DRAFT DETAILED PROJECT REPORT

TANGIER ISLAND JETTY
ACCOMACK COUNTY, VIRGINIA
SECTION 107
NAVIGATION STUDY

APPENDIX A
ENGINEERING, DESIGN AND COST ESTIMATES

U.S. Army Corps of Engineers
Norfolk District
803 Front Street
Norfolk, Virginia 23510

TANGIER ISLAND JETTY, ACCOMACK COUNTY, VIRGINIA SECTION 107, NAVIGATION STUDY, DRAFT DETAILED PROJECT REPORT
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PURPOSE

The purpose of this appendix is to provide detailed information concerning the engineering design (coastal and geotechnical engineering) related aspects of the study area and are shown in two reports attached to this appendix. Detailed cost estimates are also included.

The technical report entitled *Modeling Study for Tangier Island Jetties, Tangier Island, Virginia* (EDRC/CHL TR-14-8) was published in March 2015. This report includes the coastal engineering and design analysis, and detailed design of the coastal structures for five alternative plans. The report also includes the details of the modeling efforts performed for the project. The report was written by the Project Delivery Team (PDT) members from the Engineering Research Development Center (ERDC), Coastal Hydraulics Laboratory (CHL). The United States Army Corps of Engineers (USACE), Norfolk District, performed shoreline, nearshore, and bathymetry surveys in support of ERDC's engineering design and modeling efforts. Bathymetric surveys are referenced to Mean Lower Low Water (MLLW). Planimetric features, developed by stereo-photogrammetric methods taken from aerial photographs flown in 2001 by Earth Data, also support the technical report. The horizontal coordinates are in U.S. survey feet referred to the Virginia State Plane Coordinate System (South Zone) and are based on North American Datum 1983. Norfolk District also provided ERDC survey data available for Tangier Island from recent LIDAR (LIght Detection And Ranging) survey. As mentioned in the first attachment of this appendix, at the time of the coastal modeling, geotechnical data of the soil at the footprint of the proposed structure(s) was not available. However, since the development of ERDC report, the Geotechnical analysis has shown that 15 inches of settlement could occur at the proposed project area. To account for this, the final jetty(s) design shall be raised one foot to compensate for the settlement. Other data and images used to complete the coastal engineering design and modeling are referred in the first attachment of this appendix.

The Geotechnical Engineering Design Analysis Report of this appendix discusses the geotechnical investigation and foundation analysis results. USACE, Norfolk District partnered with Savannah District to perform a subsurface investigation for the Tangier Island Jetty project. Savannah District and Norfolk District collected split spoon and vibracore samples during the week of 20 May 2013. Due to the shallow water conditions, the drillers used a barge-mounted cone penetration test rig to collect the samples as well as a crane mounted vibracore core sampler. Penetrations and vibracores were performed in the vicinity of the proposed breakwater/jetty, to support the jetty design analysis. Samples collected during the subsurface investigation are classified according to the Unified Soils Classification System. Selected samples were analyzed for Atterberg Limits, Gradations and Moisture Content. Savannah District was not able to obtain an undisturbed sample due to the type of material encountered and the method necessary for collecting samples in such shallow waters. Refer to the attached geotechnical report for boring logs, grain size distribution graphs and Atterberg limits results. A foundation analysis was also performed based on the assumption that the proposed jetties are underlain by high tensile strength woven geotechnical fabric. Based on the foundation analysis, bearing capacity and stability will not be a problem. However, there is a potential that up to fifteen (15) inches of settlement could occur in the clay layer. It is recommended that the top elevation of the structure be raised to compensate for the settlement. Proper subgrade preparation will also reduce settlement and allow for controlled settlement.

The detailed Cost Estimates of this project alternatives and used a basis for the economic analysis, shown in the third attachment of Appendix A.

The Coastal and Geotechnical reports both mention that the preferred engineering plan is Alternative 4. This is due to the modeling results showing that Alternative 4 had the highest percentage of wave reduction. As it was mentioned in the modeling report, all the alternatives provided some form of wave reduction benefits. A comparison of the alternatives showed that the three that include a south spur jetty (Alternatives 3, 4, and 5) outperformed the other two (Alternatives 1 and 2, with no S spur) in reducing wave energy in the channel. However, based off of the economic analysis (see Appendix B) the tentatively selected plan is Alternative 1. This plan maximized net National Economic Development benefits and was selected as the National Economic Development plan. Choosing Alternative 1 over the Alternative 4 does not affect the coastal modeling and geotechnical calculations and results. Also, the lengths of the jetty(s) structure mentioned in the main portion report is different from that of the Appendix A. As mentioned in the modeling report, the land of where the original north jetty tie-in into (which was what was modeled) had eroded severe. It was decided to move the tie-in further north and therefore slightly increasing the length of the north jetty.

ATTACHMENT A-1

MODELING STUDY FOR TANGIER ISLAND JETTIES

ERDC/CHL TR-14-8

Coastal and Hydraulics Laboratory

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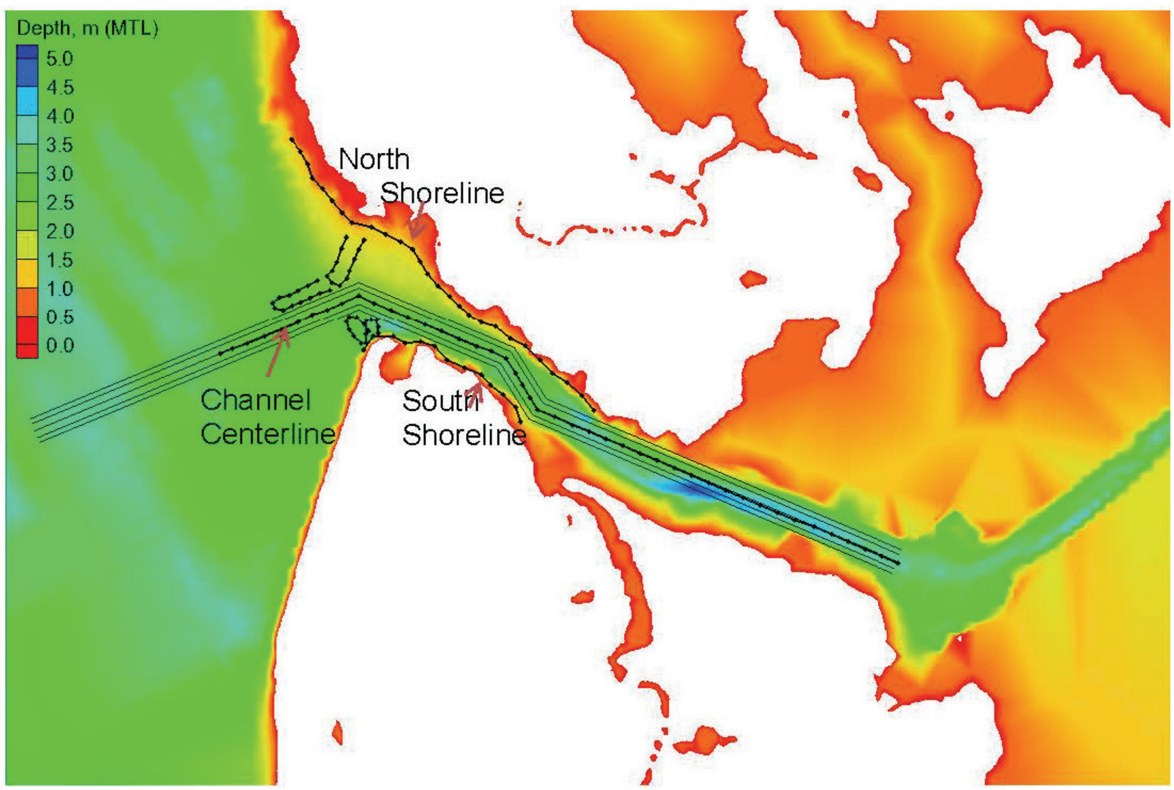
Coastal Inlets Research Program

Modeling Study for Tangier Island Jetties, Tangier Island, Virginia

Zeki Demirbilek, Lihwa Lin, Donald L. Ward, and David B. King

March 2015



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Modeling Study for Tangier Island Jetties, Tangier Island, Virginia

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U.S. Army Engineer Research and Development Center
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Final report

Prepared for U.S. Army Engineer District, Norfolk
803 Front Street, VA 23510

Under Coastal Inlets Research Program

Abstract

This report documents numerical wave and flow modeling for evaluation of the jetties on a shallow draft navigation channel on Tangier Island, VA, located in Chesapeake Bay. Because it is heavily used by the local fishing fleet, the U.S. Army Engineer District, Norfolk (CENAO) maintains the Tangier Island boat canal. CENAO is considering the construction of structures to protect the western entrance of the channel and reduce the wave energy in the lee of the structures, and asked the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) to perform a numerical modeling study to investigate how waves and hydrodynamics would be affected by structures, to identify the optimal location for the structures, and to develop a preliminary structure design. The primary goal of the study was to develop a quantitative estimate of waves and wave reduction in the canal for a relative comparison of alternatives investigated and for the preliminary structural design calculations.

CMS-Wave, a spectral wave model, was used to estimate waves in Chesapeake Bay and propagate waves into the entrance channel and boat canal. The numerical modeling results indicated that maximum wave energy reduction inside the canal was obtained using a dogleg jetty connecting to the north shoreline and a spur on the south shoreline.

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Preface

This study was conducted for the U.S. Army Corps of Engineers (USACE), Norfolk District. This study was partially supported by the Coastal Inlets Research Program (CIRP), a research and development program in the Navigation Business Line administered by the USACE-Headquarters under the direction of W. Jeff Lillycrop, Technical Director, and Charles E. Wiggins, Associate Technical Director. Dr. Julie Rosati was Program Manager of CIRP during the period of study. Alicia Farrow and Lawrence Ives of the USACE District, Norfolk, provided input and oversight for the study.

Dr. Zeki Demirbilek of the Harbors, Entrances, and Structures Branch (HNH) of the Coastal Hydraulics Laboratory (CHL), Navigation Division and Dr. Lihwa Lin of the Coastal Engineering Branch (HNC) of the CHL Navigation Division conducted the study and wrote this report, with contributions by Dr. Donald Ward, HNH, and Dr. David King of the Coastal Processes Branch (HFC) in the Flood and Storm Protection Division.

At the time of this study, Dr. Donald Ward, was Acting Chief, HNH; Tanya Beck, was Acting Chief, HNC, and Mark Gravens was Chief, HFC. Dr. Jackie Pettway was Acting Chief, Navigation Division; Dr. Ty Wamsley was Chief, Flood and Storm Protection Division; Dr. Richard Styles was Acting Deputy Director, and Jose Sanchez was Acting Director of CHL.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
feet^2	0.0929	meters^2
gallons (U.S. liquid)	0.003785412	cubic meters
gallons (U.S. liquid) per minute per foot	0.00020699	cubic meters per second per meter
pounds (mass)	453.59237	grams
pounds (force)	4.448222	Newtons

1 Study Needs and Plan

1.1 Background

This report describes details of a numerical modeling study conducted for Tangier Island navigation channel, which is located in Chesapeake Bay. The numerical modeling study developed wave estimates inside and outside of the shallow draft and narrow boat canal. The focus of numerical modeling was the assessment of the efficacy of proposed alternatives. Impacts of waves on navigation were examined using the CMS-Wave model. Details of numerical modeling study, tasks, results, and major findings are provided in this report.

Tangier Island (75.99° W, 37.83° N) is the southernmost of a string of islands that separate the deep portions of Chesapeake Bay to the west from shallower Tangier Sound to the east (Figure 1). The island, approximately 5 miles long by 2 miles wide, is located in the Virginia portion of Chesapeake Bay 20 miles southwest of Crisfield, MD and 70 miles north of Norfolk, VA. Tangier Island is comprised of a few low, fine-grained sand ridges with intervening marshlands having numerous islets and tidal creeks. The island's highest elevations are only a few meters above mean tide level (MTL). The populated areas are primarily three interconnected ridges on the southern portion of the island. Abundant seafood and tourism are two sources of livelihood for the island residents.

A shallow-V-shaped narrow channel, known as the Tangier Island boat canal, runs east-west across the island's mid section (Figure 2). This channel varies somewhat in width and depth, but averages approximately 265 ft (80 m) wide and 13 ft (4 m) deep. Technically termed a navigation channel, this waterway is a canal engineered and maintained by the U.S. Army Corps of Engineers for small-boat traffic. Numerous mooring docks and seafood-processing sheds line both north and south shorelines and are key infrastructure for the bay's fishing fleet. Maintenance and improvement of this canal are critical to the economy of the island.

The east side of the island is well-sheltered from the effects of storms, northeasters, and hurricanes because the short fetch distances from the Delmarva Peninsula do not provide sufficient space for large wind waves to generate and grow. The western side of Tangier Island is more exposed to large wind waves approaching the island from the northwest through southwest quadrants. Consequently, the western shoreline has long experienced progressive flooding and erosion. Due to prevailing wind patterns, the longshore transport along the island's west shoreline is southerly.

Figure 1. Location of Tangier Island, VA, in Chesapeake Bay.

