# ENGINEERING APPENDIX

## Elizabeth River and Southern Navigation Improvements Draft Integrated General Reevaluation Report and Environmental Assessment

## Appendix A

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U.S. Army Corps of Engineers
Norfolk District

THE PORT OF VIRGINIA®


# Engineering Appendix
## for the
## Elizabeth River and Southern Branch Navigation Improvements

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# 1. Summary and Background

The U.S. Army Corps of Engineers (USACE) Norfolk District (CENAO), in partnership with the Virginia Port Authority (VPA), is evaluating measures which would improve the operational efficiency of commercial vessels currently using the federal navigation channel at the Elizabeth River and Southern Branch of the Elizabeth River and commercial vessels projected to use the federal navigation channel in the future. The General Reevaluation Report (GRR) and integrated Environmental Assessment (GRR/EA) will examine whether authorized improvements remain in the federal interest and allow for reformulation of the authorized plan to develop a new alternative for implementation.

This Engineering Appendix details the methodology, assumptions and analyses completed to determine sufficient details to prepare costs of alternatives leading to a NED plan.

# 2. Existing Channels, Study Segments and Reaches

The Elizabeth River and Southern Branch of the Elizabeth River are authorized as a separable element within the Norfolk Harbor and Channels, Virginia, Project. The larger Norfolk Harbor and Channels Project is a single purpose, deep draft navigation project located in Hampton Roads, a 25-square mile natural harbor serving the port facilities in the cities of Norfolk, Newport News, Portsmouth, Chesapeake, and Hampton in southeastern Virginia. Since its authorization in 1986, the project has been constructed in separable elements based on the needs of the port community and the financial capability of the non-federal sponsor. An overview of the study area, with its relationship to the Norfolk Harbor Channel is shown in Figure 1. Appendix A contains detailed plates of the project.

The Elizabeth River 45-Foot and the Southern Branch of the Elizabeth River 40-Foot Channel Project is the current separable project element under consideration. Within this separable element, the project has three reaches shown in the attached project Plates and described below.

The Elizabeth River Federal Navigation Channel is a continuation of the Craney Island reach of the Norfolk Harbor and Channels project and extends approximately six miles south (upriver) from Lamberts Point on the Elizabeth River to the Norfolk and Southern Railroad Bridge on the Southern Branch of the Elizabeth River. Within the Southern Branch of the Elizabeth River Channel, Segment 2 extends approximately 2.4 miles further south (upriver) from the Norfolk and Southern Railroad Bridge to the Gilmerton Bridge. The final reach of the federal navigation channel continuing from the Gilmerton Bridge approximately 2.1 miles south (upriver) to the Chesapeake Extension.

In total, the three reaches originally considered a part of the study are approximately 10 miles in length. The third segment has been eliminated from the plan selection due to lack of benefiting facilities, and is therefore not discussed in detail in this report. Therefore, the study entails approximately 9 miles of channel.

Within these 9 miles are two authorized project depths: (1) The authorized 45-foot project depth, and the (2) authorized 40-foot project depth. Within these separable elements, the federal channel has varying authorized depths and widths, as shown in Table 1.

Within the downstream-most five miles of Segment 1 (See Plate 1 in Appendix), the U.S. Navy has deepened a portion of the channel width to provide aircraft carriers with continuous safe and expeditious transit routes to Lamberts Point Deperming Station and the Norfolk Naval Ship Yard (US Navy, 2009). The Navy's action deepened the existing federal channel at Lamberts Bend to the Deperming Station to a controlling depth of -50 feet MLLW, plus two feet of allowable overdredge. The remainder of the Navy's deepening within the federal channel was deepened to a controlling depth of -47 feet MLLW plus two feet of allowable overdredge (US Navy 2009 and USACE 2010). The Navy's deepening extended for approximately the lowest five miles of Segment 1 and deepened the existing channel for approximately 600 feet of the 750-foot


***Figure 1: Southern Branch of the Elizabeth River Study Area (in green)***

width of the authorized channel. Where the existing channel width was constrained to only 450 feet within Segment 1, the Navy's deepening remained within the constructed channel's existing width. The Navy's deepening also had variable dredged widths near the Deperming Station, in channel bends, and at the turning basin adjacent to the Norfolk Naval Ship Yard.

***Table 1: Elizabeth River and Southern Branch Channel Dimension***

| Channel Segment | Channel Reach Names | Channel Depth (ft) Authorized/ Constructed | Channel Width (ft) Authorized/ Constructed | Approx. Length (miles) | Beginning Station | Ending Station |
|---|---|---|---|---|---|---|
| **Segment 1** | Elizabeth River Reach | 45/40 | 750/750 | 3.4 | 333+09.3 | 154+03.3 |
| | Southern Branch Lower Reach | 45/40 | 750/450 | 2.0 | 154+03.3 | 54+10.08 |
| | Southern Branch Middle Reach | 45/40 | 375/375 | 1.0 | 54+10.08 | 0+00.0 |
| **Segment 2** | Upper Channel Reach A | 40/35 | 250-500/250-500 | 2.6 | 243+36.7 | 106+30.9 |
| **Segment 3 – Eliminated from Study** | Upper Channel Reach B | 35/35 | 300/300 | 0.5 | 106+30.9 | 81+00.1 |
| | Upper Channel Reach C | 35/35 Not Maintained | 250/250* | 1.5 | 81+00.1 | 00+00.0 |

*Note: Stationing shown is based on existing channel geometry and centerline.*

# 3. Geotechnical Evaluation of Dredged Material

## 3.1. Summary

This section provides an overview of existing sediment data within and adjacent to the project area, providing available data to evaluate alternatives and identify a tentatively selected plan (TSP). Attached as Appendix B is the "Geotechnical Evaluation" for the project, characterizing the sediments to be dredged based on available historic subsurface and bathymetric data. The existing data also inform assumptions regarding the material placement plans for each reach of the project and are sufficient to inform the TSP. Additional sampling is proposed to finalize material placement decisions, but the necessary additional sampling would not discriminate among the alternatives being evaluated and the Project Delivery Team (PDT) determined sampling should be deferred to PED.

Over 20 studies have been conducted in the reaches of the Southern Branch including geotechnical and environmental sediment sampling. The data sources include federal as well as private investigations containing sediment data within and adjacent to the channel have been incorporated into a GIS.

The Project Delivery Team (PDT) developed a sub-group to focus on the sediment data ("Geo Sub-group"). Below are summaries of the existing data for each reach, and a summary of the Geo Sub-group's conclusions regarding the adequacy of the existing data for this phase of study decision making.

## 3.2. Segment 1

### 3.2.1. Elizabeth River Reach and Southern Branch Lower Reach

The federal channel in these reaches is approximately five miles long, 750 feet wide throughout most of the reach, and currently maintained to 41 feet + 1 foot (allowable overdredge). In 2011, the Navy deepened within the existing federal channel to -49 feet (47 feet +2 feet overdredge) and a width which varied from 600 feet in the Elizabeth River Reach, and from 450 to 700 feet in the Southern Branch Reach. The area of the federal channel within these reaches is approximately 454.5 acres of which approximately 364 acres have been already deepened by the Navy. Because the data for previous studies examined both of these reaches in a single evaluation, the Geo Sub-group evaluated them in similar fashion.

Geotechnical and environmental sediment sampling was completed in this reach to support the Navy deepening. The Navy project was completed using hydraulic dredge with the material (~3.2 MCY) being direct pumped into the upland cells of CIDMMA. Based on the available data and prior projects, the material from this reach is assumed be hydraulically dredged and placed into the upland cells of the CIDMMA. The sediments in this reach are predominately clay and silt sized particles, with areas of variable sand content.

The summary of existing sample data in these two reaches is shown in the table below, and provided in Appendix B.

***Table 2: Number of existing samples in Elizabeth River Reach and Southern Branch Lower Reaches***

| Reach name | Environmental | Geotechnical | Both | Unclassified | Total |
|---|---|---|---|---|---|
| Elizabeth River Reach | | 62 | 12 | 10 | 84 |
| Lower Reach | | 19 | 19 | | 38 |

### 3.2.2. Southern Branch Middle Reach

This reach extends from the Belt Line Railroad Bridge (just north of the new Jordan Bridge) to the NS Railroad lift bridge. The federal channel in this reach is approximately one mile long, 375 feet wide throughout most of the reach, and currently maintained to 41 feet + 1 foot (allowable overdredge). The last maintenance dredging in this reach was in 2003, with the material being mechanically dredged and placed into the CIDMMA re-handling basin.

This reach passes by the United States Environmental Protection Agency (EPA) superfund site, Atlantic Woods Industries (AWI). Dredging at AWI, by the EPA, is complete (adjacent to the channel), with dredged material placed behind a sheet pile wall along the AWI property. Environmental sampling in the channel (within the federal channel limits), and below the depth of the maintenance material, is limited. There is data from sampling within several adjacent properties (e.g., AWI, Apex Oil, Enviva, and Seagate) that provide an indication that some material within the federal channel would likely not be suitable for placement in the CIDDMA (either directly or in the re-handling basin).

The summary of existing sample data in this reach is shown in the table below, and detailed in the Geotechnical Appendix. Riverbed sediments in this reach contain some sand, overlain by clay and silt. The layers are highly heterogeneous.

***Table 3: Number of existing samples in Middle Reach***

| Reach name | Environmental | Geotechnical | Both | Unclassified | Total |
|---|---|---|---|---|---|
| **Middle Reach** | 223 | 46 | 38 | | 307 |

Based on the available data and prior projects, it is recommended (for the GRR study and cost estimates) that the material from this reach be assumed to be mechanically dredged and barged to an upland placement area suitable to take contaminated material (i.e., not CIDMMA). Additional sampling would be necessary for PED; however, the Geo Sub-group determined that additional sampling would not likely support the selection of either different channel dimensions or a different placement alternative.

## 3.3. Segment 2, Upper Channel Reach A

This reach extends from the Norfolk Southern Railroad lift bridge to the Gilmerton Bridge, and includes the "Money Point" area. The federal channel in this reach is approximately 2.4 miles long, varies from 250-500 feet wide throughout the reach, and is currently maintained to 35 feet + 2 feet (allowable overdredge). The last maintenance dredging in this reach was in 2003, with the material being mechanically dredged and placed the CIDMMA re-handling basin.

This reach passes along an area with prior creosote plants and has well-documented areas of high TPHs. Extensive sampling and testing results (see Table 4 below) are available in this reach, most recently by the USACE in 2014. Environmental sampling below the depth of the maintenance material is limited; however, available information from prior testing suggests the material would not be suitable for CIDMMA.

The summary of existing sample data in this reach is shown in the table below, and detailed in the Geotechnical Appendix.

***Table 4: Number of existing samples in Upper Channel, Reach A***

| Reach name | Environmental | Geotechnical | Both | Unclassified | Total |
|---|---|---|---|---|---|
| **Upper Channel, Reach A** | 149 | | 163 | | 312 |

Based on available data and prior projects, it is recommended (for the GRR study and cost estimates) that the material from this reach be assumed to be mechanically dredged and barged to an upland placement area suitable to take contaminated material (i.e., not CIDMMA). Additional sampling was discussed as a necessity for PED; however, the Geo Sub-group determined that additional sampling would not likely support the selection of either different channel dimensions or a different placement alternative.

# 4. New Work Quantities

## 4.1. Maintained Depth

The historically maintained depths provide the basis for determining the volume considered maintenance material and the volume for new work. Based on the District's maintenance records, Table 5 summarizes the historically maintained depts.

***Table 5: Elizabeth River and Southern Branch Channel's Maintained Depth***

| Channel Segment | Channel Reach Names | Maintained Depth (feet, MLLW) |
|---|---|---|
| **Segment 1** | Elizabeth River Reach | -41 |
| | Southern Branch Lower Reach | -41 |
| | Southern Branch Middle Reach | -41 |
| **Segment 2** | Upper Channel Reach A | -35 |

## 4.2. Surveys

The basis for the quantity calculations are the most recent condition surveys available at the time of performing the calculations, started in July 2015. The following table summarizes the survey data, acquired by the Norfolk District, used for the quantities.

***Table 6: Surveys used for quantity calculations***

| Channel Segment | Channel Reach Names | Date of Survey |
|---|---|---|
| **Segment 1** | Elizabeth River Reach | October 2012 |
| | Southern Branch Lower Reach | October 2012 |
| | Southern Branch Middle Reach | January 2010 |
| **Segment 2** | Upper Channel Reach A | March 2010 |

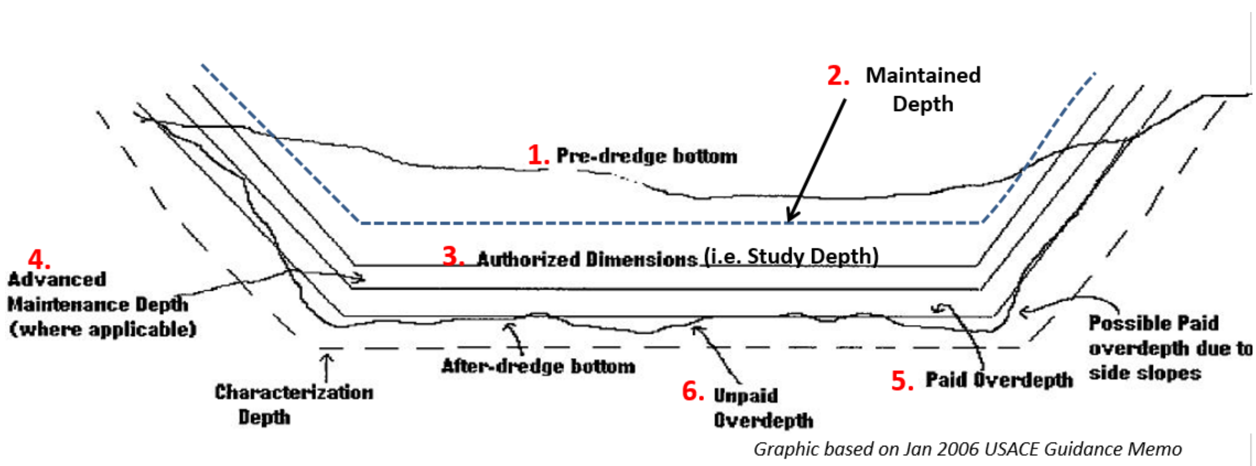
## 4.3. Quantity Calculations Methods

Quantities were developed based on the latest condition surveys provided by the USACE. Dates of the surveys are noted above. Quantities include 1 Vertical to 3 Horizontal side slopes, to match existing channel width. No channel widening is considered in plan formulation. Volume calculations were completed for each channel reach at 1 foot increments to inform plan formulation. AutoCAD® Civil 3D® software is used to perform the volume calculation. Volumes are broken into "dredging zones," to clarify the calculated volumes, as described in the following section.

## 4.4. Quantity Summary

The following tables summarize the volume to be dredged to determine project costs. We note that for evaluating environmental impacts the PDT requested volumes that included depth beyond pay depths to evaluate maximum impacts. The maximum volumes used for environmental impact analysis are presented in the relevant sections in the Environmental Assessment. In the tables below, the following definitions apply based on Figure 2:

***Figure 2: Typical Channel Cross Section with Dredging Zones and Channel Nomenclature, based on USACE Guidance Memo (USACE, 2006)***




1. **Pre-Dredge/ Existing Grade/Mudline** – The mudline based on the latest condition survey of the channel.

2. **Maintained Depth** – Without-Project Condition – The maintenance quantity is the volume of dredging required to dredge from the existing condition (based on the latest condition survey of the channel) to the currently maintained channel dimensions. This volume to restore the channel to the District's historically maintained depth is included for inclusion in the Dredged Material Management Plan, but is not a new work dredging cost.
3. **Authorized Dimensions / Project Depth / Grade** – This is the Nominal Depth used for Plan Formulation Increments and includes consideration for Underkeel Clearance (UK).
4. **Advanced Maintenance** – For cost estimates no advanced maintenance is included, per District's historic dredging activities in the subject reaches.
5. **Allowable (Paid) Overdepth** – To be consistent with historic dredging in these project reaches, 1 foot of paid overdetph is included in Segment 1, and 2 feet in Segment 2.
6. **Over-dig (Non-Pay/Unpaid) Overdepth** – Non-pay volume is dredging beyond the new work quantity above due to inaccuracies in dredging, dredge type, dredge area, wind and wave conditions, etc. For cost estimates, the volume of non-pay dredged is based on the dredging area. For hydraulic (cutterhead) dredges, this equates to about ½ foot of non-pay depth, while the hopper dredges average less non-pay volume with about 3 inches. These non-pay volumes are based on assumptions developed in the Cost Engineering Dredge Estimating Program (CEDEP) worksheet that accounts for the efficiency of the dredges for each reach based upon the areas, volume, amount of pay, amount not dug on average, and the amount dug in excess of the allowable pay amount, any many other factors associated with dredging operations. CEDEP is the basis for the unit cost for dredging. For NEPA documentation non-pay volume is considered a contingency allowance to be included in the total for new work improvements. Note the inclusion of non-pay is in accordance with a USACE memorandum (USACE, 2006) providing guidance on adequacy of describing the total volumes to be dredged (ex. Allowable overdepth and non-pay volumes).
7. **Additional Required Dredging for Contamination Mitigation** – As described above in the Geotechnical Evaluation of Dredged Material, the Middle Reach (Segment 1) and Upper Channel Reach A (Segment 2) have higher potential for encountering contaminated material. Because of that, pay volumes in these two reaches include required overdredging of 1 foot to allow for leaving material with acceptable residual contaminate levels. The additional cost to overdredge is considered in the Cost and Schedule Risk Analysis for comparing alternatives.

For the economic alternatives, Segment 1 and Segment 2 were analyzed individually and then combined. The following table summarizes the dredge volumes used for the cost development for the new work dredging (volume above maintenance volume). Note that Segment 1 Middle Reach was divided into two sections, the first up to the Perdue facility (MR-A), and then the remaining length to Segment 2 (MR-B). This allowed the channel depths to be optimized.

*Table 7: Segment 1: Dredge Volumes, Elizabeth River Reach (ERR), Lower Reach (LR), Middle Reach up to Perdue (MR-A) and Middle Reach past Perdue (MR-B)*

| Economic Alternatives for Plan Formulation | Nominal Depth (feet) | | | | Available Pay Volume, CY |
|---|---|---|---|---|---|
| | ERR | LR | MR-A | MR-B | |
| Nominal 42 feet Segment 1 | 42 | 42 | 42 | 42 | 209,568 |
| Nominal 43 feet Segment 1 | 43 | 43 | 43 | 42 | 346,010 |
| Nominal 44 feet Segment 1 | 44 | 44 | 44 | 42 | 513,870 |
| Nominal 45 feet Segment 1 | 45 | 45 | 45 | 42 | 710,748 |

*Table 8: Segment 2: Dredge Volumes, Upper Reach A*

| Economic Alternatives for Plan Formulation | Nominal Depth (feet) | Available Pay Volume, CY |
|---|---|---|
| Nominal 36 feet Segment 2 | 36 | 214,530 |
| Nominal 37 feet Segment 2 | 37 | 357,267 |
| Nominal 38 feet Segment 2 | 38 | 532,129 |
| Nominal 39 feet Segment 2 | 39 | 724,260 |
| Nominal 40 feet Segment 2 | 40 | 927,861 |

# 5. Future Maintenance Quantities

As part of the impact assessments associated with the proposed deepening projects, a desktop analysis has been conducted for a first-order estimate of the maintenance dredging rate to be expected in the navigation channels following deepening. Attached, as Appendix C, is the report entitled “Desktop Assessment of Future Sedimentation Rates” (M&N, 2016). The report provides an overview of the approach for estimating the future sedimentation rate, the data used, and the results of this desktop analysis.

Historic maintenance dredging records were provided by the USACE for the period 1980 to 2014, and reviewed to inform this study (USACE 1994, USACE 2016). The available maintenance dredging records were used to develop an estimate of the annual sedimentation rate within the navigation channels in the study area. Historical (from 1980 onwards) and recent data were examined and used for developing the sedimentation report.

## 5.1. Projected Maintenance Dredge Volumes

Based on the study, the following table summarizes the current annual sedimentation rate (based on historic volumes), and the estimated annual sedimentation rate (from the sedimentation study) based on the deepened channel.

***Table 9: Maintenance Volumes***

| Segment | Reach | Current Annual Sedimentation, CY/Year | Estimated Annual Sedimentation, CY/Year |
|---|---|---|---|
| 1 | Elizabeth River Reach | 31,600 | 33,510 |
| 1 | Lower Reach | 1,430 | 1,510 |
| 1 | Middle Reach | 770 | 830 |
| 2 | Upper Channel, Reach A | 17,700 | 19,650 |

# 6. Dredged Material Management

This section will describe the areas proposed for placement of dredged material for the new work dredging, as well as future maintenance needs. The project's Dredged Material Management Plan (DMMP) is a separate report as an appendix to the GRR. The DMMP describes existing conditions as well as the anticipated future 20 years of dredged material placement.

## 6.1. Summary of Existing Management Plan

### 6.1.1. Craney Island Dredged Material Management Area (CIDMMA)

The Craney Island Dredged Material Management Area (CIDMMA) is a 2,500-acre confined dredged material disposal site located near Norfolk, VA. Development of the CIDMMA was recommended and approved by Congress under the River and Harbor Act of 1946. Actual construction of CIDMMA was completed in 1957. Since that time, this site has received maintenance, private, and permit dredged material from numerous dredging projects in the Hampton Roads area. The site provides a disposal area for material dredged from the channels and ports in the Hampton Roads area. Hampton Roads, including the ports of Norfolk, Portsmouth, Chesapeake, Newport News, and Hampton, comprises Virginia's greatest port complex (USACE, 2016). The character of the material suitable for placement in CIDMMA requires meeting requirements under the Clean Water Act (CWA), and being acceptable to the Norfolk District Engineer. In general, the District Engineer requires material being placed to be tested for for contaminants in accordance with the EPA document EPA-823-B-98-004, dated February 1998, "Evaluation of Dredged Material Proposed For Discharge in Waters of the U.S. -Testing Manual". This manual is commonly referred to as the Inland Testing Manual (USACE, 2005). The attached Plate 1, Appendix A, shows the location relative to the project area.

CIDMMA receives dredged material which is pumped hydraulically into the cells. Dredged material is typically pumped in over the east dike. This is evidenced by the large sand mounds observed at the influent points where these heavier sand particles quickly settle out of the dredge slurry.

CIDMMA is currently operated using the guidance from the existing DMMP prepared in 1981. The 1981 DMMP has been credited with allowing CIDMMA to accept over 250 MCY of dredged material (since it began operation in 1957), a significant increase over the original capacity estimate of 96 MCY.

The existing DMMP is based on the current configuration of CIDMMA, which is divided into three cells: South Cell (734 acres for storage), Center Cell (766 acres for storage) and North Cell (689 acres for storage). Currently, Norfolk District rotates each of the three cells as necessary to allow adequate drying before dredged material is again pumped into the cell. The District also typically caps the volume of dredged material that can be pumped into an individual cell at no more than 5 MCY annually. Monthly inflows are typically limited to 650,000 CY.

Existing dikes are continually maintained to compensate for consolidation settlement of the marine clay foundation beneath the dikes, and the need to maintain adequate freeboard on the dikes.

Each cell has two spillboxes along the west dike, which are operated by the dredging contractor pumping into the cell. The dredging contractor is responsible for ensuring effluent being released from CIDMMA is clarified water. The contractor verifies by sampling the effluent total suspended solids (TSS). The target, or goal, is to release only clarified water from the spillboxes, with the daily average effluent TSS concentration of 500 mg/l as an upper action limit. Typically measured effluent TSS values are 100 mg/l or less.

**Remaining Capacity of CIDMMA**. As part of the Craney Island Eastward Expansion's (CIEE) Final Feasibility Report (USACE, 2006) a detailed assessment of the remaining dredged material capacity was completed for the existing CIDMMA. An appendix to the 2006 report included a 2005 study by the U.S. Army Engineer Research and Development Center (ERDC) detailing the lifespan of CIDMMA. The study was based on assumptions of dredged material inflows into CIDMMA that was inclusive of all federal, local and private dredging work, in addition to consideration of historic inflows. The computer model Primary Consolidation, Secondary Compression and Desiccation of Dredged Fill (PSDDF) (Stark 1996) was used to model dredged material inflows and estimating the height of dredged material within the cells through the inflow assumptions. With that, PSDDF estimated the volume of fill that could be placed within CIDMMA and the resulting elevation of dredged material within the area.

For the Baseline condition (no Craney Island Eastward Expansion cells considered) the inflows modeled spanned the years 2000 to year 2055. The 2005 study estimated that, with the existing 3 disposal cells under present management conditions, CIDDMA will reach the limiting elevation of +47 feet MLLW in approximately the year 2025. The total dredged material volume (in channel volumes) capacity of CIDMMA, based on the estimated inflows, from 2000 to 2025 was calculated to be 117.5 MCY. The annual inflow volume assumptions are shown in Table 10 below.

To estimate the remaining CIDMMA capacity available for future dredged material placement, for this study, the total inflow volume estimated in the 2005 study was subtracted from the actual inflows based on USACE records of use of CIDMMA. Note that as assumed in the ERDC study, O&M will be available to continue to raise the dikes to meet inflows.

As shown in the table below, with a capacity of 117.5 MCY and actual inflows of 68.8 MCY, the remaining capacity in CIDMMA, based on the ERDC analysis, is 48.7 MCY (117.5 – 68.8 = 48.7).

***Table 10: CIDMMA Baseline Inflow Assumptions versus Actual Inflows***

| Year | Inflow Assumptions for 2005 ERDC Study "Baseline CIDMMA", CY | Actual Inflows based on USACE Records, CY |
|---|---|---|
| **2000** | 4,010,000 | 4,743,227 |
| **2001** | 3,110,000 | 2,548,028 |
| **2002** | 3,020,000 | 4,722,609 |
| **2003** | 3,050,000 | 6,244,604 |
| **2004** | 11,780,000 | 2,335,501 |
| **2005** | 11,680,000 | 10,184,962 |
| **2006** | 4,030,000 | 12,105,324 |
| **2007** | 5,150,000 | 2,687,955 |
| **2008** | 5,580,000 | 1,709,180 |
| **2009** | 7,400,000 | 2,883,972 |
| **2010** | 3,720,000 | 3,815,874 |
| **2011** | 4,300,000 | 6,218,781 |
| **2012** | 4,020,000 | 552,194 |
| **2013** | 3,900,000 | 2,692,878 |
| **2014** | 4,620,000 | 2,228,070 |
| **2015** | 3,950,000 | 3,155,374[1] |
| **2016** | 4,600,000 | |
| **2017** | 4,700,000 | |
| **2018** | 2,500,000 | |
| **2019** | 2,650,000 | |
| **2020** | 4,100,000 | |
| **2021** | 2,500,000 | |
| **2022** | 2,650,000 | |
| **2023** | 3,500,000 | |
| **2024** | 3,500,000 | |
| **2025** | 3,500,000 | |
| **Sum** | **117,520,000** | **68,828,533** |

Based on the ERDC report (Pranger et al, 2004), the CIDMMA (Baseline conditions) would reach the fill elevation of 47 feet in 2025, based on assumed inflows, from 2000 to 2025, totaling 117.5 MCY.

[1] Note that the District's data for actual inflows did not have the 2011 Navy deepening, this number includes 2.9MCY for the Navy deepening, which was the bid volume.

Actual inflows from 2000 to 2015 have been 68.8MCY. Therefore, with a capacity of 117.5 MCY and actual inflows of 68.8 MCY, the remaining capacity in CIDMMA is 48.7 MCY (117.5 – 68.8 = 48.7).

### 6.1.2. Craney Island Eastward Expansion

The Craney Island Eastward Expansion's (CIEE) Southeast Cell is currently under construction, with its completion dependent on state and Federal funding. If available at the time of the proposed deepening, the cells could be considered as a placement area. The CIEE project expands the existing CIDMMA to the east by constructing a new approximately 522-acre placement area. The cell will be subdivided with a cross dike to form the Southeast Cell and the Northeast Cell. With the proposed filling to elevation +18 feet MLLW, the Southeast Cell and Northeast Cell have a neat volume capacity of 6.7 and 12.7 MCY respectively. This is the neat volume within the cell. Following initial filling a large amount of fill/capacity is required/available to make up for ongoing consolidation settlement of the placed dredged fill and the soft foundation clays. Consolidation settlements are estimated to be on the order of 20 to 30 feet. Because of this, additional dredged material will be placed as settlement is occurring to make up for that volume lost due to settlements. The initial capacity together with this additional fill provides for a 43.5 MCY capacity for the CIEE. The capacity is documented in the recent Limited Reevaluation Report (LRR, USACE, 2015).

CIEE will effectively provide an additional cell to CIDMMA. After the cell dikes are completed (confined), filling with material from both the proposed deepening and maintenance dredging can occur.

Hydraulic filling will be similar to what is currently done at the existing CIDMMA by the use of a hydraulic pipeline cutterhead dredge.

### 6.1.3. Norfolk Ocean Dredged Material Disposal Site (ODMDS)

At such time when CIDMMA is no longer available, suitable dredged material can be disposed of at the U.S. Environmental Protection Agency (USEPA) designated ocean disposal site (Norfolk Ocean Dredged Material Disposal Site), located approximately 35 miles from CIDMMA and 17 miles east of the mouth of the Chesapeake Bay. From the Norfolk Ocean Disposal Site Management and Monitoring Plan (SMMP):

- The Norfolk ODMDS is a 42,600-acre area.
- The site is delineated by a circle with a radius of 4 nautical miles centered at 36 degrees, 59 minutes north latitude, and 75 degrees, 39 minutes west longitude.
- Water depth at the site ranges from 43 to 85 feet.
- The Norfolk Ocean Disposal site is permitted to receive both coarse and fine grained materials that meet the Environmental Protection Agency's (EPA) requirements for ocean disposal

- The SMMP specifically accounts for the future condition when the CIDMMA is no longer available, allowing suitable material from channels that would have normally be placed in CIDMMA to go to the Norfolk ODMDS.
- Estimated total capacity of 1,300 MCY.

Material dredged for placement at NODS, from the Elizabeth River reaches will most likely be dredging via mechanical dredge with material transported to the site using bottom dump scows. Placement will be performed and monitored in accordance with the Norfolk District's Site Management and Monitoring Plan.

The other offshore disposal site near the mouth of the Chesapeake Bay is the Dam Neck ODMDS. The Dam Neck ODMDS is currently permitted for disposal of suitable material from only three Federal navigation Channels: the Atlantic Ocean Channel, the Cape Henry Channel and the Thimble Shoal Channel (USACE, 2009). Therefore, the Dam Neck ODMDS will not be considered for material from the Elizabeth River.

### 6.1.4. Upland Sites

Dredging within the Elizabeth River Southern Branch Navigation Improvements Study area is anticipated to generate material with contamination that exceeds the acceptance criteria of CIDMMA or in-water placement sites. This dredged material will need to be disposed of at an approved upland site(s). This section summarizes potential upland placement areas for dredged material that does not meet the acceptance criteria established for the CIDMMA and conclusions supporting which upland site(s) to use for plan formulation.

The following upland placement/disposal sites were identified and vetted during development of the GRR:

- Charles City County Landfill
- CFS, Tri-City Regional Landfill & Recycling Center
- John C. Holland Enterprises Landfill
- Southeastern Public Service Authority (SPSA) Regional Landfill
- Portsmouth City Craney Island Landfill
- Bethel Landfill
- King and Queen Sanitary Landfill

Additionally, the following soil processing services were identified:

- Port Tobacco/Weanack Land, LLC (also can accept some dredged material)
- Clearfield MMG, Inc. Soil Recycling

The areas are shown in the Appendix  A, Plate 1. Additionally, acceptance criteria was evaluated, and is documented in Technical Letter 14, "Upland Placement Areas – Preliminary Findings" (M&N TL14, 2016).

TL14's recommendation was to assume material that was not suitable for CIDMMA to be mechanically dredged and transported by barge to Port Weanack (approximately 70 nautical miles via the James River). Once at Port Weanack, the material would be processed and loaded onto 12 CY dump trucks for placement in one or both of the nearby landfills for permanent placement.  The local landfills include the Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg, with one-way truck haul distances of 13 and 17-miles, respectively.

In discussing the project with the other facilities noted, some concern was expressed regarding the volume of dredge material.  Initial indications provided by points of contact indicate that the SPSA, John C. Holland, and Portsmouth landfill facilities are unlikely to accept the material or place significant limits on it.

Bethel Landfill and the King and Queen Sanitary Landfill facilities are potential sites but would have higher transportation costs than other alternatives.  Neither of the Clearfield MMG facility locations are strategically located where they could mitigate transportation costs.

Therefore, Port Tobacco/Weanack, in conjunction with Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg, appears to be the most viable upland disposal sites depending on the contamination levels found in the dredge material. This recommendation is similar to completed projects in the Elizabeth River.

### 6.1.5. Beneficial Use

Due the material in the Elizabeth River and Southern Branch of the Elizabeth River Navigation Improvements, Virginia being predominately fine grained sediments (2016, Fugro) there is no known opportunity for beneficial use of the dredged material.

# 7. Construction Assumptions and Methodology

The following describes the actions what would take place if the Federal channels in the Elizabeth River and Southern Branch of the Elizabeth River were to be deepened.

## 7.1. Navigation Aids

Existing navigation buoys are not anticipated to be relocated to accommodate the new channel depth (USCG is currently making this determination).  No new ranges are required because the project will continue to use the existing channel centerline and existing width.

## 7.2. Dredging

Assumptions on materials to be dredged is describe above and in attached Appendix B. During PED, additional sediment sampling will be performed to verify that materials are suitable for their proposed placement locations and the appropriate permits will be obtained. There are no time of year dredging restrictions for the channel in the Elizabeth River and Southern Branch Project.

Dredging is projected to occur sequentially, beginning in the Elizabeth River reach and progressing upstream. The method of dredging varies by reach based on the assumed placement area. Below is a description of the assumed method of dredging, crew sizes, placement areas and time to dredge.

### 7.2.1. Segment 1

Segment 1 is approximately six miles long extending from Lamberts Bend to the Norfolk Southern railroad lift bridge and includes the Elizabeth River Reach, Southern Branch Lower Reach and the Southern Branch Middle Reach.

#### *7.2.1.1. The Elizabeth River Reach and the Southern Branch Lower Reach*

The Elizabeth River Reach and the Southern Branch Lower Reach were deepened by the Navy in 2011 to -49 feet (47 feet + 2 feet allowable overdredge). The width of the navy deepening varied from 600 feet in the Elizabeth River Reach, and from 450 to 700 feet in the Southern Branch Reach. Assumptions for the construction of these two reaches follows similar methodology.

Dredging will be performed by use of a 24-inch hydraulic pipeline cutterhead dredge at a typical production rate of approximately 1,400 to 2,000 cubic yards per hour. The dredged material will be pumped through submerged pipelines approximately 38,000 feet from the Elizabeth River branch to CIDMMA and approximately 45,000 feet from the Lower reach to CIDMMA. The pipeline will use up to two diesel driven booster pumps. The booster pumps are estimated to be 3,600 HP each.

The pipelines would discharge upland of the main dikes on the east side of CIDMMA. Excess water is decanted through the manually operated spill boxes on the west side of CIDMMA. Excess water is sampled and tested based on USACE protocols prior to discharge through the spill boxes.

The crew on a large cutterhead dredge, where crew live aboard, is estimated to be 46 inclusive of required captains, engineers, leverman, tug captains, deckhands, maintenance engineers and support, and shore crews. The dredge operates 24/7, with personnel shifts assumed to be 8 hrs/day, 7 days a week.

The cutterhead dredge is assumed, with downtime, to effectively dredge 340 hrs/month. Based on this, the time to dredge the Elizabeth River Reach and the Southern Branch Lower Reach is estimated to be 3 months.

### 7.2.1.2. *Southern Branch Middle Reach*

Dredging in the Southern Branch Middle Reach will be done using a mechanical dredge equipped with a 10 cubic yard bucket. The mechanical dredge will place material into a barge at the dredge site. Excess water will be decanted from the barge back into the river during the dredging process. Typically, 3,000 cubic yard capacity barges will be used to transport this material approximately 70 nautical miles to Port Weanack on the James River. One tug (3,000 HP) will transport two barges together. The crew on a bucket dredge with barge and tug support is estimated to be 25 people inclusive of captain, engineers, mates, deckhands, tug operations, etc. Dredge operations is assumed to be 10 hours per day, 6 days a week, with an effective 55 hours per week of dredging. Production is estimated to be 3,500 cubic yards per day.

At Port Weanack, a cement mixture will be added to the material while it remains in the barge. Cement is mixed into the material via a paddle wheel or "rake". The purpose of the add-mixture is to solidify the consistency of the dredged material so that it can be moved with an excavator and loaded onto trucks. Production at Port Weanack is typically in the range of 2,000 cubic yards per day, but according to the operator by adding additional equipment they can obtain 3,500 cubic yards per day.

After a short curing time (typically not more than 24 hours) the material will be unloaded using excavators. The material will be loaded onto 12 CY dump trucks for placement in one or both of the nearby landfills for permanent placement. The local landfills include the Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg, with one-way truck haul distances of 13 and 17-mile respectively. Mixing and unloading of barges can be a 24/7 operation, but hauling out of Port Weanak and to the landfill is limited to 5:30 AM - 10:30 PM M-F and 6 AM - 6 PM on Saturday.

In the Southern Branch Middle Reach, in addition to the neat volume to be dredged to reach the project depth, the volume includes 2 feet additional overdredge for environmental considerations (to avoid leaving exposed sediment with high PAHs. This volume is included the summary tables. This additional volume and cost will be addressed and accounted for in the Cost Schedule Risk Analysis). Additional sampling, to be completed during PED, will better define and verify the volume of material that would be required for overdredge and placement in the landfill. Likely some of the material would be suitable for placement at Port Weanack, without having to be placed in a landfill; however, as discussed above in the geotechnical section, it was determined that for the GRR the assumption would be that all the material would be placed in a landfill.

At the dredge production rate of 3,500 CY/day, the time to dredge this reach is 2 to 5 months.

### 7.2.1.3. *Maintenance Dredging, Segment 1*

The current averaged annual maintenance dredging from Segment 1 is approximately 33,800 cubic yards of material; the largest channel improvements being evaluated in detail would result in an annual maintenance dredging of approximately 37,500 cubic yards. Therefore, the maximum incremental increase in annual maintenance dredging could be as much as an additional 3,700 cubic yards per year. Maintenance dredging in these reaches would not be required annually. Based on historic dredging frequency and the estimated sedimentation rates, the following future maintenance frequency, volumes and placement areas are assumed:

The Elizabeth River Reach would be dredged every approximate 7 years, using 24-inch hydraulic pipeline cutterhead dredge, to remove a shoaled 275,000 CYs. The material would be placed in CIDMMA. For long term considerations, once CIDMMA capacity is reached, the material would be mechanically dredged and barged for placement in the NODS.

For the Lower Reach the frequency of maintenance dredging is significantly lower and only expected on the order of every 30 years, when the shoaled volume of 50,000 CYs would be removed. Dredging this reach would be similar (likely mechanical dredging) to the Elizabeth River Reach.

For the Middle Reach the frequency of maintenance dredging is also low and only expected on the order of every 30 years, when the shoaled volume of 25,000 CYs would be removed. Similar means and methods as the new work dredging is assumed, with mechanical dredging, barging to Port Weanack on the James River, and placement in an upland landfill. After the initial maintenance dredging cycle, the material will continue to be assumed to be mechanically dredged, but will be suitable for placement in CIDMMA. Beyond the timeframe of the existing DMMP, when current CIDMMA reaches its capacity, least cost maintenance dredging is expected to be similar in cost to disposal within the existing CIDMMA, based on continued efforts to optimize CIDMMA, capacity in the Craney Island Eastward Expansion, and availability of Norfolk Ocean Disposal Site as appropriate.

### 7.2.2. Segment 2

Segment 2 is approximately 2.6 miles long extending from the Norfolk Southern Lift Bridge to the Gilmerton Bridge and is the Southern Branch of the Elizabeth River’s Upper Channel Reach A.

#### *7.2.2.1. Upper Channel Reach A*

Within Segment 2, the largest volume of material to be dredged for the alternatives being assessed in detail would result in 1.5 MCY being removed from the channel. Dredging will be performed mechanically as described for the Southern Branch’s Middle Reach of Segment 1.

The entire quantity would be disposed of at one or both of the landfills, described above, after being barged to Port Weanack, solidified, and trucked to the landfill. Upland disposal of the material in Segment 2 would require a total of up to 245 tug trips (2 barges per tug trip) and 34,500 nautical miles traveled by tug to Port Weanack and 122,500 truck trips and 3.2 million truck-miles traveled to the landfill for placement. Dredging would take 6 to 14 months.

As described above for the Southern Branch Middle Reach, an additional 2 feet of dredging is assumed with the goal to removing any material that would be unsuitable to be left exposed on the river bottom.

The footprint of dredging required for maintenance of the existing navigation channel in Segment 2 is 115 acres. The action alternative being evaluated with the largest depth increase would result in a total footprint of disturbance of 135 acres in Segment 2, or an increase of approximately 20 acres in the channel footprint compared to maintaining the existing channel. Deepening the channel to the greatest depth being evaluated would be expected to take approximately five weeks to complete.

#### *7.2.2.2. Maintenance Dredging, Segment 2*

The current averaged annual maintenance dredging from Segment 2 is approximately 17,700 cubic yards of material; the largest channel improvements being evaluated in detail would result in annual maintenance dredging of approximately 19,600 cubic yards. Therefore, the maximum incremental increase in annual maintenance dredging would be an additional 1,900 cubic yards per year. Maintenance dredging in this reach would not be required annually. Based on historic dredging frequency and the estimated sedimentation rates, the following future maintenance frequency, volumes and placement areas are assumed:

The Upper Channel Reach A would be dredged every approximate 5 years, when the shoaled volume of 100,000 CYs would be removed. Similar means and methods as the new work dredging is assumed, with mechanical dredging, barging to Port Weanack on the James River, and placement in an upland landfill. After the initial maintenance dredging cycle, the material will continue to be assumed to be mechanically dredged, but will be suitable for placement in CIDMMA. Beyond the timeframe of the existing DMMP, when current CIDMMA reaches its capacity, least cost maintenance dredging is expected to be similar in cost to disposal within the existing CIDMMA, based on continued efforts to optimize CIDMMA, capacity in the Craney Island Eastward Expansion, and availability of Norfolk Ocean Disposal Site as appropriate.

# 8. Constraints

This section summarizes the tunnel, bridge, and utility infrastructure in close proximity to the project channels that may become constraints and/or drive additional improvements for the dredging alternatives under consideration. The data contained herein was collected from a variety of available references including USACE project drawings and reports, NOAA charts, and input from owners of the utilities.

## 8.1. Tunnels

Two pairs of tunnels cross the channels within the Elizabeth River Southern Branch study area.

- Midtown Tunnel / US Route 58 (MTT)

- Downtown Tunnel / Interstate 264

The main channel in vicinity of the tunnels is 750-ft wide with a constructed depth of 40-ft (authorized to 45-ft). In 2011, a 47-ft deep channel was constructed within the main channel to accommodate U.S. Navy vessels (the Navy Channel Project). Both sets of tunnels cross this deepened segment.

With input from VDOT, the following table summarizes the top elevation of the tunnels. VDOT notes an assumed fill cover of 5 feet.

***Table 11: Summary of Tunnel Constraints***

| Bridge-Tunnel | Top of Structure Elevation in Channel (ft, MLLW) | Channel Width (ft) | Notes |
|---|---|---|---|
| Midtown Tunnel (Eastbound, Original) | -61 MLW, 1961 | 750 | General Plan and Profile Rev 1 2/1/61. Scaled Values. 0.0 based off U.S.E.D. MLW datum. |
| Midtown Tunnel (Westbound, 2016) | -63.5 MLLW (1983-2001) | 750 | Initial Placement Surveys for Elements 5-7. Based off NAVD88, 2016. |
| Downtown Tunnel (Westbound) | -57.5 MLW, 1950 | 450 | Sheet PI-8 Dredging Plan and Profile 5/1/50. Scaled values. 0.0 based off U.S.E.D. MLW datum. (MLW=MSL-1.5) |
| Downtown Tunnel (Eastbound) | -73 MSL, 1985 | 450 | As-built 254-00 sheet 60 of 245 Tunnel Profile 3/29/85. 0.0 based off U.S.C.&G.S. MSL Datum. |

## 8.2. Bridges

Several bridges span the channel within the Elizabeth River Southern Branch Navigation Improvements Study area. The majority of the bridges have moveable elements to permit the passing of taller vessels. Where the channel passes under each bridge, the channel narrows and is constrained by bridge supports and fender systems on either side.

During PED, coordination with the owners of the two railroad bridges noted below will be necessary to further evaluate foundation capacity due to the deeper channel. It is noted that the condition surveys indicate the bathymetry of the channel under the bridges is naturally at a depth where the proposed channel would be indicating minor dredging along the edges, on the order of 1 to 3 feet in the areas adjacent to bridge fender systems.

The bridges within the study area are summarized in the table below.

***Table 12: Summary of Bridges along Channel Reaches***

| Segment/Reach | Structure | Horizontal Constraint (ft) | Maximum Air Draft Elevation (ft, MHW) |
|---|---|---|---|
| 1/Southern Branch Middle Reach | Belt Line Railroad Lift Bridge | 300 | +142 |
| 1/Southern Branch Middle Reach | South Norfolk Jordan Bridge (Fixed Bridge) (SR337) | 270 | +145 |
| 1/Southern Branch Middle Reach | Norfolk Southern Railroad lift Bridge | 220 | +135 |
| 2/Upper Channel Reach A | Gilmerton Lift Bridge (US13) | 125 | +135 |
| 2/Upper Channel Reach A | Norfolk Southern RR Bascule (Draw) Bridge | 125 | n/a |

## 8.3. Underground Utilities

Numerous underground utility crossings are located within the study area. Table 13 and Table 14 below summarize specific utility crossings documented in previous USACE dredging projects and on NOAA charts. NOAA charts further identify several general areas where pipeline and cable crossings may be present. While these typically correspond to the utilities listed below, other utility infrastructure may be present.

***Table 13: Summary of Underground Utilities, Segment 1***

| No. | Study Segment / Reach | Utility Description / Comments | Owner | Approx. Channel Station (USACE Stationing) | Depth (ft, MLLW) | Action |
|---|---|---|---|---|---|---|
| **13** | 1/Southern Branch Lower Reach | 8” Water Main | U.S. Navy | 112+52 | -58 | Abandoned |
| **14** | 1/Southern Branch Lower Reach | Telephone Cables | U.S. Navy | 112+52 | -58 | Noted as abandoned in Navy FEIS. |
| **15** | 1/Southern Branch Lower Reach | 10 – 4.5” Conduits | AT&T | 138+39 | -58 | Abandoned |
| **16** | 1\Elizabeth River Reach | Submarine Cables | Western Union | 165+60 | -49 | Abandoned, this was also noted the FEIS for the NHC dredging by the Navy, verifying the abandoned cables at -49 MLLW. |

| | | | | | | |
|---|---|---|---|---|---|---|
| **17** | 1\Elizabeth River Reach | 36" Water Main Line | City of Norfolk | TBD | -100+ | Relocated during construction on the new mid-town tunnel. Record drawing (dated 7/24/2013) provided by District, to verify vertical alignment varies from 155 to over 200 feet below project datum. |
| **18** | 1\Elizabeth River Reach | 42" Sanitary Sewer Pipe | HRSD | 252+85 | -70 | This was also noted the FEIS for the NHC dredging by the Navy, verifying the -70 ft MLW. |

***Table 14: Summary of Underground Utilities, Segment 2***

| No. | Study Segment / Reach | Utility Description / Comments | Owner | Approx. Channel Station (USACE Stationing) | Depth (ft, MLLW), or as noted | Notes/Action |
|---|---|---|---|---|---|---|
| **8** | 2/Upper Channel Reach A | 14" Petroleum Pipeline | Colonial | 135+90 | -50 | Colonial confirmed active pipe, at proposed channel depths, pipe has sufficient cover. |
| **9** | 2/Upper Channel Reach A | 14" Petroleum Pipeline | Colonial | 235+82 | -50 | Colonial confirmed this is NOT an active line, at proposed channel depths, pipe has sufficient cover. |

| No. | Study Segment / Reach | Utility Description / Comments | Owner | Approx. Channel Station (USACE Stationing) | Depth (ft, MLLW), or as noted | Notes/Action |
|---|---|---|---|---|---|---|
| **10** | 2/Upper Channel Reach A | 42" Water Main | City of Norfolk | 240+48 | -45 MLW (1949) | City of Norfolk provided record drawings "Raw Water Supply Transmission main – Simonsdale to Moore's bridges", dated 1/28/1949, shows the water line within the limits of the channel to a minimum depth of 45 feet based on the MLW datum of 1949 year. |
| **11** | 2/Upper Channel Reach A | 48" Water Main | City of Norfolk | 242+50 | -95 MLW (1990) | City of Norfolk provided record drawings "48-inch Raw Water Transmission Main Elizabeth River – Southern Branch – Horizontal Directional Drilling", dated July 1990, shows the water line within the limits of the channel to a minimum depth of 95 feet based on the MLW datum of 1990 year. |
| **12** | 2/Upper Channel Reach A | Submerged Cables | Unknown | 243+32 | -48.5 | Defer to PED |

## 8.4. Overhead Utilities

Overhead power lines cross the study area within the Upper Channel Reach C (which is upstream of the project's Segment 1 and Segment 2) in two locations at approximately +152-ft MLLW and +161-ft MLLW, respectively. The tower structures for these crossings are on land and should not be impacted by channel deepening activities unless the shoreline modifications are proposed.

## 8.5. Adjacent Properties

The FEIS for the Navy Deepening (Navy, 2009) project considered impacts to waterfront structures from the proposed deepening. The FEIS included a technical report (TEC, 2007) evaluating the stability (slope stability analysis) of the structures in the area of concern, all along the Portsmouth Riverfront. The report concluded that the stability of the slopes are essentially unaffected by the dredge cut. The Navy's 2011 deepening was successfully completed along this area, to a depth of -47 feet MLLW (-49 feet with 2 feet of allowable overdepth) with no reported problems with adjacent structures. Based on this, the PDT determined that no additional analysis will be required for the GRR, and impacts to adjacent properties would be a low risk in the project's Risk Register.

## 8.6. Constraints Summary

**Tunnels**

Deepening the channels will not impact the four tunnels, and no cost will be included for mitigation due to dredging over the tunnels. The tunnels are within Segment 1, where the maximum dredge depth is anticipated to be -47 feet MLLW. Based on the information provided by VDOT, the minimum tunnel cover will remain greater than 10 feet.

**Bridges**

At the proposed channel depths, no impacts are expected for bridges, and no cost is included for mitigation due to dredging beneath the bridges..

**Underground Utilities**

Based on information, there is no known utility conflicts to be included in the costs. There are several utilities identified that, during PED, will be further investigated. There include:

Segment 1: No impacts noted.

