MASONVILLE DREDGED MATERIAL CONTAINMENT FACILITY
DREDGING ENGINEERING & DESIGN

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ABSTRACT

The new Masonville Dredged Material Containment Facility (DMCF) is located in Baltimore, Maryland, within the Patapsco River. This DMCF provides 11.8 million cubic meters (mcm) (15.4 million cubic yards (mcy)) of dredged material capacity for the Baltimore Harbor and will ultimately become a marine terminal.

Major considerations for the DMCF design included identification of dike material, site preparation, future raisings, infrastructure coordination, relocation of existing infrastructure, end-use design, environmental and site constraints, geotechnical conditions, scheduling, and sequencing. The selected DMCF design composed of a hydraulically placed dike, armored on the north dike face and a fringe wetland on the west dike face; mechanically placed landside dikes; and steel cellular cofferdams on the eastern side.

During initial design, onsite borrow was integrated into the dike design to increase site capacity and reduce project costs. Geotechnical investigations were required to characterize the site due to a history of mining, dumping, and natural shoaling in this area. Post-award, an additional expansive geotechnical investigation was undertaken by a contractor/owner joint boring program. The combined efforts included multiple boring operations, vibracores, wash probings, hydrographic surveys, lead-lines, test pits, and test sections, which provided the engineering support to develop a design which was completely reliant upon a questionable borrow source and guided numerous pre- and post-award engineering decisions and change order design efforts.

The Masonville DMCF project has been on a fast track schedule and required innovative planning, engineering, and design to meet schedule and stay within budget. Specific design/engineering challenges encountered throughout the initial design and subsequent dredging contracts included: dredging/filling plan, undercutting of unsuitable foundation, integrating a nearby deepening project, owner/contractor jointly developed dredging template, construction over existing utilities, stockpiling of suitable fill, protection of a bordering federal navigation channel, and dike closure.

Keywords: Fringe wetland dike, rock armored dike, subaqueous borrow

INTRODUCTION

The average volume of dredging required on an annual basis for maintaining and improving the Port of Baltimore channel system is approximately 4.0 mcm (5.2 mcy). The average annual volume of dredged material for which the State of Maryland is responsible is 3.6 mcm (4.7 mcy), which includes 1.1 mcm (1.5 mcy) from within Baltimore Harbor. The Port’s main Dredged Material Containment Facility (DMCF) for Harbor dredged material, Hart-Miller Island (HMI), was over 4.5 kilometers squared (km²) (1,100 acres) and provided near 76.5 mcm (100 mcy) of capacity and was closed by legislative mandate on December 31, 2009. To replace this facility, the Maryland Port Administration (MPA) developed the Masonville DMCF, which is key to a long-term effort by the MPA to identify, study, design, permit, and construct new confined placement sites to meet the annual 1.1 mcm (1.5 mcy) Harbor need. Masonville is located in the Baltimore Harbor portion of the Patapsco River,

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Construction of the Masonville DMCF will be completed in 2010. Figure 1 shows the project location before and after construction of the DMCF.

The Masonville DMCF was designed to accommodate Baltimore Harbor dredged material, which is statutorily required to be placed in a confined disposal facility. Limited options for placement facilities in Baltimore Harbor led the MPA’s project team to develop an in-water facility that required the fill of 0.6 km² (141 acres), including 0.5 km² (130 acres) of tidal open water. The Masonville DMCF has a placement capacity of 11.8 mcm (15.4 mcy) and a projected operational life span of approximately 20 years.

Figure 1. Before and after pictures of completed DMCF

The facility’s in-water footprint was overlain with 4.6 to 9.1 meters (15 to 30 feet) of unsuitable foundation material underlain by suitable dike construction material. The use of subaqueous borrow from onsite and concurrent Harbor dredging was identified as key to reducing dike fill costs and increasing placement capacity. However, use of this material was seen as difficult due to irregular site geology, existing infrastructure in the site footprint, agency/environmental design constraints, scheduling with multiple large-scale projects, and a fast-track schedule. The engineering and contracting approach developed by MPA to construct the Masonville DMCF by using subaqueous borrow from onsite and concurrent large-scale Harbor dredging has allowed the project to provide cost-effective placement capacity.