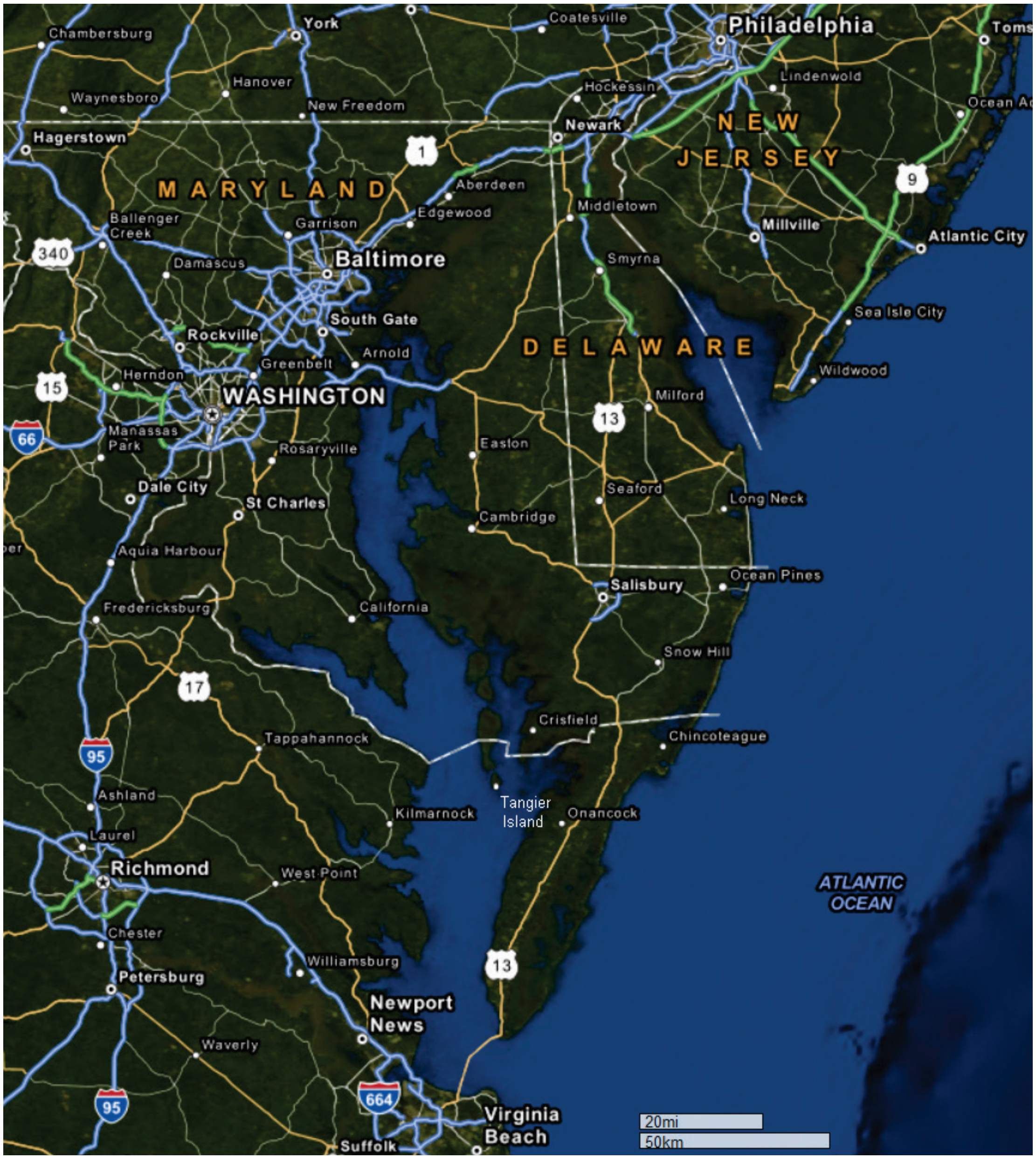
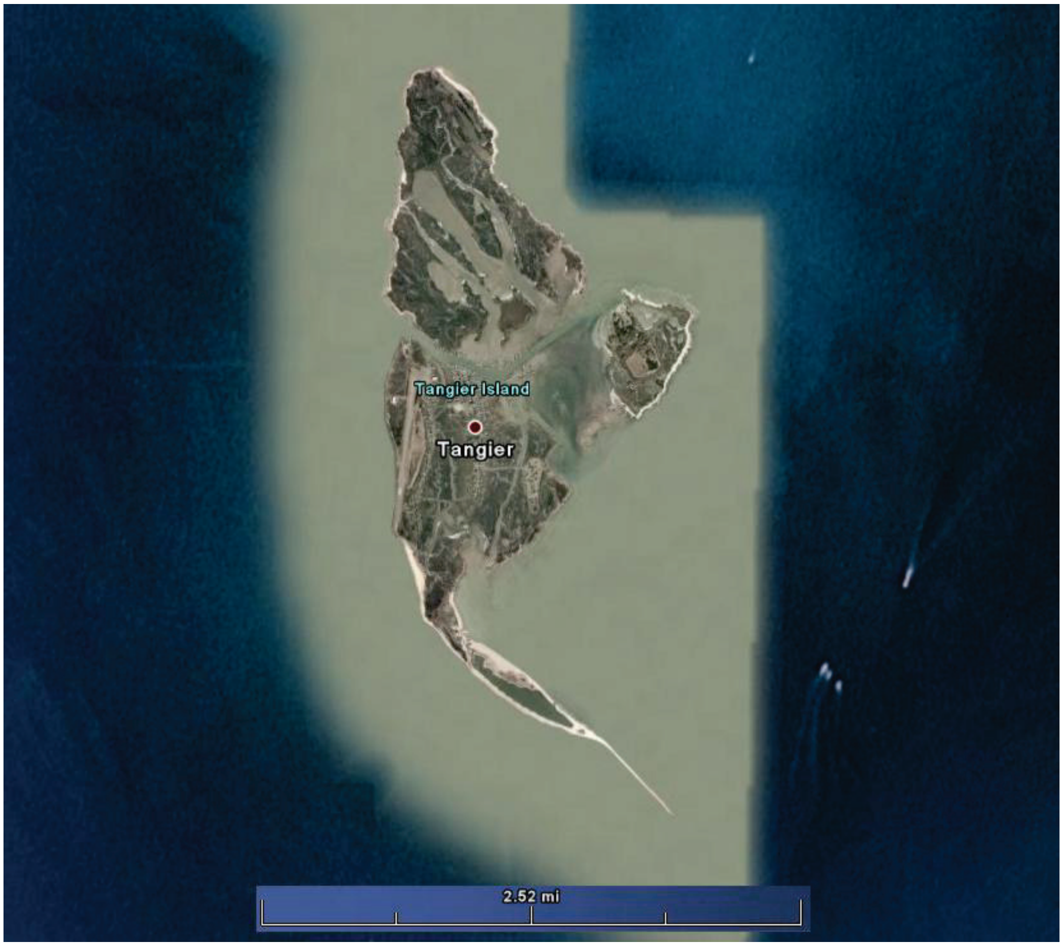


Figure 2. Tangier Island, VA.



1.2 Objectives

In the past, storm waves have frequently entered the western end of the Tangier Island boat canal and caused damage to shoreline structures. The objectives of this project are to perform a numerical modeling study for engineering design of a structure intended to reduce wave energy in the western portion of the canal and to provide preliminary structural design guidance. Figure 3 shows an example of a hypothetical structure location attached to the northern shoreline.

1.3 Approach

Idealized wind and wave simulations were performed for nine wind directions (see Chapter 2 for details) and two water levels, 0 and 5 ft (0 and 1.5 m). The idealized wind conditions, representing the 50 yr return period, were used in the numerical simulations for the existing west channel without a structure (without project) and for five alternatives with structures (with project). The 50 yr wind condition was based on a previous study. The calibration and validation of CMS has been described in detail in a series of four reports (see Demirbilek and Rosati 2011 for a summary), which included approximately 30 test cases. For field testing at bays and estuaries, Grays Harbor, WA, and Matagorda Bay, TX, were amongst the calibration and validation cases. The primary goal of the study was to develop a quantitative estimate of waves and wave reduction in the canal for a relative comparison of alternatives investigated and preliminary structural design calculations. Because there was no field data at Tangier Island, the qualitative estimates of flow and sediment transport developed were not used in the selection of recommended solutions. This report presents details of modeling tasks and findings of the study and results of structure design.

Figure 3. An example jetty location (in red) at the western entrance of the Tangier Island boat canal.

Structural designs were estimated based on numerical wave and hydrodynamic modeling conducted for 50 yr design wind speeds, waves, and water level conditions. The 50 yr wind speed was considered as idealized condition and was based on a previous study by Basco and Shin (1993). Different structure alternatives were evaluated to determine an optimal design based on the level of wave-energy reduction in the navigation channel. The wave and hydrodynamic modeling study results (e.g., wave height, period, direction, and water level) along the western side of the proposed structure footprint were used in the preliminary wave-control structural design calculations. These calculations included structural stability, run-up/overtopping, and transmission through and over the structure.

1.4 Data

A variety of field data were required to generate model grids and other inputs for numerical models used in this study. These data can be grouped into two general categories: (1) bathymetric, shoreline and land-elevation data, and (2) meteorological and oceanographic (metocean) inputs used as forcing conditions. CENAO provided survey data available for Tangier Island from a recent lidar (Light Detection and Ranging) survey, past study reports, and other pertinent GIS (Geographic Information System) images and data files.

The CHL identified metocean data (winds, waves, and water levels) available from various data sources and previous studies by Corps, other government agencies, and academic institutes. Land-based wind data have been modified to "over water" conditions as needed. Storm-wind fields for hurricanes Sandy and Isabel were assembled. Hurricane Isabel was selected as the 50 yr representative design hurricane event. Numerical models were set up with these data and conditions. Simulations were performed for "as is" and "with project" alternatives described in Chapter 2.

1.5 Tasks

The scope of work for this study was initially formulated between the CENAO and CHL engineers in 2009, and refined in 2012. The main elements of the study plan were to: a) collect, generate, and format input data for numerical models; b) set up and run models for "with project" and "as is" conditions; c) analyze model results to develop a structure design; and d) discuss issues, progress, findings with the District on a regular basis; and e) make appropriate adjustments to study plan as executed. The following tasks were performed in the implementation of study plan.

1.5.1 Task 1. Metocean forcing (winds, waves, tides, currents, water levels)

Because Tangier Island is not exposed to open ocean waves, locally generated wave climates for the west side of the island were derived by using local winds as input to the Coastal Modeling System (CMS) described in Appendix A.

1.5.2 Task 2. Investigation of jetty location and geometry.

A spectral (phase-averaged) wave model, CMS-Wave (Lin et al. 2008; Demirbilek et al. 2007; Lin and Demirbilek 2005), was used to provide locally generated wind-wave estimates at the project site. This model can run on a grid with variable rectangular cells. It is suited to large area applications in which wider spacing cells can be specified in the far site, where wave property variation is small and away from the area of interest, to save computational time. Wave diffraction, reflection, and transmission caused by structures are approximated in this class of wave models.

1.5.3 Task 3. Modeling channel hydrodynamics

The Tangier Island boat canal (Figures 2 and 3) is a federally maintained waterway which is regularly dredged by CENAO. One of the project design parameters was that the proposed structure should not exacerbate shoaling problems in the channel. Channel sediments are a mixture of sands and fine-grained material at Tangier Island, which were modeled with the CMS (Demirbilek and Rosati, 2011). Model simulations with and without structures were conducted to calculate water levels, currents, and sediment transport in the channel. Model results were used to identify potential depositional and erosional areas in the west channel and possible impacts of proposed structures.

1.5.4 Task 4. Structure design

Once the optimal structure location was determined, CMS-Wave was used to generate storm wave conditions at the seaward face of the structure. A joint-probability wave-distribution curve was calculated to compute stable stone sizes, damage progression, run-up, and overtopping transmission for different structure designs. The result of these analyses formed the basis of an optimal structural cross-section design that included the specification of the crest elevation, crest width, side slopes, and armor stone sizes. The structure design incorporated the latest Corps guidance on sea-level rise. Local soil subsidence due to weight of the structure was not considered in structure design calculations because geotechnical data of the soil at the footprint of the jetty were not available. For the pre-sent level of design, zero local structural settlement was assumed. Howev-er, regional settlement of the Chesapeake Bay is considered.

1.5.5 Task 5. Technical report

CHL and CENAO personnel conducted two site visits at the beginning and during the study. The two groups conducted regular monthly telephone meetings to discuss issues and progress. There were frequent additional communications via telephone and e-mail. The findings of the modeling study are documented in this Technical Report.

1.6 Report layout

Chapter 2 describes details of the numerical modeling study tasks, including model domain, bathymetry, grids, forcing types, structural alternatives, save stations, conditions simulated, comparison of alternatives, and study findings and recommendations. Chapter 3 describes the structural design calculations that examine three different crest elevations and include determination of structure stone size on both the seaside and leeside of the structures and transmitted wave heights for each of the crest elevations. The effects of sea-level rise and the general subsidence of the Chesapeake Bay are also considered. The study's conclusions are presented in Chapter 4.

2 Numerical Modeling for Wave-Energy Reduction in the Tangier Island Boat Canal

2.1 Purpose

A numerical modeling study investigated waves and hydrodynamics in and adjacent to the western portion of the Tangier Island boat canal. The study developed wave- and water-level estimates for design of a structure to reduce wave energy entering the western end of the navigation channel. The modeling study's results included the selection of the appropriate location, size, and geometry of a wave-control structure that reduced wave energy entering the channel, did not exacerbate the channel dredging requirements, and ensured continued boat traffic use of the channel.

2.2 Numerical models

The CMS was used to simulate waves, currents, sediment transport, and morphology change in this study. The CMS includes wave, flow, and sediment transport modeling tools for coastal inlets and navigation projects. Development and enhancement of CMS capabilities continues to evolve as a research and engineering tool for desk-top computers. The CMS uses the Surface-water Modeling System (SMS) (Zundel 2006) interface for grid generation and model setup, as well as plotting and post-processing. See Appendix A for additional information about the CMS and its capabilities.

The development of a number of advances to CMS-Wave to address the project's specific needs was funded by the CIRP. These included testing of the full-plane and parent-child capabilities of model for hurricanes and northeasters in an estuary, and development of pre- and post-processing analysis codes for model setup and structural design calculations. The calibration and validation of CMS has been described in detail in a series of four reports. See Demirbilek and Rosati (2011) for a summary, which included approximately 30 test cases. For field testing at bays and estuaries, the Grays Harbor, WA, and Matagorda Bay, TX, were amongst the calibration and validation cases. The primary goal of the study was to develop a quantitative estimate of waves and wave reduction in the canal for a relative comparison of alternatives investigated and preliminary structural design calculations. Due to absence of field data at Tangier Island, the qualitative estimates of flow and sediment transport developed were not used in the selection of recommended solutions. Details of modeling tasks and findings of the study and results of structure design follow.

2.3 Model domain, bathymetry, and forcing

The primary area of interest in this modeling study is the west channel section of the Tangier Island boat canal (Figure 4). This shallow and narrow canal is the only navigation route that cuts through the middle of Tangier Island and connects the east and west sides of island. The average west-channel base width is 60 ft (18.3 m), top width is 100 ft (30.5 m), and channel depth varies from 7.5 to 13 ft (2.3 to 4 m). The narrowest cross section (bank-to-bank) of the west channel is 230 ft (70 m).

Figure 4. Footprint of the western portion of the Tangier Island boat canal.

CENAO provided available survey data to the CHL modeling team for the east channel, west channel, and adjacent areas. To properly resolve the details of channel geometry and bathymetry, irregularly shaped shorelines, and elevations of the joining land areas for numerical modeling purposes, these survey data were augmented with data from other sources including USGS coastal shoreline data, USACE LIDAR data, and NOAA digital elevation model (DEM) data. The extent of all available bathymetry data and surveys is shown in Figures 5 through 9, where survey points are sparse in some areas and denser in others.

Figure 5 shows the NOAA DEM data available in the Chesapeake Bay. Figure 6 shows the lidar data available for the post-Hurricane Sandy elevations in Tangier Island and vicinity area. Figure 7 shows the coverage area of the west channel entrance and vicinity depth contours. Figure 8 shows the west channel and north shoreline survey depth contours. Figure 9 shows the east channel survey-depth contours.

Figure 5. DEM bathymetry data covering Chesapeake Bay and vicinity.