Segment 2: The City of Norfolk's 42-inch water line is shallowest of the pipelines, with a top of pipe at -45 feet MLW. However, at an anticipated maximum depth of -42 feet no pipeline are shown to be impacted that require relocations.

There are several submerged cables noted by the USACE as "on the bottom" located adjacent to bridges, these cables may need to be relocated. The current owners and usage of some of the cables are presently unknown. The cables will be further evaluated during PED.

During PED, it is recommend that owners of all submarine cables and pipelines be contacted to discuss the authorized project. Further investigation may be warranted during PED to field verify locations and assess potential dredge constraints and/or relocation efforts.

**Overhead Utilities.**

No impacts.

# 9. Costs

This section summarizes the methodology used in developing the costs for the array of alternatives, details can be found in the GRR's Cost Appendix. The costs to dredge the channels at their existing maintained depths, as well as 1 foot increments up to the elevations described above in Section 4.4 are calculated. Quantities were developed based on the latest condition surveys provided by the USACE. Quantities include the 1 Vertical:3 Horizontal side slope volume.

## 9.1. New Work

### 9.1.1. Dredging

Dredging costs are developed using the Corps of Engineers Dredge Estimating Program (CEDEP) worksheet that accounts for the efficiency of the dredges for each reach based upon the areas, volume, amount of pay amount not dug on average, and the amount dug in excess of the allowable pay amount, and many other factors associated with dredging operations. CEDEP sheets can be found in Cost Appendix. All costs associated for the contractor including overhead, profit, and bonds are included in the unit price calculated. The CEDEP spreadsheet also calculates costs for mobilization and demobilization, which are provided separately from the unit costs. It was assumed that the USACE would provide the post construction survey. The unit costs include progress surveys throughout dredging to be completed by the contractor. For the initial deepening scenarios, it is assumed that the initial mobilization is included in the maintenance dredging (where applicable).

### 9.1.2. LERRS

There are no lands, easements, rights-of-way and relocations (LERR) identified for this project.

### 9.1.3. PED

Pre-construction, engineering and design (PED) are estimated for input into the total project costs. The estimate for PED is shown in Cost Appendix and includes a breakdown of field work including Cultural Resources, sediment sampling and testing, engineering and surveys to assemble bid documents, as well construction management and support through construction.

### 9.1.4. Local Service Facilities

As part of the total cost development, improvements to Local Service Facilities is estimated. Input from the major marine terminal facilities indicated that the wharfs and piers were adequate for deepening to the range of nominal depths studied, and the only cost would be to deepen the existing berths to the projects depth. The Local Service Facility Construction Costs for the Elizabeth River Southern Branch were estimated for the major port facilities in the Lower Reach, Middle Reach, and Upper Reach A. These included 11 facilities as described in the Table below.

*Table 15: Local Service Facilities*

| Local Service Facility Name | Dredging Area (SF) | Reach |
|---|---|---|
| U.S. Gypsum: Aggregates, sand, stone | 100,000 | Lower |
| Transmontaigne (Arc Terminal): Petroleum products | 93,750 | Lower |
| Kerneos Aluminate Technologies: high alumina cement production | 75,000 | Lower |
| Apex Oil Terminal: Petroleum products | 120,000 | Middle |
| Perdue Farms: Grains | 150,000 | Middle |
| Enviva Wood Pellet Terminal: Wood pellets | 120,000 | Middle |
| Kinder Morgan South Hill | 180,000 | Upper Reach A |
| Hess Oil: Petroleum products | 120,000 | Upper Reach A |
| Kinder Morgan Money Point Terminal: Aggregates, sand, stone | 100,000 | Upper Reach A |
| DCP Midstream Propane Terminal: Propane and other natural gas liquids | 100,000 | Upper Reach A |
| Elizabeth River Recycling: Scrap metal | 75,000 | Upper Reach A |

For the Lower and Middle Reaches, the berths were assumed to currently be 40 feet deep, while Upper Reach A berths were assumed to currently be 35 feet. The corresponding volumes were then calculated by multiplying the dredging area by the depth of dredging needed to equal the proposed adjacent channel depth. This volume was then multiplied by the unit cost of $110 / CY to determine the project cost for each depth. It should be noted that the $110 / CY unit cost assumes the material is contaminated, requiring upland disposal at the Weanack Plantation site in Charles City County, Virginia. Material would be barged to the site and unloaded with excavators. No material is estimated to go to CIDMMA for this analysis.

### 9.1.5. Abbreviated Risk Analysis

To better develop contingences to evaluate alternatives and Plan Selection, the PDT evaluated uncertainties associated with each major construction cost item or feature in coordination with input with other members of the project development team. This was completed via Walla Walla's guidelines to develop an abbreviated risk analysis (ARR). Since a full Cost Schedule Risk Analysis was completed subsequent to the ARR, see below, the ARR is not included in this report.

## 9.2. Maintenance Costs

Similar to New Work costs, dredging costs are developed using CEDEP worksheet that accounts for the efficiency of the dredges for each reach based upon the areas, volume, amount of pay amount not dug on average, and the amount dug in excess of the allowable pay amount, any many other factors associated with dredging operations. CEDEP sheets can be found in the Cost Appendix. For the initial deepening scenarios, it is assumed that the initial mobilization is included in the maintenance dredging (where applicable).

# 10. Cost Schedule Risk Analysis

A Cost Schedule Risk Analysis (CSRA) was completed on the Tentatively Selected Plan. The CSRA Report is included in the Cost Appendix.

# 11. References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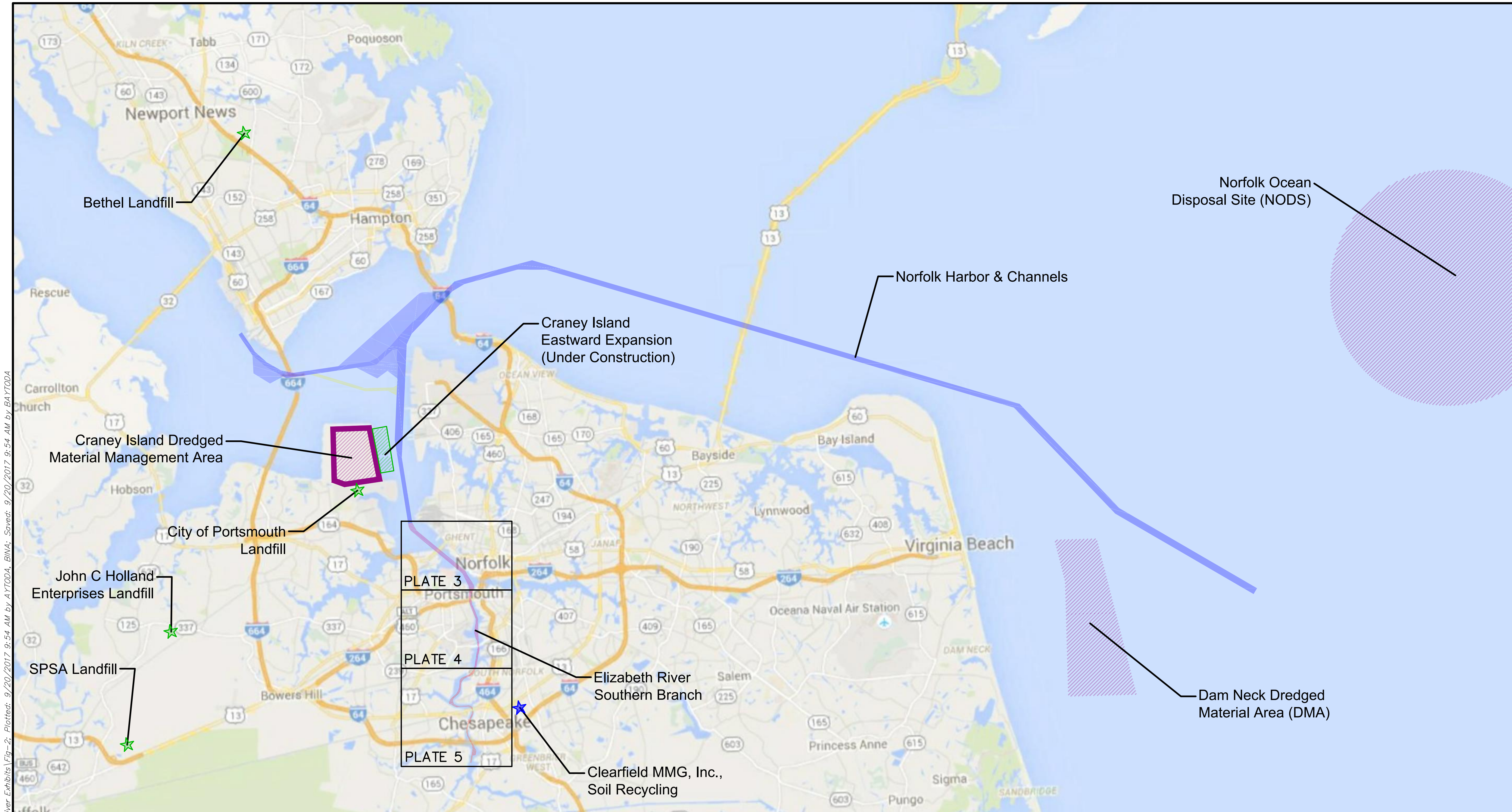
# Appendix A: Figures


File: Q:\NOR\8885-01\500 CADD_Active_Elizabeth River Exhibits\Fig-1; Plotted: 9/20/2017 9:54 AM by AYTODA, BINA; Saved: 9/20/2017 9:50 AM by BAYTODA

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 1 - OVERALL PLAN

moffatt & nichol




## Legend

- Upland Placement Sites
- Soil Processing Sites
- Existing Placement Areas
- Norfolk Harbor Channel
- Elizabeth River Southern Branch Navigation Improvements Study Areas

10000' 0' 10000' 20000'

SCALE: 1"=20000'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 2 - ENLARGED PLAN

moffatt & nichol

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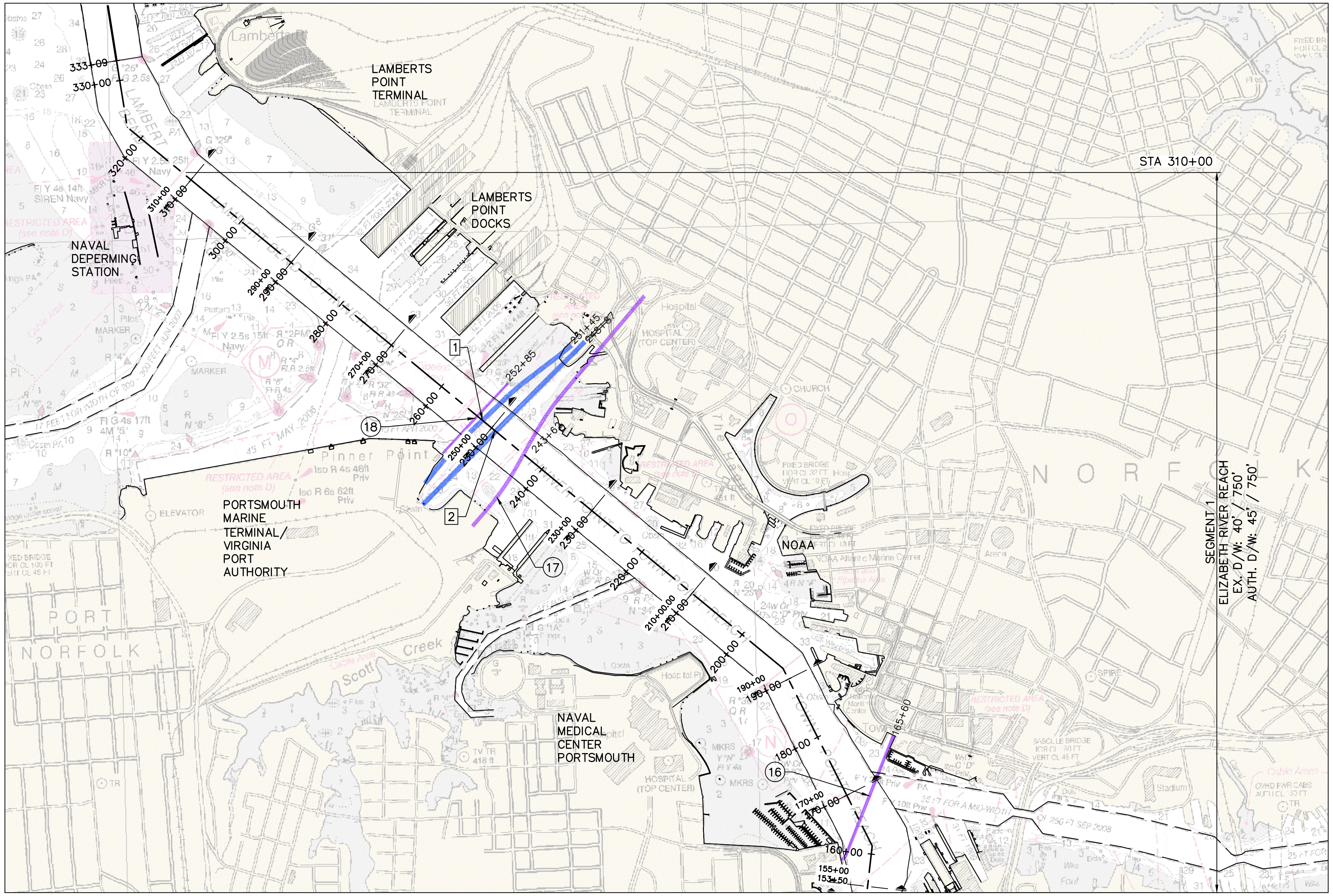



## KEYED NOTES (BRIDGES & TUNNELS):

1. MIDTOWN TUNNEL (NEW)
   HORIZONTAL CONSTRAINT: 750'
   VERTICAL CONSTRAINT: −63.5' TOP OF STRUCTURE
2. MIDTOWN TUNNEL (ORIGINAL)
   HORIZONTAL CONSTRAINT: 750'
   VERTICAL CONSTRAINT: −61.0' TOP OF STRUCTURE

## LEGEND:

- SUBMERGED UTILITY
- TUNNEL
- BRIDGE
- OVERHEAD UTILITY
- SECTION CUT

SUBMERGED UTILITY CROSSINGS

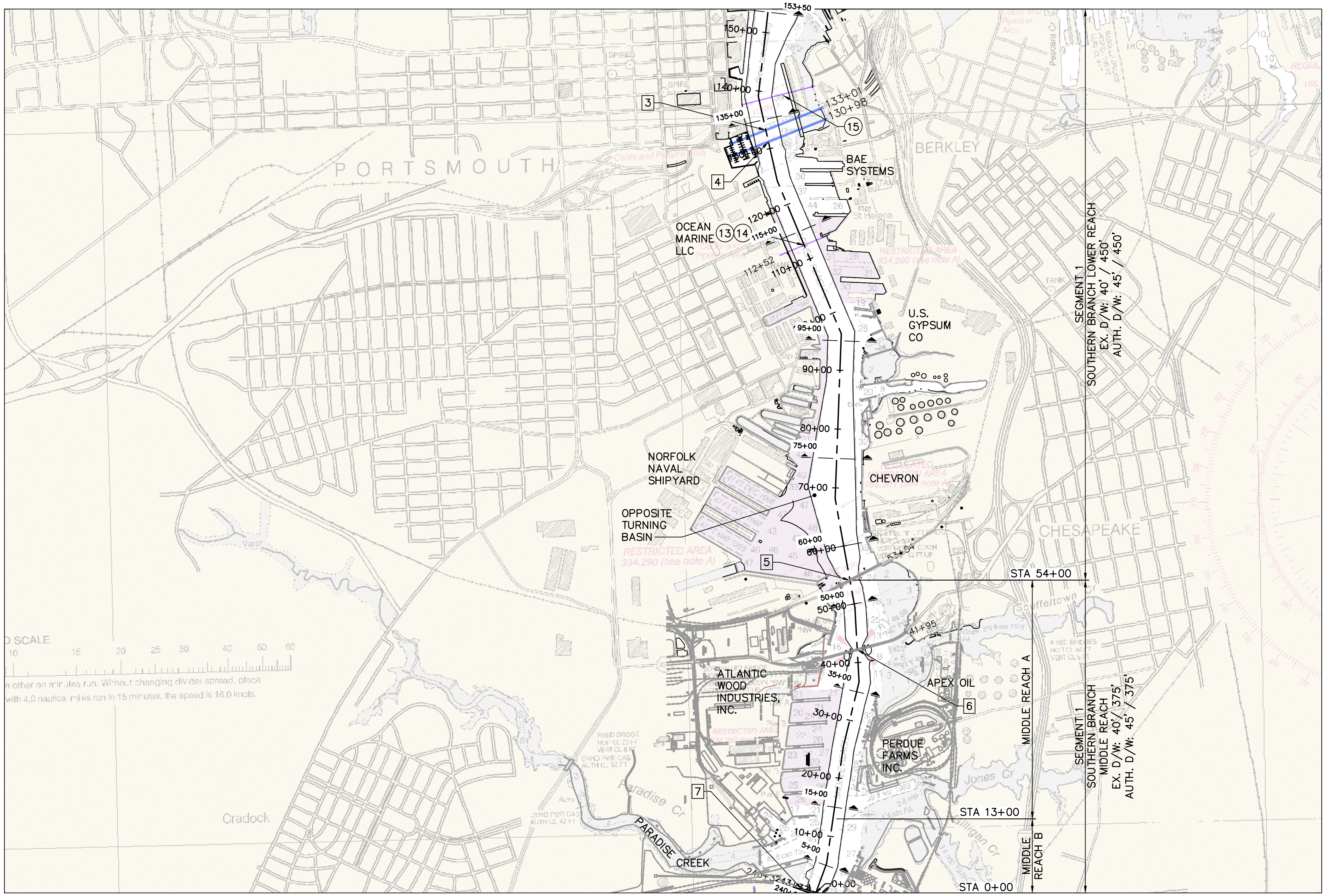
| NO. | DESCRIPTION | OWNER | DEPTH CONSTRAINT (FT. MLW) | NOTES |
|---|---|---|---|---|
| 16 | SUBMARINE CABLES | WESTERN UNION | −49 | ABANDONED |
| 17 | 36" WATER MAIN | CITY OF NORFOLK | −150 (AND DEEPER) | APPROX LOCATION |
| 18 | 42" SANITARY SEWER PIPE | HRSD | −70 | |

1000' 0' 1000' 2000'
SCALE: 1"=2000'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 3 - ENLARGED PLAN

moffatt & nichol




## KEYED NOTES:

3. DOWNTOWN TUNNEL (WESTBOUND)
HORIZONTAL CONSTRAINT: 450'
VERTICAL CONSTRAINT: −58.5' TOP OF STRUCTURE

4. DOWNTOWN TUNNEL (EASTBOUND)
HORIZONTAL CONSTRAINT: 450'
VERTICAL CONSTRAINT: −63.0' TOP OF STRUCTURE

5. BELT LINE RR LIFT BRIDGE
HORIZONTAL CONSTRAINT: 300'
VERTICAL CONSTRAINT: +142'

6. SOUTH NORFOLK JORDAN BRIDGE (FIXED)
HORIZONTAL CONSTRAINT: 270'
VERTICAL CONSTRAINT: +145'

7. NORFOLK SOUTHERN RR LIFT BRIDGE
HORIZONTAL CONSTRAINT: 220'
VERTICAL CONSTRAINT: +135' (OPEN)

## LEGEND:

- SUBMERGED UTILITY
- TUNNEL
- BRIDGE
- OVERHEAD UTILITY
- SECTION CUT

SUBMERGED UTILITY CROSSINGS

| NO. | DESCRIPTION | OWNER | DEPTH CONSTRAINT (FT. MLW) | NOTES |
|---|---|---|---|---|
| 13 | 8" WATER MAIN | U.S. NAVY | −58 | ABANDONED |
| 14 | TELEPHONE CABLES | U.S. NAVY | −58 | |
| 15 | 10 − 4.5" CONDUITS | AT&T | −58 | ABANDONED |

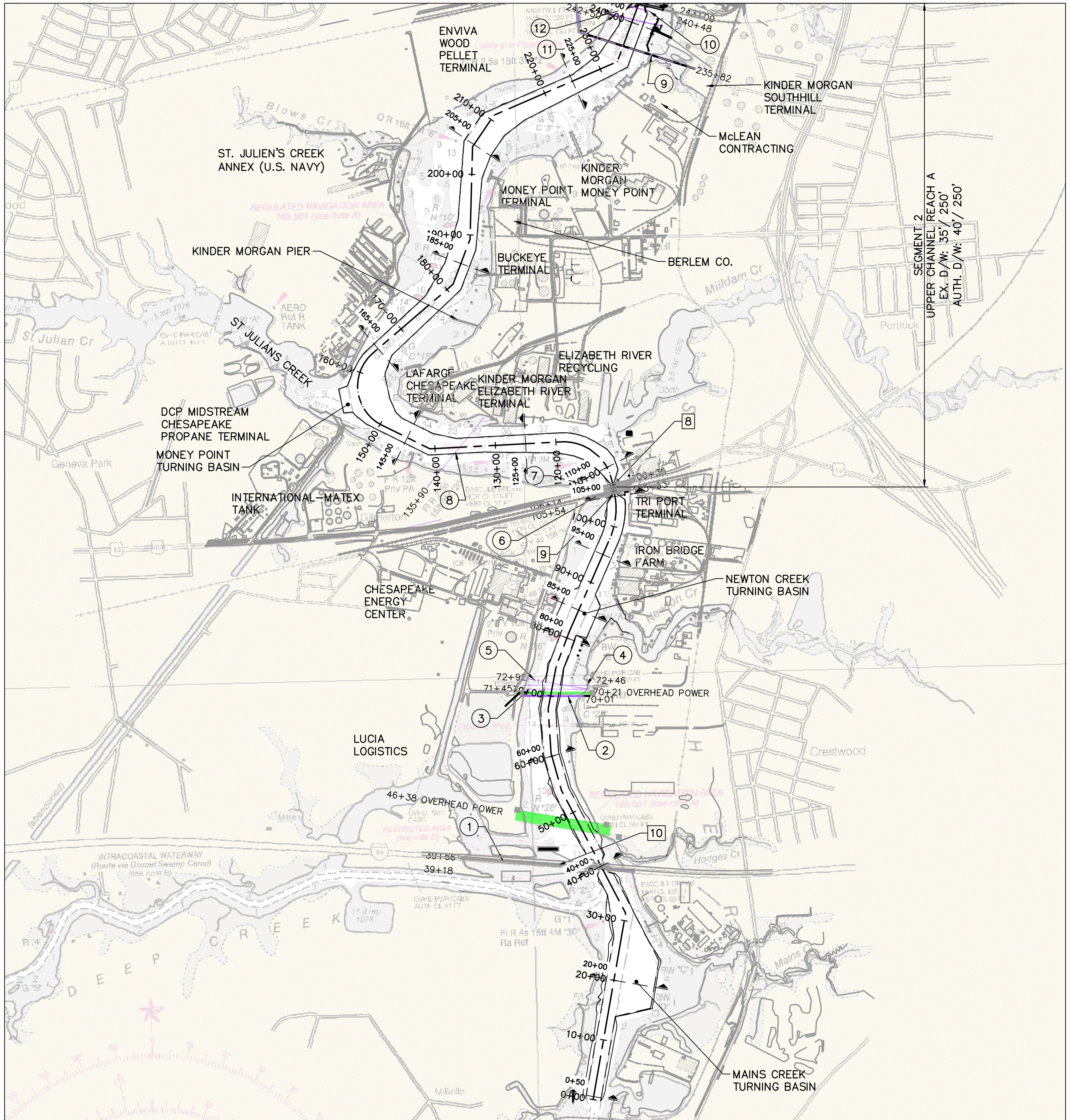
1000' 0' 1000' 2000'
SCALE: 1"=2000'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

## PLATE 4 - ENLARGED PLAN

moffatt & nichol

File: Q:\NOR\8885-01\500 CADD_Active_Elizabeth River Exhibits\Fig-3,4,5; Plotted: 11/28/2017 9:38 AM by AYTODA, BINA; Saved: 11/28/2017 9:37 AM by BAYTODA




## KEYED NOTES (BRIDGES & TUNNELS):

8 GILMERTON LIFT BRIDGE
HORIZONTAL CONSTRAINT: 125'
VERTICAL CONSTRAINT: +135'

9 NORFOLK SOUTHERN RR BASCULE BRIDGE
HORIZONTAL CONSTRAINT: 125'
VERTICAL CONSTRAINT: N/A

10 HIGH RISE BASCULE BRIDGE (I-64)
HORIZONTAL CONSTRAINT: 125'
VERTICAL CONSTRAINT: N/A (OPEN)

| SUBMERGED UTILITY CROSSINGS | | | | |
|---|---|---|---|---|
| NO. | DESCRIPTION | OWNER | DEPTH CONSTRAINT (FT. MLW) | NOTES |
| 1 | SUBMERGED CABLE | | -48.5 | |
| 2 | 24" SANITARY SEWER PIPE | HRSD | -43 | |
| 3 | 12.75" GAS PIPE | COLUMBIA GAS | -43 | |
| 4 | 16" GAS PIPE | COLUMBIA GAS | -43 | |
| 5 | WATER MAIN | CITY OF CHESAPEAKE | -43 | |
| 6 | SUBMARINE CABLES | | "ON BOTTOM" | |
| 7 | SUBMARINE CABLES | | "ON BOTTOM" | |
| 8 | 14" PETROLEUM PIPELINE | COLONIAL | -50 | |
| 9 | 14" PETROLEUM PIPELINE | COLONIAL | -50 | |
| 10 | 42" WATER MAIN | CITY OF NORFOLK | -45 | |
| 11 | 48" WATER MAIN | CITY OF NORFOLK | -75 | |
| 12 | SUBMERGED CABLES | | -48.5 | |

LEGEND:

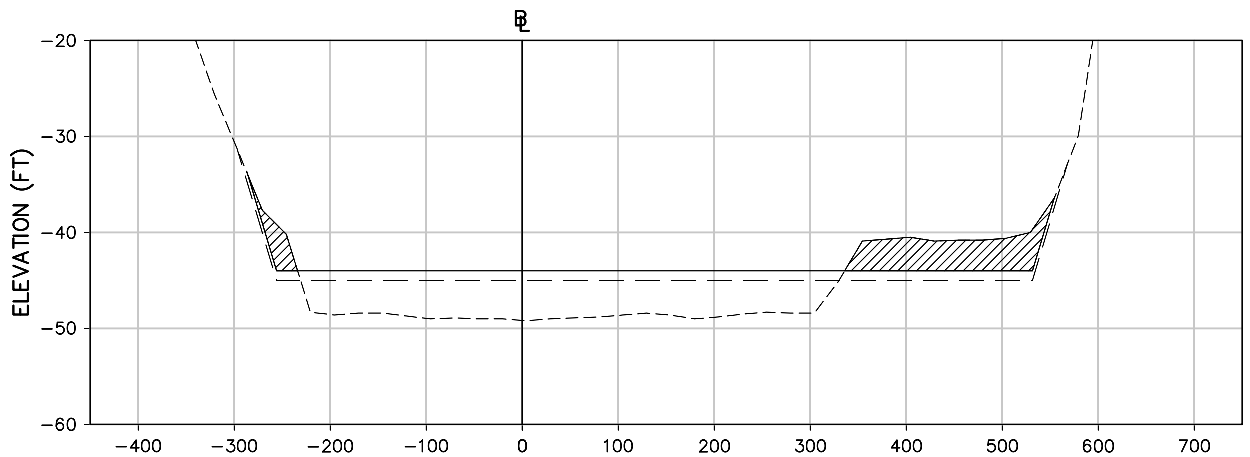
SUBMERGED UTILITY
TUNNEL
BRIDGE
OVERHEAD UTILITY
SECTION CUT

1000' 0' 1000' 2000'
SCALE: 1"=2000'

ELIZABETH RIVER SOUTHERN BRANCH
NAVIGATION IMPROVEMENTS STUDY

PLATE 5 - ENLARGED PLAN

moffatt & nichol



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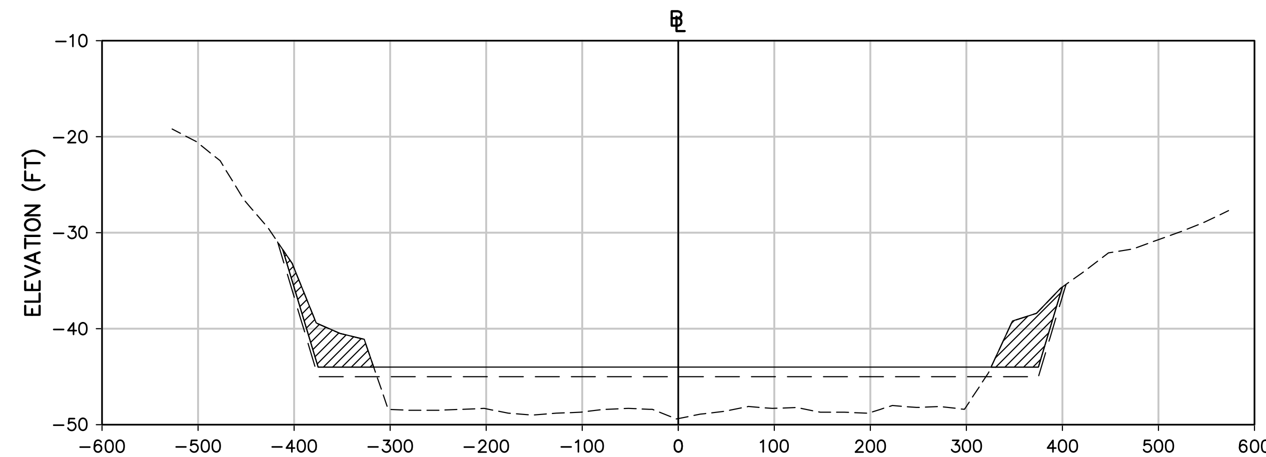

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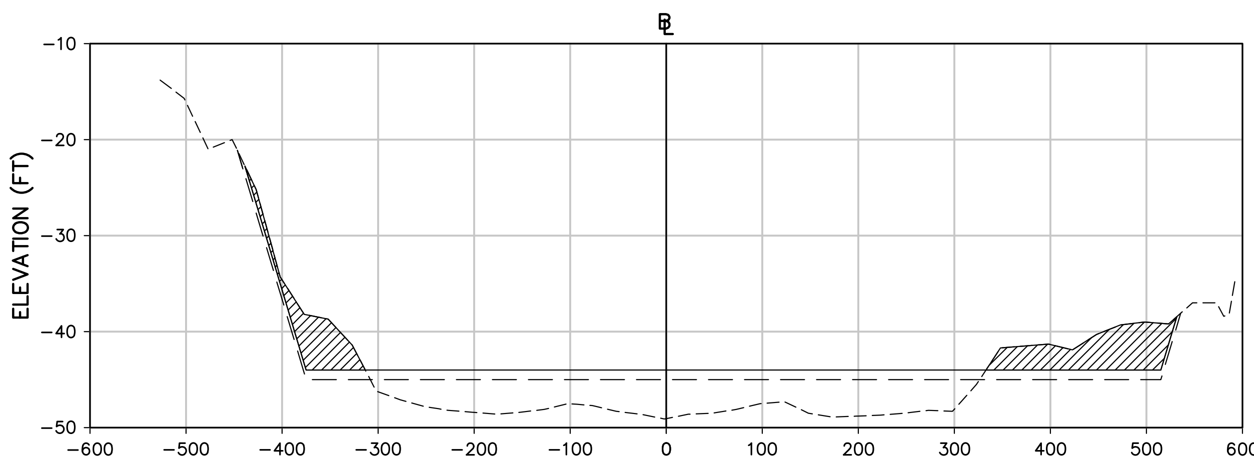

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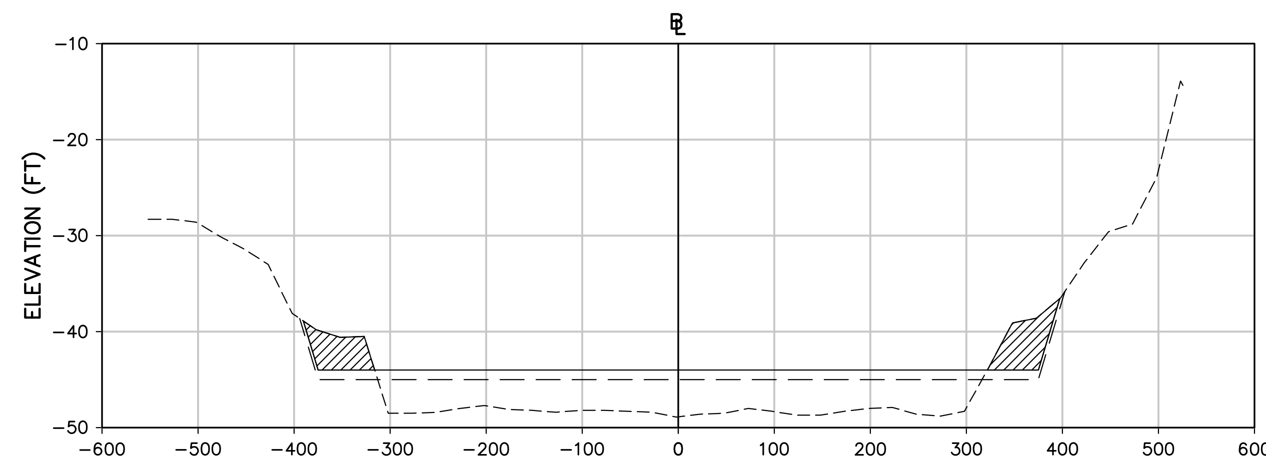

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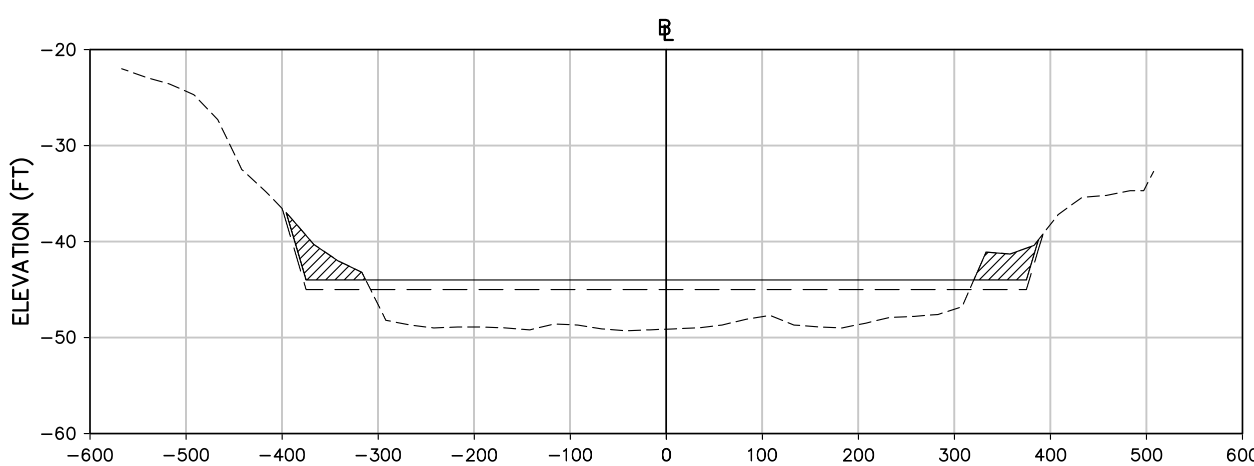

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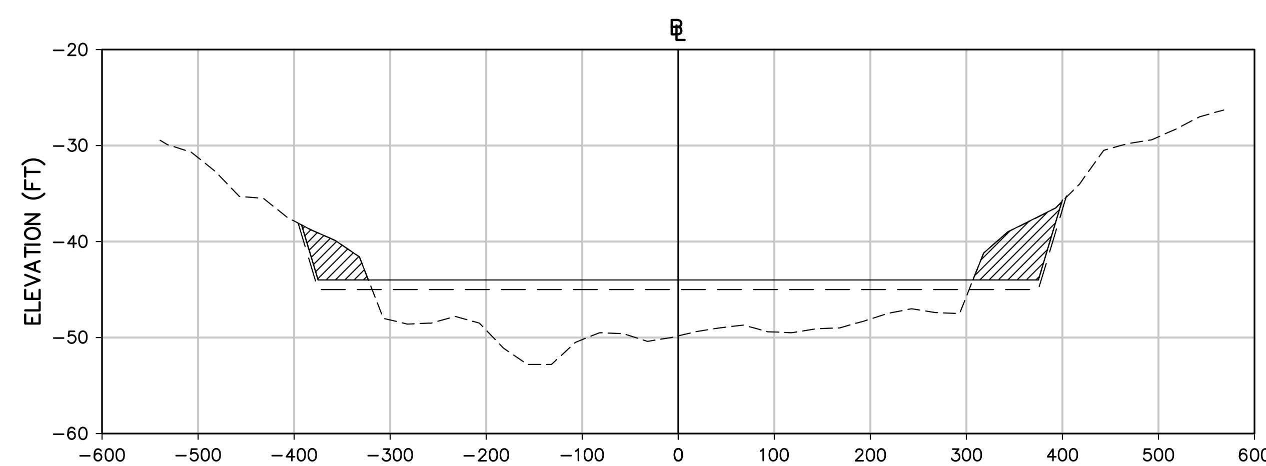


250+00

LEGEND:

EXISTING SURFACE

DREDGING TO EL -44'

REQUIRED DEPTH EL -44'

PAID ALLOWABLE DEPTH EL -45'

10' 0' 10' 20'

VERTICAL SCALE: 1"=20'

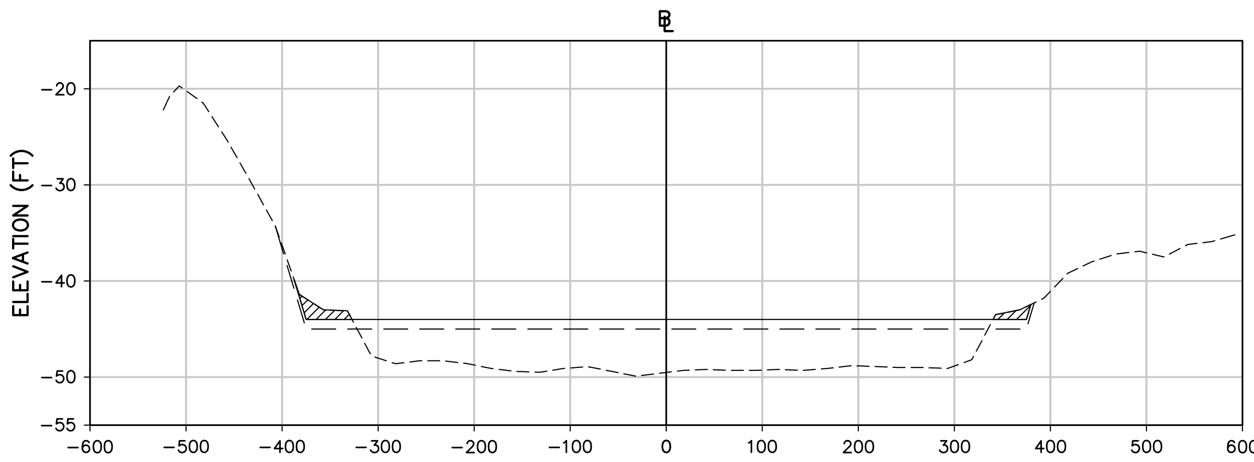
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 7 - SECTIONS - SEGMENT 1 - ELIZABETH RIVER REACH

moffatt & nichol

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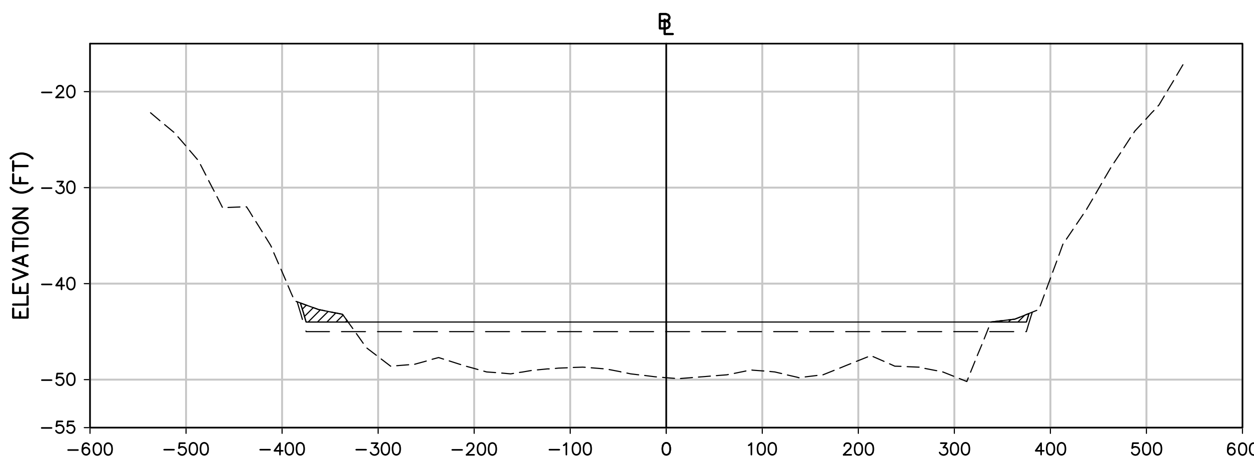


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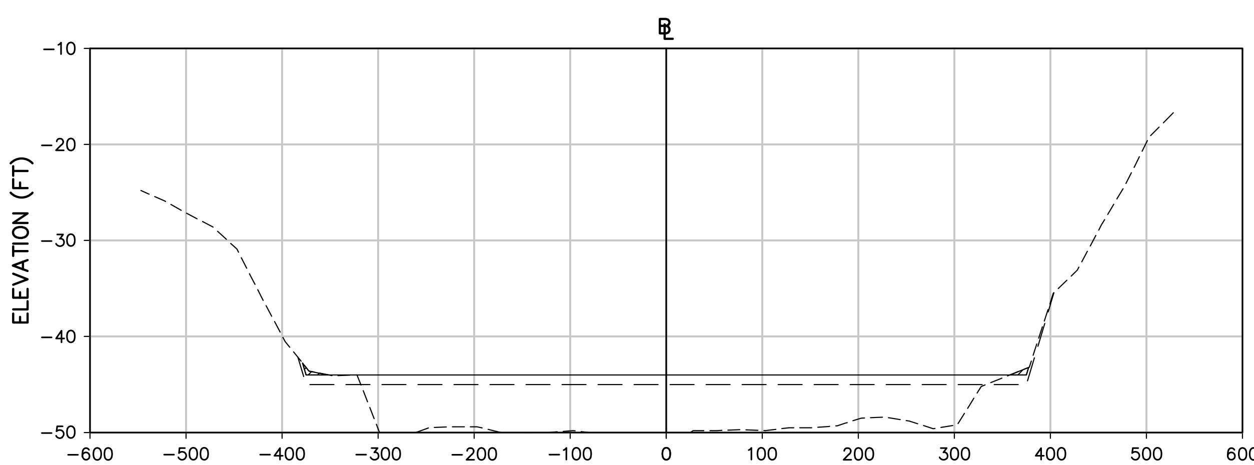



310+00

LEGEND:

- EXISTING SURFACE
- DREDGING TO EL -44'
- REQUIRED DEPTH EL -44'
- PAID ALLOWABLE DEPTH EL -45'

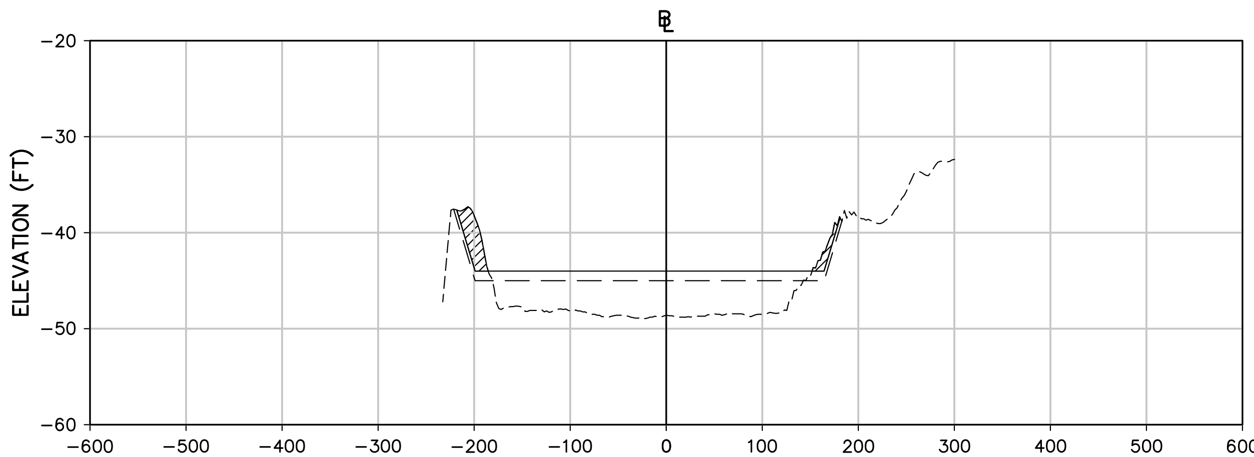
10' 0' 10' 20'
VERTICAL SCALE: 1"=20'

100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 8 - SECTIONS - SEGMENT 1 - ELIZABETH RIVER REACH

moffatt & nichol

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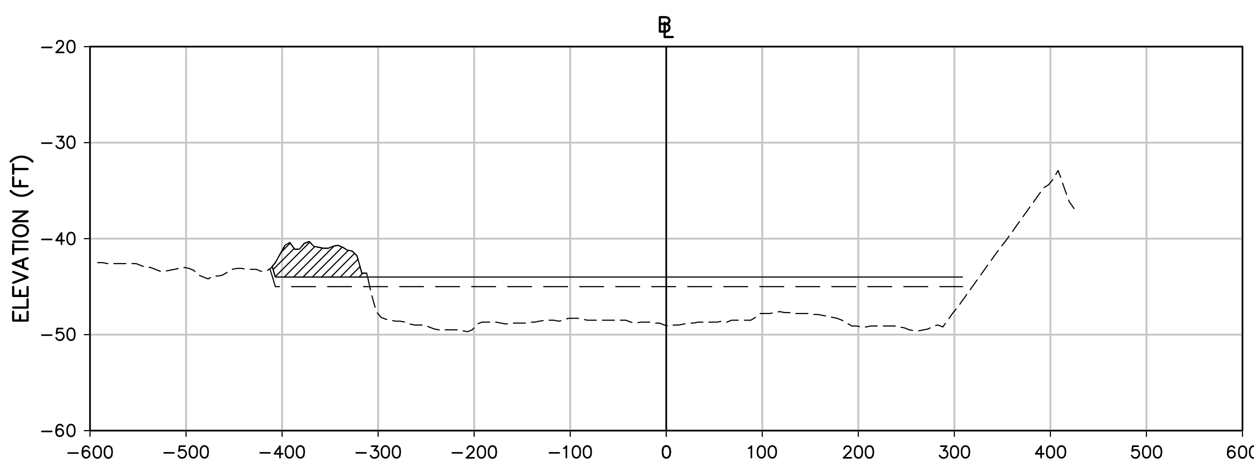
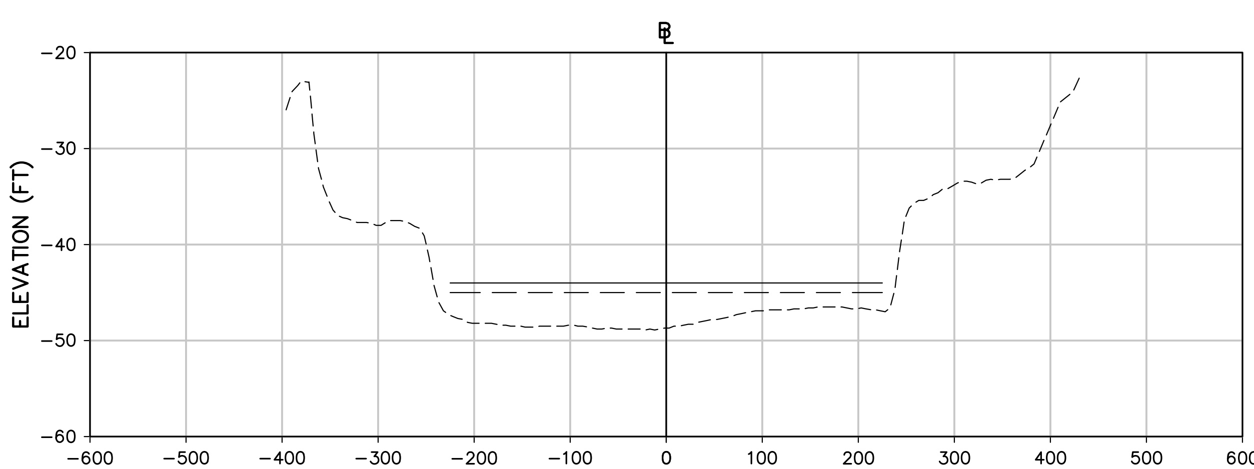
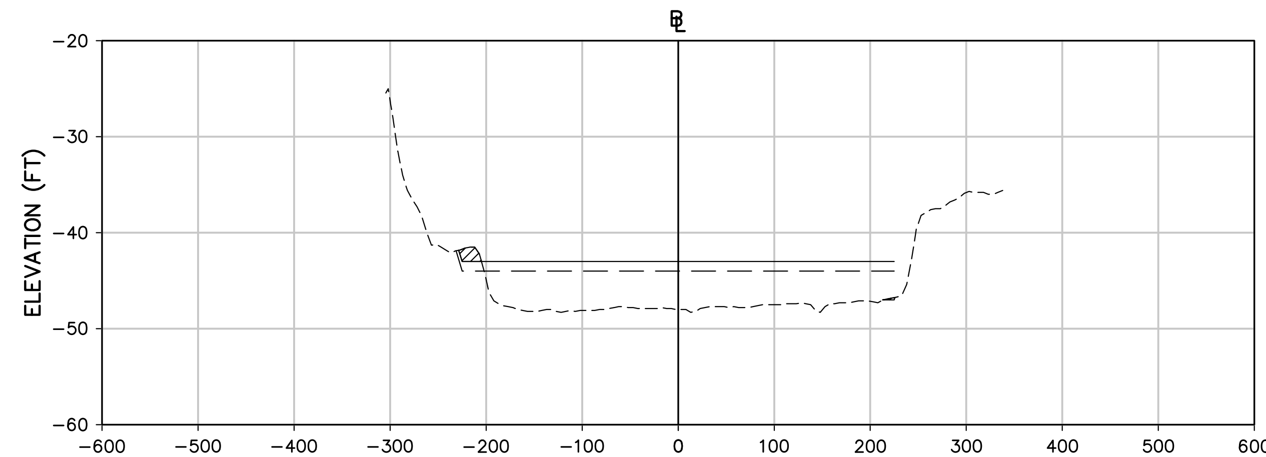


