/N5U9011373), which clarified that sites must be shallow water areas where munitions releases are known or suspected from Navy activities that occurred prior to September 30, 2002 and were no deeper than 120 feet. View example WAMS reports for Naval Surface Warfare Center Crane Division, Indiana (NAVFAC, 2005a and NAVFAC, 2005b).

Archive Search Reports (ASRs). The USACE developed ASRs for sites within the FUDS program to summarize the military-related activities associated with the particular FUDS property. ASRs typically include copies of maps, charts, and other historical documents that support conclusions about the types of munitions associated with the property in question. If the planned dredging site and/or planned borrow area is within or adjacent to a known FUDS property, the RPM should determine if an ASR is available.

Historic Ordnance Assessments (HOAs). A document to summarize the military-related activities associated with a particular property with respect to ordnance-related activities (e.g., former ranges, training areas).

Historical Records Reviews (HRRs) and Comprehensive Site Evaluations (CSEs). HRRs and CSEs are essentially the Army Military Munitions Response Program (MMRP) and Air Force MMRP equivalent of the FUDS ASR with some minor differences in the way data are presented and analyzed. If the planned dredging site and/or planned borrow area is within or adjacent to a known Army or Air Force MMRP site, the RPM should determine if any HRRs or CSEs are available.

National Oceanic and Atmospheric Administration (NOAA) Charts. NOAA maintains charts and other navigational aids that contain information on danger areas. However, based upon experience, the NOAA charts do not reflect all known or suspected MEC/MPPEH sites and are not necessarily updated with recent MEC/MPPEH finds at dredging projects.

For example, despite the more than 3,000 MEC/MPPEH items being deposited onto the Surf City, New Jersey beach in 2006 from dredging operations in a borrow area 2.5 miles from shore where the munitions-laden sand came from, the borrow area was never updated on NOAA Chart 12323 to reflect a danger area or a potential for UXO. A copy of NOAA Chart 12323 is shown in Figure 3-2 with the approximate locations of the borrow area and Surf City site superimposed onto the map.

However, if Chart 12323 is downloaded from the NOAA Web site, there is no indication on the chart of any danger areas at Surf City, reports of UXO, or markings to suggest that the area contains MEC/MPPEH. See the chart linked at https://www.charts.noaa.gov/PDFs/12323.pdf. Therefore, RPMs must be aware of the potential limitations of these data sources.

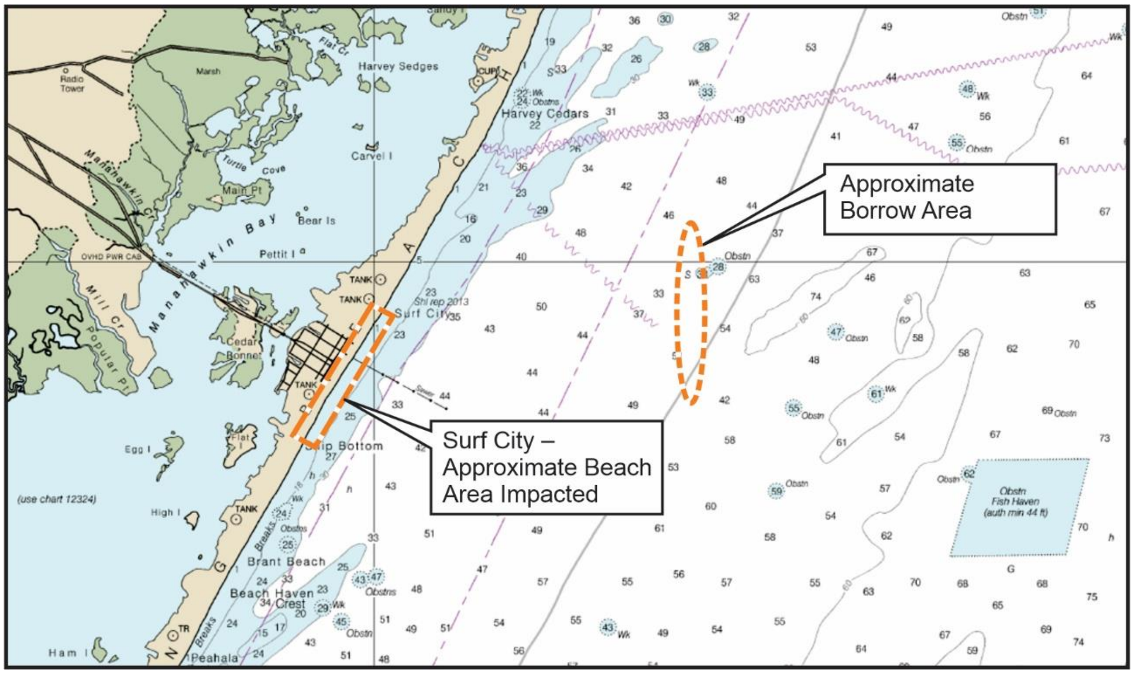

Figure 3-2. NOAA Chart 12323 with Surf City Beach Area and Borrow Area Highlighted (Source: NOAA)

NOAA UXO in U.S. Waters Database. NOAA maintains its own database, accessible online[1], which according to NOAA, "represents known or possible former explosive dumping areas and UXOs." This is NOT a complete collection of UXO on the seafloor, nor are the locations considered to be accurate. Two related datasets should be viewed in tandem: "UXO Locations" displays known/possible individual or tightly grouped UXO on the ocean floor and "FUDS" displays areas identified by the USACE where UXO may exist. Although NOAA acknowledges the FUDS properties as possible areas of UXO, it fails to mention DON, Air Force, Army MRP and/or Base Realignment and Closure (BRAC) sites, as well as documented sea disposal sites (see below) or operational range areas as possible sources of UXO.

Wrecks and Sunken Vessels. NOAA's Office of Coast Survey maintains the "Automated Wreck and Obstruction Information System (AWOIS)," which contains information on over 10,000 submerged wrecks and obstructions in the coastal waters of the U.S. (https://www.nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html). AWOIS records include the latitude and longitude along with brief historic and descriptive details of each wreck. Although the brief description is not focused around munitions/MEC/MPPEH, it does provide the name of the vessel which can be cross referenced with other historical records to determine if the potential exists for ordnance at the wreck site. It should be noted that MEC/MPPEH at wreck sites is generally ordnance that has not been previously fired, armed, launched, or projected, but rather similar to discarded military munitions (DMM).

[1] https://data.noaa.gov/dataset/dataset/unexploded-ordnance-areas

Munitions Sea Disposal Sites. As required under the National Defense Authorization Act (NDAA) in 2006, DoD conducted an inventory of munitions sea disposal sites in deep waters off the coasts of the Atlantic and Pacific Oceans and the Gulf of Mexico between 1919 and 1970. Annual updates to the inventory were published in the Defense Environmental Restoration Program (DERP) Reports to Congress with annual updates published in 2007-2009. In general, the effort identified approximately 30,000 tons of CWM munitions and CA containers dumped at sea. However, with the exception of sites in the Bush River, Maryland (associated with Aberdeen Proving Grounds), a Gulf of Mexico site (LA-X01) near Braithwaite, Louisiana, and Ordnance Reef site off the coast of Oahu, Hawaii, the inventory focused on sites more than 5 miles from shore in water depths in excess of 500 feet. Although interesting data, the sites identified, with the exceptions noted above, would not be associated with sediment dredging projects due to the distances from shore (i.e., greater than 5 miles) and in deep water. The inventory is not considered comprehensive and does not focus on shallow water sites or areas where dredging activities typically occur.

National and Regional Archives. The National Archives in Washington, DC as well as regional and Naval archival repositories contain data related to historic military activities which included sea disposal activities, as well as training and testing sites. The efforts identified above such as the ASRs, PAs, HRRs, and Munitions Sea Disposal inventory all utilized historical records from these repositories in one form or another. The level of detail reported, and types of records found were greatly dependent upon the experience and knowledge of the SME conducting the research. It should be noted that conducting archival research is a time-consuming effort as records are organized in a variety of ways and are stored in a variety of formats from paper copies to microfiche.

The record repositories listed above are not easily navigable and often require a SME in military history and/or experience with these data repositories to formulate an accurate understanding of the history of the dredge site with respect to munitions-related activities. For more information on conducting archival research, RPMs should consult SMEs and/or recommendations in the DON Environmental Restoration Program Manual (DON, 2018) and the USACE "Environmental Cleanup at Former and Current Military Sites: A Guide to Research" (USACE, 2001).

3.3 Pre-Design Investigation Methods

As appropriate for a specific site, the extent of MEC/MPPEH may also be evaluated in the field using a pre-design investigation approach. The primary types of anomaly detection technologies available for use at underwater sites include sonar, electro-optical, laser line scanner, and electromagnetic induction. Compared to terrestrial technologies which are fairly mature, underwater detection is considered evolving. Equipment and techniques equivalent to terrestrial advanced geophysical classification technology have not yet been applied for use at underwater sites but are under active development via electromagnetic and sonar technologies.

There are several geophysical and other methods that can be used to detect the presence of MEC/MPPEH or debris in sediment as follows:

- **Metal Detectors and Magnetometers.** A variety of types and sizes of metal detectors and magnetometers are used on land and under water. For sediment investigations, these are typically lowered into the water from a vessel and then towed above the sediment surface. Metal detectors detect both ferrous and non-ferrous metals and can detect metals buried in the sediment, in addition to metal on the sediment surface. Magnetometers only detect ferrous metals. Both of these instruments detect metallic debris, not just MEC/MPPEH items. Metal detection is a relatively low-cost investigation tool and is a good tool to use as the first step in site investigations.

- **Side-Scan Sonar.** Side-scan sonar instruments can be lowered into the water from a vessel and towed above the sediment surface. Autonomous underwater vehicles can also be used as a platform to deploy side-scan sonar. The sonar provides images of objects above the sediment surface using sound waves, so it works in water bodies with low visibility. The images can be compiled into a mosaic that shows a visualization of material on top of the sediment. Side-scan sonar shows images of all types of materials on the sediment, not just metallic materials. Therefore, it is often used in conjunction with metal detection in initial site investigations. The images generated by side-scan sonar can be used to further examine targets identified by metal detection.
- **Underwater Video.** Video cameras can be lowered into the water and towed by vessel to generate video of objects on the sediment surface. This method is only effective in water bodies with clear water and only works at depth of light penetration. One advantage of video is that it is easier to identify the objects.
- **Diver Observations.** In water bodies with clear water and low to moderate currents, diver observations can be used to visually identify objects.
- **Test Dredge.** At sites where there is a significant amount of debris and where there is potential for MEC/MPPEH, it may be beneficial to perform test dredging on selected objects. This would be the last step in an investigation and done after examination of data from geophysical data and other observations. The advantage of performing test dredging is that this is a safe method to retrieve debris and MEC/MPPEH and it provides samples of the material likely to be encountered during dredging.

Recall that an ESS must be approved before any intrusive investigation work begins at a site due to the likely contact with munitions. More in-depth information on the technologies used to perform underwater MEC/MPPEH investigations, including bathymetric surveys, is provided in NAVFAC's Munitions Response RI/FS Guidance (2019a).

3.4 Pre-Dredging Planning Considerations

Appendix A provides an overall framework for pre-dredging planning of MEC/MPPEH-related projects. It covers the initial research to determine the presence of MEC/MPPEH and associated hazards. Decision-making related to leaving MEC/MPPEH in place under water is then addressed. Finally, a screening logic is presented for evaluating multiple process options for dredging, screening/separation, and placement. Factors to consider during these key decision points are discussed below.

3.4.1 Determining MEC/MPPEH Presence at Sediment Sites

As early as possible in the planning process, research should be conducted as part of a desktop study to determine if the potential exists for MEC/MPPEH encounters at a sediment site. RPMs should be aware that in the past dredging sites have often contained more MEC/MPPEH and other debris than anticipated prior to construction. As an example, Appendix E includes a case study from Joint Base Pearl Harbor Hickam, Hawaii (NAVFAC, 2019b). The case study described dredging and dredged material disposal operations at the site. The report stated: *"During the transfer operations (e.g., seafloor to transfer barge), larger quantities of MEC/MPPEH were encountered than were anticipated."*

When planning a dredging project, knowledge of the age of the sediment and site dredging history can be used to assess the risk that MEC/MPPEH (and other debris) is present in the sediment to be dredged. MEC/MPPEH materials and debris generally remain near the top of the sediment surface when released into a water body. Therefore, knowing the age of the sediment can be correlated with the risk of the presence of MEC/MPPEH.

The risk of MEC/MPPEH in sediment can first be divided into two broad categories:

1) Sediment that was deposited before MEC/MPPEH was present has zero risk of containing MEC/MPPEH. In North America, there is zero risk of MEC/MPPEH in sediment that was deposited prior to European colonization.
2) Sediment that was deposited after MEC/MPPEH materials were present in a region may contain MEC/MPPEH. Sediment deposited after MEC/MPPEH was used in a region is further subdivided into two categories:
    a) Sediment that has never been dredged, which is also referred to as "native sediment". Dredging native sediment is also referred to as "new work dredging."
    b) Sediment deposited after previous dredging, which is also referred to as "recent sediment." Dredging recent sediment is also referred to in the industry as "maintenance dredging" because the purpose of dredging recent sediment is often to maintain a desired water depth.

The potential for MEC/MPPEH to be present at a proposed dredge site can be determined by:

1) Using published information to determine site conditions. In the U.S., the USACE district offices maintain records of dredging permits and have records of the history of dredging in federally authorized navigation channels. Current and historic bathymetric survey maps are available from NOAA.
2) Using historic information on the use of MEC/MPPEH at the site. In this step, consider past and current munitions manufacture, assembly, storage, transport, testing, use in training exercises and disposal.
3) Using the above information to make an initial assessment of the potential for MEC/MPPEH and debris to be present.
    a) There is no risk of MEC/MPPEH being present or man-made debris in sediment that was deposited before MEC/MPPEH was used in a region;
    b) There is low risk of MEC/MPPEH being present in native sediment that was deposited prior to WWI; however, it is possible that MEC/MPPEH deposited in the 19th century was subsequently buried by sediment deposits in areas that have

never been dredged. One example scenario would be a river delta where no previous dredging has been done;

   c) The risk of MEC/MPPEH being present increases as the age of the sediment decreases;

   d) The highest risk for the presence of MEC/MPPEH is in recent sediment deposited after WWII in areas that have not been previously dredged.

4) Deciding how much data are needed for a pre-design investigation. In assessing the need for additional data, consider the following impacts to the dredging project if unknown MEC/MPPEH is encountered during dredging:

   a) Safety risk of not being prepared to identify or handle potentially explosive materials;

   b) Risk of contract disputes and claims;

   c) Risk of schedule delays; and

   d) Risk of cost escalation.

The process described for assessing the risk of MEC/MPPEH in sediment also applies to other debris. Debris in sediment includes a wide variety of man-made materials including compressed gas cylinders, which may also be an explosive hazard and chemical containers which may become unstable when exposed to the atmosphere. Other debris includes items such as steel cables and chains; anchors; timbers; bricks and concrete; sheet metal and structural steel; and other waste materials. Debris and MEC/MPPEH may have been accidently lost into the water body, but in some cases, these materials were intentionally placed into water bodies for disposal following historic practices. It is common for MEC/MPPEH materials to be intermixed with all other types of debris. This is an important consideration when planning, designing and implementing dredging in sediment with MEC/MPPEH.

3.4.2 Determining if MEC/MPPEH Remains under Water or Requires Removal

As summarized in Appendix A, an important step early in the pre-design planning process is to determine if MEC/MPPEH can remain in place or warrants removal during dredging operations. The decision to remove MEC/MPPEH or to leave it in place is often dependent on the future use of the water body. In sites where dredging is needed to maintain water depth, the MEC/MPPEH must be removed.

For sites where dredging is not needed for other uses, there are advantages for leaving the MEC/MPPEH under water. Leaving MEC/MPPEH under water may be appropriate for sites with the following conditions:

- The MEC/MPPEH is stable and there is no potential risk of explosion when present under water;
- There is low risk of release of chemicals to sediment or overlying surface water;
- There is low risk of future unintended disturbance by human or natural activities; and
- The presence of MEC/MPPEH is compatible with future use of the water body.

At sites where it is suitable to leave MEC/MPPEH on the bottom (e.g., not collected and disposed), hydraulic dredging systems can be configured with screens at the intake to exclude MEC/MPPEH. More information on screening options is summarized in Section 5. The main advantages of leaving MEC/MPPEH under water are reduced risk to construction workers and less short-term impact to the environment from MEC/MPPEH removal operations.

However, there may be sites with areas of significant concentrations of MEC/MPPEH materials, which would result in slow dredge production. In these situations, the overall project costs would be less if MEC/MPPEH materials were retrieved prior to dredging.

3.4.3 Assessing Remedial Process Options and Costs

An important part of the CERCLA process includes conducting an FS, along with preparation of conceptual order-of-magnitude cost estimates. The FS should summarize ARARs; the screening of technologies, process options, and remedial alternatives; and the comparative assessment of those alternatives including associated costs. More information on developing an FS for an underwater MEC/MPPEH site can be found in NAVFAC's Munitions RI/FS Guidance (2019a).

This guidance focuses primarily on key considerations after dredging has been selected as the remedy. Following this decision, various process options must be further evaluated including material transport, screening/processing, and placement. Appendix A provides an overall screening logic for evaluating these process options at MEC/MPPEH dredging sites. See Sections 4 and 5 for an in-depth review of technology/process options and design considerations for MEC/MPPEH dredging projects.

As noted above, the presence of MEC/MPPEH can have major impacts on cost, schedule and implementation. Appendix D describes the process for developing cost estimates for sediment dredging at sites with MEC/MPPEH. The presence of MEC/MPPEH will increase costs due to factors such as:

- MEC/MPPEH requires additional staff with munitions expertise, which increases planning and construction costs. For example, there may be dredge projects where multiple UXO teams are needed to work on the dredge, in the upland processing area, and to handle MEC/MPPEH storage and disposal (see Appendix B for a typical project organization chart);
- MEC/MPPEH presence adds significant time for planning, investigations, design and construction;
- MEC/MPPEH generally results in slower dredging, which increases costs and completion time;
- MEC/MPPEH generally requires more dredged material processing, which may be the limiting factor in dredge production rate, which increases costs and completion time; and
- MEC/MPPEH may need to be removed prior to dredging, which adds to construction time.

Equipment costs are another major cost item for dredging projects. When MEC/MPPEH is present, there may be added costs for items such as:

- Blast protection and screening on the dredge;
- Blast protection and screening on and around upland processing equipment;
- Magazines for temporary storage of MEC/MPPEH;
- Equipment to process dredged material to separate MEC/MPPEH from sediment and other debris;
- Magazines and equipment to conduct disposal/demolition operations of MEC/MPPEH found; and
- Material handling and disposal charges related to managing MPPEH to include inspecting, certifying and verifying MPPEH as material documented as safe (MDAS) or MDEH and disposing of the material accordingly.

Typical costs for navigation and environmental dredging are provided in Appendix D, along with an assessment of the impact of MEC/MPPEH materials on these costs.

4.0 EVALUATION OF DREDGING AND DREDGED MATERIAL TRANSPORT OPTIONS

This section describes equipment and methods used to remove sediment by dredging or excavation. Dredging is removal of sediment that is under water. Excavation is removal of sediment that is normally under water and exposed after lowering the water level. Sections 4.1 to 4.3 provide an overall introduction to dredging, excavation, and transport processes, while the specific implications of dredging in the presence of MEC/MPPEH are discussed in Sections 4.4 and 4.5.

4.1 Dredging Equipment

Dredges are commonly classified as mechanical, hydraulic, or pneumatic, each of which is described below. Hybrid arrangements use mechanical devices to remove the sediment and then mix it with water to create a slurry that is transported in a hydraulic pipeline. This section provides a general overview of dredging equipment that may be applicable for use at sites with MEC/MPPEH present in sediment. The descriptions in this section summarize the equipment and processes that apply to all dredging projects. Sections 4.4 and 4.5 describe specifically how the presence of MEC/MPPEH impacts dredging and dredged material transport.

Mechanical dredges use digging buckets such as clamshells suspended by a cable from a crane, excavators on a fixed arm, or dragline buckets suspended by a cable from a crane. Mechanical dredges remove sediment with a similar density and water content as the in-place material. Some water is added to the sediment because the clamshell buckets are not always completely full of sediment. Mechanical dredges typically add a water volume that is 0.2 to 0.5 times the in-place sediment volume. Some sediment also is released into the water column as the bucket is raised. Environmental dredging buckets, having specially designed seals, often are employed to minimize release of sediment during dredging. Figure 4-1 shows a schematic diagram of a mechanical dredge.

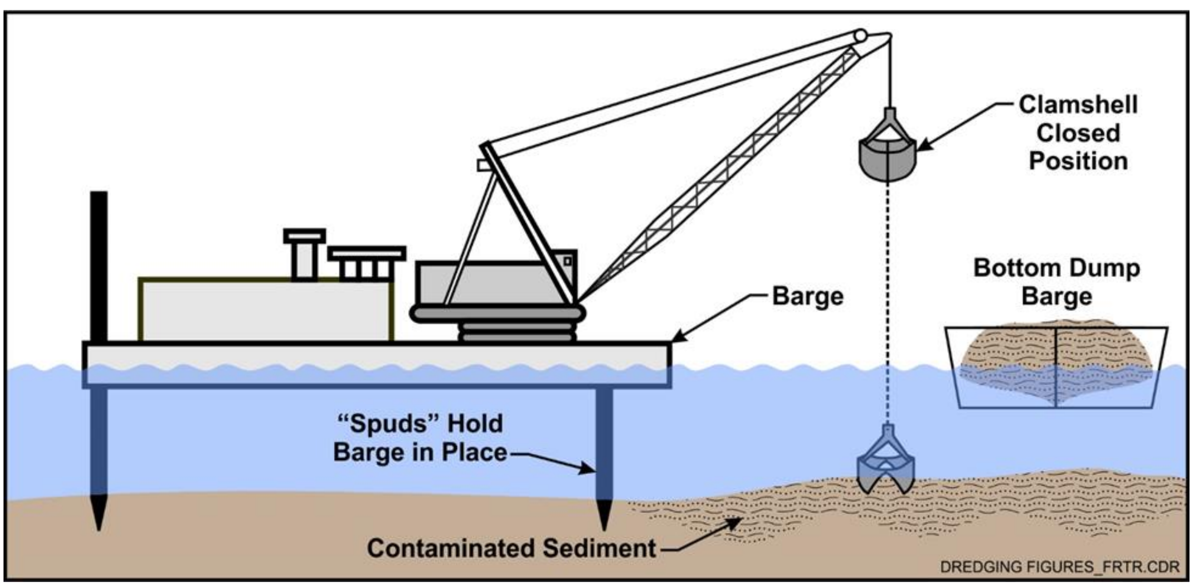

Figure 4-1. Schematic of Mechanical Dredge
(Source: Federal Remediation Technology Roundtable [FRTR], 2020a)

Hydraulic dredges add water to sediment to create a slurry that can be pumped through a pipeline to the disposal site. There are several types of hydraulic dredges that use different methods to loosen sediment and guide the material into a suction pipe. A cutterhead dredge has a rotating head that cuts into the sediment. An auger dredge has a horizontal auger that loosens the sediment and pulls it to the center of the dredge where the suction inlet pipe is located. Some hydraulic dredges do not use any cutting device and rely only on suction to remove the sediment. In order to create a slurry and remove sediment, a large amount of water must be added. Typically, the volume of water added is 5 to 10 times the in-place volume of sediment removed. Figure 4-2 shows a schematic diagram of a hydraulic dredge.

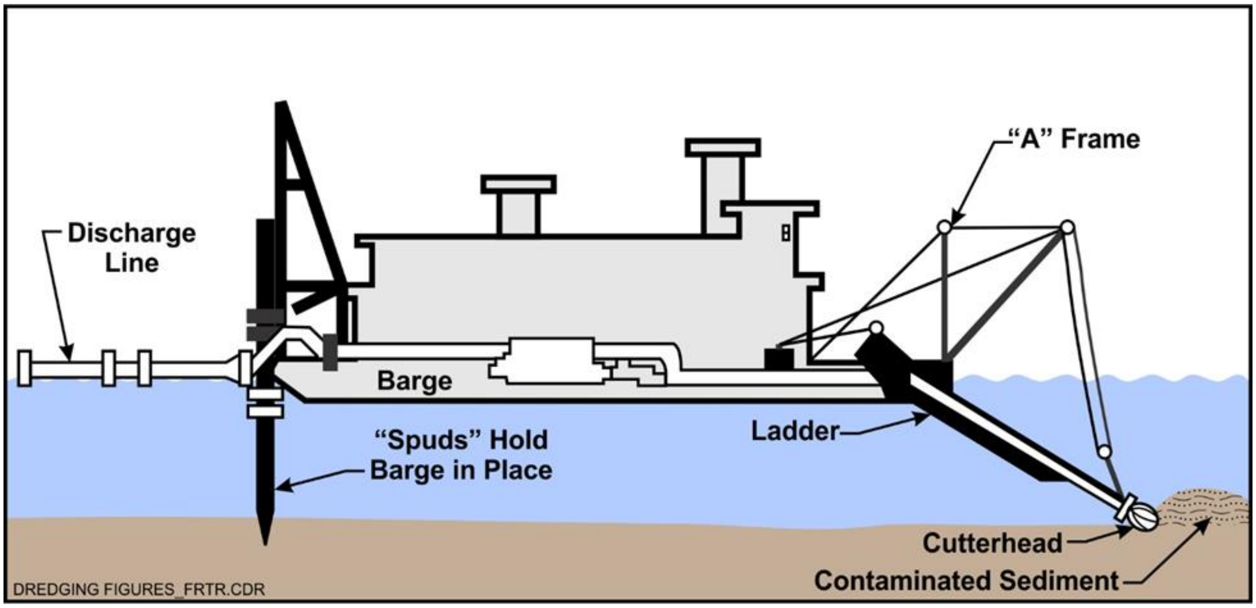

Figure 4-2. Schematic of Hydraulic Dredge (Source: FRTR, 2020a)

Pneumatic dredges operate with submerged air-actuated pumps. They are designed to entrain very small quantities of water during the removal process (Palermo et al., 2008). These types of dredges are more effective in deep water (30 ft) than shallow water because they need high pressures to operate. Pneumatic dredges are not common and have limited use for sites with MEC/MPPEH because they cannot readily pump sediment with significant debris.

Recent advances in dredge positioning and stability have improved the accuracy of dredging. The accuracy of both mechanical and hydraulic dredges is affected by many of the same factors, such as wind speed, currents, positioning system accuracy, and operator skill. At many sites, dredge operators have addressed accuracy limitations by over dredging (overlapping cuts). Over dredging materials, however, can become significant where the processing and disposal costs for removed sediments are high. For example, site managers who try to address a positioning accuracy of ±1 ft with a minimal overlap of 6 inches must target a mapped overlap of as much as 2.5 ft. The USACE guidance document for environmental dredging contains a more detailed discussion of vertical and horizontal dredging accuracy (Palermo et al., 2008).

Several recent advances in dredging operations have improved targeted removal operations (ITRC, 2014). One advanced positioning system, real-time kinematic global positioning, allows dredging to be focused on specific areas and depths, thus minimizing the requirement for over dredging to achieve design goals. At some sites, this advanced positioning system can be an alternative to over dredging and its associated increased costs and materials handling. Finally, operator training and experience are other important variables that affect the success of contaminated sediment removal.

4.1.1 Mechanical Dredges

A clamshell bucket is similar to the system used for land-based crane and bucket excavations. The bucket is dropped through the water column and penetrates into the sediment. The bucket is then lifted from the sediment, which closes the clamshell and the bucket is lifted up through the water column. When the bucket is above the water surface, the operator swings the crane to deposit the dredged material into a container for transport. The container is usually a barge but could be a hopper and conveyor system or land-based trucks. Figure 4-3 shows a clamshell dredge and two hopper barges. The barge adjacent to the dredge is empty. The barge at the bottom of the picture is fully loaded and is being pushed to the disposal site with a tugboat. Notice that the deck of the loaded barge is close to the water surface, while the empty barge is several feet above the water surface. The barges shown have a capacity of approximately 1,500 cubic yards and need about 10 feet of water depth to float when loaded (Battelle, 2010).

Figure 4-3. Loaded and Empty Hopper Barges (Source: Battelle, 2010)

Traditional clamshell buckets used for navigation projects leave an irregular, cratered sediment surface and sediment usually leaks from the bucket as it is raised. Enclosed environmental buckets have been designed and manufactured to remove sediment in relatively thin layers and are enclosed to minimize sediment resuspension. These types of buckets have been used in several projects in the Great Lakes, the Pacific Northwest, and in New Bedford, Massachusetts.

Some environmental buckets use hydraulic cylinders to close the clamshell, which provides a tighter seal and further reduces sediment loss. Figure 4-4 shows the environmental bucket used in a pilot test at the New Bedford Harbor Superfund project. Figure 4-5 shows a close-up photograph of an environmental bucket and highlights the features that are used to limit resuspension of sediment during dredging.

