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Screening Dredged Material to Meet Placement Requirements

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Abstract

Certain types of dredging projects require screening of the dredged material (DM) to achieve the project's DM placement requirement(s). Screening in the context of this report will be defined as the separation of an oversized fraction of the DM from the remaining fraction to meet project-specific placement compliance criteria (or criterion). Examples of DM placement requirements include aspects such as removing Munitions and Explosives of Concern (MEC) to address safety concerns and extracting over-sized material for beneficial use of DM (e.g., gravel and debris from sand to meet beach nourishment placement standards). Welp et al. (2008) provide detailed guidance for personnel involved in dredging projects with sediment containing MEC. The purpose of this document is to not only update the previous MEC-centric guidance with newly developed or identified technology but to also expand upon screening aspects to provide guidance for personnel involved in dredging projects that require removal of an oversized fraction for screening purposes other than just MEC removal.

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Preface

This study was conducted for the Dredging Operations Technical Support (DOTS) Program (Funding Account Code U4381377; AMSCO Code 08600) overseen by Dr. Burton Suedel, DOTS program manager of the US Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), and Mr. Charles E. Wiggins, Navigation program manager of the ERDC Coastal and Hydraulics Laboratory (CHL).

The work was performed by the Coastal Engineering Branch, Navigation Division, ERDC-CHL. At the time of publication of this report, Ms. Lauren Dunkin was chief, and Ms. Ashley E. Frey was chief, respectively. The deputy director of ERDC-CHL was Mr. Keith W. Flowers, and the director was Dr. Ty V. Wamsley.

COL Christian Patterson was the commander of ERDC, and the director was Dr. David W. Pittman.

1 Introduction

1.1 Background

Dredging can be defined as the process of excavating sediments and other materials usually from underwater locations, including the transportation and placement of dredge material for the purpose of constructing new waterways (new work), maintaining existing waterway dimensions (maintenance dredge), and/or obtaining fill for land reclamation, beach nourishment, dike and levee construction, creating wetlands and marshes, or other beneficial uses.

From the variety of different dredging projects, some require screening of the dredge material (DM) to achieve that respective project's DM placement requirement(s). Examples of DM placement requirements include aspects such as the following:

- extraction of Munitions and Explosives of Concern (MEC) to address safety concerns
- removal of oversized material for beneficial use of DM (e.g., gravel and debris from sand to meet beach nourishment placement standards)
- pre-processing DM to remove oversized material and debris to prepare it for subsequent treatment (e.g., hydrocycloning, filter belt presses)
- removal of debris to avoid creating hazards to commercial fishing and navigation, altering habitat quality, and jeopardizing public acceptance of the continued use of open-water disposal or placement sites

1.2 Objective

Welp et al. (2008) provide detailed guidance for personnel (e.g., planners, cost estimators, specification writers, engineers, managers, and dredging contractors) involved in dredging projects with sediment containing MEC. The objective of this study is to not only update the previous MEC-centric guidance with technology identified or developed and used since 2008 but also to expand upon screening aspects to provide guidance to personnel involved in dredging projects that require removal of an oversized fraction for screening purposes other than MEC removal.

1.3 Approach

A technical literature search was conducted, and various US Army Corps of Engineers (USACE) district personnel were surveyed to identify respective screening requirements and technologies used in various dredging projects nation-wide. Additional information, where available, was collected on district-identified screening technologies and results synthesized to produce this report.

2 History of Dredging and Screening

From a purely operational perspective, screening, in the general usage of this word, has been applied by hydraulic dredges since they were invented in the mid-1800s (as described in greater detail in Chapter 3). These types of dredges use centrifugal pumps to transport DM through pipelines, with screens installed over the pipeline suction mouth to exclude oversized objects from clogging the pump (USACE 1954).

In this report, the term *screening* will be specifically defined as the separation of an oversized fraction of the DM from the remaining undersized fraction to meet project-specific placement compliance criteria (or criterion). Screening technologies have been used by the USACE in dredging projects for multiple decades to attain dredging personnel or public safety, and/or process the DM to meet project-specific placement or beneficial use requirements. Design elements, and in some cases specific screening technologies used in these projects, have been taken from the dredging sand and gravel industry that have been in use since at least the early 1900s. Mallory and Nawrocki (1974) considered the feasibility of using sand and gravel screening technologies such as grizzlies, vibrating screens, hydraulic scalpers, etc., for processing DM under the USACE Dredged Material Research Program (DMRP).

The personnel/public safety aspect generally involves the removal and proper disposal of MEC from DM. MEC (USC 2019) distinguishes specific categories of military munitions that may pose unique explosives safety risks, such as unexploded ordnance (UXO, as defined in 10 USC. 101(e)(5); discarded military munitions, as defined in 10 USC. 2710(e)(2); or munitions constituents (e.g., TNT, RDX), as defined in 10 USC. 2710(e)(3) present in high enough concentrations to pose an explosive hazard.

Welp et al. (2008) provide detailed guidance involved in dredging projects with sediment containing MEC. This guidance is presented primarily in the form of compiled information gained from experiences on past dredging projects involving MEC that was compiled from a variety of sources. Different types of dredges and dredging projects that can encounter MEC are presented in relation to how these dredges' operational methodologies can be impacted by MEC, and past project methodology modifications that have been used to deal with MEC are discussed. Additional aspects of past MEC/dredging projects are presented with regard to (1) engineering controls to mitigate detonation hazards, (2) underwater MEC detection and discrimination technologies, (3) contracting, (4) public awareness, (5) safety requirements, and (6) MEC separation techniques and where available, subsequent impacts on production rates and costs.

DM from navigation dredging projects has also been screened to remove an oversized fraction to make it suitable for beneficial use (Maher et al. 2019; Averett and Estes 2011; Meyers and Adrian 2000; etc.). As offshore sand-borrow sites that contain sediment with the most suitable physical characteristics for beach nourishment are being depleted, less desirable sites that contain more oversized materials that require screening are increasingly being mined. Navigation project DM has also been screened to remove debris to avoid creating hazards to commercial fishing and navigation, increase habitat quality, and/or jeopardize public acceptance of the continued use of open-water disposal sites (Hoffman et al. Fox 2015).