CONTAINMENT DIKE DESIGN

The DMCF containment structure consists of four distinct sections, totaling approximately 3,048 linear m (10,000 linear ft). The sections are a fringe wetland dike, a rock armored dike, cellular cofferdams, and a sand dike on existing shoreline (Figure 2). The facility has initially been constructed to +3.4 m (+11 ft) Mean Lower Low Water (MLLW), with the fringe wetland section to +5.5 m (+18 ft) MLLW. The ultimate dike crest elevation for the Masonville DMCF is 12.8 m (+42 ft) MLLW. The initial constructed dike crest elevation was based upon an estimate of the borrow material available onsite, taking into account geotechnical properties, properties of hydraulically placed materials, and equipment capabilities. Future raisings, from the initial construction to the final elevation, are to be completed with a combination of granular fill and recovered dried dredged material from within the site.
Site Design Constraints

The selected dike alignment is a product of numerous design iterations and studies of geographic, geotechnical, navigational, and environmental constraints. The Ferry Bar Channel, a federally maintained navigation channel, is heavily used and provides 12.8 m (42 ft) access to major MPA terminals. MPA was required by the Coast Guard to maintain a distance of 76.2 m (250 ft) from the toe of the dike to the toe of the Ferry Bar Channel. This constraint and geotechnical considerations dictated the northern dike alignment. Public and regulatory concern over encroaching on Masonville Cove determined the western boundary. The eastern cofferdam alignment was designed to allow construction of a relieving platform to provide a berthing area for handling roll on-roll off (RO-RO) cargo and to maintain a safe operating distance from nearby existing Fairfield Pier 4, which services the adjacent Masonville-Fairfield Marine Terminal Complex.

Geotechnical Considerations

Figure 3 is a soil profile depicting conditions typical of those found at the Masonville site. As shown, the site generally has three strata. The first, Stratum I, is a layer of soft silts and clays, generally 15 to 30 ft thick. The second, Stratum II, is composed of sand and gravel, generally 3.0 to 6.1 m (10 to 20 ft) thick, although 12.2 m (40 ft) thick layers were located within the borrow area. The third, Stratum III, is a stiff red clay layer that extends beyond the reach of the borings. Stratum I material was found to be geotechnically unsuitable as a dike foundation and for use as a fill material. Stratum I in the northeast corner of the originally proposed rock armor dike alignment (parallel to the Ferry Bar Channel) was over 10.7 m (35 feet) thick and Stratum II material was not found until elevations of at least –15.2 m (-50 ft) MLLW. This prompted a shift in the rock armored dike alignment location away from the Ferry Bar Channel, to the southeast and tie-in directly with the cofferdam berthing area.

The Stratum II layer was identified as a suitable dike foundation and a potential source of borrow for dike construction early in the Masonville design process. The use of Stratum II material from within the dike alignment for dike construction became the key to allowing the project to provide affordable placement capacity. The final horizontal delineation of the borrow area is identified earlier in the Figure 2.
Figure 3. Typical soil profile

Typical Dike Sections

This section provides the three typical design cross-sections for the dike containment structure. Prior to the hydraulic placement of the fringe wetland and rock dikes, the excavation of geotechnically unsuitable material (undercut) was required. The horizontal pay limits of the undercut were designed to ensure dike stability with a safety factor greater than 1.3 while also minimizing the quantity of undercut. The undercut width did not extend under the full dike section. The abbreviated undercut width was designed to displace the remaining unsuitable material towards the interior of the site by the granular material placed during dike construction. Cross-sections shown in Figures 4 and 5 depict the unsuitable excavation and the design geometry of the rock armor dike and the fringe wetland dike.