Figure 4-4. Hydraulic Environmental Bucket (Source: Battelle, 2010)

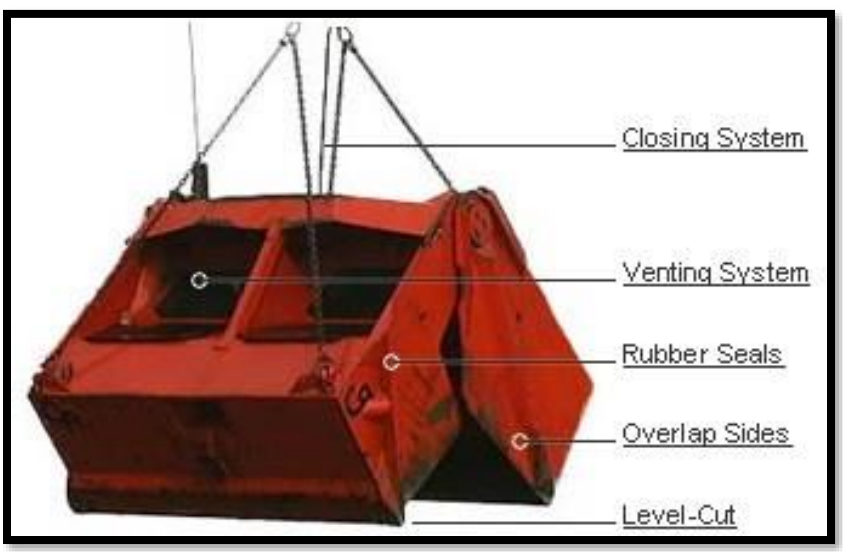

Figure 4-5. Environmental Bucket Features (Source: Battelle, 2010)

Backhoes or excavators are similar to land-based equipment but have been placed on barges and used to dredge sediment. Backhoes are better than clamshells for removing dense or hard material and are more effective in dredging slopes along shorelines. Backhoes are most effective in shoreline or shallow-water work where they can be placed either on land or on shallow-draft pontoon barges.

Dragline dredges use a barge-mounted crane that is similar to clamshell dredging. The difference is that dragline buckets are open on one side and are lowered into the sediment with a lifting cable, then pulled back towards the crane with a second cable. Draglines have been used in navigational dredging and are also used in mining operations because they are efficient in removing large quantities of sediment.

4.1.2 Hydraulic Dredges

Hydraulic dredges are routinely used throughout the U.S. to move large volumes of sediment each year. The size of hydraulic dredges is generally defined by the diameter of the dredge pump discharge pipe. Size classifications according to Environmental Protection Agency [EPA] (1994) are:

- Small (4 to 14-inch diameter),
- Medium (16 to 22-inch diameter), and
- Large (24 to 26-inch diameter).

There are four main components of a hydraulic dredge (Palermo et at., 2008). They are:

1) the dredgehead, which is the part that digs into the sediment and contains the suction pipe inlet and may contain some type of sediment digging device;
2) the support system, which is usually a ladder-shaped support structure that is hinged at the barge and is used to support and control the location of the dredgehead;
3) the hydraulic pump, which provides suction at the dredgehead to pull the sediment and water into the system and discharges the slurry through a pipeline towards the dewatering site; and
4) the pipeline, which carries the slurry to the dewatering and/or disposal site.

There are various types of dredgeheads used to loosen and collect the sediment. Hydraulic dredges are usually classified by the type of dredgehead. Conventional cutterhead dredges are the most commonly used. As the name implies, cutterheads have a rotating cutting device that loosens the sediment by physically digging into the sediment to loosen the material and mix in some water. The suction inlet is usually mounted inside the cutterhead, so that a mixture of freshly loosened sediment and water is pulled into the suction line. Cutterhead dredges can remove a wide variety of sediment types and can be designed to loosen dense sand and hard clay. Figures 4-6 and 4-7 show small cutterhead dredges.

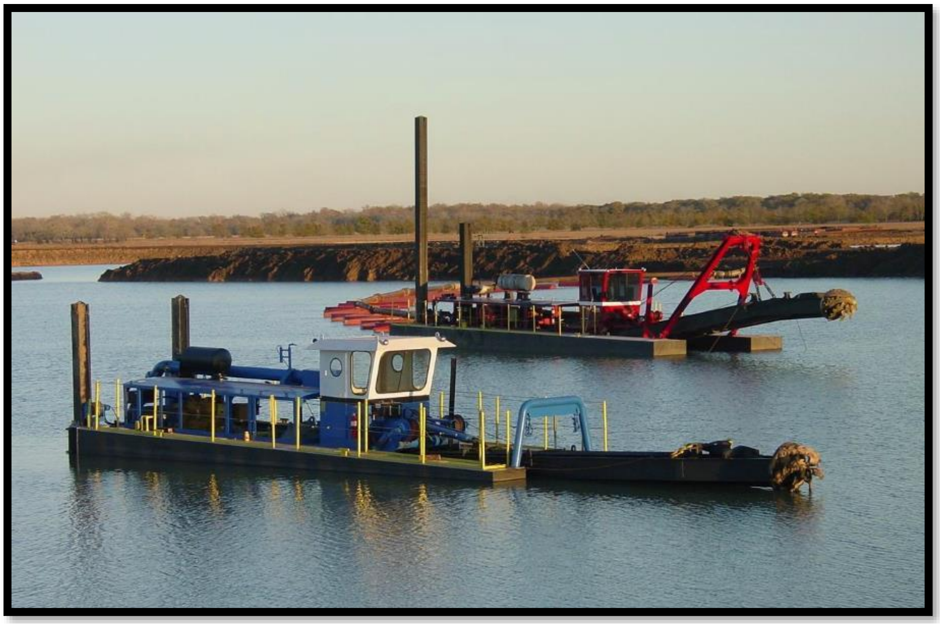

Figure 4-6. Two Raised Cutterhead Dredges (Source: Battelle, 2010)

Figure 4-7. Raised Cutterhead on Land (Source: Battelle, 2010)

Cutterhead dredges usually operate by swinging the cutterhead in a pattern of arcs over the bottom. This is usually done by one of two methods. In a swinging ladder dredge, the dredge is stationary, and the ladder is swung from side to side. With a fixed ladder, the entire dredged barge is swung from side to side using winches and cables attached to each side of the dredge barge.

Horizontal auger dredges use an auger to loosen sediment and move the loosened material to the suction pipe inlet. Horizontal auger dredges are generally small hydraulic dredges designed for shallow water and confined working areas. They work well in ponds, shallow lakes and near-shore areas. Figure 4-8 shows an auger dredge.

Figure 4-8. Raised Auger Dredge (Source: Battelle, 2010)

Suction dredges do not use any device to loosen the sediment. Since these dredges do not have a digging device, they can only remove soft sediments with little debris. Some suction dredges have been modified to use water jets to help loosen sediment.

Dustpan dredges use a dredgehead that resembles a very large vacuum cleaner or dustpan. A dustpan dredge is essentially a suction hydraulic dredge that may use water jets to help loosen the sediment. The dredgehead is generally the same width as the dredge barge and can be up to 30 feet wide. Dustpan dredges have been used in the Mississippi River, where they remove large volumes of soft sediment.

Hopper dredges are ships that combine hydraulic suction dredgeheads with large holding tanks. The dredgehead is usually suspended from the side of the ship, so that it removes sediment as the ship moves forward. These are also called "trailing suction dredges" because the dredgehead is pulled through the sediment and trails behind the point where the ladder connects to the ship.

4.1.3 Other Methods

Hybrid dredges use mechanical dredge equipment to remove the sediment and then mix the dredged material with water to transport via hydraulic pipeline. These systems have the ability to use recycled water to make the slurry needed for pipeline transport because the water is added to the sediment on the dredge (rather than under water at the suction pipe as with hydraulic dredges). With hybrid dredges, debris can be removed from the dredged material before mixing with water and the density of the slurry can be better controlled and more uniform than a hydraulic dredge. Figure 4-9 shows a hybrid system. The excavator is on the left and is used to place dredged material into a hopper. Figure 4-10 shows the system used in a pilot test at the New Bedford Harbor Superfund Site.

Figure 4-9. Aerial View of a Hybrid Dredge (Source: Battelle, 2010)

Figure 4-10. Hybrid Dredging System Used in New Bedford Harbor (Source: Battelle, 2010)

Submersible pumps have been used to dredge sediment by placing the pump directly into the sediment (Welp et al., 2008). These pumps are usually centrifugal pumps with discharge diameters from 100 to 300 mm (4 to 12 inches). They can be powered from the surface using electric or hydraulic motors. Some manufacturers add an external agitator to loosen sediment to assist flow into the suction pipe. Screens can be placed over the suction pipe to prevent debris and MEC/MPPEH materials from entering the suction pipe. These pumps have seldom been used for dredging sediment with MEC/MPPEH. One advantage of submersible pumps is that they can be suspended from a crane, which provides separation from the dredge crew and dredgehead.

Amphibious equipment that floats or moves over very soft sediment has been developed for working in shallow water and wetland areas. This equipment has wide tracks to distribute the weight of the equipment over a large area, which results in low-ground pressure. The body is water-tight so that the equipment can also float and work in shallow water environments. Mechanical dredge equipment has been mounted on amphibious equipment. Figure 4-11 shows an excavator mounted on amphibious tracks floating in open water. Amphibious dredges can be equipment with long-reach excavators, as shown in Figure 4-12. These help to reduce the short-term impact of potential damage to wetland vegetation since the dredge does not have to be close to the dredge area or to haul trucks.

Another innovative method includes freeze dredging, which is an innovative technique performed by freezing the sediment and lifting it up while it remains in a frozen state. The contaminated sediment is removed in a stabilized state for subsequent treatment and disposal after thawing.

Figure 4-11. Floating Amphibious Dredge (Source: Battelle, 2010)

Figure 4-12. Long Arm Amphibious Dredge (Source: Battelle, 2010)

4.2 Sediment Excavation

Sediment excavation is done “in the dry” after the water level has been lowered to expose the sediment surface. The water level can be lowered by utilizing industrial pumps or gradually opening the gates of a dam. The method chosen for lowering the water level is based on site-specific conditions. Backhoes, bulldozers, and front-end loaders are typically used to remove the sediment. During the removal process the soil or sediment is placed into containers (i.e., railway cars or trucks), into stockpiles, or placed on a conveyor system for transfer to an on-site confinement or treatment facility. If material is stockpiled, it can be placed on tarps or another impermeable surface and covered to prevent wind or rain from transporting the material. Covers also help minimize the exposure of site workers and site visitors to the contaminated material.

This section provides a general overview of excavation equipment applicable to sites with MEC/MPPEH present in sediment. The descriptions in this section summarize the equipment and processes that apply to all sediment removal projects. Sections 4.4 and 4.5 describe how the presence of MEC/MPPEH impacts dredging and dredged material transport.

Removal using excavation is typically more accurate than dredging, sediment is not re-suspended by the removal work and less disturbed sediment would be left in place by excavator than by dredging. Therefore, only limited excavation below the design depth is needed; this means that the volume of material removed using excavation is significantly less than the volume removed using dredging.

To perform excavation of sediment, the overlying water is temporarily removed and a temporary water containment barrier (cofferdam) is often needed. There are several types of cofferdams. One common type of cofferdam is a berm made from natural earth materials; these are similar to earth dams or flood control levees along rivers. Cofferdams are often built with steel sheet piles. For sites with shallow water (less than 10 to 15 feet) and the proper soil conditions, a single row of vertical sheet piles can be used. A fabric dam is illustrated in Figure 4-13; these types of cofferdams can typically only be used in relatively shallow water (12 feet or less).

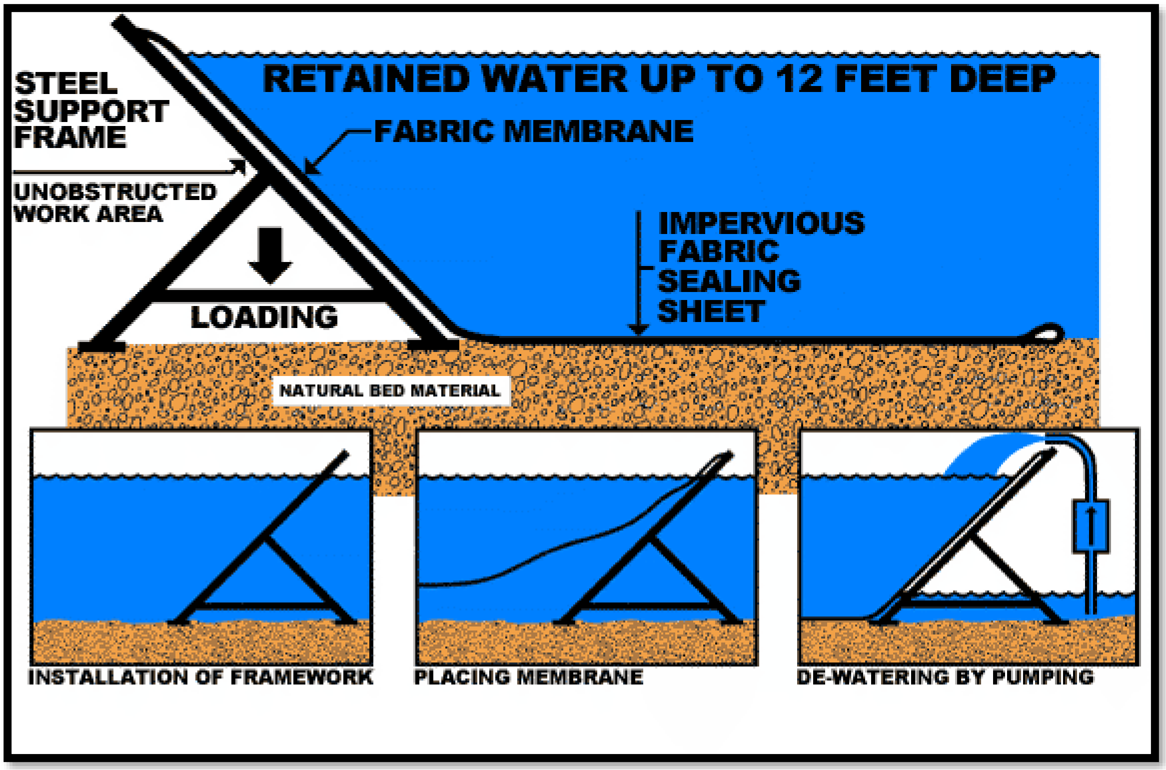

Figure 4-13. Portable Fabric Cofferdam
(Reprinted with permission from Portadam)

For deeper water depths (10 to 30 feet), a single sheet pile does not have adequate strength to resist the water pressure. In this situation, cofferdams can be made by installing two parallel rows of sheet piling and placing sand between the sheets, or by installing the sheet piles in an inter-locking circular shape and filling the inside with sand.

Once the water is removed, the exposed sediment can be removed using conventional upland excavation equipment such as excavators, backhoes, and bulldozers (Figure 4-14). In areas with very soft sediment, it might be necessary to install temporary roads to allow equipment to access the site. Long-armed equipment, such as the amphibious machine pictured in Figure 4-12, can then be positioned on the access road. If the sediment has enough strength or density to support low-ground pressure equipment, then roads may not be required.

Figure 4-14. Excavation inside Cofferdams (Source: Battelle, 2010)

Where feasible, the primary advantages of excavation over dredging for MEC/MPPEH sites is that the sediment surface is exposed so debris and MEC/MPPEH materials on the sediment surface are visible and newly exposed sediment can be observed as the excavation is performed. In addition, at some sites the sediment may be firm enough to support UXO personnel so they can examine and retrieve MEC/MPPEH materials as they are exposed.

4.3 Dredged Material Transport

Dredged material can be transported from the barge to land using either mechanical or hydraulic methods. In the majority of projects, sediment removed with mechanical equipment is transported with mechanical methods and sediment removed hydraulically is transported by hydraulic methods. If material is removed by mechanical dredging and must be transported via pipeline, additional water is needed to create a slurry that can be pumped. The sediment slurry dredged with hydraulic equipment behaves more like a liquid than solid material and it is typically not practical to transport slurries with most mechanical equipment; however, there are situations where hybrid systems have been used successfully.

This section provides a general overview of equipment used to transport dredged material. The descriptions in this section summarize the equipment and processes that apply to all sediment removal projects. Sections 4.4 and 4.5 describe how the presence of MEC/MPPEH impacts dredged material transport.

4.3.1 Mechanical Transport

Mechanical methods include floating barges, amphibious vehicles, wheeled vehicles, railroads, or conveyors. For sediment projects, conveyors have been used to move sediment from barges onto shore, between dewatering or other processing equipment, and to spread material at the disposal site (see Figure 4-15.) Barges are the most common method of transport for mechanically-dredged sediment. Hopper barges hold the dredged material in compartments during transport and can be unloaded by clamshells or excavators. Split-hull barges are a special type of hopper barge that are constructed in two halves which are connected by hinges at the top. One compartment runs the entire length of the barge. At the disposal site, hydraulic cylinders or cables split the two halves apart at the bottom and the material is released. Deck barges simply have flat surfaces to hold equipment or materials. Some deck barges have sideboards to prevent materials from falling into the water. With all mechanical methods, essentially no change in water content occurs during transport. After the dredged material is transported to land, it can be moved using conveyors, railcars, or trucks. For sediment projects, conveyors have been used to move sediment from barges onto shore, between dewatering or other processing equipment, and to spread material at the disposal site.

Figure 4-15. Conveyor Belt Transport (Source: Battelle, 2010)

4.3.2 Hydraulic Transport

Hydraulic transport is defined as the process of pumping sediment slurry through a pipeline. This process can be an economical method of transporting large volumes of bulk materials, especially when connected directly to a hydraulic dredge. No additional water is required to transport hydraulically-dredged materials; however, it is necessary to add water to create a slurry if the sediment was dredged using a mechanical technique. Transport pipelines can either float on the water surface or be submerged and rest on the bottom of the water body. Steel and high-density polyethylene are the most common pipe materials used in dredging projects, although any pipe material that is compatible with the sediment and water salinity can be used. For long transport distances, booster pumps (to increase the pressure) can be installed along the pipe routes. The maximum distance that hydraulically-dredged material can be transported can range from 2 to 10 miles. Longer distances are theoretically possible but would require multiple pumping stations and result in an increased likelihood of operational problems.

4.4 Debris and MEC/MPPEH Recovery Prior to Dredging

There may be sites where debris and MEC/MPPEH materials need to be retrieved from near-surface sediment prior to dredging or excavation. For dredging projects without MEC/MPPEH, debris retrieval is done in cases where there are significant concentrations of debris on or near the sediment surface and the debris would have a significant impact on dredging operations and production.

For sites with MEC/MPPEH materials, removal may be warranted prior to dredging. Methods used to accomplish MEC/MPPEH removal/recovery include:

- Divers to carry items to the surface or to attach lifting lines to items too large to carry;
- Mechanical grapple bucket to retrieve MEC/MPPEH and debris; and
- Electric magnet attached to a crane to sweep over the sediment surface and retrieve ferrous debris and MEC/MPPEH.

Electric magnets are commonly used in many industries, including steel recycling operations; however, these are not common in dredging projects. Electric magnets were successfully used at two DoD sites for retrieval of debris and hazardous materials prior to dredging. One site is the Bremerton Naval Complex, where an electric magnet was used to retrieve compressed gas cylinders of unknown age and conditions that were discovered under water near the docks. Since the age, condition and contents of the cylinders were unknown, there was a risk that if they were removed during dredging, they would be ruptured, which would result in an explosive release of gas. The cylinders were located using geophysical investigation tools and the electric magnet was used to safely retrieve the cylinders. A second site is MOTCO where geophysical investigations showed the presence of metallic debris but could not distinguish between MEC/MPPEH and other types of debris. The electric magnet was used during a pre-design investigation to retrieve debris from selected targets to obtain information on the type of MEC/MPPEH (Shank et al., 2017). More information is provided in Section 6 on under water MEC/MPPEH removal operations.

4.5 Application of Sediment Removal to MEC/MPPEH Sites

MEC/MPPEH materials and sediment can be removed in one operation using the dredging and excavation methods described above in Sections 4.1 to 4.3. This section describes how dredges can be used at MEC/MPPEH sites.

4.5.1 Application of Mechanical Dredging or Excavation

Mechanical dredging is effective for removal of sediment, debris and MEC/MPPEH under a variety of site conditions. Mechanical dredging equipment ranges in size from large derrick barges equipped with a clamshell bucket that can carry 20 cubic yards, or more, to small barge-mounted crawler-excavators with buckets of less than 1 cubic yard. Pontoon barges can be assembled from standard components into a variety of shapes and sizes for specific projects. Barges can work in water depths as low as 2 feet or work in water depths of over 100 feet. Barges can be assembled from components that can be transported using conventional highway trucks and delivered to upland lakes, ponds, creeks, canals, etc. It is common practice to place land-based equipment on barges for dredging projects, increasing the resources available for a specific project.

The most economical method to dredge or excavate sediment with MEC/MPPEH is to use the same equipment and methods used for conventional dredging. This is the most common state-of-the-practice.

Mechanical dredges cannot keep MEC/MPPEH out of the buckets, so it is not possible to remove sediment without also removing MEC/MPPEH and debris at the same time. On the other hand, because MEC/MPPEH and debris are removed simultaneously with sediment removal, the presence of MEC/MPPEH and debris has less impact on dredge production than it does with hydraulic dredging (as explained below).

One advantage of mechanical dredging compared to hydraulic dredging is that the dredge operator and personnel on the barge can visually observe each bucket of material after it is released from the bucket. Large debris or suspected MEC/MPPEH that is visible can be removed from the dredged material using the dredge bucket or an auxiliary crane and placed into a separate stockpile. This is commonly done for large debris such as large anchors, steel cables, or timbers that are removed in conventional dredge projects. Debris smaller than 50 to 150 mm (2 to 6 inches) is typically left in sediment for conventional dredging projects and only removed if required for disposal. However, sediment containing MEC/MPPEH will have more stringent screening requirements compared to conventional dredging projects.

Mechanical dredges can be equipped with blast shields on the operator cab and on the barge for personnel protection. In normal operations, there is no need for personnel to be directly exposed to dredged material as it is being removed and placed into stockpiles, barges or trucks. Removal of large MEC/MPPEH and debris (such as bombs, 16-inch projectiles, etc.) could be done using cranes or excavators with all dredge personnel behind blast shields. There is no need for personnel to be in close proximity to MEC/MPPEH.

4.5.2 Application of Hydraulic Dredging

Hydraulic dredges are effective for removal of all types of sediment but have limited capacity to remove MEC/MPPEH and debris. The dredge operator and dredge crew cannot visually observe dredged material until it is discharged from the end of the pipeline. Therefore, they cannot know what types of materials are in the slurry.

MEC/MPPEH and other large debris can cause significant issues for hydraulic dredging. For example, long debris such as steel cables, chains, and lines are likely to become entangled in the cutterhead, which slows or stops production. The only way to remove the tangles is to stop dredging, bring the dredgehead to the surface, and have deckhands manually remove the debris. Likewise, MEC/MPPEH materials may become stuck in the cutterhead posing a safety risk when the dredgehead is brought to the surface. Material that makes it through the cutterhead may get stuck in the slurry pump or in the pipeline. This requires the dredge to stop and typically requires disassembly of the pipeline. As discussed in Section 6, incidents where MEC/MPPEH become caught in the dredge screen or other equipment will require UXO technician and/or EOD support to clear.

To mitigate these operational and safety issues, screens can be installed over the cutterheads to prevent MEC/MPPEH and debris larger than the screen opening size from entering the dredge. With this system, MEC/MPPEH and debris are pushed laterally by the dredgehead and remain at the dredge site. For more information, examples of sites where screens were used on hydraulic dredges to prevent MEC/MPPEH from entering the dredges are given in Welp et al. (2008).

Another advantage of hydraulic dredging is that it is easier to process the resulting slurry with a screen than to process dredged material from mechanical dredging. Dredged material screening options are described in Section 5.

5.0 EVALUATION OF DREDGED-MATERIAL PROCESSING AND MATERIAL PLACEMENT OPTIONS

Materials removed by dredging or excavation of sediments require transport and may require processing prior to placement at a disposal site. Dredged materials removed during navigational projects are often suitable for beneficial reuse on beaches or upland sites, unrestriced placement in public water bodies, or unrestriced placement on upland properties. Dredged material produced during environmental dredging generally requires significant processing prior to disposal or reuse due to the presence of chemical contaminants within the material. Dredged material with debris and MEC/MPPEH materials also requires appropriate processing prior to placement.

Processing of dredged sediment generally includes removal of water that initially separates from the sediment particles followed by one or more types of treatment prior to disposal. The type and degree of treatment are based on the types of MEC/MPPEH, debris and contaminants in the sediment, regulatory requirements, remedial goals, costs, and other site-specific considerations. Treatment may include separation, solidification, dewatering, thermal desorption or incineration, and adding amendments to create various products for beneficial reuse (if applicable).

Conventional debris is generally separated and washed, and then reused, recycled, or disposed in an appropriate landfill. Debris that is retained on screens with opening sizes of 25 mm or larger may require processing separately from sediment particles. Debris smaller than 25 mm is typically processed and disposed with sediment particles. However, for MEC/MPPEH sites with munitions smaller than 25 mm, these materials need to be separated from sediment particles, processed separately, and disposed according to DoD and DON requirements. Figure 5-1 shows a schematic diagram of dredged material processing and disposal. Figure 5-2 shows process flow diagrams for materials generated by mechanical or hydraulic dredging (Federal Remediation Technology Roundtable [FRTR], 2020b).

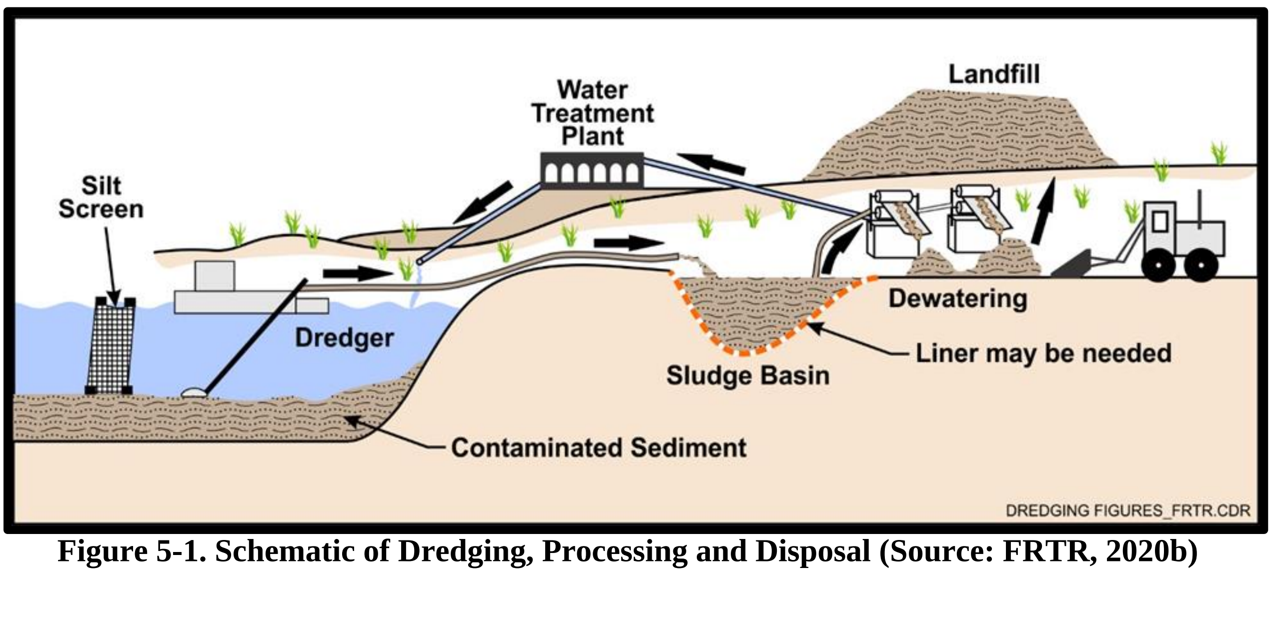

Figure 5-1. Schematic of Dredging, Processing and Disposal (Source: FRTR, 2020b)

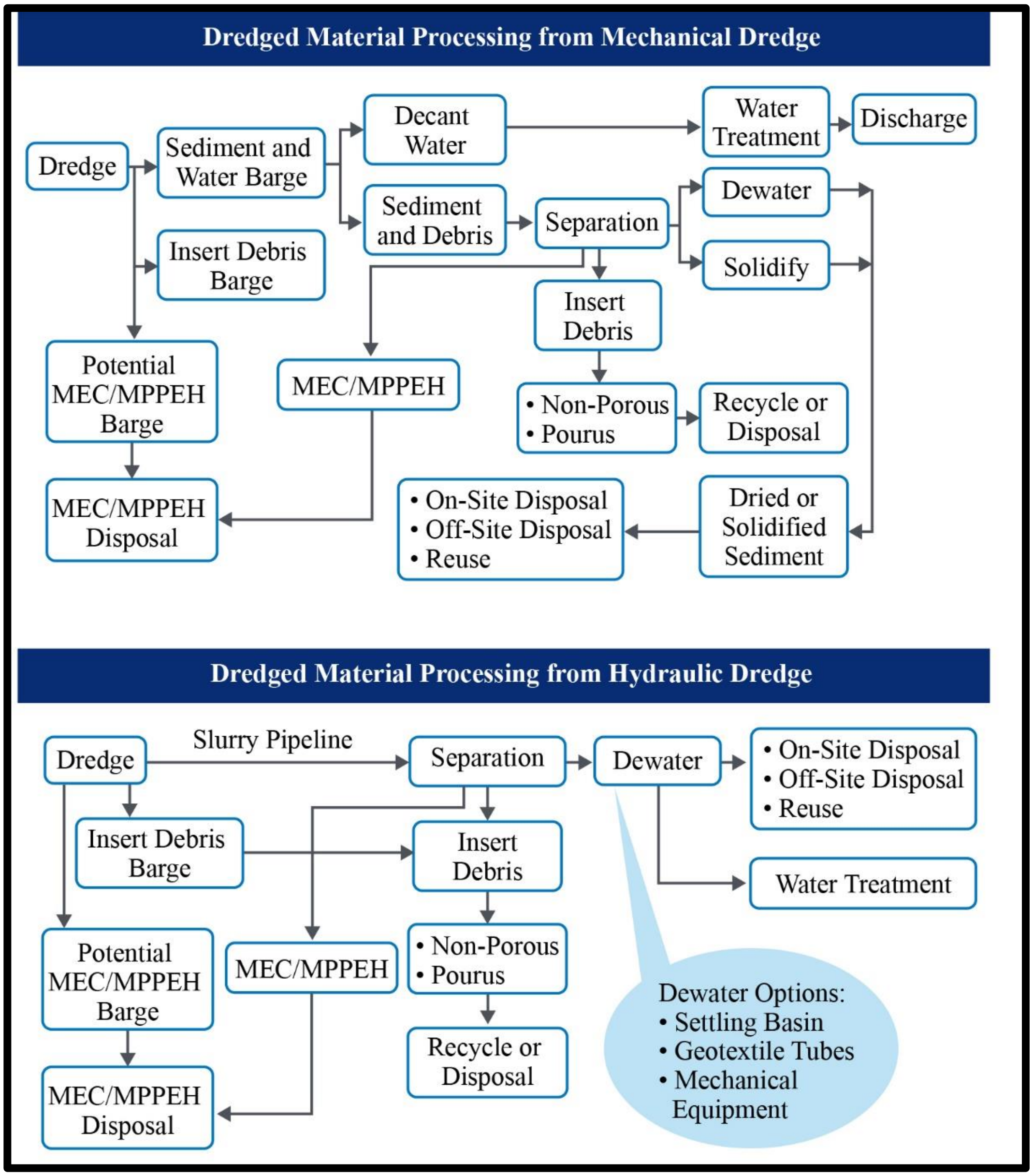

Figure 5-2. Dredged Material Process Flow Diagrams (Source: FRTR, 2020b)

Dredging or excavation of sediment produces four categories of dredged material that require processing including:

1) Sediment particles and entrained porewater;
2) Water (or other liquid) that separates from the sediment particles;
3) Debris; and
4) MEC/MPPEH.