Relatively limited volumes of contaminated DM have also been pre-processed by screening in environmental dredging projects where contaminated sediments are removed from a waterbody for purposes of sediment remediation (Palermo et al. 2008). These environmental dredging projects have involved the removal of an oversized fraction such that it does not impact downstream processing methods (e.g., liquid/solids separation including filter presses, hydrocyclones).

3 Dredging Process and Equipment

Screening of DM to meet placement requirements will impact the dredging process in some manner. These screening-induced aspects include reduced production rates, additional safety procedures and/or equipment, labor, etc. This generally increases project costs. The type of screening used, and location and manner in which it is applied in the dredging process, can have a profound influence on the severity of these impacts.

The process of dredging consists of the four following stages (Spigolon 1993):

- Excavation (loosening or dislodging) of the material from the bottom
- Removal of the loosened material to the dredge vessel
- Transportation of the material to the placement area
- Placement of the material.

For readers not familiar with dredging, the following section includes brief descriptions of the dredging process and major types of dredging equipment used in the United States. These descriptions are presented to give the reader a better understanding of specific dredging processes and equipment and how they work relative to the four dredging process stages. As previously mentioned, the introduction of a screening technology into any of those four stages (or a combination of any of them) will, to some degree, increase project costs.

Optimization of the screening system design and operation reduces the relative degree of impact that these negative effects can have on a project. A wide variety of dredge plants (the dredge proper and its auxiliary equipment) excavate, transport, and place and/or dispose of sediment in many different ways to accomplish respective project objectives. The term *placement* is used to denote that the sediment is being deposited such that there is benefit derived by its deposition (e.g., keeping sediment in the system) as opposed to it being disposed of with no benefit being rendered (e.g., disposal in a deep offshore DM disposal site).

During extraction, energy is applied to the sediment by mechanical and/or hydraulic means to alter sediment physical characteristics. Mechanical dredges generally use some type of bucket for digging the sediment, then hoist or boom the load to the surface. Hydraulic dredges use a centrifugal pump in converting kinetic energy into a pressure gradient to create a water flow that erodes and entrains sediment into a slurry (water and sediment mixture).

The sediment is transported from the dredge site to placement area by hydraulic or mechanical methods. In hydraulic applications, the centrifugal pump discharge can either be collected in a temporary storage container (usually a barge or scow) for later transportation to the placement area, or it can be conveyed directly into the placement area as slurry via the discharge pipeline. Mechanical dredges dump the bucket load within swing radius directly into the placement area, or into a transportation unit (e.g., barge, truck, conveyor belt) for haulage to the placement area.

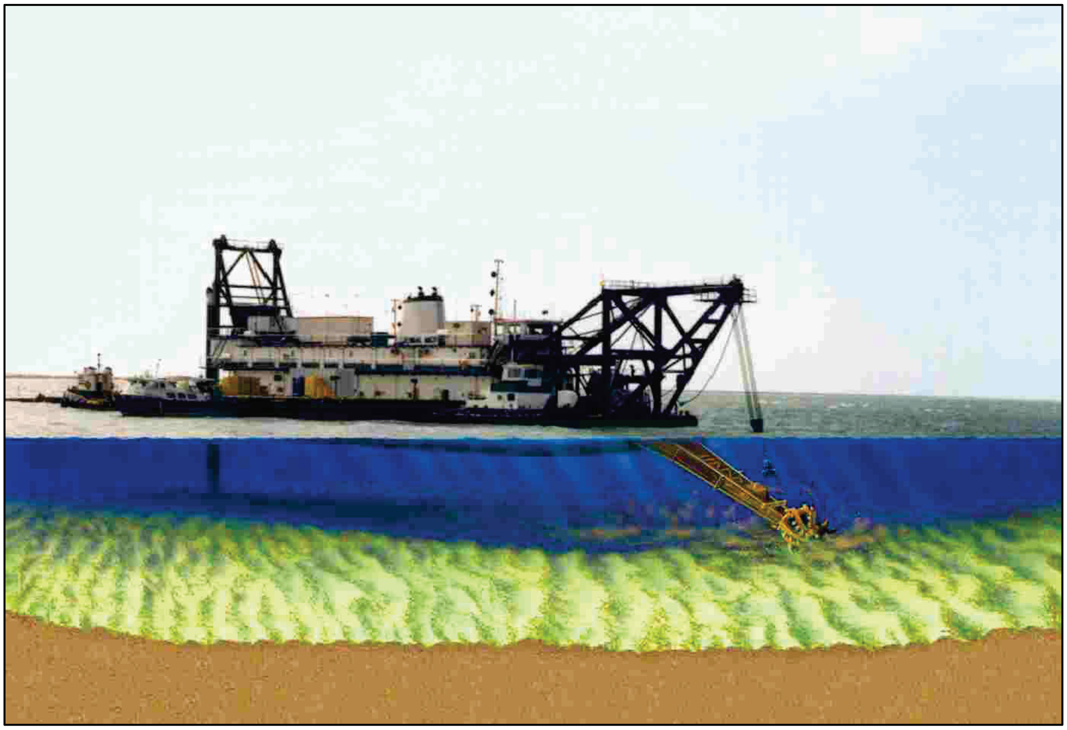
Dredges are usually classified by either the hydraulic or mechanical manner in which they achieve the excavation and removal stages. Hydraulic and mechanical dredges have enabled the transformation of rivers and harbors throughout the world into navigable waterways, allowing the transport of commerce and people where water passage was historically unavailable. The hydraulic dredge has been a major contributor to this transformation by providing for the movement of large quantities of DM in relatively short time periods.

Hydraulic dredges

Hydraulic dredges are characterized by their use of a centrifugal pump to dredge sediment and transport it in a slurry (mixture of solids and water) to a discharge (placement) area. The major types of hydraulic dredges are cutterhead pipeline and hopper dredges. The pipeline and hopper dredges are named for the method they use to transport DM from the dredging site to the placement area.

Hydraulic pipeline (cutterhead) dredges are normally non-self-propelled dredges that employ a mechanical cutter to break up the material that is then excavated hydraulically and transported to the placement site through a pipeline. The hydraulic pipeline cutterhead dredge (Figure 1) is the most commonly used dredge type and is generally the most efficient and versatile. The size of a cutterhead dredge is determined by the inside diameter of the dredge pump discharge. Because it is equipped with a rotating cutter apparatus surrounding the intake end of the suction pipe, it can efficiently dig and pump most types of alluvial materials and compacted deposits. This dredge has the capability of pumping DM long distances to upland disposal areas.