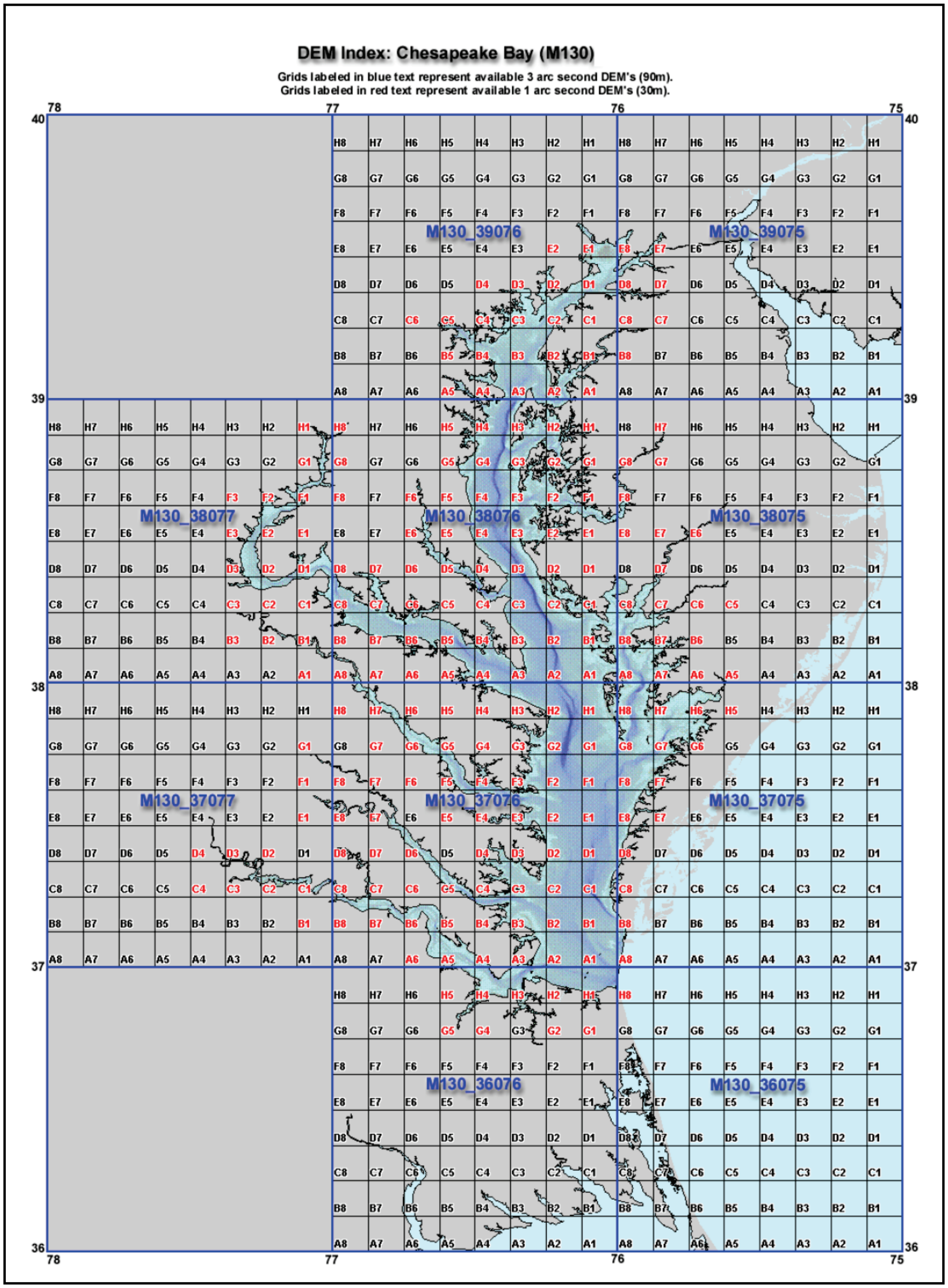


Figure 6. Post-Hurricane Sandy (2012) elevation contours (m, MTL) for Tangier Island and vicinity.

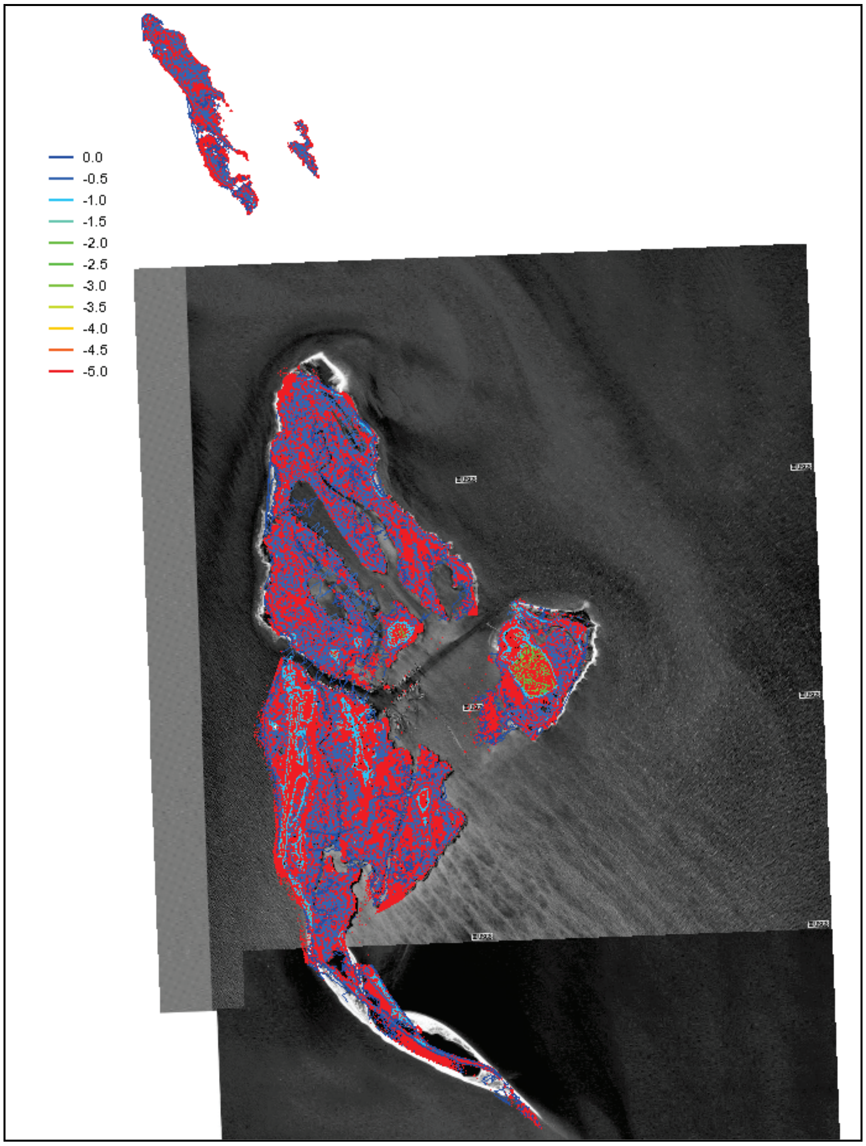


Figure 7. West channel entrance and vicinity depth contour lines (m, MTL); data locations shown as red points.

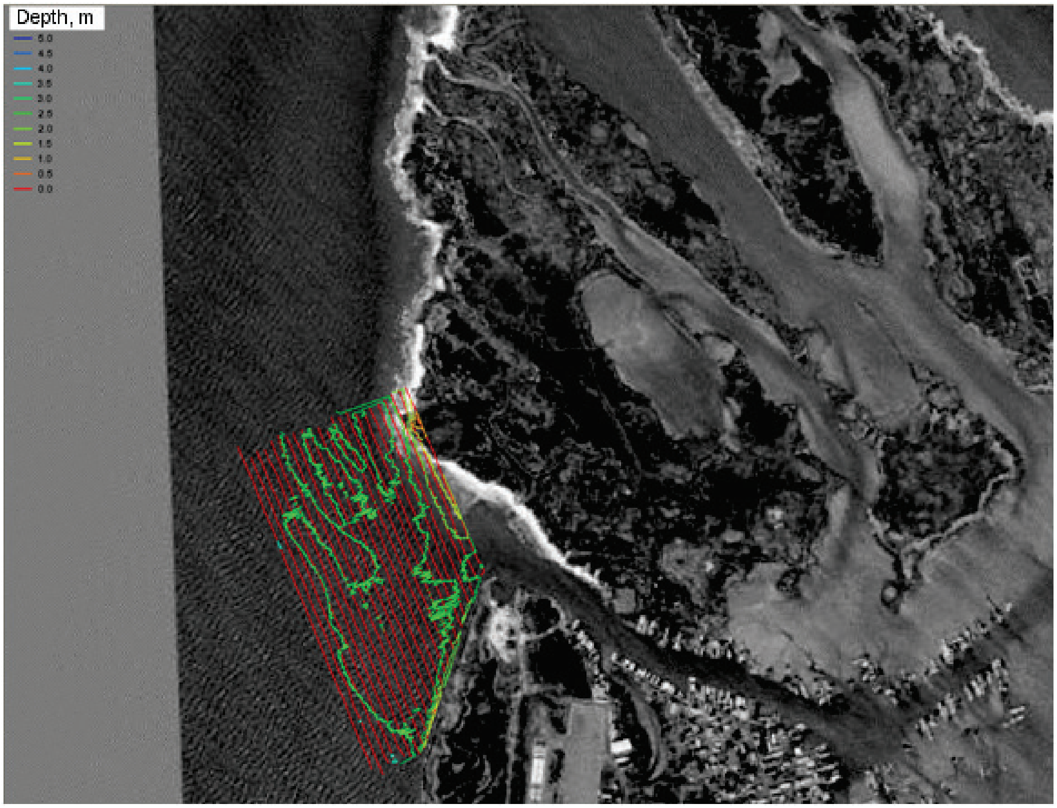


Figure 8. West channel and north shoreline depth contour lines (m, MTL); data locations shown as red points.

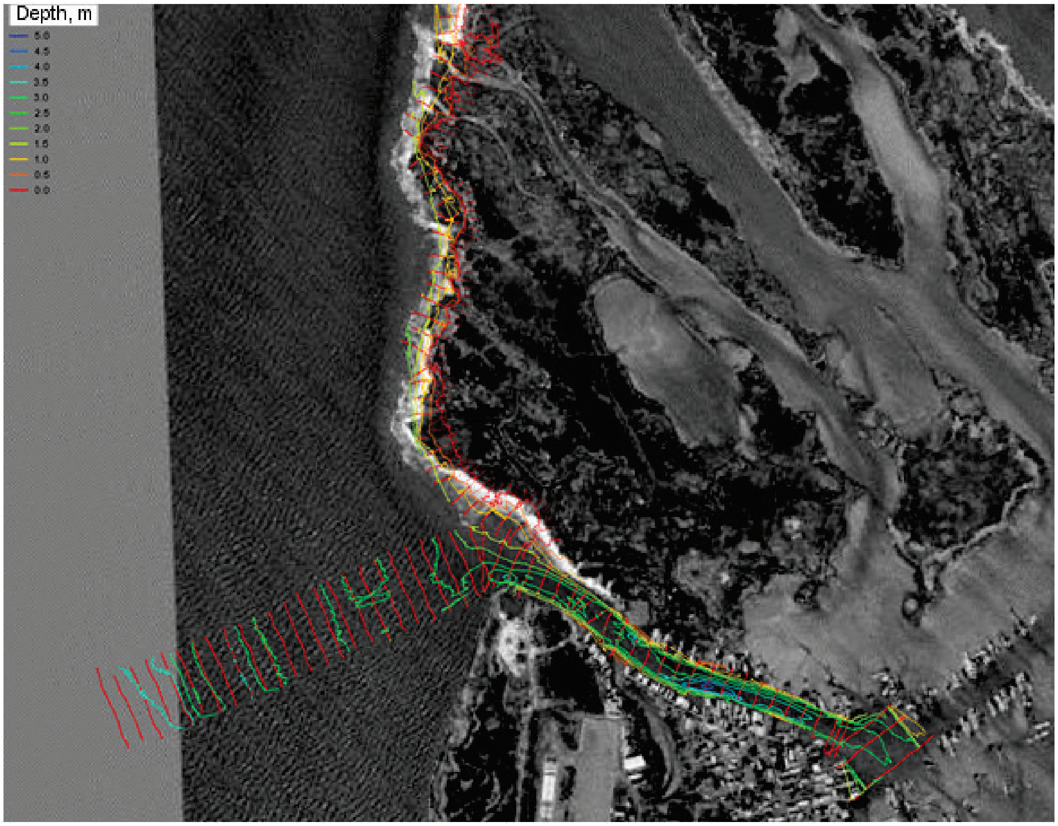
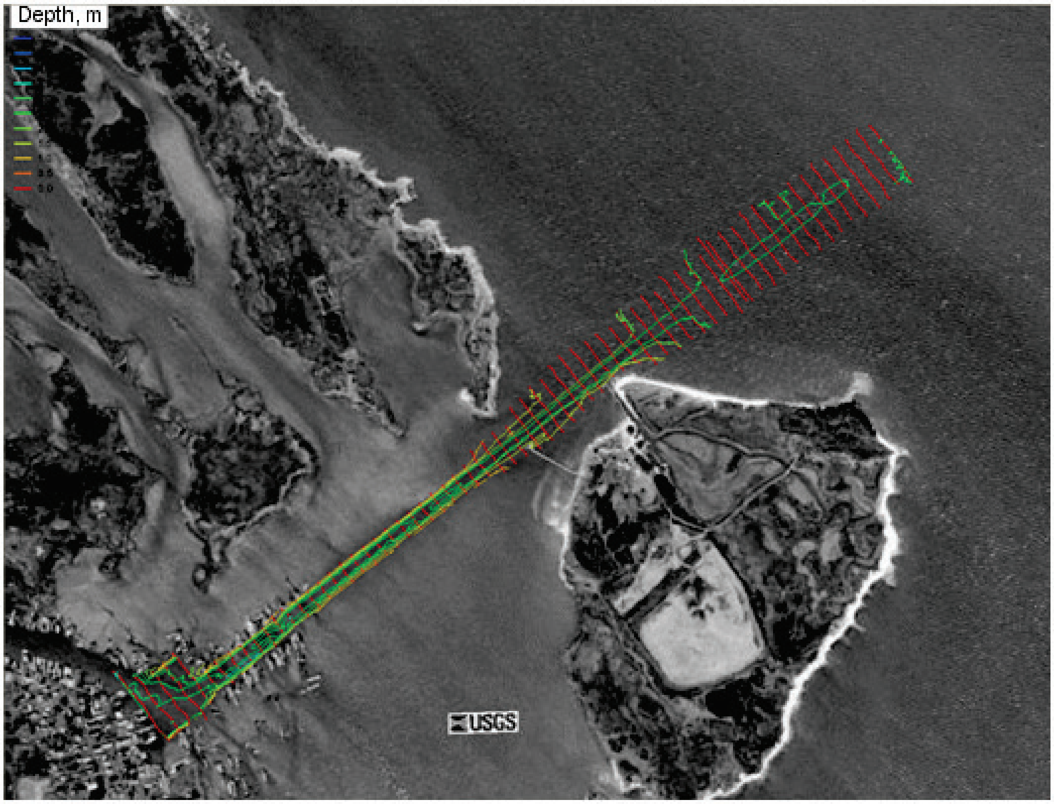


Figure 9. East channel depth contour lines (m, MTL); data locations shown as red points.