5.1 Dredged Material Characteristics and MEC/MPPEH Size

Sediment is typically composed of inorganic soil particles that were hydraulically or mechanically removed and transported from an upland source and allowed to settle and separate from overlying water during transport and/or processing. As a result, sediment is like soil except for the following characteristics (FRTR, 2020b):

- Sediment generally has a higher percentage of water and lower percentage of solid particles than soil. Sediment commonly contains 30 to 70% solids by weight, compared to 60 to 90% for upland soils.
- Near-surface sediment generally has a higher percentage of natural organic material from vegetation that settles into the surface sediment.
- Sediment from marine water bodies contains natural salts in porewater that are adsorbed onto the sediment particles.

Sediment and soil particles are classified by particle size and one system commonly used is the Unified Soil Classification system, defined in American Society of Testing Materials (ASTM) Standard D-2487. This system is based on particles that are retained or pass through a specified sieve size, as shown in Table 5-1.

Table 5-1. Sediment Particle Size Classifications

Particle Size Classification	Sieve Size that Retains Particles (inches or US Sieve)	Sieve Size Particles Pass Through (inches)	Nominal size (mm / inches)
Boulders	12	N/A	Over 300 mm (12 in.)
Cobbles	3	12	75 to 300 mm (3-12 in.)
Coarse Gravel	¾ inch	3	19 to 75 mm (3/4 to 3 in.)
Fine Gravel	No. 4 sieve	¾ inch	4.75 to 19 mm (1/4-3/4 in.)
Sand	No. 200 sieve	No. 4 sieve	0.074 to 4.75 mm

The types of MEC/MPPEH materials that may be in sediment are described in Section 3. The relationship between sediment particle size classification and MEC/MPPEH material sizes is summarized below:

- Projectiles are 20 to 406 mm in diameter. The largest projectiles would be boulder size and the smallest would be gravel size.
- Projectiles from 3-inch and 5-inch ammunition (76 to 127 mm) would be cobble size.
- Mortars are 25 to 280 mm (1 to 11 inches) in diameter with 60, 81 and 300 mm the most common. The largest size and most common would be cobble size. The smallest would be gravel size.
- Rockets are 37 to 380 mm in diameter. The largest would be boulder size and the smallest gravel size.
- SAA are generally 30 Cal to 50 Cal (7.6 to 13 mm). These are gravel size.

All MEC/MPPEH materials greater than 19 mm in diameter are coarse gravel size or larger (i.e., larger than 19 mm, which is the opening size of a 3/4-inch sieve). After separation, this means that MEC/MPPEH would be mixed with boulder, cobble, and coarse gravel size sediment. Fine gravel, sand, silt and clay size sediment particles would not contain intact MEC/MPPEH larger than 19 mm in diameter. SAA from 50 Cal down to 22 Cal (13 to 5.6 mm) would pass through a 3/4-inch (19 mm) sieve and would be retained on a U.S. No. 4 sieve (4.75 mm), which is the same particle size as fine gravel.

5.2 Dredged Material Separation Equipment and Methods

For navigational dredging, treatment of dredged material is typically not required if contamination and physical hazards do not pose unacceptable risks to human health and the environment. In select cases, the dredged material may be suitable to be taken directly from the dredge site to the disposal site. However, for environmental dredging projects, additional steps are required for MEC/MPPEH removal prior to disposal.

MEC/MPPEH greater than 19 mm in diameter are the size of coarse gravel, cobbles or boulder particles, which are defined as particles retained on a screen with opening size of 19 mm (about 3/4 inch). MEC/MPPEH can be separated from fine gravel, sand and silt size sediment using the same equipment commonly used to separate gravel or larger material in conventional dredging or earthwork projects.

Sediment in nearshore marine sites and navigable rivers is predominantly sand, silt and clay size particles, which are much smaller than MEC/MPPEH materials. As a result, separation of dredged material by particle size is an effective first step in recovering MEC/MPPEH from dredged material. At many sites, there are no particles larger than coarse gravel size material (i.e., smallest dimension of about 19 mm) and there are few sites with more than 2 to 5% gravel by weight.

Dredged material separation methods include screens, magnetic separation, and manual removal.

5.2.1 Screens

Mechanical screening is effective in separating gravel and larger material from sand and smaller material. Screen size and types are selected based upon the size of the munition items requiring removal and the type of dredge material to be screened.

Sediment, debris and MEC/MPPEH materials can be processed through mechanical screens to separate materials by particle size. Screens with openings of 19 mm to about 150 mm (3/4 to 6 inches) can be used with all types of dredged sediment, debris and MEC/MPPEH material and are effective in separating the sediment particles, debris and MEC/MPPEH materials by size.

The moisture content of the dredged material will also impact how it flows through the screens and the potential for screens to become plugged or blocked. As the screen size becomes smaller, screening becomes much more difficult to implement because the screens become plugged, especially for sediment with silt and clay and natural vegetative matter. It is easier to screen sediment slurries and screening of hydraulically dredged sediment is more easily performed than screening of mechanically dredged sediment due to the higher water content in the sediment.

Oftentimes, water is added to mechanically dredged sediment to create a pumpable slurry that can be processed the same as slurries from hydraulic dredges; however, this increases cost and time to separate the dredged materials.

Sediment slurries can be processed through smaller screens with openings down to about 5 mm, but these systems typically require water spray bars to facilitate separation. Separating smaller sand particles (i.e., 5 mm to 0.08 mm) can be done with special equipment such as hydrocyclones that use centrifugal force to separate particles by size.

Mechanical screening of soils and rock is commonly performed in mining and earthwork construction projects. The same equipment designed and manufactured for mining and earthwork is used for screening dredged materials. The most common and effective types of screens for dredged material are grizzly, trommel (rotating) and vibrating screens. These are described in more detail in a report prepared for the Environmental Security Technology Certification Program (ESTCP) titled *Dredging Equipment Modifications for Detection and Removal of Ordnance* (Halkola et al., 2006). Halkola et al. (2006) also described a test of the effectiveness of visual inspection and screening to detect and remove inert 20-mm ammunition rounds from sediment that was performed at the Mole Pier site at NBSD, California. In summary, the authors reported:

- Visual inspection captured only 10% of the rounds;
- A trommel screen with 25-mm (1-inch) screen opening size captured 76% of the rounds; and
- A vibrating screen with 25-mm (1-inch) screen opening size captured 100% of the rounds.

Mechanical screening provides an effective method of separating material by size since it is not possible for materials to pass through screen openings smaller than the smallest dimension of an object. The Mole Pier report noted above did not give the exact dimensions of the ammunition, but 20-mm ammunition is typically 150 mm long, or longer, and the cartridge portions have a diameter greater than 20 mm. Screens will likely capture a percentage of objects with diameters smaller than the opening size because objects that are angled on the screen will not pass through.

An example screening process for dredged material with MEC/MPPEH would be as follows:

1) Screen through sieves with 50 to 76 mm (2 to 3 inch) opening size. This would retain cobble and boulder size particles and MEC/MPPEH and debris with smallest dimension greater than 50 to 76 mm. Therefore, this screen would retain larger MEC/MPPEH items such as bombs, projectiles, mortars or rockets.
2) Screen through sieves with 19 to 50 mm (3/4 to 2 inches) opening size. This would retain coarse gravel size particles and MEC/MPPEH and debris with smallest dimension greater than 19 mm, which would include 20-mm and 40-mm ammunition, smaller projectiles, mortars, and rockets.
3) The dredged material that passes through the second step would not contain intact MEC/MPPEH materials. Only fragments of MEC/MPPEH would be able to pass through the sieve, along with coarse gravel, sand, silt and clay-sized dredged material particles.

4) The dredged material that passes through 19 mm (3/4 inch) screens would contain SAA.
5) If separation of SAA is needed, it is feasible to screen dredged material through a U.S. No. 40 sieve (4.75 mm screen opening), which will remove SAA down to 22 Cal size. Screening sediment with silt and clay through screens smaller than 3/4 inch is difficult and may require that flushing with significant volumes of water and may require adding water to make the dredged sediment a slurry that can be pumped through processing equipment used with hydraulic dredges.
6) The materials retained on the screens would require further processing to separate MEC/MPPEH (or SAA) from gravel or other debris.

In conclusion, mechanical screening is an effective and reliable method of separating MEC/MPPEH and debris from sediment particles smaller than the screen opening size.

5.2.2 Magnetic Separation

Magnets are commonly used in metal recycling operations to separate ferrous metals from non-ferrous materials. One application is to place materials to be sorted onto conveyor belts and then use magnets installed along the conveyor to pull out ferrous metals. Halkola et al. (2006) described a conceptual approach for using an electromagnet to remove MEC/MPPEH and ferrous metal from moving conveyor belts. A Magnetic UXO Recovery System (MURS) technology has also been demonstrated by ESTCP (Lewis, 2008).

Magnets have not been commonly used in processing dredged material but are a technology that could be applied to separation of MEC/MPPEH with ferrous metals from other debris. Electromagnets manufactured for scrap metal recycling are available that can be used underwater or upland. One type are circular magnets several feet in diameter that are suspended from a crane. These can be moved over the surface of sediment or over dredged material in an upland processing area to pull out ferrous materials.

The advantage of using magnets is that this method minimizes the need for personnel to be in direct contract with the MEC/MPPEH mixed with other debris. Since magnets pull out all ferrous materials, additional processing would be needed to separate MEC/MPPEH from other metallic debris.

Use of magnets for MEC/MPPEH sites is an innovate concept that has advantages. However, it is unlikely that magnets alone will be 100% effective in removing MEC/MPPEH items. In addition, subsequent processing would be required to separate MEC/MPPEH from other ferrous debris.

5.2.3 Manual Removal

Manual removal of MEC/MPPEH from dredged material can be accomplished using the same methods that are used for upland soil areas. Dredged material can be spread out in an upland processing area, then qualified UXO personnel use magnetometers and metal detectors to locate metallic targets, which would then be examined and MEC/MPPEH removed following appropriate procedures.

A hybrid approach may also be used that combines screening and manual methods. For example, at NBSD, prior to the discovery of MEC/MPPEH, stockpiles of dredged material had been placed in a confined disposal facility (CDF). These “existing stockpiles” were 10 to 12 feet high and littered with all manner of debris. To accomplish MEC/MPPEH removal, the debris piles were sectioned into work units (grids) and UXO technicians conducted “mag and dig” removal of ferrous metal (and removed other debris) to 24 inches below ground surface.

Following the 24-inch deep clearance and quality control (QC) checks of the “grid”, the top 20 inches was removed and staged at an adjacent area. This process of scan and removal was repeated until the entire depth of the stockpile/grid was checked. The scanned stockpiles were moved to an adjacent open area for additional drying and screening down to a ¾-inch fraction to remove any possible 20-mm size munitions. Screened stockpiles were marked for removal to an upland landfill.

Dredged material screened to 300 mm (12 inches) only were removed from the scow using a clamshell bucket and deposited (wet) into a series of earthen-bermed cells. The wet dredged material was spread across the cells until a depth of 20 inches was reached. The UXO technicians then conducted “mag and dig” operations within the cells to detect and remove ferrous metal to the 20-inch target depth. When finished, shielded earth moving machinery (EMM) was used to clear the cells and move the material to an adjacent area for drying and additional screening.

Dredged material screened to 76 mm (3 inches) did not require a “mag and dig” process as EMM could be protected from the MGFD (fragmentation protection and 11-feet separation for blast protection). Dredged material was offloaded from the scow using a clamshell bucket and stockpiled for drying and screening to the ¾-inch fraction to screen for 20-mm rounds.

5.3 Dredged Material Processing Considerations

Additional administrative and technical issues to consider for dredged material dewatering, processing and treatment include:

Administrative Considerations

- **Permit Requirements.** For activities involving discharge of wastes off site from the CERCLA site, the need for permits should be evaluated. Water generated during dredging operations is classified as “Dredge Return Water” in permits issued by the USACE and the water quality for water returned to the surface water body is specified in Water Quality Certifications issued by the State where the dredge work is performed. Water quality criteria may be established by the EPA or other State agency. Industrial pre-treatment criteria may apply to water sent to industrial or public wastewater treatment plants.
- **Disposal Criteria.** Disposal or reuse facilities for sediment, debris and water have criteria for the physical and chemical properties of materials that they can accept. For example, an off-site landfill will have criteria for the physical properties of sediment, as well as chemical concentration limits.

- **Access Agreements.** In situations where off-site access agreements are needed for upland processing areas or transportation routes, these may have conditions that impact the work.
- **Adjacent Property Use.** Other ARARs may determine work hours, sound levels, and air quality at the perimeter of the work area. Requirements related to air quality, noise, light, work hours, and material transportation may be more stringent at sites adjacent to properties used for education, consumer businesses or residential housing.

Technical Considerations

- **Upland Process Area.** The size and location of upland processing areas is a major cost factor for dredged material processing. Most land adjacent to major water bodies is developed and there is limited available open space for temporary facilities to support dredging and dredged material processing. Limited space may dictate the need to use mechanical dewatering, off-site water treatment and off-site disposal, which are usually more expensive than on-site technologies.
- **Transportation Routes.** The size and capacity of local roads and availability of a rail line to upland processing areas will impact the cost. For example, if the only roads to the site are designed for residential use, they will limit the size of trucks and often limit the hours of trucking. On the other hand, if there are active rail lines to the site, transportation by rail may be less expensive.
- **Distance from Dredge Site to Processing Site.** The distance and site conditions between the dredge areas and processing area will impact the costs, with sites located farther from the processing facility incurring much greater costs.
- **Presence of Other Debris.** It is difficult to clean porous debris, such as concrete or wood, so these types of materials may require cutting or crushing to reduce the size and then transport to appropriate solid waste disposal facilities.

5.4 Dredged Material Placement

After processing to remove MEC/MPPEH, dredged material that contained MEC/MPPEH items may contain SAA and residual items such as fragments of non-explosive materials and chemical contaminants (e.g., metal fragments, MCs, etc.) that must be considered when selecting options for disposal or reuse.

Disposal options for contaminated sediment include placement of sediment solids, residual items, and debris into a containment facility to reduce exposure of the material to humans or the environment. In addition to disposal, suitable dredged material can be used for various purposes. Figure 5-3 shows a conceptual figure of disposal options for dredged material. These options are described in more detail below.

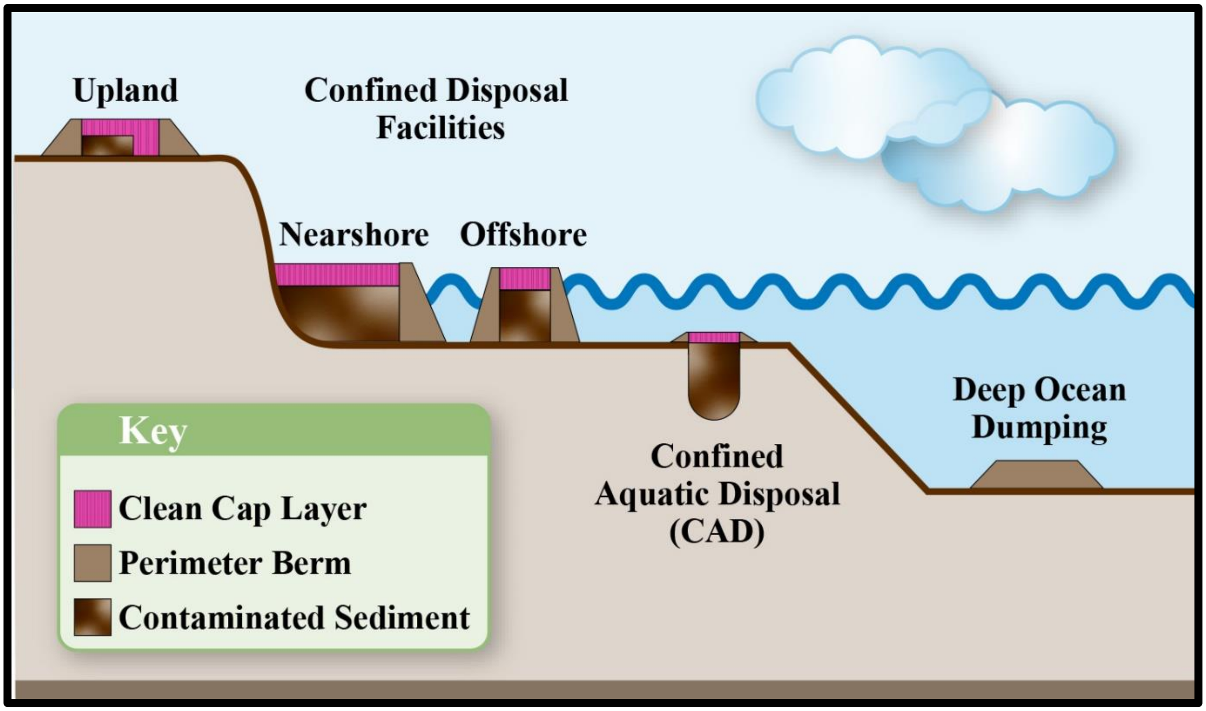

Figure 5-3. Various Designs for Confined Disposal Facilities (Adapted from NRC, 1997)

5.4.1 Confined Aquatic Disposal

In a confined aquatic disposal (CAD) site, dredged material is typically placed directly into a subaqueous disposal site without any type of treatment and covered with cap material (USACE, 2015). The thickness of the cap is site-specific and depends on bioturbation at the disposal site and the need to isolate the contaminated sediments. The disposal site can be made by dredging a pit or by using a natural depression. With this technology, it is not feasible to place impermeable liners in the site or to attempt collection and treatment of porewater. CAD is only practical with mechanical dredging and transport because contaminated dredged material must drop through the water column and land at a predetermined disposal site. Even so, depending on sediment type and degree of consolidation within the bucket, sediment will be released into the water column to some degree and may result in suspension and transport of fine-grain sediment outside of the disposal area. In the case of hydraulic dredging, the slurry that would be forcibly discharged and dispersed into the water column is much more likely to spread contamination into the surrounding areas of the disposal site.

For sediment that was processed to remove MEC/MPPEH, the presence of residual contamination and/or the potential for the continued presence of SAA must be considered on a case-by-case basis. There is a risk that a small percentage of material placed into a CAD cell is moved laterally by currents and falls to the bottom outside the limits of the CAD cell. It is difficult to monitor and control future operations over a CAD cell, so there would be some risk of future disturbance of the cap and underlying contaminated sediment. These long-term risks must be evaluated when selecting this disposal option.

The characteristics of the potential CAD site are critical to determine the feasibility of this technology because contaminated sediment would remain under a cap. In general, the site should be classified as non-dispersive, where sediment is in a stable depositional area. Ideally, the CAD site should be in a low-energy location with little potential for cap erosion. However, higher energy sites can be successfully used provided that the design accounts for erosion potential.

5.4.2 Nearshore or Offshore Confined Disposal Facility

A nearshore or offshore CDF is a containment technique where dredged material is placed in subaqueous or intertidal areas (USACE, 2015). The principal difference between nearshore or offshore and aquatic disposal is that in the nearshore or offshore technology, the disposal area is separated from the surface water by dikes built up above the water level surface. This provides more protection of the adjacent surface water since contaminated material is confined. There may be a pond inside the CDF to facilitate placement of a floating hydraulic pipeline, or the area may extend above the water level to provide placement by conventional EMM. Figure 5-4 shows a photograph of a nearshore CDF.

Figure 5-4. Nearshore CDF (Source: Battelle, 2010)

Mechanical or hydraulic dredging and mechanical or hydraulic transport can be utilized and transport sediment to a nearshore CDF. If hydraulic transport is used, the area inside the perimeter dikes is usually filled with water and one or more floating pipelines are used to distribute dredged material throughout the site. The ponded area also serves as a detention basin for dewatering the dredged material and for initial gravity settling of the supernatant water that separates from the dredged slurry.

If mechanical transport is utilized, the water inside the dikes may be left in place or removed. If the site is deep enough, it may be possible to leave a small opening in the dike and bring haul barges into the disposal area. As the depth decreases, it is usually necessary to close the dike, remove surface water and completely fill in the "dry" area.

For sediment that was processed to remove MEC/MPPEH, the presence of residual contamination and/or the potential presence of SAA must be considered on a case-by-case basis. Containment in a nearshore or offshore CDF provides secure, long-term containment of contaminated sediment and residual items and debris. However, there would be long-term responsibility for monitoring and maintenance of CDFs. These long-term risks must be evaluated when selecting this disposal option.

5.4.3 Upland CDF

An upland CDF is similar to a solid waste landfill where dredged material is placed on existing upland areas. The following are three types of disposal facilities that may be utilized: a monofill, designed and built solely for dredged material from one project; a multi-user facility that accepts dredged material from several dredge projects; or a permitted solid waste landfill that can accept dredged material, as well as municipal solid waste.

A monofill may be able to accept material by hydraulic transport in a manner similar to a nearshore CDF. The monofill disposal facility consists of perimeter dikes and possibly a bottom liner, leachate collection system, and a water treatment system. Dredged slurry can be discharged directly into the monofill containment area for the duration of the dredging work, then passive dewatering can be performed after the completion of dredging. Once the dredged material has been dewatered, a cover could be placed similar to a conventional landfill. Figures 5-5 and 5-6 show photographs of an upland monofill.

Figure 5-5. Grading the Side of a CDF (Source: Battelle, 2010)

Figure 5-6. Armoring the Side of a CDF (Source: Battelle, 2010)

With a solid waste landfill, the dredged material must be dewatered prior to disposal. These facilities are designed and operated to transport and place waste material with conventional upland EMM and cannot handle slurry material.

For sediment that was processed to remove MEC/MPPEH, the presence of residual contamination and/or the potential presence of SAA must be considered on a case-by-case basis. Containment in an upland CDF provides secure, long-term containment of contaminated sediment and residual items and debris. However, there would be long-term responsibility for monitoring and maintenance of CDFs. These long-term risks must be evaluated when selecting this disposal option.

5.4.4 Beneficial Reuse of Dredge Material

The concept of beneficial reuse of dredge material embraces the idea that suitable dredge material can be used to benefit society and the natural environment. Under certain circumstances, dredged material can be used to provide environmental and economic benefits in various areas including beach expansion, inter-tidal or sub-tidal habitat, parks and recreation, strip-mine reclamation, construction/industrial development, and multi-purpose activities. The beneficial reuse of dredged material simultaneously addresses multiple economic and environmental objectives to provide the greatest public benefit possible. For environmental dredging projects, beneficial reuse may only be feasible in limited circumstances and would require MEC/MPPEH removal and SAA removal. Residual MEC/MPPEH fragment and debris such as rusty metal fragments, broken ceramic or glass, jagged concrete or brick fragments would not be acceptable for sites where the public or wildlife would have direct contact with the reused dredged materials because this would create unsafe conditions. Sediment suitable for open water disposal or beneficial reuse falls into three categories depending on chemical concentrations:

1) **Sediment with chemical concentrations below criteria for open water disposal**. This is common for navigational dredge projects, but less common for environmental dredging. Only dredge material that meets the criteria for open water disposal could be reused in aquatic or upland environments without restrictions, provided the dredged material poses no hazards from residual MEC//MPPEH or SAA items or debris .
2) **Sediment with chemical concentrations below criteria for residential use**. For some contaminants (copper and zinc for example), the criteria for sediment quality is much lower than the criteria for residential use or for protection of groundwater. In these situations, sediment that is not suitable for placement in open water or on beaches could be placed in upland projects without restrictions, provided the dredged material poses no hazards from residual MEC/MPPEH or SAA items or debris.
3) **Sediment with chemical concentrations above criteria for residential areas**. Contaminated sediment that is unsuitable and unsafe for use in residential developments or agriculture can sometimes be used in development of commercial sites, for mine reclamation, and for fill in open spaces. These uses generally require that the contaminated material be managed in a manner that contains the contamination in an environmentally-safe manner. Contaminated sediment that is used for mine reclamation or subgrade fill on contaminated properties (i.e., “brownfield development”) is generally isolated from direct contact with the public or wildlife and land use controls limit future use of the properties. While it may be acceptable to leave some types of conventional debris, the dredged material for this type of reuse should pose no hazards from residual MEC/MPPEH or SAA items.

6.0 IMPLEMENTATION CONSIDERATIONS FOR MEC/MPPEH DREDGING PROJECTS

Proper implementation for dredging operations in the presence of MEC/MPPEH should include site-specific procedures to address engineering controls (e.g., screens) and contingency actions to be taken in the event MEC/MPPEH gets trapped in the screen(s) or is deposited onto the land. This section covers basic considerations for onboard MEC/MPPEH dredge finds, MEC/MPPEH screening operations, underwater MEC/MPPEH recovery and disposal operations, along with additional factors to consider during project implementation.

6.1 Onboard MEC/MPPEH Dredge Finds

There are numerous documented cases of MEC/MPPEH finds aboard dredges. A few incidents cited by the USACE Norfolk District (2019b) include:

> "*During the Sandbridge Hurricane Protection Projects constructed in 2002 and 2007, over 100 UXO were recovered during dredging operations and were transported to and properly disposed of at an undisclosed Naval installation.*
>
> *On April 1, 2006, the Dredge Padre Island operated by the Great Lakes Dredge & Dock Company was conducting maintenance dredging activities in the Atlantic Ocean Channel (AOC) when it suffered a ruptured dredge cleanout section and severed drag head as a result of an explosion presumed to be from an ordnance device that was pumped into the draghead and associated lines. UXO had been previously retrieved from the draghead on three different occasions in February 2006. During the last dredging cycle of the AOC in February 2011, it was documented that UXO/MEC was encountered four times, mostly 5-inch shells, two of which were determined to be live ordnance.*
>
> *A UXO/MEC device also is presumed to be the cause of an explosion on a hydraulic cutter-head dredge conducting maintenance dredging in Norfolk Harbor in April 2005 rupturing the primary pump casing on the dredge. The Coast Guard rendered assistance to the dredge plant to provide additional pump-out capacity for the incoming water and stabilize the plant.*
>
> *Fortunately, in most incidents ordnance has not detonated and has been safely removed or jettisoned from the vessel*."

Onboard dredge finds of MEC/MPPEH can be dangerous and pose challenges for responding UXO technicians and/or military EOD personnel. On typical USACE dredging projects where the potential exists for UXO, contract requirements often include a specification for MEC/MPPEH construction support (Section 01-35-30 of USACE [2019a]). For hopper dredging projects, USACE contracts typically include an option for an on-dredge UXO technician team, which is implemented based upon the frequency of MEC/MPPEH finds on dredge as well as the types of MEC/MPPEH encountered. The responsibilities of on-dredge UXO technicians include inspecting the dragheads for the presence of MEC/MPPEH and munitions debris after each load is taken on board and removing munitions-related items, only if determined safe to do so, from the draghead screens and transferring items deemed safe to move to the shore for proper disposal.

On projects where contract UXO support is not available or an option, the common response is to notify military EOD through the Coast Guard to initiate an emergency response. Whether or not UXO contractor support is used, all items deemed unsafe to move or handle are typically handled as an EOD emergency response. Figures 6-1 and 6-2 show MEC and MPPEH, respectively, caught in the dredge screen, which required UXO technicians and/or EOD support to clear.

Figure 6-1. Intact Projectile Caught in Dredge Screen (Source: OHI)

Figure 6-2. Partial Munition (i.e., MPPEH) Caught in Dredge Screen (Source: OHI)

The responding UXO technicians and/or EOD team determine the safest and most effective way to remove the items from the dredge. In some cases, due to the explosive safety hazard, the dredge may have to be evacuated of all non-essential personnel before MEC/MPPEH removal operations can commence. In the case of USACE projects with civilian UXO technicians responding, there is typically constant communication with the designated OESS if

MEC/MPPEH is found. Military EOD personnel typically have greater capability and flexibility compared to contractors as they have the mission to respond to emergencies involving munitions and are exempt from certain regulations such as the EPA Military Munitions Rule when responding to emergencies. Navy EOD can also transport demolition explosives in vessels. This allows EOD to relocate the MEC/MPPEH to deeper water or the shore for proper disposal. The USACE SOP for UXO technicians providing MEC/MPPEH support aboard hopper dredges allows DMM to be transferred from the dredge to shore via a dedicated crew boat consisting of essential personnel and a UXO technician as an escort. The SOP requires the DMM to be placed "in a lightweight, flexible, securable container (such as a military kit or duffel bag)" provided that it is locked and secured by line if the seas are rough (USACE, 2019a).