Figure 1. Hydraulic cutterhead pipeline dredge.



Hopper dredges are seagoing vessels that excavate material hydraulically and transport it into the dredge into a hopper that is built into the vessel's hull (Figure 2). While the rated capacity of a hopper dredge is based on the volumetric capacity of its hoppers, that value is not necessarily based on the amount of material it can safely load; American hopper dredges are rated as either small (up to 3,000 yd^3 ~2,300 m^3)*, medium (3000 – 6000 yd^3 ~2,300 – 4,600 m^3), or large (6000+ yd^3 ~ 4,600+ m^3) (USACE 2005). Hopper dredges are equipped with propulsion machinery, sediment containers (hoppers), dredge pumps, and other special equipment required to perform their essential function of removing material from a channel bottom or ocean bed and placing that material in open water or upland sites. Hopper dredges have propulsion power adequate for

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

required free-running speed and dredging against strong currents and excellent maneuverability for safe and effective work in rough, open seas. The vessel hull is compartmented with one or more hoppers.

Normal configuration has two dragarms, one on each side of the ship. A dragarm is a pipe suspended over the side of the vessel with a suction opening called a draghead. The dragarm is connected to a dredge pump, usually located inside the hull. In some cases, the dredge pump is located on the dragarm to increase its hydraulic efficiency. The draghead is moved along the channel bottom as the vessel moves forward. The DM is entrained into the draghead, up the dragpipe, and deposited and stored in the hoppers of the vessel. After the hopper is full, the dredge stops pumping and sails to the placement site where the DM is either gravity dumped out of the hoppers or pumped ashore (after being re-fluidized and pumped from the hopper).

Figure 2. Trailing suction hopper dredge.

Mechanical dredges are characterized as utilizing some form of bucket to excavate and raise the bottom material. Mechanical dredges may be classified into two subgroups by how their buckets are connected to the dredge: wire rope-connected (clamshell or dragline) and structurally connected (a backhoe). A clamshell mechanical dredge is shown in Figure 3, and a backhoe mechanical dredge in Figure 4. They are not normally utilized to transport the DM to the ultimate placement area. In some cases, the DM can be deposited directly in-water or on the bank immediately adjacent to the dredging area. Normally, the mechanical dredge deposits material into a barge that transports the material to the placement site. The loaded bucket is hoisted to the surface and side dumped into a transportation unit, or into the disposal site. Transportation units are usually barges (scows) that are towed or pushed by tugs. Barges place DM in a variety of methods: dumping through doors mounted in the hull bottom or having the hull split open, pumping out the material in slurry form (direct-pumpout), or unloading by other bucket, auger, or conveyor machinery. Clamshell bucket sizes range from 2.5 to 55 yd^3 (2 to 42 m^3), and the backhoe bucket sizes generally range from 6 to 25 yd^3 (4.6 to 19 m^3).

Figure 3. Mechanical (clamshell) dredge.

Figure 4. Mechanical (backhoe) dredge.

The factors that influence the selection of dredging equipment and method(s) used to perform the dredging include the following:

- Physical characteristics of material to be dredged
- Quantities and physical layout of material to be dredged
- Dredging depth
- Location and distance between the dredging and placement sites
- Physical environment and differences between the dredging and placement areas
- Contamination level of sediments
- Method of placement
- Production required
- Type of dredges available
- Environmental considerations.

4 Dredge Screening Technology Considerations

Welp et al. (2008) provide detailed guidance for personnel involved in dredging projects with sediment containing MEC that include screening considerations and technologies to remove MEC from the DM. The purpose of this report is to augment the list of screening technologies available in Welp et al. (2008) by providing the practitioner with an update on additional screening equipment/methodologies that have been used on dredging projects to separate MEC and/or oversized debris (trash, rocks, shell hash, etc.) from DM.

Many screening considerations for MEC-dredging projects are also applicable to these other types of dredging projects (beach fill, etc.) that require screening. These technologies can be used for processing material for projects that include navigation and/or borrow site-dredging applications. Critical aspects that should be taken into consideration to design and operate efficient and economical DM screening systems include the following:

- Type and size of dredge, transport, and placement (or disposal) equipment
- Dredge production rates
- DM geotechnical sediment characteristics
- Size, number, and composition of objects that require separation
- Manner in which the oversized fraction is removed and properly disposed of relative to management of the under-sized material
- Physical space constraints for screening and disposal equipment and operations.

Summary descriptions of the different types of dredges and their general operational methodologies were described in Chapter 3. These different pieces of equipment and respective operational methodologies influence the design and installation location (in the dredging process) of the screening system (or systems) (Welp et al. 2008). The type of dredge used (i.e., hydraulic or mechanical) will have a profound impact on the physical characteristics of the DM (and how it can be efficiently screened) throughout the excavation/removal/transport/placement process. The hydraulic dredges rely on water to entrain and fluidize the solids to make it pumpable. Cutterhead and hopper dredges typically pump a solids and water mixture (slurry) at a solids concentration of approximately 20% by volume, with the remaining 80% of the slurry consisting of water. If the hopper dredge is pumping DM ashore from its hopper, the solids concentrations are usually somewhat higher. The mechanical dredges can excavate and transport DM at nearly the DM in situ (in the channel or borrow area) solids concentration. Table 1 summarizes general operational processes for mechanical and hydraulic dredges.

Table 1. Dredge excavation, removal, transport, and placement operational processes.

Dredge Type	Excavation Method	Removal Method	Transport Method	Placement Method
Hydraulic Dredges				
Hopper Dredge	Hydraulic suction, Hydraulic erosion, Mechanical dislodgement using knives or blades	From bottom to dredge vessel in hydraulic pipeline as a sediment-water slurry approximately 20% solids by volume	Fluidized sediment settles in hopper (solids concentration increases in this fraction, though usually not to the pre-dredging levels), vessel moves to placement site	Bottom discharge by gravity or pump out with slurry typically +20% solids by volume
Cutterhead Dredge	Mechanical dislodgement using rotary cutter, Hydraulic suction, Hydraulic erosion	From bottom to dredge vessel in hydraulic pipeline as a sediment-water slurry approximately 20% solids by volume	From dredge vessel to placement site in pipeline[1]	Pipeline discharge on land, water, or beneficial use site
Mechanical Dredges				
Wire Rope-Connected (Bucket) Dredge	Mechanical dislodgement, scooping with bucket	Wire rope with clamshell or dragline. Dredge sediment (particularly fine-grained) at solids concentration at or near those of in situ conditions	Barge, land- based conveyor belt, trucks, material may be sidecasted	Bottom discharge, pump out, or mechanically to unload. Direct discharge from belt, truck, or bucket
Structurally Connected (Backhoe) Dredge	Mechanical dislodgement, scooping with backhoe bucket	Rigid structural members with backhoe bucket. Dredge sediment (particularly fine-grained) at solids concentration at or near those of in situ conditions		

[1]May be pumped into barges and moved to placement site.