2.4 Model grids

Figures 10 and 11 show the CMS modeling domain for the Chesapeake Bay region and corresponding depth contours, respectively. This bay-wide large grid domain, approximately 60 mi by 180 mi (100km by 300 km), is referred to as the regional grid, which has a constant grid cell size of 1,600 ft by 1,600 ft (500 m by 500 m). The depths in this grid vary from 0 to 150 ft (0 to 45 m).

Figure 10. CMS regional grid modeling domain for this study. The small rectangle shows the location of the local grid for Tangier Island.

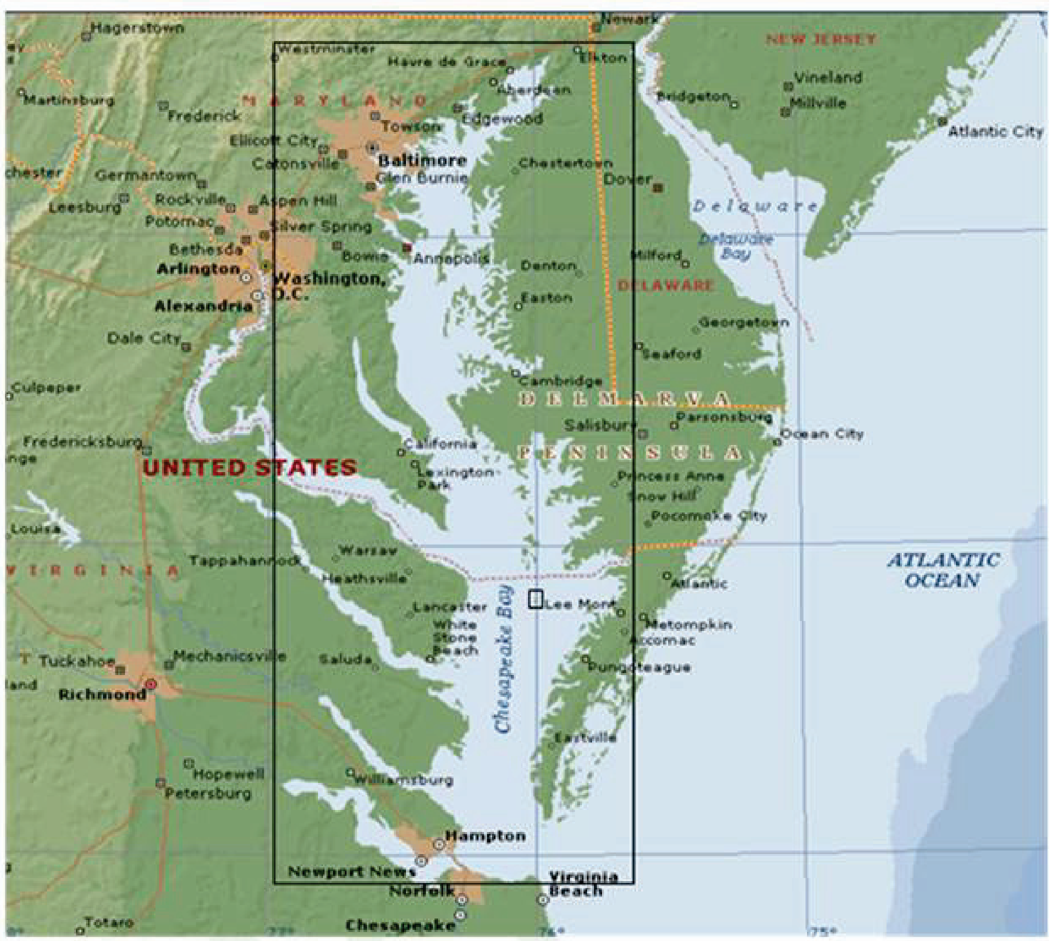
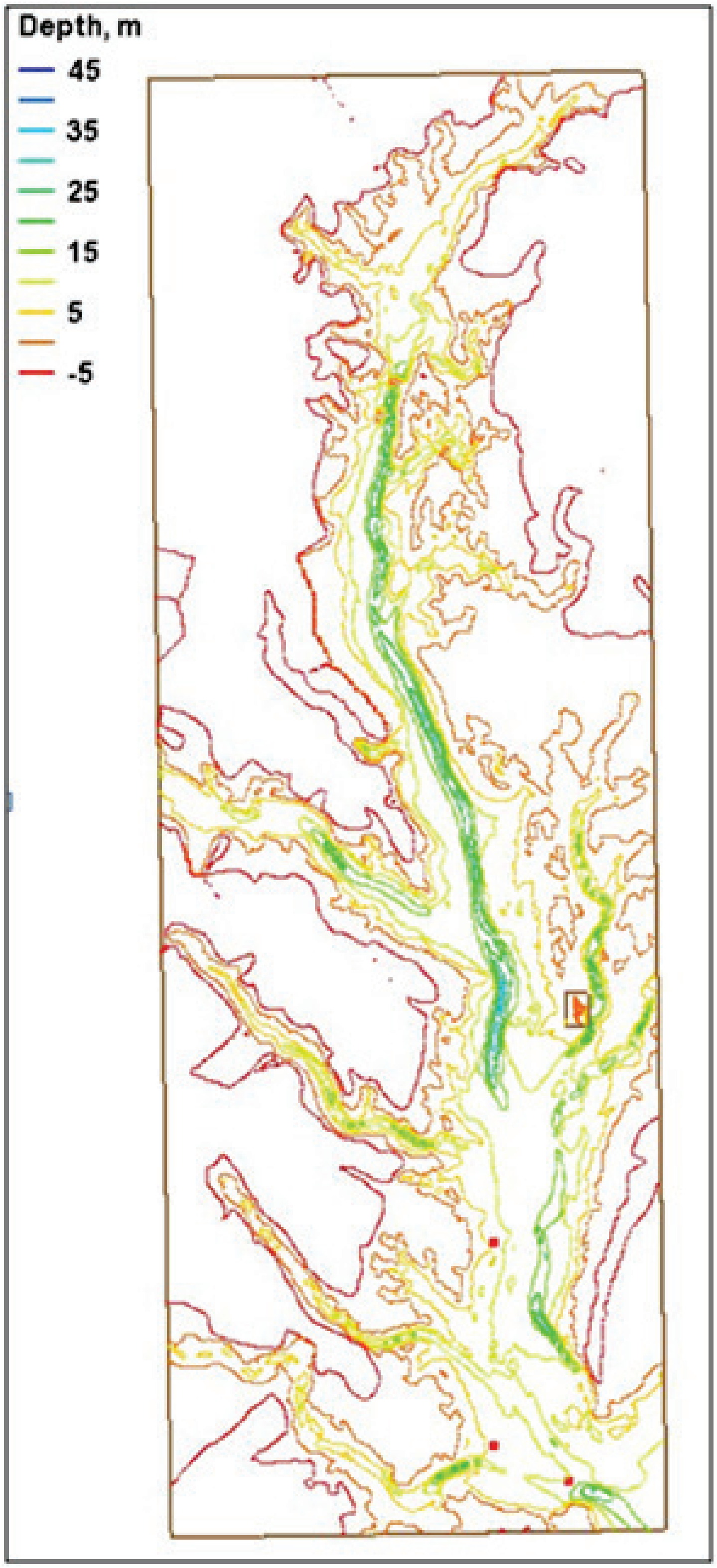
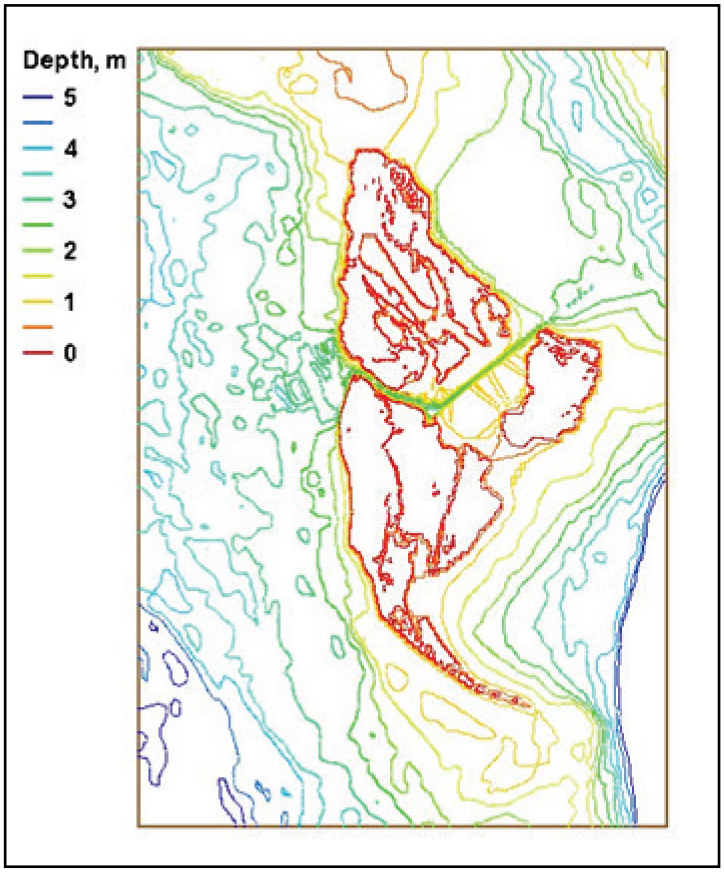


Figure 11. Depth contours (m, MTL) for the CMS Chesapeake Bay regional grid domain.



The CMS modeling includes a second domain, referred to as the local grid for Tangier Island, which is shown in Figures 10 to 12. This grid is more detailed and has a finer resolution of bathymetry to cover Tangier Island. The domain is approximately 3 mi by 4.4 mi (5 km by 7 km). The local grid cell size varies from 10 ft to 160 ft (3 m to 50 m).

Figure 12. Local grid depth contours (m, MTL) covering Tangier Island and vicinity.



2.5 Existing channel and structural alternatives

Five alternatives and the existing channel geometry were investigated. All five alternatives have a jetty system that includes a structure con-necting to the north shoreline. Alternatives 3, 4, and 5 include an optional short structure (spur) joining to the south shoreline. The north structure is either a one-piece straight structure or a two-piece dogleg structure. Due to cost constraints, the District requested that the total length (linear foot) of structures in each alternative not exceed 650 ft (200 m).

The location, length, and orientation of structures used in the alternatives were determined in close consultation with the District. Because the goal was to minimize wave-energy propagation into the canal, structures were positioned as close to the channel as possible at a safe (for navigation) distance of 164 ft to 328 ft (50 m to 100 m) from the channel edges. The geometry of each alternative was configured and sized according to these requirements. Data on the footprints of these alternatives are provided in Table 1. The information in Table 1 represents the location of the modeled alternatives. Subsequent to the modeling, adjustments were made to the position of the landward root of the north jetty for the purpose of selecting the best landward connection area for the jetty. The final recommended construction footprint coordinates are provided in Chapter 3.[*]

Table 1 Location (Footprint, State Plane, m, Virginia South 4502) of alternatives.

		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
North Jetty	Type	Straight	Dogleg	Dogleg	Dogleg	Straight
	Landward End Easting (m)	3720196	3720196	3720196	3720196	3720196
	Landward End Northing (m)	1169385	1169385	1169385	1169385	1169385
	Turning Point Easting (m)		3720161	3720161	3720161	
	Turning Point Northing (m)		1169306	1169306	1169306	
	Seaward End Easting (m)	3720161	3720089	3720089	3720089	3720161
	Seaward End Northing (m)	1169306	1169271	1169271	1169271	1169306
	Shore Segment Length (m)		86.4	86.4	86.4	
	Bay segment Length (m)		80.1	80.1	80.1	
	Tot Length (m)	86.4	166.5	166.5	166.5	86.4
South Spur Jetty	Type	None	None	Straight	Straight	Straight
	Landward End Easting (m)			3720203	3720206	3720206
	Landward End Northing (m)			1169209	1169220	1169220

* The final recommended construction footprint coordinates are located in Table 24, Chapter 3.

		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
	Seaward End Easting (m)			3720203	3720181	3720181
	Seaward End Northing (m)			1169249	1169251	1169251
	Length (m)			40	39.8	39.8

Figures 13-18 show the existing (without project) and five alternatives (with project), respectively. For all alternatives, the structures were represented in the numerical model with a crest elevation of 3.3 ft (1 m) and crest width of 13 ft (4 m). The west channel and vicinity depth ranges from 0 to 15 ft (0 to 5 m) and are color-contoured in the figures, and land elevations are white.

Figure 13. Existing west channel configuration and depth field (m, MTL).