A variable of any dike design is the side slopes, which, together with the crest height, is generally dictated by soil conditions and dike construction methodologies. Soil conditions varied drastically across the project footprint. Dike construction methodologies included mechanical and hydraulic dredging of borrow material and subsequent placement of material in the dike section. Based on the analyses performed for prior projects and the geotechnical analysis performed for this project, the dike design for both inboard and outboard slopes was determined to be achievable at 3H:1V with hydraulic placement. The designed slopes were initially contested by bidding contractors, but the measured side slopes of the constructed dikes indicated that the design analysis was accurate.
Figure 4. Armored/north dike section

The rock armor dike was designed to consist of a matrix predominantly comprised of sand and gravel hydraulically pumped into place. The armor consisted of 0.8 m (2.5 ft) of Maryland class II riprap (approximately equivalent to 113.4 kilograms (250 pound) armor stone). The crest width is 19.8 m (65 ft) and the elevation is +3.4 m (+11 ft) MLLW. The crest elevation of +3.4 m (+11 ft) MLLW was based on coastal design criteria. The designed elevation allows the dike to be armored, the site to become operational, and to be constructed with available onsite borrow. The 19.8 m (65 ft) crest width allows future raising to +5.5 m (+18 ft) MLLW with minimal fill material through the continuation of the existing 3H:1V side slopes. Raising the dike to +5.5 m (+18 ft) MLLW provides a 6.7 m (22 ft) crest width which will serve as the site’s permanent roadway, as raisings above +5.5 m (+18 ft) MLLW will be constructed of dried dredged material and set inside the +5.5 m (+18 ft) MLLW dike.

Similar to the rock armor dike, the fringe wetland dike (Figure 5) was designed to consist of a matrix predominantly comprised of sand and gravel hydraulically pumped into place. Coastal analysis of the fringe wetland dike alignment, with a reduced fetch and protection within Baltimore Harbor, determined that an armored slope was not required. Due to its proximity to the Masonville Cove, the outboard slope is designed with a 3H:1V slope down to –0.3 m (-1 ft) MLLW, a 6.1-meter (20-foot) bench, and then a 10H:1V slope to the existing bottom. Once vegetated with tidal plants, the bench and slope assist in achieving mitigation requirements and provide a transition zone to the adjacent Masonville Cove restoration area.
The fringe wetland dike was designed as it appears in Figure 5. Initial quantity estimates of the borrow area provided that the fringe wetland dike, unlike the rock armor dike, could be constructed directly to +5.5 m (+18 ft) MLLW. Stockpiled material is currently placed above the future fringe wetland and will provide material for other dike construction activities, such as the mechanical construction of the shoreline dikes (Figure 6), which is scheduled for mid-2010.

The shoreline dike is designed to an elevation of +3.4 m (+11 ft) MLLW with a minimized crest width of 6.1 m (20 ft). Not included in the dike construction contract due to the volume estimates of recoverable fill from the site borrow area, the dikes were planned to be constructed in a separate contract, using purchased offsite common borrow. To reduce initial construction costs and expedite the project schedule, the crest width was minimized to 6.1 m (20 ft). Future raising to +5.5 m (+18 ft) MLLW will require more material per linear foot than the rock armored dike, but it is anticipated that future new work dredging projects may reduce the need for purchasing offsite common borrow.
Integration of Nearby Deepening Project

During the design of the Masonville DMCF, analysis concluded that the borrow material available onsite did not match the volume required for initial dike construction. Initially, the preferred option was to address the material shortfall with purchased offsite common borrow. Material was readily available, but cost prohibitive to the initial construction. Common borrow purchased in-place was estimated to cost at nearly three times as much as borrowing onsite.