The dredge's production rate in navigation dredging projects (usually expressed in units of cubic yards per hour of solids [yd^3/hr]) has a major impact on screening system design. If the throughput capacity of the screening system cannot keep up with the dredge, resultant delays will usually negatively impact the project by incurring schedule delays, increasing cost, or in the case of MEC, by possibly reducing safety. Table 2 lists volumes of slurry that are delivered by different-sized hydraulic dredges operating at different pipeline slurry velocities to give the reader an idea of the volumes of slurry that need to be screened.

Table 2. Hydraulic pipeline dredge discharge rates (USACE 2015).

Discharge Velocity		Discharge Pipe Diameter yd^3/sec (m^3/sec) (gal/min)							
m/sec	(ft/sec)	8 in. (203 mm)		18 in. (457 mm)		24 in. (610 mm)		30 in. (762 mm)	
3	(10)	0.13 (0.1)	(1,575)	0.65 (0.5)	(7,877)	1.16 (0.9)	(14,100)	1.82 (01.4	(22,056)
4.5	(15)	0.19 (0.15)	(2,303)	0.98 (0.75)	(11,876)	1.75 (1.33)	(21,207)	2.73 (2.09)	(33,083)
6	(20)	0.26 (0.2)	(3,150)	1.31 (1.0)	(15,875)	2.33 (1.78)	(28,236)	3.64 (2.78)	(44,111)
7.6	(25)	0.32 (0.24)	(3,878)	1.64 (1.25)	(19,874)	2.91 (2.23)	(35,265)	4.54 (3.47)	(55,018)

Note: Discharge rate = pipeline area × discharge velocity.

The following example is given to illustrate a production rate of a mechanical dredge. If a 30 yd^3 (23 m^3) clamshell bucket is being used and has an average bucket fill factor of 85% (i.e., percentage of bucket capacity that is filled per cycle) at a cycle time of 60 sec, it is capable of placing 1,530 yd^3/hr (1,170 m^3/hr) of DM into a barge.

The DM geotechnical sediment characteristics will, to some degree (depending on other factors listed above) affect screening operations.

For mechanical dredges, the photograph in Figure 5 of the heaped material inside of a scow illustrates how a clamshell bucket can excavate sediment at near in situ solids concentration. The presence of these clods of cohesive fine-grained material could have a pronounced impact on screening efficiency.

Figure 5. Photo of cohesive sediment excavated by a clamshell bucket mounded up in a barge (source: Cable Arm).

The size, number, and composition of objects that require separation, in conjunction with the way it is removed from the process stream and properly disposed of, must be considered. Technical aspects of the separation and safe disposal of MEC is discussed in detail in Welp et al. (2008) with regard to engineering controls to mitigate detonation hazards, MEC separation techniques, contracting, public awareness, safety requirements, and (where available) subsequent impacts on production rates and costs.

While separation of objects other than MEC does not usually require the higher level of safety, the other considerations are readily applicable. In the mining and aggregate dredging industry, the oversized material is often recovered as a product while the separated over-sized material of navigation, borrow area, or environmental dredging is almost always the undesired component. The under-sized material predominantly consisting of sediment is, for navigation and environmental dredging projects, preferably placed for beneficial use.

Screening can be divided into two general categories — static (stationary) or vibrating. Past MEC projects described by Welp et al. (2008) have predominantly used static screening. For hydraulic dredges, these screens have been installed with varying degrees of success:

- At the suction mouth (cutterhead and hopper dredges)
- In a rock box at pump suction before it reaches the pump (cutterhead and hopper dredges)
- Screening DM leaving the pump and entering the hopper (hopper dredge)
- Screening material at pipeline point of discharge (cutterhead and hopper dredge).

For mechanical dredges, static screens have been installed over barges to separate MEC from sediment while it was being loaded. In the Toussaint, OH, dredging project, the screen aperture maximum dimensions were 19 mm (0.75 in.) in one direction and 127 mm (5 in.) in the other direction. These dimensions were based upon the design objective of retaining 20 mm (0.8 in.) projectiles. In the Hart Miller Island (HMI) project, the debris and MEC remaining in the bottom of barges (after the majority of sediment had been removed by a pumpout system) were unloaded by a separate clamshell crane into haulage trucks. The truck loads were subsequently placed upon a static screen that consisted of 1 in. (25.4 mm) square screen apertures. For both the Toussaint River and the HMI projects, water jets were used to facilitate the gravity flow of undersized material through the screen. After application of the water jetting systems, Unexploded Ordnance Disposal personnel were required to visually inspect the screens for the presence of MEC and remove it when located (Welp et al. 2008). The design and operation of these screening systems for the mechanical dredges required consideration of the physical space constraints for screening equipment and visual identification and removal/disposal operations (especially when used onboard the barges).

Relationships between independent and dependent variables of the previously listed considerations are illustrated by the following example[*]. The Southwest Division Naval Facilities Engineering Command conducted an analysis (NAVFAC Southwest Division 1998) to evaluate screening

[*] Presented in the context of independent and dependent variables used in modeling where the independent variables are those that are input (controlled) and the dependent variables represent the outcome or output that result from the inputs.

alternatives for removing MEC at the discharge of a large hopper dredge's pump ashore pipeline for a beach nourishment project.

The analysis production values were based on a large hopper dredge, specifically dredge *Stuyvesant* with a 11,144 yd^3 (8,520 m^3) capacity hopper.