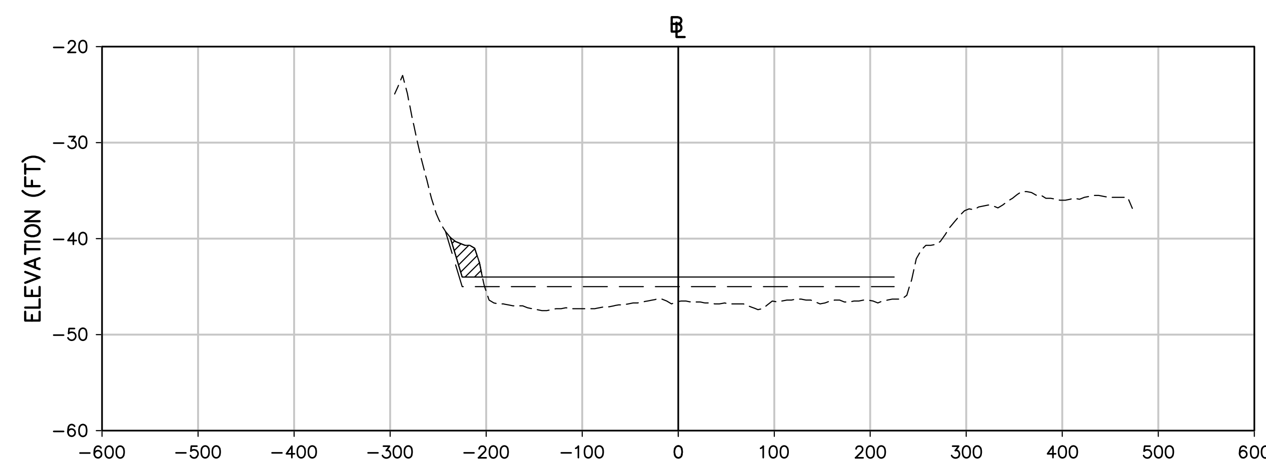

75+00



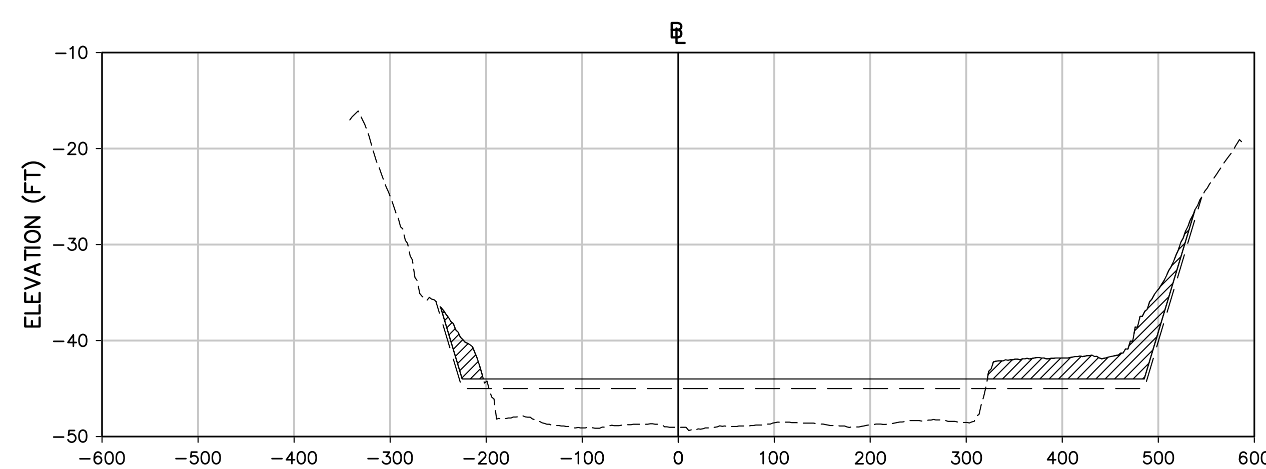

95+00




115+00




134+00




153+50

**LEGEND:**

- EXISTING SURFACE
- DREDGING TO EL −44'
- REQUIRED DEPTH EL −44'
- PAID ALLOWABLE DEPTH EL −45'

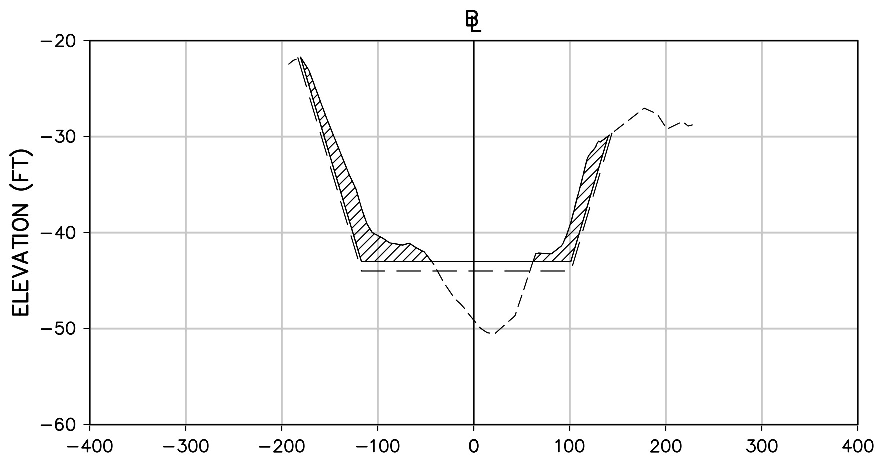
10' 0' 10' 20'
VERTICAL SCALE: 1"=20'

100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

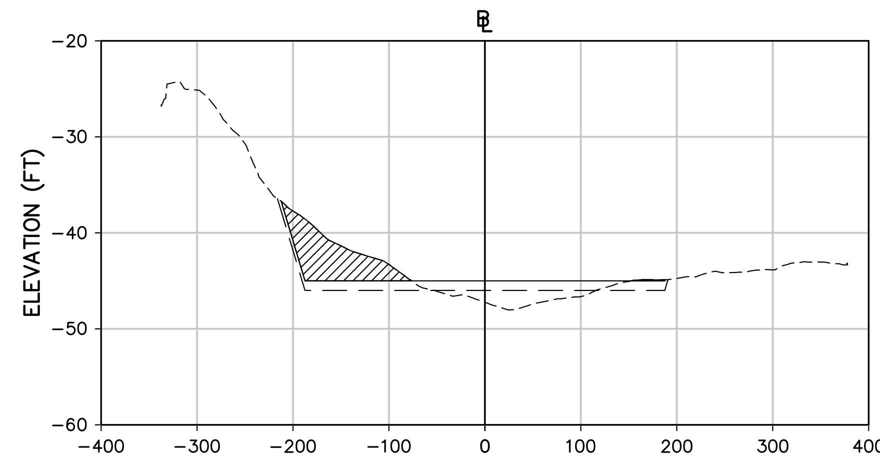
# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 9 - SECTIONS - SEGMENT 1 - SOUTHERN BRANCH LOWER REACH

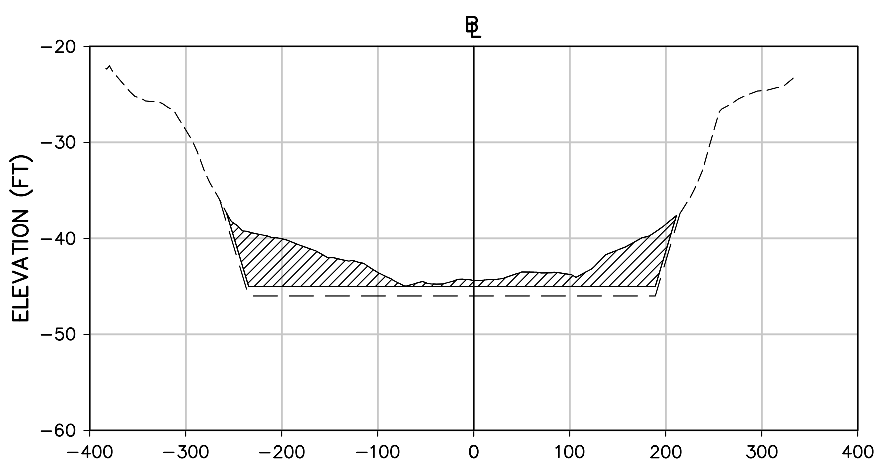
moffatt & nichol



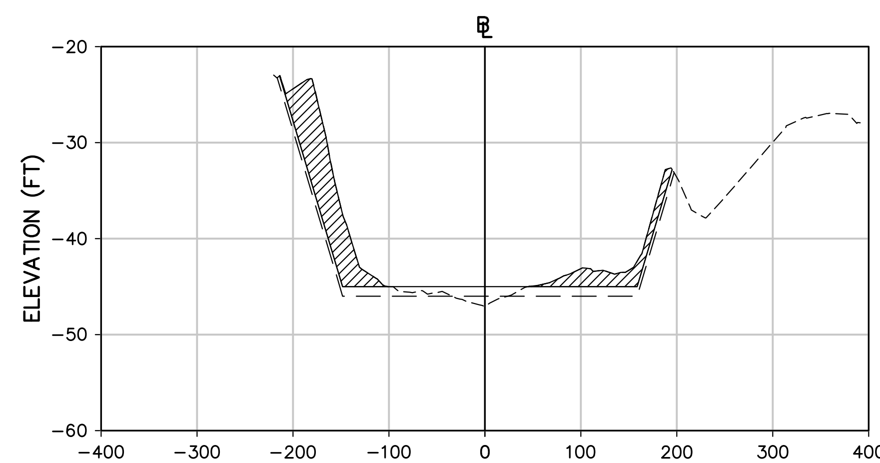

0+50 (MIDDLE REACH B)




15+00 (MIDDLE REACH A)




35+00 (MIDDLE REACH A)




54+00 (MIDDLE REACH A)

LEGEND:

- – – – – EXISTING SURFACE
- DREDGING TO EL -45'
- ——— REQUIRED DEPTH EL -45'
- — — PAID ALLOWABLE DEPTH EL -46'

10' 0' 10' 20'
VERTICAL SCALE: 1"=20'

100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

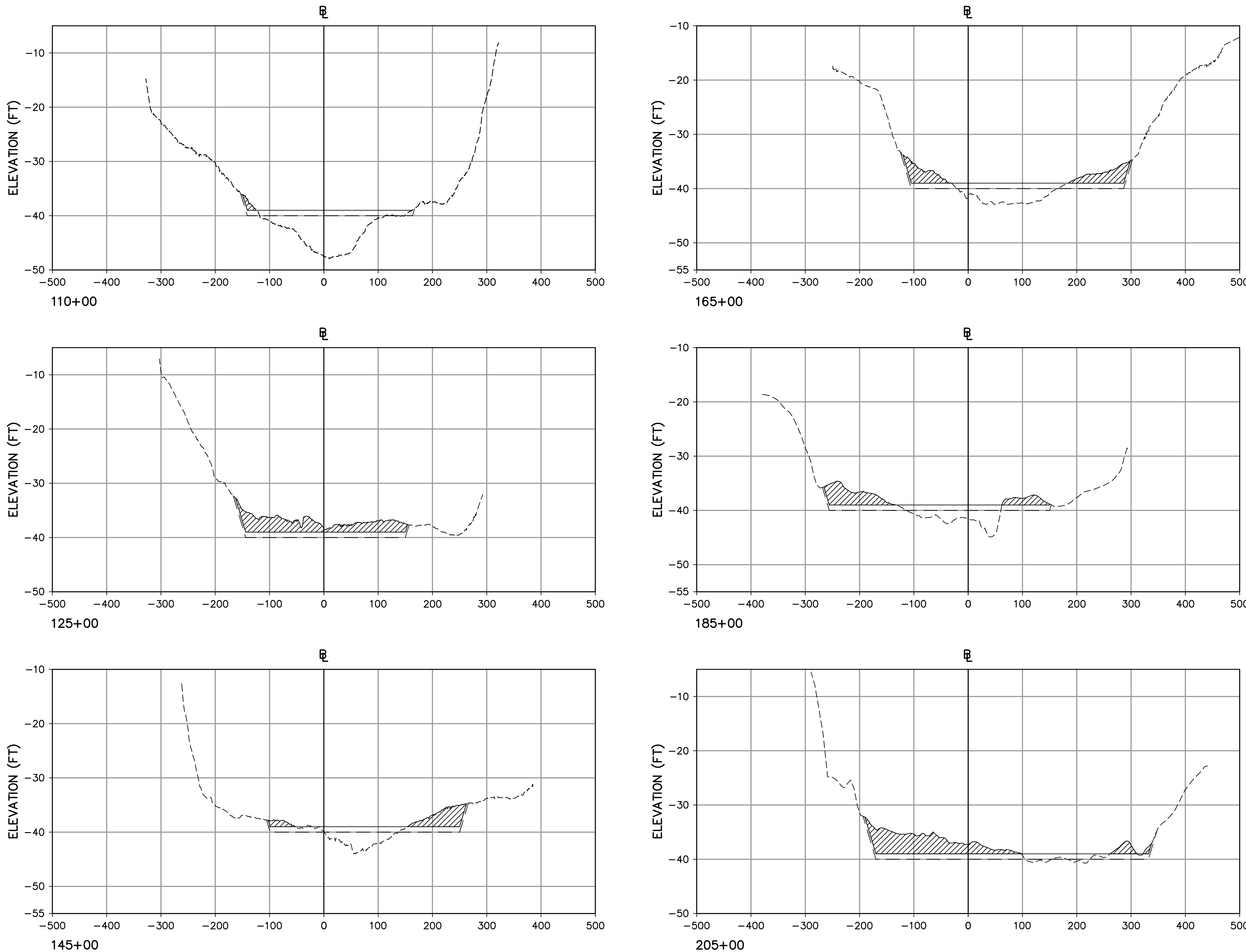
# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 10 - SECTIONS - SEGMENT 1 - SOUTHERN BRANCH MIDDLE REACH

moffatt & nichol

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

## PLATE 11 - SECTIONS - SEGMENT 2 - UPPER CHANNEL REACH A



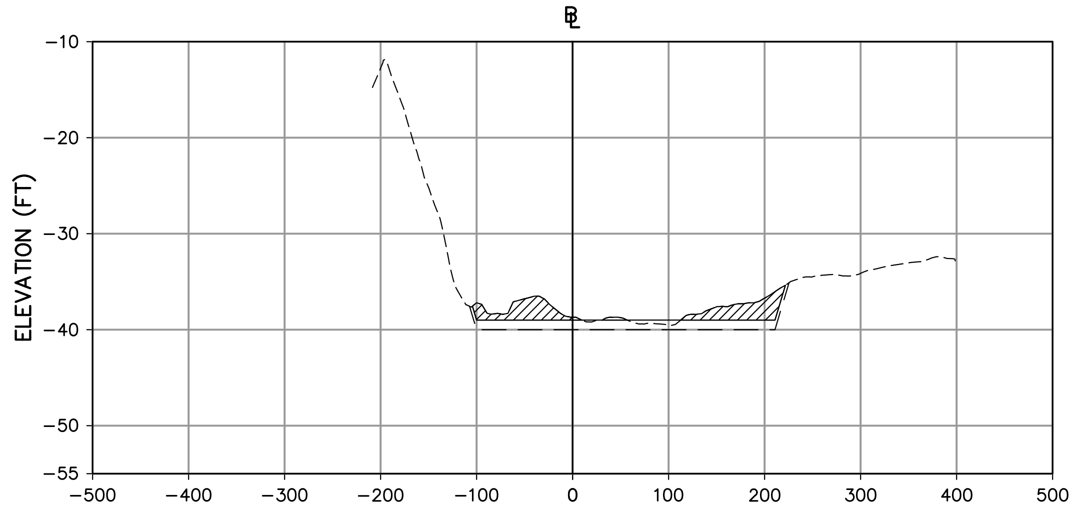

LEGEND:

- EXISTING SURFACE
- DREDGING TO EL -39'
- REQUIRED DEPTH EL -39'
- PAID ALLOWABLE DEPTH EL -40'

VERTICAL SCALE: 1"=20'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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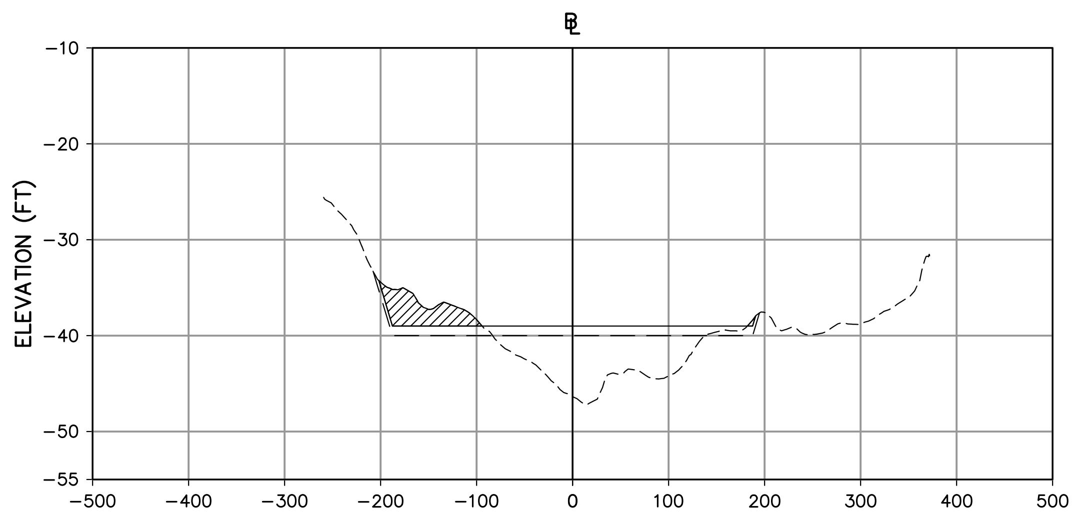


240+00

LEGEND:

- EXISTING SURFACE
- DREDGING TO EL -39'
- REQUIRED DEPTH EL -39'
- PAID ALLOWABLE DEPTH EL -40'

VERTICAL SCALE: 1"=20'

HORIZONTAL SCALE: 1"=200'

# ELIZABETH RIVER SOUTHERN BRANCH NAVIGATION IMPROVEMENTS STUDY

PLATE 12 - SECTIONS - SEGMENT 2 - UPPER CHANNEL REACH A

moffatt & nichol

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# Appendix B:
# Geotechnical Study

FUGRO CONSULTANTS, INC.

# GEOTECHNICAL EVALUATION
# ELIZABETH RIVER AND
# SOUTHERN BRANCH OF THE ELIZABETH RIVER
# DEEPENING STUDY
# HAMPTON ROADS, VIRGINIA

Prepared for:
MOFFATT & NICHOL

April 2016
Fugro Job No. 04.81150012

World Trade Center
101 West Main Street, Suite 350
Norfolk, Virginia 23510
**Tel: (757) 625-3350**
Fax: (757) 625-3352

April 28, 2016
Project No. 04.81150012

Moffatt & Nichol, Inc.
800 World Trade Center
Norfolk, Virginia 23510

Attention: Mr. Ira Brotman, P.E.

Subject: Geotechnical Evaluation, Elizabeth River and Southern Branch of the Elizabeth River, Deepening Study, Hampton Roads, Virginia

Dear Mr. Brotman:

Fugro Consultants, Inc. (Fugro) is pleased to submit this geotechnical evaluation of subsurface conditions in the Elizabeth and River Southern Branch of the Elizabeth River. This report has been prepared by Fugro to evaluate geotechnical characteristics of sediments within the Southern Branch of the Elizabeth River. Sediments are characterized in this study using available historical subsurface and bathymetric data. The objective of this study is to provide geotechnical characterization of materials that may be dredged as part of future navigation improvements in the Elizabeth River and Southern Branch of the Elizabeth River.

The work was performed in accordance with Moffatt & Nichol's Subconsultant Agreement, Moffatt & Nichol, Inc. (M&N) Project number 8885-01 dated November 10, 2015.

We appreciate the opportunity to support the Elizabeth River and Southern Branch Channel Deepening project. Please let us know if you have any questions or if we may be of further assistance.

Sincerely,

FUGRO CONSULTANTS, INC.

Kevin Smith
Associate Engineering Geologist

Saba Esmailzadeh, Ph.D.
Staff Engineer

William R. Mack, P.E.
Senior Engineer

Copies Submitted: 1 electronic

# CONTENTS

## TABLES



## FIGURES

# 1.0 INTRODUCTION

This report presents the findings of a desktop study intended to provide geotechnical characterization of sediments anticipated to be encountered during dredging within the Federal Navigation Channel of the Elizabeth River and Southern Branch of Elizabeth River (herein after referred to as SBER). Figure 1 presents the location of the study area. This evaluation was conducted in support of the navigation improvements study being performed by the United States Army Corps of Engineers (USACE) and the Virginia Port Authority.

The objective of this study is to characterize the physical, chemical and ecotoxicological properties of the near surface sediments within SBER based on available historical data. Information presented in this report can be used by project partners to aid their assessment of the placement options for future dredged material. The navigation channels studied include (Figure 1):

- Elizabeth River Reach,
- Lower Reach,
- Middle Reach,
- Upper Channel Reach A,
- Upper Channel Reach B, and
- Upper Channel Reach C.

This report provides a description of the data compiled and reviewed in this study and presents a summary of our geotechnical evaluation of the subsurface material characteristics based those data. Maps, cross sections, and graphs of geotechnical data used to aid our evaluation are included in this report.

## 1.1 AUTHORIZATION

This geotechnical study was authorized under Project No. 8885-01 dated November 10, 2015 between Moffatt & Nichol and Fugro. We performed our services in general accordance with the scope of work outlined in Fugro Proposal No. 04.81159023 dated July 8, 2015.

## 1.2 STUDY METHODOLOGY

We conducted a literature search to identify, collect and synthesize existing bathymetric and geotechnical data. We also utilized geotechnical and geological information from Fugro's in-house Hampton Roads Database to support this study. Relevant data were synthesized into a GIS database that was used to characterize existing water depths and subsurface conditions within potential future dredging envelopes.

We also used bathymetry data collected in channel conditions assessment surveys conducted in 2010, 2012 and 2014. Those data were provided to Fugro and Moffatt & Nichol by the USACE during the study.

Geotechnical and environmental data compiled during this study were collected by various companies between 1983 and 2015 using a variety of sampling and in-situ testing methods. Locations of the explorations are presented on Figure 2. Those exploration methods utilized vibracores, gravity cores, grab samplers, boreholes, cone penetration test (CPT) soundings to collect samples and perform in situ testing. Geotechnical data, including laboratory test results, related to those explorations were reviewed and assimilated into the project GIS database used in this study. Some explorations assimilated in this study contained primarily environmental test data. Locations of those environmental explorations conducted within or adjacent to the navigation channel are presented on Figures 3a and 3b.

Subsurface sediments were characterized in each channel reach using the compiled geotechnical data. The extent of each channel reach is presented in Figure 1. Based on the reviewed data, generalized subsurface material type zones were defined as shown on Figure 4. Subsurface material type zones are also presented on a series of plan and profiles. Subsurface profile locations, key to symbology used on the profiles, and subsurface cross sections are presented on Figures 5 through 7.

Subsurface material type zone boundaries were selected based on approximate boundaries between generalized material types and channel reach boundaries shown in Figure 1. Physical characteristics of the sediments used to delineate the different zones include soil classification, fines content, and Atterberg limits. Section 7 of this report provides a description of material types in each zone. The sediment characterization was provided in terms of elevation to assist in choosing the optimum dredging elevation within each reach.

M&N provided Fugro with the authorized depths for the different reaches. The authorized depths are shown on the cross sections in Figures 6 and 7 and also summarized in Table 1. It is important to note that at some locations, those authorized depths are shallower than existing channel bottom based on the most recent bathymetric survey. Craney Island and Elizabeth River reaches (Figure 6a), where the US Navy recently conducted a channel deepening, are examples of where the existing channel bottom is lower than the authorized channel depth.

## 2.0 BATHYMETRIC DATA

USACE Norfolk District provided bathymetric survey data from the recent condition surveys performed within the harbor and channels. Table 1 provides a summary of the survey dates for the respective channel reach bathymetries. The survey data were input into the Fugro GIS database and used to create three dimensional bathymetric surfaces and contours displayed on the cross sections and maps in this report. Channel bottom elevations within each reach and dates of surveys that the elevations are based upon are summarized in Table 1. Note that the channel bottom elevations listed in Table do not include the channel slope and accretionary (shoal) areas that may be present along the toe of the channel slopes.

**Table 1. Current Bathymetric Data Summary**

| Reach | Most Recent Reported Survey Date | Average Channel Bottom Elevation[a] (ft) | Channel Bottom Elevation Range within Center of Channel[b] (ft) | Authorized Channel Bottom Elevation[a] (ft) |
|---|---|---|---|---|
| Elizabeth River Reach | October 2012 | -47 | -40 to -50 | -45 |
| Lower Reach | October 2012 | -47 | -40 to -47 | -45 |
| Middle Reach | January 2010 | -44 | -40 to -47 | -45 |
| Upper Reach A | March 2010 | -38 | -30 to -41 | -40 |

| Reach | Most Recent Reported Survey Date | Average Channel Bottom Elevation[a] (ft) | Channel Bottom Elevation Range within Center of Channel[b] (ft) | Authorized Channel Bottom Elevation[a] (ft) |
|---|---|---|---|---|
| Upper Reach B | March 2010 | -37 | -35 to -41 | -35 |
| Upper Reach C | March 2010 | -30 | -30 to -40 | -35 |

[a] Elevations reference Mean Lower Low Water (MLLW)

[b] Elevation range does not include the channel side cut and localized areas where bathymetry is lower due to scour, utility trenches, or localized dredging

## 3.0 HISTORICAL GEOTECHNICAL AND ENVIRONMENTAL DATABASE

Fugro's Hampton Roads geotechnical database was used to supplement this desktop study. Fugro maintains a GIS-based database that includes geotechnical, environmental, geophysical and bathymetric data within the Hampton Roads region. Readily available historical data collected from several investigations conducted within the studied area were also integrated into Fugro's existing GIS database. The geotechnical exploration types consist of grab samples, vibracore, soil borings and cone penetrometer tests. Prior to mapping, the data was reviewed for consistency between soil classification schemes, coordinate systems and datums, quality, and relevance.

The data were originally presented in the following reports:

- United States Army Corps of Engineers, Norfolk District (1986), "*Geology and Soils Subsurface Investigation Norfolk Harbor Channel, Norfolk Harbor and Channels,"* dated May 1986. Logs dated 1983.
- Waterway Survey & Engineering, Ltd. (1998), "*Evaluation of Sediment Test Results for the Southern Branch, Norfolk Harbor Federal Navigation Project, Norfolk Virginia,"* prepared for USACE, dated June 1998.
- Science Application International Corporation (2007), "*Focused Feasibility Study for the Offshore Area at Money Point, Elizabeth River, Virginia, Volume I-Main.*" Prepared for the Elizabeth River Project, dated April 2007.
- Fugro Consultants (2008). "*Geotechnical Data Report, Marine Drilling, In Situ Testing, and Laboratory Testing Proposed Midtown Second Parallel Tunnel,*" prepared for Virginia Department of Transportation, dated June 2008. Logs dated 2008.
- Malcom Pirnie (2009). "*Craney Island Design Partners Elizabeth River Remediation Project: Appendix A Republic Site"*, dated March 2009. Logs dated 2008.
- United States Army Corps of Engineers, Norfolk District (2009), "*Channel Deepening, Norfolk Harbor Channel from Lamberts Bend on the main branch of the Elizabeth River Norfolk Naval Shipyard in the Southern Branch of the Elizabeth River"* dated March 2009. Logs dated 2008.
- Haley & Aldrich (2010). "*South Norfolk Jordan Bridge Site and Subsurface Exploration Plan,*" dated July 2010. Logs dated 2010.

- EA Engineering, Science and Technology (2011). "*Final Evaluation of Dredged Material, Norfolk Harbor Federal Navigation Project: Southern Branch of the Elizabeth River,*" prepared for USACE. Dated March 2011. Logs dated 2010.
- United States Army Corps of Engineers, Norfolk District (2011), "*Remedial Design – Phase 1C Offshore Sheet Pile Containment Wall, AWI Superfund Site Portsmouth, VA,"* dated April 2011. Logs dated 2010.
- CDM Smith (2012). "*Amendment 0002 to W91236-14-R-0019 for Environmental Dredging and Dredged Material Handling at Atlantic Wood Industries Superfund Site,*" dated May 2012. Logs dated 2005.
- EA Engineering, Science and Technology (2012). "*Amendment 0002 to W91236-14-R-0019 for Environmental Dredging and Dredged Material Handling at Atlantic Wood Industries Superfund Site,*" prepared for USACE, dated May 2012. EA vibracore logs presented in this study dated 2008 and 2012.
- EA Engineering, Science and Technology (2013). "Dredged Material Sampling and Testing – Enviva Terminal, Port of Chesapeake, Chesapeake, Virginia," prepared for Enviva Port of Chesapeake, LLC, dated June 2013."
- Waterway Survey & Engineering, Ltd. (2014), "APEX Preliminary Sediment Analysis, Chesapeake, Virginia," Prepared for APEX Oil Company Inc., dated March 2014.
- Anchor QEA and O'Brien & Gere (2015), "*Technical Memorandum: Money Point Phase 3 Sampling Summary,*" Prepared for Elizabeth River Project, dated January 2015. Logs dated October 2014.
- EA Engineering, Science and Technology (2015). "Evaluation of Dredged material, Norfolk Harbor Federal Navigation Project, Southern Branch of the Elizabeth River," prepared for USACE, dated March 2015. Logs dated 2014.
- Waterway Surveys & Engineering Ltd. (2015), *Sediment Sampling and Laboratory Test Results*, Seagate Terminals, Chesapeake, Virginia. Prepared for Seagate Terminals.

The following sections of this report describes the exploration data reviewed and incorporated in this study. For this study, we developed an exploration identification number (ID) that is unique for each exploration. The exploration ID code is encoded with each data record (e.g. grain size test result) in the project database and is used to relate the data to the original exploration ID and original source of the data. This unique naming convention provides the ability to differentiate data points if exploration ID's for two explorations were identical in two separate reports (e.g. Boring B-1 or Vibracore V-1). Exploration prefixes developed for this study are described in the following sections and displayed in the legends of relevant figures included in this report. The Figure 2 shows the location of the different explorations used in this study.

## 3.1 USACE, NORFOLK DISTRICT (1986; VIBRACORES)

In May 1983, August 1984 and July 1985, USACE in support of the Norfolk Harbor and Channel Deepening Project, performed a subsurface investigation of the Norfolk Harbor Channel in the Elizabeth River and Hampton Roads Harbor, Virginia. The 1983 exploration program consisted of twenty-nine (29) vibracores within the Norfolk Harbor Channel which were advanced to depths ranging from approximately 15 to 20 feet below the river bed. One of the vibracore samples fell within the designated area of this study in the vicinity of Lamberts Point. Geotechnical laboratory testing on the disturbed vibracore samples was performed by Century Engineering, Inc., of Towson, Maryland, Schnabel Engineering Associates of Richmond, Virginia and Law Engineering Testing Company of Norfolk, Virginia. Test results are based on moisture content, Atterberg limits, partical size analysis, No. 200 wash sieve, specific gravity, natural density, strength and consolidation testing. Environmental laboratory testing was not conducted on those samples. Exploration identification prefix used in this study is CEC83V.

### 3.2 WATERWAY SURVEY & ENGINEERING, LTD. (1998; VIBRACORE)

Waterway Surveys and Engineering, Ltd. performed an environmental sampling and testing program under contract to USACE Norfolk District to evaluate the existing sediment conditions in the Southern Branch navigation channel. The project site included the portion of the navigation channel from the Norfolk and Western Railroad Bridge at Paradise Creek to the turning basin at Newton Creek. The data were collected in two separate delivery orders during August 1995 and September 1996. A gravity coring system with a 6-foot long sampler was used to collect a 1.0 to 2.5 feet sediment core at about 100 target locations. Laboratory testing was conducted by Analytical and Consulting Laboratories (ANACON). Sediment samples were analyzed for metals, PCBs, pesticides, PAHs, semi-volatile organic compounds (SVOCs) and VOCs. The chemical analyses for elutriate samples included a quantification of metals, PCBs, pesticides, PAHs, Total Organic Carbon (TOC), COD, total suspended solids (TSS), oil and grease, ammonia and pH. In addition, grain size analysis was performed on each sediment sample. Exploration identification prefix used in this study is WWA98.

### 3.3 SCIENCE APPLICATION INTERNATIONAL CORPORATION (2007; ENVIRONMENTAL STUDY)

Science Applications International Corporation (SAIC) conducted a study sponsored by the non-profit Elizabeth River Project (ERP) on behalf of the Living River Restoration Trust (LRRT) to evaluate the feasibility of the cleanup of approximately 19 acres of contaminated sediment at the Money Point section of the Elizabeth River, Chesapeake, Virginia. During September 2005, 47 sediment sample cores were collected to assess the degree of pollution in the area. A combination of hand-held piston cores and deeper penetrating electric vibracores were obtained. The recovered samples were analyzed for Total PAHs using immunoassay techniques, and 5 cores were subject to comprehensive laboratory analysis of PAHs for validation of the immunoassay data. Exploration identification prefix used in this study is SAA07E.

### 3.4 FUGRO CONSULTANTS (2008; BORINGS AND CPTS)

Fugro Consultants (Fugro) performed an extensive marine geotechnical exploration and laboratory testing program in support of Virginia Department of Transportation (VDOT) Midtown Parallel Tunnel in the Lamberts Bend Reach of the SBER. The exploration consisted of ten (10) Standard Penetration Test (SPT) marine borings and forty (40) CPT tests. The borings were performed during February and March of 2008. Termination depth of the borings ranged from about 78 to 127 feet below the river bottom, with water depths ranged from about 11 to 48 feet. All of the borings lie within the vicinity of the navigation channel and are included in the present desktop study. The CPT soundings were performed with termination depths ranging from about 15 to 98 feet below the river bottom. Three (3) of the conducted CPTs located within the study area were used in the present desktop study. Geotechnical laboratory testing was conducted on collected samples. Testing included grain size distribution including sieve analyses and hydrometer tests, Atterberg limits, organic content, specific gravity, strength tests and consolidation testing. Exploration identification prefixes used in this study are FA08B and FA08C for borings and CPTs, respectively.

### 3.5 MALCOM PIRNIE (2009; VIBRACORES)

Craney Island Design Partners, LLC (CIDP) conducted a geotechnical-environmental site investigation program composed of bathymetric and topographic survey, vibracore explorations and laboratory testing in support of an Elizabeth River sediment restoration project at the Republic and Republic South sites located in Chesapeake, Virginia. Eighty-seven (87) vibracore explorations were conducted to depths ranging from about 2 to 10 feet below the river bed during October and November 2008. The vibracores were performed by Aqua Survey, Inc. and logged by Malcolm Pirnie Inc. Thirty-one (31) of the vibracores lie within the vicinity of the Navigation Channel. Laboratory testing was conducted by Test America and consisted of sieve and hydrometer analyses, percent fines, water content and environmental tests PAH, copper, PCB, mercury and zinc. Exploration identification prefixes used in this study are RCMP08 and RSMP08.

### 3.6 USACE, NORFOLK DISTRICT (2009; BORINGS)

In 2008, USACE performed a subsurface exploration and laboratory testing program in support of the Navy's requirement to deepen a portion of the Elizabeth River Channel between Lamberts Bend and Norfolk Naval Shipyard in SBER. The subsurface exploration program consisted of twenty-two (22) borings channel. The borings were performed during the period of August and September 2008. Standard penetration testing (SPT) was conducted in the borings. Penetration depths of the borings range from approximately 8 to 22 feet below the mudline to reach a planned termination depth of 55 feet below mean lower low water (MLLW). All borings are located within the current study area footprint.

The geotechnical laboratory testing program was performed by S&ME, Inc. and consisted of grain size distribution, Atterberg Limits and moisture contents tests. In addition to the geotechnical exploration program, an environmental subsurface investigation was conducted. Eight (8) environmental borings were conducted in the channel in the vicinity of Norfolk Naval Shipyard and Crown Central Petroleum. Exploration prefix identification assigned to this exploration is CE08B. All of the environmental vibracores are used in this study.

The environmental borings were completed in September 2008. The environmental soil samples were obtained using the same drilling equipment and sampling techniques as the geotechnical samples (SPT split barrel sampling). The environmental laboratory testing program performed on representative samples included benzene, toluene, ethylene, and xylene (BTEX), total petroleum hydrocarbons – diesel range organics (TPH-DRO), TPH-GRO (total petroleum hydrocarbons – gas range organics), toxicity characteristic leaching procedure metals (TCLP), and total organic halides (TOX). Exploration identification prefix assigned to the environmental explorations is CEA08V.

### 3.7 HALEY & ALDRICH (2010; BORINGS)

Haley & Aldrich, Inc. conducted an exploration consisting of (5) marine borings conducted to depths ranging from approximately 130 to 135 feet below the river bed during May 2010 within the Middle Reach of SBER in the vicinity of the Jordan Bridge. Geotechnical laboratory testing included sieve analysis and fines content tests. Four (4) marine boring located within the navigation channel is included in this study. Exploration identification prefix used in this study is AA10B.

### 3.8 EA ENGINEERING, SCIENCE AND TECHNOLOGY (2011; ENVIRONMENTAL VIBRACORES)

EA Engineering Inc. advanced thirty-eight (38) vibracores to depths ranging from approximately 2 to 6 feet below the riverbed during 2010 in areas located within the Middle Reach of SBER from the Jordan Bridge area to south to Paradise Creek. Full scale environmental testing including total petroleum hydrocarbons (TPHs), PAH, VOCs, sequential extraction procedure (SEP) metals and polychlorinated biphenyls (PCBs) tests conducted at the site in addition to geotechnical testing that included grain size, specific gravity, Atterberg limits, and total solids on composite samples. All the vibracore explorations are included in this study. Exploration identification prefix used in this study is EA11E.

### 3.9 USACE, NORFOLK DISTRICT (2011; BORINGS)

Schnabel Engineering performed a subsurface exploration and laboratory testing program consisting of twenty (20) land and twenty (20) marine borings as part of remedial design of the AWI superfund site located in Portsmouth, Virginia under contract to USACE Norfolk District. The exploration was conducted during September and November 2008. Two (2) borings are located within the vicinity of the navigation channel and penetrated to a depth of approximately 75 feet below the river bottom, where the water depth is about 23 feet (MSL). The geotechnical laboratory testing program consisted of moisture contents, unit weights, Atterberg limits, grain size analyses, consolidated undrained (CU) and unconsolidated undrained (UU) triaxial tests. Exploration identification prefix used in this study is SEA08B.

### 3.10 CDM SMITH (2012; ENVIRONMENTAL VIBRACORES)

In support of Atlantic Wood Industries Superfund Remediation Project, CDM Smith, Inc. advanced fifty-nine (59) vibracores to depths ranging from approximately 4 to 20 feet below the river bed during June and July 2005. Fifteen (15) vibracores are located within the navigation channel and its vicinity and are included in this study. The work was performed by Aqua Survey under contract to CDM Smith, Inc. within the Middle Reach of SBER in the vicinity of Atlantic Wood Industries (AWI). Environmental tests included volatile organic compound (VOCs) and immunoassay polycyclic aromatic hydrocarbon tests (PAHs) conducted on sediment samples. Geotechnical laboratory testing was not conducted on these samples. Exploration identification prefix used in this study as shown on the cross sections is CDA05V.

### 3.11 EA ENGINEERING, SCIENCE AND TECHNOLOGY (2012; ENVIRONMENTAL VIBRACORES)

EA Engineering Inc. advanced sixty (60) vibracores to depths ranging from approximately 11 to 55 feet below the river bed during June and July 2008 in areas located within the Middle

Reach of SBER adjacent to AWI and Norfolk Naval Ship Yard (NNSY). PAH testing was conducted on sediment samples. Thirty-three (33) vibracores are located within the navigation channel and are included in this study. Geotechnical laboratory testing was not conducted on these samples. Exploration identification prefix used in this study is EA08V.

### 3.12 EA ENGINEERING, SCIENCE AND TECHNOLOGY (2013; ENVIRONMENTAL STUDY)

EA Engineering Inc. conducted a surficial sediment sampling and testing program under contract to Enviva in support of the proposed deepening of the berthing area of the Enviva Port, Chesapeake Terminal, Chesapeake, Virginia. Enviva proposed deepening the berthing site from El. -37 feet to -40 feet (MLLW) plus a 2-ft over-dredge to accommodate increased ship volume and size. River bed sediments were analyzed in order to determine an appropriate dredge material disposal site. Field sampling was conducted during March 2013 at four locations using vibracore equipment. The water depth at the sampling locations ranged from about 26 to 38 feet (MLLW). Exploration identification prefix used in this study is EA13E.

### 3.13 WATERWAY SURVEY & ENGINEERING, LTD. (2014; ENVIRONMENTAL STUDY)

Waterway Surveys & Engineering, Ltd. under contract to APEX Oil Company Inc. performed an environmental study with the purpose of investigating the potential of dredging the berth at APEX facility in Chesapeake Virginia to a design project depth of El. -40 feet (MLW) (+2 feet of over depth). During January 2014, a sediment screen was performed on the top layers of material at the site to investigate the potential for dredge material contamination. Surface sediment samples were collected at five locations in the proposed dredging area. The samples closer to the channel were collected with a Ponar grab sampler and a diver using PVC tubing collected the samples closer to the shoreline. PAHs, TPH, PCBs and heavy metal measurements were conducted as part of the laboratory testing program. Exploration identification prefix used in this study is WW14E.

### 3.14 ANCHOR QEA AND O'BRIEN & GERE (2015; ENVIRONMENTAL STUDY)

Anchor QEA, O'Brien & Gere Joint Venture conducted surficial sediment sampling and testing to support the Phase 3 remedial design for the Money Point site located in Chesapeake, Virginia. The purpose of the sampling was to collect data to characterize the physical and chemical quality of the sediments from the Phase 3 remedial footprint to support dredging and subsequent capping of the Phase 3 area. Total of 9 sediment cores were collected in the Money Point Phase 3 footprint using vibracore and Ponar grab sampler equipment with penetration depths ranging from about 6 to 11 feet in water depths ranging from about 2 to 37 feet (MLLW). The sampling was conducted during October 2014. A suite of chemical testing was performed on composite samples. The laboratory analyses were performed by Test America-Pittsburgh. The chemical testing program was consisted of TPH diesel range organics (DRO) and gasoline range organics (GRO), benzene, toluene, ethylbenzene, and xylene (BTEX), polychlorinated biphenyl (PCB) aroclors tests and also the toxicity characteristic leaching procedure (TCLP), which includes metals, semivolatile organic compounds, volatile organic compounds, chlorinated pesticides, herbicides, pH, ignitability, total cyanide, and total sulfides. Exploration identification prefix used in this study is AQA15E.

### 3.15 EA ENGINEERING, SCIENCE AND TECHNOLOGY (2015; ENVIRONMENTAL STUDY)

EA Engineering, Inc. was contracted by USACE Norfolk district to conduct the 2014 dredged material evaluation for the navigation channel in the Southern Branch of the Elizabeth River. This study was conducted to provide supplemental information to a previous evaluation of the SBER dredge material conducted in 2010 (Report E, EA11). The project involved collecting sediment cores using vibracore equipment at 51 locations within the navigation channel. Physical and chemical characteristics of 14 composite samples from 25 locations in the SBER were analyzed. As part of the laboratory testing program, chemical concentrations of metals, PAHs, PCB congeners, total organic carbon (TOC) and total petroleum hydrocarbons (TPH) were identified in sediment samples. Exploration identification prefix used in this study is EA15E.

### 3.16 WATERWAY SURVEYS & ENGINEERING LTD. (2015; ENVIRONMENTAL STUDY)

During May and June 2015, Waterway Surveys & Engineering conducted a sediment sampling and laboratory testing program at the Seagate Handling Facility, Southern Branch of the Elizabeth River, Chesapeake, Virginia. The sediment samples have been analyzed for PAHs, TPH, PCBs and metals. Exploration identification prefix used in this study is WW15E.

### 3.17 ELIZABETH RIVER SHELBY SAMPLES (EXPLORATION DATE UNKNOWN; GRAB SAMPLES)

Surface grab sample data that comprise the Shelby data set were obtained from the Elizabeth River Project (accessed through www.elizabethriver.org). Grab samples were collected along most of the Southern Branch of the Elizabeth River and contain grain size and environmental test result data. Exploration identification prefix used in this study is "E".

### 3.18 SUMMARY OF THE AVAILABLE GEOTECHNICAL AND ENVIRONMENTAL DATA

Three hundred fifty-two historical explorations from 16 investigations were identified to be with the navigation channel and its vicinity and used in this study. Those explorations consist of 311 vibracores/gravity cores, 38 marine borings and 3 cone penetrometer tests. The exploration locations are shown in Figures 2 and 3. Table 2 provides a summary of the explorations, year they were conducted, exploration type, and company responsible for conducting the exploration.

**Table 2. Summary of Exploration Data Sources**

| Report | Exploration Year | Exploration Type | Exploration Testing Type | Quantity within or adjacent to the navigation channels | Reporting Company |
|---|---|---|---|---|---|
| CDM (2012) | 2005 | Vibracores | Environmental | 15 | CDM Smith |
| EA Engineering (2011) | 2010 | Vibracores | Environmental | 38 | EA Engineering |
| EA Engineering (2012) | 2008 | Vibracores | Environmental | 33 | EA Engineering |
| Fugro (2008) | 2008 | Borings/<br>CPTs | Geotechnical | 10<br>3 | Fugro Consultants |

| Report | Exploration Year | Exploration Type | Exploration Testing Type | Quantity within or adjacent to the navigation channels | Reporting Company |
|---|---|---|---|---|---|
| Haley & Aldrich (2010) | 2010 | Borings | Geotechnical | 4 | Haley & Aldrich |
| Malcom Pirnie (2009) | 2008 | Vibracores | Environmental and Geotechnical | 31 | Malcom Pirnie |
| USACE (1986) | 1983 | Vibracores | Geotechnical | 1 | USACE |
| USACE (2009) | 2008 | Vibracore/ Borings | Environmental and Geotechnical | 8<br>22 | USACE |
| USACE (2011) | 2008 | Borings | Geotechnical | 2 | Schnabel Engineering |
| Waterway Surveys & Engineering (1998) | 1995 and 1996 | Vibracores | Environmental | 98 | Waterway Surveys |
| Science Applications International Corporation (2007) | 2005 | Piston Cores/ Vibracores | Environmental | 36 | Science Applications International Corporation |
| Anchor QEA, O'Brien & Gere (2015) | 2014 | Vibracore/ Ponar grab sampler | Environmental and Geotechnical | 9 | Anchor QEA, O'Brien & Gere |
| Waterway Surveys & Engineering (2015) | 2015 | Vibracores | Environmental | 14 | Waterway Surveys & Engineering |
| Waterway Surveys & Engineering (2014) | 2014 | Ponar grab sampler/ Diver | Environmental | 5 | Waterway Surveys & Engineering |
| EA Engineering (2013) | 2013 | Vibracore | Environmental | 3 | EA Engineering |
| EA Engineering (2015) | 2014 | Vibracore | Environmental | 14 composite samples collected from 25 locations | EA Engineering |

## 4.0 ENVIRONMENTAL CONSIDERATIONS

Previous studies indicate that the sediment in portions of the Elizabeth River have been sampled and tested for chemical concentrations including Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), total petroleum hydrocarbons (TPH) and various heavy metals such as Arsenic, Cadmium, Chromium, Lead and Mercury. The potential impacts from elevated contaminant concentrations within the dredging envelope are often evaluated prior to dredging operations.

Historical environmental data has been collected, reviewed and studied to assist the project partners to evaluate existing sediment in SBER. Chemical test results from 14 different investigation programs performed between 1998 and 2015 were studied in this report. Table 2 provides a summary of the environmental investigation programs. Figures 3a and 3b present the locations of environmental explorations conducted in and adjacent to the navigation channel. Environmental explorations are also displayed on the cross sections presented on Figures 6 and 7.

Fugro was advised that the major chemicals of concern at this stage of the feasibility study are PAH, TPH, and heavy metals. The exceedance level criteria for the TPH and PAH were considered 500 ppm and 45 ppm, respectively. No screening level criteria for heavy metals was provided, therefore, we only report if heavy metals measurements are present per reach. The environmental data is summarized in Tables 3a and 3b. Table 3a presents the environmental investigation summary within the channel limits. Since limited testing is available inside the channel boundary, we also included data in the vicinity of the navigation channel. Summary of explorations in the vicinity of the channel are provided in Table 3b.

We note the some of the environmental explorations were conducted in support of navigation channel maintenance dredging. Those maintenance dredging explorations were typically do not penetrate below the authorized channel depth and were commonly conducted along the toe of the slopes where the thickest amount of sediments had deposited. Therefore, those maintenance dredging vibracores provide limited to no information about sediments below the authorized dredge depth. Refer to exploration series EA11x and EA15x from the Upper Reach A shown on Figures 6d and 6e.

**Table 3a. Summary of the Environmental Data (inside the Channel)**

| Planning Segment | Reach | Measured Range | | | Exceedance Met [2] |
|---|---|---|---|---|---|
| | | TPH (ppm) (min-max) median | PAH (ppm) (min-max) median | Metals | |
| Segment 1 | Elizabeth River Reach | N/A | (2 - 7) 3 | No | No |
| | Lower Reach | (42 - 448) 310 | (8 - 26) 17 | Yes | No |
| | Middle Reach | N/A | (0 - 1000)[1] | No | Yes |
| Segment 2 | Upper Channel Reach A | (25 - 956) 215 | (0 - 1964) 27 | Yes | Yes |
| Segment 3 | Upper Channel Reach B | (34 - 93) 68 | (1 - 28) 6 | Yes | No |
| | Upper Channel Reach C | N/A | (12 - 13)[3] | No | No |

| Planning Segment | Reach | Measured Range | | | Exceedance Met [2] |
|---|---|---|---|---|---|
| | | TPH (ppm) (min-max) median | PAH (ppm) (min-max) median | Metals | |

N/A denotes No Data Available

1. PAH data in EA08V and CDA05V explorations were provided as a range (not the measured values), therefore only the minimum and maximum ranges values are provided

2. Shows whether exceedance criteria met for either PAH or TPH based on ranges discussed in text

3. Not enough data available to provide a median

**Table 3b. Summary of the Environmental Data (inside and near the Channel)**

| Planning Segment | Reach | Measured Range | | | Exceedance Met [2] |
|---|---|---|---|---|---|
| | | TPH (ppm) (min-max) median | PAH (ppm) (min-max) median | Metals | |
| Segment 1 | Elizabeth River Reach | N/A | (2 - 7) 3 | No | No |
| | Lower Reach | (42 - 448) 309 | (1 - 114) 19 | Yes | Yes |
| | Middle Reach[1] | (16 - 3700) 820 | (0 - 1174) | Yes | Yes |
| Segment 2 | Upper Channel Reach A | (25 - 5907) 230 | (0 - 7707) 49 | Yes | Yes |
| Segment 3 | Upper Channel Reach B | (34 - 93), 68 | (1 - 28) 5 | Yes | No |
| | Upper Channel Reach C | N/A | (2 - 14) 10 | No | No |

N/A denotes No Data Available

1. PAH data in EA08V and CDA05V explorations were provided as a range (not the measured values), therefore only the minimum and maximum value in this reach is provided

2. Shows weather exceedance criteria met for either PAH or TPH

## 5.0 INTERPRETATION OF CPT DATA

CPT soundings provide a near-continuous record of sleeve friction and cone tip resistance. The friction ratio, expressed as a percent, is computed by dividing the sleeve friction measurement taken at the depth of the center of the sleeve by the average of the tip resistance measured over the length of the sleeve.