6.2 MEC/MPPEH Screening Operations

Key implementation considerations for projects with screening operations at discharge points and over water are described below.

6.2.1 MEC/MPPEH Screened at Discharge Points

On dredges where material is pumped to the shore, hopper dredge screens or baskets can be used to screen the material at the discharge points. Designs for screening baskets vary across the industry but generally include 19-mm (0.75-inch) screens with uniform dimension (i.e., grid or series of round holes) made from rugged steel or composite material with welded members.

MEC/MPPEH baskets often have doors that open and an access point for entry into the basket in the event that material is lodged, and basket entry is required. It should be important to note that depending on the design of the basket, it may be considered a confined space and, as a result, confined space entry procedures may have to be included in the work and safety plans for the site. Examples of MEC/MPPEH screening baskets at discharge points are shown in Figures 6-3 and 6-4.

Figure 6-3. MEC/MPPEH Screening Baskets, Atlantic Coast Dredge Project (Source: OHI)

Figure 6-4. MEC/MPPEH Screening Basket, Chesapeake Beach, Virginia (Source: OHI)

An example approach for deploying discharge point screening baskets includes the use of secondary baskets which are placed alongside the primary basket before the doors are opened for cleaning. Material is washed from the primary baskets into the secondary baskets which are further rinsed for excess sand. The leftover materials are then raked and checked for MEC/MPPEH. Best management practices include the use of a UXO technician support (Level II or higher, as defined in DDESB TP-18 [2016]), to sort through the debris for MEC/MPPEH items. On Navy projects, a SUXOS and UXOSO should be available on the site to make a "safe to move" determination on any items found as required by NAVSEA OP5. Figure 6-5 illustrates the steps involved in implementing this type of MEC/MPPEH screening process for a navigational dredging project. The process as illustrated would need to be appropriately adapted for environmental dredging to contain contaminated sand/sediment and wastewater discharges. Another example MEC/MPPEH screening project at NBSD is described in Appendix E, which utilized a hybrid "spread and scan" or a "mag and dig" approach combined with various screening configurations prior to dredged sediment disposition in a CDF and upland landfill.

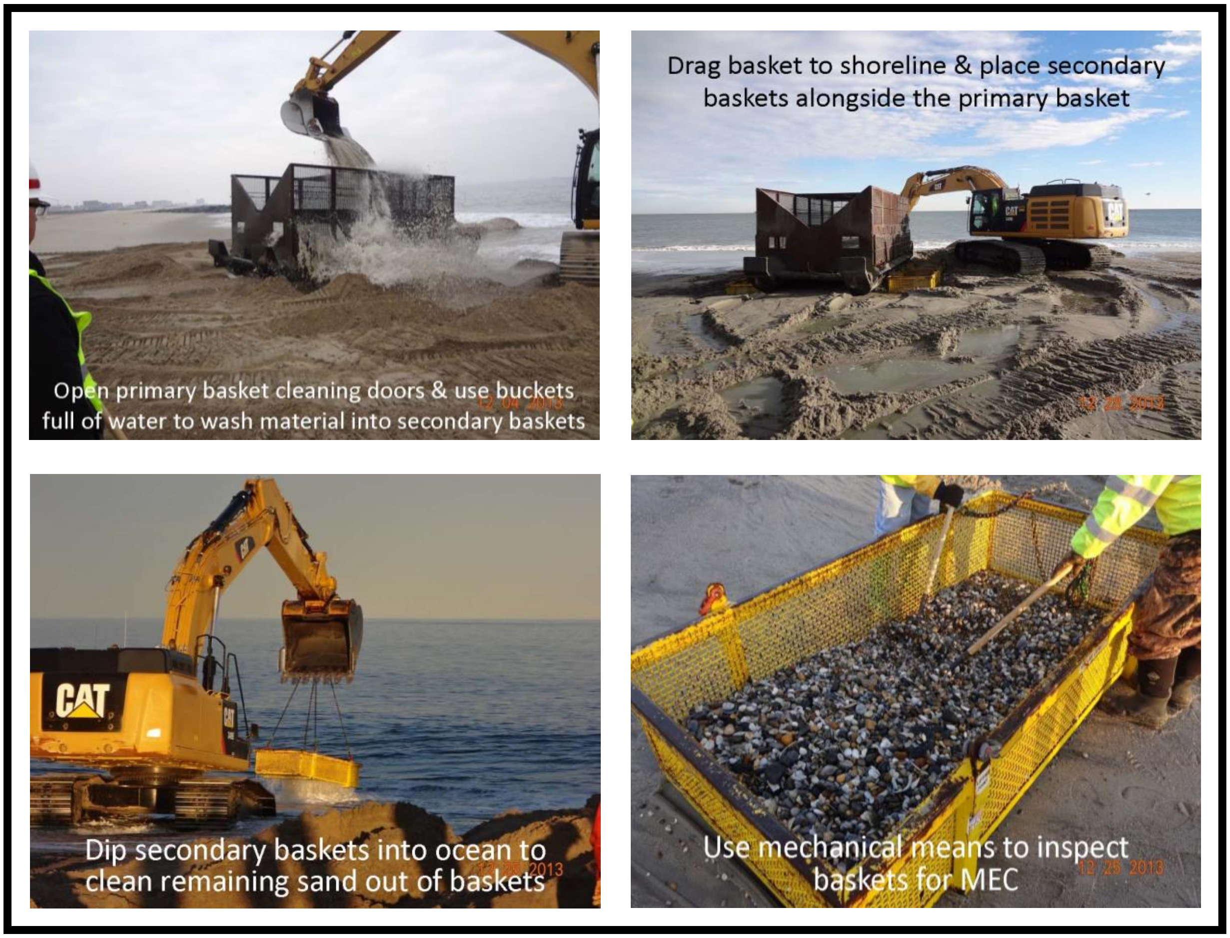

Figure 6-5. Screening Dredged Material on Land (Source: OHI)

6.2.2 MEC/MPPEH Screened Over Water

For backhoe and clamshell type dredges, another approach to screen for MEC/MPPEH that has been deployed at multiple sites including maintenance dredging at NBSD (2012) and Philadelphia Navy Yard (2016/2017) is the use of over-water screening techniques such as a scow barge positioned alongside the dredge fitted with a grizzly screen such that excavated dredge material is loaded through the screen onto the barge. Material excavated with the clamshell or backhoe bucket passes through one or more screens placed directly over the hopper of the scow. Screen sizes are selected based upon the size of the smallest munition that may be encountered. Common sizes include 300-mm (12-inch) screens for large projectiles and 76-mm (3-inch) screens for 3-inch diameter items and larger. Standard protocol is to position a UXO technician in the area to observe the operation to identify whether any MEC/MPPEH are deposited on the screens. Operations are halted if MPPEH items are observed and a SUXOS and UXOSO are called to make a safe-to-move determination in accordance with NAVSEA OP5.

6.3 Underwater MEC/MPPEH Removal and Treatment Operations

As described in Section 3, the decision to remove MEC/MPPEH or to leave it in place is often dependent on future use of the water body and the extent of MEC/MPPEH at the site. Selection of an underwater removal technology is highly dependent on a combination of the number, type, configuration, and condition of the munitions and the site characteristics. Where underwater MEC/MPPEH must be removed, the following technologies are available:

- Hand excavation (using water jets or airlifts);
- Lift bags and baskets;
- Robotics/remotely operated vehicles;
- Magnetic lift systems; and
- Dredging and screening.

Conducting underwater munitions removal operations using these technologies is significantly more expensive than similar operations on land. Efficiency in the rate of production is decreased in comparison to terrestrial operations along with an increased potential to leave MEC/MPPEH items behind. More information on underwater MEC/MPPEH removal technologies is provided in NAVFAC's Munitions Response RI/FS Guidance (2019a). Operational considerations are discussed below for MEC/MPPEH removal by dive teams, including Navy EOD or commercial UXO dive teams, and other means.

6.3.1 EOD Divers

Although fully qualified to discover and dispose of MEC/MPPEH in the underwater environment, Navy EOD's mission as it relates to dredging operations is primarily to serve in an emergency response capacity. EOD is often called to respond to MEC/MPPEH finds that are determined unsafe to move by on-site UXO contractors which can include underwater targets.

6.3.2 Commercial UXO Divers

Qualified commercial UXO dive companies are also capable of underwater MEC/MPPEH recovery and disposal. The size and scope of the commercial UXO dive operations is driven by the particulars at the site. Proper planning is required to support dive operations including the submittal and approval of a dive plan. In addition, commercial dive operations must comply with EM 385-1-1 *Safety and Health Requirements Manual* (USACE, 2014); Federal Occupations Safety and Health Administration regulations for safe diving and for the storage of explosives and underwater blasting (29 CFR 1910.109 and 1926.912), as well as applicable U.S. Coast Guard regulations (46 CFR Subpart B - Commercial Diving Operations). In addition, each state may impose additional regulations on dive operations.

Common diver detection methods include visual identification (visibility permitting) and diver-held sensors such as sonar and magnetometers. Water currents, temperatures, and depths place limits on dive operations and production schedules and, as a result, drive costs. Commercial dive operations are expensive due to added labor (e.g., safety diver, tender) and equipment required (e.g., dive boat, decompression chamber).

6.3.3 Other Recovery Techniques

As discussed in Section 5, electromagnetic systems or a remote-operated mechanical grappler operated from a barge can be used to recover MEC/MPPEH. For example, the MURS technology was demonstrated by ESTCP for this purpose (Lewis, 2008). Implementation considerations must include procedures for managing explosive safety issues and concerns such as potential shielding of operators and procedures to properly handle and dispose of MEC/MPPEH once recovered.

6.3.4 Underwater MEC/MPPEH Treatment Options

For underwater sites, the following treatment technologies are available:

- Blow in place (BIP) (high order);
- BIP (high order) with bubble curtain;
- BIP (low order);
- Consolidated detonation ashore/afloat;
- Abrasive water jet cutting; and
- Encapsulation and capping.

More detailed information on underwater MEC/MPPEH treatment is provided in NAVFAC's Munitions Response RI/FS Guidance (2019a).

6.4 Overall MEC/MPPEH Dredging Project Considerations

This section presents additional considerations when implementing MEC/MPPEH dredging projects.

6.4.1 Dredging Operations and Explosives Hazards Analysis

As discussed in Section 2, the ESS will define the ESQD or safe standoff distances required based upon the MGFD associated with the site. The munition types associated with the site also drives the pressure contours (i.e., distance-based K-factor) and whether or not shielding of equipment and operators is required. Shielding requirements are further defined in the DDESB Blast Fragmentation Sheets (DDESB Technical Paper 16 [2009]) with applicable fragmentation sheets included for reference in the ESS. The DDESB fragmentation data review forms provide details on the minimum thickness of shielding required based upon shielding material type in order to protect dredging/equipment operators within the EZ. Common shielding includes plexiglass and Lexan around the operating cabs of heavy equipment involved with the handling of dredge materials that potentially contain MEC/MPPEH.

6.4.2 Risk Assessment for Dredging Operations

DON explosive safety policy is to "emphasize safe and efficient operating procedures while: (1) providing the maximum possible protection to personnel and property from the damaging effects of potential accidents involving DON ammunition and explosives, (2) limiting the exposure of a minimum number of persons, for a minimum time, to the minimum amount of ammunition and explosives consistent with safe and efficient operations" (NAVSEA OP5). Proper explosive safety planning involves the identification of essential versus non-essential personnel as it relates to the dredging operation. Essential personnel are those personnel essential to the operations being performed. For example, heavy equipment operators and on-site UXO technicians would be considered essential personnel, while administrative personnel would not be essential personnel. Dredging operations are considered to be mechanized operations from an explosives safety standpoint thus governed by the applicable sections of NAVSEA OP5.

Protection of essential personnel within the EZ is accomplished primarily through engineering controls such as shielding as defined in the ESS/DDESB TP 16 (2009) fragmentation sheets and through personal protective equipment (PPE) such as single or double ear protection for operators based upon the associated K-factors (as discussed in Section 2).

Protection of non-essential personnel is done through EZs as established in the ESS as only essential personnel should be allowed to work and operate in the explosives safety EZ during intrusive operations. There have been projects such as the maintenance dredging of Piers 10, 12, and 13 and Mole Pier at NBSD (2012) where an Explosives Safety Waiver was granted to deviate from the requirements of NAVSEA OP5 to allow non-essential personnel access within the EZs established in the ESS. This waiver is described below with more detail in Appendix E.

> "*These personnel were non-essential to the MEC work, but mission essential to the ship repairs occurring at NBSD. The waiver allowed limited access for mission essential personnel and equipment to transit through EZs during dredging operations. It [the waiver] also required an operational necessity endorsement and regional (area) concurrence. The command was required to ensure only those personnel limited to ships' force personnel, DoD contractors, and other personnel responsible for shipboard maintenance were allowed to enter the EZs. When considering the need for an ESS deviation, NOSSA should be consulted and the additional review time factored into the planning process* (NAVFAC, 2019c)."

Explosive safety planning for dredge operations should also consider the potential hazards and minimum separation distances associated with underwater unintentional detonations. For example, if the construction activities involve divers, planners need to ensure that all diving is conducted at proper separation distances from dredging operations where the potential exists for UXO. Minimum safe separation distances for swimmers in 1 foot or less of water are calculated based upon the peak pressure, while safe separation distances for swimmers/divers in depths exceeding 1 foot are based upon the impulse pressure of an unintentional detonation (CNO 8020 Ser N41/14U130469).

A Notice to Mariners should be submitted to the U.S. Coast Guard to alert the public of hazards and restrictions for in-water operations. A message should also be sent out as applicable to all ships and commands requiring that all swimming/diving activities be secured during dredge operating hours. Plans should include contingencies for emergency in-water activities for non-essential personnel requiring access within the EZ.

6.4.3 Dredged Material Profile and Screen Selection

Screen size and types are selected based upon the type of dredged material to be screened and the size of the munition items. The evaluation of MEC/MPPEH processing/screening options was discussed in Section 5 and further summarized in the flow chart in Appendix A. If material screens are selected as an engineering control (EC) to separate anomalies to include MEC/MPPEH, they should be designed to properly fit the equipment with features built in to allow the screens to be checked and cleared of MEC/MPPEH. Protocols or SOPs for checking and clearing the screens should be outlined in the work plan. RPMs should keep in mind that screens will impact production rates, and, at some point, it may be easier to spread and scan the dredged material for MEC/MPPEH. The NBSD example described in Section 5 utilized a hybrid “spread and scan” or a “mag and dig” approach combined with various screening operations prior to dredged sediment disposition.

6.4.4 Pre- and Post-Dredge MEC/MPPEH Sampling

Clearing MEC/MPPEH from an underwater site may not always be practical depending upon the specifics associated with the site (e.g., size, water depth, water temperature).

If time and funding allow, pre-construction geophysical surveys and MEC/MPPEH sampling (i.e., investigating targets suspected of being MEC/MPPEH) can prove useful in providing details on the types and quantities of munitions that may be encountered at the site. MEC/MPPEH sampling can be accomplished through the use of dive teams or other methods such as backhoe-mounted barges. Post-dredge geophysical surveys and MEC/MPPEH sampling could be useful in determining the amount of residual anomalies that remain at the site which were not removed from dredging activities.

More in-depth information on the technologies that can be used to perform underwater MEC/MPPEH investigations is provided in NAVFAC’s Munitions Response RI/FS Guidance (2019a). RPMs must also keep in mind that any pre- and/or post-dredging sampling involving intentional contact with MEC/MPPEH will require an ESS.

6.4.5 Movement of Underwater MEC/MPPEH

The potential for movement of underwater MEC/MPPEH by hydrodynamic means (e.g., waves, currents) or ice-induced forces could impact a MEC/MPPEH dredging project. For example, MEC/MPPEH located in adjacent areas could be transported into the dredging area or navigational channel and be encountered by subsequent dredging operations.

The DoD ESTCP is currently funding several research projects to improve UXO mobility analysis (including the UXO Mobility Model). Other DoD studies have been conducted with simulated MEC/MPPEH such as a study at the Former Erie Army Depot impact range in Lake Erie, Pennsylvania. This two-year study concluded that there was a significant potential for MEC migration with the net transport largely due to ice, but waves and drag netting for fishing also contributed (Welp et al., 2004).

Due to the potential for MEC/MPPEH movement, best practices during the planning process should include considering not only the potential for MEC/MPPEH within the immediate dredge area, but also expanding the scope of site due diligence (e.g., archival research) to include potential MEC/MPPEH sources in close proximity to the proposed dredge site.

6.4.6 Quality Assurance/Quality Control (QA/QC) of the Dredge Process

DON's goal is to ensure that an auditable, objective record is maintained for all aspects of DON munitions response actions. To meet this objective, OPNAVINST 8020.15 (Series)/MCO 8020.10 (Series) *Explosives Safety Review, Oversight, and Verification of Munitions Responses* requires that NAVFAC develop QA/QC procedures for all munitions response actions to ensure the integrity of the data gathered through appropriate reviews and inspections. In addition, an audit record documenting the completion of QA/QC activities and procedures should be maintained as part of the QA/QC program (NAVFAC, 2019a).

QA is a process-oriented technique that ensures all processes are defined and appropriate. QA reviews focus on the process elements of a project and the definition of project requirements. This includes a review of data quality elements defined in the statements of work (SOWs), work plans, Quality Assurance Project Plans (QAPPs), Quality Control Plans (QCPs), ESSs, and SOPs, as well as requirements ensuring that qualified personnel, and proper geophysical and positioning equipment are used during the project. QA reviews are documented following the process established in the Naval Installation Restoration Information Solution (NIRIS) database. In addition, NOSSAINST 8020.15 (Series)/MCO 8020.10 requires that third-party, independent QA be performed in the field by either an independent UXO contractor, Field Engineering Command (FEC)-qualified UXO staff member, or the Naval Surface Warfare Center Indian Head EOD Technology Division (NAVFAC, 2019a). Third-party, independent QA oversight for dredging projects helps to ensure that MEC/MPPEH are indeed being properly screened for and managed and disposed of when found.

QC is a product-oriented technique or activity designed to evaluate a completed task or product. QC activities are focused on finding defects in specific deliverables by comparing a completed product against the requirements. Three phases of QC inspection (i.e., preparatory, initial, and follow-up) are performed for each definable feature of work (DFW). QC activities are performed by the production contractor (NAVFAC, 2019a). Dredge contractors, and their UXO subcontractor, should implement a robust QC program in the field to ensure that MEC/MPPEH are properly screened for and when found, properly managed. Similar to land-based MEC/MPPEH operations, QC programs on dredge sites should consider the following: quality checks on screened material prior to placement/disposal, QC sweeps of beach fill areas as applicable, QC checks of screens to ensure integrity, QC checks on MEC/MPPEH staged on site, QC of the MPPEH inspection/verification processes, and QC checks of paperwork/site documentation.

6.4.7 Other Hazards

As stated previously, RPMs should be aware of other hazards that may exist at dredging projects in addition to MEC/MPPEH including radiological hazards and pressurized cylinders that can be commingled with debris. Best management practices include developing contingency plans for these hazards so if any of the items are found during dredging, adjustments can be made to the field operations in a timely manner.

6.4.8 Underwater Use Controls

Underwater use controls include ECs and institutional controls (ICs) to limit access to designated areas and exposure to MEC/MPPEH left in place at underwater MRSs (NAVFAC, 2019a). Underwater use controls should be utilized at sediment dredging sites where a decision is made to leave MEC/MPPEH in place under water.

ECs can include fences along the shoreline, signs, and warning buoys, guards, patrol boats, and caps. All of these engineered methods are designed to limit access to MRSs where MEC/MPPEH remains in place so that potential exposure is minimized. Long-term monitoring and maintenance of ECs is required to ensure that they remain protective in the future (NAVFAC, 2019a).

ICs are legal devices imposed to ensure that ECs and/or restrictions on site use remain in place and are enforced. ICs can consist of notices to mariners, information in coast pilots, notices to navigation interests, marking on nautical charts, educational materials, permits/danger zones, etc. (NAVFAC, 2019a).

6.4.9 Notification on Charts and Deeds

One method to communicate dangers and potential hazards is to request that the impacted areas be included on NOAA charts for the region. As described in Section 3, NOAA maintains a UXO areas database and is responsible for publishing and updating navigation charts. The NAVFAC RPM should ensure that areas known or suspected to contain MEC and/or MPPEH are included on applicable navigational aids including charts managed by NOAA.

7.0 SUMMARY

RPMs should utilize this guide to support their efforts in determining the potential for MEC/MPPEH to be present in planned dredging areas. If MEC/MPPEH are known or suspected to be present, the explosive hazards must be effectively managed in compliance with DoD and DON policies to ensure the safety of workers, the public, and dredging/process equipment. The information provided in this guidance is meant to serve as a technical resource and summary of best practices for RPMs in the management of sediment dredging projects where the potential for MEC/MPPEH exists. It is not meant to replace existing DON explosives safety policies and guidance. RPMs should continue to rely on munitions-related SMEs on site and account for site-specific conditions when managing potential MEC/MPPEH during dredging operations.

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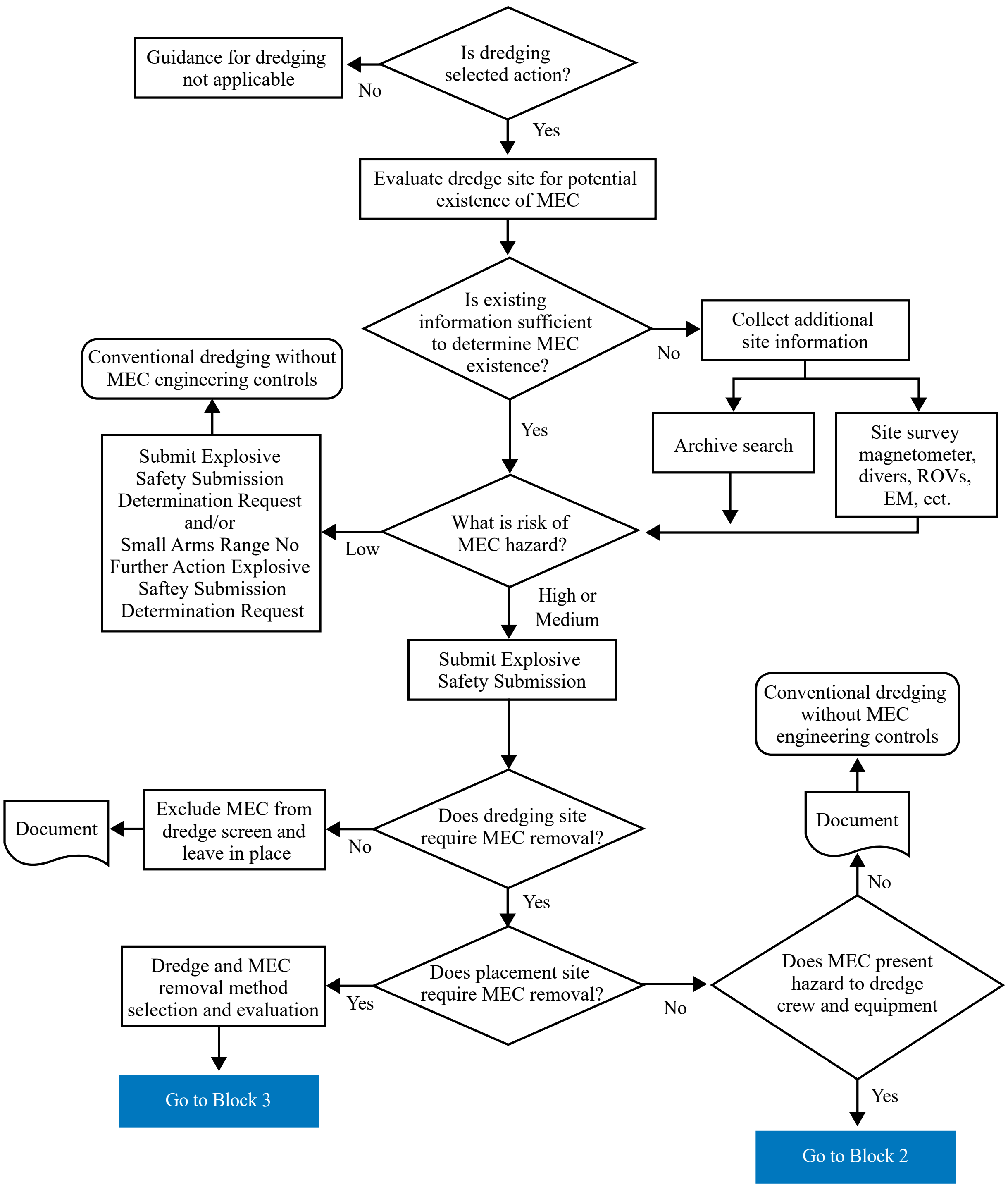
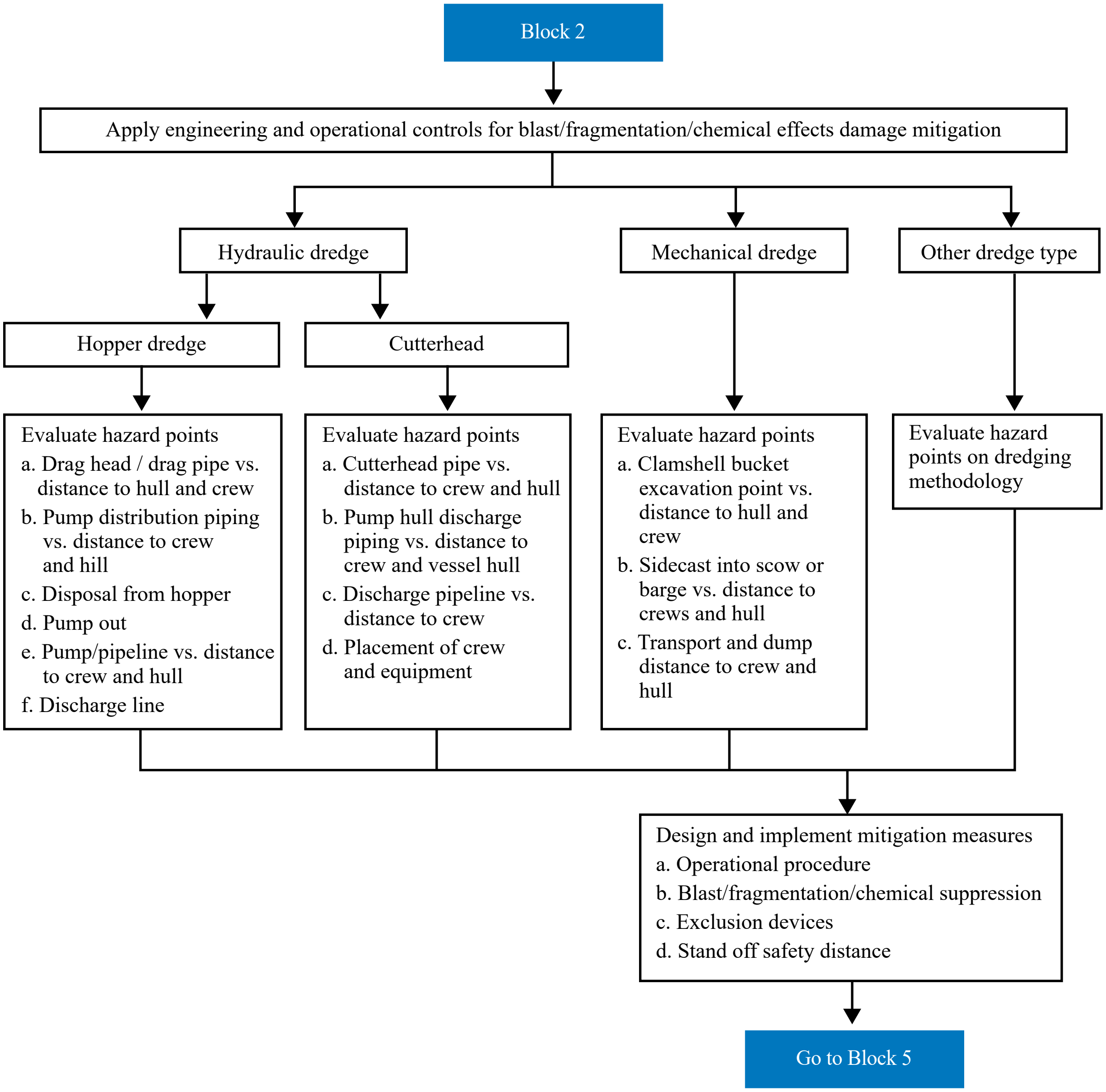
APPENDIX A