> Each load for pump out on the beach is approximately 6,000 cu m (7,800 cu yd) or the equivalent of 600 dump truck loads at 10 cu m (13 cu yd) each. This load is discharged on the beach over a period of 1.5 hrs or at a rate of approximately seven dump truck loads per minute, 400 truck loads per hour. (NAVFAC Southwest Division 1998)

In this analysis, it was reported that angled screens are readily available from mining and aggregate industry equipment suppliers, but for the San Diego project conditions, the required size of screen would require special fabrication. Conceptual sketches of this report's version of angled screens are presented in Figures 6 and 7.

At an estimated design flow of 100,000 gpm (378 m^3/min) with 2.2 tons/sec (2.0 tonnes/sec) of solids to be screened at 8 mm (0.3 in.), it was anticipated that the angled screen would clog intermittently and would be extremely large, on the order of 100 m^2 (1,076 sq ft). This operation was anticipated to be labor intensive and costly, and as with all screening operations, crew safety would be a concern. This alternative appeared capable of achieving the necessary screening requirements; however, it "was not proven that the equipment will work for this application. The beach installation would be large and details, i.e., placement, stability, and a system to get the screened sand to the beach fill section remained to be worked out" (NAVFAC Southwest Division 1998).

Figure 6. Angled screen plan view (source: NAVFAC Southwest Division [1998]).

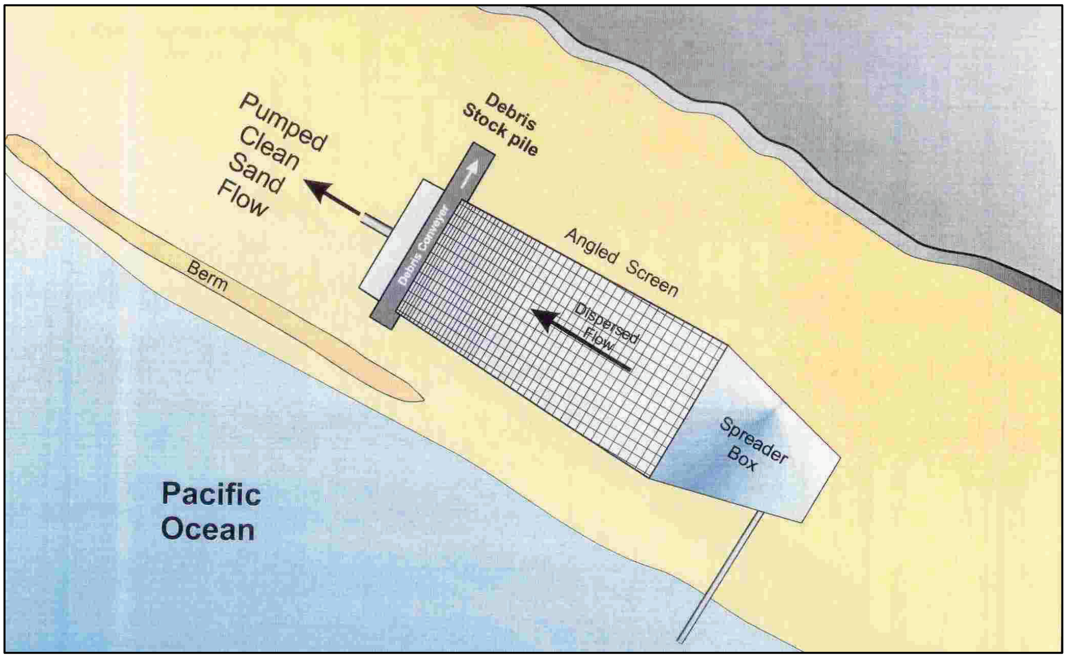
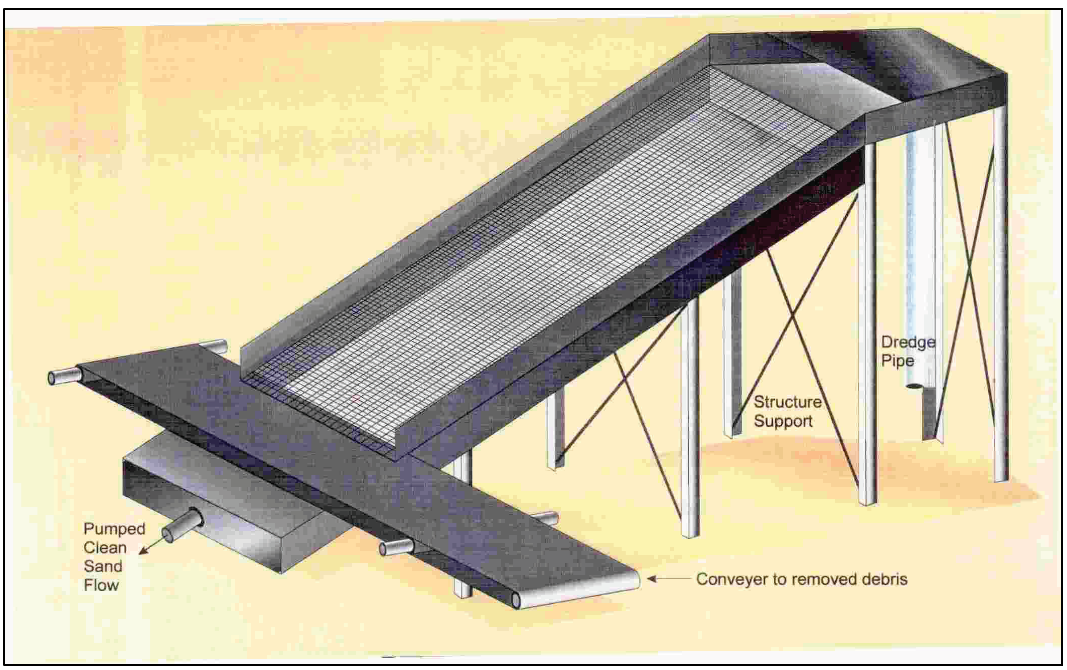


Figure 7. Angled screen side view (source: NAVFAC Southwest Division [1998]).



The following chapters present information on two different screening systems and discuss respective aspects relevant to the previously listed considerations.

Chapter 4 describes a mechanical dredge screening technology that, while similar in basic configuration to the barge-mounted Toussaint River MEC separation system, this system was (and is being) used on an intermittent basis to separate general debris in DM before it goes to offshore DM disposal (placement) sites. The system described in Chapter 5 is based on vibrating screens mounted on a mobile platform that is connected to the discharge pipelines of cutterhead and hopper dredges conducting beach nourishment projects to screen out MEC and/or general debris.