Empirical relationships between CPT measurements and soil classifications have been derived from thousands of measurements for all different classifications of soils. Robertson and Campanella (1988) proposed a chart that divides the graph of tip resistance versus friction ratio into 12 soil classification zones. This chart is shown in Figure 5b. The CPT measurements can be associated with a specific soil classification zone. Hence, this chart was used to differentiate between primarily fine-grained and primarily coarse-grained soil layers. Additionally, a procedure by Robertson and Wride (1998) was used to estimate the percentage of fine-grained sediments (refer to Figure 9b).

## 6.0 CROSS SECTIONS

Centerline cross sections are presented on Figures 6a through 6f. Transverse cross sections are presented on Figures 7a through 7c. Cross sections were developed using proprietary software and Environmental Systems Research Institute's (ESRI) ArcGIS program. ArcGIS is a software package used by Fugro for mapping spatial data. Logs of vibracores, boreholes and CPT soundings are set to the same vertical scale and projected onto the line of cross section. The sections also project the recent bathymetric survey data onto the line of the section at the same vertical scale of the other exploration.

The cross sections present several key pieces of information including:

- Soil type as logged and classified from vibracores and boreholes;
- CPT tip resistance, friction ratio, and soil behavior type;
- Standard penetration tests blow counts;
- Fines content from laboratory tests;
- Authorized channel depth; and
- Bathymetry based on the most recent USACE condition survey (refer to Table 1 for a summary of the data).

The vertical scale for all cross sections in this report is the same, 1 inch = 20 feet. The horizontal scale was set at 1 inch = 1,000 feet and 1 inch = 400 feet for the centerline and transverse cross sections, respectively.

## 7.0 GEOLOGY AND GENERAL SUBSURFACE CONDITIONS

### 7.1 GEOLOGIC SETTING

The study area is located in the Coastal Plain physiographic province. Flat-lying plains and terraces dominate the landscape. The Coastal Plain is underlain by a wedge of Cretaceous to Holocene age sediments that thicken to the east. Jurassic-Triassic age basement rocks lie approximately 1,800 feet beneath the study area. The wedge of Cretaceous and younger sediments was deposited as a result of multiple marine transgressions and regressions. Sediments within the upper 100 feet beneath the site are Pliocene to Recent in age. The Pliocene age and younger sediments have been deposited and subsequently eroded in places during the rising and falling sea levels that resulted from glacial and interglacial periods.

Surficial deposits in the Elizabeth River and South Branch of the Elizabeth River are predominantly Holocene age fluvial-estuarine deposits comprised predominantly of clay and silt sized particles. Shoals with variable sand content may be present in localized areas near river bends or confluences with tributaries. Interbedded sand and fine-grained deposits of the Pleistocene aged Tabb formation are inferred to generally underlie the surficial fine-grained deposits. The interbedded deposits are inferred to represent the initial flooding sequence when sea level began to rise after the last Glacial Maximum through the time that Chesapeake Bay became inundated. In some areas, the interbedded deposits may be predominantly sand with a low fines content and may be of potential beneficial use for other projects (e.g. river bed restoration, artificial fill, etc.). Pliocene aged Yorktown formation generally underlies the Pleistocene deposits. The Yorktown formation is a shallow marine deposit predominantly comprised of silty to clayey sand deposits.

Past channel deepening activities have removed some of the Holocene aged fine-grained deposits and currently the interbedded deposits may be exposed in the navigation channel or shallowly buried (refer to the Elizabeth River and Lower Reaches shown on Figure 6b and Middle Reach shown on Figure 6c).

The Elizabeth River and South Branch of the Elizabeth River are sub-estuaries of the James River, the most southern tributary of the Chesapeake Bay. The South Branch flows north and connects to the main stem of the Elizabeth River at the confluence with the Eastern Branch of the Elizabeth River (Figure 1). The main stem of the Elizabeth River also flows north to its confluence with the James River. Two high tides and two low tides occur each day in the Elizabeth River and tributaries. Tidal range at NOAA's Money Point Station No. 8639348 located on the Upper Channel Reach A is about 2.4 feet.

Anthropogenic-related features and past activities may also influence future deepening projects. Waterfront of the Elizabeth River and the Southern Branch is highly industrialized. Past activities and incidents have led to contamination in areas within the river and some of those areas are undergoing remediation or restoration. However, there is a potential that future deepening activities could encounter contaminated sediments and handling and placement of those sediments can be complex and costly. Other human-related factors that could influence channel deepening activities are the presence of utilities that cross the river. Channel deepening may require some utilities to be relocated to deeper depths in order to accommodate dredging. Inventorying and verifying vertical positions of utility crossings is not part of the current study.

## 7.2 SUBSURFACE CONDITIONS

Each channel reach is divided into subareas, referred to as material type zones, as shown on Figure 4. Zone boundaries are defined by transitions of the engineering and geologic character (fines content, median grain size (D50), relative density and consistency). The level of sediment (chemical and eco-toxicological) analysis was not regarded in defining the material zones. The sediments are characterized up to the maximum depth of available explorations within each zone. Most of the exploration depths range from about 5 to 30 feet below the most recent bathymetric survey data (Figures 6a through 6f).

Centerline cross sections are presented on Figures 6a through 6f. Transverse cross sections are presented on Figures 7a through 7c.

Grain size characteristics are the primary factors in determining suitability and performance of material for use in construction. Primary criteria considered in engineering evaluations are fines content, particle size distribution, and median ($D_{50}$) grain size. Grain size curve data was compiled and entered from the different historical reports. Figures 8a through 8c present the grain size curves in each reach. The fines content profiles derived from laboratory tests and CPT soundings for the different reaches are presented on Figures 9a and 9c. Fines content was estimated from CPT data using the procedure by Robertson and Wride (1998). As shown in Figures 9a through 9c, the fines content estimates from CPT data using Robertson and Wride (1998) is generally in agreement with the laboratory test data. Median ($D_{50}$) grain size profiles are presented on Figures 10a through 10c. Atterberg limits and water content profiles are presented on Figures 11a through 11c. Each one of the aforementioned figures present data from a specific reach. The data presented in each figure is grouped by zones within each reach.

The name of each zone starts with a prefix letter(s) that denotes the name of the channel/reach (e.g., ER = Elizabeth River reach, LR = Lower Reach). This prefix is followed by the zone number. The zone number is sequential beginning at the entrance of each reach. It is worth mentioning that the subsequently reported zones are highly generalized material type zones that were delineated based on a limited amount of shallow explorations and laboratory tests.

Soil characteristics are described in the region to a depth where data collection supports classification using a combination of field and available laboratory testing. There is the potential for variation of sediment over relatively short distances within the channel due to changes commonly seen in the subsurface as a result of river bed morphology.

### 7.2.1 Elizabeth River Reach

Two zones were delineated within the Elizabeth River reach as described below. The distances presented are approximate and are measured from drown river to up river.

**Zone ER1: From the Northern end of the Elizabeth River Reach to CE08B-7 (Between approximately 0 and 12,000 feet).** The sediments below the existing mudline are predominantly clays and organic silt, underlain by sand (below El. -60 to -65 feet). Fine-grained sediments in this zone are characterized as fat clay, organic clay or elastic silt (Figure 9a). The sand within this zone is predominantly fine in size with variable amount of fines content typically ranging between 2 to 30% (Figures 8a, 9a and 10a). Figures 6a and 6b show the plan views and vertical cross sections along with the explorations available in this zone. The transverse cross section is presented in Figure 7a.

**Zone ER 2: From CE08B-8 to the Southern end of the Elizabeth River Reach (Between approximately 12,000 to 17,500 feet).** The surficial sediments in this zone are identified as sand. This characterization is based on limited geotechnical borings in this zone, which penetrated less than 7 feet below the latest bathymetric survey. The sand within this zone was identified as loose to medium dense silty and clayey sand with fines content ranging between 21 and 36 percent (Figures 8b, 9a and 10a). In the southernmost portion of this zone sediments become fines grained (fat clay and silt). Figure 6b shows the plan views and vertical cross sections along with the explorations available in this zone. The transverse cross section is shown in Figure 7b.

### 7.2.2 Lower Reach (Zone LR1)

This reach presents similar physical properties as zone ER2. Riverbed sediments in this zone are predominantly clay, underlain by sand. The upper clay layer was described as very soft fat clay with a varying thickness along the navigation channel. The underlying sand (below El. -

50 feet) is generally characterized as poorly graded sand to silty sand with variable fines content ranging between 3 to 25 percent (Figures 8c, 9c and 10c). Two explorations in this zone (CE08B017 and CE08B018) encountered fine-grained sediments to the maximum depth of the borings (El. -55 feet). These explorations could have been drilled through a paleochannel that was filled with fine grained material. Figures 6c and 7b show the plan views, vertical and transverse cross sections along with the explorations available in this reach.

#### 7.2.3 Middle Reach (Zone MR1)

Riverbed sediments in this zone are predominantly sand and appear to be overlain by a thin layer of clay or silt (organic or non-organic). The thickness of the surficial fine grained stratum is highly variable along the channel and not present in some borings. In general, riverbed deposits are highly heterogeneous. The majority of the historical explorations identified during the study in this reach are environmental and the amount of geotechnical laboratory data is very limited. The material types assigned in the majority of the explorations in this reach are based only on visual classification and should be regarded with caution. Multiple thin clay layers with thicknesses ranging between 2 to 3 feet were observed at varying depths within the sand stratum. Figures 6d, 7c, 8d, 9c, 10c and 11c show the plan views, vertical cross sections, the explorations available in this reach and the geotechnical laboratory data.

#### 7.2.4 Upper Channel Reach A, Reach B and Reach C

The plan views of these reaches along with the vertical cross sections showing nearby available explorations are presented in Figures 6e and 6f. No geotechnical investigation has been performed within the channel limits in these three reaches. The existing explorations have been conducted for environmental purposes and most were conducted in support of the USACE maintenance dredging program. Vibracores and testing conducted in support of maintenance dredging typically target sampling and testing of sediments within the maintenance dredging envelope and along the toe of the channel slopes where the thickest accumulation of sediments had deposited.

Since only a few explorations in Upper Reaches A and B penetrated a few feet below the riverbed based on the most recent bathymetric survey and they have limited geotechnical information it is not possible to characterize the upper 5 to 10 feet of sediments. We did not identify geotechnical explorations or data located in Upper Reach C.

### 7.3 BENEFICIAL USE OF DREDGED MATERIALS

Disposal of dredged materials can be accomplished by placing them at designated disposal areas like the Craney Island Dredge Material Management Area (CIDMMA) or ocean disposal areas (e.g. Dam Neck Ocean Disposal Site or Norfolk Ocean Disposal sites). Use of ocean disposal sites can be costly to due long vessel transit times or can use up highly valued storage at CIDMMA, a facility that is approaching its storage capacity. An alternative to using CIDMMA or ocean disposal areas, is to use the dredged materials for beneficial use in various projects around the area. Evaluation of dredge materials for use in other projects is usually based on geotechnical properties including fines content and median particle size (e.g. $d_{50}$) and environmental characteristics. Evaluation of the potential use of dredge materials for some project types (e.g. beach renourishment) may also be based on material colors and shell content. Typical types of projects that derive benefit from dredging projects include:

- Land reclamation (high quality fills or lower quality fills for shading materials or surcharge),
- Beach renourishment and shoreline stabilization,
- Riverbed restoration projects,
- Sea grass, shallow water habitat creation, or environmental improvement projects, or
- Confined underwater disposal areas.

Land reclamation and beach nourishment projects typically have the strictest requirements for material specification and typically target materials with low fines content. Fines content requirements are typically less strict for riverbed restoration and environmental improvement projects. Confined underwater disposal areas may utilize fine-grained deposits with a low permeability for construction.

Table 4 provides a summary of where historical geotechnical data, when compared to recent bathymetric data, indicate that sandy deposits may be located at the existing channel bottom or within 5 feet of the channel bottom. Indication of the potential beneficial use is based solely on whether the material is predominantly sand and note suitability for use as fill in projects with strict material specifications. Based on the information presented in the profiles in Figures 6 and Table 4, the data indicate that sandy deposits may be present at or near the channel bottom in some portions of the study area.

**Table 4. Summary of the Potential for Beneficial Use**

| Planning Segment | Reach | Material Type Zone | Potential for Beneficial Use | Comments Based on Evaluation of Historical Data |
|---|---|---|---|---|
| Segment 1 | Elizabeth River Reach | ER1 | Low | Top of sand is ~5 feet below exiting channel bottom at ~El. 63 feet |
| | | ER2 | High | Sand is at or within 5 feet of existing channel bottom |
| | Lower Reach | LR1 | High | Sand is within 5 feet of existing channel bottom; sand may be overlain by 2 to 6 feet of fine grained deposits over much of the area |
| | Middle Reach | MR1 | High | Sand is at or within 5 feet of existing channel bottom; sand may be deeper in local areas |
| Segment 2 | Upper Channel Reach A | -- | Unknown | Geotechnical data do not penetrate deep enough to evaluate |
| Segment 3 | Upper Channel Reach B | -- | Unknown | Geotechnical data do not penetrate deep enough to evaluate |
| | Upper Channel Reach C | -- | Unknown | No data present |
| Potential for beneficial use is based predominantly on if sand is present within 5 feet of existing channel bottom. | | | | |

## 8.0 REFERENCES

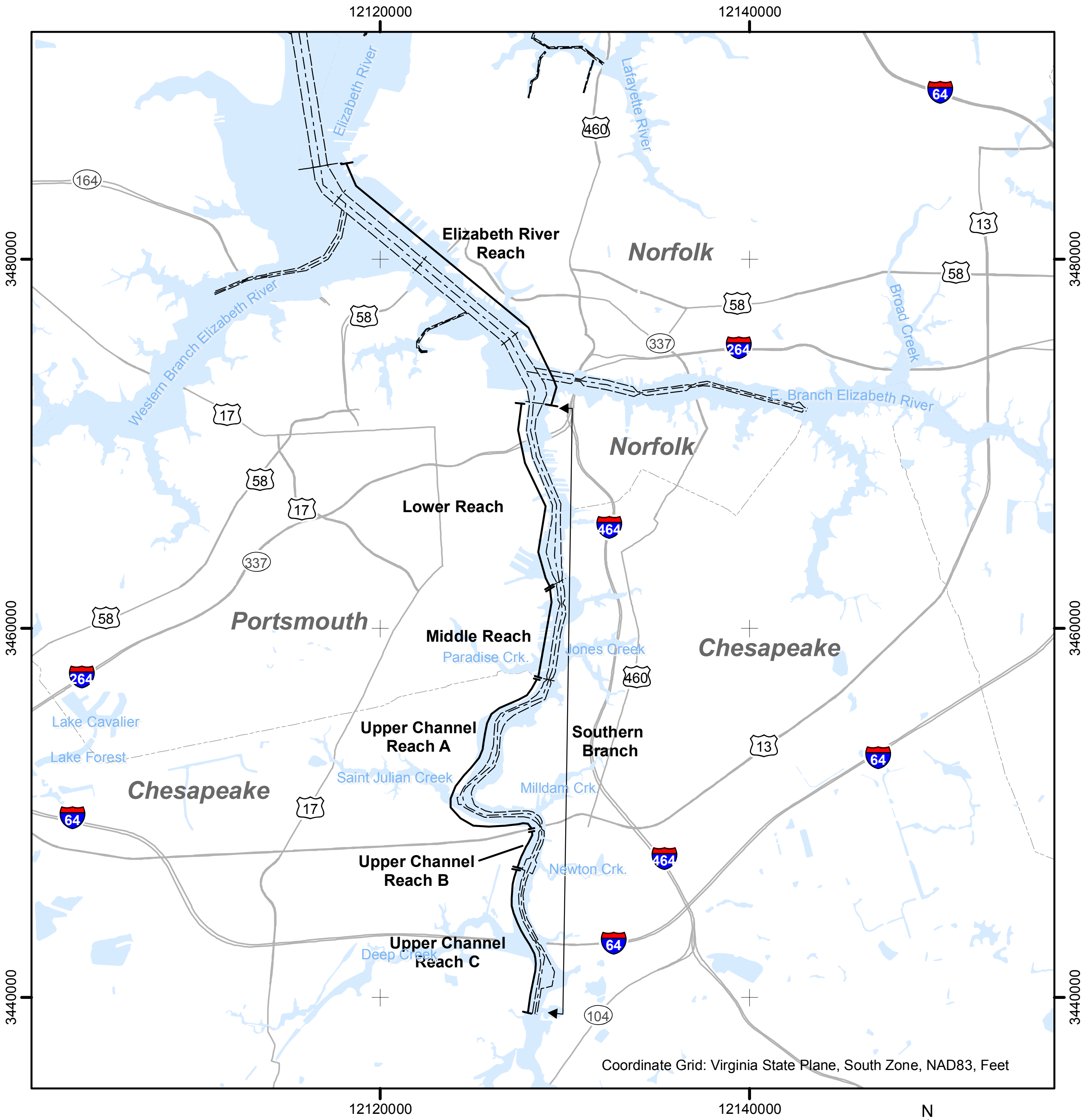
Baez, J.I., Martin, G.R., and Youd, T.L. (2000) Comparison of SPT-CPT Liquefaction Evaluations and CPT Interpretations. In *Innovations and Applications in Geotechnical Site Characterization, Geotechnical Special Publication No. 97*, Mayne, P.W. and Hryciw, R. editors, pp. 17-32.

Department of Geological Sciences, School of Sciences and Health Professions, Old Dominion University (1985). "*Sediment Analysis: Mineralogy and Particle Roundness of Borehole Samples*," Technical Report No. GSTR-86-1, prepared for the U.S. Army Corps of Engineers, Norfolk District, Virginia.

Fugro Atlantic (2009). Site characterization report, Atlantic Ocean Channel, Offshore Southeastern Virginia. Prepared for Craney Island Design Partners, LLC. Dated November 2009.

Robertson, P.K. and Wride, C.E. (1998) Evaluating cyclic liquefaction potential using the cone penetration test. Canadian Geotechnical Journal, Vol. 35, Issue 3, pp. 442-459.

Moffatt and Nichol, Inc.
Project No. 04.81150012




**LEGEND**

Navigation Channel Centerline

Navigation Channel Boundary

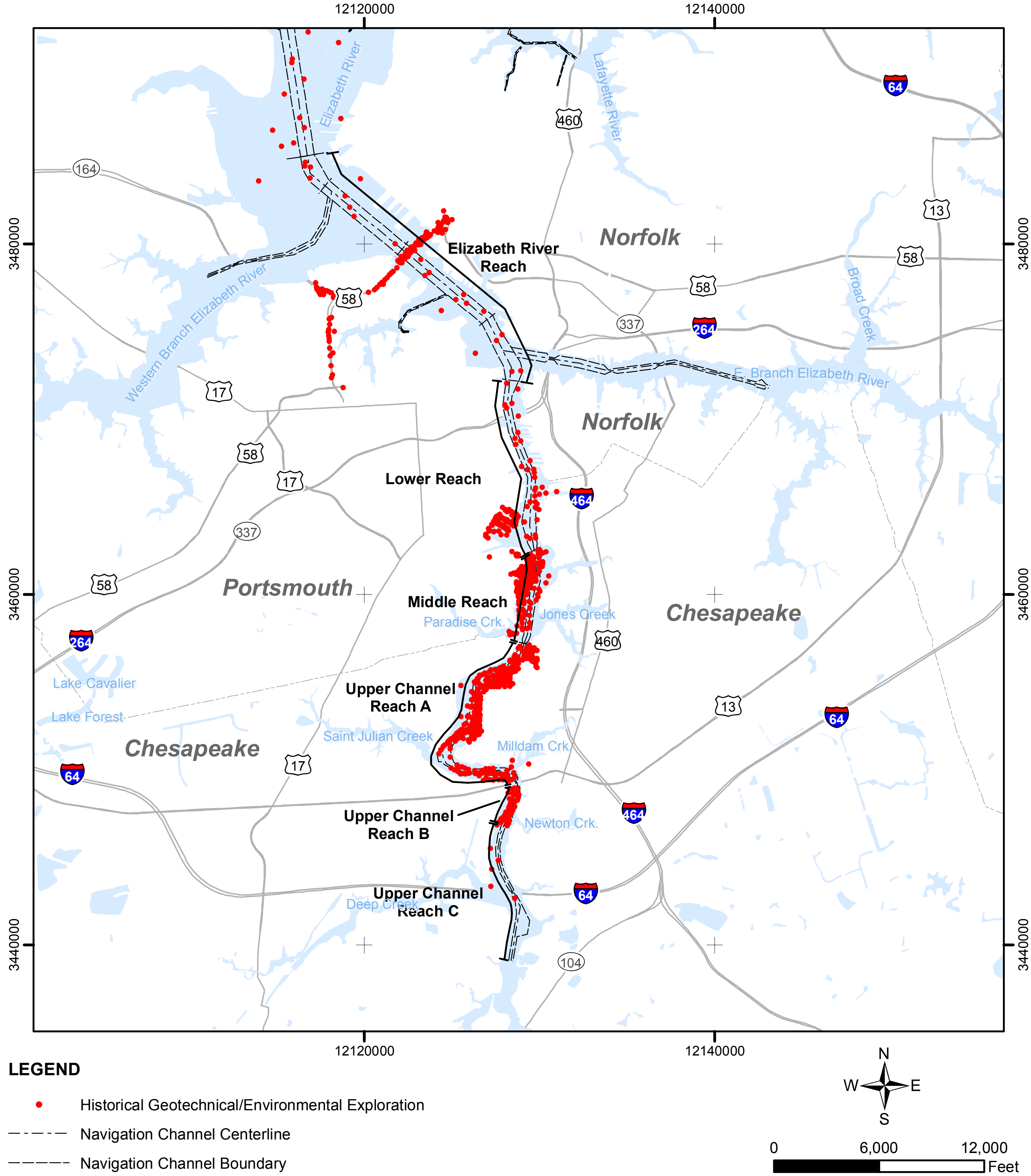
N W E S

0 6,000 12,000 Feet

**STUDY AREA**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 1

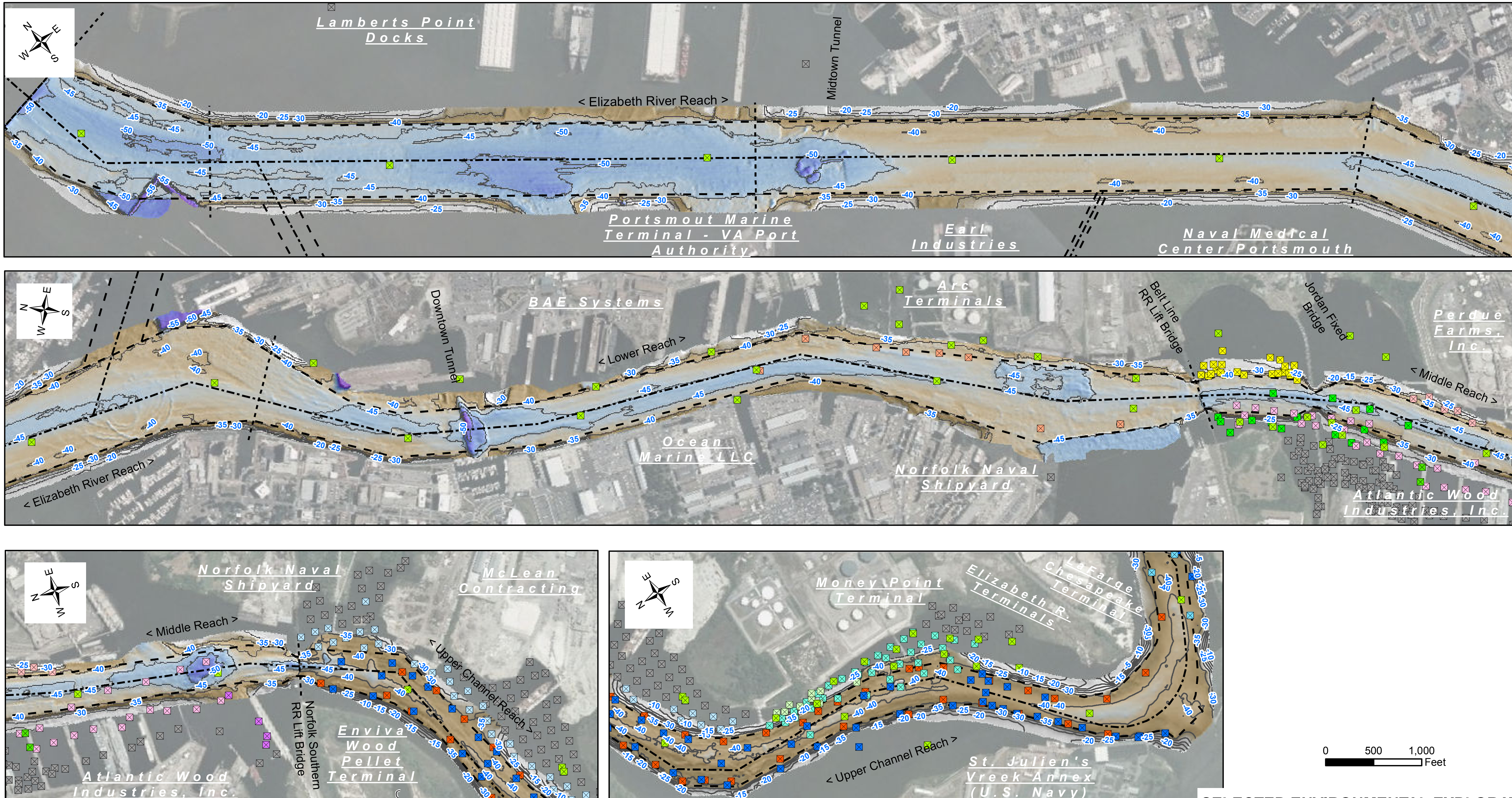
N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\April2016_Draft_Reports\ElizabethRiver_SBranch\MXD\Fig_01_Study_Area.mxd, 4/28/2016, wcupples




**EXPLORATION LOCATIONS**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 2

N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\April2016_Draft_Reports\ElizabethRiver_SBranch\MXD\Fig_02_Exploration_Locations.mxd, 4/28/2016, wcupples




**LEGEND** Environmental Vibracores and Grab Sample Explorations (Refer to report text for descriptions of data sources and content)

AQA15V, CDA05V, CEA08V, EA08V, EA11E, EA12V, EA13E, EA15ESB, RCMP/RSMP08, SAA07V, Elizabeth River Shelby, WW14E, WW15E, WWA98B, Environmental data not selected for statistics

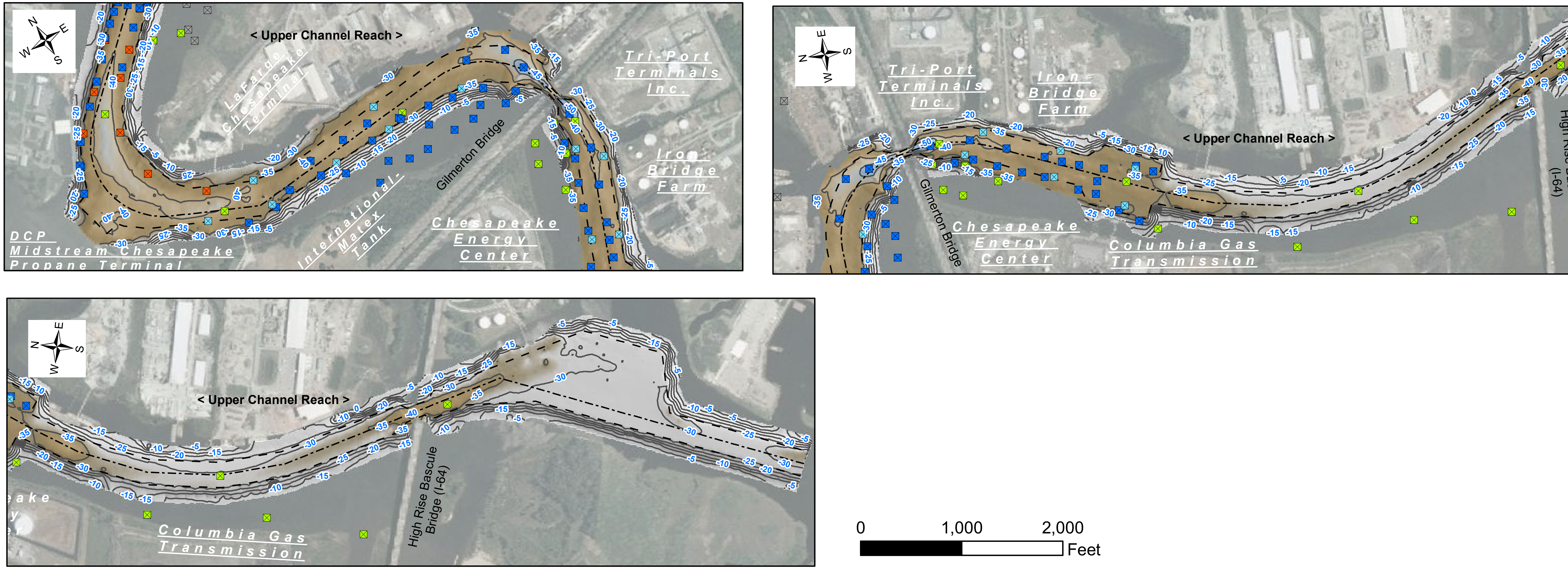
**2010 USACE Bathymetry (Feet, MLLW)**
High : -30
Low : -60

Channel Centerline
Channel Boundary
Channel Reach Boundary

**SELECTED ENVIRONMENTAL EXPLORATIONS**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 3a

N:\Projects\04_2015\04_8115_0012_Port_of_Virginia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\Fig_3a_Environmental_Exploration_Location.mxd, 4/28/2016, wcupples




N:\Projects\04_2015\04_8115_0012_Port_of_Virginia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\Fig_3b_Environmental_Exploration_Location.mxd, 4/28/2016, wcupples

**LEGEND** Environmental Vibracores and Grab Sample Explorations (Refer to report text for descriptions of data sources and content)

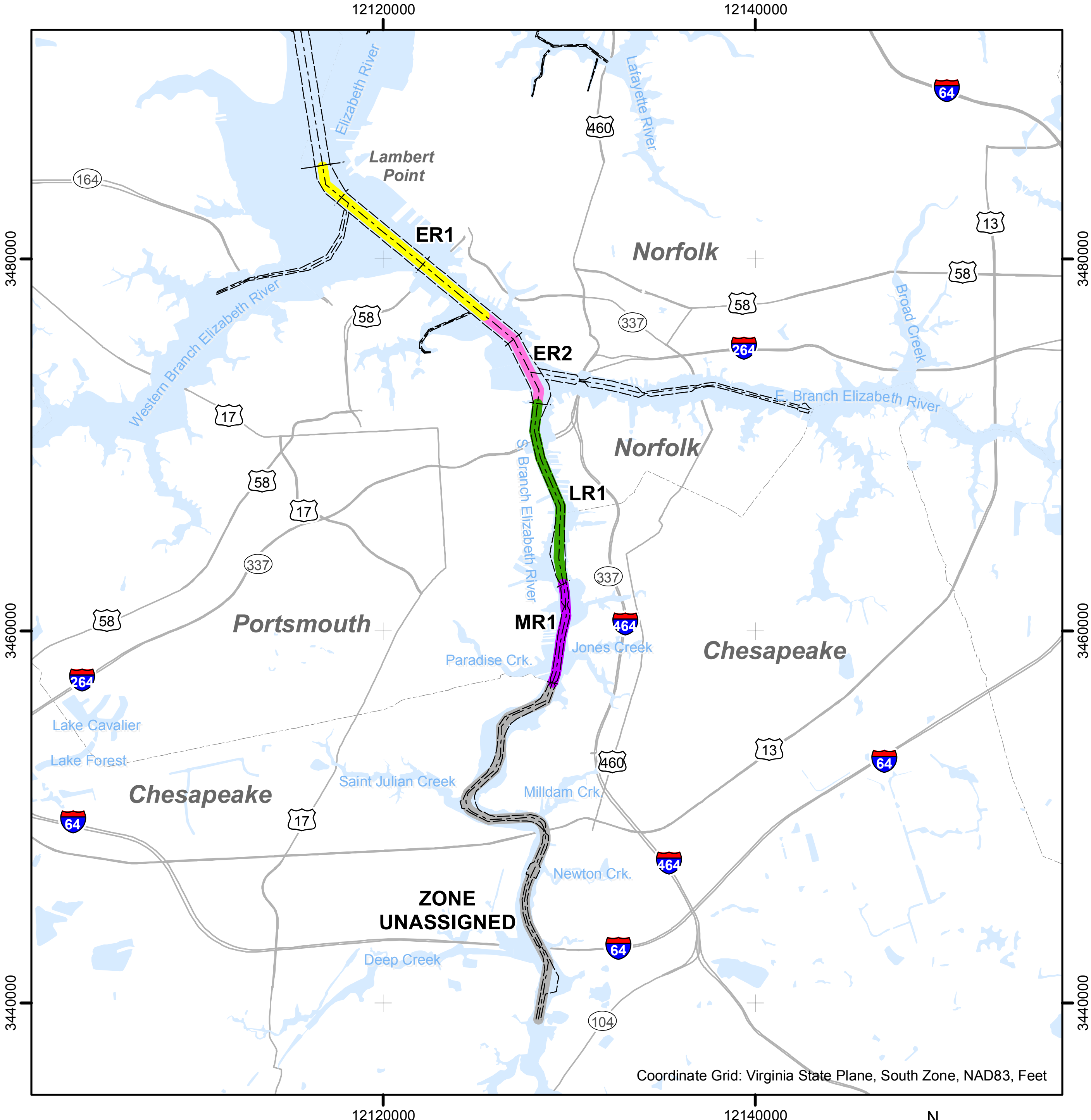
| | | | | |
|---|---|---|---|---|
| AQA15V | EA08V | EA13E | SAA07V | WW15E |
| CDA05V | EA11E | EA15ESB | Elizabeth River Shelby | WWA98B |
| CEA08V | EA12V | RCMP/RSMP08 | WW14E | Environmental data not selected for statistics |

**2010 USACE Bathymetry (Feet, MLLW)**
High : -30
Low : -60

Channel Centerline
Channel Boundary
Channel Reach Boundary

**SELECTED ENVIRONMENTAL EXPLORATIONS**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 3b




**LEGEND**

**C1** Generalized Subsurface Material Type Zone
Zones interpreted to represent generalized material types that may be encountered during channel deepening. Interpretation based on review of historical subsurface data. Refer to report text for description of interpreted material types.

Navigation Channel Centerline

Navigation Channel Boundary

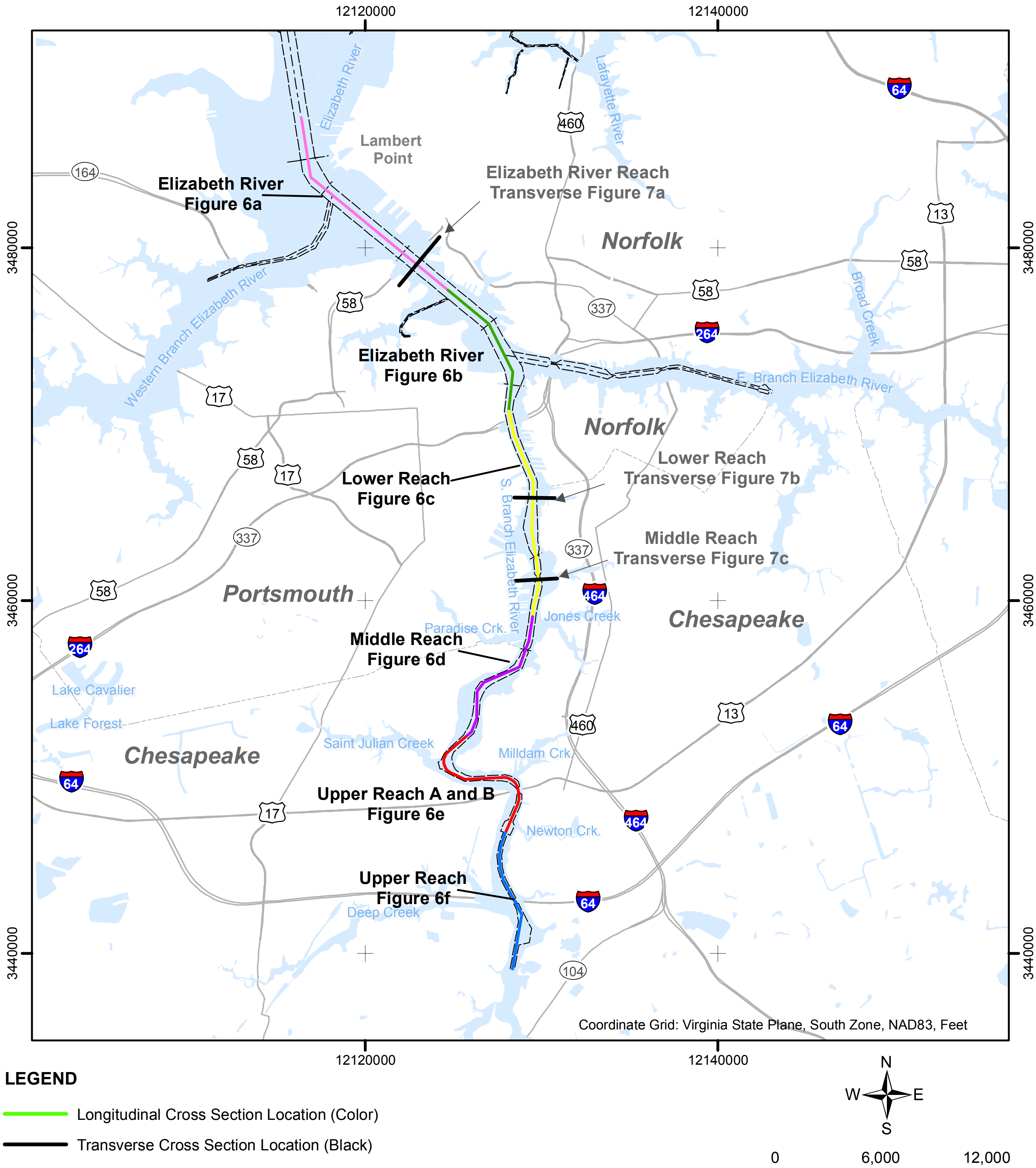
N W E S

0 6,000 12,000 Feet

**SUBSURFACE MATERIAL ZONATION**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 4

N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\April2016_Draft_Reports\ElizabethRiver_SBranch\MXD\Fig_03_Zonation_Map.mxd, 4/28/2016, wcupples




**LEGEND**

Longitudinal Cross Section Location (Color)

Transverse Cross Section Location (Black)

Navigation Channel Centerline

Navigation Channel Boundary

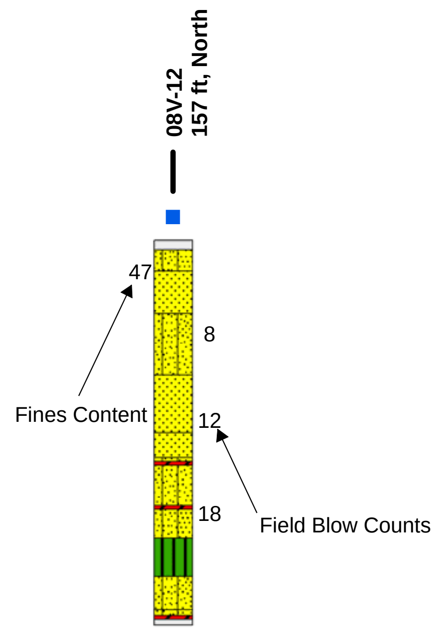
**CROSS SECTION LOCATIONS**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 5a

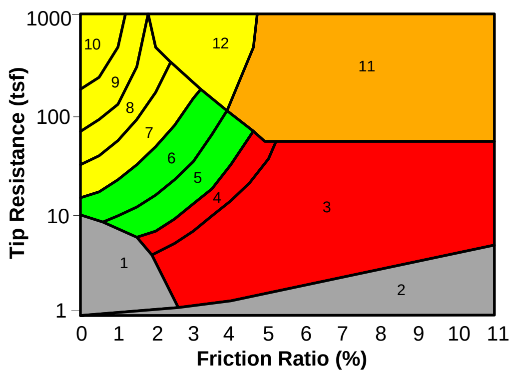
N:\Projects04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\April2016_Draft_Reports\ElizabethRiver_SBranch\MXD\Fig_01_Study_Area.mxd, 4/28/2016, wcupples

## SOIL TYPES

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Lean to Fat CLAY (CL-CH)
- Fat CLAY (CH)
- Silt (ML)
- Clayey SILT (ML)
- Sandy SILT (ML)
- Elastic Silt (MH)
- Elastic Silt with Sand (MH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Clay (SP-SC)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND (SW)
- Clayey SAND (SC)
- Silty SAND (SM)
- Poorly-Graded GRAVEL (GP)
- Low-Plasticity Organic (OL)
- High-Plasticity Organic (OH)
- PEAT
- Claystone
- ROCK Fragments
- Fill



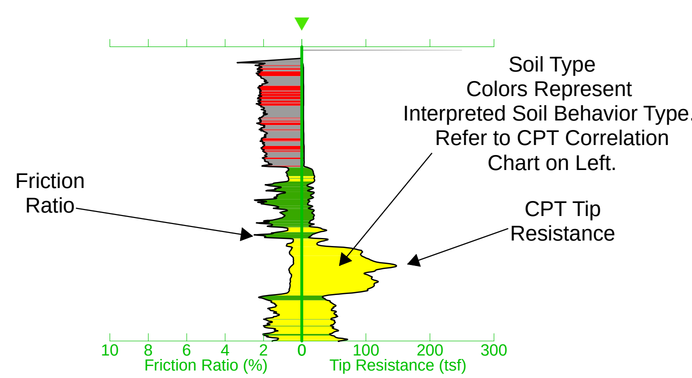

**SOIL BORING LITHOLOGY WITH INDEX TESTS MEASURED IN LABORATORY AND FIELD BLOW COUNTS**




| Zone | Soil Behavior Type | U.S.C.S. |
|---|---|---|
| 1 | Sensitive Fine-grained | OL-CH |
| 2 | Organic Material | OL-OH |
| 3 | Clay | CH |
| 4 | Silty Clay to Clay | CL-CH |
| 5 | Clayey Silt to Silty Clay | MH-CL |
| 6 | Sandy Silt to Clayey Silt | ML-MH |
| 7 | Silty Sand to Sandy Silt | SM-ML |
| 8 | Sand to Silty Sand | SM-SP |
| 9 | Sand | SW-SP |
| 10 | Gravelly Sand to Sand | SW-GW |
| 11 | Very Stiff Fine-grained * | CH-CL |
| 12 | Sand to Clayey Sand * | SC-SM |

*overconsolidated or cemented

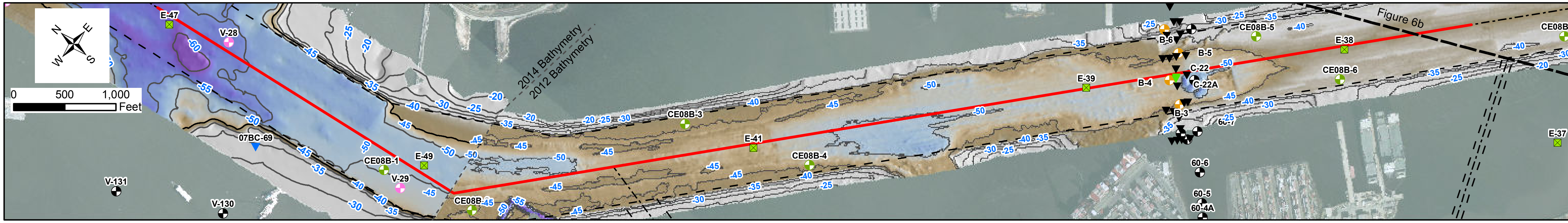
**CPT CORRELATION CHART**
(Robertson and Campanella, 1988)

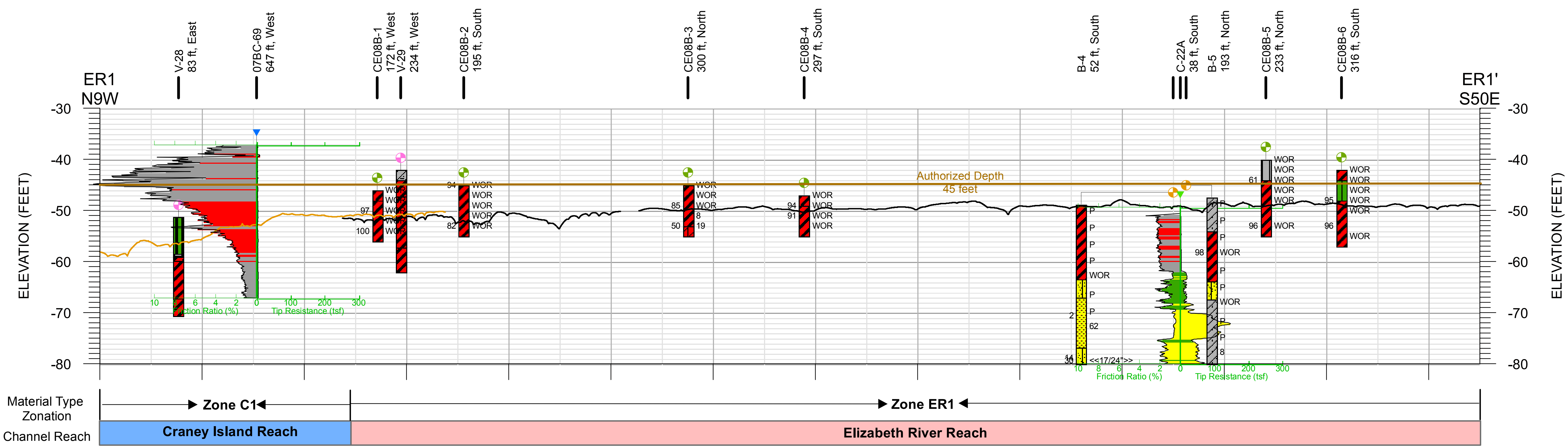



**CPT SOUNDING WITH FRICTION RATIO AND TIP RESISTANCE**

# KEY TO SUBSURFACE CROSS SECTIONS
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 5b




Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft
1000 ft
Vertical exaggeration is 50x.

## PLAN VIEW LEGEND

- 2008 USACE Boring
- 2008 Fugro Boring
- 1983 USACE Boring
- Exploration (not shown on the cross section)
- 2008 Fugro CPT
- 2007 S&ME CPT
- Elizabeth River Shelby
- Cross Section Location
- Navigation Channel Limit

**2012 and 2014 USACE Bathymetry (Feet, MLLW)**
High : -40
Low : -60
Contour interval is 5 feet.

## CROSS SECTION LEGEND

- 2014 Bathymetry
- 2012 Bathymetry

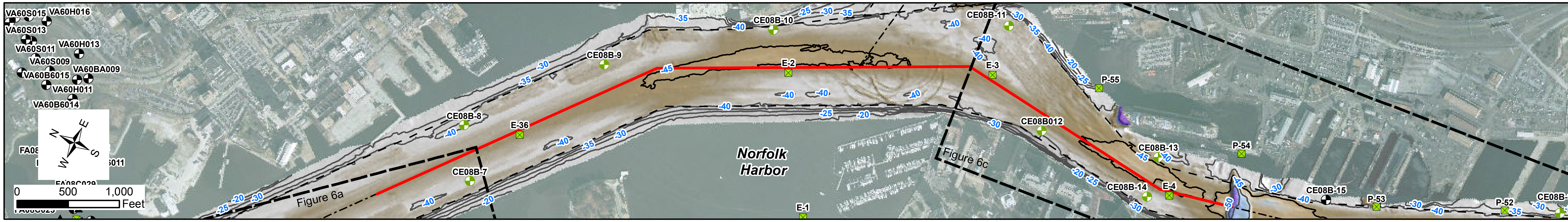
**Boring/Vibracore Symbology**
96 WOR WOR 3 1 5
Fines Content (%)
Standard Penetration Test N-Value

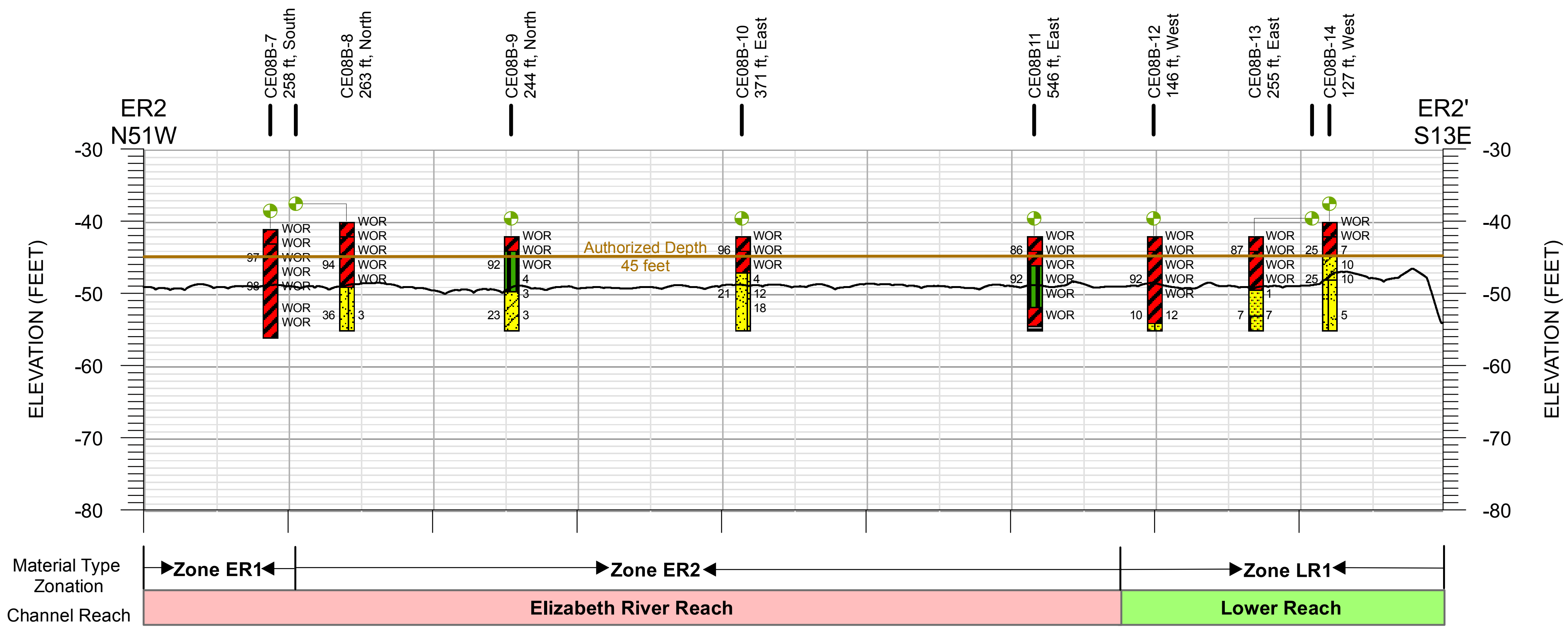
**Lithology Type**
- Silty CLAY (CL-ML)
- Fat CLAY (CH)
- Silt (ML)
- Elastic Silt (MH)
- Poorly-Graded SAND (SP)
- Silty SAND (SM)
- Low-Plasticity Organic (OL)
- High-Plasticity Organic (OH)
- PEAT

**ELIZABETH RIVER REACH CROSS SECTION**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 6a

FUGRO




Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft
1000 ft
Vertical exaggeration is 50x.