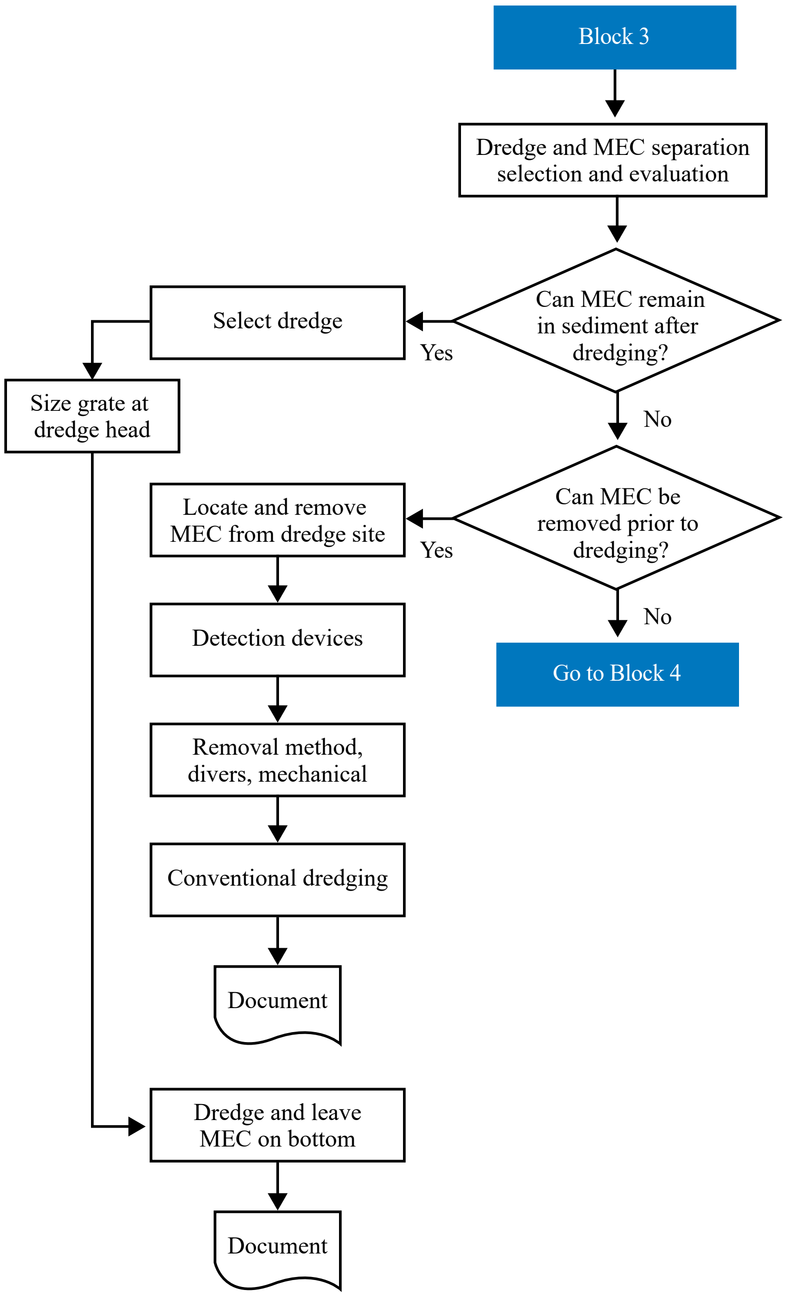
MEC DREDGING PROJECT PLANNING FLOW CHART



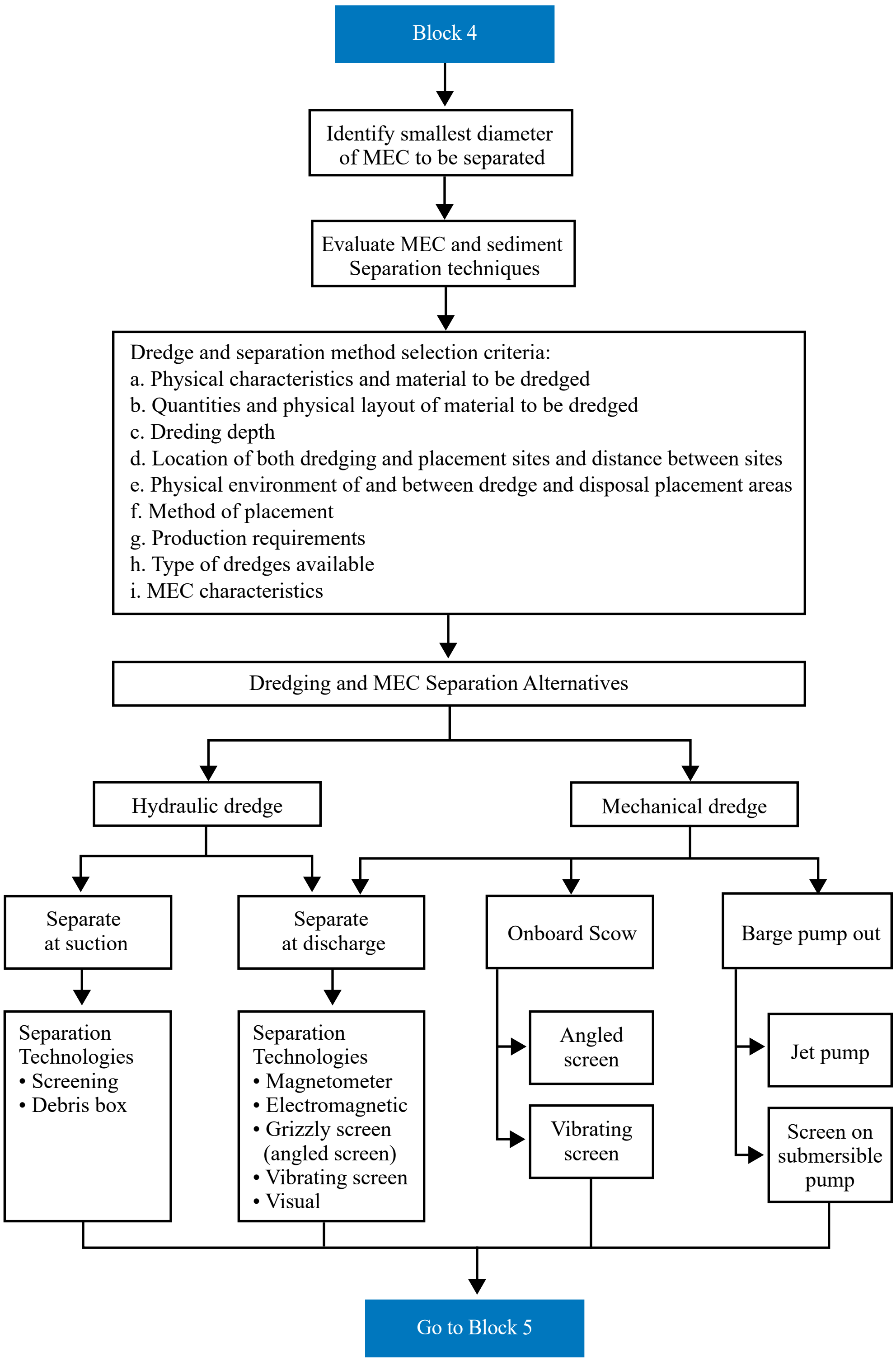
BATTELLE	MEC Dredging Project Planning Flow Chart	FIGURE A-1	MEC Sediment-02



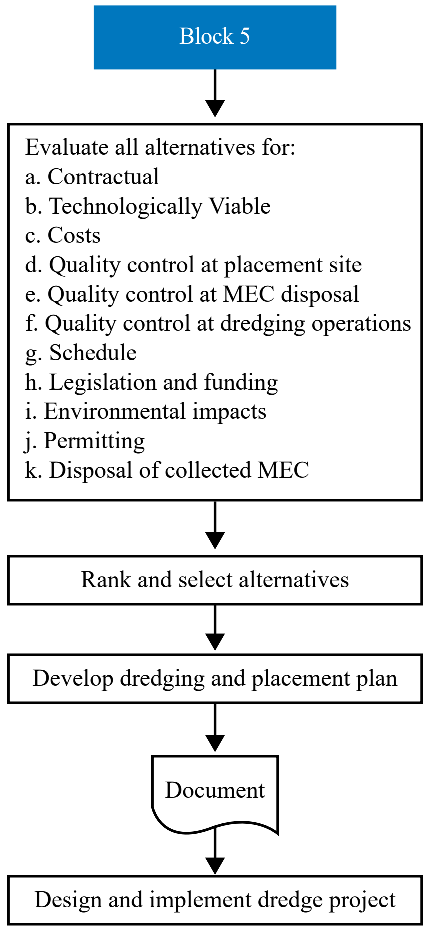
BATTELLE	MEC Dredging Project Planning Flow Chart	FIGURE A-2	MEC Sediment-02



BATTELLE | MEC Dredging Project Planning Flow Chart | FIGURE A-3 | MEC Sediment-02



BATTELLE	MEC Dredging Project Planning Flow Chart	FIGURE A-4	MEC Sediment-02

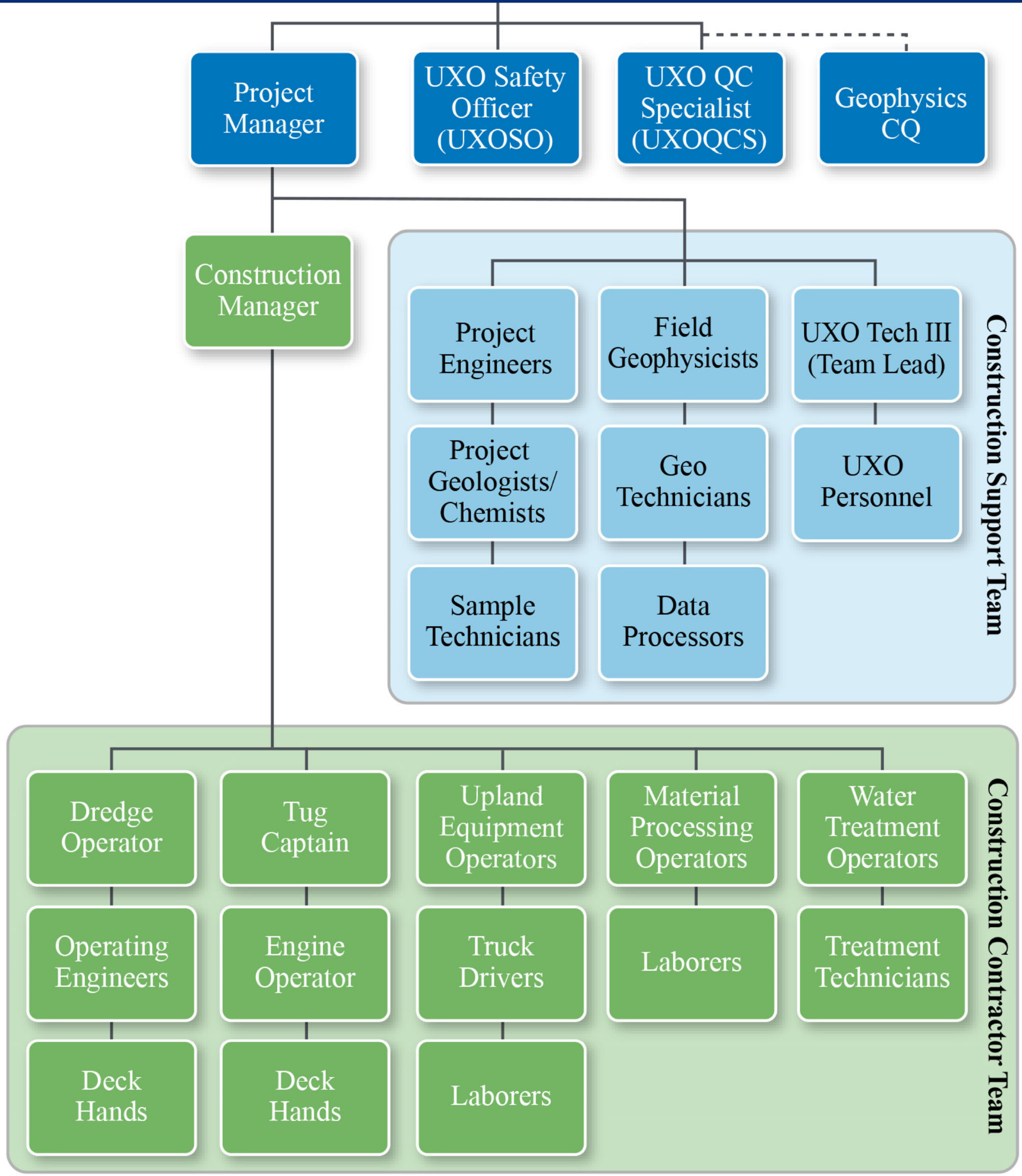


Note: These flow charts were adapted for NAVFAC from Welp, T., G. Follett, M. Crull, and C. Pollock. 2008. *Dredging in Sediments Containing Munitions and Explosives of Concern (MEC)*, ESTCP Project No. 200321, ERDC/CHL/TR-08-12, U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, August.

APPENDIX B

EXAMPLE MEC DREDGING PROJECT ORGANIZATIONAL CHART

Typical Dredging and Dredged Material Processing with MEC



BATTELLE

FIGURE B-1

MEC Sediment-01

APPENDIX C

MEC-RELATED PLANNING DOCUMENTS

CONTENTS

C.1 INTRODUCTION

This appendix describes the basic munitions and explosives of concern (MEC)-related planning documents that may be required for sediment dredging projects along with a basic outline of the content associated with each. The list and brief descriptions of the planning documents are not comprehensive or prescriptive, as each sediment dredging project is unique in terms of location; scope of work; type and quantity of MEC- and munitions-related material associated with the dredging site; stakeholders and regulators involved; and the type of dredging equipment used at the site. The location of the dredge project will impact the specific laws, policies and guidelines that may also influence the project, as well as any installation-specific guidance if the project site is located on an active Department of Navy Installation.

MEC-related plans covered in this section include the Explosive Safety Submission Determination Request (ESSDR), Explosive Safety Submission (ESS), MEC Work Plan, Contractor Standard Operating Procedures (SOPs), and MEC Safety Plan. In addition, information is provided on Dive Safety Plans as needed. These plans are typically standalone documents designed to complement other plans and documents but can be combined with other plans depending upon the project requirements defined by the DON Remedial Project Managers (RPMs), stakeholders, and regulators involved with the project.

C.1.1 Explosive Safety Submission Determination Request

The format for an ESSDR for Navy installations is provided in Naval Ordnance Safety and Security Activity (NOSSA) Instruction 8020.15 (series) and Marine Corps Order (MCO) 8020.10 (current version) for Marine Corps installations. The format for Navy and Marine Corps installations varies according to the referenced guidance, but general data fields and information required for an ESSDR include the following: site name, location, project points of contact, site history, MEC/material potentially presenting an explosive hazard (MPPEH) known or suspected at the site, description of activities, and likelihood of encountering MEC or MPPEH.

C.1.2 Explosive Safety Submission

The ESS shall be completed in accordance with NOSSAINST 8020.15 (Series)/MCO 8020.10, Enclosure (3)/MCO 8020.10 Appendix A "*Guide for Preparing an Explosives Safety Submission*." The format for Navy and Marine Corps installations varies according to the referenced guidance, but data fields and information required for an ESS include the following: site name; location; scope of operations; previous studies; types and quantities of MEC / MPPEH known or suspected at the site; munition with the greatest fragmentation distance (MGFD); maximum credible event; detection and navigation equipment, methods, and standards; exclusion zones; MEC and MPPEH transportation, storage, management, and final disposition procedures; quality assurance/quality control (QA/QC) measures; and environmental, ecological, cultural, and/or other considerations.

C.1.3 MEC Work Plan

A MEC Work Plan should be developed outlining the specific procedures and technical approach the UXO team will follow to screen for, recover, manage, and properly dispose of MEC, MPPEH, and munitions debris (MD). The exact content of the MEC Work Plan is tailored for the specific scope of the dredging project. A list of topics generally included in a MEC work plan includes:

- Site history and background
- MEC known or suspected at the site
- UXO Team (e.g., members, qualifications, roles and responsibilities)
- Geophysical survey and mapping of MEC pre- and post-dredging
- Site worker MEC awareness training
- Maps / site layout figures (e.g., maps showing ingress and egress routes, soil/sediment screening areas, explosive safety quantity distance (ESQD), collection points/MPPEH processing areas)
- Environmental sampling and analysis
- Explosives management procedures and protocols
- Engineering controls (e.g., screens, MEC baskets, grizzly screens) utilized to screen out oversized materials and MEC from sediment
- Sediment searching, scanning, and/or screening procedures
- Procedures for managing and disposing of MPPEH
- Procedures for MEC management and disposal

The items above only include MEC-related topics. Other non-MEC dredging-related activities (e.g., site surveys, permits, logistics, environmental protection, and dredge spoil staging and disposal) are covered in other plans and reports required for dredging projects.

C.1.4 Contractor SOPs

The UXO contractor performing the fieldwork should have corporate SOPs in place to perform the types of activities that will be required on a sediment support dredging project. Examples of SOPs include but are not limited to:

- SOP for MEC construction support including dredging operations
- SOP for screening / sifting soils and sediments for MEC, MPPEH, and MD
- SOP for conducting spread and scan searches of soils and sediment
- SOP for managing, inspecting, processing and safely disposing of MPPEH
- SOP for demolition operations for MEC and material documented as hazardous (MDEH)
- SOP for commercial demo explosives receipt, management and use
- SOP for explosives storage
- SOP for UXO personnel (e.g., screening, qualifications, and training requirements)
- SOP for QC of MEC operations

C.1.5 MEC Safety Plan

EM 385-1-1, *Safety and Health Requirements Manual*, outlines the safety requirements including the requirement for a site Accident Prevention Plan (APP). Depending upon the size, scope and complexity of operations, multiple safety plans covering various activities/specialties (e.g., survey, tug operations, explosives) and/or sub-sections of the overall site APP may be required. The following is a list of items that should be considered when developing the MEC Safety Plan either as a standalone document or a sub-section to the overall site APP:

- MEC hazards (specific to the types of munitions known or suspected at the site)
- Personal protective equipment (PPE) for UXO personnel
- UXO personnel qualification and training requirements
- Medical surveillance requirements for UXO personnel
- Safe work practices
- Exclusion zones / arcs
- Site control measures and communications
- Emergency equipment and first aid requirements
- Emergency contacts and notification procedures
- Accident / incident reporting
- Directions to hospital and nearest medical facility
- Completed activity hazard analysis (AHA) and/or job safety analysis (JSA)

If MEC safety is documented in a separate plan, authors should ensure that the elements of the plan do not contradict the safety procedures and protocols in the overall site APP.

C.1.6 Dive Safety Plan

When conducting underwater investigation activities, additional dive safety requirements must be considered. NAVFAC or the Field Engineering Command (FEC) District Diving Coordinator must review and approve all dive safety plans per Business Management System F-12.17.10 Contract Dive Safety Oversight Program. The following is a list of references for developing a dive safety plan:

- Occupational Safety and Health Administration Code of Federal Regulations (CFR) 29 1910T
- Navy Dive Manual
- Applicable State Department of Labor requirements
- EM 385-1-1, Safety and Health Requirements (USACE, 2014; contractor diving operations)

The requirements for the dive safety plan depend upon whether government or contractor divers will be utilized. OPNAVINST 3150.27C addresses Navy diving policy. A qualified Dive Safety

Inspector or District Diving Coordinator must monitor contractor diving operations. Also, the most current version of these manuals must be used.

C.2 REFERENCES

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APPENDIX D

DREDGING COST ESTIMATES

CONTENTS

TABLES

D.1 INTRODUCTION

This appendix describes the process for developing capital cost estimates for sediment dredging at sites with munitions and explosives of concern (MEC). Dredging, dredged material processing and disposal costs are discussed. Capital cost is construction cost plus non-construction costs (e.g., planning, investigations, permitting, design, construction oversight and reporting). This appendix presents typical costs for navigation and environmental dredging and shows the impact of MEC materials on those costs. Several site-specific factors have major impacts on costs and must be evaluated for each site to develop costs for a specific project.

D.2 TYPES OF ESTIMATES

As described in Rosengard et al. (2008), different methods are used to estimate costs during planning phases of a construction project. These methods are shown in Table D-1, along with descriptions and limitations for each method.

Table D-1. Types of Cost Estimates for Project Planning

Type of Estimate	Description	Limitation
Analogy	Compare current project with past projects	Difficulty finding truly comparable projects. Does not quantify impacts of site-specific conditions.
Parametric	Use costs related to design parameters and mathematical algorithms	Requires large database to derive relationships between parameters and costs. Does not quantity impacts of some site-specific conditions.
Build-Up	Estimate quantities and develop site-specific unit costs to build up total cost from sum of each activity	Requires the most time to prepare estimate. Estimates prepared in planning phase requires input from experts in planning, permitting, risk management, design and construction.

Analogy and parametric cost estimates are applicable to projects that are built frequently using standard practices. Residential housing construction is an example of the type of project where these estimates work well. Unit costs, such as cost per square foot of floor area, can be back calculated from past projects and used to prepare planning level estimates for future projects.

Analogy and parametric cost estimating works for routine navigational dredging projects, especially in areas of the country where dredging is frequently implemented. These types of estimates are less accurate for environmental dredging because project-specific factors can produce a wide variation in unit costs. The additional costs resulting from the presence of MEC would have to be accounted for separately through previously awarded contracts and/or other methods as described below. For example, the Munitions Response Workgroup has prepared an underwater Remedial Investigation/Feasibility Study (RI/FS) cost estimating tool, which is a user-friendly Excel program that contains modifiable fields to fit site-specific requirements. More information on the worksheets included in the underwater site RI/FS cost estimating tool is provided in the NAVFAC Munitions Response RI/FS guidance (NAVFAC, 2019).

If analogy type estimates are made, the costs are assumed to be the same as long as major scope items are the same (i.e., if the dredge volume is unchanged, then the costs are assumed to be the same). If parametric type estimates are made, costs are assumed to be the same, as long as dredge volume is the same.

The recommended method for estimating capital costs on MEC dredging projects is the build-up method. This should be started at the conceptual or planning phase and updated throughout the subsequent phases of work through completion of construction. The presentation by Carscadden, et. at. (2015) described how estimated costs for dredging projects often increase as the project moves from planning to construction stages.

D.3 FACTORS THAT AFFECT COSTS

Papers by Rosengard et al. (2008), and Otten (2015) describe factors that impact cost and schedule for dredging projects. These factors are summarized here because costs cannot be estimated unless the impacts of site-specific factors are understood and can be quantified.

The factors that have the most impact on project cost can be divided into two groups: site-specific sediment and waterbody features; and project-specific conditions, requirements or constraints. The factors are listed in Tables D-2 and D-3 and discussed in the text following the tables.

Table D-2. Sediment Factors that Affect Costs

Cost Factors	Description
1. Quantity & Type of MEC	The quantity and type of MEC in sediment to be dredged has a significant impact on dredging, transport, processing and disposal. Other types of debris also have a significant impact on dredging projects.
2. Sediment Type	The physical properties of sediment that will be dredged have significant impacts on material transport, dewatering, disposal and potential for beneficial use.
3. Chemical Concentrations and Regulatory Classification	Chemical concentrations in dredged material impact all aspects of material processing, not just ex situ disposal. In the U.S., all contaminated materials that are taken off site must be designated under various regulatory programs for transportation and disposal of materials that contain hazardous substances.
4. Volume of Dredge Material or Cap Area	The unit cost for disposal of dredged material depends on the volume of material to be processed.

Table D-2 (continued). Sediment Factors that Affect Costs

Cost Factors	Description
5. Water Depth and Currents	Water depth directly impacts the type of equipment that can be used to excavate, dredge or cap contaminated sediment.

Table D-3. Project and Site Factors that Affect Costs

Cost Factors	Description
6. Remedial Action Level	Lower remedial action levels will generally increase costs because it is more difficult to achieve lower action levels through dredging.
7. Schedule and Allowable Workdays and Work Hours	Project costs typically increase if the schedule requires work at an accelerated rate or if the schedule requires work over multiple years. Restrictions on work hours or work seasons may have a significant impact on costs.
8. Site Access & Upland Support Area	Public concerns often impact cost due to restrictions or added requirements.
9. Community Concerns	Public opinions and concerns can impact costs when additional measures are required to address real or perceived environmental impacts from the work.
10. Contract Method	The method of selecting and paying contractors impacts the cost and schedule.

1. Quantity & Type of MEC. The quantity and type of MEC in sediment to be dredged has a major impact on dredging, transport, processing, disposal and the ability to make beneficial use of dredged sediment. Theses impacts are discussed in more detail below. In summary, the presence of MEC will increase costs and cause schedule delays due to:

- Added time for planning, investigations, design and construction,
- MEC generally results in slower dredging, which increases costs and completion time,
- MEC generally requires more dredged material processing, which may be the limiting factor in dredge production rate, which increases costs and completion time,
- MEC requires additional staff with munitions expertise, which increases the daily crew costs.
- MEC may need to be removed prior to dredging, which adds to construction time.

2. Sediment Type. Sediment type impacts every step of dredging and dredged material processing including sediment removal, water quality impacts, dredged material dewatering, water treatment, beneficial reuse, and disposal. Sediment properties that are most useful to evaluate impacts are particle size distribution, water content (or percent solids), organic content, Atterberg Limits and presence of separate-phase oil.

3. Chemical Concentrations and Regulatory Classification. The chemical concentration in the sediment impacts every step in the dredging process. If there are high levels, containment around the dredge may be required to protect surface water quality, which adds direct costs and slows dredge production. Chemical concentrations affect the treatment of dredge return water. For example, if chemical concentrations are low, it may be permissible to allow overflow from hopper barges without treatment. However, if the material has high contaminant concentrations or is designated as hazardous waste, then regulatory agencies may prohibit any overflow without treatment and may require water treatment prior to discharge.

Designation of dredged material as hazardous or non-hazardous impacts processing, transport, storage and disposal of dredged sediment and dredge return water.

4. Volume of Dredge Material or Cap Area. Variation in dredge material volumes impacts cost of dredging projects more than typical upland construction projects due to the relatively high cost of equipment mobilization and temporary material processing facilities. The unit cost for smaller projects may be high due to the relatively high costs of mobilization, equipment assembly and demobilization required for dredging and dredged material processing equipment.

5. Water Depth and Currents. The depth of water affects the type and size of marine equipment that can be used for dredging. If the water is shallow, it may be feasible to work in the "dry" by diverting water or installing cofferdams. If the water is deeper than about 3 meters, large marine equipment can be used which provides for higher production rates.

Shallow water depths of 1 to 3 meters are the most difficult and expensive condition for dredging projects. This depth range is too shallow for efficient marine equipment and it may be expensive to divert or pump water to allow excavation using the "dry" approach.

Water currents due to river flow or tides also impact dredge costs. Special operating methods are required to work in flowing water and additional equipment may be needed to perform the work safely.

6. Remedial Action Level. For dredging projects, lower remedial action levels may require special equipment and precision dredging, which is generally slower than navigational dredging. Dredging to deeper depths and residual dredging (i.e., re-dredged areas in thin layers) may be required to achieve required remedial action levels. Lower remedial action levels generally require more water treatment prior to return of the dredged water back to the surface water body.

7. Schedule and Allowable Workdays and Work Hours. If the required schedule is short, multiple dredged sessions may be required to meet deadlines. Restrictions on work season (e.g., fish spawning or migration windows) generally increase costs due to additional mobilizations and premium costs for seasonal work. It is common for marine work to be done 24 hours per day, 6 days per week. If night or weekend work is restricted, daily production rates will be lower and costs may be higher.

8. Site Access and Upland Support Area. Dredging and dredged material processing require upland support areas for docking barges and personnel vessels, dredged material processing, stockpiling and water treatment. For sites with MEC, additional area is needed to provide adequate safety zones around MEC handling and storage areas.

Unlike navigation projects, many contaminated sediment projects are performed in lakes, rivers or inlets where access from the water is limited. In some cases, all water-borne equipment must be delivered to the site by truck and subsequently assembled as part of mobilization. Lack of a suitable construction area and/or facilities can increase costs for items such as temporary docks and equipment maintenance sites.

Lack of material processing space and time for ex situ treatment may dictate the use of more expensive mechanical dewatering processes and water treatment systems. Although mechanical dewatering (e.g., belt press, plate and frame press, or centrifuge) methods are effective for most sediment types, they are more expensive than passive dewatering methods (e.g., geotextile tubes, confined disposal facilities, hydrocyclones, and frac tanks).

9. Community/Stakeholder Concerns. Public opinions and concerns can impact costs when additional measures are required to address real or perceived safety or environmental impacts from the work. Key stakeholders include environmental groups, local business organizations and residential neighborhood groups. Additional measures may be required to address stakeholder concerns. Examples of additional measures include:

- Odor control,
- Limits on transport truck operating hours,
- Noise and light limits,
- Additional water quality protection.

10. Contract Method. The method of selecting and paying contractors impacts cost and schedule. Contracting approaches that work well for navigational dredging and marine infrastructure projects may not be optimal for MEC or environmental work. Common contract methods are:

<u>Owner-led Method.</u> This is a common and traditional method to perform project work from planning through construction. The owner (in this case the Government) selects and contracts with consultants and construction contractors to perform defined scopes of work. The owner is responsible for managing each contract and manages the overall project schedule. The contracts may use different methods of payment for the work. The common methods are lump sum, unit price and cost reimbursable (e.g., reimbursable with incentives or time and materials). These are discussed in more detail below in Section D.5.

Design-build Method. In this method, the owner (e.g., the Government) has one contract with a company that provides all work except tasks that require a subcontract with specialty firms. Advantages of this method are:

- One company is responsible to the owner for all phases of work. This eliminates risk to the owner of gaps or duplication between prime contracts and eliminates risk of disputes between individual prime contractors,
- Requires less management and coordination of day-to-day tasks by the owner,
- Potentially faster schedule and lower costs because one company can efficiently manage resources and sequence work efficiently.

D.4 ESTIMATING COSTS FOR DREDGING WITH MEC

This section presents guidance for preparing capital cost estimates for dredging projects with MEC. Examples are provided of typical construction costs for dredging sites without MEC and a discussion is provided regarding how the presence of MEC impacts costs.

D.4.1 Typical Costs without MEC

Construction costs for dredging, dredged material processing and disposal are usually presented in terms of unit price per in-situ cubic yard (cy) of material dredged. Two common dredging project scenarios include navigational dredging and environmental dredging projects. There is a wide range in unit costs for dredging and disposal. The range for dredging and disposal ranges from less than $25/m^3 ($20/cy) to more than $1,000/m^3 ($1,300/cy).