5 Mechanical Dredge Barge Static Screening System

This chapter presents information on select design and operational considerations of a mechanical dredge static screening method that has been used on various west coast dredging projects to remove debris prior to DM disposal (or placement) in open water sites.

A primary goal of the Dredge Material Management Plan (DMMP) in the US Northwest is to provide affordable and environmentally protective options for open-water disposal of DM. The DMMP consists of four agencies: US Army Corps of Engineers, Seattle District; the US Environmental Protection Agency, Region 10; the Washington Department of Ecology; and the Washington State Department of Natural Resources. These agencies work collaboratively to make sure that material proposed for dredging in Washington State is appropriately tested and managed (https://www.nws.usace.army.mil/Missions/Civil-Works/Dredging/).

While suitability is based largely on chemical and biological testing of sediment, management of debris in DM is also an important consideration. This proper management of debris is needed to avoid creating hazards to commercial fishing and navigation, altering habitat quality, and jeopardizing public acceptance of the continued use of open-water disposal sites (Hoffman et al. 2015).

As per the December 2018 *Dredged Material Evaluation and Disposal Procedures User Manual*:

> In general, debris is not allowed to be disposed at the DMMP open-water sites. This includes all floatable debris, large non-floatable debris such as logs, piling, rip rap and concrete, and all solid waste (e.g., tires, rebar, garbage.) As described in the 2015 DMMP Clarification on Debris Screening Requirements effective June 16, 2016 (DMMP, 2015e [Hoffman et al., 2015]), all projects must use a 12-inch x 12-inch (30.5-cm x 30.5-cm) screen to remove debris unless it can be demonstrated that debris is unlikely to be present or that the debris present is large woody debris that

> can be easily observed and removed by other means during dredging. (DMMP 2018)

Because DMMP guidance on debris management has been focused primarily on larger debris, such as logs and rip rap, barge-mounted screens are rarely used in Washington State dredging projects to meet this placement requirement. Usually, a visual approach has been used to observe large debris and solid waste (e.g., tires, rebar, garbage) when observed in the dredge bucket (e.g., bucket will not close) or identified on the surface of the sediment barge. These debris are removed from the barge using the clamshell bucket and placed in a separate debris barge or containment area for later disposal at an upland facility. Since 1993, there have been only two dredging projects in the State of Washington where barge static screening has been used (Hoffman et al. 2015). Hoffman et al. (2015) also include photographs of other barge static screening equipment that have been used on Port of Long Beach and San Francisco Bay, CA, dredging projects.

Typically, these rigid screens have been designed to cover, or be attached to, only a portion of the barge's coaming. Figure 8 is a photograph of one of these barge (grizzly) screens that was used in the Port of Long Beach, CA. The screen frame is constructed such that after the barge is filled to capacity with undersized material immediately underneath the screen, it can be moved forward or aft along the coaming to continue barge loading. Figure 9 shows this screen being loaded by a clamshell dredge, and Figure 10 shows how the screen was lifted off the loading barge prior to debris being deposited onto a flat deck debris barge in preparation for transportation off site. A variation of this screen design constructed of chain was also used on a California dredging project (Figure 11), but no additional information about its design, operation, or on the previously described systems was available.

Figure 8. Steel (grizzly) barge screen used at Port of Long Beach, CA (Hoffman et al. 2015).

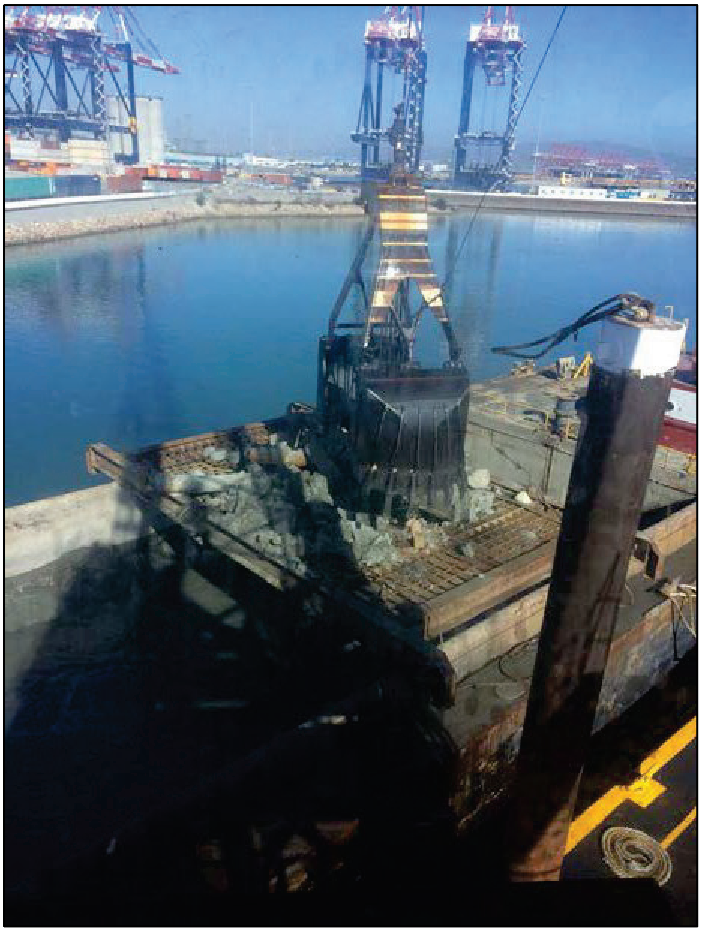


Figure 9. Clamshell dredge loading steel (grizzly) barge screen at Port of Long Beach, CA (Hoffman et al. 2015)

Figure 10. Screen positioned over flat deck debris barge prior to removal at Port of Long Beach, CA (Hoffman et al. 2015).