**PLAN VIEW LEGEND**

- 2008 USACE Boring
- Exploration (not shown on the cross section)
- Elizabeth River Shelby
- Cross Section Location
- Navigation Channel Limit

**2012 USACE Bathymetry (Feet, MLLW)**

- High : -40
- Low : -60
- Contour interval is 5 feet.

**CROSS SECTION LEGEND**

- 2012 Bathymetry

**Boring/Vibracore Symbology**

96 WOR WOR 3 1 5
Fines Content (%)
Standard Penetration Test N-Value

**Lithology Type**

- Fat CLAY (CH)
- Elastic Silt (MH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Clayey SAND (SC)
- Silty SAND (SM)
- PEAT

**ELIZABETH RIVER REACH CROSS SECTION**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 6b

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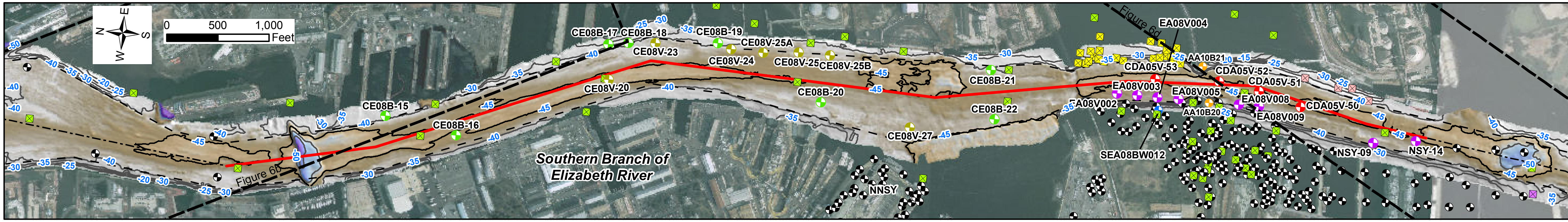


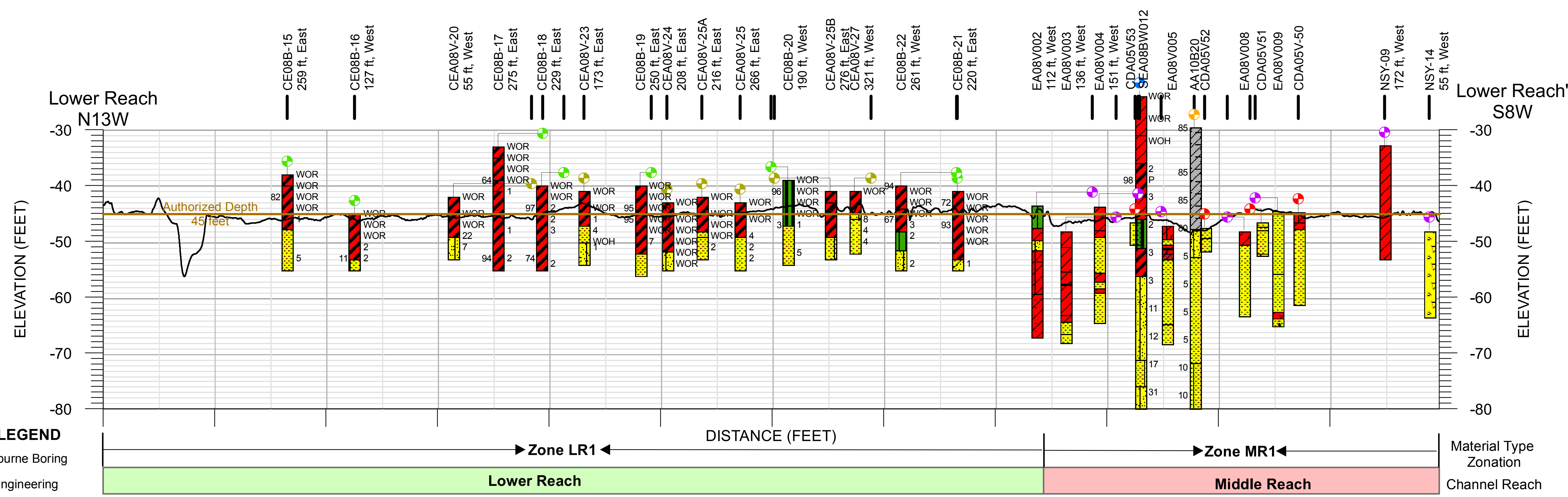


## PLAN VIEW LEGEND

- 2010 Fishburne Boring
- 2008 EA Engineering Vibracore
- 2008 SE Boring
- 2008 USACE Boring
- 2008 USACE Vibracore
- 2005 CDM Vibracore
- Exploration (not shown on the cross section)
- EA13E
- Elizabeth River Shelby
- WW14E
- WW15E

- Cross Section Location
- Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**

- High : -40
- Low : -60

Contour interval is 5 feet.

## CROSS SECTION LEGEND

- 2010 Bathymetry

**Boring/Vibracore Symbology**

Fines Content (%) — Standard Penetration Test N-Value

**Lithology Type**

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Lean to Fat CLAY (CL-CH)
- Fat CLAY (CH)
- Silt (ML)
- Sandy SILT (ML)
- Elastic Silt (MH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Clayey SAND (SC)
- Silty SAND (SM)
- Poorly-Graded GRAVEL (GP)
- High-Plasticity Organic (OH)

Notes:

1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft / 1000 ft

Vertical exaggeration is 50x.

**LOWER REACH CROSS SECTION**

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 6c

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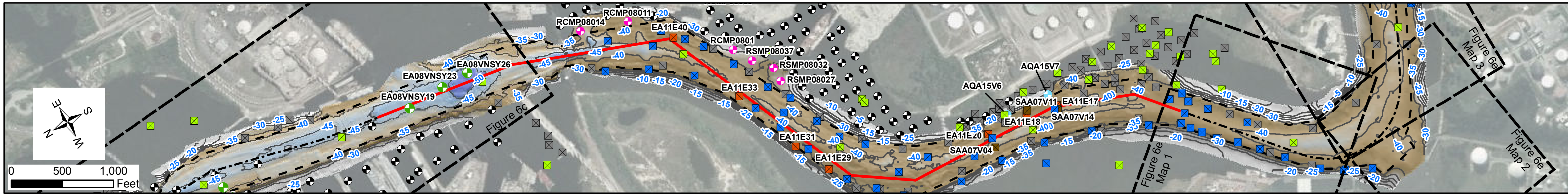
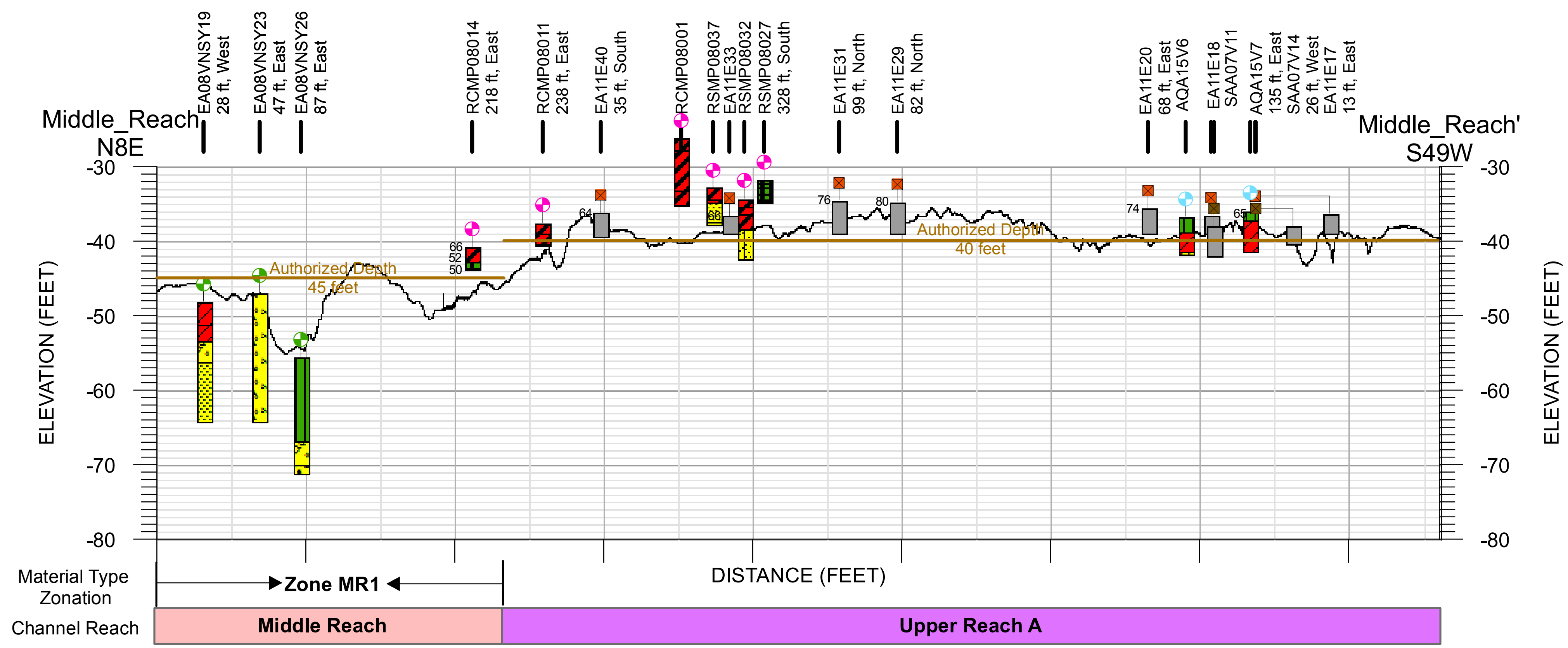
Project No. 04.81150012




## PLAN VIEW LEGEND

- AQA 2015 Vibracore
- 2008 EA Engineering Vibracore
- 2008 Malcom Pernie Vibracore
- Exploration (not shown on the cross section)
- EA11E
- Elizabeth River Shelby
- SAA07E
- WWA98
- Environmental data not shown on cross section
- Cross Section Location
- Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**

High : -30

Low : -60

Contour interval is 5 feet.

## CROSS SECTION LEGEND

2010 Bathymetry

**Boring/Vibracore Symbology**

96 WOR WOR 3 1 5

Fines Content (%)

Standard Penetration Test N-Value

**Lithology Type**

- Lean CLAY (CL)
- Silty CLAY (CL-ML)
- Lean CLAY with Sand (CL)
- Fat CLAY (CH)
- Silt (ML)
- Clayey SILT (ML)
- Elastic Silt (MH)
- Elastic Silt with Sand (MH)
- Poorly-Graded SAND (SP)
- Silty SAND (SM)
- Poorly-Graded GRAVEL (GP)
- ROCK Fragments
- Environmental Vibracore

Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft

1000 ft

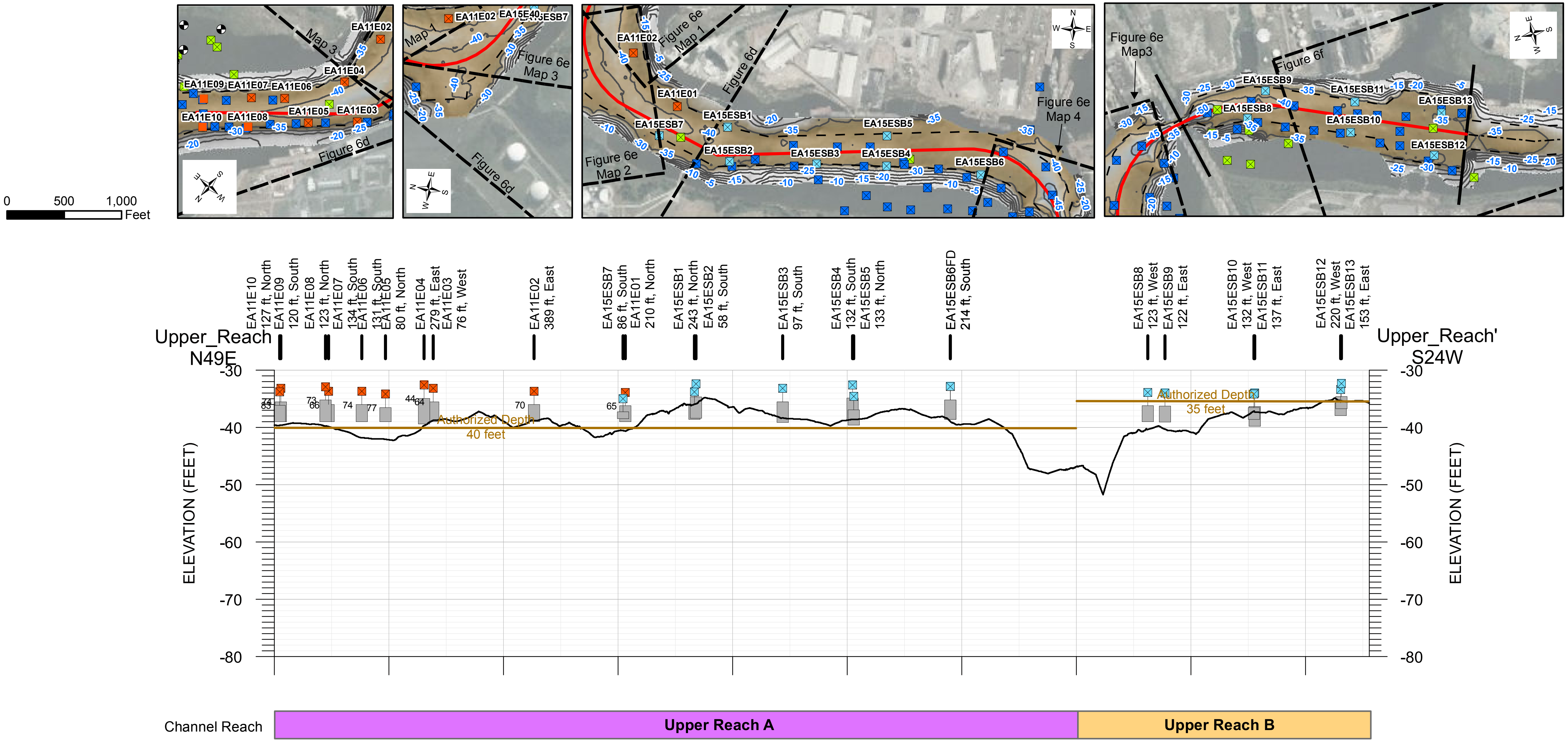
Vertical exaggeration is 50x.

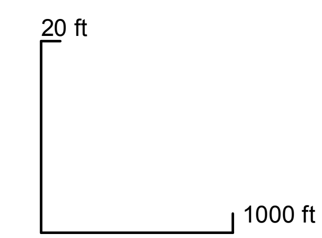
**MIDDLE REACH CROSS SECTION**

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 6d



Vertical exaggeration is 50x.

**PLAN VIEW LEGEND**

- EA11E
- WWA98
- EA15ESB
- Environmental data not shown on cross section

- Cross Section Location
- Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**

- High : -30
- Low : -60
- Contour interval is 5 feet.

**CROSS SECTION LEGEND**

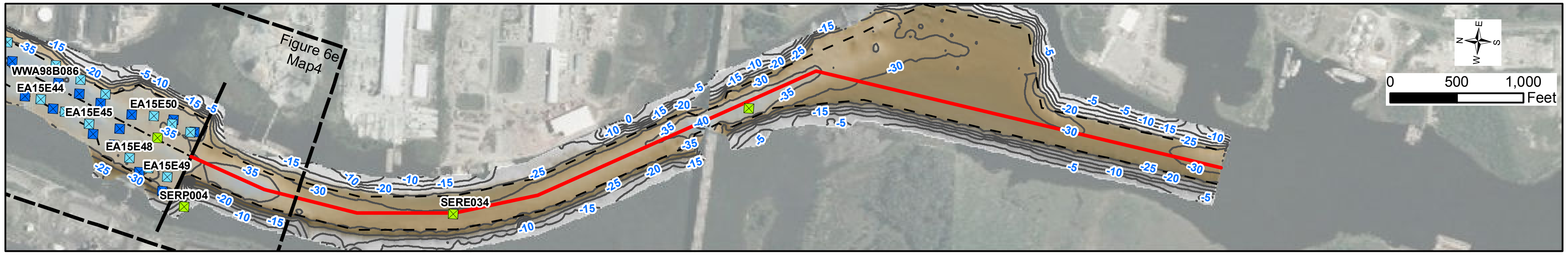
- 2010 Bathymetry

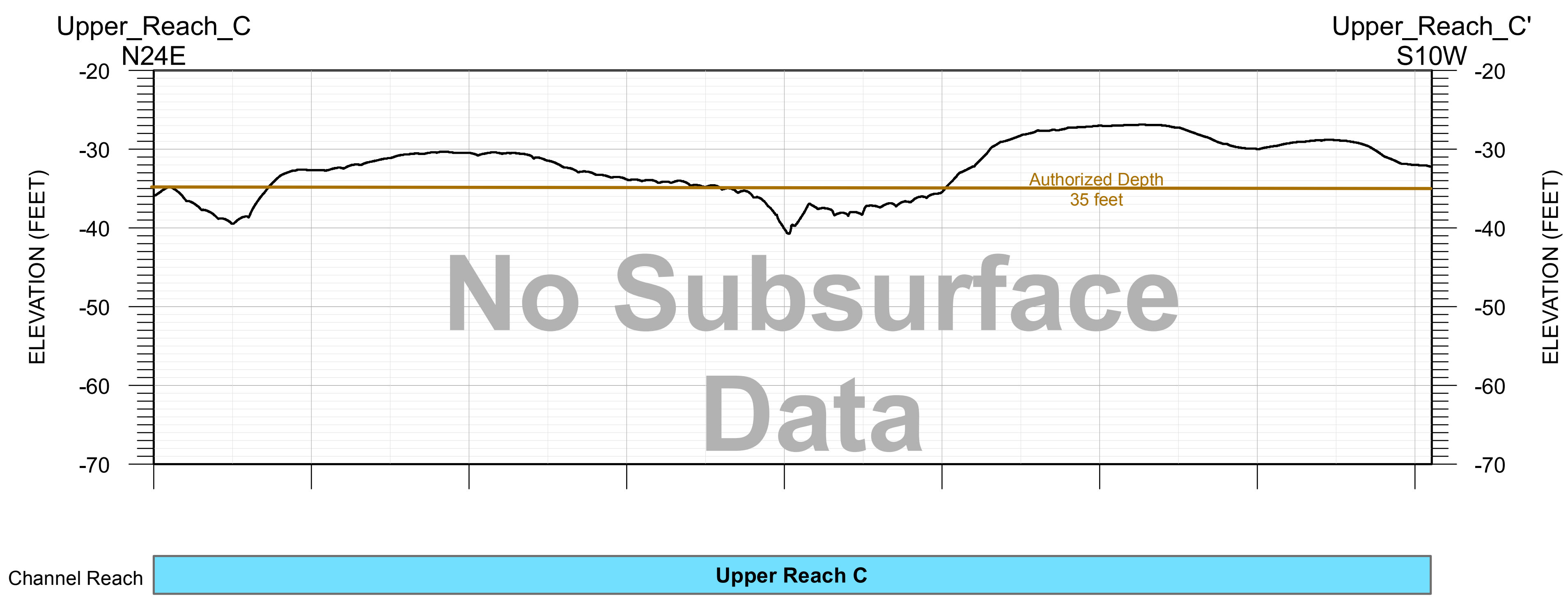
**Lithology Type**

- Environmental Vibracore

**UPPER REACH A AND B CROSS SECTION**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 6e




**PLAN VIEW LEGEND**

- EA15E
- Elizabeth River Shelby
- WWA98
- Cross Section Location
- Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**

High : -20

Low : -60

Contour interval is 5 feet.

**CROSS SECTION LEGEND**

- 2010 Bathymetry

20 ft

1000 ft

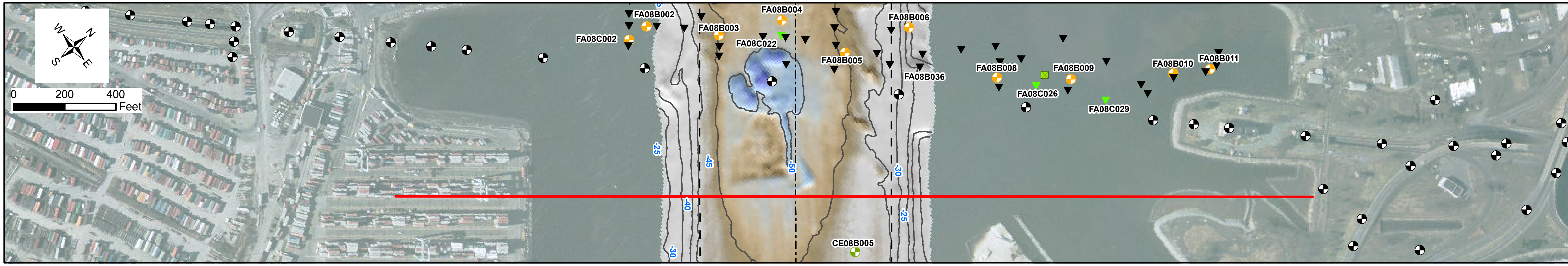
Vertical exaggeration is 50x.

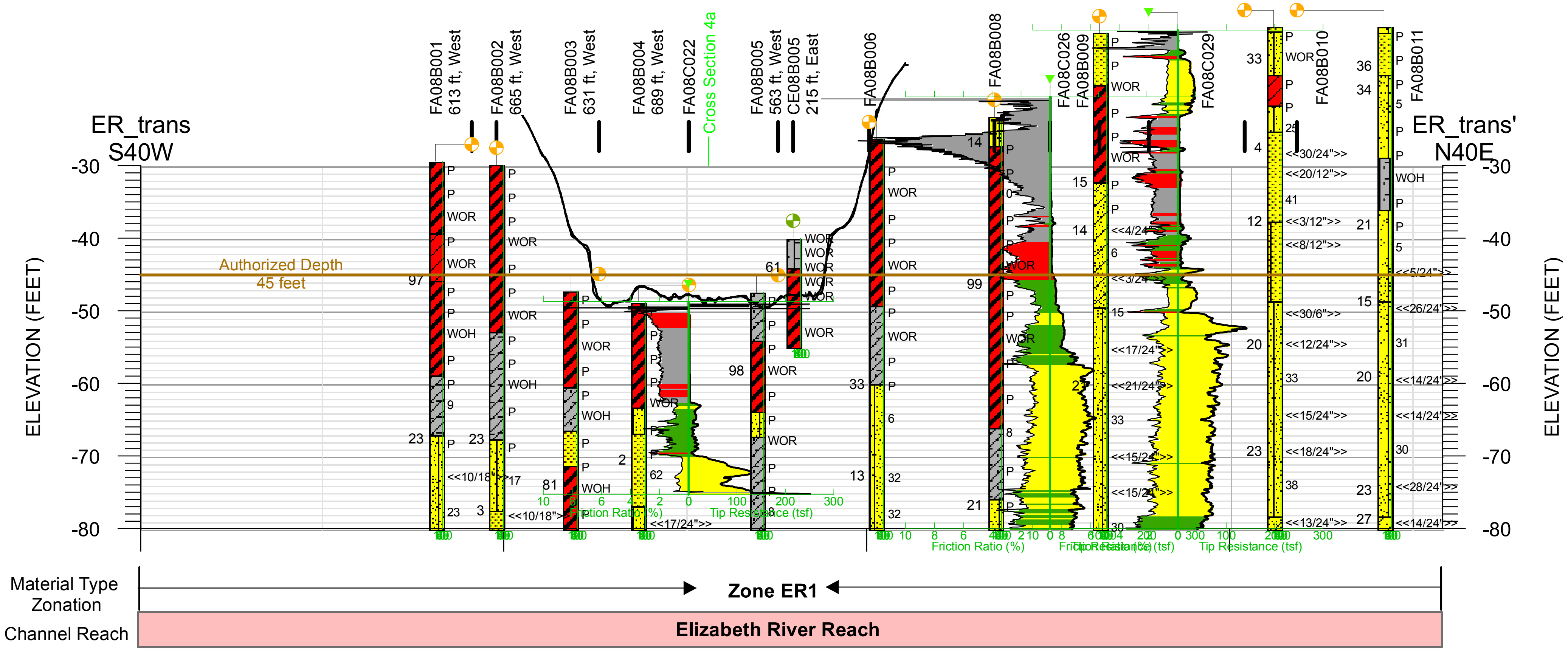
**UPPER REACH C CROSS SECTION**

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 6f

FUGRO




Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft
400 ft
Vertical exaggeration is 20x.

**PLAN VIEW LEGEND**

- 2008 USACE Boring
- 2008 Fugro Boring
- Exploration (not shown on the cross section)
- 2008 Fugro CPT
- CPT not shown
- Elizabeth River Shelby
- Cross Section Location
- Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**

- High : -40
- Low : -60
- Contour interval is 5 feet.

**CROSS SECTION LEGEND**

- 2010 Bathymetry

**Boring/Vibracore Symbology**

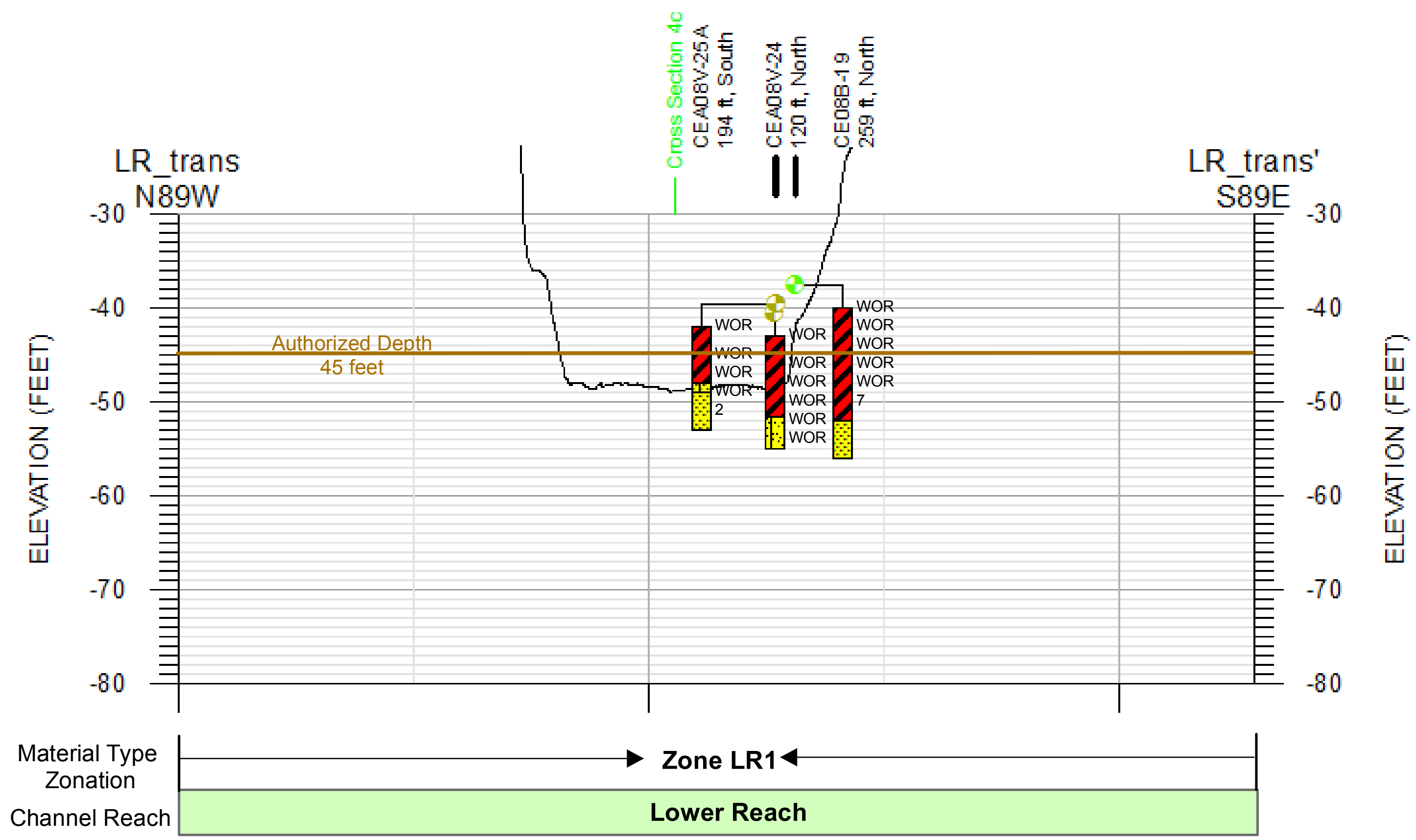
96 WOR WOR 3 1 5
Fines Content (%)
Standard Penetration Test N-Value

**Lithology Type**

- Lean CLAY (CL)
- Fat CLAY (CH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Clayey SAND (SC)
- Silty SAND (SM)
- Low-Plasticity Organic (OL)
- High-Plasticity Organic (OH)

**ELIZABETH RIVER REACH**
**TRANSVERSE CROSS SECTION**
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 7a


Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft
400 ft
Vertical exaggeration is 20x.

**PLAN VIEW LEGEND**

- Cross Section Location
- Navigation Channel Limit
- 2008 USACE Boring
- 2008 USACE Vibracore
- Elizabeth River Shelby

**2010 USACE Bathymetry (Feet, MLLW)**

High : -40
Low : -60

Contour interval is 5 feet.

**CROSS SECTION LEGEND**

2010 Bathymetry

**Boring/Vibracore Symbology**

96 WOR WOR 3 1 5
Fines Content (%)
Standard Penetration Test N-Value

**Lithology Type**

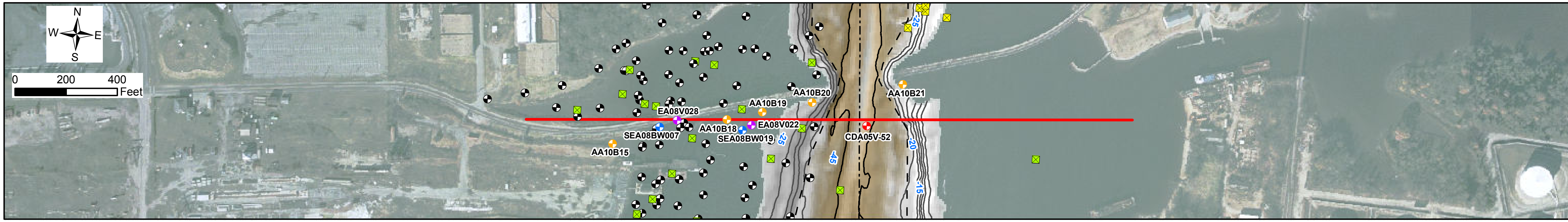
- Fat CLAY (CH)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Silty SAND (SM)

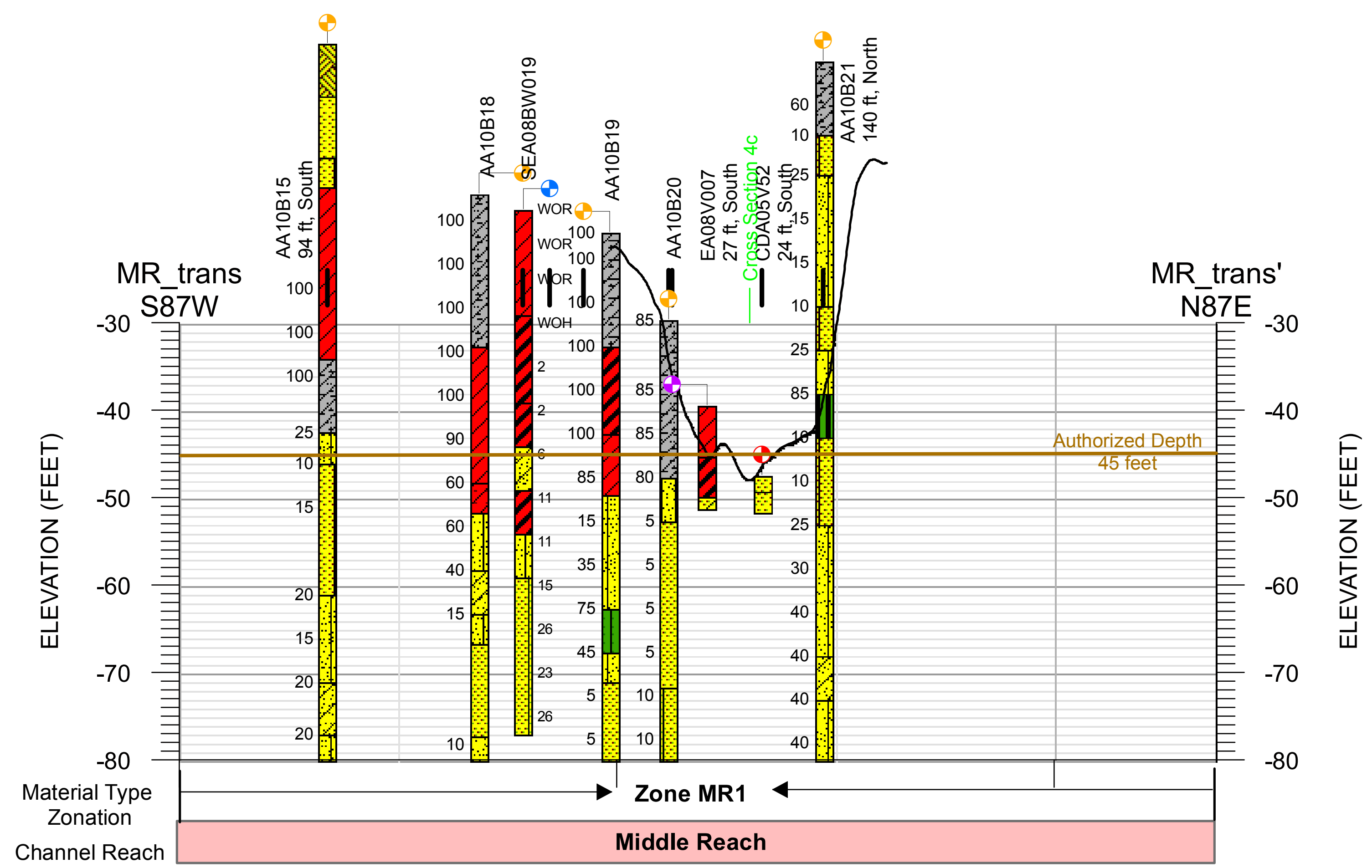
**LOWER REACH**
**TRANSVERSE CROSS SECTION**

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 7b

N:\Projects\04_2015\04_8115_0012_Port_of_Virginia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\CrossSections\Fig_7b_Lower_Reach_Transverse_XSection_Southern_Branch.mxd, 4/28/2016, wcupples




Notes:
1. Elevation is referenced to Mean Lower Low Water (MLLW).
2. CPT soil behavior type is based on Robertson and Campanella (1988).
3. Refer to Key to Subsurface Cross Sections.

20 ft
400 ft
Vertical exaggeration is 20x.

**PLAN VIEW LEGEND**

- 2010 Fishburne Boring
- 2008 EA Engineering Vibracore
- 2008 SE Boring
- 2005 CDM Vibracore
- Exploration (not shown on the cross section)
- EA13E
- Elizabeth River Shelby
- WW14E
- WW15E

Cross Section Location
Navigation Channel Limit

**2010 USACE Bathymetry (Feet, MLLW)**
High : -40
Low : -60
Contour interval is 5 feet.

**CROSS SECTION LEGEND**

2010 Bathymetry

**Lithology Type**

**Boring/Vibracore Symbology**
96 WOR WOR 3 1 5
Fines Content (%)
Standard Penetration Test N-Value

**MIDDLE REACH**
**TRANSVERSE CROSS SECTION**
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 7c

N:\Projects\04_2015\04_8115_0012_Port_of_Virginia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\CrossSections\Fig_7c_Middle_Reach_Transverse_XSection_Southern_Branch.mxd, 4/28/2016, wcupples

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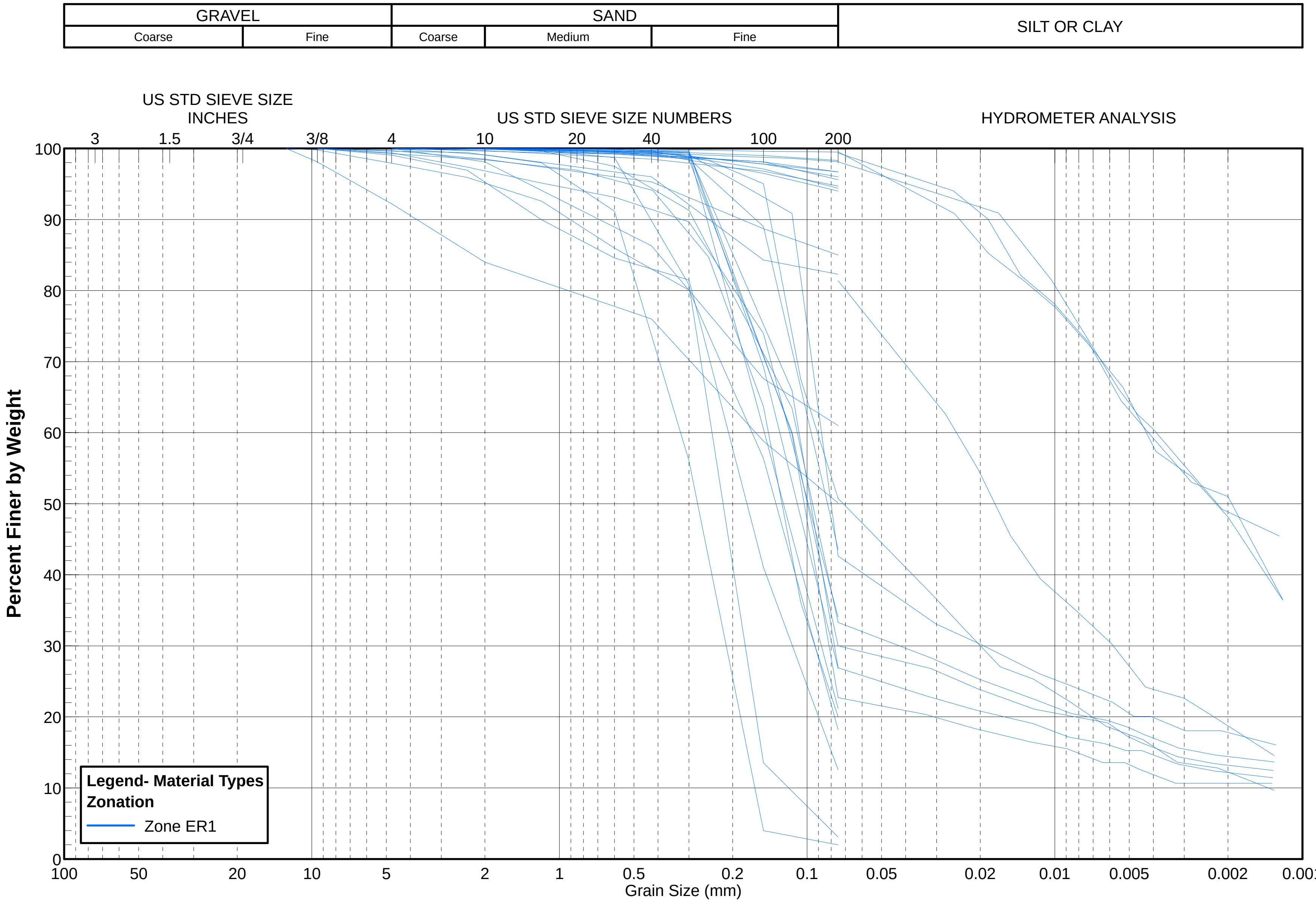


**GRAIN SIZE CURVES**

Elizabeth River Reach Zone ER1

Elizabeth River and Southern Branch of the

Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 8a

Moffatt and Nichol, Inc.

Project No. 04.81150012

FUGRO

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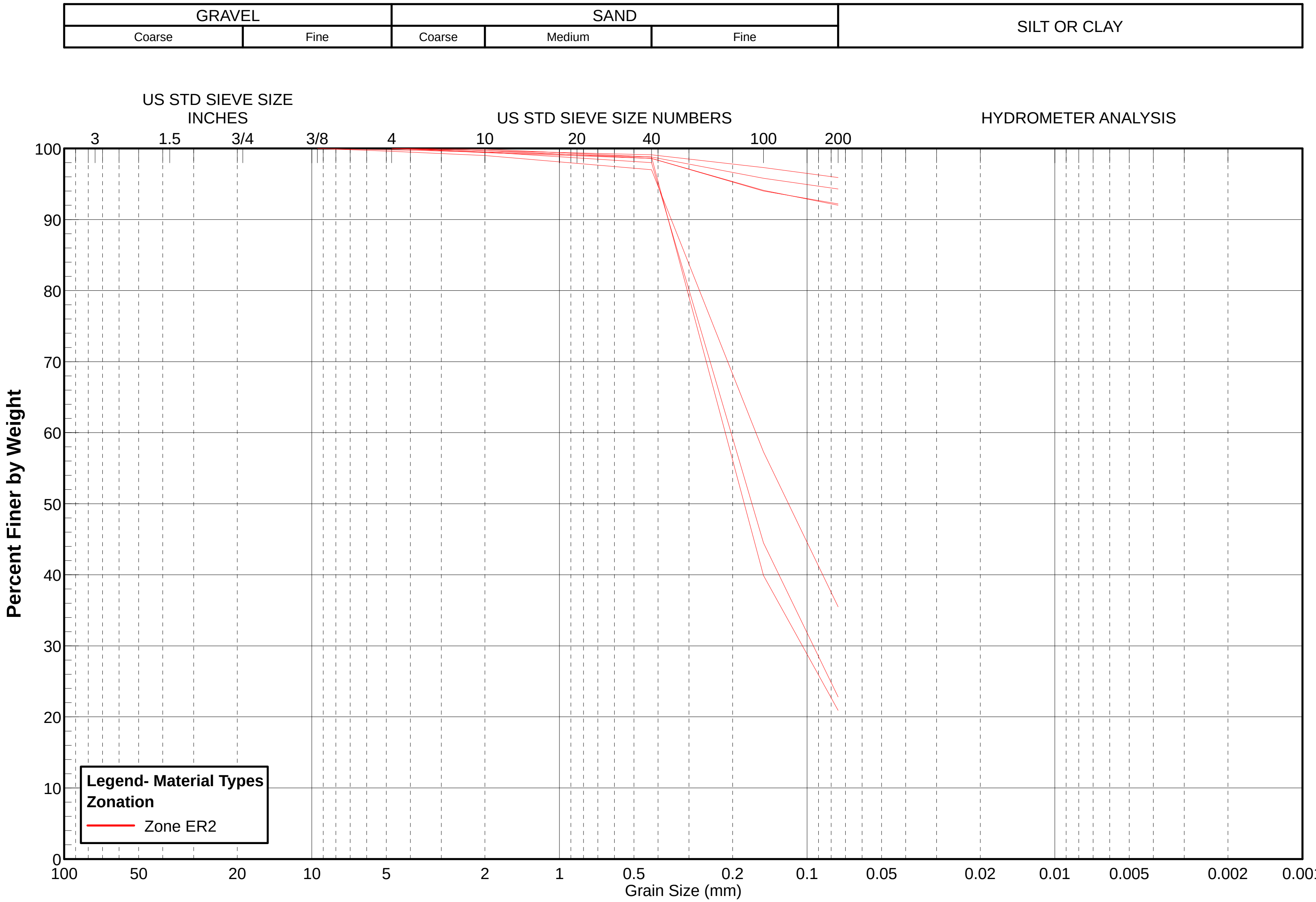


# GRAIN SIZE CURVES

Elizabeth River Reach Zone ER2
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 8b

Moffatt and Nichol, Inc.
Project No. 04.8115012

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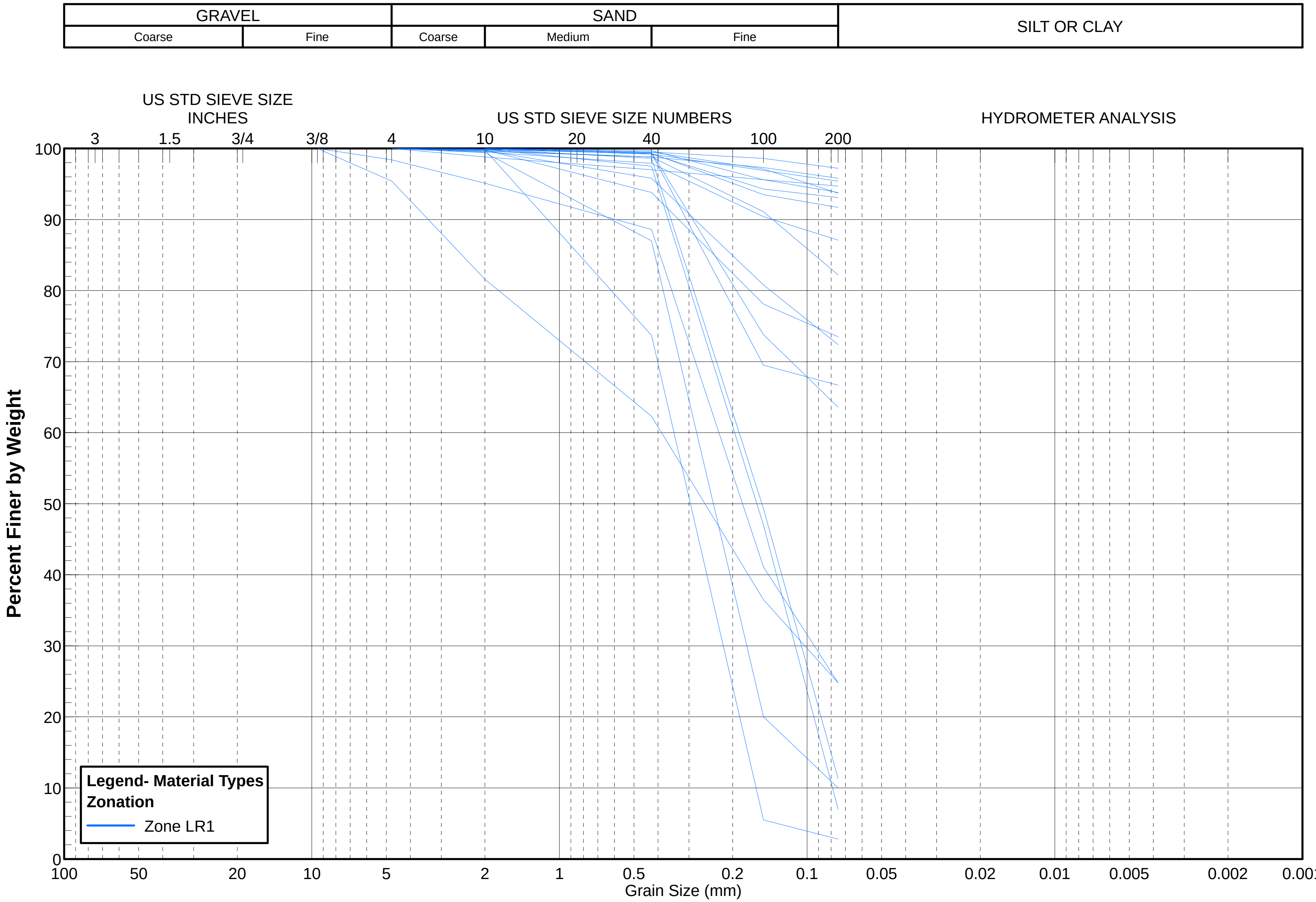