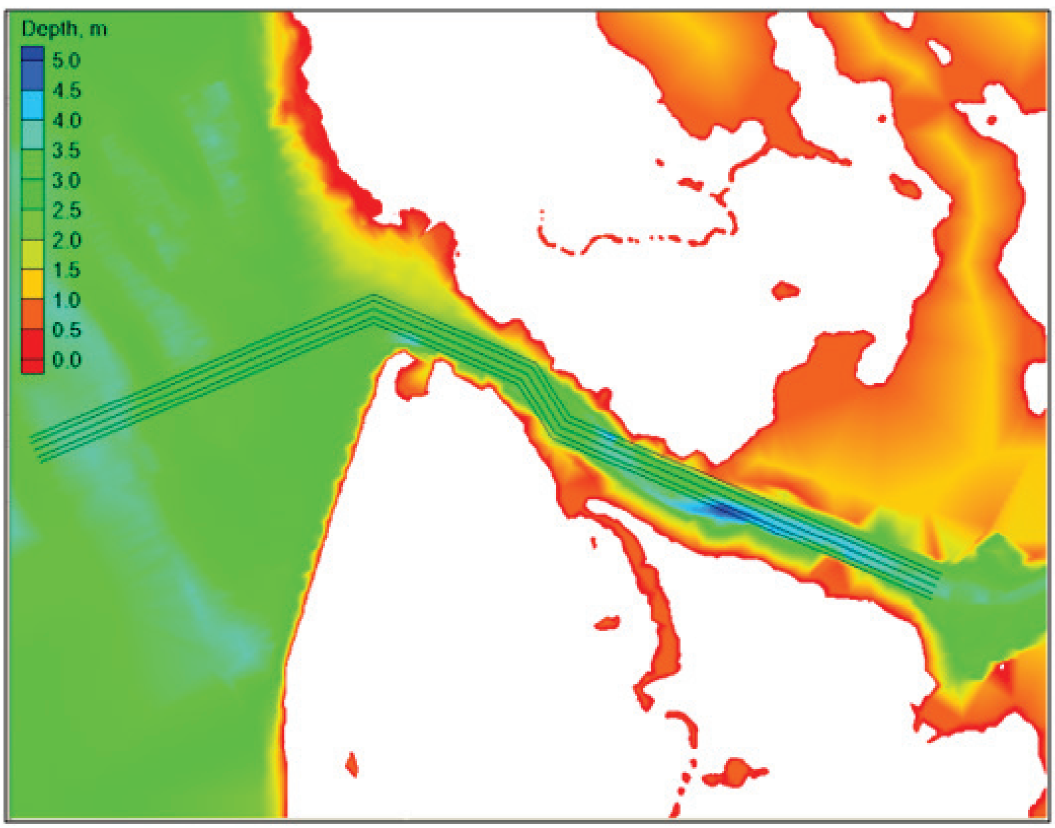
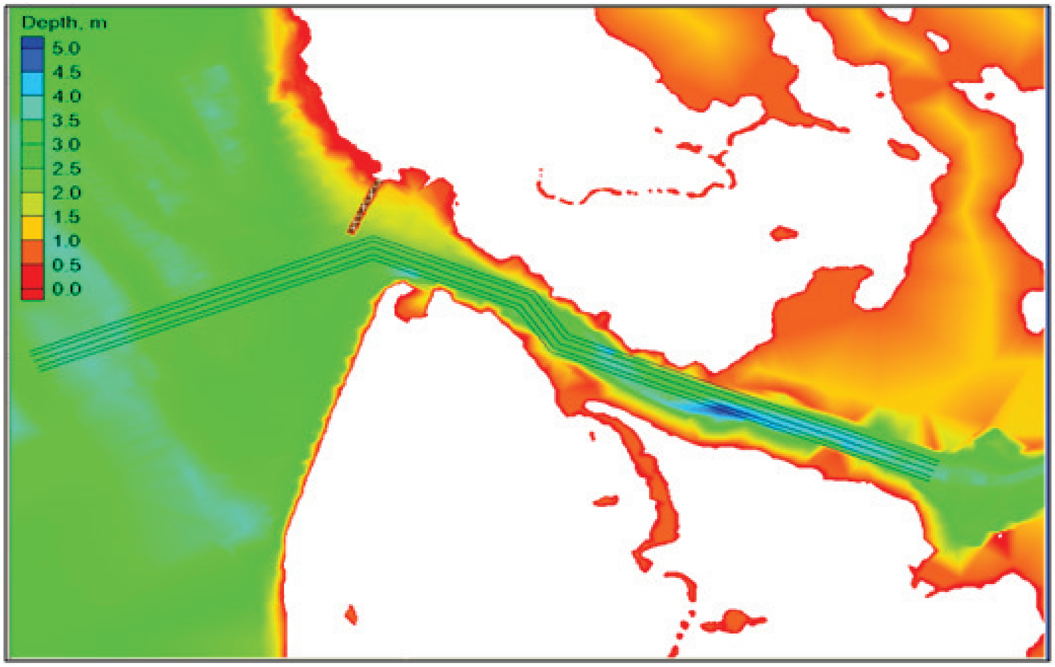


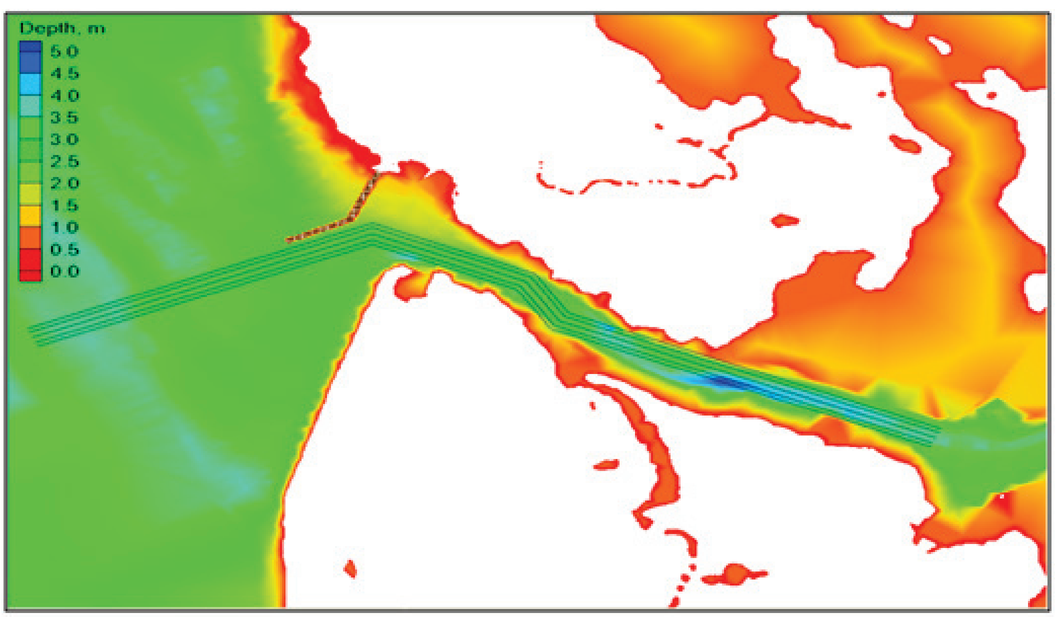
Figure 14 shows the Alternative 1 (Alt 1) channel configuration with a one-piece straight structure. The length, crest elevation, and crest width of the Alt 1 structure are 280 ft (85 m), 3.3 ft (1 m, MTL) and 13 ft (4 m), respectively.

Figure 14. Alt 1 with channel and structure configuration.



Alternative 2 (Alt 2) has a two-piece dogleg north structure (Figure 15). The total length, crest elevation, and crest width of the structure are 560 ft (170 m), 3.3 ft (1 m, MTL) and 13 ft (4 m), respectively.

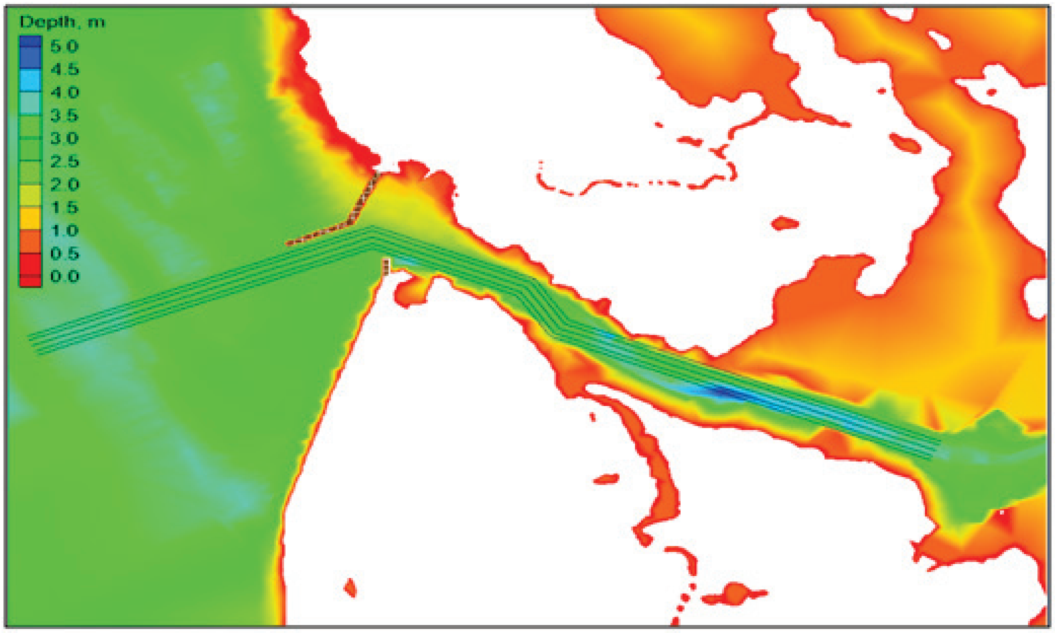
Figure 15. Alt 2 with channel and structure modification.



Alternative 3 (Alt 3) has a two-piece dogleg north structure and a straight south side spur structure pointing to north (Figure 16). Total length, crest

elevation, and crest width of Alt 3 north structure are 560 ft (170 m), 3.3 ft (1 m, MTL) and 13 ft (4 m), respectively. The south spur is 82 ft (25 m) long with its crest height and width the same as those of the north structure.

Figure 16. Alt 3 with channel and structure configuration.



Alternative 4 (Alt 4) has a two-piece dogleg north structure and a straight south side spur structure pointing towards northwest (Figure 17). Total length, crest elevation, and crest width of Alt 4 north structure are 560 ft (170 m), 3.3 ft (1 m, MTL) and 13 ft (4 m), respectively. The south spur is 82 ft (25 m) long with its crest height and width the same as those of the north structure.

Alternative 5 (Alt 5) has a one-piece straight north structure and a straight south side spur structure pointing towards northwest, as shown in Figure 18. The length, crest elevation, and crest width of Alt 5 north structure are 280 ft (85 m), 3.3 ft (1 m, MTL) and 13 ft (4 m), respectively. The south spur is 82 ft (25 m) long with its crest height and width the same as those of the north structure.

Figure 17. Alt 4 with channel and structure configuration.

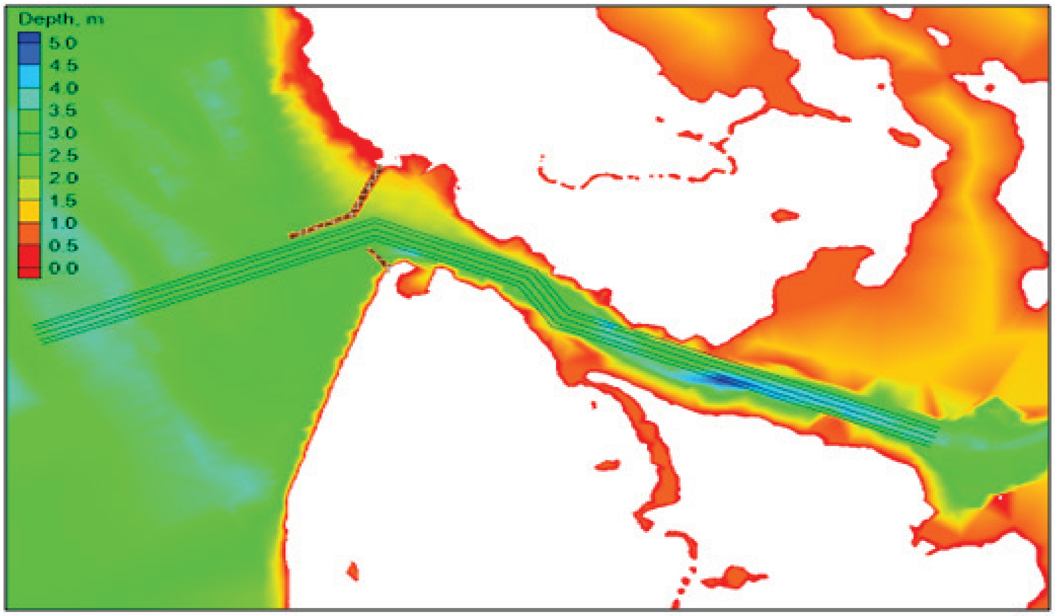
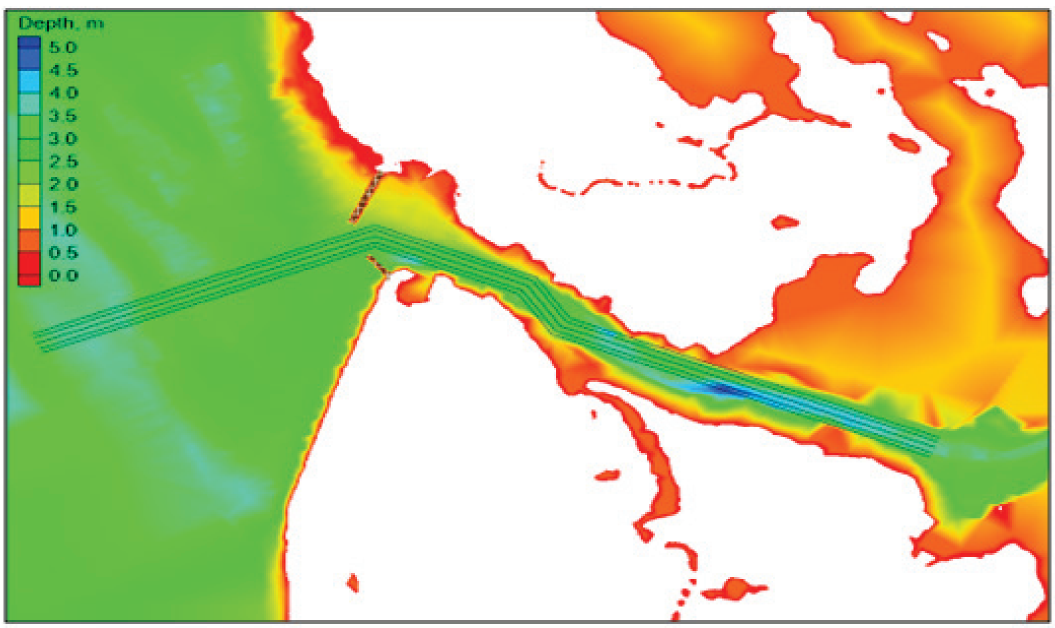


Figure 18. Alt 5 with channel and structure configuration.



2.6 Forcing conditions

Winds, waves, and tidal conditions affecting Tangier Island change year to year, as well as seasonally. These forcings consist of metocean events including storms, northeasters, and hurricanes, which can impact the Chesapeake Bay and reach Tangier Island from all directions. As seen in Figure 19, the wind rose shows winds blowing from different directions during two years, 2011 and 2012, at NOAA station 8632837. The modeling effort was designed to address both the survivability of the jetty during a 50 yr return period storm and also its effectiveness at reducing wave energy in the channel for much more common, less intense events.

Figure 19. Wind rose for years 2011 and 2012 at NOAA station 862837.