The design team began to search for alternative solutions, including cut material from ongoing Maryland Department of Transportation projects, expanding the borrow area, dike design modifications, and alternative sources of material. One such source was the material slated to be dredged by the MPA at Seagirt and Dundalk Marine Terminals. Channels servicing the Seagirt and Dundalk Marine Terminals were to be maintained and deepened in particular sections. The dredged material was originally anticipated to be placed at the MPA’s HMI DMCF. The design team quickly recognized the deepening as an opportunity to supplement the need for fill material at Masonville while also reducing the cost of the Seagirt/Dundalk Deepening.

A geotechnical and environmental boring program focused on the sections of the Dundalk West Access Channel to be deepened, indicated that the material was geotechnically suitable for dike construction and posed no adverse environmental impacts. The design concept was to isolate the granular material, mechanically excavate the material, and place it into bottom dumping scows for transport and placement at Masonville. Once onsite, the scows would then be aligned over the dike undercut section utilizing scow mounted survey positioning equipment and tracking software installed in the tug’s wheelhouse to place the granular material (see Figure 7).

Figure 7. Seagirt/Dundalk deepening Masonville integration
This process required a detailed dredging template design to isolate agency approved material and the development of a contract that combined the excavation of unsuitable material at Masonville with the dredging work from the Seagirt and Dundalk Marine Terminals. The integrated design and contracting enabled the MPA to recover nearly 382,277 m³ (500,000 cy) of granular material for dike construction that would have otherwise been discarded into the HMI DMCF. Additionally, the MPA recognized a significant contract savings in the deepening work by modifying the original concept from transporting 382,277 m³ (500,000 cy) of granular material 22.2 kilometers (12 nautical miles) to HMI and hydraulically unloading into a +15.2 m (+50 ft) MLLW DMCF to transporting the material 5.6 kilometers (3 nautical miles) and using bottom dump scows for placement.

**Borrow Area Analysis – Key to Masonville Design**

Conceptual level borings identified dike alignments that minimized the need for foundation improvement and undercutting. In addition to serving their intended purpose, the borings also indicated that material suitable for dike construction (sand and gravel) existed within the site footprint, but under 4.6 to 9.1 m (15 to 30 feet) of unsuitable material (silts and clays). The use of onsite material for the dike construction provided the opportunity for increased site capacity and eliminated the need for offsite borrow material, resulting in reduced construction costs.

A comprehensive feasibility level geotechnical investigation, including over 300 wash-probings and borings both along the dike alignment and within the interior of the site footprint, served to guide the design of the dike undercutting, cofferdam undercutting, delineation of suitable borrow, and stripping of fine grained unsuitable material above the borrow. The geotechnical data collected in the design phase was used to create various digital terrain models (DTMs) for analysis of both cross-sections and contour maps of the dredging site. Analysis of the borrow area and the dike undercut revealed an irregular surface and indicated that a defined dredging template (dredging to a flat elevation) would not yield the most favorable results for the MPA or the prospective contractor. Concerns with template dredging included the removal of too much granular material, potentially leading to dike material shortfalls during construction; hydraulic unloading complications at the placement site, and not removing enough unsuitable material, potentially leading to problems associated with hydraulic dike construction.

The engineering team recommended that two contracts be used to construct the DMCF. The first contract would remove the unsuitable material, and the second contract would provide for hydraulic dredging of the borrow area and direct pumping into the dike section. The team proceeded with the concept of using a performance dredging specification for the dike undercutting and the stripping of unsuitable materials above the borrow area. The performance specification required the contractor to use a mechanical dredge equipped with a lighter (maintenance) clamshell bucket for unsuitable material excavation. Prior to commencing dredging, the contractor was required to perform a test section to demonstrate that their work plan and equipment package would meet the requirements of the specifications and would not remove the coarse grained strata. Horizontal dredging limits with 3:1 side slopes and instructions to clear the limits with an approved work plan and equipment package were provided in the contract plans and specifications. Dredging results were monitored with the use of the geotechnical data, inspector reporting, regular surveys, and bucket files (capturing x, y, and z positioning of each bucket at refusal depth) collected by the contractor.