# GRAIN SIZE CURVES

Lower Reach Zone LR1

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 8c

Moffatt and Nichol, Inc.
Project No. 04.8115012

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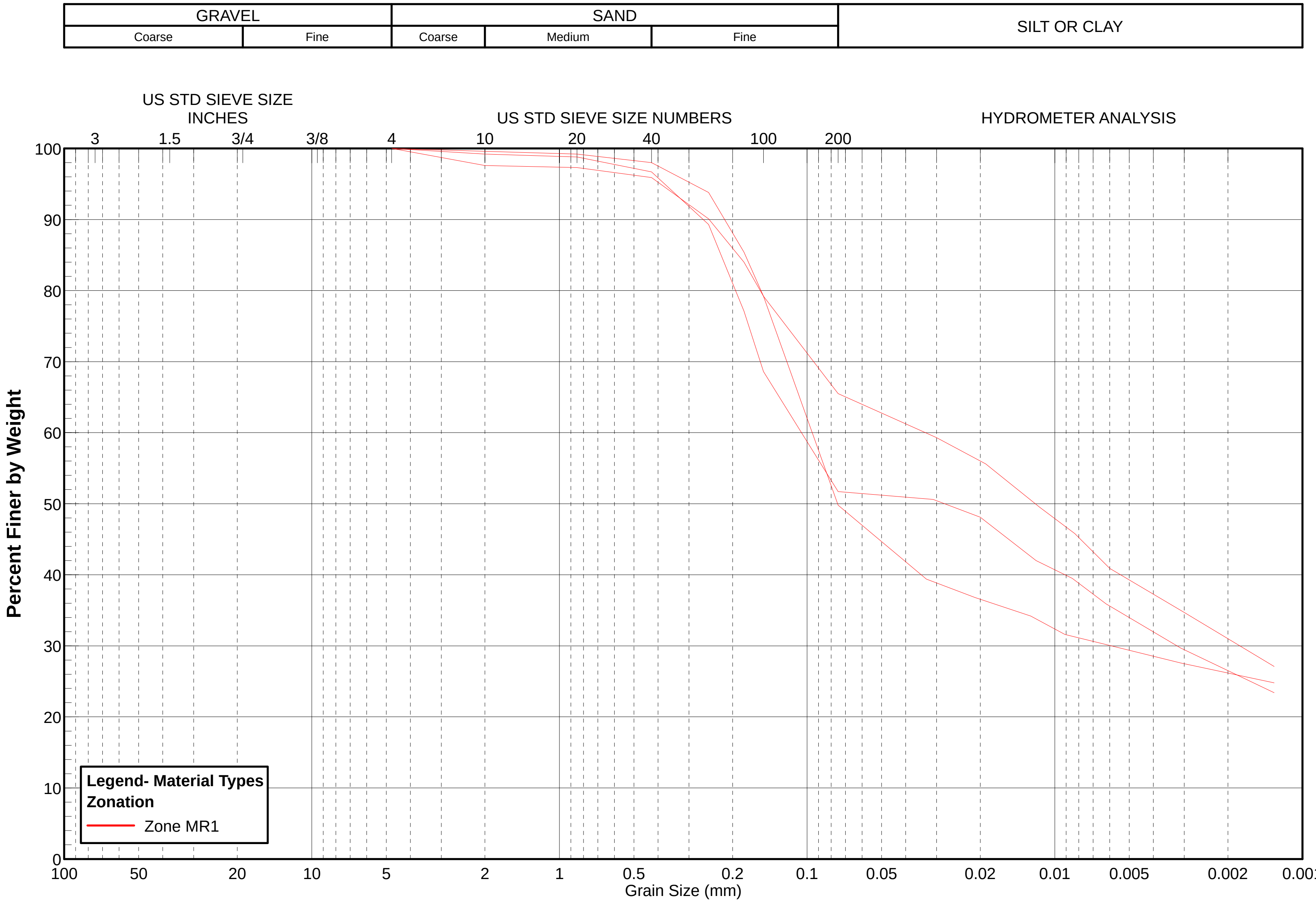
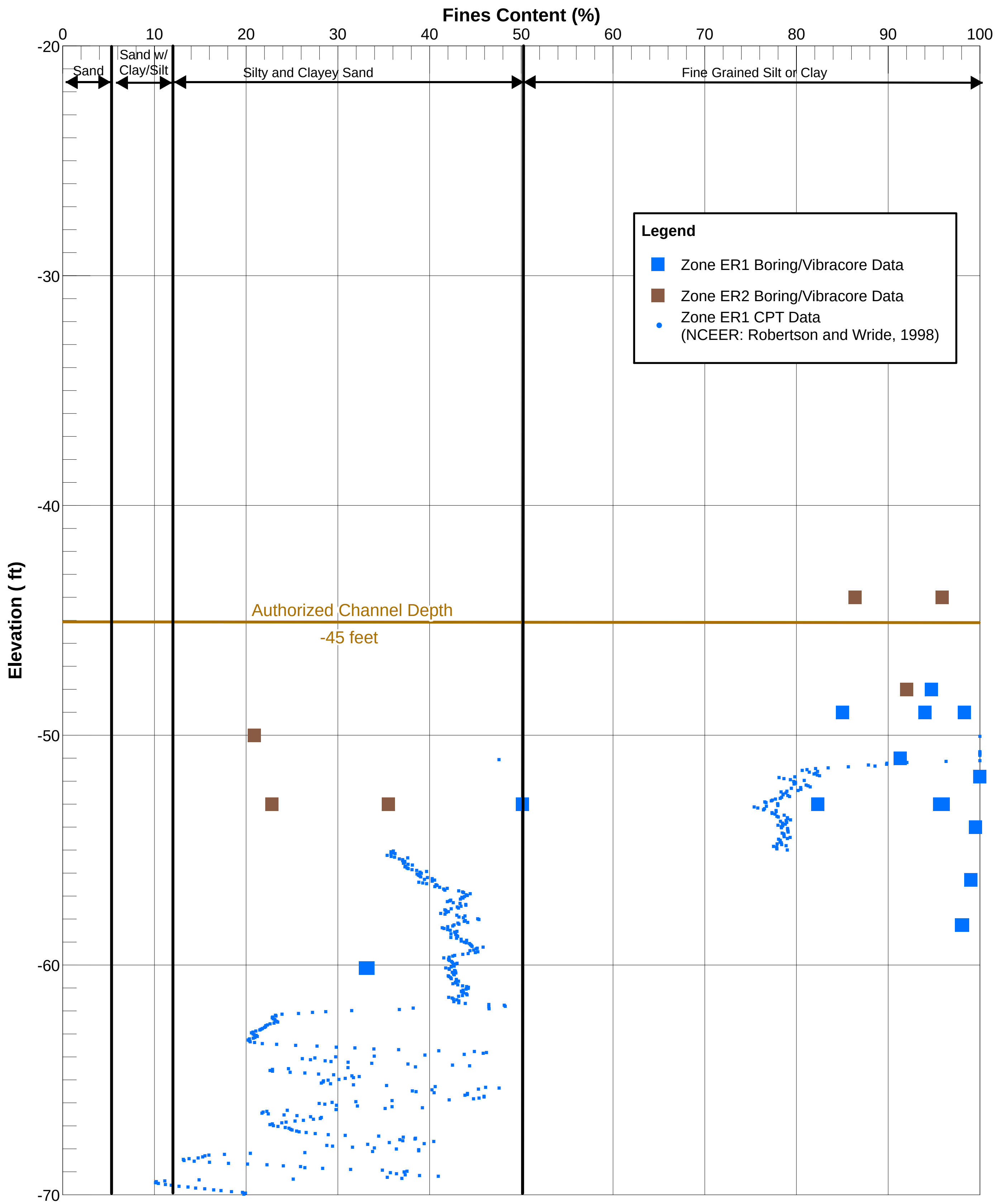



# GRAIN SIZE CURVES

Middle Reach Zone MR1
Elizabeth River and Southern Branch of the
Elizabeth River Deepening Study
Hampton Roads, Virginia

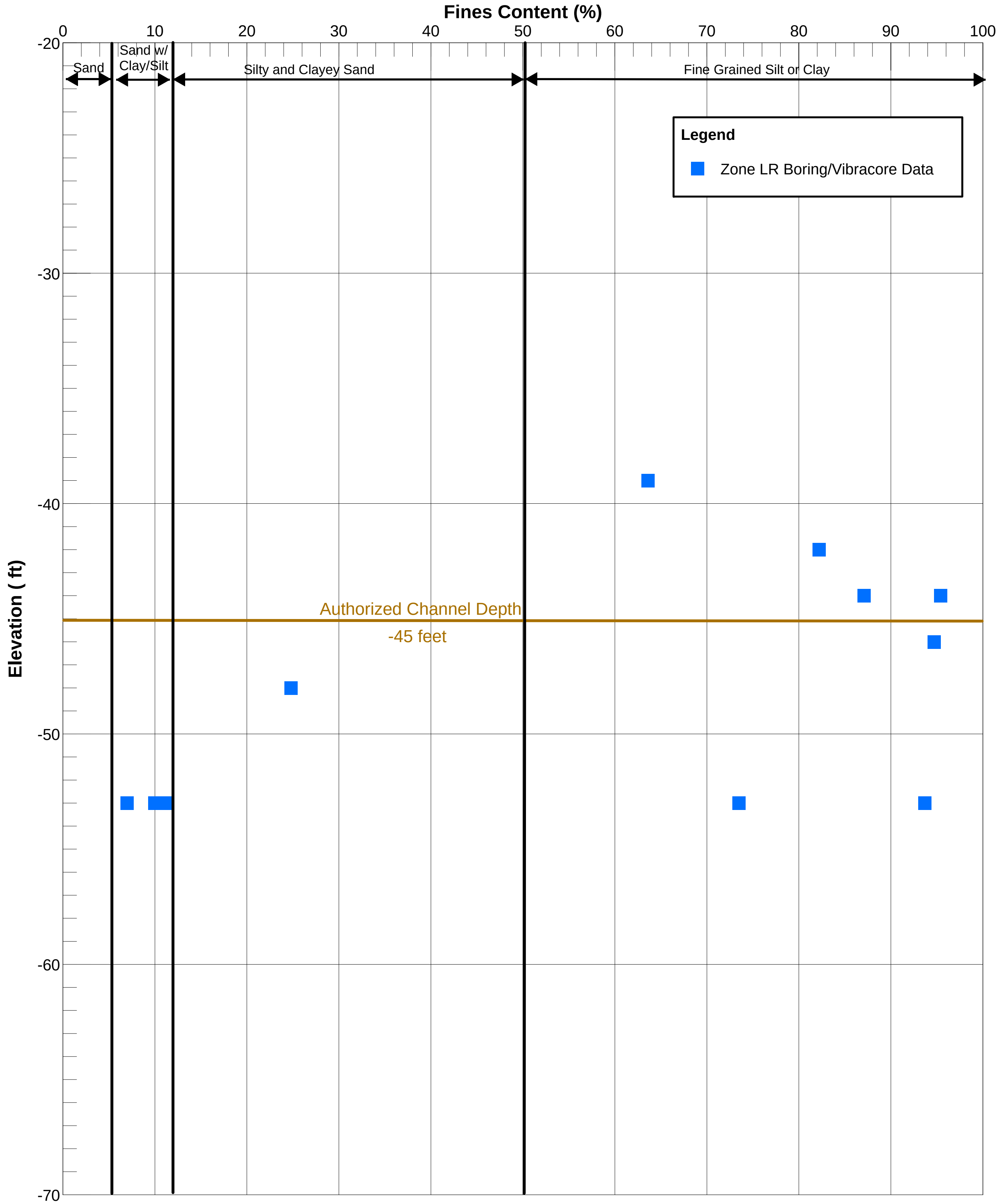
FIGURE 8d

Moffatt and Nichol, Inc.
Project No. 04.81150012




**FINES CONTENT**
Elizabeth River Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

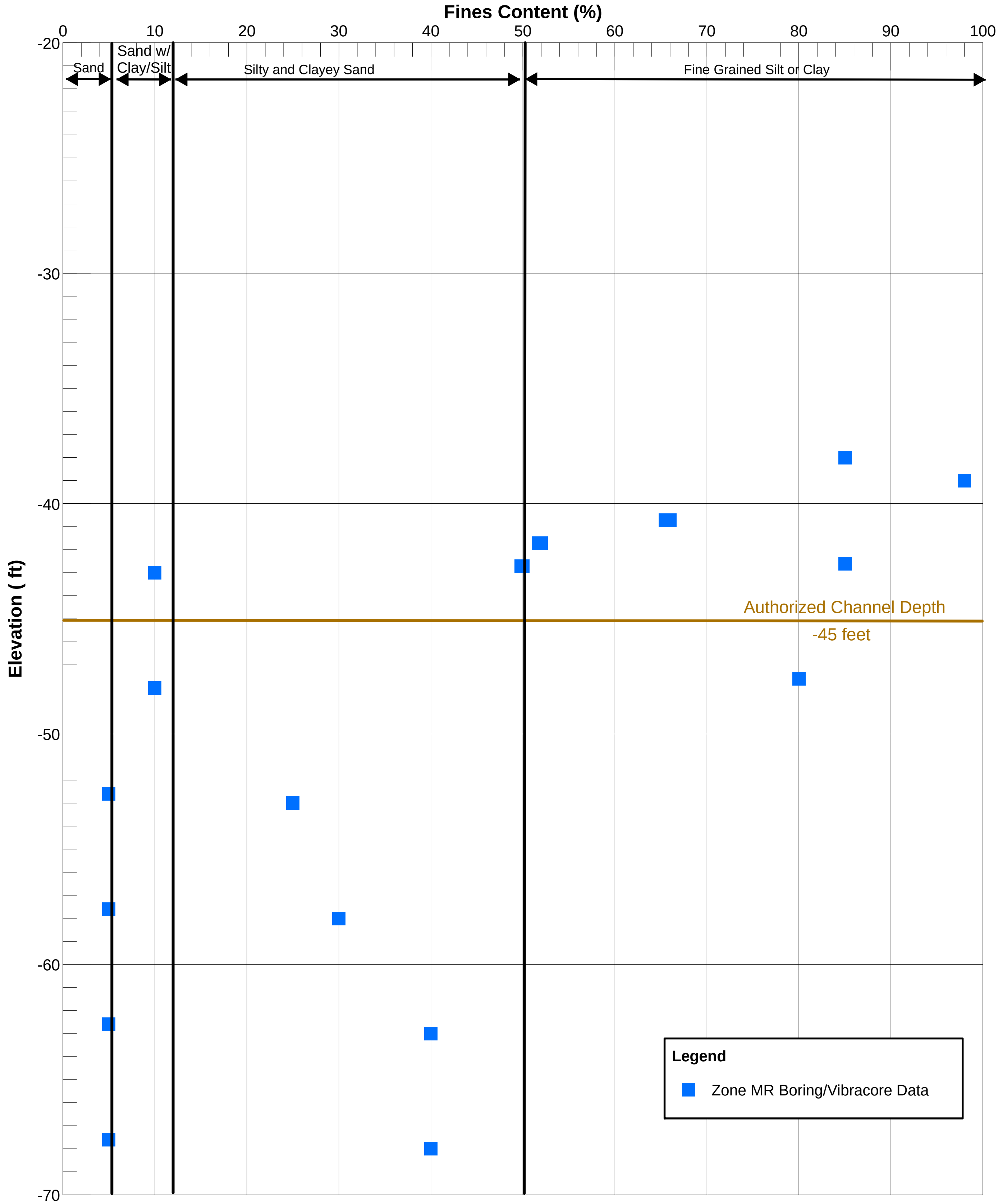
FIGURE 9a




**FINES CONTENT**
Lower Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 9b

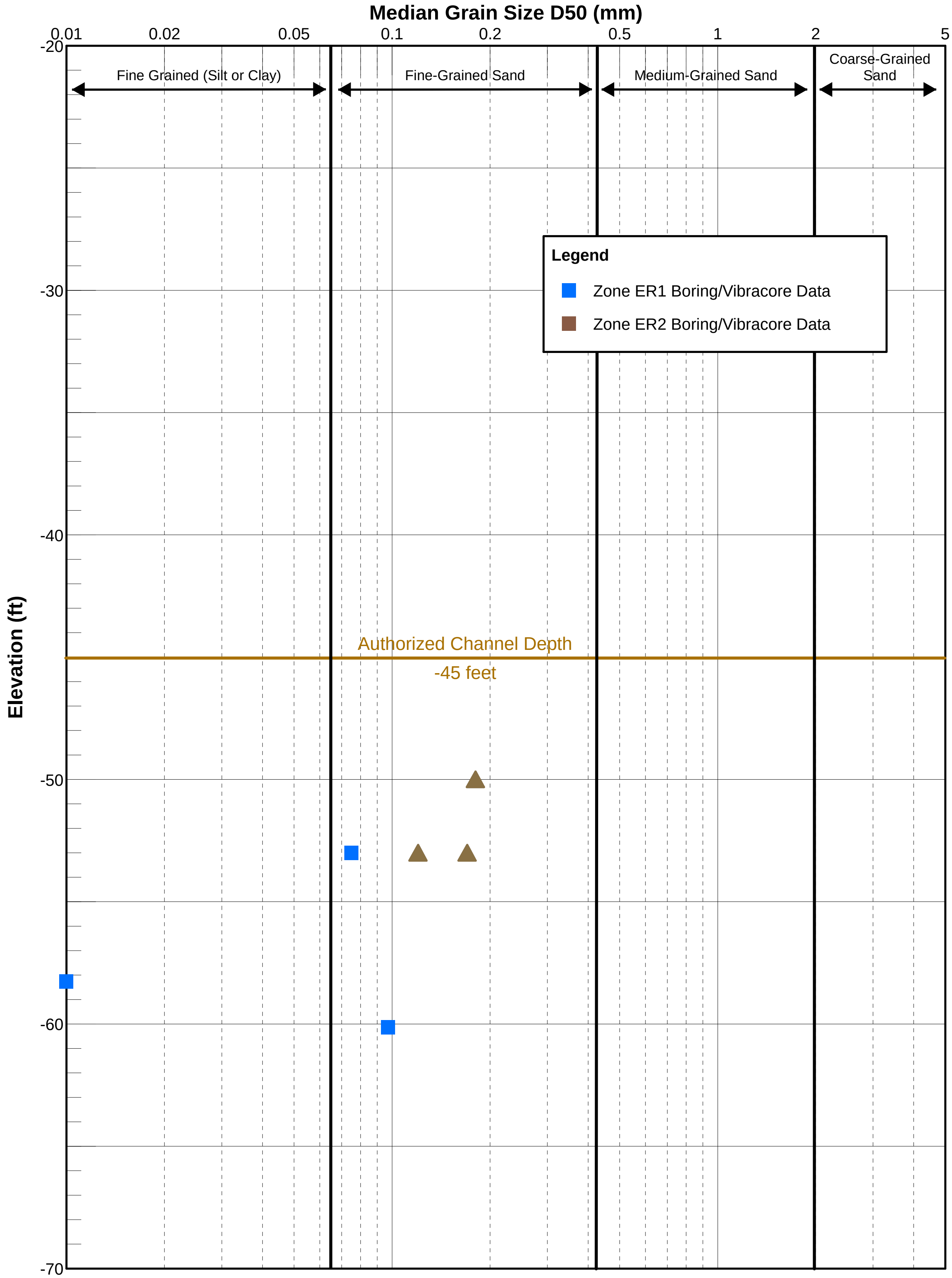
N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\PPlots\Fig_9b_FC_vs_Elev_LR.mxd, 4/28/2016, wcupples




**FINES CONTENT**
Middle Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

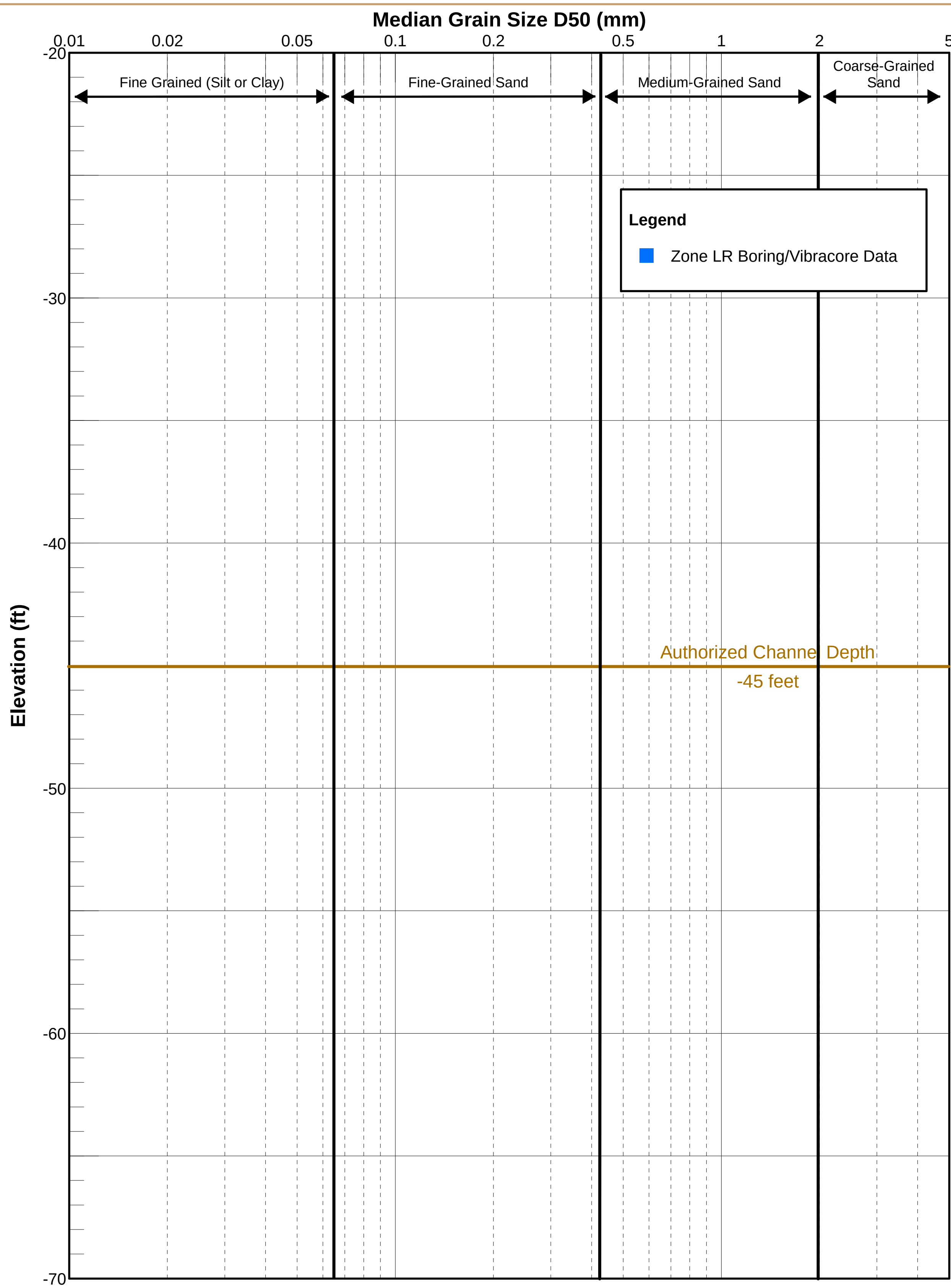
FIGURE 9c

Moffatt and Nichol, Inc.
Project No. 04.81150012



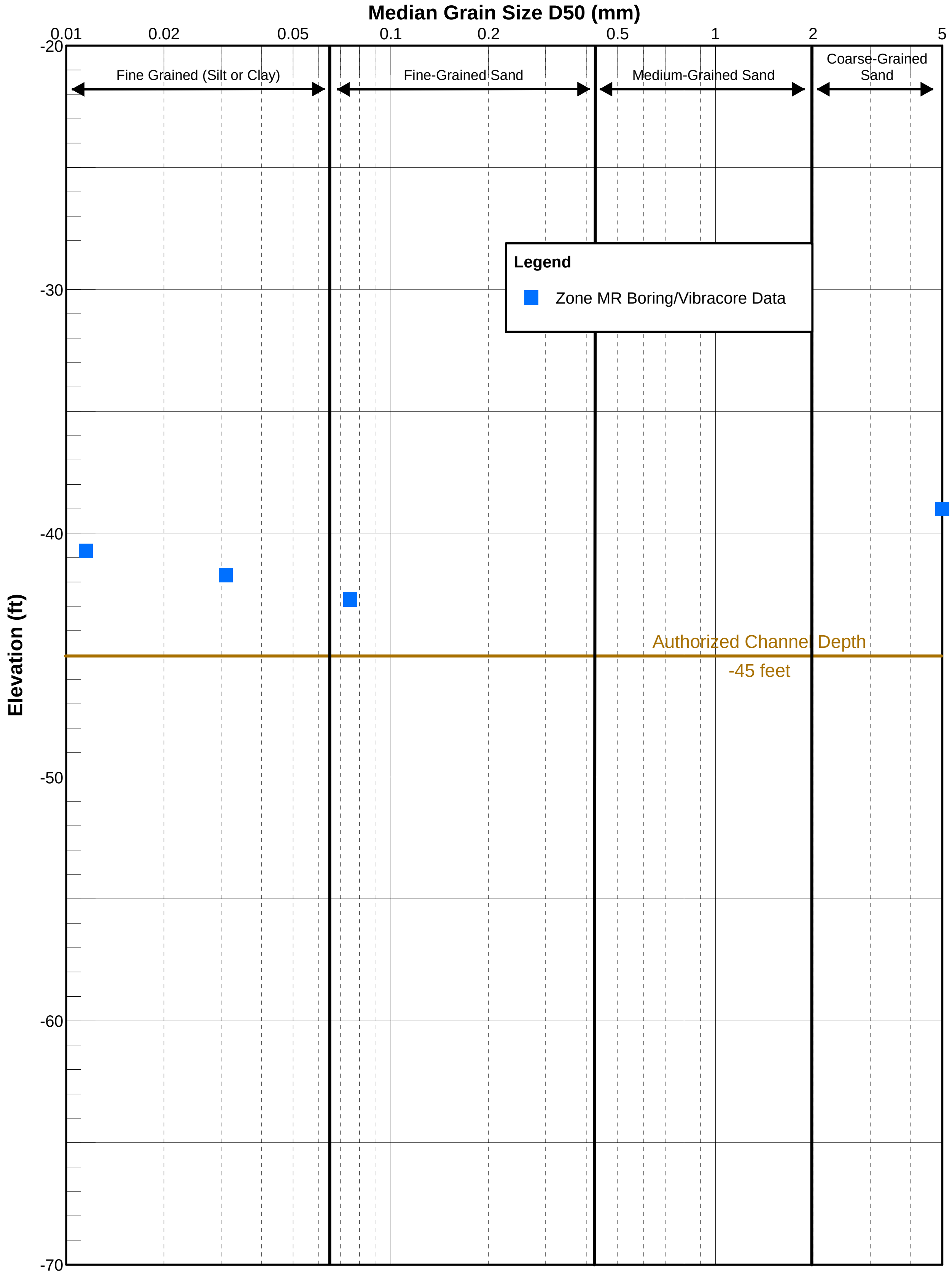

**MEDIAN GRAIN SIZE ($D_{50}$)**
Elizabeth River Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 10a




**MEDIAN GRAIN SIZE ($D_{50}$)**
Lower Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 10b




**MEDIAN GRAIN SIZE ($D_{50}$)**

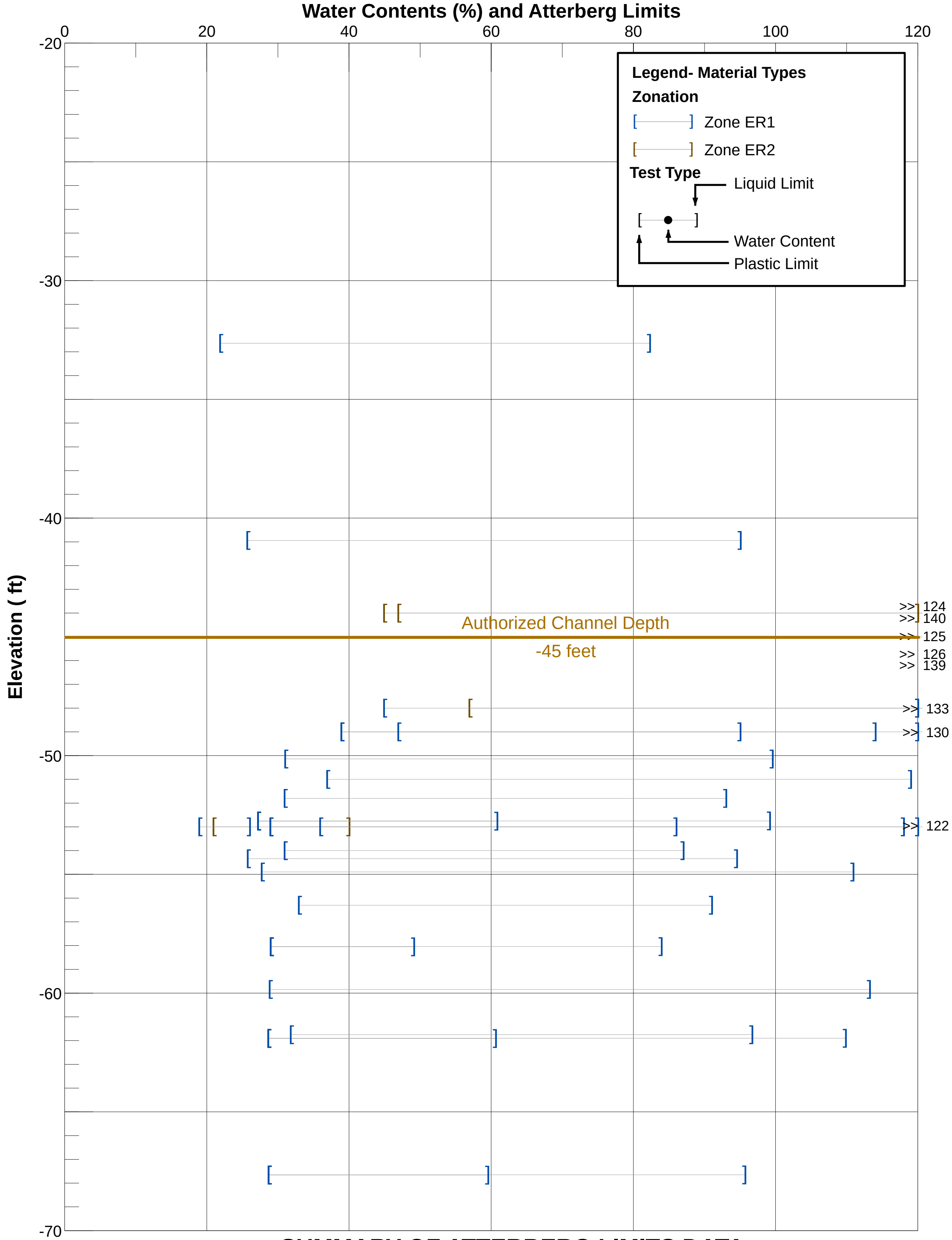
Middle Reach

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 10c

Moffatt and Nichol, Inc.
Project No. 04.81150012




**SUMMARY OF ATTERBERG LIMITS DATA**

Elizabeth River Reach

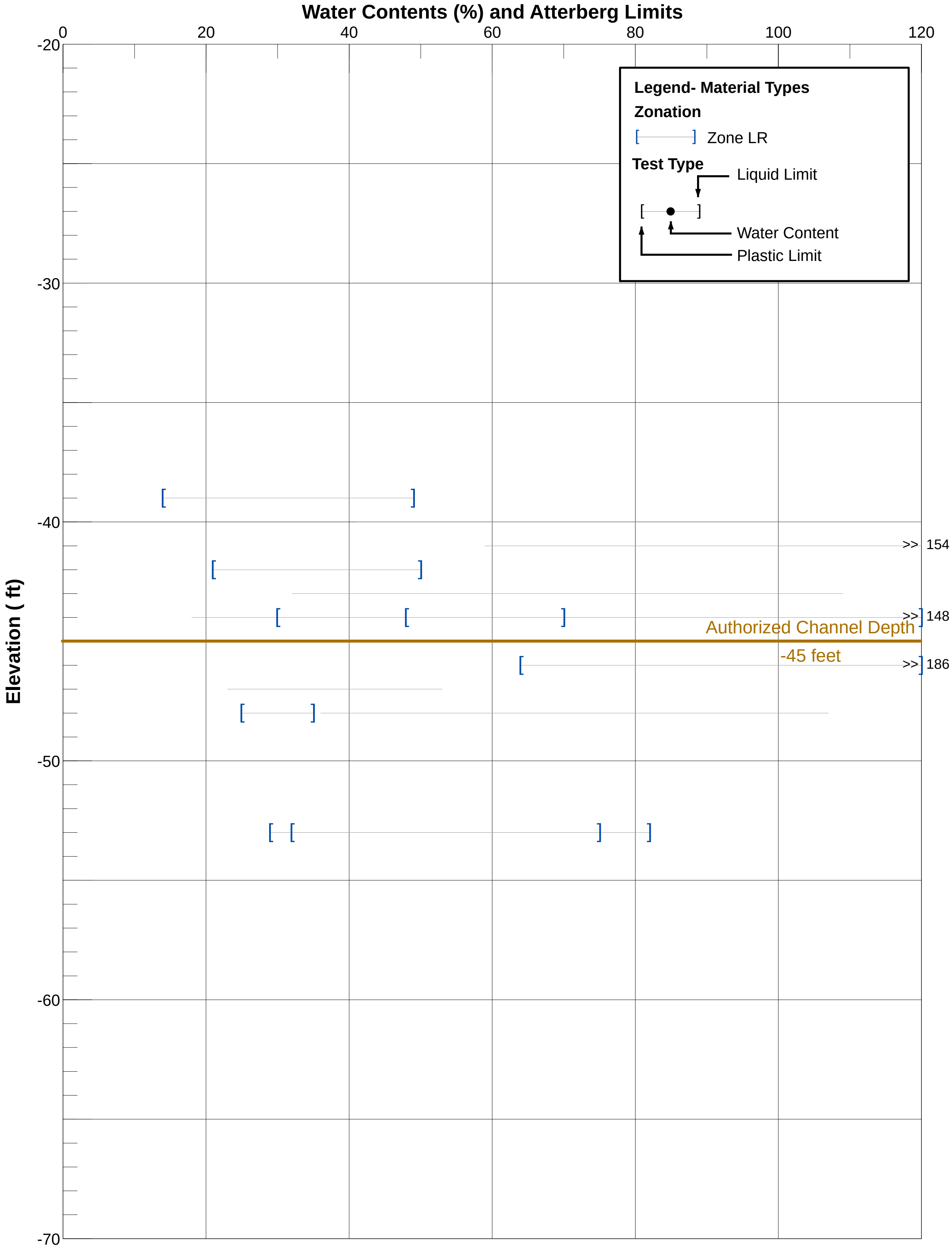
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 11a

N:\Projects\04_2015\04_8115_0012_Port_of_Virginia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\PPlots\Fig_11a_Atterberg_Limit_vs_Elev_ER.mxd, 4/28/2016, wcupples

Moffatt and Nichol, Inc.
Project No. 04.81150012




# SUMMARY OF ATTERBERG LIMITS DATA

Lower Reach

Elizabeth River and Southern Branch of the Elizabeth River Deepening Study

Hampton Roads, Virginia

FIGURE 11b

N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\PPlots\Fig_11b_Atterberg_Limit_vs_Elev_LR.mxd, 4/28/2016, wcupples

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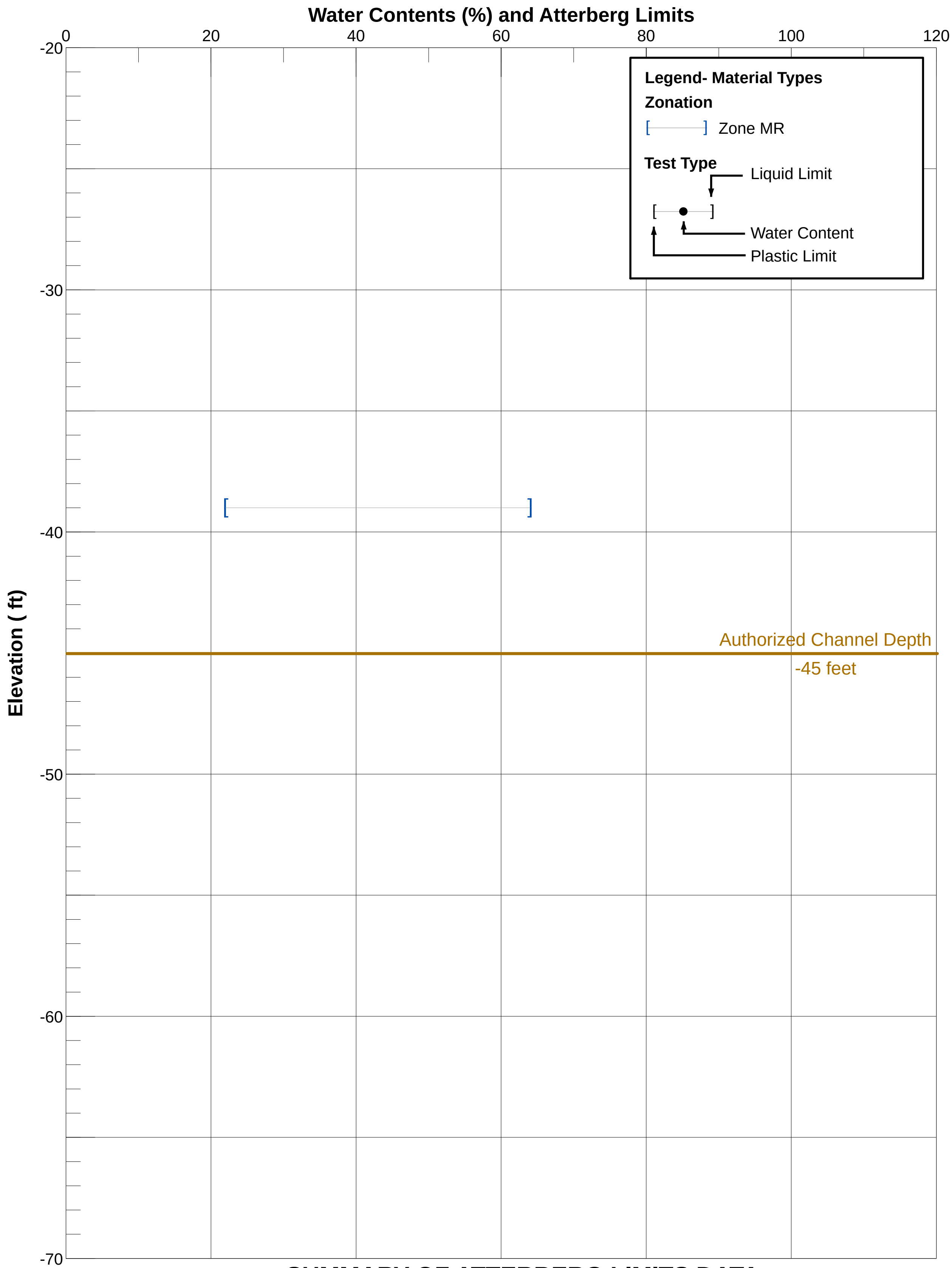
Project No. 04.81150012




## SUMMARY OF ATTERBERG LIMITS DATA

Middle Reach
Elizabeth River and Southern Branch of the Elizabeth River Deepening Study
Hampton Roads, Virginia

FIGURE 11c

N:\Projects\04_2015\04_8115_0012_Port_of_Virgnia_Deepening\Outputs\Feb2016_Report\mxd\Southern_Channel\PPlots\Fig_11c_Atterberg_Limit_vs_Elev_MR.mxd, 4/28/2016, wcupples

# Appendix C:
# Sedimentation Study

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800 World Trade Center
Norfolk, Virginia 23510
Phone: (757) 628-8222

**11/11/2016**

**Memorandum**

| Revision | Date | By | Reviewed By | Comment |
|---|---|---|---|---|
| 1 | 7/20/2016 | R Mathew | R Canizares | Initial Draft, for DQC |
| 2 | 9/29/2016 | R Mathew | B Joyner, I Brotman | Updated w/ TSC Meeting Areas & AOC maintenance dredging rate |
| 3, Final | 11/11/2016 | R Mathew | I Brotman | Updated w/ District DQC comments |

**Subject:** **Desktop Assessment of Future Sedimentation Rates**
*Norfolk Harbor and Channels Deepening, Virginia and Elizabeth River* and *Southern Branch of the Elizabeth River, Virginia Navigation Improvements* General Reevaluation Reports

## 1. Introduction

The navigation channels leading into Norfolk Harbor from the Chesapeake Bay and the Atlantic Ocean, along with the channels within Norfolk Harbor and the Southern Branch of the Elizabeth River are currently the subject of two feasibility studies (General Reevaluation Reports) for deepening and navigation improvements. As part of the impact assessments associated with the proposed deepening projects, a desktop analysis has been conducted for a first-order estimate of the maintenance dredging rate to be expected in the navigation channels following deepening. Since the periodic maintenance dredging primarily includes sediments deposited on top of the native sediment surface within the channel (the native sediment surface is the sediment strata exposed following the deepening of the channel), the maintenance dredging rate can be considered to be the same as the sedimentation rate. Therefore the terms maintenance dredging rate and sedimentation rate are used interchangeably in the remainder of this document. The following provides an overview of the study area, followed by an overview of the approach for estimating the future sedimentation rate, the data used, and the results of this desktop analysis.

## 2. Study Area

Figure 1 shows a map with the layout of the navigation channel in the vicinity of Norfolk Harbor. Discrete portions of the navigation channel relevant to the analysis presented here are also identified in this map. For purposes of this study, the estimates of sedimentation rates have been developed separately for the following zones:

- Elizabeth River Channel (ERC)
- Norfolk Harbor and Craney Island Reaches (NH-CIR)
- Norfolk Harbor Entrance Reach (NHER)
- Newport News Channel (NNC)

- Thimble Shoals Channel (TSC)
- Atlantic Ocean Channel (AOC)

The channel segments (as designated by the US Army Corps) comprising these zones as well as the current and proposed channel dimensions are shown in Table 1. Current channel depths (as constructed) range from about 35' in the Elizabeth River to 52' in the Atlantic Ocean Channel. Natural channel depths (i.e. depth in the cross-section outside the channel) range from about 15' in the Elizabeth River to 44' in the Atlantic Ocean Channel. In other words, the channel bottom in the Elizabeth River is currently about 20' deeper than the areas outside the channel. In comparison, the channel bottom in the Atlantic Ocean Channel is currently only 8'-10' deeper than the adjacent seafloor outside the channel. This has implications for the estimated future sedimentation rate as discussed subsequently in this memorandum. In addition to the deepening of the navigation channels, within the Thimble Shoals Channel (TSC), two meeting areas are also under consideration. Each of the meeting areas include an additional 200 feet of bottom width on either side of the channel. Therefore, the analysis of future sedimentation rates in zone TSC includes estimates with and without these meeting areas.

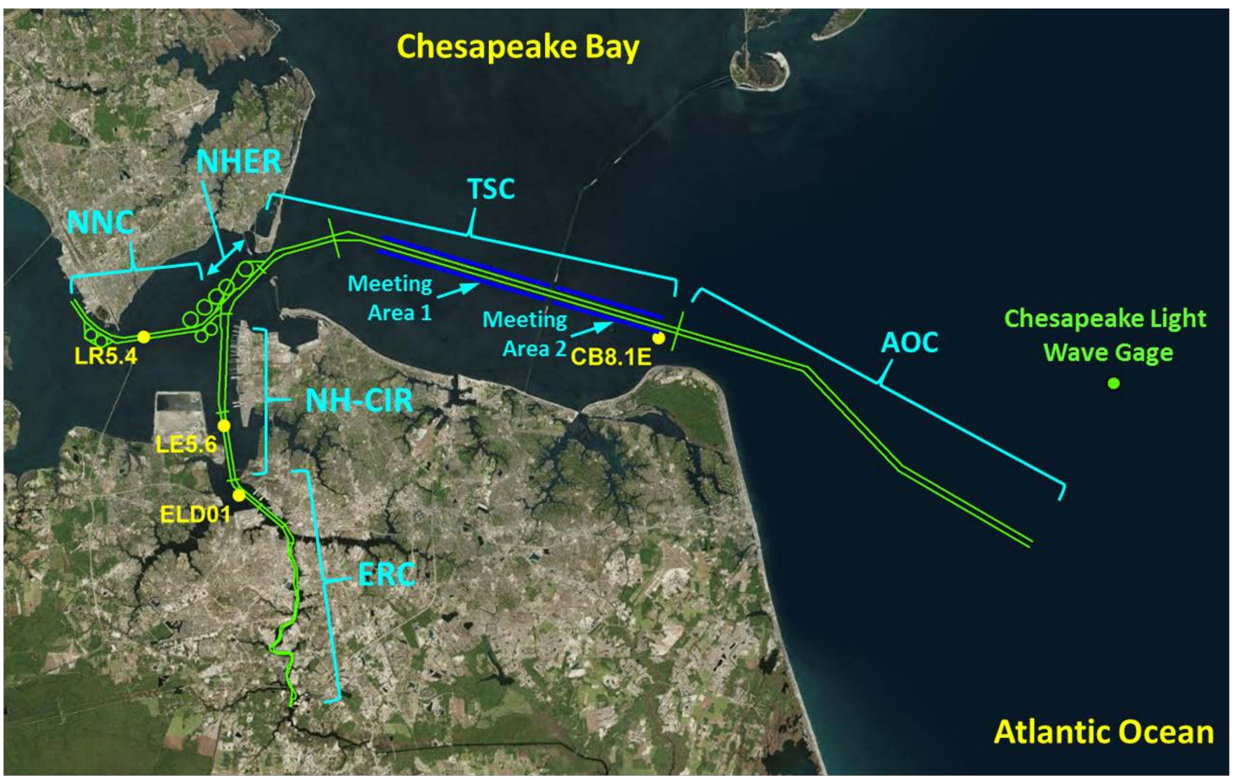


**Figure 1. Site map showing the layout of the navigation channel in Norfolk Harbor and Elizabeth River along with locations of various data referenced in this analysis.**

**Table 1. Current and proposed dimensions of the various channel segments in Norfolk Harbor and Elizabeth River.**

| Zone | Channel Segment | Length (ft) | Design Side Slopes (H toV) | Natural Depth[1] (ft) | Bottom Width[2] (ft) | USACE Maintained Channel Depth (ft) | Estimated Approximate Current Top Width[3] (ft) | Proposed Channel Depth (ft) | Estimated Approximate Proposed Top Width[4] (ft) |
|---|---|---|---|---|---|---|---|---|---|
| ERC | Elizabeth River Reach | 15840 | 3 to 1 | 23 | 750 | 40 | 852 | 47 | 894 |
| ERC | Lower Reach | 10560 | 3 to 1 | 32 | 450 | 40 | 498 | 47 | 540 |
| ERC | Middle Reach | 5280 | 3 to 1 | 26.5 | 375 | 40 | 456 | 47 | 498 |
| ERC | Upper Reach A | 12672 | 3 to 1 | 25 | 375 | 35 | 435 | 42 | 477 |
| ERC | Upper Reach B | 3168 | 3 to 1 | 18 | 300 | 35 | 402 | 37 | 414 |
| ERC | Upper Reach C | 7920 | 3 to 1 | 15 | 250 | 35 | 370 | 37 | 382 |
| NH-CIR | Craney Island Reach | 15840 | 3 to 1 | 15 | 800 | 50 | 1010 | 58 | 1058 |
| NH-CIR | Norfolk Harbor Reach | 21120 | 3 to 1 | 20 | 1200 | 50 | 1380 | 58 | 1428 |
| NHER | Norfolk Harbor Entrance Reach | 10560 | 3 to 1 | 27 | 1220 | 50 | 1358 | 58 | 1406 |
| NNC | Newport News Channel | 28512 | 3 to 1 | 22 | 800 | 50 | 968 | 58 | 1016 |
| TSC | Thimble Shoals Channel | 68640 | 3 to 1 | 40 | 1000 | 50 | 1060 | 58 | 1108 |
| TSC | Meeting Area 1[5] | 36457 | 3 to 1 | 40 | 1400 | 50 | 1060 | 58 | 1508 |
| TSC | Meeting Area 2[5] | 21266 | 3 to 1 | 40 | 1400 | 50 | 1060 | 58 | 1508 |
| AOC | Atlantic Ocean Channel | 52800 | 3 to 1 | 44 | 1300 | 52 | 1348 | 61 | 1402 |

[1] Natural depth refers to the depth of the seabed outside the channel. In other words, the depth of the seabed before construction of the channels.
[2] With the exception of the two Meeting Areas, width listed indicates the current width. For the two Meeting Areas, with listed is the future width.
[3] Since the navigation channel is constructed with a side slope of 3 to 1, width is larger at the top of the channel than at the bottom.
[4] The width at the top of the channel increases from current conditions because of the increase in channel depth which causes a widening of the channel up to the top to maintain a side slope of 3 to 1.
[5] Meeting Areas 1 & 2 both include an 200 feet of additional bottom width on either side of the channel

In addition to the channel segments described here, anchorage areas adjacent to the Norfolk Harbor Entrance Reach (zone NHER), and Newport News Channel (zone NNC) are also proposed to be deepened. These areas are also shown in Figure 1, apparent as circular areas adjacent to the channel in zones NHER and NNC. However, this memorandum does not include estimates of future maintenance dredging in the anchorage areas because (1) the methods used for estimating maintenance dredging in the channel segments are not suitable for the circular planform geometry of these areas, and (2) as described subsequently, the maintenance dredging in the anchorage areas is relatively small compared to the channel segments.

## 3. Methods to Estimate Future Sedimentation Rate

Future sedimentation rates within the study area have been estimated by analytical and empirical methods. As described subsequently, two different analytical methods were used in different parts of the study area, mainly driven by the physical processes considered responsible for sedimentation. The analytical approaches follow the basin sedimentation approach of Eysink and the channel sedimentation approach of Van Rijn. The approach chosen for a given zone is a function of the physical processes expected to dominate sediment transport in that zone. Table 2 lists the physical processes expected to be responsible for sedimentation in each zone, and the resulting analytical approach used. Both approaches are implemented as spreadsheet-based tools applied for a representative tidal condition. In addition, specifically for the TSC zone, future sedimentation rates have also been estimated using the Volume of Cut empirical approach described in Van Rijn. Each of these approaches is described briefly. All three methods were first applied to and calibrated to reproduce the ongoing sedimentation rate (i.e., the current maintenance dredging rate). Subsequently, the calibrated method for each zone was applied to estimate the future sedimentation rate in that zone. This is further described in the following sections.

**Table 2. Physical processes expected to influence sedimentation and the analytical approach used to estimate future sedimentation rate for various zones.**

| Zone | Analytical Approach | Physical Processes Expected to Influence Sedimentation |
|---|---|---|
| ERC | Eysink | Tidal infilling and density (salinity) driven circulation |
| NH-CIR | Eysink | Tidal infilling and density (salinity) driven circulation |
| NHER | Van Rijn | Tidal currents |
| NNC | Van Rijn | Tidal currents |
| TSC | Van Rijn | Tidal currents and waves |
| TSC w/ Meeting Areas | Van Rijn | Tidal currents and waves |
| AOC | Van Rijn | Tidal currents and waves |

### 3.1 Basin Sedimentation Method

The harbor basin sedimentation approach of Eysink and Vermaas (1983) and Eysink (1989) has been used to calculate sedimentation in the ERC and NH-CIR zones. This method is applicable to enclosed or semi-enclosed basins or tidal channels. Briefly, it involves the calculation of the water exchange between the basin and adjacent marine environment due to the vertical gradient in density (salinity) within the basin, due to tidal inflow and outflow, and due to horizontal eddies generated by horizontal gradients in currents at the mouth of the basin. The latter two processes are depicted in Figure 2. The exchange of water between the basin and surrounding waters when associated with a suspended sediment concentration (SSC) provides a sediment load entering the basin per tidal cycle. Due to lower flow velocities within the basin, a fraction of this total sediment influx can deposit in the basin, with the deposition flux calculated based on the trapping efficiency of the system which is a function of the settling velocity of the suspended sediments, and other basin-specific parameters such as the total water depth and residence time within the basin. Thus, the outflowing water (during the ebb tide), will be associated with a lower SSC compared to the inflowing water. The net difference in SSC reflects the sedimentation in the basin during that tidal cycle.