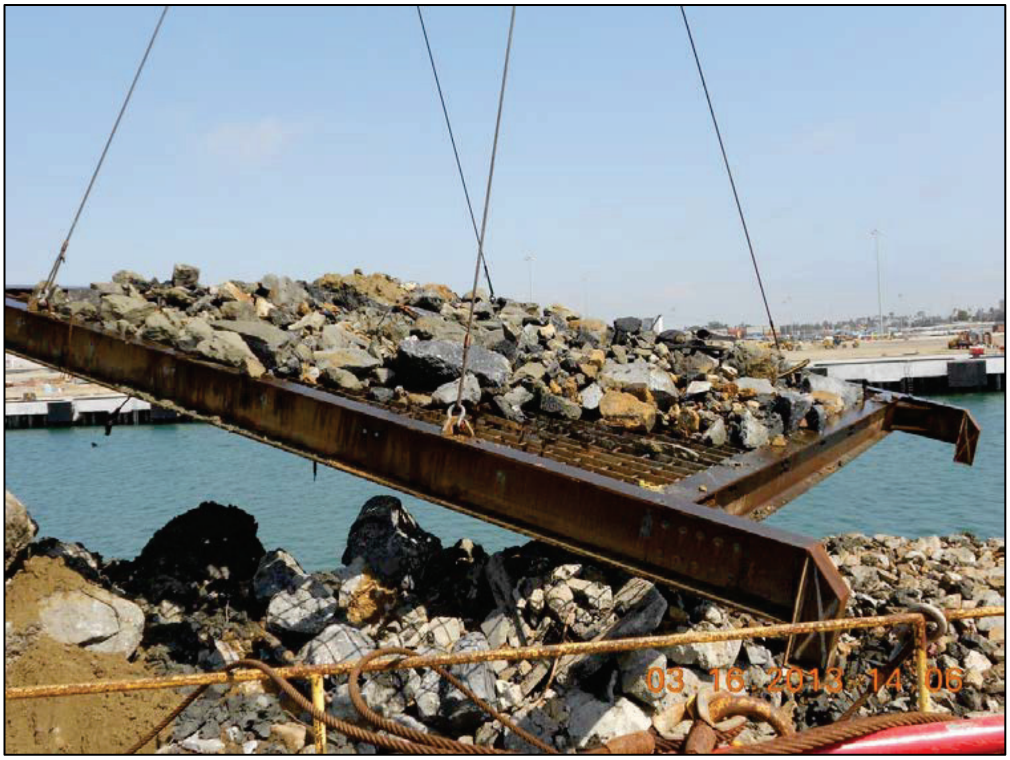


Figure 11. Barge screen constructed of chain used in a CA dredging project (Hoffman et al. 2015).

Hoffman et al. (2015) also reported that the USACE San Francisco District (SPN) has standard permitting conditions requiring use of 12 in. × 12 in. (30.5 cm × 30.5 cm) debris screens for the majority of projects using open-water disposal sites in San Francisco Bay. Figure 12 is a photograph of a fixed barge (grizzly) screen being used in conjunction with a backhoe (mechanical) dredge.

Figure 12. Small bottom-door barge with fixed grizzly – San Francisco Bay, CA.

In addition to a water-jetting system that was used during dredging at the Toussaint River, Ohio, MEC dredging project, clamshell bucket loads of water were dumped upon material lying on the screens to facilitate undersized material throughput. It is assumed that this technique was used for the California clamshell dredge projects.

6 Hydraulic Dredge (Vibrating) Screening System

An innovative screening system for hydraulic dredges has been developed and used on the East Coast and Gulf of Mexico beach nourishment projects to remove oversized material (e.g., rocks, broken shell, and coral fragments). One of these flood risk reduction projects also involved MEC. While similar in fundamental operating concept to the previously described Southwest Division Naval Facilities Engineering Command design (NAVFAC Southwest Division 1998) (illustrated in Figures 5 and 6), this system is based on the use of vibrating screens instead of static screens. This system is called the Fluidized Rock System (FRS) and is shown in Figure 13.

Figure 13. Fluidized Rock System (FRS).

As shown in Figure 13, the dredge's discharge pipeline is connected to the FRS such that the transported slurry initially impacts a velocity box to reduce its kinetic energy. This slows down its velocity before flowing on top of a double-stacked inclined vibrating screen system. These two screening decks are interchangeable, and respective opening sizes are selected to optimize throughput while achieving the designated cut point between oversized and undersized material. The screens can be woven wire or polymer, and typical opening sizes to date have ranged between 0.75 in. to 4 in. (19 to 102 mm). Angle of the top screening deck is also adjustable such that its screen size and inclination angle can be tuned to the feed material's physical characteristics and flow rate to split the volume of separated oversized material between the two screen decks. The smaller screens (e.g., 0.75 in. [19 mm] openings) are always on the bottom. These screens are visually inspected during project execution and panels replaced as they wear out.

The elliptical motion of the screens and direction of the water carry the oversized material forward to a common conveyor belt that discharges into either a containment box or articulated dump trucks as shown in Figure 14. The undersized material consisting of predominantly sediment (sand) and water flows onto a discharge flume that channels this mixture onto the shore where it is usually formed into the beach template by bulldozers (Figure 15).

Figure 14. FRS process flow of over and undersized material.

The entire FRS unit is self-propelled on a tracked chassis (Figure 16) that, in addition to the screening and conveyor belt components, is diesel/hydraulic powered. The diesel prime mover and hydraulic control station (Figure 17) utilize environmentally acceptable hydraulic fluid. After a section of beach is sufficiently filled with sand, the FRS unit is advanced, and additional pipe added behind it.

Figure 15. FRS discharge flume depositing undersized material (slurry consisting predominantly of water and sand) onto beach. Note Manson hopper dredge *Glenn Edwards* in background, pumping ashore.

Figure 16. Self-propelled FRS unit mounted on a tracked chassis.

Figure 17. FRS diesel prime mover and hydraulic control station.

This system has been used on several beach nourishment projects funded by federal and/or state sources to remove oversized objects (typically greater than 0.75 in. [19 mm]) from the slurry before placing it on the beach. Figure 18 shows a pile of oversized material separated during a USACE Jacksonville District and State of Florida beach nourishment project on Treasure Island, Florida, in 2018.

Figure 18. Oversized material separated by the FRS during a beach nourishment project on Treasure Island, Florida. Note Norfolk Dredging's 24 in. (610 cm) discharge diameter cutterhead dredge *Charleston* in far background, pumping ashore.