Following the removal of unsuitable materials and preceding the dike construction, additional geotechnical investigations were performed within the borrow area limits for the design of the hydraulic dredging and dike construction. Vibrocores, borings, test pits, lead lines, and surveys were performed within the borrow area. This additional information was required to determine the geotechnical properties of the material left in-place after the completion of the mechanical dredging operation and to facilitate the development of a work plan. The work plan detailed an order of work, additional overburden to be dredged, dredging sequence, expected dredging quantities (both pay and gross), and estimated losses. The suggested work plan, in addition to modifications in the specifications, was credited for the successful re-solicitation of the dike construction contract after rejecting the original bids that were significantly higher than the engineer’s estimate.

Following award of the hydraulic dredging contract to McLean Construction and Norfolk Dredging, the contractor and MPA structured a jointly funded geotechnical boring investigation, because of the complexity of the borrow area. Figure 8 shows a plan view of all standard penetration test (SPT) borings completed throughout the project planning and the post award program in the vicinity of the borrow area.
A grid was established with X (north-south) and Y (east-west) lines at 30.5-meter (100-foot) intervals throughout the borrow area. The intersection of these lines indicated target boring locations for the joint program. The resultant boring locations of the joint program are defined with red targets in Figure 8. The joint investigation included 148 borings, with continuously performed SPTs and sampled using a two-inch split spoon. Laboratory tests of the samples included grain size analysis, Atterberg limits, natural moisture content, and unconfined compressive strength. MPA and the contractor reviewed the boring logs, lab results, and cross-sections to mutually identify material suitable for hydraulic dike construction and establish a mutually agreeable dredging template.

The collected geotechnical data was essential to the design of numerous DTM surfaces, subsequently used to delineate dike material (dredged for fill) and unsuitable material (stripped or avoided). The DTMs, survey results, and geotechnical investigation data were incorporated into X (north-south) and Y (east-west) cross-sections of the borrow area (Figure 9).
Figure 9 is a typical Y cross-section through the borrow area. The final presentation included the cross-section, the inset location map, and the individual borings proximity to/offset from the cut section line. The cross-section includes results of two hydrographic surveys: post-dredge survey (depicting the geotechnically unsuitable Stratum I dredging results) and the post-bottom dump survey (collected after material from the Seagirt-Dundalk Channel Deepening Project was placed in the dike footprint and within the eastern boundary of the borrow area). The borings were color coded based on sieve analysis results (>80% retained on 200 sieve, >60% retained, etc.). Boring inscribed SPT N-Values, material descriptions, lab results, lead-line data, vibracore data and the wash-probing surface were also available to overlay onto the sections.

As part of the specifications, the contractor was required to submit a detailed dredging plan, which included but was not limited to layout of dredge cuts, cut volumes, cut to fill ratios, placement areas, distribution of material, and a schedule that detailed equipment, resources, production rates, and line item sequencing. The cross-sections enabled MPA’s Team to better review all pre-work contract submittals, contract progress, and dredging activities to ensure that the borrow area was fully exhausted.

CONCLUSIONS

The use of subaqueous borrow from onsite and concurrent Baltimore Harbor dredging was a key component of the Masonville DMCF project’s success. It was also known from the beginning that using this material would be difficult due to irregular site geology, existing infrastructure in the site footprint, agency/environmental design constraints, scheduling with multiple large-scale projects, and a fast-track schedule. The MPA’s engineering and contracting approach maximized the volume of material obtained from subaqueous sources and completed initial site construction in time to allow operations in the year following the closure of the HMI DMCF. Overall, the use of subaqueous borrow is estimated to have provided about $58 million in savings to MPA. This includes a reduction in DMCF construction costs by over $11 million, a reduction in Seagirt-Dundalk dredging by over $5 million, and an increase in Masonville site capacity worth over $42 million.