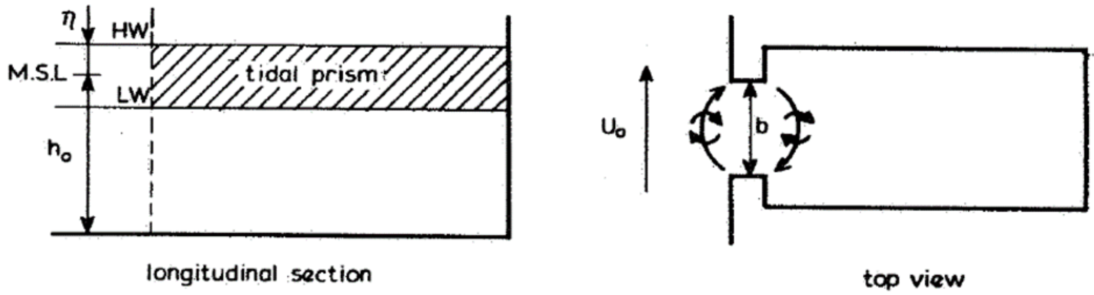


**Figure 2. Schematic of volume exchange for tidal basins: tidal exchange (left) and horizontal eddy filling (right). Adapted from Eysink and Vermaas (1983).**

The method requires information on the geometry of the channel (length, width, and depth), tidal range, density (salinity) gradient, SSC, currents just outside the basin, and settling velocity. This approach was used for the ERC zone (only tidal exchange and salinity-driven circulation active), and for the NH-CIR zone (tidal exchange, salinity-driven circulation, and horizontal eddies active). The basin geometries were defined using the information presented in Table 1; the remaining inputs were derived using a combination of empirical data and numerical model results as described subsequently. Note that in addition to sediments originating from the marine source, zones ERC and NH-CIR are also expected to include sediments originating from the freshwater inflow to the Elizabeth River. The effect of the sediment loadings from the two sources is integrated into the SSC used as an input to this methods. As described subsequently, the SSC is defined on the basis of measured data at appropriate locations for both zones.

### 3.2 Channel Sedimentation Method

The channel sedimentation approach of Van Rijn (2013) has been used to calculate sedimentation in the NHER, NNC, TSC, and AOC zones. This method is applicable to navigation channels cutting through coastal zones and wide basins. Briefly, this approach involves the calculation of the change in flow velocity within the channel (due to the larger water depth relative to areas outside the channel), and therefore the reduction in sediment transport capacity within the channel. The plan view on the upper panel of Figure 3 shows a schematic of flow (from the bottom left to upper right of the panel) over a channel oriented at an arbitrary angle relative to the direction of tidal currents. The reduction in flow velocity within the channel is calculated using basic equations of motion and continuity. In addition to a reduction in velocity within the channel, the currents also experience refraction (a change in direction). The velocity component perpendicular to the channel experiences a reduction in magnitude that is inversely proportional to the local water depth, while the velocity component parallel to the channel may increase in magnitude due to a reduction of bottom friction. As a result, the streamlines show a refraction-type pattern in the channel (see Figure 3). Associated with SSC, the sediment load entering the channel is calculated, and using the trapping efficiency of the channel (a function of the flow velocity, settling velocity, and channel geometry), the sediment deposition rate is calculated. In addition to deposition associated with advection (i.e. the horizontal transport of suspended sediment with the tidal currents), wave-driven sediment mobilization from the seafloor adjacent to the channel and potential deposition within the channel can also be calculated.

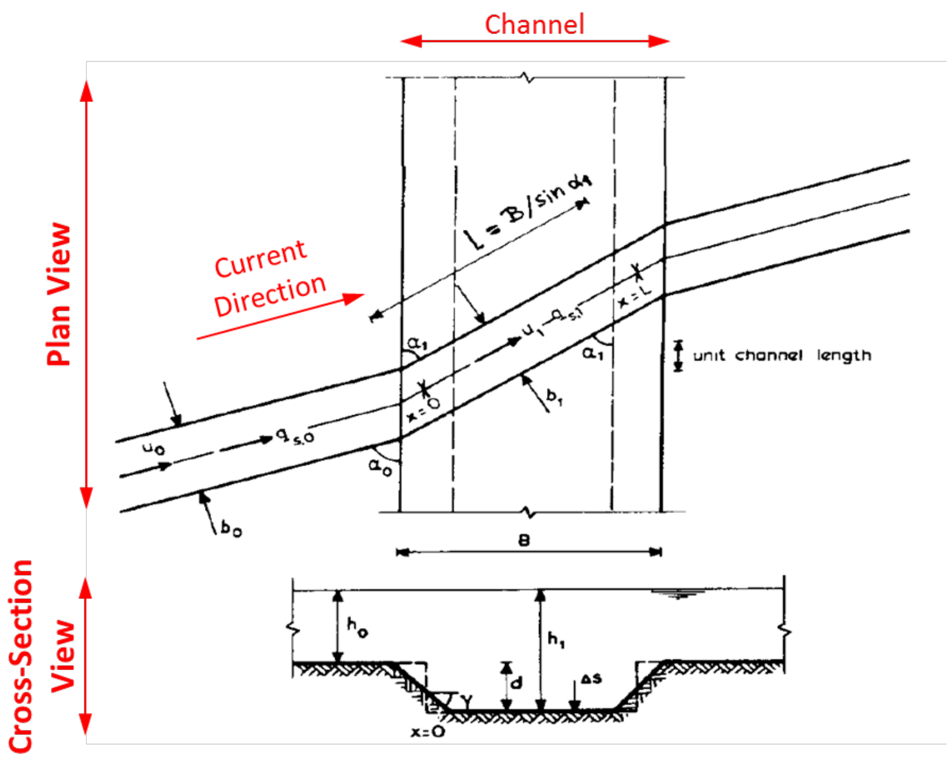


**Figure 3. Schematic of flow over a channel oriented at an arbitrary angle relative to the tidal current direction. Adapted from Van Rijn (2013).**

The application of the Van Rijn method for calculating sediment deposition due to advection and waves requires information on water depth and currents (over the entire tidal cycle), orientation of the channel relative to tidal current direction, SSC, channel geometry, water depths outside the channel, wave characteristics (height and period), particle size characteristics for the sediments in the bed, and settling velocity. This approach was used for NHER and NNC zones (only considering advection, especially due to the predominantly fine sediments depositing in this zone), and for the TSC and AOC zones (considering advection of fine sediments and wave-driven sand transport which are considered to represent the majority of the sediments currently depositing in this zone as described subsequently in this memorandum). The channel geometries were defined using the information presented in Table 1; the remaining inputs were derived using a combination of empirical data and numerical model results as described subsequently.

### 3.3 Volume of Cut Method

In addition to the analytical approaches described above, the future sedimentation rate was also estimated using an empirical approach, namely the Volume of Cut approach (Van Rijn, 2013). According to this approach, the volume of sediment deposited in the channel is related to the volume of sediment that was removed beyond the natural depth (i.e. the volume of cut) to create a channel of given dimensions or to expand an existing channel. For instance, in the example shown in Figure 3, the volume of cut is the cross-sectional area of the channel below the surrounding seafloor, i.e. with depth *d* and associated bottom-width, top-width, and length. Accordingly, this is expressed as:

$$V_d = \gamma V_{Cut} \tag{1}$$

where, $V_d$ is the volume of sediment deposited in the channel on an annual basis, $V_{Cut}$ is the volume of cut, and $\gamma$ is the proportionality factor.

This approach has been applied to the TSC zone as an additional check on the results of the analytical approach. $V_d$ is set equal to the reported current annual average maintenance dredging rate in this zone, and $V_{Cut}$ is calculated using the channel geometry and seafloor depths given in Table 1. The proportionality term $\gamma$ is first calculated using the current channel geometry and the current reported maintenance dredging rate. The future maintenance dredging rate is subsequently estimated using the calculated value of $\gamma$ and the future channel geometry, i.e., the value of $V_{Cut}$ for the future geometry.

## 4. Data

The application of the analytical and empirical methods described in the preceding section requires information on various physical parameters and processes relevant for sediment transport in the study area. Furthermore, the choice of analytical approach to be applied for a given zone depends upon the physical characteristics of the zone as well as an understanding of the physical processes responsible for sedimentation in that zone. This conceptual understanding of sediment transport dynamics in the study area and the inputs and parameters necessary for the various approaches for estimating future sedimentation rates in the study area were derived from a number of sources as described below.

### 4.1 Sediment Substrate

Information on the sediment substrate was obtained from the dredged materials characterization study performed by Fugro (2016a, and 2016b). These reports were reviewed to develop a qualitative understanding of the sediments depositing within the various zones and thus guide the representation of various processes within the analytical methods (eg. only currents, or currents and waves). Based on data presentations of the fine sediment content (fraction smaller than 63 μm) in the surficial sediments of the zones relevant to this analysis, the depositing sediments within these zones were classified as either predominantly fine grained or sandy (for purposes of this analysis, depositing sediments were considered to be the sediment strata located at depths shallower than the authorized channel depth for given zone). Accordingly, the sediments within zones ERC, NH-CIR, NHER, and NNC were considered to be predominantly fine sediments. Based on presentations of cross-sections showing the sediment stratigraphy as well as grain size distribution, the depositing sediments within zone AOC were found to be predominantly sandy, with only about 20% fines content. Based on presentations of cross-sections showing the sediment stratigraphy, the depositing sediments within zone TSC were found to be more variable, with predominantly sandy sediments east of the Chesapeake Bay Bridge Tunnel, and fine sediments to the west. Due to the lack of data on grain size distribution in the depositing sediments, the average fines content over the zone TSC was assumed as 40%. Since typical tidal currents within the TSC and AOC zones are not strong enough to result in appreciable suspended sand transport, the presence of significant sandy sediments in zones TSC and AOC suggests that wave-driven sediment transport in the offshore zone may be the likely mechanism responsible for sediment transport and accumulation within the navigation channel in these zones. Therefore, wave-driven sediment transport was included as a transport process in zones TSC and AOC for the Van Rijn channel sedimentation approach described in Section 3.2. Table 3 lists the composition of the depositing sediments assumed for purposes of this analysis.

**Table 3. Composition of sediments depositing in various zones**

| Zone | Composition of Depositing Sediments |
|---|---|
| ERC | Predominantly fine (100%; smaller than 63 μm) |
| NH-CIR | Predominantly fine (100%; smaller than 63 μm) |
| NHER | Predominantly fine (100%; smaller than 63 μm) |
| NNC | Predominantly fine (100%; smaller than 63 μm) |
| TSC | Mix of fine sediments (40%) and sands (60%; greater than 63 μm) |
| AOC | Predominantly sand (80%) with 20% fine sediment |

In addition to the information on sediment substrate, the data on sediment grain size distribution presented in Fugro (2016a) was also used to develop inputs on the median diameter $D_{50}$, and the $D_{90}$ (the diameter corresponding to the $90^{th}$ percentile passing), both of which are required for the calculation of wave-driven sediment transport. The $D_{50}$ was thus determined as 200 μm and the $D_{90}$ as 1000 μm. Both analytical approaches also require information on the sediment dry bulk density. The formulations calculate the sediment accumulation in terms of mass over a given time period. The mass accumulation rate is converted to a volumetric sediment accumulation rate using the dry bulk density. This was assumed (based on representative values for similar sediments at other sites) to be 31 $lb/ft^3$ for the fine sediments depositing in zones ERC, NH-CIR, NHER, and NNC and 75 $lb/ft^3$ for the predominantly sandy sediments depositing in zone AOC. The sediments in zone TSC were assigned an intermediate dry density of 47 $lb/ft^3$.

### 4.2 Water Quality Data

Information on the average SSC within all the zones and the vertical salinity gradient near the downstream ends of zones ERC and NH-CIR was obtained from the water quality database maintained by the Chesapeake Bay Program (http://www.chesapeakebay.net). Figure 1 shows the locations where relevant data were obtained for purposes of this study. Data collected over 1989-2016 were retrieved for this purpose; sample size was on the order of several hundred at each location. SSC was calculated as an average of the entire dataset, with average SSC of 14 mg/L for zone ERC (station ELD01), 21 mg/L for zone NH-CIR (station LE5.6), 19 mg/L for zones NHER and NNC (station LE5.4), and 20 mg/L for zones TSC and AOC (station CB8.1). The vertical salinity gradient required for the application of the basin sedimentation approach was calculated as an average of surface measurements and of bottom measurements as 16 PSU and 18 PSU, respectively at station ELD01, and 16 PSU and 25 PSU at station LE5.6.

### 4.3 Tidal Current and Water Depth Data

Information on the tidal water depths, tidal range, and tidal currents in the study area were obtained from an existing regional-scale numerical hydrodynamic model of Chesapeake Bay developed by Moffatt & Nichol and used for several marine infrastructure and coastal projects in and around Chesapeake Bay. Figure 4 shows the peak flood and ebb tidal depth-average currents calculated by the model. Maximum currents range between 1-2 ft/s in the vicinity of the navigation channels. Currents were characterized at several locations in the vicinity of the channel in zones NHER, NNC, TSC, and AOC. The average tidal currents over the tidal cycle during a representative tide was specified as an hourly input to the channel sedimentation approach. In addition, Figure 4 also shows the tidal currents oriented at an angle of approximately 10° relative to the channel in most of the study area. This was also an input parameter for the channel sedimentation calculations. Similarly, water level variations over a typical tidal cycle were extracted from the numerical model and used as an input in the channel sedimentation approach. The tidal range associated with a typical tidal cycle was also extracted from the numerical model and used as an input in the basin sedimentation approach.

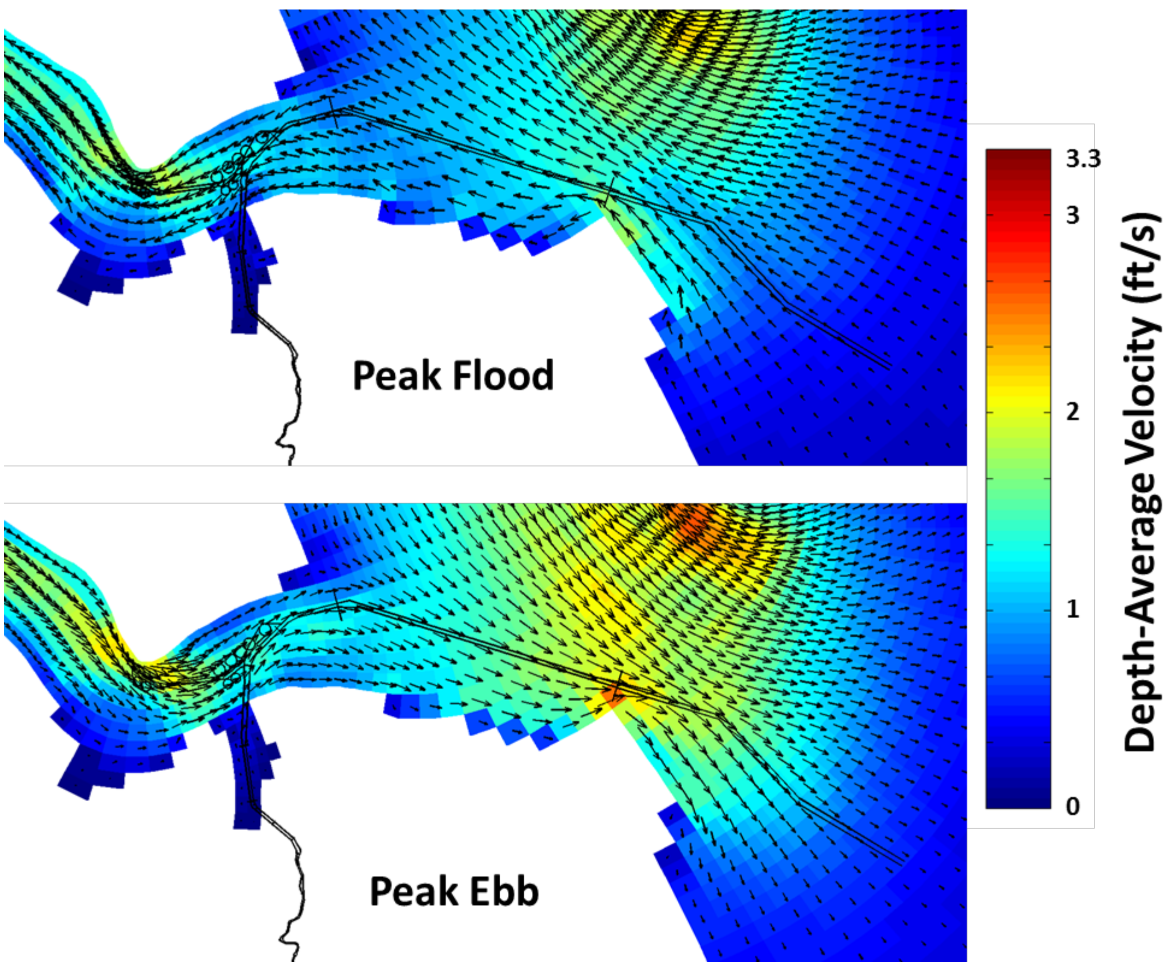


**Figure 4. Snapshot of peak flood and peak ebb tidal currents in the study area.**

### 4.3 Wave Data

Information on the wave climate in the vicinity of the navigation channels in zone AOC was determined using measurements from the NOAA wave gage located at the Chesapeake Light station about 5 miles east of the navigation channel as shown in Figure 1. Figure 5 shows a cumulative probability distribution of the significant wave heights recorded at the Chesapeake Light station over 1984-2004 (http://www.ndbc.noaa.gov/station_page.php?station=chlv2). In addition, wave measurements over 2008-2016 at an adjacent location, Cape Henry, (http://www.ndbc.noaa.gov/station_page.php?station=44099) about 100 feet away were examined. Comparison of wave heights over the two periods suggested that the long-term wave climate was relatively similar. Therefore the measurements at the Chesapeake Light station over 1984-2004 were used for the analyses presented here.

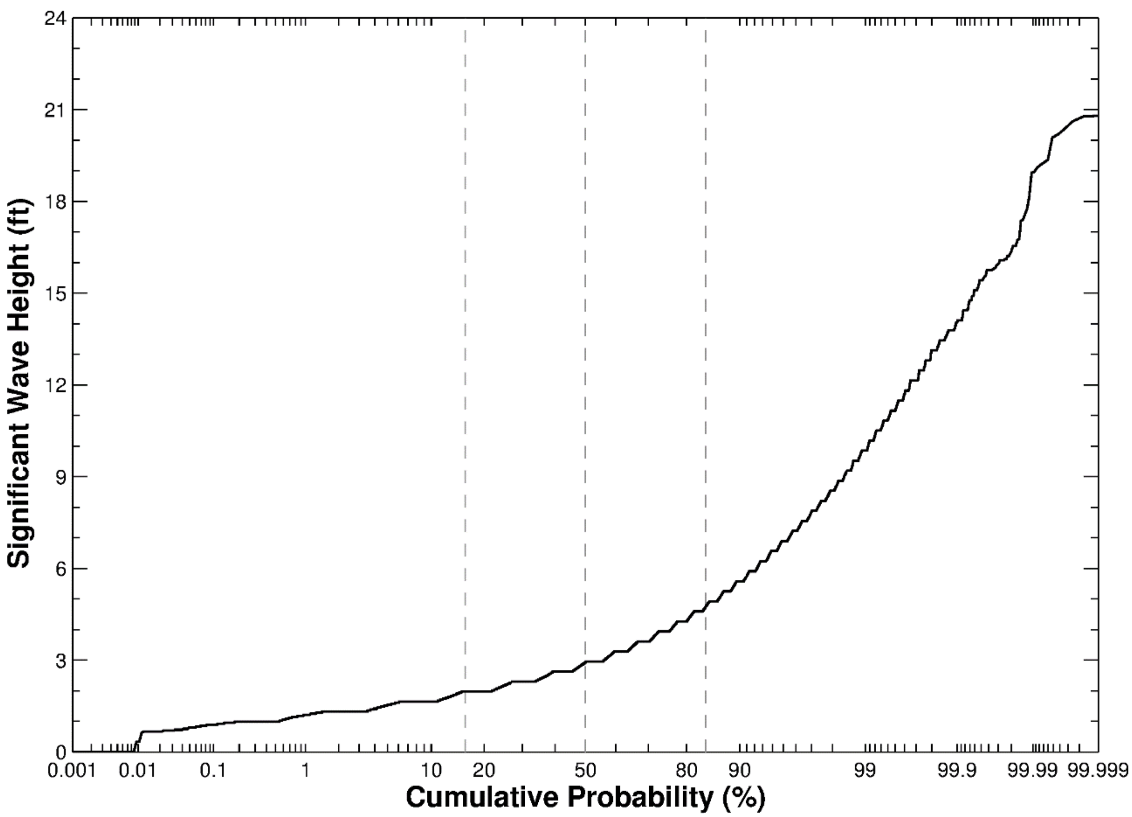


**Figure 5. Cumulative probability distribution of significant wave height measured at the Chesapeake Light station over 1984-2004.**

As seen in Figure 5, historical wave data at the Chesapeake Light location shows significant wave heights in excess of 18 ft occasionally, with wave periods of up to 20 s. In reality, some of these larger wave heights can be expected to be attenuated with distance into Chesapeake Bay and towards the shore, leading to more spatially variable wave characteristics. In other words, wave-driven sediment (mainly sand) transport is expected to decrease in magnitude with distance into Chesapeake Bay. This is also consistent with the observation of sediment stratigraphy and grain size distribution in the depositing sediments in zones AOC and TSC, which show predominantly sandy sediments depositing in zone AOC and towards the eastern end of zone TSC, and finer sediments depositing towards the western end of zone TSC. However, the precise definition of the wave climate within the study area is beyond the scope of this desktop exercise. Rather, the wave climate measured at the Chesapeake Light station has been taken as indicative of the wave characteristics within zone AOC. Since similar information is lacking in zone TSC, the wave data from the Chesapeake Light station is applied to zone TSC, with a calibration parameter in the analytical formulations adjusted to reproduce the reported maintenance dredging rates.

It is a well-accepted that sediment transport rate is a non-linear function of the wave height and period. Therefore, the probability distribution in Figure 5 has been discretized into various wave height conditions (along with corresponding wave periods) and associated with corresponding frequency of occurrence. The average wave height (and associated frequency of occurrence and wave period) was calculated over 0.8 ft intervals. The channel sedimentation calculation was then performed for each of these discretized wave conditions, and the sedimentation rate for the individual wave conditions scaled by the corresponding frequency of occurrence. The integrated sedimentation rate over each of these discrete wave events is then taken to be the annualized estimate of sediment (sand) deposition driven by waves.

### 4.5 Maintenance Dredging Data

In order to calibrate the various methods described in Section 3, available historical dredging records were reviewed. Historic maintenance dredging records were provided by the USACE for the period 1980 to 2014. During this period, the channels were deepened (e.g. Norfolk Harbor Channels were deepened to -50-ft MLW in the 2005 – 2006 timeframe). However, there was no clear indication of an increase in maintenance dredging due to the deepened channels. We note that through informal discussions with USACE personnel it has been suggested that factors such as the following have contributed to what appears to be a decrease in maintenance dredging rate:

- Budget constraints within the USACE have shifted maintenance from a proactive program of advanced maintenance to a more reactive operation focused on correcting deficiencies as they are identified.
- Evolving environmental policies may have contributed to reduced sediment transport and resultant accumulation within the channels.
- Continued trends toward vessels with deeper drafts approaching the limit of the channel, combined with higher vessel traffic may be generating a “self-maintaining” effect as the prop wash of transiting vessels prevents accumulation of sediment within the high-traffic regions.

The available maintenance dredging records were used to develop an estimate of the annual sedimentation rate within the navigation channels in the study area. Historical (from 1980 onwards) and recent data were examined; however, only the post-50’ deepening records were used within the TSC, AOC, NH-CIR, NHER, and NNC zones. Within zone ERC, all available data were used since the 50’ deepening project did not extend to this zone.

Figure 6 shows the current annualized maintenance dredging rate by channel segment based on the afore-mentioned dredging records from the USACE. The dredging rate reported for Norfolk Harbor, Sewells Point to Lamberts Bend represents the dredging within zones NHE and the Norfolk Harbor and Craney Island channels (located in zone NH-CIR). However, the dredging records do not distinguish between these individual channel segments. Therefore, the dredging rate reported for Norfolk Harbor, Sewells Point to Lamberts Bend was apportioned to the Norfolk Harbor Entrance channel and the channels in zone NH-CIR based on the individual segment lengths.

Figure 7 shows the resulting dredging rates, calculated (existing) for the individual zones examined in this study. Note that the dredging rate reported for the anchorage areas in Norfolk Harbor is only about 5,000 cy/year, an order of magnitude smaller than the next higher dredging rate, reported for zone ERC as 53,000 cy/year. Given this relatively insignificant dredging rate, the sedimentation rate calculations have therefore not been performed for the anchorage areas.

In addition, the reported dredging volumes within zone AOC also include some borrow projects. However, the current dredging volume associated with ongoing sedimentation in this zone cannot be separated from the dredging volume associated with the borrow activities (without significant effort in obtaining and reviewing the pre- and post-dredge bathymetric surveys, dredging design documents, etc., as available). Therefore, although this total dredging volume in zone AOC is included in Figure 6 and Figure 7, it is not used in the remainder of the analysis described in this memorandum. The maintenance dredging rate for the remaining zones was considered to be representative of the current sedimentation rate and used in the sedimentation rate calculations as described in the next section. Therefore, the terms maintenance dredging rate and sedimentation rate are used interchangeably in this memorandum.

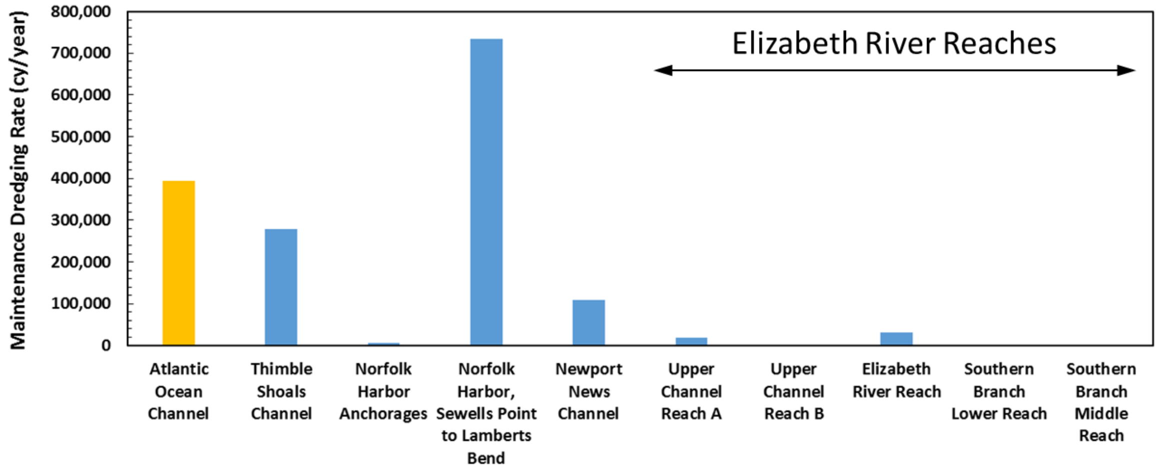


**Figure 6. Current maintenance dredging rates for the various channel segments in the study area based on dredging records from the USACE. Note that AOC dredging data also includes removal associated with borrow activities.**

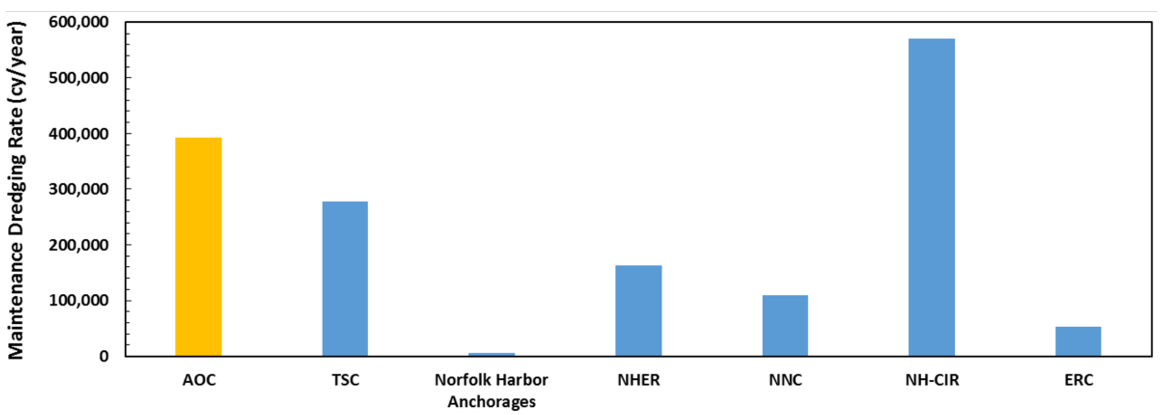


**Figure 7. Current maintenance dredging rates for the zones used for sedimentation calculations based on dredging records from the USACE. Note that AOC dredging data also includes removal associated with borrow activities.**

## 5. Results

Information on the physical processes, physical parameters, and channel geometry described in the preceding sections were used to develop and parameterize the basin and channel sedimentation approaches described previously. Based on the observations of the depositing sediments in the various zones, only fine sediment transport and accumulation was considered in zones ERC, NH-CIR, NHER, and NNC. The sediments accumulating in zones TSC and AOC was considered to be a mix of fine sediments and sands (about 20% fines in AOC and 40% in TSC), and the transport of both sediment types was considered for these zones. Sand accumulation was assumed to be associated only with waves, and fine sediment accumulation was assumed to be associated only with tidal currents, i.e. advection.

The calculations were first performed for current conditions using the current channel geometry, and the effective settling velocity of the sediments optimized to reproduce the reported current maintenance dredging rates. The settling velocity was varied only for the fine sediments in the various zones. In zone TSC, the settling velocity of the fine sediments was adjusted such that the calculated sediment accumulation represented about 40% of the reported current maintenance dredging rate, consistent with the approximate fines content of the depositing sediments. The remainder of the sediment accumulation consists of sands; a calibration parameter which scales the sedimentation rate in the channel sedimentation calculation was adjusted to reproduce the reported accumulation rate for sand in this zone. Physically, this represents the effects of wave attenuation with distance from the wave gage location towards zone TSC. Within zone AOC, due to the uncertainty in the actual sedimentation rate as mentioned previously, the current sedimentation rate was estimated by a direct application of the channel sedimentation approach without the afore-mentioned tuning parameter. In other words, the data measured at the wave gage location was considered to be representative of the wave climate in the vicinity of zone AOC. The sand accumulation in zone AOC was thus estimated and the fines accumulation estimated by adjusting the settling velocity such that fine sediments accounted for 20% of the total estimated sedimentation due to sands plus fines.

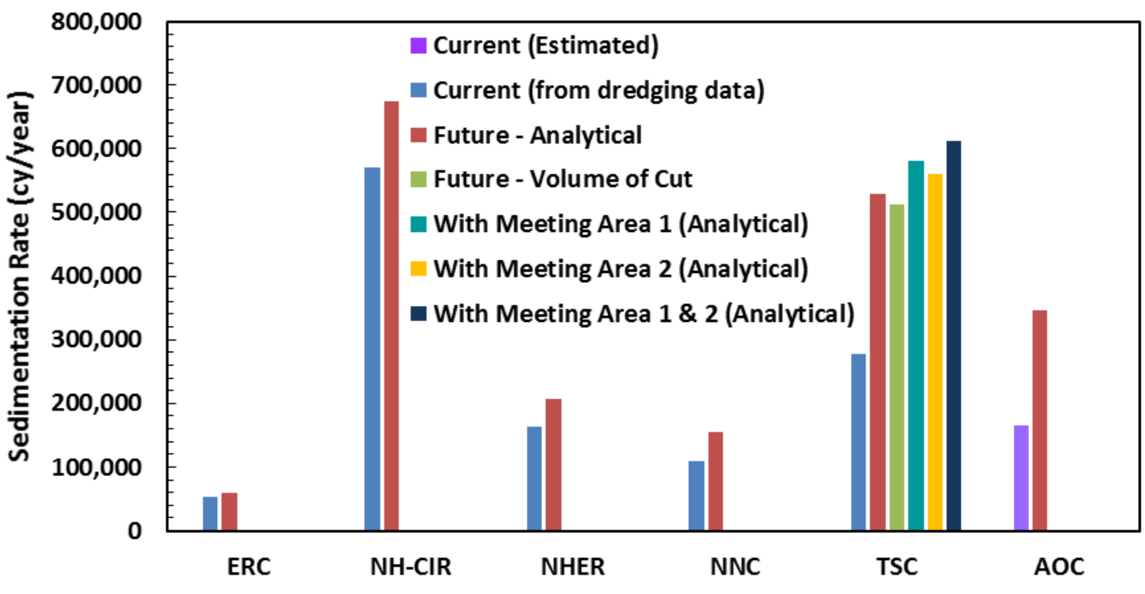


**Figure 8. Current and estimated future sedimentation (maintenance dredging) rates using analytical and empirical approaches.**

Following optimization to reproduce/estimate the current maintenance dredging rates, the settling velocity and other inputs were used to estimate the future sedimentation rates in the various zones using the future channel geometry. Figure 8 shows the resulting estimated future sedimentation rates (same as maintenance dredging rates) using the analytical approaches compared to the current maintenance dredging rates. The relative increase in the estimated future maintenance dredging rates (compared to current conditions) is shown in Figure 9. Table 4 summarizes the results presented in Figure 8 and Figure 9.

For zone TSC, the calculations were performed for a base channel configuration (which does not include either meeting area), with Meeting Area 1, with Meeting Area 2, and with Meeting Area 1 & 2.The relative increase in the maintenance dredging rate ranges from a low of 11% in zone ER to 120% in zone TSC (with Meeting Areas 1 & 2). In four of the six zones (ERC, NH-CIR, NHER, and NNC), the increase in sedimentation rate is less than 42%. Converting the volumetric sedimentation rates into an average bed accretion rate over each of the zones results in somewhat smaller increases under future conditions – 7% for ERC, 16% for NH-CIR, 24% for NHER, and 39% for NNC. The bed accretion rates may be considered to be more relevant to issues such as limiting depths for navigation, and the frequency of maintenance dredging. The additional sedimentation in these areas is due to changes in sediment trapping efficiency, additional water exchange (due to salinity gradients and horizontal eddies) in the case of ERC and NH-CIR, and partly due to the increased cross-sectional area of the channel under future conditions (since the top width of the channel is a function of the channel depth for given side slope). Note that the assumption of additional water exchange driven by the salinity gradient is consistent with the results of the interim hydrodynamic model (Zhang et al., 2016) which shows increased salinity (which implies additional water exchange) in the Elizabeth River under future conditions (with deepened navigation channels) as compared to existing conditions.

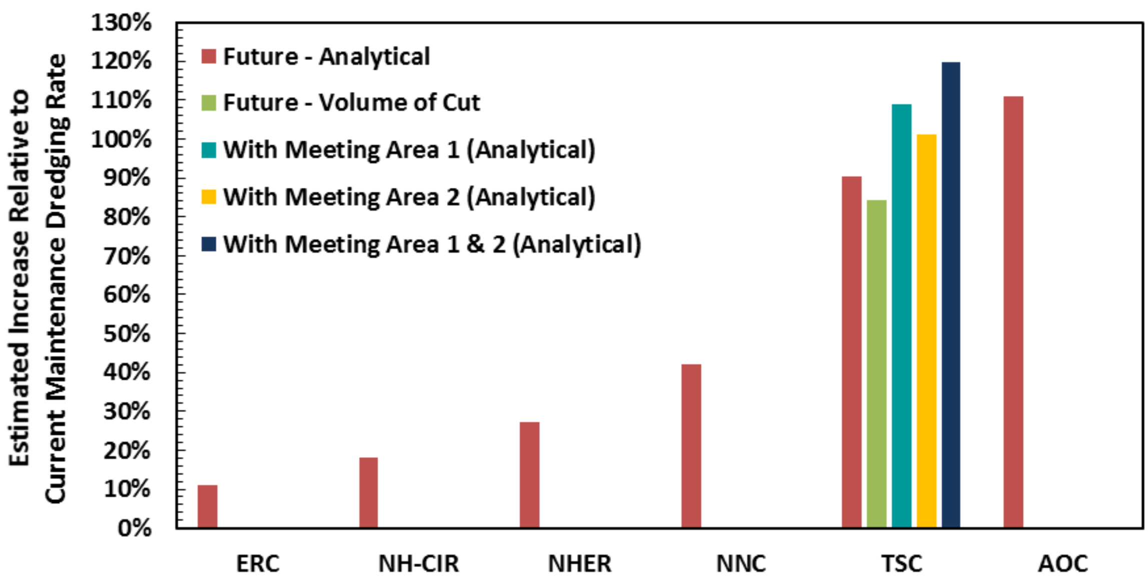


**Figure 9. Relative increase in estimated future maintenance dredging rate relative to current conditions using analytical and empirical approaches.**

In comparison to the zones within Norfolk Harbor and the Elizabeth River, zones TSC and AOC show significantly larger sedimentation rates (up to 120% higher than current conditions). In order to provide another line of evidence in this regard, the future sedimentation rate for zone TSC (for the base channel configuration without either meeting area) was also estimated following the volume of cut approach described previously. Terms $V_d$ and $V_{Cut}$ in Eq. (1) were determined using the current maintenance dredging rate and the current channel geometry. The proportionality term $\gamma$ was calculated using Eq. (1). The future estimated maintenance dredging rate was then calculated using the calculated value for $\gamma$ and the future channel geometry. These estimates are also included in Figure 8, Figure 9, and Table 4.

**Table 4. Current and estimated future maintenance dredging rates and the relative increase from current rates using the analytical and empirical approaches. Estimated current maintenance dredging rate indicated by an asterisk.**

| Zone | Maintenance Dredging Rate (cy/yr) | | | Relative Increase (%) | |
|---|---|---|---|---|---|
| | Current[6] | Future - Analytical[7] | Future – Empirical[7] | Future - Analytical | Future - Empirical |
| ERC | 53,152 | 59,063 | - | 11% | - |
| NH-CIR | 570,601 | 674,762 | - | 18% | - |
| NHER | 163,029 | 207,192 | - | 27% | - |
| NNC | 109,624 | 155,922 | - | 42% | - |
| TSC | 278,135 | 529,182 | 512,308 | 90% | 84% |
| TSC w/ Meeting Area 1 | 278,135 | 581,337 | - | 109% | - |
| TSC w/ Meeting Area 2 | 278,135 | 559,717 | - | 101% | - |
| TSC w/ Meeting Areas 1 & 2 | 278,135 | 611,344 | - | 120% | - |
| AOC | 164,359* | 346,506 | - | 111% | - |

The results from the empirical approach are very similar to the results from the analytical approach for zone TSC with the estimated future maintenance dredging rate 84% higher than current maintenance dredging rate – in comparison, the analytical approach estimates a 90% increase. The reason why both the analytical and empirical approaches predict a significantly larger sedimentation rate is likely related to the current and proposed channel depths in relation to the natural channel depths in this zone. Review of the channel geometries in Table 1 shows that compared to the natural channel depth of 40' in this zone, the current channel is only 10' below the surrounding seafloor. Following the proposed deepening, the channel bottom will be located between 18' below the surrounding seafloor. This represents roughly a doubling of the channel depth relative to the adjacent seafloor compared to current conditions. The volume of cut approach, which gives maintenance dredging rates that scale with the depth of the channel bottom relative to the adjacent seafloor (i.e., the volume of the dredge cut), accordingly calculates a near-doubling of the maintenance dredging rates from current conditions. From a physical standpoint, compared to current conditions, the near-doubling of the channel bottom relative to the adjacent seafloor causes a significant decrease in sediment transport capacity (due to both tidal currents and waves), thereby increasing the trapping efficiency of the channel, and thus

[6] Based on maintenance dredging records provided by the USACE except for zone AOC which is an estimate for the reasons described in the text.
[7] Estimates developed using the proposed future channel geometry as shown in Table 1.

increasing the maintenance dredging estimates with the future channel geometry in the analytical approach.

The volume of cut approach provides an additional line of evidence and an empirical check on the results of the analytical approach in zones TSC. It should be noted that barring zone AOC, none of the other zones exhibit a similar magnitude of increase in the channel depths relative to the natural depths. The increase in channel depth relative to natural depths ranges from 25% to about 40% for the other zones. As a consequence, sediment trapping efficiency, and therefore sedimentation rates are not estimated to increase as dramatically for the other zones.

## 6. Summary

The future maintenance dredging rates within the navigation channels in and around Norfolk Harbor have been estimated in a desktop study using a combination of analytical and empirical approaches. The analyses make use of the channel geometries, information on the physical forcings, and the physical parameters responsible for sediment transport and deposition in the study area. Data from a number of sources was utilized as part of this analysis. The performance of the analytical approaches was constrained by the reported current maintenance dredging rates; this provides a measure of confidence in the projected future maintenance dredging rates. The analytical approaches calculate increases in maintenance dredging rates (on volumetric basis) of less than 42% within Norfolk Harbor and Elizabeth River. The largest increase in estimated maintenance dredging rate is in the Thimble Shoals and Atlantic Ocean channels, primarily driven by a large future increase in channel depth relative to the adjacent seafloor depths. The results of the analytical approach for these channels are also comparable to an empirical approach, namely the volume of cut approach.

The desktop analysis presented in this memorandum represents a first-order estimate of the future sedimentation rates. A number of caveats and limitations are inherent in the results from such an approach. Some of these caveats and limitations include, in no particular order:

- The analyses rely on a limited study/understanding of sediment dynamics and transport in the study area.
- The analyses do not explicitly consider any spatial variation in the wave climate within the study area.
- The analyses are based on limited information on the sediment substrate within the study area which provides source material for the sands deposited in the navigation channel in zones TSC and AOC. In particular, the analytical solutions assume an equilibrium condition or an unlimited supply of sediments available for deposition in the navigation channels.
- The application of the analytical approach within zone TSC relied on an assumption of the fines content in the depositing sediments in this zone.
- The analytical approaches are based on limited calibration/validation (only to historical maintenance dredging rates). More sophisticated approaches for estimating future sedimentation rates would involve numerical modeling tools, which would be calibrated/validated against various metrics such as water levels, wave characteristics, currents, salinity, SSC, sediment fluxes, and bathymetric changes in addition to historical maintenance dredging rates. The extensive calibration/validation involved with such tools would provide more confidence in the future estimates of sedimentation rate than the results of the desktop study presented here.

Resolving these limitations will involve a much larger level of effort in various aspects – data collection and analysis, numerical model development (hydrodynamics, waves, and sediment transport), and model application. Although such studies have been performed at other sites around the world in a similar context, the level of effort involved is likely to be orders of magnitude larger than involved in this desktop study. However, such a study would provide more confidence in the estimates of future sedimentation rates, and can provide a better spatial and temporal resolution of the sedimentation patterns.

## 7. References

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# Appendix D:
# DMMP

**Elizabeth River and Southern Branch Navigation Improvements, Virginia**

**Dredged Material Placement Plan**

# 1 Introduction

USACE policy (ER 1105-2-100 section 3-2b(8) Dredged Material Management Plans) states the following:

> *Dredged material management planning for all Federal harbor projects is conducted by the Corps to ensure that maintenance dredging activities are performed in an environmentally acceptable manner, use sound engineering techniques, are economically warranted, and that sufficient confined disposal facilities are available for at least the next 20 years. These plans address dredging needs, disposal capabilities, capacities of disposal areas, environmental compliance requirements, potential for beneficial usage of dredged material and indicators of continued economic justification. The Dredged Material Management Plans shall be updated periodically to identify any potentially changed conditions*

A Preliminary Assessment conducted as a part of this project concluded that there was sufficient disposal capacity for a 20-year period and identified the least cost disposal plan (Technical Memorandum dated 25Jul16). The Preliminary Assessment evaluated placement alternatives for each channel segment and identified the least cost placement site and any beneficial use opportunities for that material. Each placement site identified in the Preliminary Assessment, including beneficial use sites, has completed the requirements of the National Environmental Policy Act (NEPA) of 1969, which evaluated the potential environmental consequences dredged material placement at each site.

The existing DMMP for the Federal navigation projects at Hampton Roads is based on three placement areas: the Craney Island Dredged Material Management Area (CIDMMA) and the Norfolk Ocean Dredged Material Disposal Site (ODMDS). Additional upland sites are considered in this DMMP as a site for material unsuitable to be placed at the above mentioned areas. Although considered, there are no known beneficial uses of the predominately sits and clays to be dredged from these channels.

This Dredged Material Placement Plan (DMPP) is organized as follows:

- Chapter 2: Characteristics of material dredged from each channel segment;
- Chapter 3: Placement area site characteristics and material requirements (including beneficial use sites);
- Chapter 4: Historical quantities and placement locations for maintenance and construction material;
- Chapter 5: Dredging and placement projections for 20 years

- Chapter 6: Identification of the least cost plan (the Federal standard).

On 4 August 2016, a Vertical Team Meeting was held on this project to discuss the Dredged Material Management Plan (DMMP). The meeting was conducted as a webinar and the attached PowerPoint presentation was used to facilitate the discussion. The DMMP was to be presented in the GRR/EAs as component to support the Plan Formulation Appendix. The Vertical Team concurred with the PDT's way forward on the DMMP for this study.

# 2 Sediment Characteristics

The sediments within the navigation channels are briefly discussed below. A detailed discussion of project sediments is contained in the Geotechnical attachment to the Engineering Appendix. Planning reaches (Table 1) identify the grouping of channel reaches used for plan formulation.

**Table 1: Navigation Channel Dimensions**

| | | Channel Depth (ft) | | Channel Width (ft) | | |
|---|---|---|---|---|---|---|
| Planning Reach | Channel Reaches | Authorized | Constructed | Authorized | Constructed | Length (miles) |
| Segment 1 | Elizabeth River Reach | 45 | 40 | 750 | 750 | 3.4 |
| | Southern Branch Lower Reach | 45 | 40 | 750 | 750 | 2.0 |
| | Southern Branch Middle Reach | 45 | 40 | 375 | 375 | 1.0 |
| Segment 2 | Upper Channel Reach A | 40 | 35 | 250-500 | 250-500 | 2.6 |
| Segment 3 | Upper Channel Reach B | 35 | 35 | 300 | 300 | 0.5 |
| | Upper Channel Reach C | 35 | 35 | 250 | 250 | 1.5 |

## 2.1 Segment 1: Elizabeth River Reach and Southern Branch Lower Reach

Geotechnical and environmental sediment sampling was completed most recently in this reach to support the Navy deepening. The Navy project was completed using hydraulic dredge with the material (~3.2 MCY) being direct pumped into the upland cells of CIDMMA. Based on the available data and prior projects, the material from this reach is assumed be hydraulically dredged and placed into the upland cells of the CIDMMA. The sediments in this reach are predominately clay and silt sized particles, with areas of variable sand content. Based on the available data and prior projects material in this reach is assumed be hydraulically dredged and placed into the upland cells of the CIDMMA.

## 2.2 Segment 1: Southern Branch Middle Reach

The last maintenance dredging in this reach was in 2003, with the material being mechanically dredged and placed the CIDMMA re-handling basin. This reach passes by the EPA superfund site, Atlantic Woods Industries (AWI). Dredging at AWI, by the EPA, is ongoing (adjacent to the channel), with material being placed behind a sheet pile wall along the AWI property. Environmental sampling in the channel (within the federal channel limits), and below the depth of the maintenance material, is limited. There is data from sampling within several adjacent properties (e.g., AWI, Apex Oil, Enviva, and Seagate) that provide an indication that some material within the federal channel would likely not be suitable for placement in the CIDDMA (either directly or in the re-handling basin). Riverbed sediments in this reach contain some sand, overlain by clay and silt. The layers are highly heterogeneous.

Based on the available data and prior projects, it is recommended (for the GRR study and cost estimates) that the material from this reach be assumed to be mechanically dredged and barged to an upland placement area suitable to take contaminated material (i.e., not CIDMMA). Additional sampling is planned for PED.

## 2.3 Segment 2, Upper Channel Reach A

The last maintenance dredging in this reach was in 2003, with the material being mechanically dredged and placed the CIDMMA re-handling basin. This reach passes along an area with prior creosote plants ("Money Point" area) and has well-documented areas of high TPHs. Extensive sampling and testing results are available in this reach, most recently by the USACE in 2014. Environmental sampling below the depth of the maintenance material is limited; however, available information from prior testing suggests the material would not be suitable for CIDMMA.

Based on available data and prior projects, it is recommended (for the GRR study and cost estimates) that the material from this reach be assumed to be mechanically dredged and barged to an upland placement area suitable to take contaminated material (i.e., not CIDMMA). Additional sampling is planned for PED.

## 2.4 Segment 3, Upper Channel Reach B and C

The last maintenance dredging in Reach B was in 2003, with the material being mechanically dredged and placed the CIDMMA Re-handling basin. Reach C has not been maintained since it was originally constructed in the late 1970's. Limited sampling and testing results are available in this Segment, with the most recent data from the USACE in 2014. Environmental sampling below the depth of the maintenance material is limited; however, available information from prior testing suggests that all of the material would not be suitable for CIDMMA.

Based on the available information and knowledge of the area, it is recommended (for the GRR study and cost estimates) that the material from this Segment be assumed to be mechanically dredged and barged to an upland placement area suitable to take contaminated material (i.e., not CIDMMA). Additional sampling, should this Segment be economically justified, would be necessary during PED.

# 3 Placement Areas

Craney Island Dredged Material Management Area (CIDMMA) has historically served and will continue to serve this project. The Craney Island Eastward Expansion (CIEE), which was authorized by Congress in 2007, will also be available to supplement the confined placement available at CIDMMA. Beyond the timeframe of the existing DMMP, when current CIDMMA reaches its capacity, least cost maintenance dredging is expected to be similar in cost to disposal within the existing CIDMMA, based on continued efforts to optimize CIDMMA, capacity in the Craney Island Eastward Expansion, and availability of Norfolk Ocean Disposal Site as appropriate.

Alternative upland/confined placement sites are also developed to allow for placement of material unsuitable for placement at CIDMMA.

No beneficial use sites have been suggested based on the character of the material.

## 3.1 Craney Island Dredged Material Management Area (CIDMMA)

CIDMMA is approximately two miles square with existing ground elevations within the cells varying from approximately +32 to +40 feet MLLW. CIDMMA receives dredged material which is pumped hydraulically into the cells. Dredged material is typically pumped in over the east dike. This is evidenced by the large sand mounds observed at the influent points where these heavier sand particles quickly settle out of the dredge slurry. Existing external dikes range in elevation from +35 to +45 feet MLLW.

CIDMMA is currently operated using the guidance from the existing DMMP prepared in 1981. The 1981 DMMP estimated that, over its operating life, CIDMMA would be able to accept over 250 MCY of dredged material (since it began operation in 1957), a significant increase over the original capacity estimate of 96 MCY.

The existing DMMP is based on the current configuration of CIDMMA, which is divided into three cells: South Cell (734 acres for storage), Center Cell (766 acres for storage) and North Cell (689 acres for storage). Currently Norfolk District rotates each of the three cells as necessary to allow adequate drying before dredged material is again pumped into the cell. The District also typically caps the volume of dredged material that can be pumped into an individual cell at no more than 5 MCY annually. Monthly inflows are typically limited to 650,000 CY.