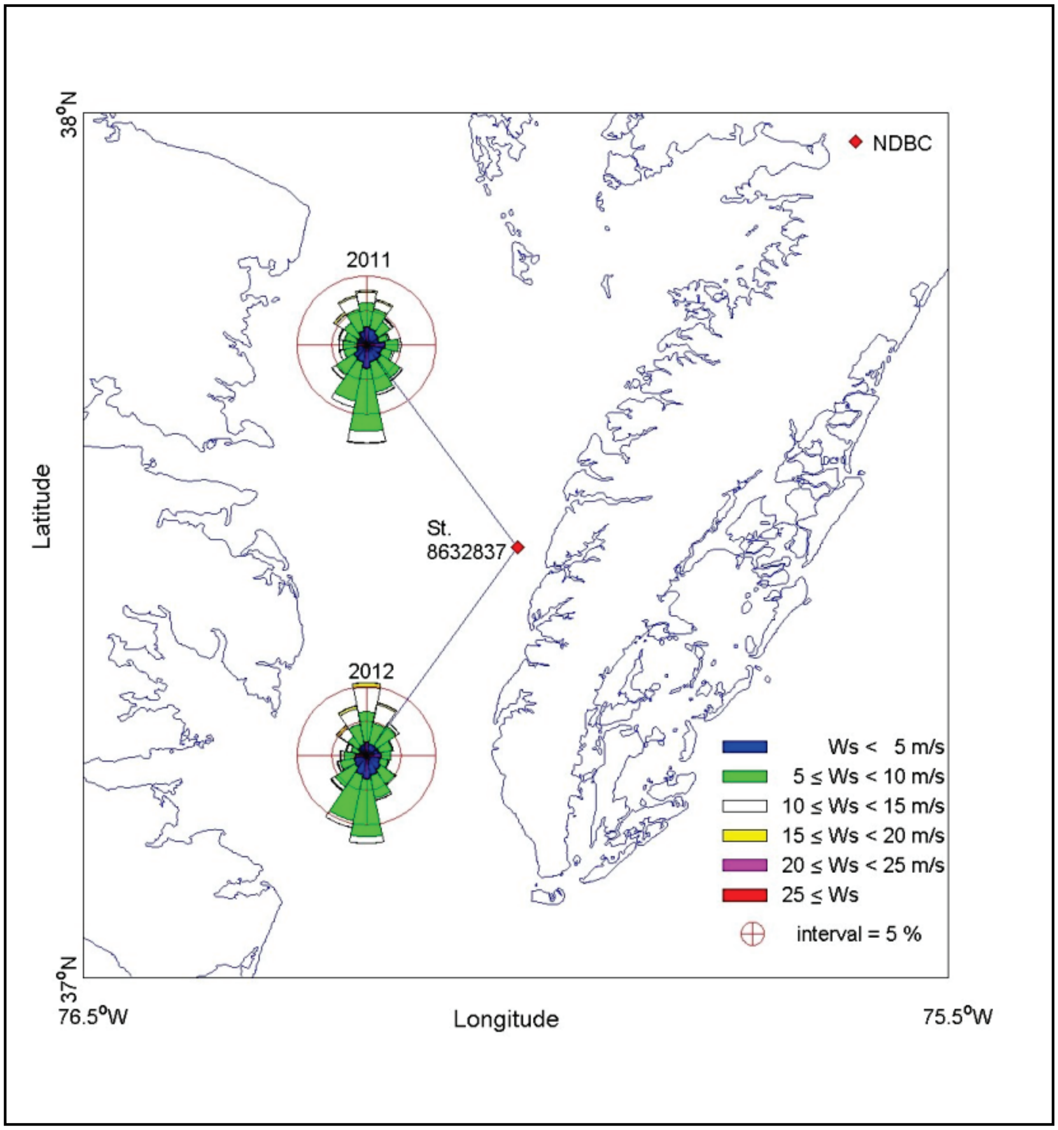


Table 2 lists the 50 yr wind and wave conditions simulated in the modeling for water levels (WL) equal to 0 and 5 ft (1.5 m). Winds and waves that affect the west channel are those approaching from the bay side, coming from all westerly directions from north to south. Note that in Table 2 the wind speed and water levels only appear once; these are constants.

Table 2. Wind, wave, and water level conditions simulated.

CASE	1 N	2 NNW	3 NW	4 WNW	5 W	6 WSW	7 SW	8 SSW	9 S
Wind speed (m/sec)					20				
Wind Dir (deg)	0	337.5	315	292.5	270	247.5	225	202.5	180
Water Level (m)					WL=0				
CASE	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Wind speed (m/sec)					20				
Wind Dir (deg)	0	337.5	315	292.5	270	247.5	225	202.5	180
Water Level (m)					WL=1.5				

The half-plane sector from north to south is split up into nine bins (or sub-sectors), which are designated by case numbers 1 through 9 for 0 m water level, and 10 through 18 apply to the 1.5 m water level simulations. These counter-clockwise directions from N to S are 22.5 deg bins, representing incident winds and waves to Tangier Island from NNW, NW, WNW, W, WSW, SW, SSW, and S directions.

The 50 yr design wind speed of 45 mph (20 m/sec) is used in this study with two water levels, 0 and 5 ft (1.5 m), representing possible mean tide level (WL = 0 m) and high water level (WL = 1.5 m) conditions observed at and around the Tangier Island by NOAA coastal stations (Figure 20). The design wind speed is based on a previous study by Basco and Shin (1993) analyzing storms for 1945-1983 at Patuxent Naval Air Station. The storms include both tropical events and northeasters.

Figure 21 shows the example of the water level measurements for year 2012 recorded at three NOAA stations: 8571421 (Bishops Head, MD), 8636580 (Windmill Point, VA), and 8638863 (Bay Bridge Tunnel, VA). The maximum water level observed at Station 8638863 (Bay Bridge Tunnel) was about 5 ft (1.5 m). The high water level WL=1.5 m at the Tangier Island is based on previous numerical modeling of Hurricane Isabel for Chesapeake Bay (Demirbilek et al. 2005).

Figure 20. NOAA coastal stations.

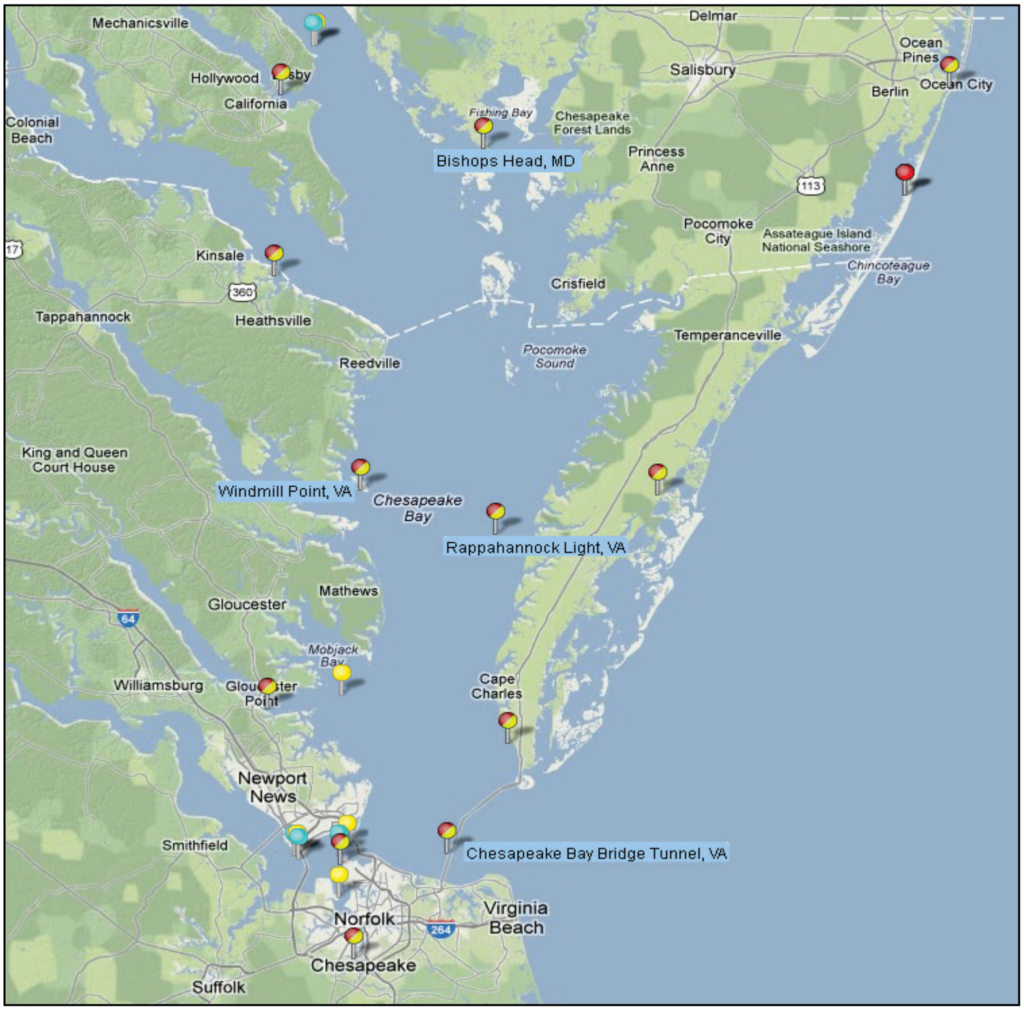
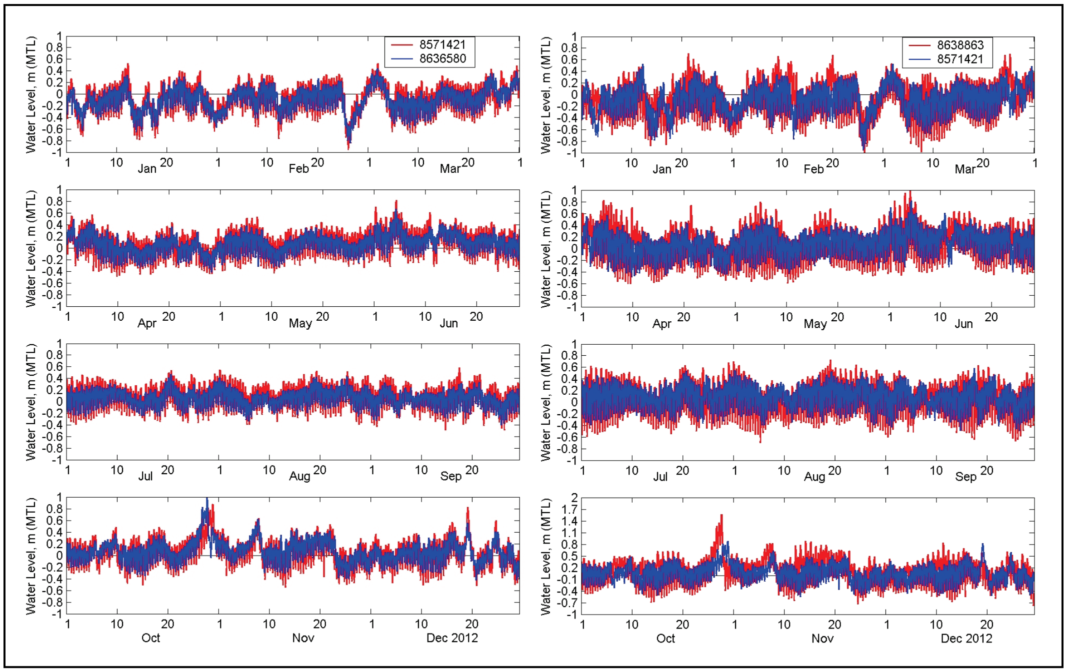


Figure 21. Water levels at Bishops Head, Windmill Point, and Bay Bridge Tunnel for 2012.



2.7 Save stations

Numerical model results have been extracted along three transact lines: the channel centerline, and along the north and south shorelines. Figure 22 shows the three transact lines. A total of 103 save stations were placed along the channel centerline, north and south shorelines, and around the perimeter of structures (Figure 23).

Figure 22. Transects (lines) where model results are extracted.

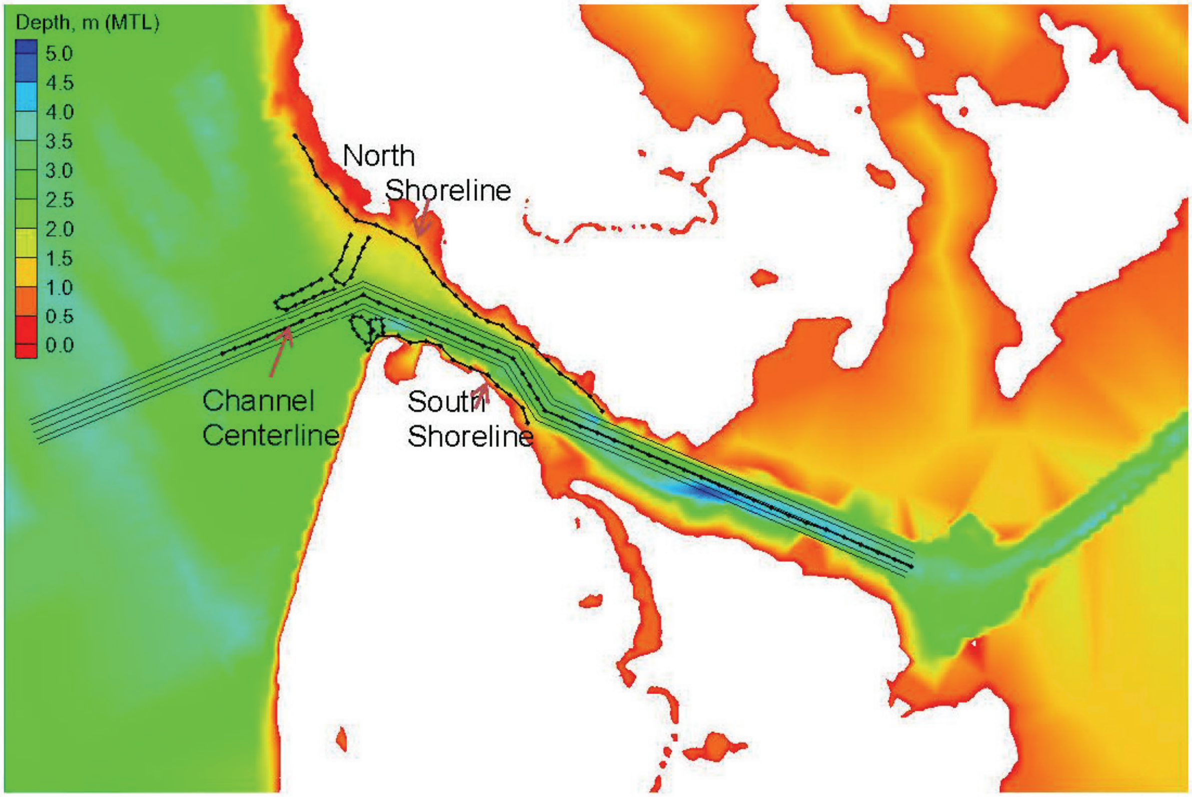
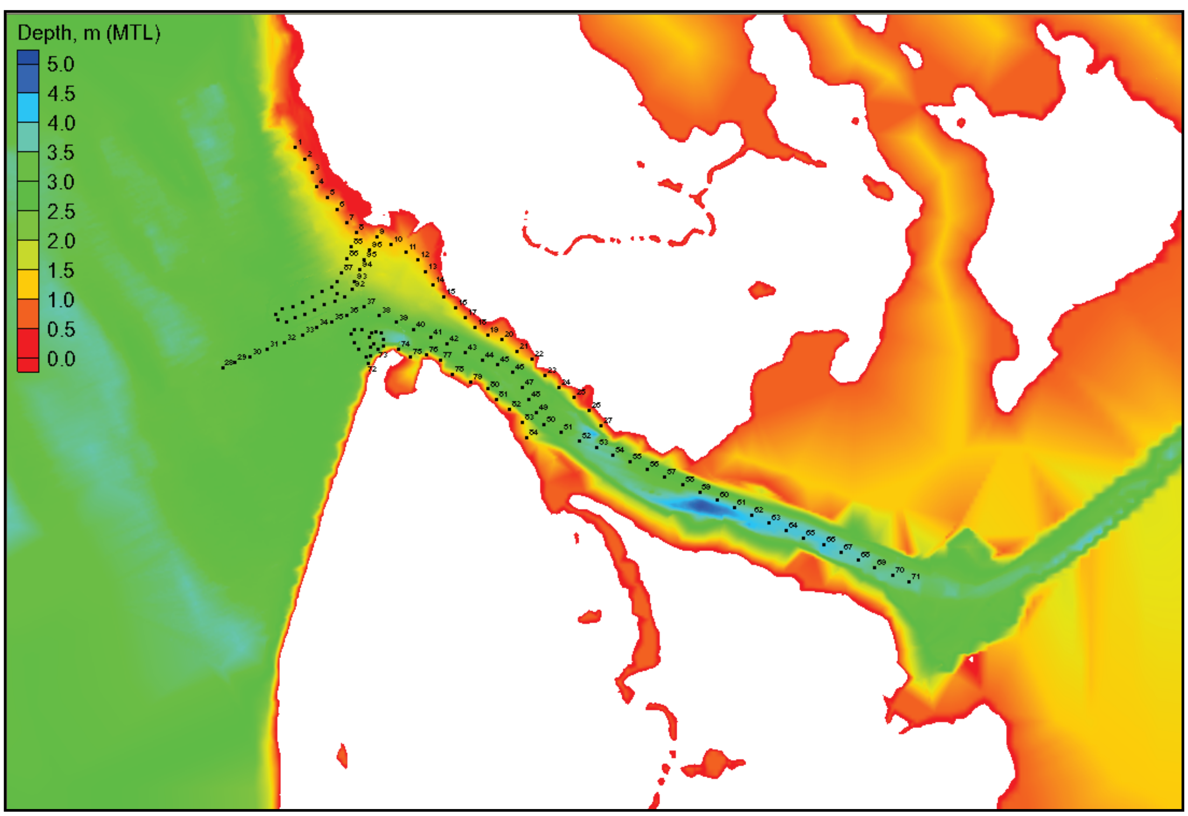


Figure 23. Point locations where model results are extracted.