In order to understand the reasons for the wide range in unit price, it is helpful to look at a high-cost scenario and a low-cost scenario (Otten, 2015) as shown below:

High Cost Scenario:

- Sediment classified as the Toxic Substances Control Act (TSCA) Hazardous Waste
- Off-site landfill disposal (add $150 to $200/m^3)
- Site features (limited site access and shallow water)
- Hydraulic dredging and sediment dewatering - water treatment requirements
- Unit cost $50,000 per day / 200 m^3/day = $250/m^3 for removal and processing only
- Total = $400/m^3 or more

Low Cost Scenario

- Disposal in on-site confined aquatic disposal (CAD)
- Dredged 300,000 m^3 in one season
- Production 4,000 m^3 per 24-hour workday
- Large equipment and placement in disposal cell

- Unit cost \$50,000 per day / 2,000 m^3 = \$25/m^3 for removal and disposal

D.4.2 Added Costs with MEC

This section describes how the presence of MEC impacts capital costs for a dredging and dredged material disposal project. The presence of MEC will increase costs and cause schedule delays due to factors such as:

- MEC requires additional staff with munitions expertise, which increases pre-construction costs for planning, permitting and design. This increases construction costs due to the added labor cost for dredging, dredged material processing and dredged material disposal,
- Added time for planning, investigations, design and construction,
- MEC generally results in slower dredging, which increases costs and completion time,
- MEC generally requires more dredged material processing, which may be the limiting factor in dredge production rate, which increases costs and completion time,
- MEC may need to be removed prior to dredging, which adds to construction time.

Labor costs are one of the major cost items for dredging projects. Appendix B shows a typical project organization and staffing chart for dredging projects. For construction in a low-cost scenario, there would only be a Dredge Operator Crew and Tug Captain Crew. For environmental dredging projects, there would typically be added crews for upland processing and water treatment.

When MEC materials are present, additional UXO teams would be required. There may be dredge projects where multiple UXO teams are needed to work on the dredge, in the upland processing area, and to handle MEC storage and disposal. Additional project support teams may be required to locate MEC prior to dredging, to confirm that all MEC has been removed from the dredge area, and to provide quality control and quality assurance for upland processing.

Equipment costs are another major cost item for dredging projects. When MEC is present, there may be added costs for items such as:

- Blast protection and screening on the dredge
- Blast protection and screening on and around upland processing equipment
- Magazines for temporary storage of MEC
- Equipment to process dredged material to separate MEC from sediment and other debris
- Magazines and equipment to conduct disposal/demolition operations of MEC found
- Material handling and disposal charges related to managing MPPEH to include inspecting, certifying and verifying MPPEH as material documented as safe (MDAS) or material documented as an explosive hazard (MDEH) and disposing of the material accordingly.

The increase in cost for handling MEC would typically be a higher percentage for navigational projects than for environmental projects. The high-cost and low-cost scenarios shown above will be used to illustrate the potential impact of MEC on construction costs.

In the low-cost scenario example, the daily crew costs may rise from \$50,000 to \$75,000 per day with the added labor and equipment. However, a larger cost impact would typically be the result of lower production. In the example shown above, the dredge production rate could be reduced from 2,000 m^3 per day to 500 m^3 per day (or even less in some cases) when there is MEC in the sediment. With a higher daily cost and lower production, the unit price could increase from \$25 to \$150/m^3.

In the high-cost scenario, the daily crew cost could rise, but the impact on production rate would be less. The high-cost example shown above used a low production rate of 200 m^3 per day. The production rate may not change with the presence of MEC. In this scenario, the unit price for dredging and disposal would increase from \$250/m^3 to \$375/m^3 due to the added daily cost.

D.4.3 Preparing Site-Specific Estimates

Conceptual, planning and budget level estimates of construction costs should be completed using the same methods and major categories as used for engineers' estimates during final design. Preparation of an estimate of non-construction cost based on the requirements of regulations and procedures should be completed as described in this guidance document and summarized in the flow chart in Appendix A. See Otten (2017) for additional information on preparing build-up estimates. At the conceptual phase, a build-up estimate should be developed as follows:

- Quantify all known elements of the project,
- Use judgement and experience to quantity methods, equipment and expert labor required to safely handle, process and dispose of MEC material,
- Use judgment and experience to quantify temporary facilities and make reasonable estimates of what will be needed to implement the remedy,
- Do not use traditional or previously used cost percentages for items such as indirect field costs, mobilization, design and pre-design investigation.

A build-up estimate can be developed at the planning or conceptual phase of a project by a team of experts in MEC handling permitting, regulatory requirements, design and construction. The factors described in this paper should be used to identify and quantify the work items that will be required to perform MEC handling and dredging.

At the planning phase, there will be project execution items where details are unknown. For these items, an experienced team of experts is needed to make realistic assumptions of all items that will be required. These assumptions should be used to quantity all work items. Examples of specific requirements that impact costs and schedule are:

- Blast protection on dredging and dredged material processing equipment,
- Added UXO crews to support dredging and dredged material processing,

- Added storage and disposal for MEC,
- Added construction support for quality control and quality assurance of the MEC work,
- Temporary access roads and work areas that need to be constructed prior to the start of dredging,
- Turbidity curtains or sheet piles around the work area to protect water quality,
- Temporary buildings to contain sediment processing operations for air quality protection,
- Treatment of water that separates from the dredged sediment prior to discharge to a surface water body.
- Disposal of MEC, debris and sediment,

D.5 CONTRACTING CONSIDERATIONS FOR DREDGING WITH MEC

Several contracting approaches can be used for measuring performance and funding dredging construction contracts. The most common methods are: (1) firm fixed price contracts (i.e., unit price per in-situ cubic yard dredged, or lump sum; and cost reimbursable contracts (i.e., time and materials or reimbursable with incentives). This section describes advantages and disadvantages of various contracting methods as applied to dredging projects with MEC.

Firm Fixed Price Contracts. Fixed price contracts are those that pay the contractor a fixed price for completed tasks specified in contract documents. The most common are lump sum and unit price contracts. Under fixed price contracts, the contractor is paid the contract amount for completion of specified tasks. In lump sum contracts, payment is made for completion of the work defined by the contract. In unit price contracts, payment is made at the contracted rate for the actual quantities of work completed.

For traditional navigation projects, the unit price per volume removed is a good choice and is the most common method used (Webb, 2009). One reason unit price per volume removed works well for traditional navigational dredge projects is because it provides the contractor motivation to perform in a way that also meets the primary objectives of the owner. These same advantages apply to lump sum contracts. Some common objectives include:

- The traditional unit price contractor motivates the contractor to remove sediment as fast as possible without leaving high spots.
- In order to meet the specifications at the lowest cost, it is common for dredge contractors to over-dredge below the allowable over-dredge depth given in the contract.
- This extra dredging actually benefits the owner because they get deeper water for the ship traffic. Extra dredging is acceptable to the permit agencies as long as the total volume is within the volume authorized by the project permits.

There is no motivation for customer service, since neither payment for the current work nor potential selection for future work depends on level of service. Fixed price contracts are appropriate for work where there are multiple qualified contractors who have experience with numerous past projects that are similar to the current contract. Navigational dredging is an example where this type of contract is appropriate. This type of dredging is routinely performed and contractors have the experience necessary to be able to prepare accurate bids for future work.

Fixed price contracts work well when the owner's primary objective is to complete the work at the lowest cost and as soon as possible. They can expect that the contractor will provide the minimum quality and service required to complete the work. The contractor is motivated to work as fast as possible with the least expensive materials because they benefit if the actual costs are less than they estimated and could lose money if the actual costs are higher than they estimated.

Cost Reimbursable Contracts. Reimbursable contracts are those that pay the contractor actual costs for performing work described in contract documents. The contracts typically include details on what will be paid, the rates for payment, and payment for indirect cost items. Reimbursable contracts are appropriate for work when there are few qualified contractors who have experience with similar past projects. They are also appropriate when it is not possible to accurately define the scope of work for a project.

With reimbursable contracts, the contractor is paid for actual costs, so the owner benefits if the actual costs are less than estimated but pays more if the actual costs are higher than estimated. There are different types of reimbursable contracts. Time and material contracts simply pay the actual costs using rates that include overhead and profit. Another type of reimbursable contract pays direct costs only plus a fixed amount for overhead and profit. A third type of contract includes reimbursable contracts with incentive provisions. These pay direct costs plus added fees based on meeting performance objectives. The objectives can be financial but can also be for safe work or for exceeding other performance criteria.

When working under reimbursable contracts with incentives, the contractor's managers and staff are motivated to provide responsive service that meet the owner's objectives, perform the work safely, follow the owner's procedures, meet all environmental regulations and permit requirements, complete the work on schedule and perform the work within the authorized contract amount. Incentives motivate the contractor's performance, so that they receive high ratings and future work. The contractor's managers and staff are also motivated to provide responsive service under reimbursable contracts because future work is usually dependent on meeting or exceeding the project's performance criteria. If there are no incentives in the contract, there is less motivation to meet all of the owner's objectives and less motivation to control costs.

Table D-4 shows how the type of contact influences the contractor's priorities, which relates directly to performance.

The type of contract best suited for an individual dredging project with MEC depends on the situation, including the ten factors that affect costs listed previously. In addition, it is not possible to accurately determine the quantity of MEC items in the sediment prior to dredging. The investigation tools described in this guidance can detect metallic objects and can provide a general idea of the quantity, but do not provide enough information for accurate quantity determination.

For those sites with moderate to high potential for MEC, contracting methods should be selected that place high priorities on working safely, protecting the environment, and ensuring complete removal and proper disposal of MEC items. The contract also needs to provide flexibility to manage unknown quantities of MEC and the potential for unknown types of MEC. In this situation, a reimbursable contract with incentives is the recommended approach.

Table D-4. Contract Types and Contractor Priorities

Payment Measurement and Method	Usual Selection Criteria	Contractor Priorities
Unit Price per Volume for Dredging and Disposal	Lowest Price, Technically Acceptable	• Complete work as fast as possible with lowest cost materials • Use lowest cost disposal allowed by contract • Minimize direct cost for dredge and disposal • Modifications required for changing field conditions and/or project assumptions • Control over means and methods • Less incentive to focus on client service, quality, or short-term impacts
Lump Sum	Lowest Price, Technically Acceptable	• Same as above
Time and Materials	Qualifications and Estimated Cost	• Incentive to keep owner satisfied to maximize income and for future contract potential • Willing to work slower, if needed, to meet owner's objectives for safety, quality of work, limiting short-term impacts. • Less incentive to focus on total cost, unless owner sets maximum total cost. • No contract modifications needed for changes in work
Reimbursable with Financial Incentives	Best Value based on Qualifications and Estimated Cost	• Work to meet contract objectives and goals to maximize financial incentive • Meet objectives for safety, quality and short-term impacts and also meet schedule and cost objectives • Negotiate revisions to project objectives and goals if scope of project changed

D.6 REFERENCES

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APPENDIX E

CASE STUDIES

TECHNICAL MEMORANDUM
APRIL 2019

DREDGING CONSIDERATIONS IN THE PRESENCE OF MUNITIONS AND EXPLOSIVES OF CONCERN

NAVAL BASE SAN DIEGO, CALIFORNIA

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4. TITLE AND SUBTITLE Sediment Dredging in Areas Known or Suspected of Containing Munitions and Explosives of Concern and/or Material Potentially Presenting an Explosives Hazard			**5a. CONTRACT NUMBER** N39430-16-D-1802 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Les Clarke, Battelle			**5d. PROJECT NUMBER** N3943018F4344 **5e. TASK NUMBER** ESTS Task Order 44 **5f. WORK UNIT NUMBER**
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ACRONYMS AND ABBREVIATIONS

AAR	After Action Report
AOPC	Area of potential concern
ARAR	Applicable or relevant and appropriate requirement
CDF	Confined disposal facility
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
cy	Cubic yard
DFW	Definable feature of work
DoD	Department of Defense
DR	Determination Request
EA	Environmental assessment
EMM	Earth moving machinery
ENV	Environmental
EOD	Explosive Ordnance Disposal
ESQD	Explosives Safety Quantity Distance
ESS	Explosives Safety Submittal
IRP	Installation Restoration Program
ISO	Industry standard object
IVS	Instrument verification strip
MDAS	Material documented as safe
MEC	Munitions and explosives of concern
MFL	Munitions found locations
MGFD	Munition with the greatest fragment distance
MILCON	Military construction
MLLW	mean lower low water
mm	Millimeter
MPPEH	Material potentially presenting an explosive hazard
MRP	Munitions Response Program
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBSD	Naval Base San Diego
NEPA	National Environmental Policy Act
NFA	No further action
O&M	Operation and maintenance
OP 5	Ordnance Pamphlet 5
OU	Operable Unit
PA	Preliminary Assessment
QA	Quality Assurance
QC	Quality control
SI	Site Inspection
SOW	Scope of Work
SUXOS	Senior UXO Supervisor
USACE	United States Army Corps of Engineers

USEPA	United States Environmental Protection Agency
UXO	Unexploded ordnance
UXOSO	UXO Safety Officer

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1.0 INTRODUCTION

In 2012, a military construction (MILCON) project was conducted to upgrade the pier infrastructure at Naval Base San Diego (NBSD), California to support modern Navy ship classes with deep draft or power intensive requirements. This case study summarizes the impact of the presence of munitions and explosives of concern (MEC) and material potentially presenting an explosive hazard (MPPEH) on NBSD's MILCON and operation and maintenance (O&M) dredging activities. Lessons learned are also summarized in relation to subsequent Navy dredging activities within San Diego Bay, as well as the implications for broader decision-making related to Navy dredging programs.

2.0 BACKGROUND

MILCON Project P327 at NBSD involved several elements as follows:

1. demolition of an inadequate existing pier (Pier 12);
2. dredging in berthing and approach areas for a new pier;
3. disposal of dredged material at an approved ocean disposal site and a permitted upland landfill;
4. construction of a new pier and associated pier utilities, including upgrades to the electrical infrastructure at the adjacent Pier 13; and
5. re-use of demolition concrete to create fish enhancement structures (artificial reefs).

Dredging to a depth of -37 feet mean lower low water (MLLW) in berthing and approach areas for the new Pier 12 was estimated to generate 442,073 cubic yards (cy) of dredged sediments. Based on sediment testing, up to 389,546 cy of dredged material was assessed as suitable for disposal at a designated open ocean disposal site, whereas 52,527 cy was assessed to require upland disposal at a permitted landfill.

3.0 SITE CHRONOLOGY

Routine military activities involving munitions have occurred within San Diego Bay since the early 1900s. NBSD was officially established in 1922 as a destroyer base. These munitions activities included loading and unloading of munitions at piers and mooring points within the Bay and training activities in and around the Bay. Figure 1 shows the locations of historical training in San Diego Bay. Training included torpedo ranges, amphibious landing training areas, depth charge training areas, and flight operations with weapons-carrying aircraft.

The MILCON dredging project was initiated in 2012 to demolish Pier 12 at NBSD. NBSD Pier 12 is located on an active Navy installation that has been in operation for over 90 years. The project site is within the boundary of Munitions Response Program (MRP) Site 100 – San Diego Bay Primary Ship Channels. The primary ship channels comprise the areas that are or were charted and marked with buoys, ranges or other navigational aids and includes the areas immediately around Navy piers and quay walls. Figure 2 shows the location and extent of MRP Site 100 and provides detail on the dates and locations where historical maintenance dredging has occurred, where dredge fill was used to build up areas adjacent to the Bay, and the locations of historical munitions finds.

In September 1997, munitions were discovered on an Oceanside, California beach that was receiving dredge material from the San Diego Bay primary ship channel. The munitions were determined to be military and ranged in size from small-caliber munitions to 81-millimeter (mm) mortars. The Navy responded by initiating an investigation under its Installation Restoration Program (IRP).

A Preliminary Assessment (PA) was completed in 2001 (*Final Preliminary Assessment of Munitions in San Diego Bay Primary Ship Channels and U.S.S. Stennis Beach Replenishment Areas* [DON, 2001]). The PA identified 28 Areas of Potential Concern (AOPCs) within the study area and two AOPCs outside the study area. The PA also listed 61 munitions found locations (MFLs), which were independent of the AOPCs. The PA recommended that time-critical or emergency removal actions were not warranted based on the information uncovered during the PA. The PA did recommend that an overall Operable Unit (OU) be established to address munitions in San Diego Bay and that additional actions under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) be initiated in the San Diego Bay primary shipping channels. MRP Site 100 comprises that overall OU. The CERCLA process was moved ahead to the Site Inspection (SI) phase and the program was moved from the IRP into the Navy's MRP.

In 2010, a Phase I SI Report was finalized (DON, 2010). Phase I was to conduct additional analysis on the Final PA to assess the likelihood of munitions to persist in the AOPCs and MFLs. A second objective was to analyze the historical dredge and fill records to determine the potential for munitions to have been removed, leaving the MFLs subject to a no further action (NFA) recommendation. The objective for Phase II of the SI was to determine, using geophysical and visual assessments, the presence, potential presence or suggested absence of munitions in San Diego Bay as identified in the Final PA and refined in the Phase I SI. The Phase I analysis resulted in the following:

- 25 MFLs recommended for NFA
- 3 AOPCs recommended for NFA
- 37 MFLs recommended for Phase II SI
- 27 AOPCs recommended for Phase II SI

The Phase II SI Report was finalized in 2015 (DON, 2015). The Phase II geophysical and visual investigations were inconclusive such that a determination of the suggested absence of MEC/MPPEH could not be made. Two groupings of individual MFLs residing in close proximity were consolidated such that 50 sites were recommended for Phase II investigation coming out of Phase I and 50 sites were recommended for further evaluation under CERCLA after Phase II.

In 2011, the Final Environmental Assessment (EA) was prepared by the Navy for P327, independent of the CERCLA MRP investigations. Its purpose was to address the requirements of the National Environmental Policy Act (NEPA) of 1969, 42 United States Code §§ 4321-4370d, as implemented by the Council on Environmental Quality Regulations, 40 Code of Federal Regulations Parts 1500-1508. The EA evaluated the potential effects of the proposed action on the following resource areas: topography, geology/soils, and seismicity; water resources; air quality; marine sediments, bathymetry and water quality; marine biological resources and essential fish habitat; terrestrial biological resources; land use; socioeconomics; transportation; noise; aesthetics and visual resources; cultural resources; public access; safety and environmental health; and utilities. As noted below, the EA did identify the potential for MEC/MPPEH as a safety and environmental health concern.

The possibility of encountering munitions was first considered in the Final EA for the MILCON project published in July 2011 and provisions to address that possibility were required (e.g., Explosives Safety Plan).

> *"A safety and environmental health concern associated with dredging bay sediments is that munitions may be present, which could represent an explosive safety hazard. However, this concern would be minimal because the potential hazard can be effectively managed by setting up and following explosive safety procedures to train and protect workers. Safety hazards from munitions in dredged sediment would be addressed by training the on-site dredge project workers. Explosive Ordnance Disposal Units are the Navy experts for disposal of waste military munitions. For dredging projects, Explosive Ordnance Disposal technicians would train on-site workers to recognize and identify different types of ordnance and to observe explosive safety standard operating procedures. In addition, an explosive safety plan would be developed and implemented, assuring that all explosive safety standards of DoD Directive 6055.9, "DoD Ammunition and Explosive Safety Standards," are upheld. If unexploded ordnance is encountered during dredging, the construction contractor must stop work and report the situation to the Commanding Officer of the Naval Ordinance [sic] Safety and Security Activity and to the NBSD Safety Officer."*

Work in the confined disposal facility (CDF) to spread, dry, stockpile and process the spoils for upland disposal began in 2012 but was stopped soon after because MEC/MPPEH was found. The discovery of MEC/MPPEH triggered the requirement that an Explosives Safety Submittal (ESS) be prepared and implemented at the site. ESS approval and the restart of work occurred in 2014. Work stopped again in 2014 due to the finding of a radiological item (deck marker) in the dredged material at the CDF. Work restarted in 2015 and continued to conclusion in 2016 with an amended and corrected ESS and the required radiological safety and management documents in place. An After Action Report (AAR) was submitted in February 2017.

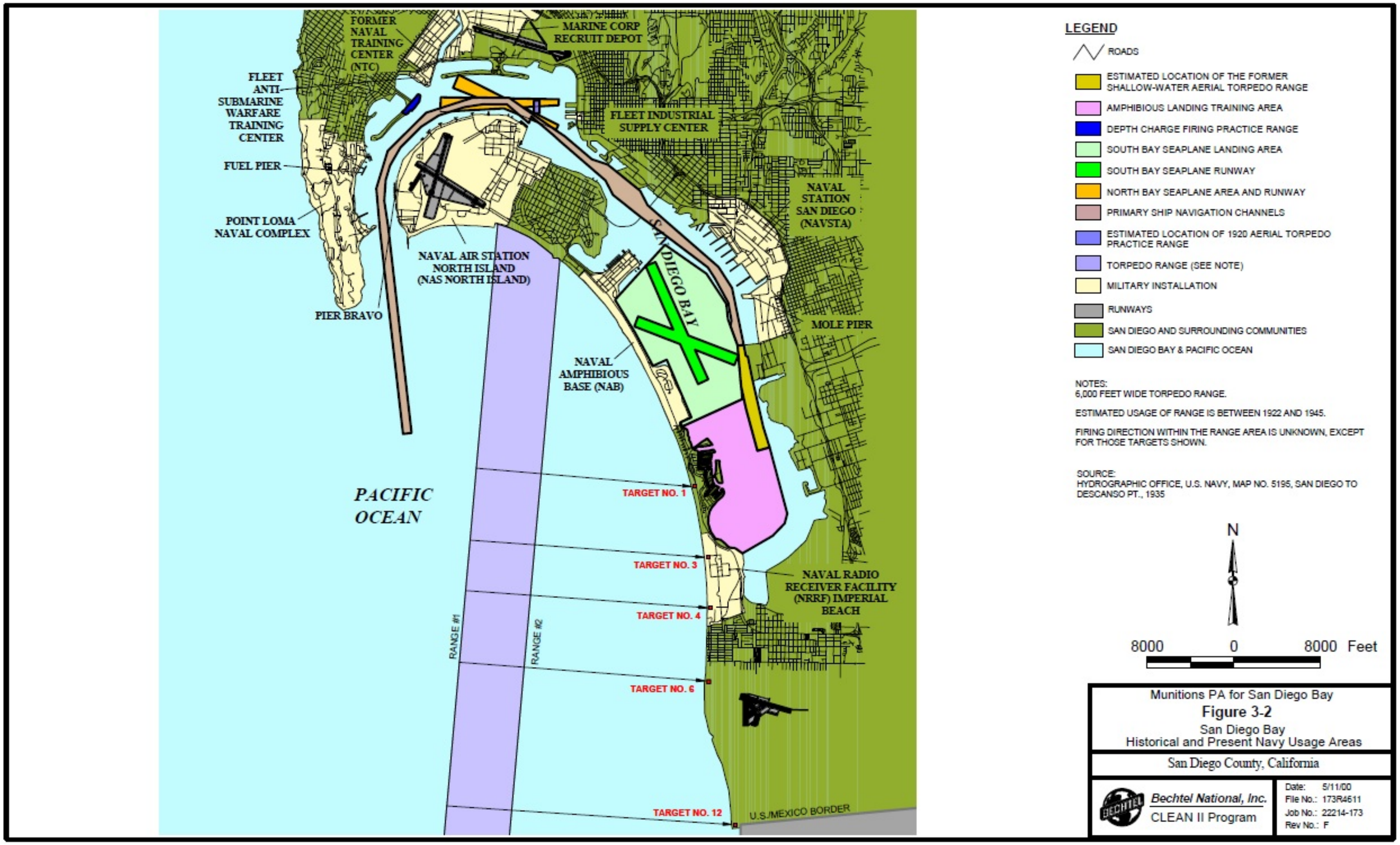

Figure 1. Historical Training Areas in San Diego Bay (Courtesy of NAVFAC)

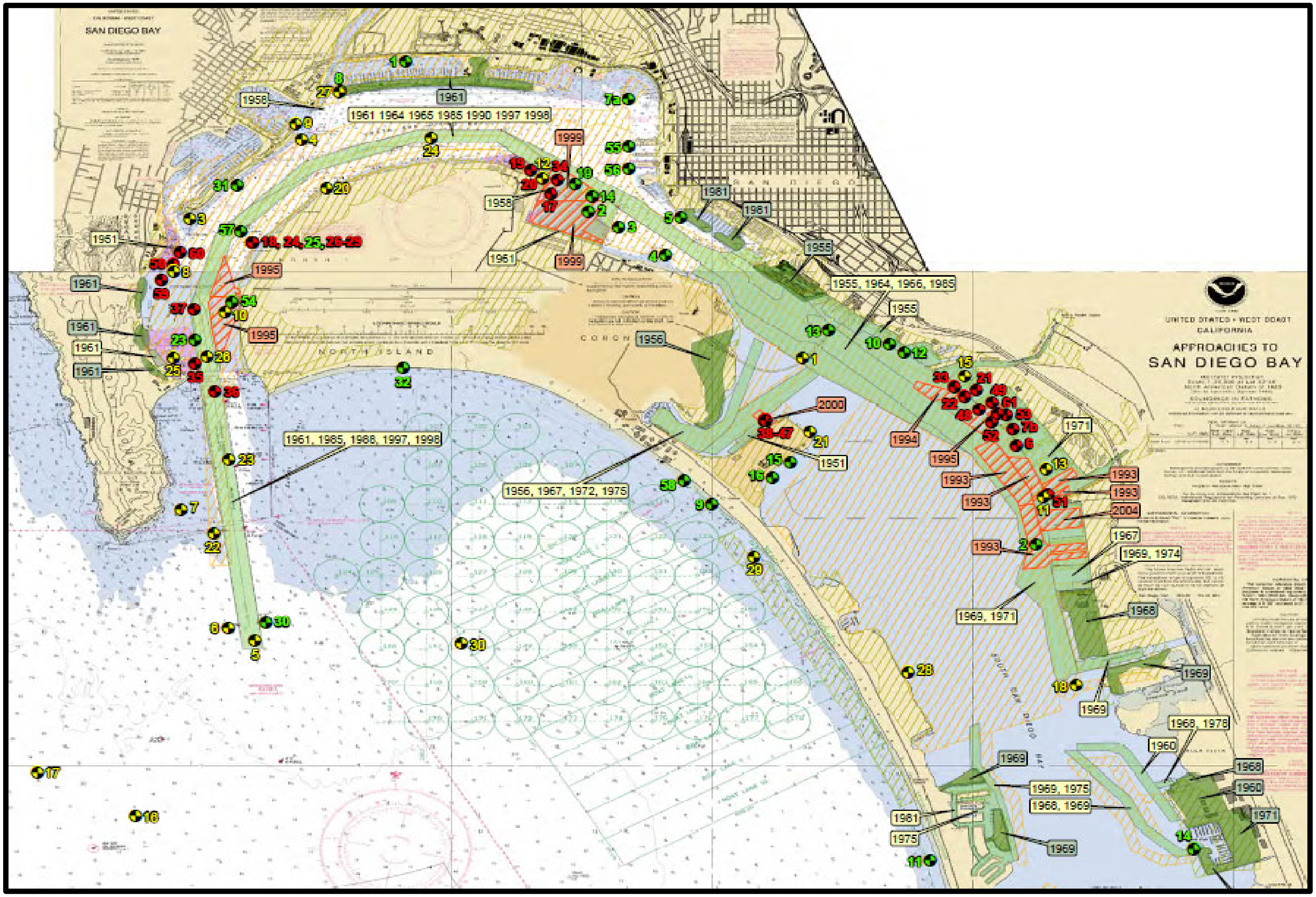

Figure 2. NBSD MRP Site 100 (Courtesy of NAVFAC)

4.0 TECHNICAL APPROACH

In 2010, the Navy conducted testing of the sediments proposed for dredging according to protocols in the United States Environmental Protection Agency (USEPA) and United States Army Corps of Engineers (USACE) Evaluation of Dredged Material Proposed for Ocean Disposal Testing Manual (known as the Green Book) (USEPA and USACE, 1991). Based on a review of the testing results, the bulk of dredge material, estimated at 389,546 cy, was determined to be suitable for disposal at the designated open ocean disposal site. The remaining 52,527 cy was determined to require staging, dewatering, drying and processing at the CDF to remove debris before being disposed in an upland landfill. Prior to discovery of MEC/MPPEH in the dredged material staged at the CDF, the dredged materials were stockpiled to dewater and dry. Then the gross debris was to be removed and the materials characterized and taken to an appropriate landfill.

After MEC/MPPEH was discovered in the dredged material, a technical approach that would address any of the munitions identified in the PA and SI was needed. These munitions ranged in size from 20 mm up to 81 mm. Constraints at the location of the CDF (e.g., explosives safety exclusion zones affecting adjacent facilities and infrastructure) restricted the practical size of munitions that could be reasonably addressed on shore to projectiles in sizes from 20 mm up to 5 inches (127 mm). Compounding the task of finding and removing MEC/MPPEH was the other debris in the dredged material (e.g., concrete, various sizes of metal, batteries, miscellaneous tools and equipment, cultural debris, etc.). As noted, radiological items were eventually identified within the dredged material along with asbestos and other hazardous materials.

The technical approach needed to reduce the possibility for oversized MEC/MPPEH (oversize based on explosives safety criteria) to arrive at the CDF. The solution chosen was to screen the spoils through a 300-mm (11.81-inch) screen at a minimum and, when possible, through a second 76-mm (3-inch) screen before loading into the receiving scow. Figure 3 illustrates the high-level concept of the operation.