The Norfolk District currently has an annual earthwork/grading contract to maintain and raise the perimeter and division dikes. Under this contract, approximately 750,000 CY of granular material is excavated and placed on the dikes annually. The material is borrowed from the eastern side of CIDMMA using conventional excavation equipment and hauled using off-road trucks to the required location. Existing dikes are continually maintained to compensate for consolidation settlement of the marine clay foundation beneath the dikes, and the need to maintain adequate freeboard on the dikes.

Each cell has two spillboxes along the west dike. Spillboxes are operated by the dredging contractor pumping into the cell. The dredging contractor is responsible for ensuring effluent being released from CIDMMA is clarified water. The contractor verifies by sampling the effluent total suspended solids (TSS). The target or goal is to release only clarified water from the spillboxes, with the daily average effluent TSS concentration of 500 mg/l as an upper action limit. Typically measured effluent TSS values are 100 mg/l or less.

As determined in the Craney Island Eastward Expansion Feasibility Report (USACE, 2006), capacity of CIDMMA is defined as when the dikes can no longer be raised. The CIEE Feasibility Report determined the maximum height of +50 feet MLLW without additional modifications to the subsurface or geometry.

CIDMMA capacity is regularly increased to meet short-term inflow projections by raising the height of the dikes. Under current conditions, the dikes are capable of being raised to elevation 50 feet, allowing for an interior fill height of 47 feet. With the dikes at 50 feet, and no additioan foundation improvements, the CIDMMA foundation is anticipated to have reached its bearing capacity (USACE, 2006).

The CIEE Feasibility Report estimated that CIDMMA would achieve its full capacity in 2025, which includes acceptance of 118 mcy from 2000 to 2025. Actual inflows from 2000 – 2015 are 69 mcy, indicating that remaining capacity is 49 mcy. This remaining capacity estimate is currently being revised with updated fill level and dike elevations.

Beyond the timeframe of the existing DMMP, when current CIDMMA reaches its capacity, least cost maintenance dredging is expected to be similar in cost to disposal within the existing CIDMMA, based on continued efforts to optimize CIDMMA, capacity in the Craney Island Eastward Expansion, and availability of Norfolk Ocean Disposal Site as appropriate. The Norfolk Ocean Dredged Material Disposal Site is a U.S. Environmental Protection Agency (USEPA) designated ocean disposal site, located approximately 35 miles from CIDMMA and 17 miles east of the mouth of the Chesapeake Bay.

## 3.2 Norfolk Ocean Dredged Material Disposal Site (ODMDS)

The Norfolk Ocean Disposal Site (NODS) is a 42,600-acre area, with an estimated total capacity of 1,300 MCY. The site is delineated by a circle with a radius of 4 nautical miles centered at 36 degrees, 59 minutes north latitude, and 75 degrees, 39 minutes west longitude. Water depth at the site ranges from 43 to 85 feet. NODS was developed, in part, to receive material after CIDMMA had achieved its capacity:

> *If in the future the Craney Island Dredged Material Management Area (Norfolk, Virginia) is no longer available, suitable material currently placed in the Craney Island DMMA could be placed in the ODMDS. (NODS Site Management Plan, February 2009)*

The Norfolk Ocean Disposal site is permitted to receive both coarse and fine grained materials that meet the Environmental Protection Agency's (EPA) requirements for ocean disposal. The site has been used since 1979. The current Site Management and Monitoring Plan (SMMP) is dated February 2009 and will be in effect until 2019.

Material dredged for placement at NODS will most likely be dredging via hopper dredge, although mechanical dredging with material transported to the site using bottom dump scows may be used. Placement will be performed and monitored in accordance with the Norfolk District's SMMP.

## 3.3 Craney Island Eastward Expansion

The Craney Island Eastward Expansion's (CIEE) Southeast Cell is currently under construction, with its completion dependent on state and Federal funding. If available at the time of the proposed deepening, the cells could be considered as a placement area. The CIEE project expands the existing CIDMMA to the east by constructing a new approximately 522-acre placement area. The cell will be subdivided with a cross dike to form the Southeast Cell and the Northeast Cell. With the proposed filling to elevation +18 feet MLLW, the Southeast Cell and Northeast Cell have a neat volume capacity of 6.7 and 12.7 MCY respectively. This is the volume within the cell, and does not include bulking of the dredged material. Following this initial filling a large amount of fill/capacity is required/available to make up for ongoing consolidation settlement of the placed dredged fill and the soft foundation clays. Consolidation settlements are estimated to be on the order of 20 to 30 feet. Because of this, additional dredged material will be placed as settlement is occurring to make up for that volume lost due to settlements. The initial capacity together with this additional fill provides for a 43.5 MCY capacity for the CIEE. The capacity is documented in the recent Limited Reevaluation Report (LRR, USACE, 2015).

CIEE will effectively provide an additional cell to CIDMMA. After the cell dikes are completed (confined), filling with material from both the proposed deepening and maintenance dredging can occur.

Hydraulic filling will be similar to what is currently done at the existing CIDMMA by the use of a hydraulic pipeline cutterhead dredge.

## 3.4 Upland Sites

New work dredging within the Elizabeth River and Southern Branch Navigation Improvements study area is anticipated to generate material with contamination that exceeds the acceptance criteria of CIDMMA or in-water placement sites. This dredged material will need to be disposed of at an approved upland site(s). This section summarizes potential upland placement areas for dredged material that does not meet the acceptance criteria established for the CIDMMA and conclusions supporting which upland site(s) to use for plan formulation.

The following upland placement/disposal sites were identified and vetted during development of the GRR:

- Charles City County Landfill
- CFS, Tri-City Regional Landfill & Recycling Center
- John C. Holland Enterprises Landfill

- Southeastern Public Service Authority (SPSA) Regional Landfill
- Portsmouth City Craney Island Landfill
- Bethel Landfill
- King and Queen Sanitary Landfill

Additionally, the following soil processing services were identified:

- Port Tobacco/Weanack Land, LLC (also can accept some dredged material)
- Clearfield MMG, Inc. Soil Recycling

Based on availbe information, the PDT's recommendation is to assume material that is not suitable for CIDMMA to be mechanically dredged and transported by barge to Port Weanack (approximately 70 nautical miles via the James River). Once at Port Weanack, the material would be processed and loaded onto 12 CY dump trucks for placement in one or both of the nearby landfills for permanent placement. The local landfills include the Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg, with one-way truck haul distances of 13 and 17 miles, respectively.

In discussing the project with the other facilities noted, some concern was expressed regarding the volume of dredge material. Therefore, Port Tobacco/Weanack, in conjunction with Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg, appears to be the most viable upland disposal sites depending on the contamination levels found in the dredge material. This recommendation is similar to completed projects in the Elizabeth River.

### 3.5 Beneficial Use Sites

Due the material in the Elizabeth River and Southern Branch of the Elizabeth River Navigation Improvements, Virginia being predominately fine grained sediments (2016, Fugro) there is no known opportunity for beneficial use of the dredged material.

## 4 Historical Placement

The placement of material dredged from the Elizabeth River and Southern Branch reaches has historically been to the CIDMMA. Table 2 below presents the historical placement of material dredged from these reaches.

Table 2: Norfolk Harbor Channels Dredged Material Volumes and Placement Locations

| ERSB Historical Maintenance Dredging | | | |
|---|---|---|---|
| Year | Dredging Volume (cy) | Dredging Location | Placement Location |
| 1991 | 538,611 | Segment 1 | CIDMMA |
| 1993 | 341,707 | Segment 1 | CIDMMA |
| 1997 | 100,577 | Segment 1 | CIDMMA |
| 2003 | 201,675 | Segment 1 | CIDMMA |
| 1981 | 239,271 | Segment 2 | CIDMMA |

| | | | |
|---|---|---|---|
| 1989 | 172,894 | Segment 2 | CIDMMA |
| 1993 | 74,118 | Segment 2 | CIDMMA |
| 1995 | 29,243 | Segment 2 | CIDMMA |
| 1999 | 34,928 | Segment 2 | CIDMMA |
| 2004 | 127,283 | Segment 2 | CIDMMA |

# 5 Projected Future Dredged Material Volumes

## 5.1 Construction Material

Table 3 presents the new work dredged material volumes for authorized (WRDA 1986) 45-foot Southern Branch project as an example of potential dredged material quantities and placement locations. These volumes will be revised upon final selection of the recommended plan. In total, for the authorized 45-foot project approximately 2.5 mcy of would be dredged, with 0.7 mcy being placed in CIDMMA and up to 1.8 mcy being placed in an upland confined site.

**Table 3: Example of Potential New Work Volumes**

| | Reach | Controlling Depth | Actual Depth | Volume, CY | Placement Area, New Work |
|---|---|---|---|---|---|
| Segment 1 | Elizabeth River Reach | 45 | -47 | 610,000 | CIDMMA |
| | Southern Branch Lower Reach | 45 | -47 | 90,000 | CIDMMA |
| | Southern Branch Middle Reach | 45 | -47 | 270,000 | Upland - Landfill |
| Segment 2 | Upper Channel Reach A | 40 | -42 | 730,000 | Upland - Landfill |
| Segment 3 | Upper Channel Reach B | 35 | -37 | 20,000 | Upland - Landfill |
| | Upper Channel Reach C | 35 | -37 | 730,000 | Upland - Landfill |
| | Total | | | 2.45 MCY | |

## 5.2 Maintenance Material

As an example of potential future maintenance volumes, Table 4 presents estimated maintenance volumes for the authorized -55-foot Norfolk Harbor Channel project. The available maintenance dredging records were used to develop an estimate of the annual sedimentation rate within the navigation channels in the study area. Historical (from 1980 onwards) and recent data were examined and used for developing the sedimentation rate (see Engineering Appendix Section 5 Future Maintenance Quantities) and future annualized maintenance dredging quantities.

**Table 4: Example of Potential Annualized Maintenance Volumes**

| | Reach | Controlling Depth + Overdredge (feet, MLLW) | Current Annualized Dredge Volume (CY) | Proposed Annualized Maintenance Volume (CY) |
|---|---|---|---|---|
| Segment 1 | Elizabeth River Reach | -47 | 31,600 | 33,510 |
| | Southern Branch Lower Reach | -47 | 1,430 | 1,510 |
| | Southern Branch Middle Reach | -47 | 670 | 720 |
| Segment 2 | Upper Channel Reach A | -42 | 100 | 110 |
| Segment 3 | Upper Channel Reach B | -37 | 17,700 | 19,650 |
| | Upper Channel Reach C | -37 | - | - |
| | Total | | 53,170 | 57,360 |

## 6 Identification of the Least Costs Plan

The primary planning objective of a DMMP is to identify the Federal Standard, or the base plan, which is the least costly disposal plan consistent with sound engineering practice that meets all Federal environmental standards and meets placement needs for the 20-year planning horizon (Planners Guidance Notebook, USACE, 2000).

For the Elizabeth River and Southern Branch Navigation Improvements project, with no known beneficial use opportunities, the least cost disposal plan becomes a function of maximizing the material that is suitable for placement in CIDMMA, which is the closest available placement facility (Figure 1). All dredged material removed from the Elizabeth River and Southern Branch of the Elizabeth River must be transported past CIDMMA on the way to an alternative placement site. Material dredged from the Elizabeth River Reach and the Southern Branch Lower Reach may be pumped to CIDMMA, which further reduces placement costs. Placement costs for this material range from approximately $8.50 to $11.50 per cubic yard. Material that is unsuitable for placement in CIDMMA, which would also not be suitable for ocean disposal, would be placed at an alternative upland site as discussed above, at estimated prices ranging from $100.00 to $130.00 per cubic yard.

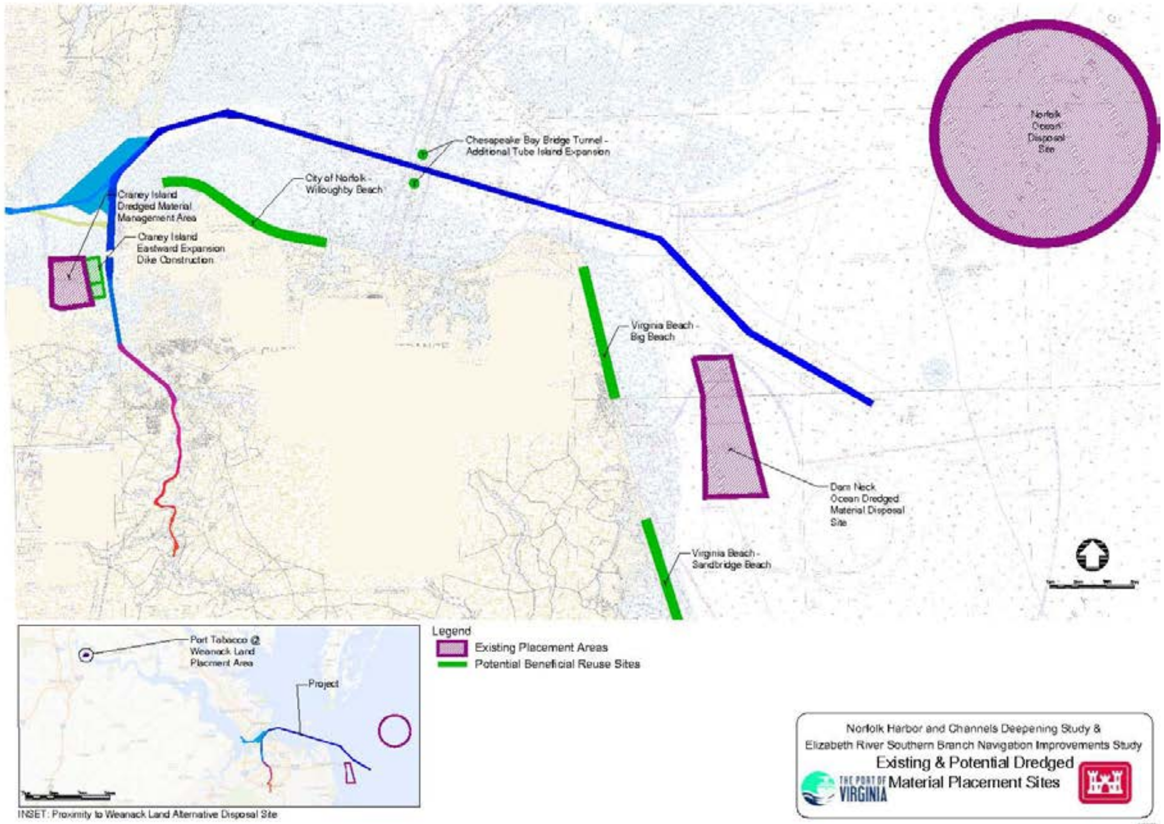


Figure 1: Dredged Material Placement Areas

This DMMP is based on new work material from Segment 1, Elizabeth River Reach and Southern Branch Lower Reach, being placed in CIDMMA, the lowest cost alternative. Other reaches, where the contamination may preclude the use of CIDMMA, used the least cost disposal of barging the material to Port Weanack on the James River, and trucking the material to the Charles City landfill and/or the CFS, Tri-City Regional Landfill & Recycling Center in Petersburg.

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USACE (2009), Site Management and Monitoring Plan for the Norfolk Ocean Disposal Site (NODS), February 2009.

CENAO-PM-C 24 August 2016

MEMORANDUM FOR RECORD

THRU: Douglas Stamper, Project Manager, Programs and Civil Works Branch

Mr. Richard Klein, Chief, Programs and Civil Works Branch

Ms. Susan Conner, Chief, Planning and Policy Branch

FOR: Office Files

SUBJECT: Norfolk Harbor and Channels and Elizabeth River Southern Branch Deepening Projects

1. On 4 August 2016, a Vertical Team Meeting was held on the subject projects to discuss the Dredged Material Management Plan (DMMP) for each of the ongoing general reevaluation studies. The meeting was conducted as a webinar and the attached PowerPoint presentation was used to facilitate the discussion. The following individuals participated in the meeting:

- Norfolk District: Doug Stamper, Susan Conner, Kristen Scheler, Richard Harr, Rachel Haug, Alicia Logalbo, Richard Klein, Robert Pruhs, Mike Anderson,
- VPA: Jeff Florin, Ira Brotman, Mike McGarry
- DDNPCX: Idris Dobbs, Todd Nettles, Eric Bush, Daniel Small, Kim Otto,
- NAD: Naomi Fraenkel
- HQUSACE (OWPR): Jeremy LaDart

2. The purpose of the meeting was to meet the following goals:

- Ensure that the DMMPs being developed for both studies meet the DMMP requirements for feasibility-level studies (**See Slide 2**);
    - o Provides for 20 years of placement capacity
    - o Establishes a base plan (least cost placement plan)
    - o Assesses potential for beneficial use
    - o Demonstrates economic justification
    - o Provides agency review and consultation
    - o Provides public involvement
    - o Demonstrates consistency with environmental requirements

- Demonstrate that continuing the current dredged material management practices will fulfill the DDMP requirements; and

- Obtain Vertical Team (NAD, DDNPCX, and HQUSACE) concurrence.

3. The following paragraphs present the major points of discussion focused on the meeting goals presented in paragraph 2.

a. Provides for 20 years of Placement Capacity. The location of the Norfolk Harbor and Channels Deepening Project and the Elizabeth River Southern Branch Navigation Improvements Project are show on **Slide 3** and the projected quantities for construction and 20-year maintenance for each project are shown on **Slide 4**.

Although no complete and approved DMMP currently exists for each of the two projects, all of the information, as presented, currently exists and additional calculations are being done to assure 20+ years of capacity for each project. The needed capacity currently exists (**See Slide 5**) at a combination of the three existing placement areas (**See Slide 6**) consisting of the Dam Neck Ocean Dredged Material Disposal Site (ODMDS), the Norfolk ODMDA, and the Craney Island Dredged Material Management Area (CIDMMA). Specific information, including estimated total capacity, was presented on **Slides 7, 8, and 9**, respectively.

b. Establishes a Base Plan (Least Cost Placement Plan). The PDT has established the following Least Cost (Base) Dredged Material Placement Plan for each project, as follows;

- Norfolk Harbor and Channels Deepening (**See Slides 10 and 11**): Plan consists of using the ODMDSs for the Thimble Shoal and Atlantic Ocean Channels and the CICMMA for the Norfolk Harbor Channel; and

- Elizabeth River Southern Branch Navigation Improvements (**See Slides 12**): Plan consists of using the CIDMMA for the suitable material and several potential upland sites for the material unsuitable for placement at CIDMMA (**See Slide 17**). One potential site, Port Tobacco at Weanak (**See Slides 17 and 18**), has proven to be a successful dredged material handling site and transfer area to the Charles City County Landfill.

c. Assesses Potential for Beneficial Use**.** Beneficial Use Opportunities (**Slides 14 and 15**)
- Big Beach, Sandbridge, Willoughby, CIEE, and CBBT
- To be addressed in more detail during PED Phase
- Based on Sponsor need, timing, and incremental costs

d. Demonstrates Economic Justification, Provides Agency Review and Consultation, Provides Public Involvement, and Demonstrates Consistency with Environmental Requirements. As indicated on **Slide 19**, dredged material placement is a component of the GRR/EA for each project. The DDMPs will be presented in the GRR/EAs as components of the Plan Formulation

Appendix for both studies which will ensure that economic justification, agency review and consultation, public involvement, and environmental consistency determination will be addressed for each project.

e. Demonstrate that continuing current dredged material management practices fulfills DMMP requirements. Continued management of CIDMMA and ODMDS sites using our existing proven successful practices will ensure long-term capacity for the project. As will be outlined in the DMMP.

4. Comments provided by the Vertical Team:

- Although the DMMP accounts for 20 years, please note that the economics for the plan formulation must account for 50 years of disposal. RESPONSE: Understood

- Please note that the eastward expansion of Craney Island has a different cost-share (86/14) than most projects. RESPONSE: noted

- Question on ocean disposal permitting now and in the future. RESPONSE: The Ocean Disposal Sites are permitted though 2019 (needs to be confirmed) and the PDT is confident that these sites will continue to be approved for use in the future (needs to be confirmed by Robert Pruhs).

- Ensure that PDT looks at beneficial use sites. RESPONSE: Although that is not the base plan, it will be mentioned in both the DMMP and the NEPA document for both studies that beneficial use opportunities exist and those will be evaluated in the future based on needs and timing.

- PDT needs to verify and document that the least cost that was originally established is still the least cost plan today. RESPONSE: Concur and PDT will document this.

5. In summary (Slide 20), both DMMPs meet all requirements from ER 1105-2-110 and continues existing dredged material management practices. The DDMPs will be presented in the GRR/EAs as components of the Plan Formulation Appendix for both studies. The Vertical Team concurred with the PDT's way forward on the DMMP for both studies.

Prepared with notes provided by Susan Conner, Chief, Planning and Policy Branch, and Douglas Stamper, Project Manager, Programs and Civil Works Branch.

Robert N. Pretlow, Jr., PE, PMP
Project Manager
Programs and Civil Works Branch
USACE, Norfolk District

ATTACHMENT

# Dredged Material Placement Plan for the

## Norfolk Harbor and Channels Deepening Project

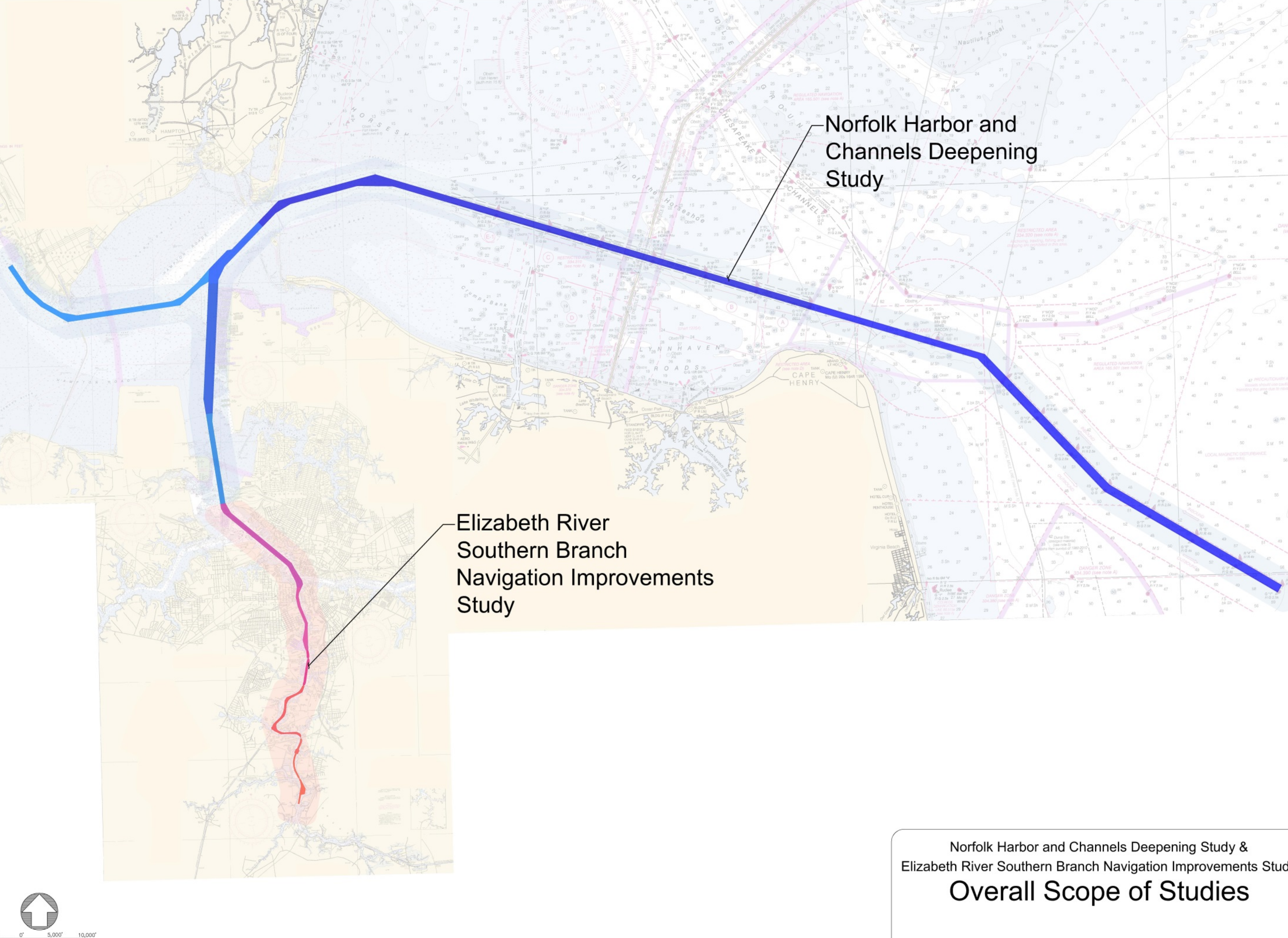
## And

## Elizabeth River and Southern Branch Navigation Improvements Project General Reevaluation Studies

28 July 2016

# Meeting Objectives

- Demonstrate that the DMMP for NH & ERSB
  - Provides for 20-years of placement capacity
  - Establishes a base plan (least cost placement plan)
  - Assesses potential for beneficial use
  - Demonstrates economic justification
  - Provides agency review and consultation
  - Provides public involvement
  - Demonstrates consistency with environmental requirements
- Demonstrate that continuing current dredged material management practices fulfills DMMP requirements




Norfolk Harbor and Channels Deepening Study &
Elizabeth River Southern Branch Navigation Improvements Stud

## Overall Scope of Studies

# Projected Quantities

- Norfolk Harbor
  - Construction: 35 MCY *(2/3rds to Offshore)*
  - Annual maintenance: 1.5 MCY to 2 MCY
  - 20-year total: 65 MCY to 75 MCY
    - *Offshore: 45 MCY*
    - *CIDMMA: 22 MCY*
- Eliz. River and So. Branch
  - Construction: 1.7 MCY
  - Annual maintenance: 60,000 CY
  - 20-year total: 2.5 MCY
    - Upland: 1 MCY
    - CIDMMA: 2 MCY

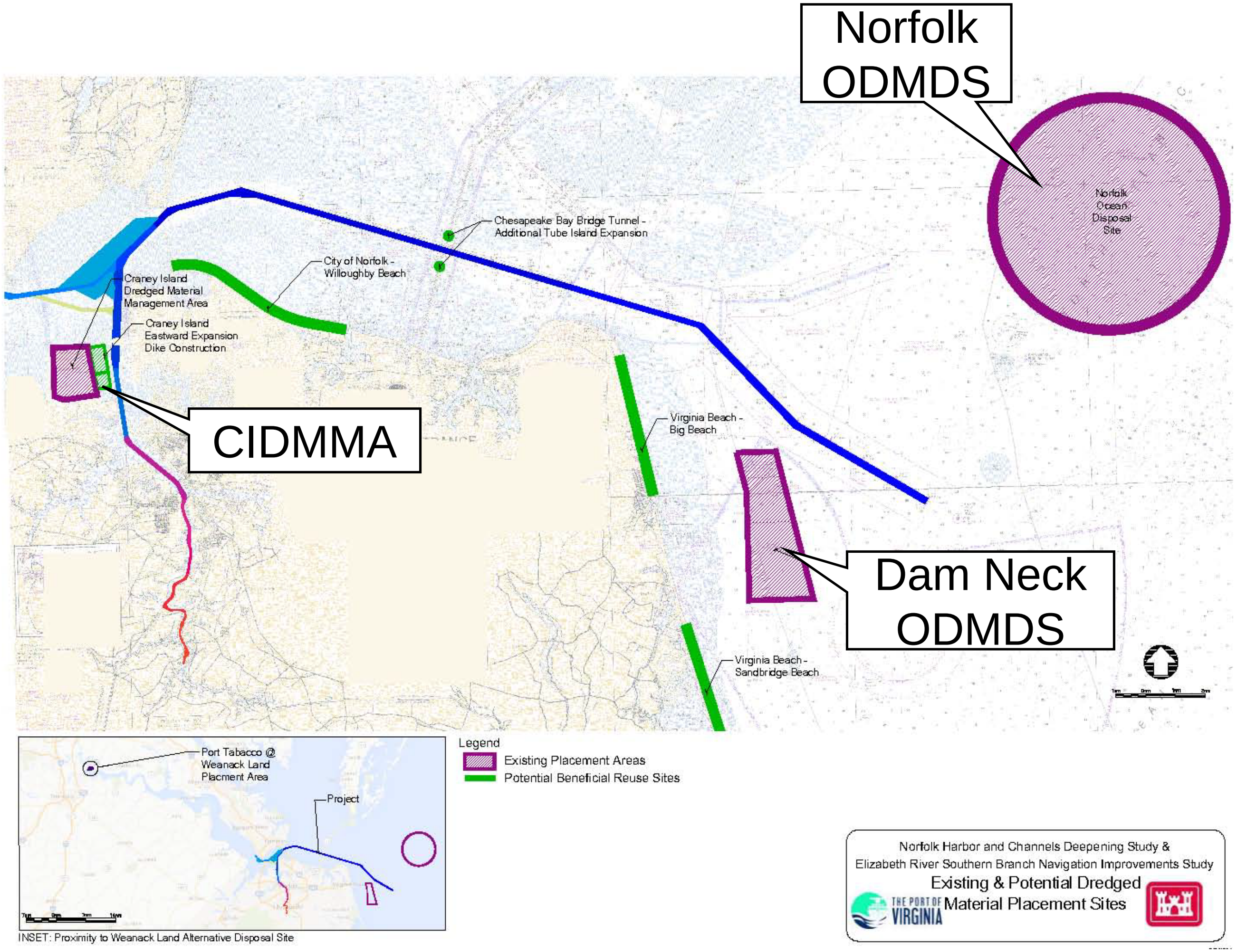
# Capacity Availability

- DMMP Based on 3 Established and Operating Placement Areas
  1. Dam Neck ODMDS
     - Initiated in 1970’s current SMMP 2009 - 2019
  2. Norfolk ODMDS
     - Initiated in 1970’s current SMMP 2009 - 2019
  3. CIDMMA
     - Feasibility Study & NEPA 1981
     - In continuous use since 1981

# Placement Areas

DMMP Exist. At Each:

- Dam Neck
- Norfolk
- CIDMMA



# Dam Neck Ocean Dredged Material Disposal Site (ODMDS)

- ~9-square Nautical Miles
- Water Depth ~40 feet
- Designed for Min 50 MCY
- SMMP allows for possible capacity expansion
- No Time of Year Restrictions

# Norfolk Ocean Dredged Material Disposal Site (ODMDS)

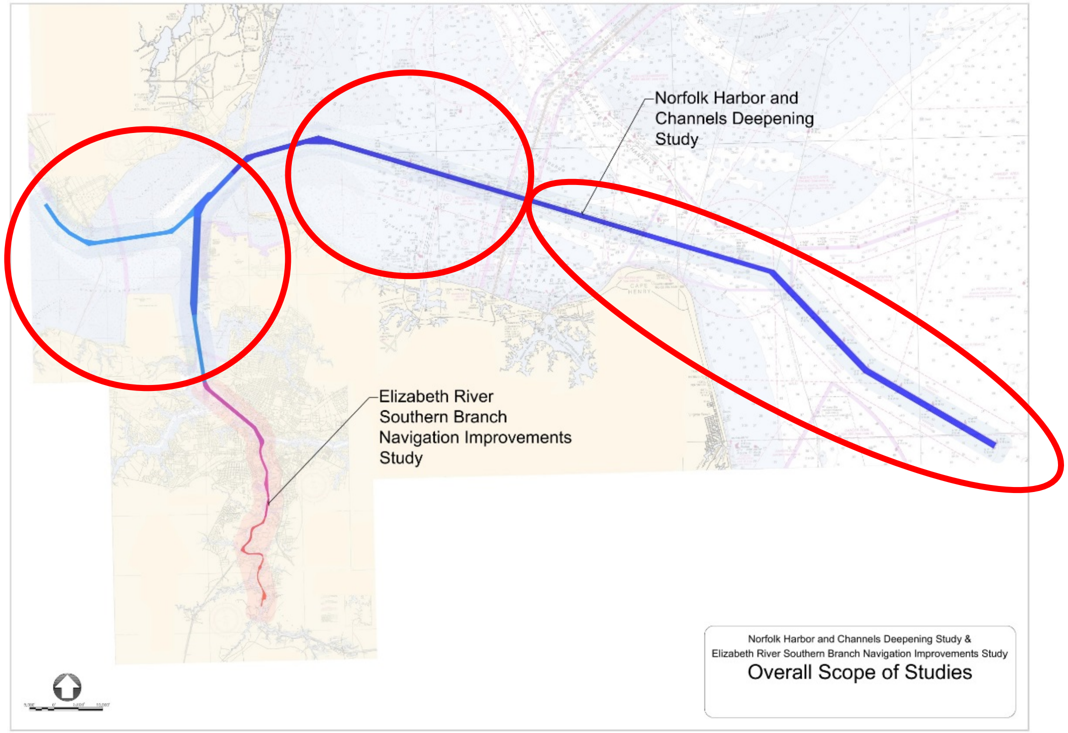
- Estimated total capacity of 1,300 MCY.
- Circle With a Radius of 4 NM (50 square NM)
- Water Depth ~43 to 85 feet
- Designed for Post-CIDMMA

# Craney Island Dredged Material Management Area Capacity

- CIDMMA, Feas Report:
  - Feas Report, Capacity ~117 MCY (2000 to 2025 )
  - Actual Inflows 2000 to 2015 ~65 MCY
  - Therefore, 117 MCY – 65 MCY = 52 MCY Capacity
  - Needs to be validated
- CIEE:
  - Adds 43 MCY to CIDMMA capacity
  - CIEE Acts as CIDMMA's 4$^{th}$ Cell
  - SE Cell Scheduled for early 2020
- Total CIDMMA & CIEE capacity = >95MCY

# Norfolk Harbor – Least Cost Plan

- Ocean Channels: TSC and AOC
  - Offshore Disposal
- Norfolk Harbor Reaches
  - CIDMMA



# “55-foot” NHC – Least Cost Plan

| Reach | Nominal Depth | Actual Depth | Comments | Volume, MCY | Placement Area |
|---|---|---|---|---|---|
| **Atlantic Ocean Channel** | 55 | -60 | 57' Reqd + 3' Allowable Overdepth | 6.5 | Dam Neck |
| **Thimble Shoal Channel** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 8.2 | Dam Neck |
| **TSC Meeting Area #1** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 8.7 | Dam Neck |
| **TSC Meeting Area #2** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 2.6 | Dam Neck |
| **Norfolk Harbor Sewells Point to Lamberts Bend** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 6.1 | CIDMMA |
| **Channel to Newport News** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 2.4 | CIDMMA |
| **Anchorage F** | 55 | -57 | 55' Reqd + 2' Allowable Overdepth | 0.6 | CIDMMA |
| **Total** | | | | **35.2** | |

Summary of New Work by Placement Area:

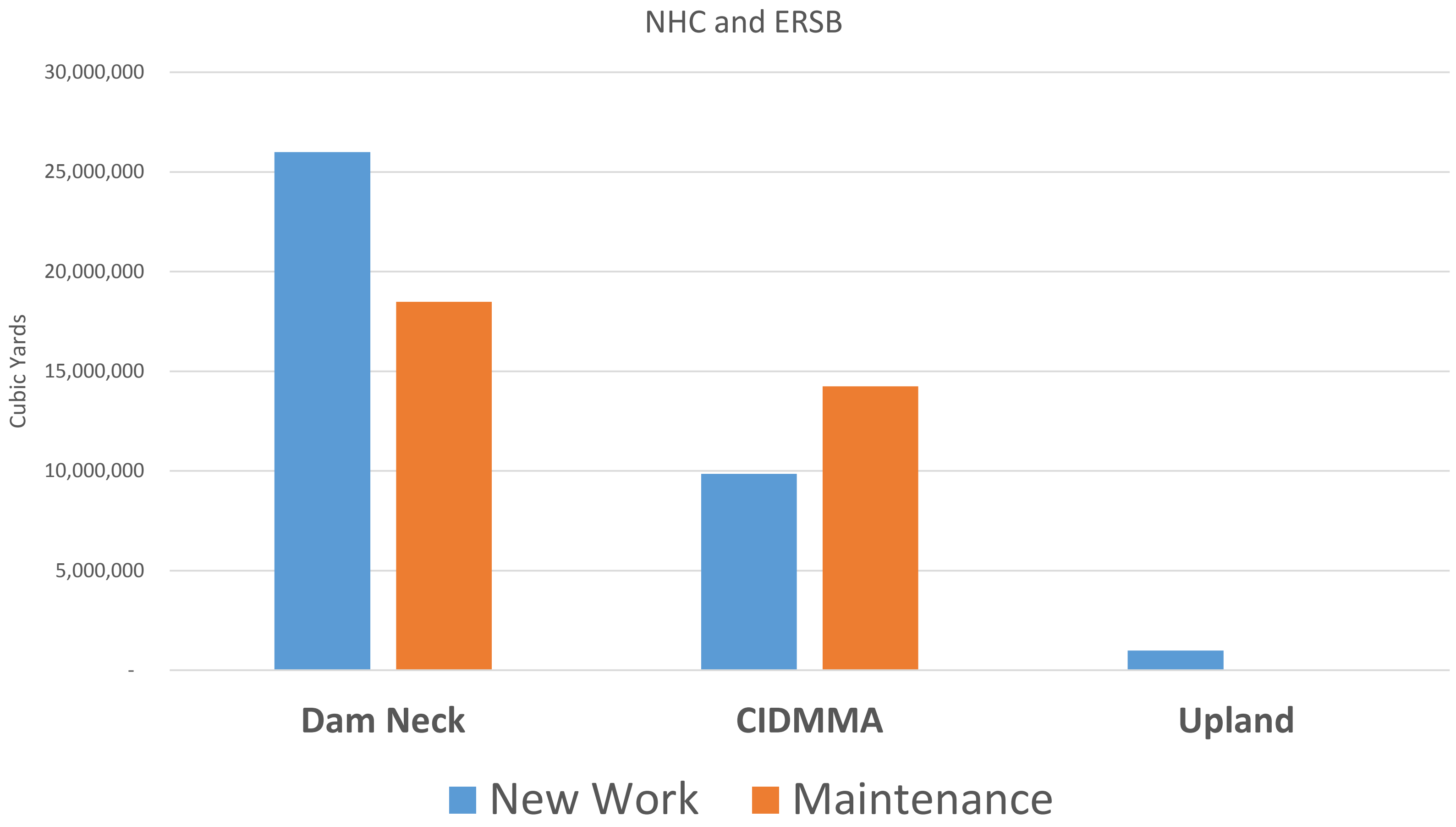
- Offshore: ~26MCY
- CIDMMA: ~9 MCY

# ERSB – Least Cost

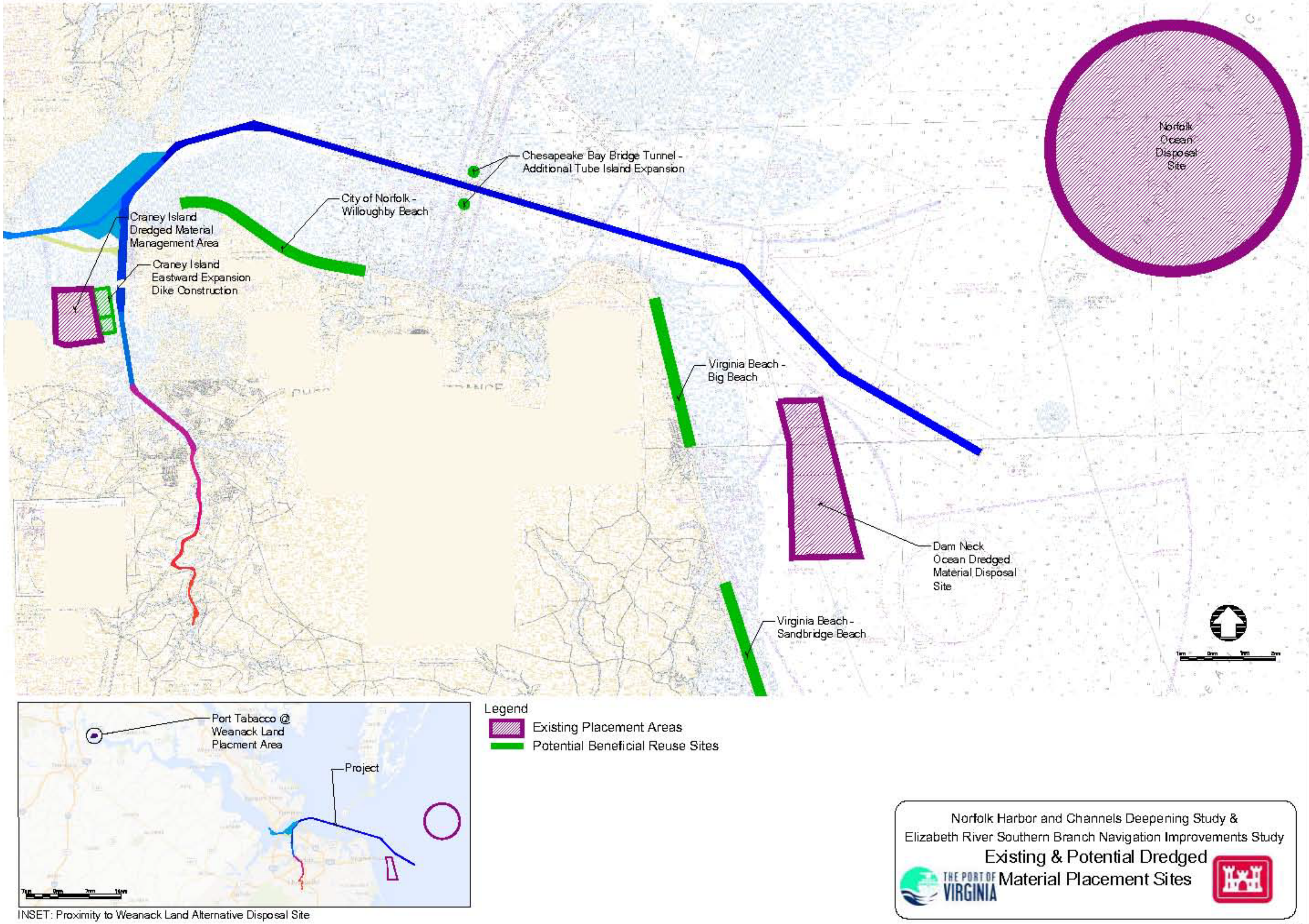
| | | Least Cost Plan | | |
|---|---|---|---|---|
| **Reach** | **Quantity (CY)** | **Placement Area** | **Unit Cost** | **Total Cost** |
| **Elizabeth River Reach (-45')** | 610,000 | CIDMMA | $6.58 | $7.7M |
| **Lower Reach (-45')** | 90,000 | CIDMMA | $11.66 | $1.1M |
| **Middle Reach (-40')** | 270,000 | Port Tobacco /Landfill | $88.48 | $23.9M |
| **Upper Reach A (to -40)*** | 726,000 | Port Tobacco /Landfill | $88.36 | $64.2M |
| **Upper Reach B (to -37)*** | 19,000 | Port Tobacco /Landfill | $103.49 | $2.0M |

* No beneficiaries – dredging unlikely

# New Work and 20-YR Maintenance Dredging Estimate



# Beneficial Reuse Sites



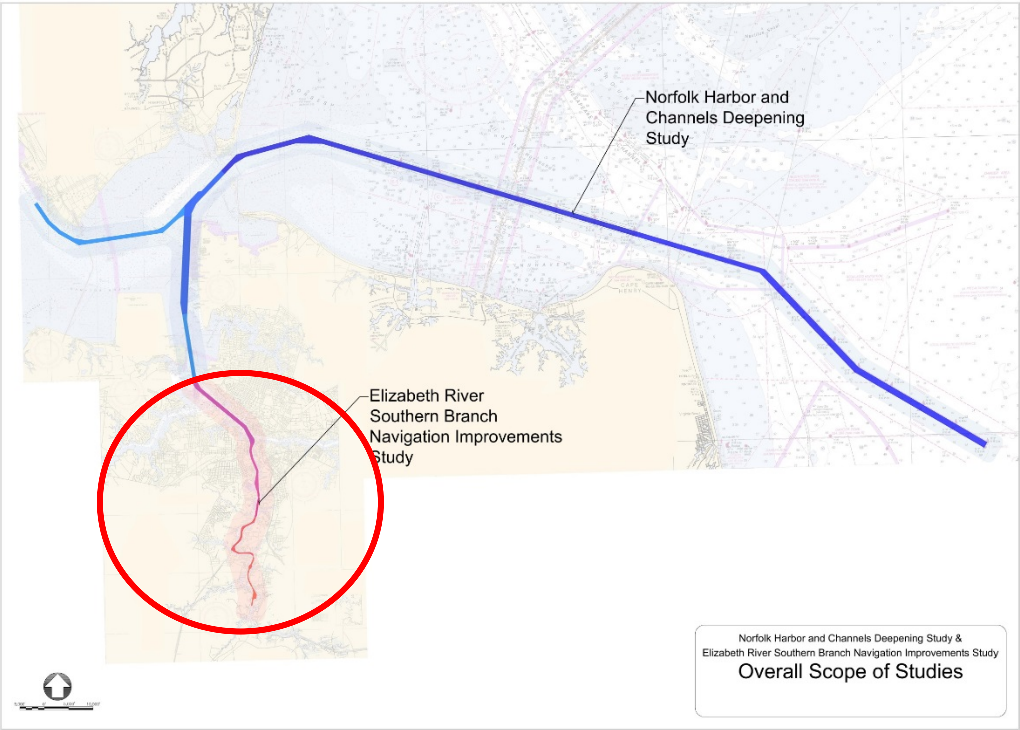
# Beneficial Reuse Sites

- NEPA Compliant
- Limited to sandy areas, including TSC (East of CBBT), AOC and TSC Meeting Area #2
- No ERSB beneficial use

| | | Least Cost Plan | | | Beneficial Use Plan | | |
|---|---|---|---|---|---|---|---|
| **Reach** | **Quantity** | **Placement Area** | **Unit Cost** | **Total Cost** | | **Unit Cost** | **Total Cost** |
| **Atlantic Ocean Channel** | 6.5 MCY | Dam Neck | $5.37 | $36.7M | Big Beach | $7.99 | $57.6M |
| **Thimble Shoal Channel East** | 1.4 MCY | Dam Neck | $7.82 | $12.1M | Willoughby | $9.36 | $15.3M |
| **TSC Meeting Area #2** | 2.6 MCY | Dam Neck | $7.36 | $20.2M | Willoughby | $8.19 | $23.4M |

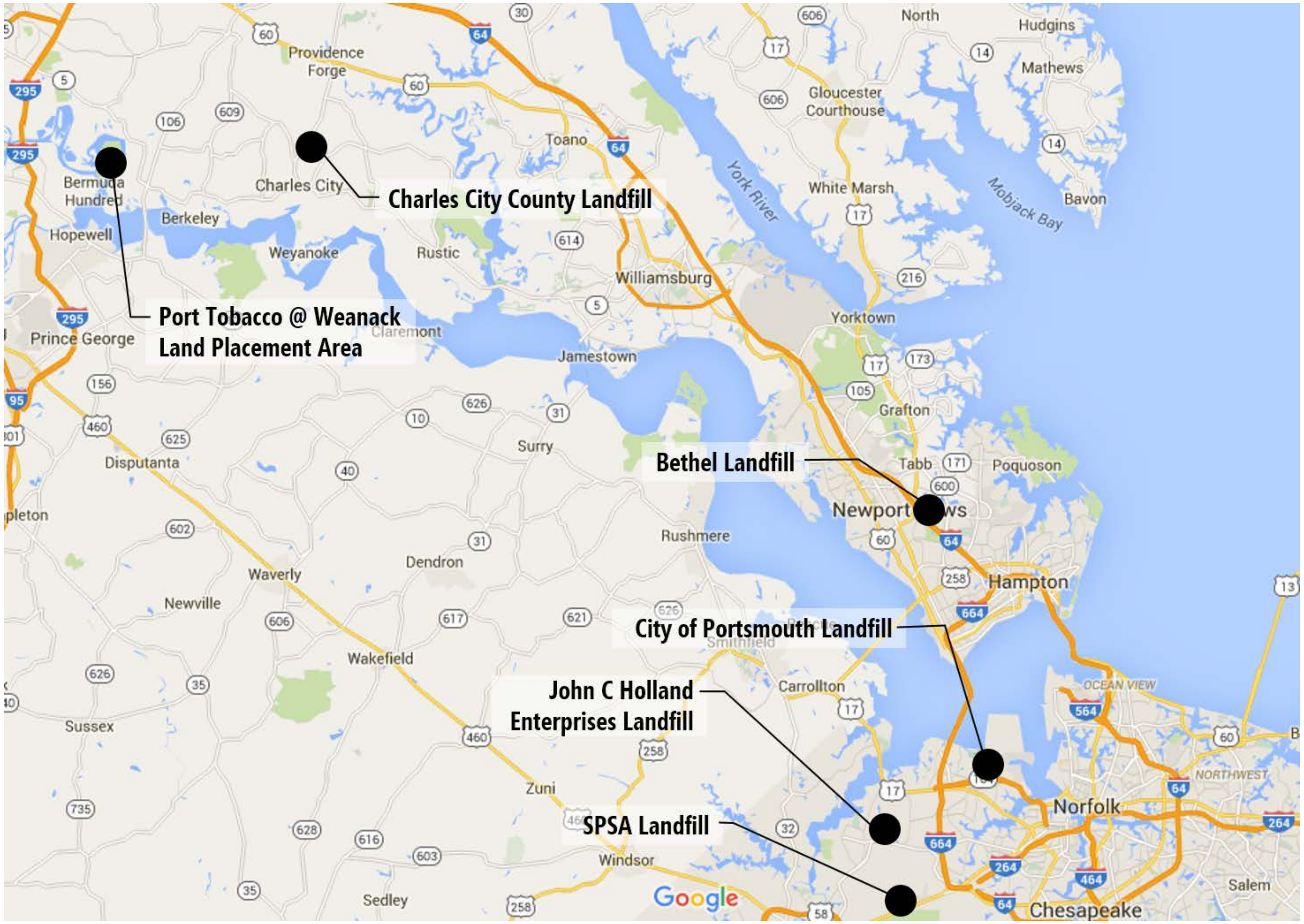
# ERSB – Some Material Unsuitable for CIDMMA

- Southern Branch
  - CIDMMA
  - Upland



# Upland Sites
# Material Unsuitable for CIDMMA

- Southern Branch



# Port Tobacco @ Weanak

- Successful track record of handling dredged material on site and transfer to Charles City County Landfill
- Current capacity to receive ~1MCY
- Expansion capacity to ~2MCY (authorized under existing permits)

# Dredged Material Placement is a Component of the GRR/EA

- Included in economic justification
- Included in agency review & consultation
- Included in public involvement
- Included in the environmental consistency determination

# DMMP Summary

- DMMP meets all requirements from ER 1105-2-110
  - Section 3.2b(8), and
  - Appendix E Section E-15
- Will be presented in the GRR/EA as a component of the Plan Formulation Appendix
- Continues existing dredged material management practices