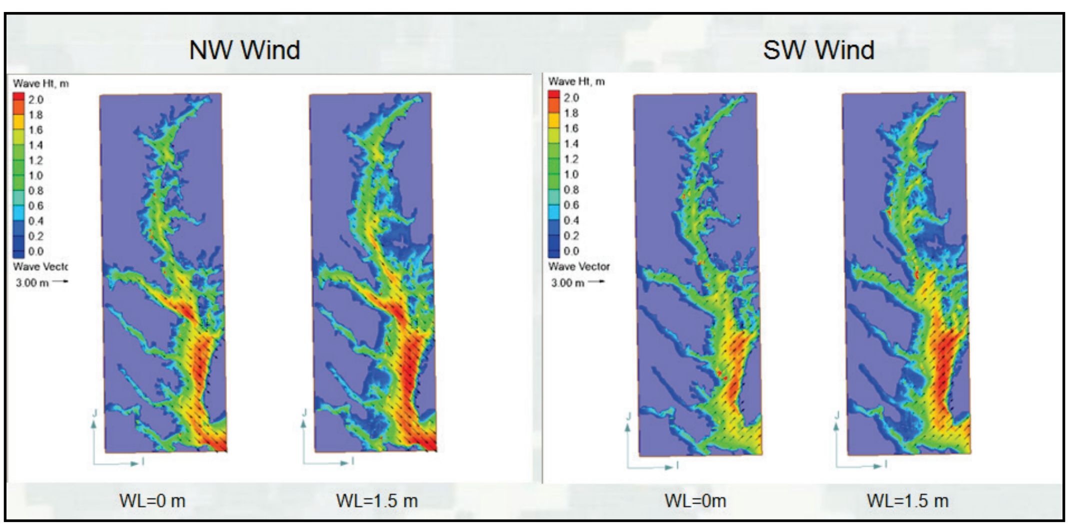


2.8 Idealized wind and water level simulations (waves without current)

Idealized wind and wave simulations were performed for nine wind directions listed in Table 2 and two water levels, 0 and 5 ft (0 and 1.5 m). The idealized wind conditions, representing the 50 yr return period, were used in the numerical simulations for the existing west channel without a structure (without project) and for five alternatives with structures (with project). The 50 yr wind condition was based on a previous study by Basco and Shin (1993). Details of existing and five alternative configurations are shown in Figures 13-18. First, the model simulations were conducted in the regional grid for waves and flow only, without sediment transport. The results from the regional simulations were provided as input to the local Tangier Island grid for wave, flow, and sediment transport calculations. Because the focus of the study was intended for structure design, the modeling was emphasized on waves and flow, not sediment transport results.

A total of 108 simulations (9 wind conditions x 2 water levels x 6 structure configurations) were performed to develop the spatially varying estimates of the winds, waves, water levels, and currents throughout the Chesapeake Bay. These simulations used the large regional grid. For example, Figure 24 shows the bay-wide wave-height fields calculated by models for two wind directions (wind speed of 45 mph or 20 m/sec blowing from NW and SW), and two water levels (0 and 5 ft or 1.5 m).

Figure 24. Examples of models of calculated wave heights in the Chesapeake Bay for the 50 yr design winds from NW and SW and two water levels.



2.9 Relative comparison of alternatives

Results from the wind-wave simulations for the entire bay were used as input to the fine resolution local grid to develop the estimates of waves, flow, and water levels at the project site. A total of 108 simulations were conducted with the local grid. Numerical model results along the channel centerline were compared to determine which structural alternative provided the greatest wave-energy reduction in the west channel section of Tangier Island. Figures 25-28 show contour plots of calculated wave heights for existing, Alt 1, Alt 2, and Alt 3 using the 50 yr design conditions (e.g., 45 mph or 20 m/sec winds from NW and SW directions, and water levels of 0 m and 5 ft or 1.5 m). For the four configurations shown, these spatial variation plots display the change in the wave heights at the bay-side entrance of the west channel. These color-coded plots show the extent of wave penetration into the canal, and also variation of wave heights occurring along the channel centerline and north and south shorelines.

Figure 25. Example of models of calculated wave heights in the west channel for the 50 yr design winds from NW and water level of 0 m.

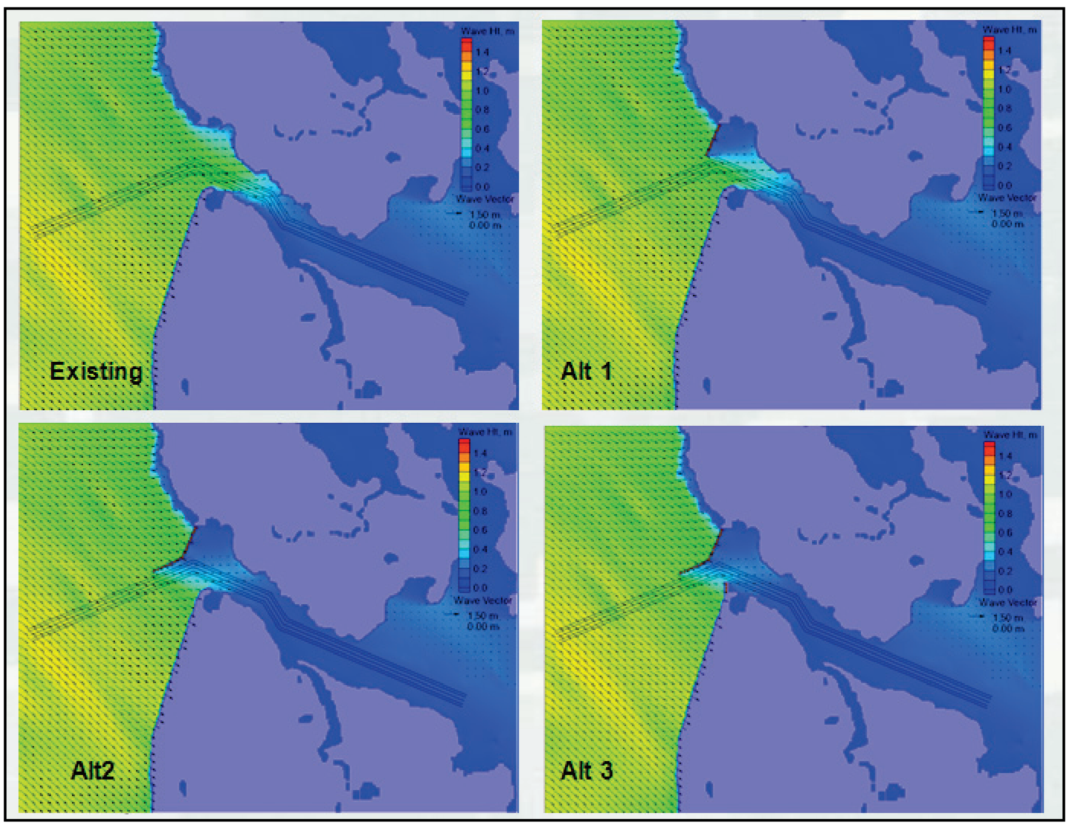


Figure 26. Examples of models of calculated wave heights in the west channel for the 50 yr design winds from SW and water level of 0 m.

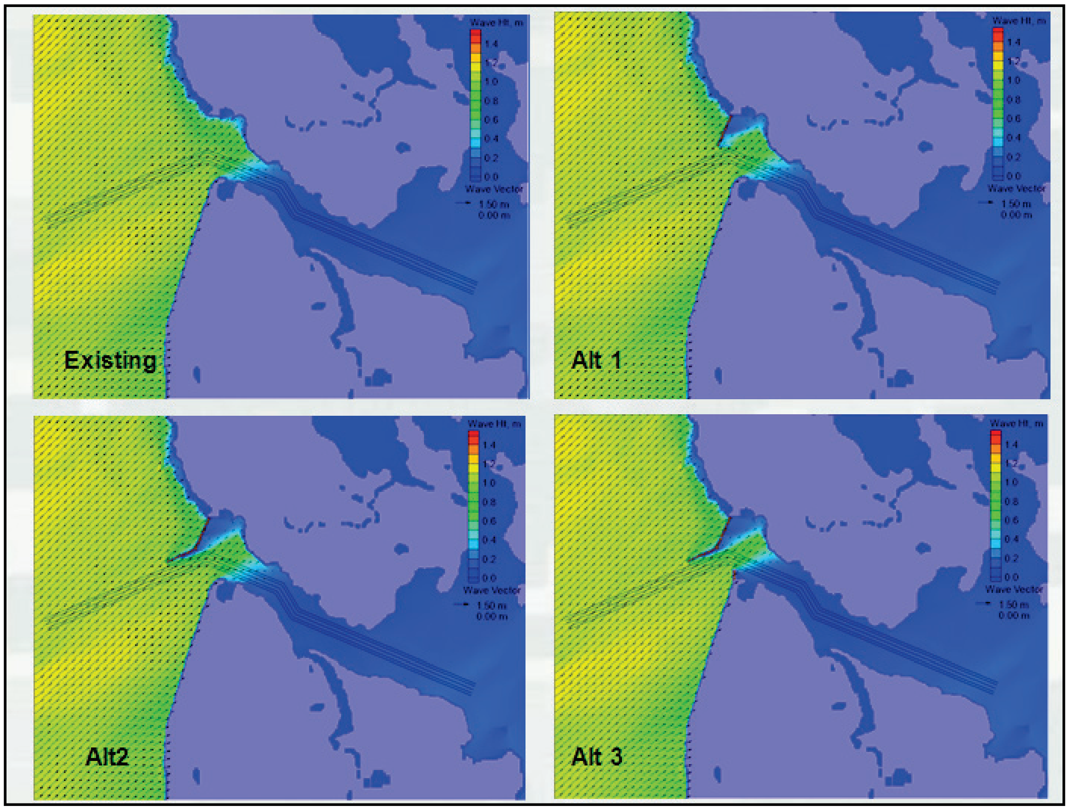


Figure 27. Examples of models of calculated wave heights in the west channel for the 50 yr design winds from NW and water level of 1.5 m.

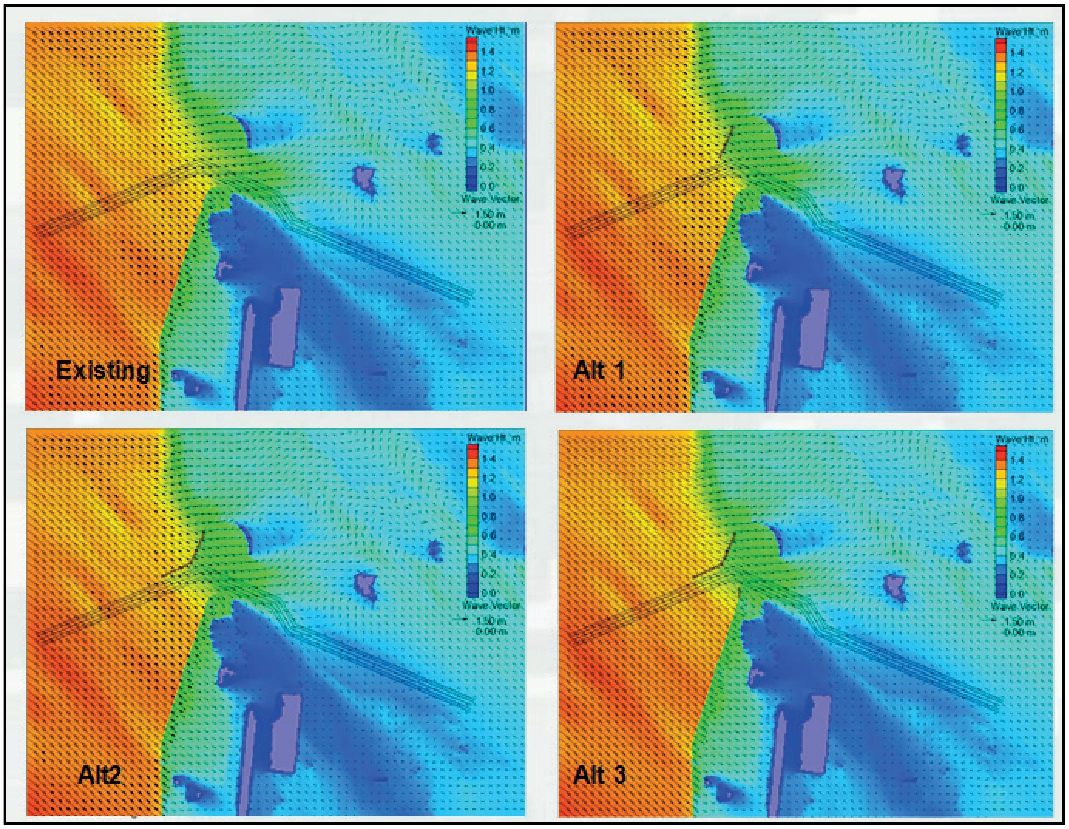
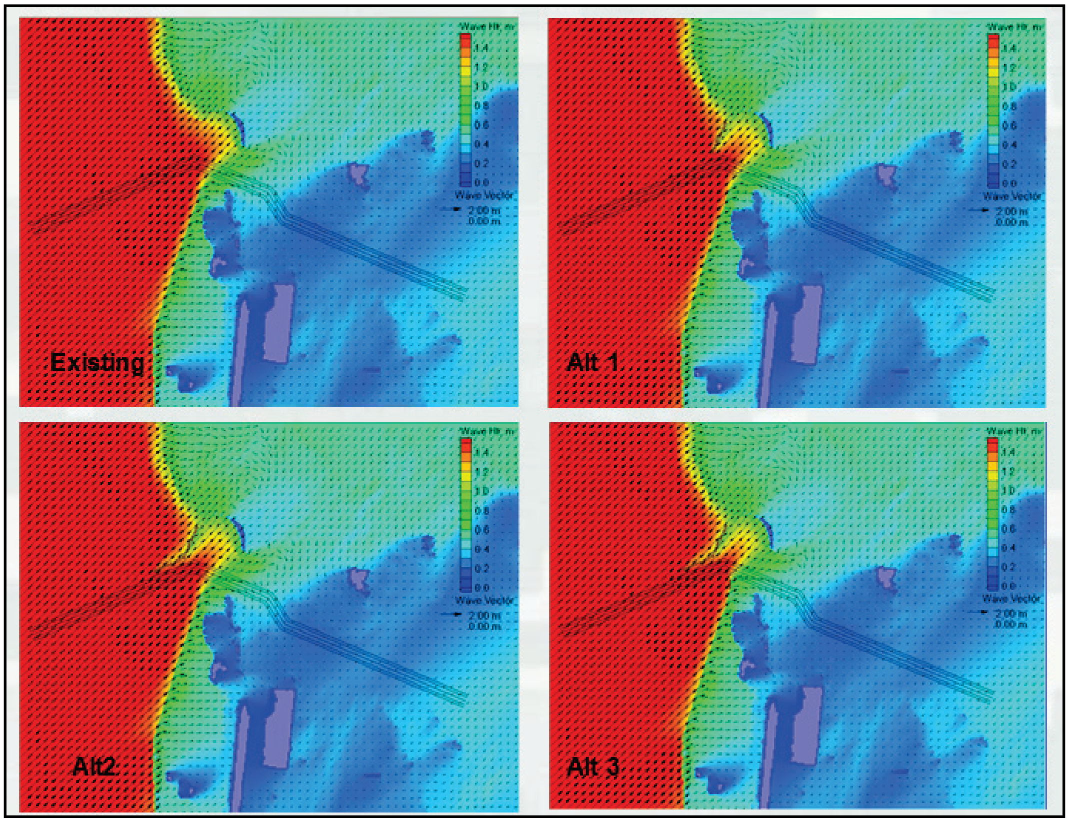