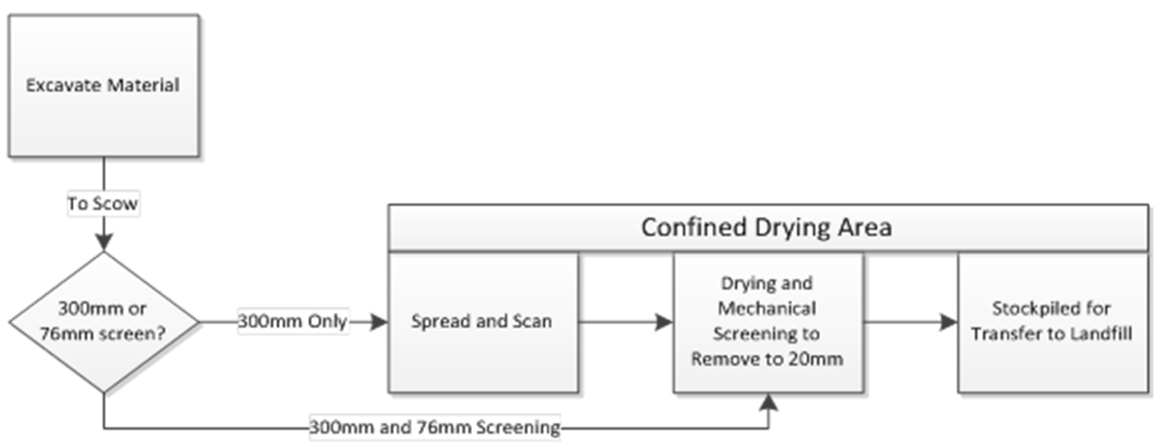

Figure 1. High-Level Concept of Operations (Courtesy of NAVFAC)

If the material composition (i.e., large cobbles, etc.) prevented screening through the smaller screen before placing it in the scow, the material was spread at the CDF and scanned by hand using metal detectors to locate and remove any large MEC/MPPEH. Material that passed through the 76-mm screen did not require this additional step. Shielded equipment was used to move the material for drying and additional screening down to ¾-inch fractions to capture 20-mm projectiles.

4.1 Over Water Screening Techniques

The dredging methodology selected for Project P327 utilized a clamshell dredge on a barge. The material was excavated using the clamshell bucket and loaded into a scow positioned alongside. The dredged materials were passed through the 300-mm screen and then, if possible, through the second 76-mm screen. The screens were placed directly over the hopper of the scow. An Unexploded Ordnance (UXO) Technician observed the operation to identify whether any MEC/MPPEH were deposited on the screens. The dredge operator was trained in basic ordnance identification to assist the observer UXO Technician during the dredging operation. Operations were halted if MPPEH items were observed and the Senior UXO Supervisor (SUXOS) and UXO Safety Officer (UXOSO) were called to make a safe-to-move determination. The dredge was armored against the munition with the greatest fragment distance (MGFD) as approved in the ESS and blast pressure controls (K-factor) were implemented. For this operation, the machine required shielding with 4.13 inches of plexiglass and a K24 (blast separation distance) of 44 feet for the Primary MGFD (5-inch Mk 41 projectile). The scow was loaded with approximately 2,000 cy of material and was moved either to the LA-5 open ocean disposal site or to the CDF. The observer was positioned behind a protective blast shield at the distance specified in the ESS and used indirect viewing using mirrors and/or remote cameras.

In the event a MEC/MPPEH item was recovered from the screen on the scow, it was to be inspected by the SUXOS and UXOSO to determine whether it was safe to move. If deemed unsafe to move, the item was to be secured in place (e.g., sandbags, etc.) and Navy Explosive Ordnance Disposal (EOD) was to be called to respond. If deemed safe to move, it was to be documented, removed from the screen, and transported to the CDF by small boat for temporary storage pending disposal. No MEC/MPPEH were recovered from the scow screening operation.

Due to the location of the dredge activities and widespread use of the bay, exclusion zones had to be established for divers and swimmers in the immediate vicinity of the dredge operations. Exclusion zones for personnel in the water were also calculated for the operation, as presented in Table 1, and were enforced throughout the dredging operations (as described in Section 5).

Table 1. Exclusion Zone for Personnel in Water

(Dredging and Loading Scow)

MGFD		EZs for the public and non-essential personnel (swimmers/divers) ft.	
Description	NEW (lbs)	Swimmers ≤1 ft	Swimmers/Divers≥ 1 ft
		$D=13000W^{1/3}/50$	$S=[15(DOB^* W^{1/5})+300]^*3$
5-inch Mk 41	6.27	480	3,304
5-inch Mk 10 rocket warhead	9.90	558	3,534

(1) D-minimum safe separation distance for swimmer; W-weight of TNT explosive charge (in pounds), ; S-minimum safe separation distance for swimmer/diver , DOB-depth of blast (in feet)
(2) EZ range calculated at 37 feet which is the maximum depth of dredging.

4.2 Confined Drying Facility Operations

Figure 4 shows the location and layout for the CDF, the demolition area, and the radiological screening area. Three types of operations were performed at the CDF:

- scanning of existing stockpiles;
- spreading and scanning of the material that was screened on the 300-mm screen only; and
- drying and screening of the material that was screened to 76 mm.

Each scenario is presented in the paragraphs below. It is noted that the quantities of material processed were not recorded in the available documentation.

Existing Stockpiles. Prior to the discovery of MEC/MPPEH, stockpiles of dredged material had been placed in the CDF. Those stockpiles were 10 to 12 feet high and littered with all manner of debris. To accomplish MEC/MPPEH removal, the debris piles were sectioned into work units (grids) and UXO Technicians conducted "mag and dig" removal of ferrous metal (and removed other debris) to 24 inches below ground surface. Following the 24-inch deep clearance and quality control (QC) checks of the "grid", the top 20 inches was removed and staged at an adjacent area. This process of scan and remove was repeated until the entire depth of the stockpile/grid was checked. The scanned stockpiles were moved to an adjacent open area for additional drying and screening down to a ¾-inch fraction to remove any possible 20-mm size munitions. Screened stockpiles were marked for removal to an upland landfill.

Dredged Material Screened to 300 mm Only. Dredged material screened to 300 mm only retained the potential to contain large munitions (>5 inch) from which earth moving machinery (EMM) could not be protected (e.g., the primary MGFD required fragmentation protection and 44-feet separation for blast protection which could not be achieved with the loader). Thus, additional scanning was needed prior to drying and screening. The spoils were removed from the scow using a clamshell bucket and deposited (wet) into a series of earthen-bermed cells created for the purpose. The wet spoils were spread across the cells until a depth of 20 inches was reached. UXO Technicians conducted "mag and dig" operations within the cells to detect and remove ferrous metal to the 20-inch depth. When finished, shielded EMM was used to clear the cells and move the material to an adjacent area for drying and screening.

Dredged Material Screened to 76 mm. No "mag and dig" process was required on material screened to the 76-mm standard. EMM could be protected from the MGFD (fragmentation protection and 11-feet separation for blast protection). Dredged material was offloaded from the scow using a clamshell bucket and stockpiled for drying and screening to the ¾-inch fraction.

4.3 Summary of the After Action Report

An AAR that summarizes the on-site construction support to MILCON P327 was prepared in February 2017. The report provides a very general summary of the actions completed. The appendices were not available in the version of the AAR reviewed for this case study that may have provided additional documentation (e.g., QC documentation).

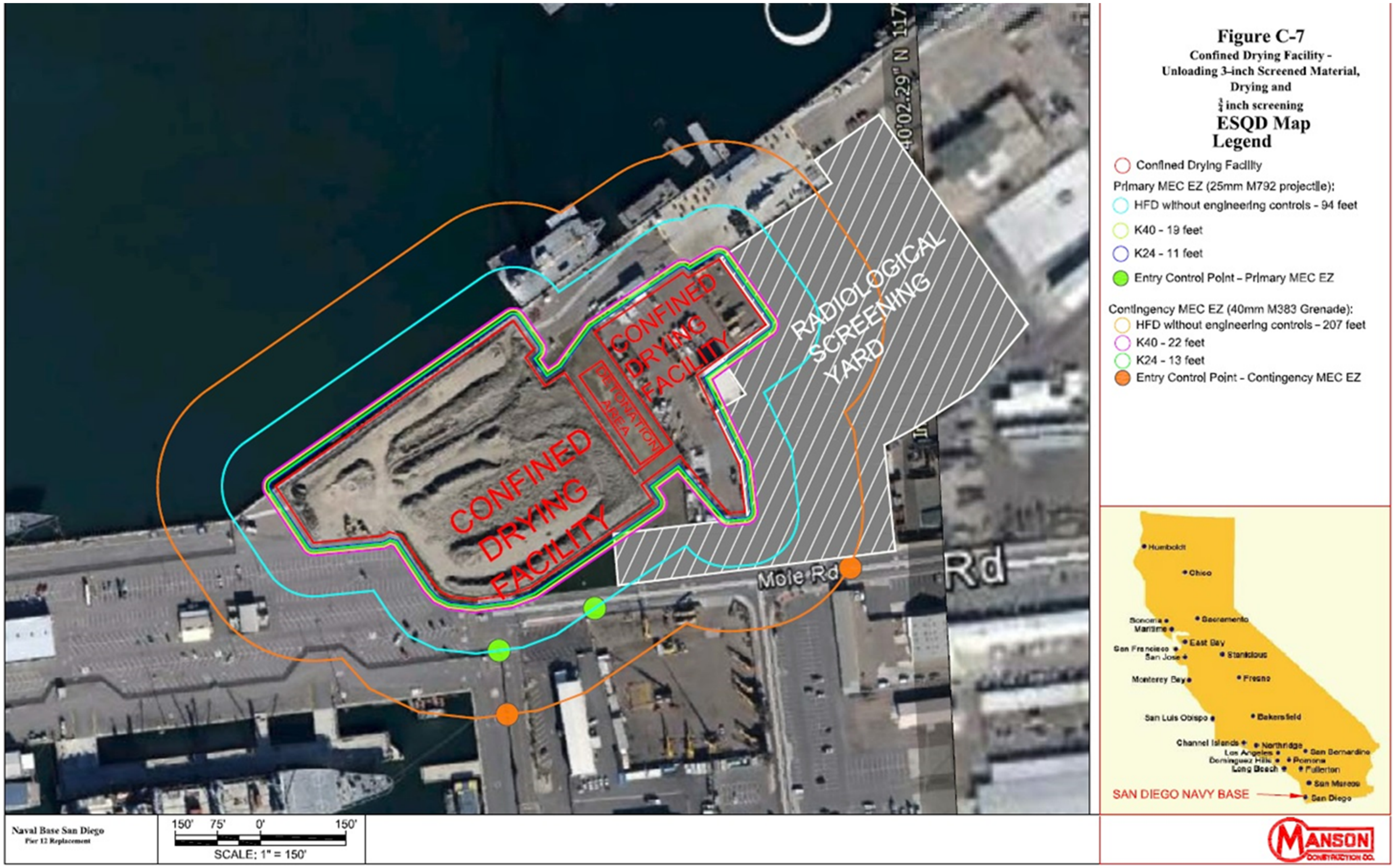

Figure 4. Confined Drying Area (Courtesy of NAVFAC)

The AAR does confirm that the exclusion zone for all activities other than mechanized screening of the dredge spoils was the primary MGFD 5-inch Mk 41 projectile and that the EZ transitioned to the contingency MGFD 5-inch Mk 10 Rocket Warhead when one of those was found in December 2015.

The EZ for the mechanized screening was the primary MGFD 20-mm M97 projectile. The contingency MGFD was not used.

A total of 20 MEC items were located during the CDF operations. No MEC was recovered during dredging operations. Of the 20 items, 17 were destroyed within the designated detonation area in the CDF. Three of the items were given to Navy EOD for disposal. Items found included (1) 5-inch Mk 10 Rocket Warhead, (2) 3-inch projectiles, (6) 20-mm projectiles, (3) 25-mm projectiles, (1) 40-mm Mk3 projectile, (1) 37-mm M54 projectile and several miscellaneous pyrotechnics and small arms.

Three steel drums of material documented as safe (MDAS) totaling 1,144 pounds was certified and shipped for recycling.

5.0 EXCLUSION ZONE CONTROL

Explosives Safety Quantity Distance (ESQD) arcs were established for the primary and contingency MGFDs under each of the screening scenarios (300-mm, 76-mm and ¾-inch fraction). Exclusion zone distances and entry control points were documented in the ESS.

In addition to the entry control provided for land-side operations, there were also restrictions for swimmers/divers in the area. A copy of the ESS exclusion zone map along with dredging operating hours were provided in a Notice to Mariners submitted to the United States Coast Guard to alert the public of hazards and restrictions for in-water operations. A message was also sent out from NBSD to all ships and commands requiring that all swimming/diving activities be secured during dredging operating hours. Contingencies were included for emergency in-water activities for non-essential personnel requiring access within the exclusion zone.

NBSD was granted an Explosives Safety Waiver to deviate from the requirements of Ordnance Pamphlet 5 (OP 5) to grant non-essential personnel access within the exclusion zones established in the ESS for Piers 10, 12, and 13 and Mole Pier. This was the first explosive safety deviation to be obtained for a munitions response project. These personnel were non-essential to the MEC work, but mission essential to the ship repairs occurring at NBSD. The waiver allowed limited access for mission essential personnel and equipment to transit through exclusion zones during dredging operations. It also required an operational necessity endorsement and regional (area) concurrence. The command was required to ensure only those personnel limited to ships' force personnel, Department of Defense (DoD) contractors, and other personnel responsible for shipboard maintenance were allowed to enter the exclusion zones. When considering the need for an ESS deviation, Naval Ordnance Safety and Security Activity (NOSSA) should be consulted and the additional review time factored into the planning process.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

QC comprised the following activities:

- daily checks with the metal detector in the instrument verification strip (IVS) to verify that the locators were working properly. The IVS contained three small industry standard objects (ISOs) and three medium ISOs buried 10 feet apart at various orientations and at depths varying from 3 to 11 times the diameter;
- daily QC inspections of definable features of work (DFWs) in compliance with the three phases of control inspection process;
- implementation of a blind seeding program requiring QC to install two blind seeds per grid, one surface and one subsurface, with 100% verification of recovery of the blind seeds;
- QC inspection of completed grids at 25% down to 10% with failure criteria established as MEC/MPPEH 3 inches or larger found by QC;
- QC of screened material at 25% down to 10% with failure criteria established as any metal larger than the smallest screen; and
- MPPEH certification (e.g., MDAS).

Quality assurance (QA) was conducted by an independent third-party vendor. The QA vendor verified and documented the following:

- implementation of the QC program (e.g., QC inspections of DFW conducted per the QC plan, etc.);
- independent QA inspections (surveillances);
- independent audit of completed work (grids and screened [300 mm/76 mm] dredged material);
- random check of disposal turn-in documentation at the rate of 10%; and
- independent check of 10% of screened material (0.75-inch screen) and acceptance statement for each lot of material.

7.0 REGULATORY REQUIREMENTS

The ESS summarizes the regulatory requirements as follows (Paragraph 9.1 from DON, 2015):

> *"The project is a MILCON funded project (P-327) for Pier 12 Demo and Replacement project to accommodate deeper draft Navy vessels. Deeper draft vessels require dredging from the current operational depth of -30ft MLLW to a depth of -37ft MLLW.*

Pier 12 Dredging operations are within the MRP Site 100 and all dredge material at the CDF are from the Pier 12 area. MRP Site 100 is identified in the MRP program and therefore is managed in accordance with CERCLA. Activities must comply with the substantive requirements identified as applicable or relevant and appropriate requirements (ARARs) or to be considered requirements specified in the Action Memorandum (Chief of Naval Operations, 2010). Under CERCLA 120 and Executive Order 12580, the Navy is the lead agency responsible for the cleanup effort."

8.0 LESSONS LEARNED

The following lessons learned were drawn from this case study as summarized below.

There are several challenges faced in the planning process for dredging projects in the presence of MEC. The affected commands must be actively reminded that there are munitions, radiological items and/or contaminants that must be addressed for any maintenance dredging. As a result of the P327 project, the Capital Improvements organization has made a concerted effort to exchange information with the Environmental (ENV) group. Scopes of work (SOWs) from waterfront engineering are routed through ENV to add language as necessary to address MEC, radiological, and other environmental issues. Instead of placing the information in an appendix where it might be overlooked, the specific language is added into the main text of the SOW, specifically noting that munitions and/or radiological items are present and defining the required safety requirements.

Munitions and/or radiological contractors are subcontracted by the dredging prime contractor. The language in the SOW should encourage the prime contractor to assemble the appropriate team, based on the requirements in the SOW, so that an ESS and other required documentation can be prepared efficiently and in concert with the schedule. It would be helpful to know which dredging contractors have experience in completing all SOW requirements (e.g., screening at the scow, preparing explosives safety documents, plans and reports, managing the UXO work, etc.) during the selection process.

It was noted during discussions on dredging in general that the USACE permit requires post-dredging information to support the permit. This also applies to munitions and radiological AARs (e.g., NOSSA requires an AAR to close an ESS). In some cases, the information is not being submitted in a reasonable amount of time.

The USACE regulates the operational dredging through its permitting process. There is no CERCLA documentation required for these projects. There is historical information available to support decisions related to the potential for encountering munitions and/or radiological items. However, the data are not readily accessible and/or compiled in one location. In many cases, planners are having to rely on what is found during dredging to make site-specific decisions.

Generally, requirements for disposal are requiring that a Grizzly be placed at the scow to screen to 12 inches. USEPA does not want large debris of any kind placed at the LA-5 disposal site. Further, since most of the dredge spoils are not clean enough for disposal at LA-5, they must go for upland disposal. All maintenance dredging is screened to 3 inches at the scow for explosives safety purposes (e.g., to only allow smaller munitions into the CDF). Spoils at the CDF are screened further for munitions and radiological items before being sent for upland disposal.

The dredging contractor was responsible for preparing the ESS, which required 3 months to prepare. Later, the ESS required an amendment and a correction, both of which required additional time for review and comment. The amendment was necessary to add hydraulic offloading of the scow to the CDF and this changed the MFGD. The correction added the use of 3-inch screens for offloading the scow using a clamshell bucket.

Future dredging operations have ESS or ESS-Determination Request (DR) language in the text of the dredging SOW so that the dredging prime contractor understands the requirements up front. This should alleviate much of the delay noted in the P327 project.

9.0 REFERENCES

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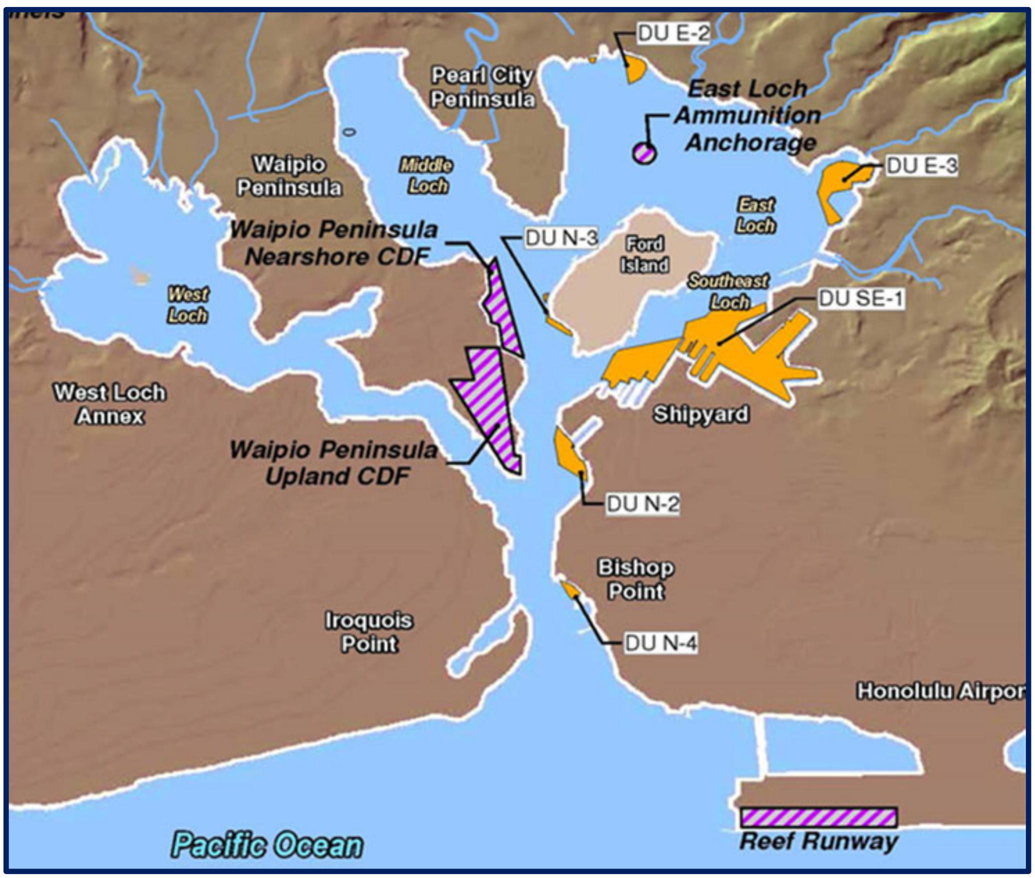
Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

TECHNICAL MEMORANDUM
APRIL 2019

DREDGING CONSIDERATIONS IN THE PRESENCE OF MUNITIONS AND EXPLOSIVES OF CONCERN

JOINT BASE PEARL HARBOR-HICKAM, HAWAII



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15. SUBJECT TERMS

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ACRONYMS AND ABBREVIATIONS

CDF	Confined disposal facility
COC	Contaminant of concern
cy	cubic yard
DGM	digital geophysical mapping
DON	Department of the Navy
DU	Decision Unit
ENR	Enhanced natural recovery
EOD	explosive ordnance disposal
EPA	United States Environmental Protection Agency
ESS	Explosives Safety Submittal
ESS-DR	Explosives Safety Submittal Determination Request
EZ	Exclusion zone
FS	Feasibility study
HFD	hazardous fragment distance
HOA	Historical ordnance assessment
JBPHH	Joint Base Pearl Harbor-Hickam
MEC	Munitions and explosives of concern
MFD	maximum fragment distance
MGFD	Munition with the greatest fragment distance
MILCON	Military construction
MNR	Monitored natural recovery
NAVFAC	Naval Facilities Engineering Command
NOSSA	Naval Ordnance Safety and Security Activity
NPL	National Priorities List
PCB	polychlorinated biphenyl
PHNC	Pearl Harbor Naval Complex
QA	Quality assurance
QC	Quality control
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
SOH	State of Hawaii
SOODMDS	South Oahu Ocean Dredged Material Disposal Site
USACE	United States Army Corps of Engineers
UXO	Unexploded ordnance

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1.0 INTRODUCTION

The confirmed presence of munitions and explosives of concern (MEC) in sediment will have major impacts on the safety of personnel, the public, the selection of dredging equipment and techniques, and the overall project schedule and budget (Welp et al., 2008). This case study summarizes the effects of the presence of MEC on the maintenance and environmental dredging programs at Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. An overview of the MEC management requirements for JBPHH dredging projects is provided.

2.0 GENERAL CONSIDERATIONS FOR DREDGING AT SITES WITH POTENTIAL MEC CONTAMINATION

Project planning in an area containing or suspected to contain MEC requires the consideration for protection of dredging personnel, the public, and equipment from the effects of an unintentional detonation. The explosives hazards analysis must be specific for the type(s) of dredging equipment to be used and types of MEC expected to be encountered. In addition, the project team should consider:

- **Evaluating removal of the MEC versus leaving the MEC underwater**. It is possible to configure the dredging equipment to screen out MEC underwater. Safety must be considered in the context of a risk analysis based on the conceptual site model and whether a complete pathway would exist if the MEC were left in the water. This option should consider the cost since screens (intake or exit) decrease throughput and require maintenance (e.g., periodic stoppages to clear debris).

- **Selecting the type of dredging equipment to be used**. Hydraulic methods are the primary option if screening to leave MEC in place and removing only the sediment. However, hydraulic methods may not be the best choice where there is the high potential for encountering MEC. Dredging at JBPHH utilizes only clamshell dredging equipment. Space limitations preclude construction of a large dredge material dewatering facility, which is necessary when using hydraulic dredging methods.

- **Determining when an explosives safety submittal (ESS) is required versus an ESS Determination Request (ESS-DR)**. This decision should be based on the weight of the evidence. Further, invariably on Naval installations, dredging will impact operations. The extent of the impact can vary from a temporary inconvenience to significantly affecting operations and readiness. In some instances, a Chief of Naval Operations waiver may be necessary to allow personnel to transit and/or work within the explosives safety exclusion zone (EZ) due to operational necessity. Remember that the possibility of the dredging causing an unintentional detonation, although considered a low probability, requires that EZs for swimmers and other watercraft be established and monitored, sometimes at long ranges. Marine mammals may also require monitoring and dredging may have to be halted until the mammals leave the area.

- **Anticipating that any process for dredging involving MEC is going to extend the schedule beyond what would normally be expected**. The focus must be on MEC identification, recovery and management, not on dredging production rates. Costs are increased proportionally as well.

- **Coordinating the management and disposal of dredge spoils**. Any soil potentially containing MEC requires that thorough documentation of the work process followed by rigorous quality control (QC) and quality assurance (QA) be implemented before that soil will be accepted for unrestricted use (e.g., transportation across public roads, as fill material, as capping material, etc.). Dredge spoils are no different. Regular communication with stakeholders and end users is necessary to keep the process moving and avoid delays and incidents.

3.0 OVERVIEW OF JBPHH DREDGING PROGRAMS

Dredging in Pearl Harbor presents many challenges related to the planning and execution of both the maintenance and environmental programs. These challenges include meeting the diverse needs and requirements of both programs, the limited dredge material disposal options, explosives safety requirements, and scheduling issues associated with the Navy's need to perform mission-critical activities. The maintenance dredging program is logistically complex with various considerations for regulations, procedures, and scheduling. Explosives safety planning must be incorporated due to the known presence of MEC in some dredge areas and the potential for MEC in others. The maintenance and environmental dredging programs at Pearl Harbor are described below.

3.1 Maintenance Dredging at JBPHH

Construction and maintenance dredging in Pearl Harbor began as early as the 1900s to establish the Navy base and accommodate the Navy's operational needs to allow larger ships to enter the harbor. Maintenance dredging required to maintain suitable navigation depths is typically performed on a four- to five-year cycle. Maintenance dredging in harbors is typically performed by the United States Army Corps of Engineers (USACE). However, maintenance dredging at Pearl Harbor is self-performed by the Navy, a unique aspect of the JBPHH dredging program. Although self-performed by the Navy, a USACE permit and State of Hawaii (SOH) Water Quality Certification are required and were obtained. As required, periodic construction dredging is performed under the military construction (MILCON) program. Periodic bathymetric surveys of the harbor by the USACE are used to assist in prioritizing and scheduling areas for upcoming dredging events. More than 10 million cubic yards (cy) of sediment was dredged between 1967 and 2011, and up to 3.4 million cy of sediment is anticipated to be dredged for maintenance purposes from 2016 through 2025 (Naval Facilities Engineering Command [NAVFAC] Pacific, 2015). The basic maintenance dredging footprint at Pearl Harbor is shown in Figure 1. Maintenance dredging is performed using clamshell dredging equipment. Space limitations preclude construction of a large dredge material dewatering facility, which is necessary when using hydraulic dredging methods.

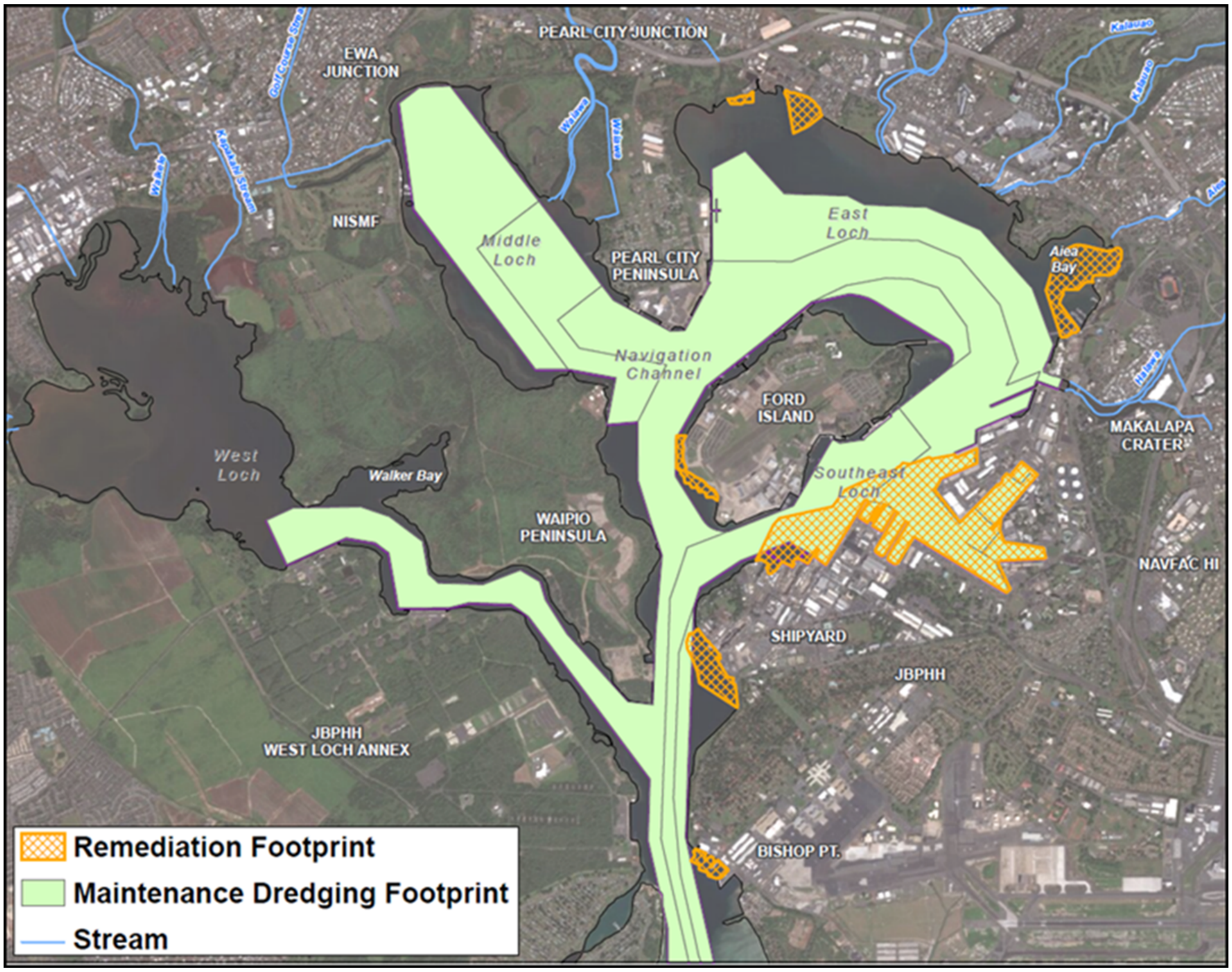

Figure 1. Maintenance and Environmental Dredging Footprint at JBPHH

Disposal options for dredge material at JBPHH are limited because of its remote location and limited island land area and resources. Typically, sediments are characterized for various disposal options. Sediment would be classified as contaminated (e.g., containing hazardous or toxic materials at levels that may adversely affect human health or the environment) or clean. Dredge material that meets the Environmental Protection Agency (EPA)/USACE-established criteria for ocean dumping (EPA/USACE, 1991) could be disposed at the South Oahu Ocean Dredged Material Disposal Site (SOODMDS), located in the Pacific Ocean approximately 3 miles south of the entrance to the Pearl Harbor navigation channel (see Figure 2). Contaminated dredge material may be disposed using one of the following options:

- Temporary storage or treatment at the Navy's upland confined disposal facility (CDF), which is in the southern portion of Waipio Peninsula (see Figure 2).
- Non-hazardous material to a Subtitle D solid waste landfill for non-hazardous industrial solid waste located on island.