Another beach nourishment project that included MEC was conducted by the USACE New York District and State of New Jersey in 2016. While screens were installed over the draghead openings to exclude larger-sized MEC from the dredging hydraulic circuit, the dredging operations explosives hazards analysis specific for the smaller-sized MEC downstream of these draghead screens permitted the use of an FRS unit modified with an extender chute (Figure 19). This extension was used to minimize external forces exerted on any UXO that got past the UXO-qualified inspection personnel as it was deposited into the collection container. The adjustable conveyor belt speed facilitated the setting of an optimum speed that balanced between an adequate oversize removal rate with the need to visually it for UXO. Both the primary FRS unit and its backup (on site in case of mechanical failure of the primary) had the capability to be controlled remotely. During the entire project where approximately 3.2M yd^3 (2.4M m^3) of sand were screened, use of the backup unit was not required.

Figure 19. FRS unit modified for use in a beach nourishment project in Deal, NJ, that involved MEC.

The FRS is adaptable to any size dredge pipe from 12 to 36 in. (30.5 to 91.4 cm^3), and the design flow of the largest FRS unit is for 30,000 gpm (114 m^3/min), but it could run in the mid-40,000s gpm (151 m^3/min) all day and possibly be able to exceed 50,000 gpm (189 m^3/min)*. This mid-40,000 gpm (151 m^3/min) value is at the upper limit of flowrates listed in Table 2 (i.e., a flow rate of 44,111 gpm (167 m^3/min) for a 30 in. (76 cm diameter discharge line pumping at 20 ft/sec [6.1 m/sec]).

One of the critical considerations to design and operate an efficient and economical DM screening system is the manner in which the oversized fraction is removed and properly disposed of relative to management of the under-sized material. The relatively continuous removal of oversized material provided by the FRS conveyer belt discharge may offer increased production efficiency over the (static) basket screen technology (described in Welp et al. [2008]) that requires that slurry flow be stopped to remove the oversized fraction. This efficiency differential depends on number of basket screen units used in the discharge pipeline circuit (such that when one fills up, the slurry flow can be directed to another via a wye valve) and also on how fast the baskets fill up with oversize. From a UXO safety perspective, it is more desirable to inspect the thinner layer of oversized material on the conveyor belt for UXO compared to either having to get inside the basket screen unit or to remove the oversized fraction heaped inside prior to inspection. While the cost of the FRS on a project depends on a host of factors, it can range from \$1.00/yd^3 to +\$2.00/yd^3 (\$1.00/0.8 m^3 to +\$1.5/m^3)† .

Reportedly, the system is relatively quiet, with typical noise levels measured at 70 db approximately 30 yd (27 m) from the system, measured using the OSHA-recognized noise monitoring app, NIOSH SLM. The FRS is designed to accept sediment continuously for 8 hr but not able to go into the surf zone to operate*.

To date, the FRS has been used only on beach nourishment projects where the DM sediment composition consisted primarily of cohesionless (non-plastic) sand. The separation efficiency of this system will be increasingly impacted as the level of sediment cohesion (or plasticity) increases (e.g., increasing clay and water content) and becomes stickier.

* Bernie Eastman. Personal communication. 7 May 2018. Eastman Aggregate Enterprises, LLC.

† Sean Kemnuir. Personal communication. 14 October 2020. Eastman Aggregate Enterprises, LLC.

7 Summary

Certain types of dredging projects require screening of the dredged material (DM) to achieve that respective project's DM placement requirement(s) (e.g., MEC removal, extracting oversized material for beneficial use of DM). The purpose of this document is to update the previous MEC-centric guidance presented by Welp et al. (2008) with technology identified or developed and used since 2008, and also to expand upon screening aspects to provide guidance to personnel involved in dredging projects that require removal of an oversized fraction for screening purposes other than just MEC removal.

When the screening of DM is required to meet placement requirements, it always impacts the dredging process in some manner. These screening-induced aspects include reduced production rates, additional safety procedures and/or equipment, labor, etc., that usually increase project costs. The type of screening used, and location and manner in which it is applied in the dredging process, can have a profound influence on the severity of these impacts.

Different types and sizes of dredges and respective operational methodologies influence the design and installation location (in the dredging process) of the screening system (or systems). The type of dredge used (i.e., hydraulic or mechanical) will have a profound impact on the physical characteristics of the DM (and how it can be efficiently screened) throughout the excavation/removal/ transport/placement process. Critical aspects that should be taken into consideration to design and operate efficient and economical DM screening systems include the following:

- Type and size of dredge, transport, and placement (or disposal) equipment
- Dredge production rates
- DM geotechnical sediment characteristics
- Size, number, and composition of objects that require separation
- Manner in which the oversized fraction is removed and properly disposed of relative to management of the undersized material
- Physical space constraints for screening and disposal equipment and operations.

This report presents information on two different screening systems not included in the original report and discusses respective aspects relevant to the previously listed considerations. The first system is a mechanical-dredge screening technology that is similar in basic configuration to the barge-mounted Toussaint River MEC separation system (Welp et al. 2008). This system was used to separate general debris in DM before it goes to offshore DM disposal (placement) sites. The second system is based on vibrating screens mounted on a mobile platform that is connected to the discharge pipelines of cutterhead and hopper dredges conducting beach nourishment projects to screen out general debris and/or MEC.

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Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	0.0254	meters
Inches	25.4	millimeters
Inches	2.54	centimeters
feet per second	0.3048	meters per second
Gallons per minute	0.00378541	cubic meters per second
tons	0.907185	tonnes
square feet	0.092903	square meters
yards	0.9144	meters

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14. ABSTRACT
Certain types of dredging projects require screening of the dredged material (DM) to achieve the project’s DM placement requirement(s). Screening in the context of this report will be defined as the separation of an oversized fraction of the DM from the remaining fraction to meet project-specific placement compliance criteria (or criterion). Examples of DM placement requirements include aspects such as removing Munitions and Explosives of Concern (MEC) to address safety concerns and extracting over-sized material for beneficial use of DM (e.g., gravel and debris from sand to meet beach nourishment placement standards). Welp et al. (2008) provide detailed guidance for personnel involved in dredging projects with sediment containing MEC. The purpose of this document is to not only update the previous MEC-centric guidance with newly developed or identified technology but to also expand upon screening aspects to provide guidance for personnel involved in dredging projects that require removal of an oversized fraction for screening purposes other than just MEC removal.

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