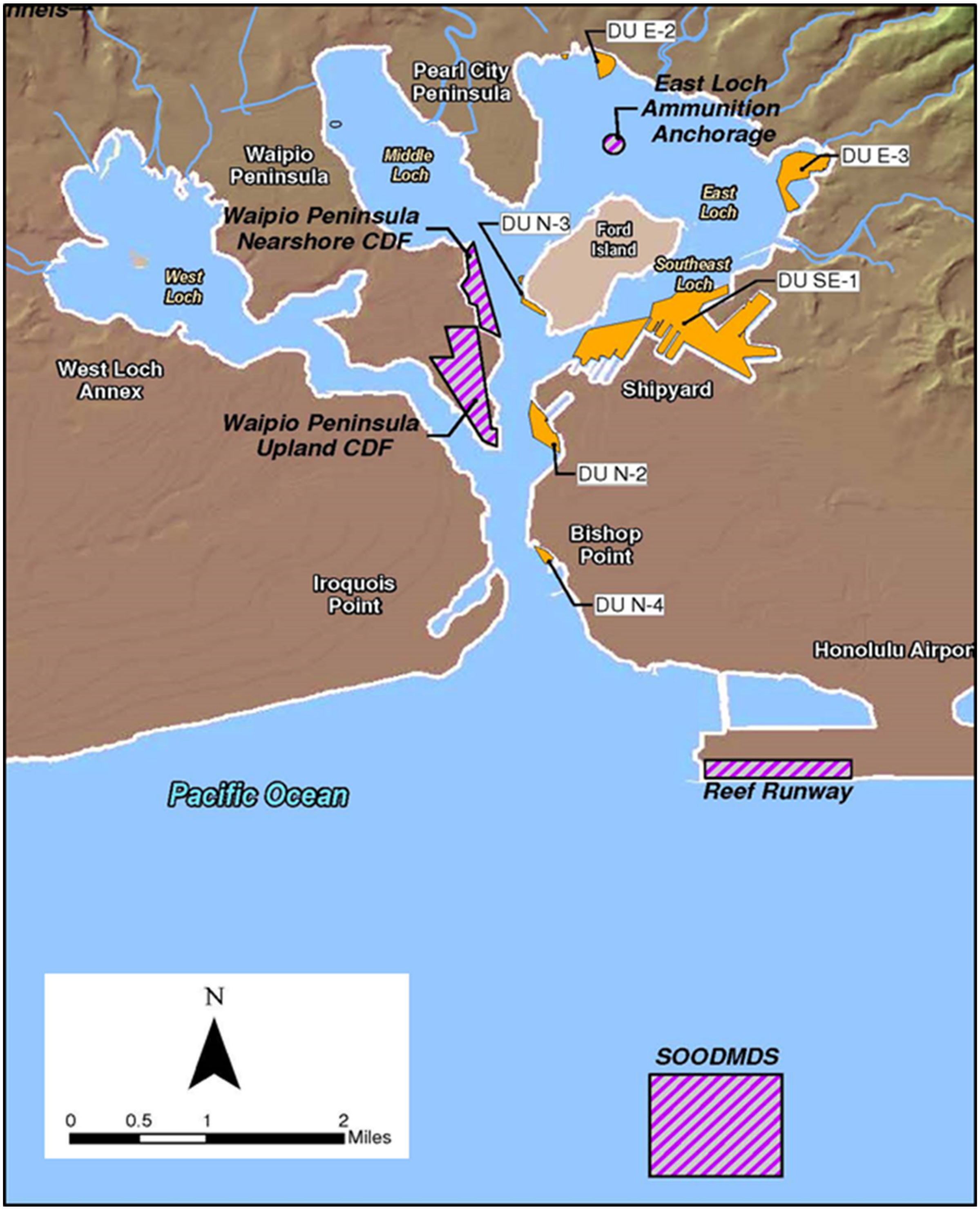

Figure 1. On- and Near-Island Sediment Disposal Options

- Hazardous material to a Subtitle C solid waste landfill (authorized under the Resource Conservation and Recovery Act [RCRA] to accept hazardous waste for disposal) only available on the U.S. mainland.

3.2 Environmental Dredging at JBPHH

Pearl Harbor Naval Complex (PHNC), including Pearl Harbor itself, was added to the EPA National Priorities List (NPL) in October 1992. The NPL site remains designated as "PHNC" even though it has since been incorporated into JBPHH as of October 2010. A Federal Facility Agreement for PHNC was signed in 1994 (EPA, SOH, and Department of the Navy [DON], 1994).

> ***Evaluation of Dredged Material Proposed for Ocean Disposal (Green Book)***
> The Green Book is a joint product of the EPA and USACE and provides technical guidance for determining the suitability of dredged material for ocean disposal through chemical, physical and biological evaluations. The manual describes a tiered-testing procedure for evaluating compliance with the limited permissible concentration as defined in ocean-dumping regulations.

A Remedial Investigation (RI) was initiated in 1996. The RI report was delivered in 2007 and an RI Addendum was completed in 2013. A Feasibility Study (FS) was completed in 2015. As a result, 10 distinct areas of the Pearl Harbor Sediment Site were identified as Decision Units (DUs) for investigation and remediation decision-making purposes and are shown in Figure 2.

- West Loch (DU W-1),
- Middle Loch (DU M-1),
- Three DUs comprising the East Loch (East Loch DU E-1, Waiau Power Plant Shoreline Area DU E-2, and Aiea Bay DU E-3),
- Southeast Loch (DU SE-1), and
- Four DUs comprising the main navigation channel area (Navigation Channel DU N-1, Oscar 1 and 2 Piers Shoreline Area DU N-2, Ford Island Landfill Shoreline Area DU N-3, and Bishop Point DU N-4).

Three remedial action objectives (RAOs) were developed for the Pearl Harbor Sediment Sites. They are:

- <u>RAO 1</u>: Reduce human health risks associated with the consumption of harbor fish and shellfish by reducing contaminant of concern (COC) concentrations in surface sediments to protective levels.

- <u>RAO 2</u>: Reduce direct contact risks to sediment associated fish from exposure to COCs by reducing concentrations of COCs in surface sediments to protective levels.

- <u>RAO 3</u>: Reduce risks to water birds that forage in shallow waters in Pearl Harbor from exposure to COCs by reducing concentrations of COCs in surface sediments to protective levels.

The February 2016 Proposed Plan for the Pearl Harbor Sediment Site (NAVFAC Pacific, 2016), which was informed by the 2015 FS (NAVFAC Pacific, 2015), recommended remedies for the DUs requiring remediation consisting of:

- focused dredging,

- enhanced natural recovery (ENR),
- amendment with activated carbon, and/or
- monitored natural recovery (MNR).

The dredging component of the remedies calls for the removal of 50,000 cy from DUs SE-1 and E-2 and another 98,000 cy to provide enough clearance for the addition of ENR material in DUs SE-1, N-2, N-3, and N-4. Note that the dredge depth for the environmental dredging may be greater than that required for maintenance dredging to accommodate the remedy (e.g., amendments or capping).

The Record of Decision (ROD) for the Pearl Harbor Sediment Site was finalized in 2018 (NAVFAC-Pacific, 2018). The DUs requiring remedial action to address COCs include the following (see Figure 2):

- DU E-2 (total polychlorinated biphenyls [PCBs]),
- DU E-3 (lead, mercury, and zinc),
- DU SE-1 (total PCBs, copper, lead, and mercury),
- DU N-2 (total PCBs, cadmium, copper, lead, mercury, and zinc),
- DU N-3 (total PCBs), and
- DU N-4 (antimony, lead, mercury, and zinc).

The DUs where no active remediation is required are:

- DU W-1,
- DU M-1,
- DU E-1, and
- DU N-1.

The dredging footprint for the Pearl Harbor Sediment site overlaps with the operational dredging areas as shown in Figure 1 so every effort is being made to coordinate the two activities. Where the dredging footprints overlap, the programs are working closely together to collaborate on funding projects. Calculations show that up to 100,000 cy of the sediment to be addressed through the environmental remedies could be removed through maintenance dredging due to the overlap. However, the dredge depth for the CERCLA remediation may be greater than required for maintenance purposes. In addition, the maintenance dredging footprint has been reduced to a very limited footprint to support immediate operational needs as of 2018. A portion of the environmental footprint may still be addressed during these activities. Another consideration is that the maintenance dredging schedule is intermittent and may not fall within the remedy schedule requirements. The remaining environmental dredging will be scheduled after the remedy design is complete and a contract is awarded.

4.0 JBPHH MEC/MPPEH MANAGEMENT CONSIDERATIONS

Planning at JBPHH presented several challenges because of the uniqueness of the location (e.g., island setting so far from a major land mass) and the history of the site. The island setting immediately limits the options for management and disposal not only of MEC/MPPEH, but of the dredge spoils in general. The long time use of Pearl Harbor as an operating naval facility with internal operations moving from one area to another over time, and the direct attack in 1941, require detailed evaluation of each area/site to quantify the probability for encountering MEC/MPPEH and then to express that in an ESS.

During the Pearl Harbor Sediment Site FS, a historical ordnance assessment (HOA) was performed to evaluate the probability that MEC and MPPEH are present in the areas of Pearl Harbor proposed for remediation (e.g., dredging, capping, ENR outside of West Loch), and to identify the types of MEC and MPPEH that may be present in each area. Results of the HOA showed a moderate-to-high probability of encountering MEC/MPPEH at the remediation sites (AECOM, 2014). Based on these results, the requirement for having an ESS was expanded from just West Loch to include the environmental dredging sites within Southeast Loch. For a variety of reasons such as funding, scheduling, regulatory, and operational constraints, the two segments of the dredging operation (dredge activities and CDF activities) are handled as separate operations and each has its own ESS.

Some areas within Pearl Harbor, such as East Loch, and portions of Middle Loch and the Navigational Channel, remain designated as low-probability MEC/MPPEH areas and undergo maintenance dredging using an ESS-DR. Recently, Pearl Harbor has successfully received an ESS-DR for environmental dredging at Bishop Point.

Historical explosive ordnance disposal (EOD) incident reports documenting emergency responses during maintenance dredging operations in West Loch provided the basis for determining that there was high probability for encountering MEC/MPPEH and in 2008 the Navy prepared an ESS for the MILCON P-181 maintenance dredging in portions of West Loch. The operation was conducted during 2008/2009. The dredge spoils were deposited in the P-181/Cell#4 area at the CDF at Waipio Peninsula for dewatering, drying and screening for MEC/MPPEH. Prior to placing these dredge spoils in P181/Cell#4, the CDF was not known or suspected of containing MEC/MPPEH. During the transfer operations (e.g., seafloor to transfer barge), larger quantities of MEC/MPPEH were encountered than were anticipated (NAVFAC Pacific, 2015). Screening of these spoils for MEC/MPPEH are ongoing with an expected completion date of February 2019.

Dredge spoils from other cells (#1, #2 and #3) not known or suspected of containing MEC/MPPEH are also managed at the CDF. The Navy routinely screens the materials in these cells for debris prior to them leaving the CDF. During screening operations in 2009, MEC and MPPEH were found in dredge material in all three of the cells. Based on these findings, the ESS for CDF MEC/MPPEH screening activities was amended to address screening operations throughout the CDF.

4.1 MEC Management during Dredging Operations at JBPHH

Dredging is to be done using a clamshell dredge with an environmental bucket. The dredge operator is protected from blast and fragmentation using a combination of shielding (e.g., plexiglass, Lexan, etc.) and distance. Dredge spoils will be excavated, and the material placed onto screens positioned on a containment barge. The screens will have openings which vary from 4 inches to 12 inches gauged to separate the MEC/MPPEH anticipated for the site. When the screens have accumulated enough debris, they will be lifted from the containment barge and placed into a debris barge. Clean screens will be placed over the containment barge and dredging will continue until the containment barge and/or debris barge is sufficiently full to move to the CDF for offloading. The purpose is to keep the MEC segregated by size to manage the EZs. Only certain cells within the CDF are sited for the larger munitions items.

As the material is removed from the bottom and emptied onto the screens on the containment barge, the debris captured by the screens is monitored by unexploded ordnance (UXO) personnel. If MEC are seen, the operation stops immediately and the UXO technicians inspect, identify, and manage the item(s) in compliance with the ESS. Actions may include removing safe-to-move items to the CDF for storage pending disposal or calling EOD to provide a response to items unsafe to move.

4.2 MEC Management in the Confined Disposal Facility

Dredge material is offloaded from the containment barge to the respective CDF cell (based on possible munition size) for screening. One of several methods for screening may be used including mechanical sifting to remove debris, an analog detector method ("spread and scan") or digital geophysical mapping (DGM). The most typical is the spread and scan method where dredge material is spread into a layer, generally about 1-foot deep, and the surface is scanned using an analog metal detector. Operators detect anomalies representative of MEC in real time by an audible or visual signal. The anomalies may be marked, typically with a pin flag or spray paint, and each marked anomaly would be excavated later to determine whether it is MEC. Generally, the anomalies are excavated immediately upon detection to allow the teams to screen the dredge material in one pass. Large areas may be subdivided into grids and those grids surveyed using DGM equipment. DGM logs the sensor readings, and metallic items (potentially MEC/MPPEH) show up as anomalies in the data and have an interpreted position. These positions are loaded into a global positioning system for reacquiring and investigation by UXO technicians later.

If known or suspected MEC/MPPEH is observed during the transfer activities, work will be halted immediately and UXO support will be summoned. If the UXO contractor determines the munition is not safe to move, EOD support will be required. Exceptionally large items (e.g., Japanese Type 91 Torpedo) will require an EOD response. MEC/MPPEH which is safe to move will be stored on site (CDF) in a temporary storage magazine. A magazine is sited in P-181/Cell#4 and there is a sited demolition area located within the CDF just outside the P-181/Cell#4.

5.0 CHANGES MADE FOR DREDGING PROJECTS AT JBPHH

The major change in approach to dredging at JBPHH was the need to prepare and implement an ESS for all dredging projects within those areas deemed to have a moderate-to-high probability of having MEC/MPPEH. Historically, an ESS was prepared for dredging in West Loch but the discovery of MEC in CDF Cells #1, #2 and #3 identified the need for additional MEC site characterization in other areas of the harbor and added to the list of areas requiring an ESS. If an area has a low probability based on no historical evidence of ordnance-related activities or storage and no historical recovery of MEC/MPPEH (e.g., East Loch for example), then an ESS-DR is submitted to request that an ESS is not required.

Implementation of the requirements in the ESS affect virtually all operations in areas adjacent to the dredging locations. Primarily, implementing the ESS requires establishing and maintaining Explosives Safety Quantity-Distance EZs and following the approved operating procedures. The EZs are based on the blast and fragmentation characteristics of the munition with the greatest fragmentation distance (MGFD) identified and approved in the ESS. EZs are established for the public and other non-essential personnel. Team separation distances are established for those operating within the EZs. UXO technicians must be present 100% of the time during dredging to provide on-site support. Table 1 shows examples of the EZs for JBPHH. The contingency MGFD zones (larger) are implemented only if the contingency item is encountered during the work. Otherwise, the primary MGFD EZs are implemented. The hazardous fragment distance (HFD) is in place to protect from fragmentation from unintentional detonations, as can occur during normal operations. The maximum fragment distance (MFD) is implemented for intentional detonations, as might be conducted for disposal of a not-safe-to-move munition. The K18 distance is the minimum distance personnel must remain from the MGFD to protect from the effects of the blast. Note that the distances for intentional detonations (MFD-H) are quite large.

Table 1. Examples of MGFD and Fragmentation Distances for JBPHH

MGFD Type	Munition	HFD (ft)	MFD-H (ft)	K18 (ft)
Primary	5-inch .38 caliber Mk 35	343	2,131	33
Contingency	Type 91 Mod 2 torpedo	1,028	3,634	165

Note: HFD: Hazardous fragment distance; MFD-H: Maximum fragment distance-horizontal; K18 is the blast protection distance.

The approved ESS describes the technical approach for conducting the work and this approach must be followed. The organization preparing the ESS describes the procedures that they want to use including the types of equipment and methods for use. Naval Ordnance Safety and Security Activity (NOSSA) reviews those procedures in the context of explosives safety and will approve or request they be modified. In the case of JBPHH, dredged material is passed through a screen as it is being placed in the transfer barge (to transfer from dredge location to the CDF). The screen is monitored by UXO personnel for MEC/MPPEH with each bucket of dredge spoils. This monitoring slows the dredging productivity (e.g., from bottom to barge) considerably. If

MEC/MPPEH are spotted, the operation stops completely while UXO personnel determine a course of action. If the MEC is deemed safe-to-move, it is removed and transported to the approved storage at the CDF. If the MEC is deemed not-safe-to-move, then Navy EOD must be called to respond and all operations halt until the situation is remedied. Any major deviations of the ESS-approved work process must be documented in either an ESS-correction or an ESS-amendment and approved by NOSSA before work can continue. On-the-fly process improvements for the sake of efficiency are not allowed. The ESS also requires the contractor to implement and document rigorous QC of the MEC-related processes.

A separate ESS that describes the procedures for CDF operations was also prepared. It also specifies EZ distances, processes and procedures, equipment and methods and QC, which must be followed.

6.0 COST CONSIDERATIONS FOR DREDGING WITH THE POSSIBILITY OF MEC

Provided below are some of the technical or procedural options that may impact the cost of dredging in areas where MEC/MPPEH may be present.

1. The option is available to leave the MEC/MPPEH on the bottom (e.g., not collected and disposed). The USACE has configured screens at both the intake (to exclude) and discharge ends (to capture) of hydraulic dredging systems. These methods have plusses and minuses concerning productivity and safety. Excluding MEC altogether by screening at both the intake and discharge does significantly reduce the possibility of MEC infiltrating the material. This may be quite suitable for activities such as beach replenishment. Screening like this may not be as suitable for harbor maintenance or environmental dredging. In any case, screens may get clogged at either end reducing throughput and requiring maintenance and monitoring with the additional associated costs. If repeat dredging over the same area, MEC screened at the intake will likely still be present during subsequent operations.

2. When clamshell dredging, screening to leave the MEC on the bottom is not feasible. Screening as a first step to separate larger items can help manage EZs at a drying facility (the JBPHH example). Screening at the dredge point will significantly reduce productivity for a variety of reasons including:

    a. The operator must wait between bucketloads for debris captured on the screen to be inspected for MEC/MPPEH;

    b. If MEC/MPPEH are found on the screen, it must be addressed before dredging may continue;

    c. The excavator arm or boom (depending on the type of machine) must provide minimum separation between the bucket and the operator consistent with the K-value specified in the ESS;

    d. The excavator must be shielded consistent with the specifications in the ESS which typically reduces operator visibility, causing slow down.

3. The working time available to dredge may be restricted. Mission-critical operations may restrict dredging to certain hours of the nighttime when primary Navy operations staff are off duty. EZs may encumber operational facilities that cannot be moved or closed during normal working hours. In these instances, overnight may be the only times available to dredge and screen for MEC.

4. Additional staff may be needed to monitor EZ control points during dredging operations. A communications network may be needed between the dredge operator, UXO staff and control point monitors to halt operations as needed to allow non-essential staff to transit the EZ. Costs are associated with the reduced productivity caused by the temporary shutdowns and with the additional staff to monitor control points.

5. Finally, significant cost is associated with the drying/screening for MEC/MPPEH at a CDF. As in the example of JBPHH, a separate ESS was prepared for the CDF. This is probably the best approach for most facilities since the two segments of the operation are so dissimilar.

7.0 REFERENCES

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Welp, Timothy, George Follett, Michelle Crull, and Cheryl Pollock. 2008. Environmental Security Technology Certification Program and Dredging Operations and Environmental Research Program. Dredging in Sediments Containing Munitions and Explosives of Concern (MEC). ESTCP Project No. 200321. US Army Corps of Engineers, Engineer Research and Development Center, Coastal and Hydraulics Laboratory, ERDC/CHL TR-08-12. August.

APPENDIX F

RESOURCE LIST

F.1 ADDITIONAL NAVY RESOURCES

NAVFAC Munitions Response Web Page
This website provides basic information and links related to Department of the Navy (DON) munitions response policy, guidance, and technical documents.
https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/go_erb/focus-areas/munitions-response.html

NAVFAC Munitions Response Remedial Investigation/Feasibility Study (RI/FS) Guidance
This guidance document includes an overview of the DON Munitions Response Program (MRP), the regulatory framework governing investigations, and response actions under the MRP. The RI/FS process is discussed, along with team member roles and responsibilities for key personnel and offices under the MRP. Detailed information is provided on scoping the Munitions Response RI/FS, terrestrial and underwater RIs, munitions and explosives of concern (MEC)/material potentially presenting an explosive hazard (MPPEH) removal and treatment technologies, the FS phase, and the RI/FS report.
https://www.navfac.navy.mil/content/dam/navfac/Specialty%20Centers/Engineering%20and%20Expeditionary%20Warfare%20Center/Environmental/Restoration/er_pdfs/m/MR-RIFS-Guidance-062019.pdf

Additional NAVFAC Munitions Response (MR) Workgroup Guidance
The MR Workgroup maintains a reference DVD that includes guidance documents, technical reference documents, templates, project documents as reference, and other MR-related documents and information. The reference DVD and its contents are available from the MR Workgroup.

NAVFAC Contaminated Sediments Web Page
This page provides an overview of sediment sampling, assessment and remediation.
https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/go_erb/focus-areas/sediment-sites.html

NAVFAC Implementation Guide for Assessing and Managing Contaminated Sediments at Navy Facilities
The document presents guidelines for conducting sediment site assessments and remedial alternative evaluations within the Navy's Environmental Restoration program. It is intended for use by remedial project managers and their technical support staff as step-wise guidance that will apply to most Navy sediment investigations. It includes discussion of the technologies available for remediation of sediments.
https://www.navfac.navy.mil/content/dam/navfac/Specialty%20Centers/Engineering%20and%20Expeditionary%20Warfare%20Center/Environmental/Restoration/er_pdfs/gpr/navfacesc-ev-ug-2053-sed-200501r2.pdf

NAVFAC Safety Shack
NAVFAC's website for safety related information including safety training on EM 385-1-1.
https://www.navfac.navy.mil/products_and_services/sf/products_and_services/construction/safety_shack.html

Naval Ordnance Safety and Security Activity (NOSSA)
As the NAVSEA Technical Authority for Explosives Safety, NOSSA is responsible for providing technical policies, procedures and design criteria associated with weapons systems safety, including software safety across the warfare disciplines. NOSSA manages all programmatic policy requirements for the five major DON Explosives Safety Program component programs: Ordnance Safety and Security, Weapons and Combat System Safety, Ordnance Environmental Support Office, Insensitive Munitions Office, and Weapons and Ordnance Quality Evaluation.
https://www.navsea.navy.mil/Home/NOSSA/

F.2 DREDGING AND DREDGED MATERIAL PROCESSING RESOURCES

ASTM E-3163. Standard Guide for Selection and Application of Analytical Methods and Procedures Used during Sediment Correction Action (2018). American Society of Testing Materials (ASTM) International, Conshohocken, PA.

Environmental Protection Agency (EPA) CLU-IN Sediments, Remediation Web Page
This web page provides links to resources on sediment remediation techniques including dredging.
https://clu-in.org/issues/default.focus/sec/Sediments/cat/Remediation/

EPA Superfund Contaminated Sediment Web Page
This web site provides an overview and links for managing contaminated sediment at Superfund sites. It includes a link to the Superfund Sediment Resource Center (SSRC) which is designed to assist on technical issues related to the cleanup of contaminated sediment sites. The site also provides numerous links to resources for sediment remediation including dredging.
https://www.epa.gov/superfund/superfund-contaminated-sediments

EPA Superfund Contaminated Sediments: Guidance Documents, Fact Sheets and Policies Web Page
This web page contains links to sediment guidance documents, fact sheets and policies and other documents relevant to contaminated sediments, including those addressing dredging.
https://www.epa.gov/superfund/superfund-contaminated-sediments-guidance-and-technical-support

EPA Regulations, Guidance, and Additional Ocean Dumping Information Webpage
This web page provides resources pertaining to ocean dumping law, regulations, and treaties and provides national policies, guidelines and reports.
https://www.epa.gov/ocean-dumping/regulations-guidance-and-additional-ocean-dumping-information

EPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites
The guidance is designed to assist sediment site managers by providing a thorough overview of methods that can be used to reduce risk caused by contaminated sediment. Chapter 6 addresses dredging and excavation.

https://semspub.epa.gov/work/HQ/174471.pdf

EPA Memorandum: Remediating Contaminated Sediment Sites - Clarification of Several Key Remedial Investigation/Feasibility Study and Risk Management Recommendations, and Updated Contaminated Sediment Technical Advisory Group Operating Procedures
This document identifies 11 recommendations based on current best practices for characterizing sediment sites, evaluating remedial alternatives, and selecting and implementing appropriate response actions for remediation of contaminated sediment at CERCLA sites.
https://semspub.epa.gov/work/HQ/196834.pdf

EPA Evaluating Environmental Effects of Dredged Material Management Alternatives – A Technical Framework
This document provides guidance to evaluate the environmental acceptability of dredged material management alternatives.
https://www.epa.gov/sites/production/files/201509/documents/2004_08_20_oceans_regulatory_dumpdredged_framework_techframework.pdf

Interstate Technology and Regulatory Council (ITRC) Contaminated Sediments Remediation: Remedy Selection for Contaminated Sediments.
This Web page provides a remedy selection framework to help project managers evaluate remedial technologies and develop remedial alternatives (often composed of multiple technologies) based on site-specific data.
https://www.itrcweb.org/Guidance/ListDocuments?TopicID=4&SubTopicID=46

U.S. Army Corps of Engineers (USACE) Dredging Operations and Environmental Research Program Web Page
The Dredging Operations and Environmental Research (DOER) Program supports the USACE Operation and Maintenance Navigation Program. Research is designed to balance operational and environmental initiatives and to meet complex economic, engineering, and environmental challenges of dredging and disposal in support of the navigation mission. Research results will provide dredging project managers with technology for cost-effective operation, evaluation of risks associated with management alternatives, and environmental compliance.
https://doer.el.erdc.dren.mil/

USACE Dredging Operations Technical Support Program Web Page
The Dredging Operations Technical Support Program, known as DOTS, provides direct environmental and engineering technical support to the USACE Operations and Maintenance dredging mission. This Web page provides links to a wide range of references on various related topics.
https://dots.el.erdc.dren.mil/

USACE The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk
The document summarizes the results of a workshop related to environmental dredging including the four Rs – resuspension, release, residuals, and risk.
https://erdc-library.erdc.dren.mil/xmlui/handle/11681/6855

USACE Technical Guidelines for Environmental Dredging of Contaminated Sediments
This report provides technical guidelines for evaluating environmental dredging as a sediment remedy component.
https://semspub.epa.gov/work/HQ/174468.pdf

USACE Dredging and Dredged Material Management
This document provides a comprehensive assessment of dredging, including dredging equipment and techniques, treatment strategies and management approaches.
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-5025.pdf

USACE and EPA Guidance for Performing Tests on Dredged Material Proposed for Ocean Disposal
This guidance document presents the sediment testing guidelines and requirements to obtain a Department of the Army permit from the New York District of the USACE for dredging and placement of dredged material at the Historic Area Remediation Site in the Atlantic Ocean.
https://clu-in.org/download/contaminantfocus/sediments/R2_dmod-2016.pdf

F.3 ADDITIONAL MEC-RELATED RESOURCES

DENIX – 3Rs (Recognize, Retreat, Report) Explosives Safety Education Program
This website includes basic explosive safely guidelines for UXO encounters with the public.
https://www.denix.osd.mil/uxo/home/

Department of Defense SERDP / ESTCP –Munitions in the Underwater Environment
This website provides information on various DoD-sponsored research and development (R&D) projects and technologies related to munitions in the underwater environment.
https://serdp-estcp.org/Featured-Initiatives/Munitions-Response-Initiatives/Munitions-in-the-Underwater-Environment

EPA Federal Facilities – Military Munitions / Unexploded Ordnance
The website has links to USEPA-related munitions policy and guidance documents.
https://www.epa.gov/fedfac/military-munitionsunexploded-ordnance

ITRC Munitions Response Documents
Links to ITRC guidance for munitions response sites including quality considerations.
https://www.itrcweb.org/Guidance/ListDocuments?TopicID=16&SubTopicID=38