Figure 28. Examples of models of calculated wave heights in the west channel for the 50 yr design winds from SW and water level of 1.5 m.



The wave-reduction analysis was performed for all simulations by comparison of the alternatives to the existing channel. Figures 29-34 show the comparison of wave-height variation along the channel centerline for NW, W, and SW directions. Figure 35 shows the example of calculated wave heights for Alt 4 along the channel centerline for 0 m water level and all directions.

Figure 29. Calculated wave heights in the west channel for 50 yr design winds from NW and water level of 0 m.

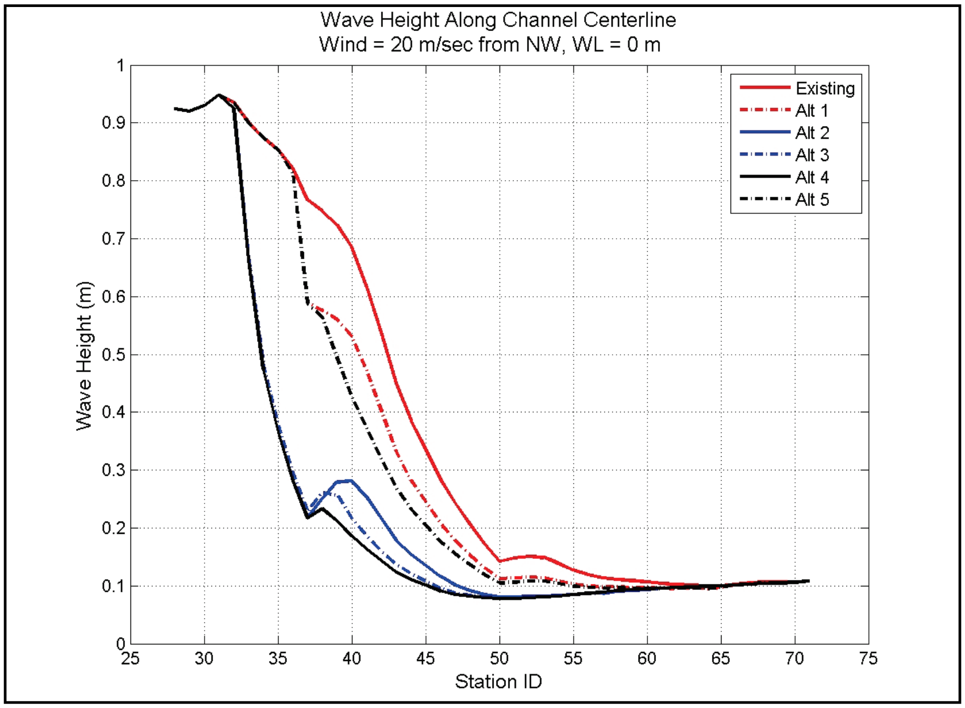


Figure 30. Calculated wave heights in the west channel centerline for 50 yr design winds from NW and water level of 1.5 m.

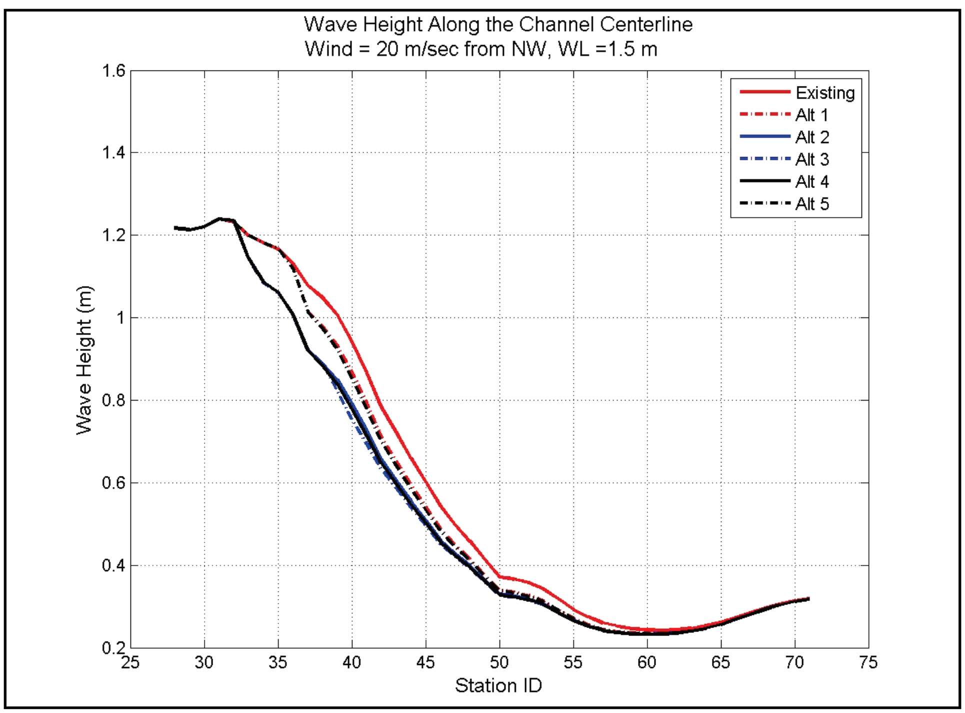


Figure 31. Calculated wave heights in the west channel for 50 yr design winds from W and water level of 0 m.

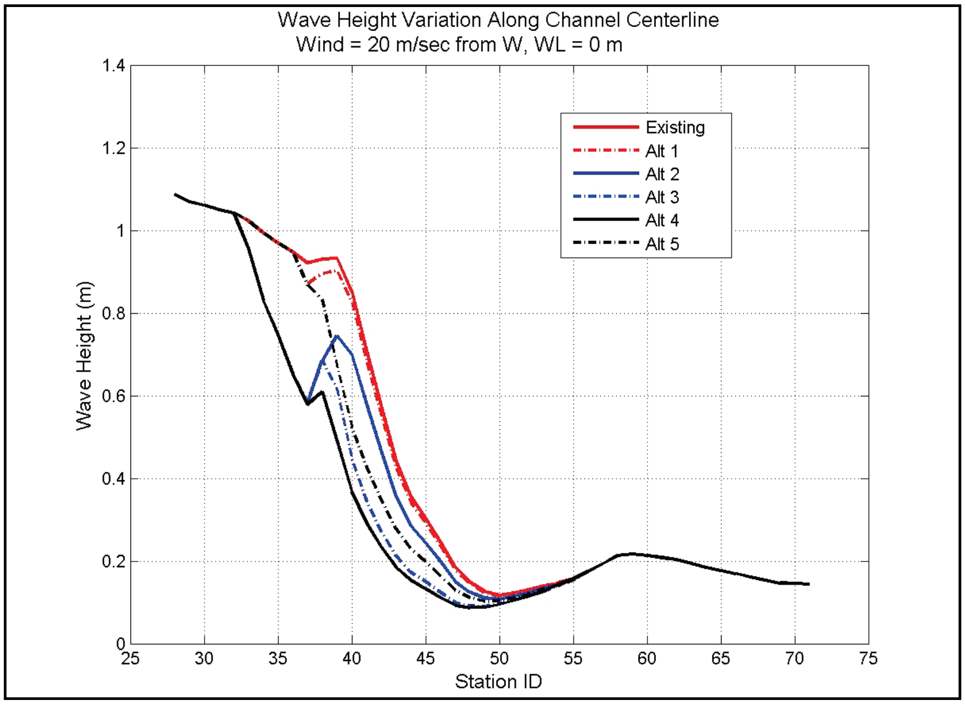


Figure 32. Calculated wave heights in the west channel centerline for 50 yr design winds from W and water level of 1.5 m.

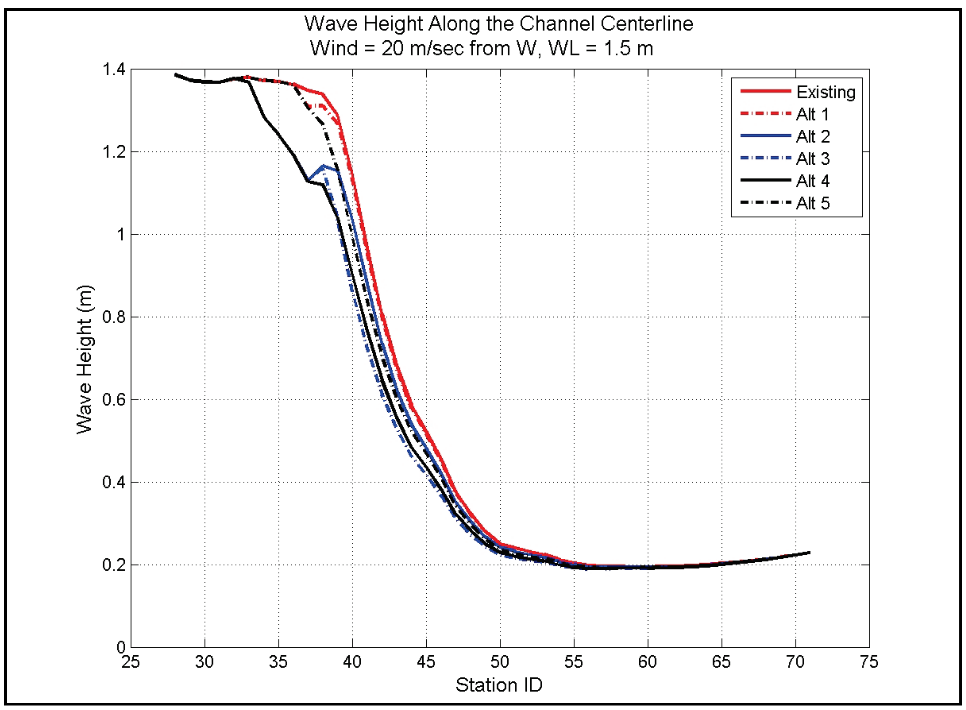


Figure 33. Calculated wave heights in the west channel centerline for 50 yr design winds from SW and water level of 0 m.

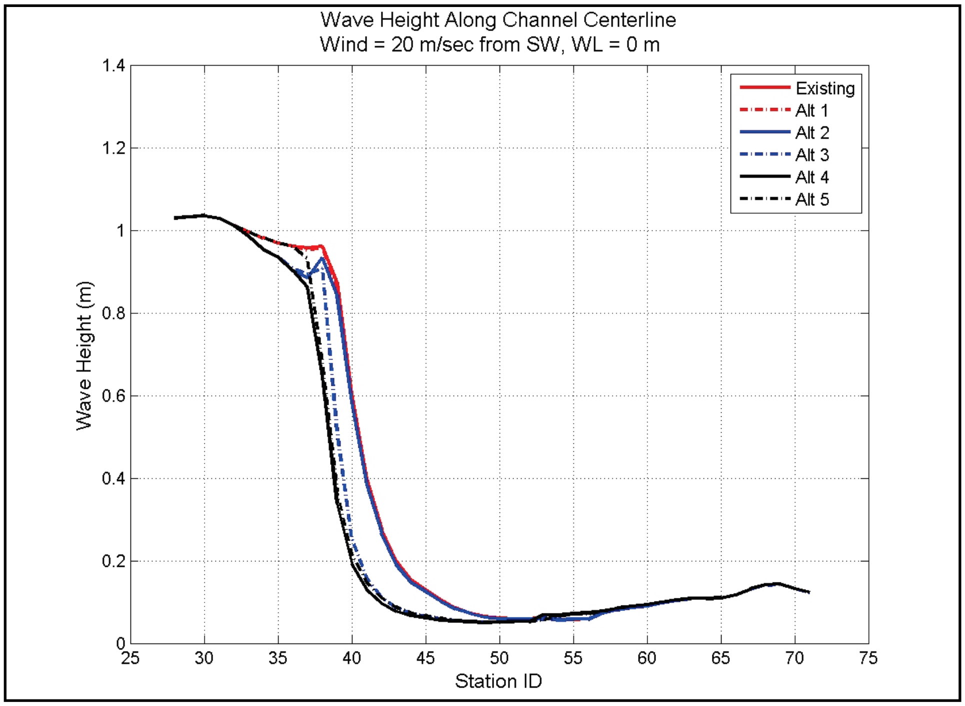


Figure 34. Calculated wave heights in the west channel centerline for 50 yr design winds from SW and water level of 1.5.

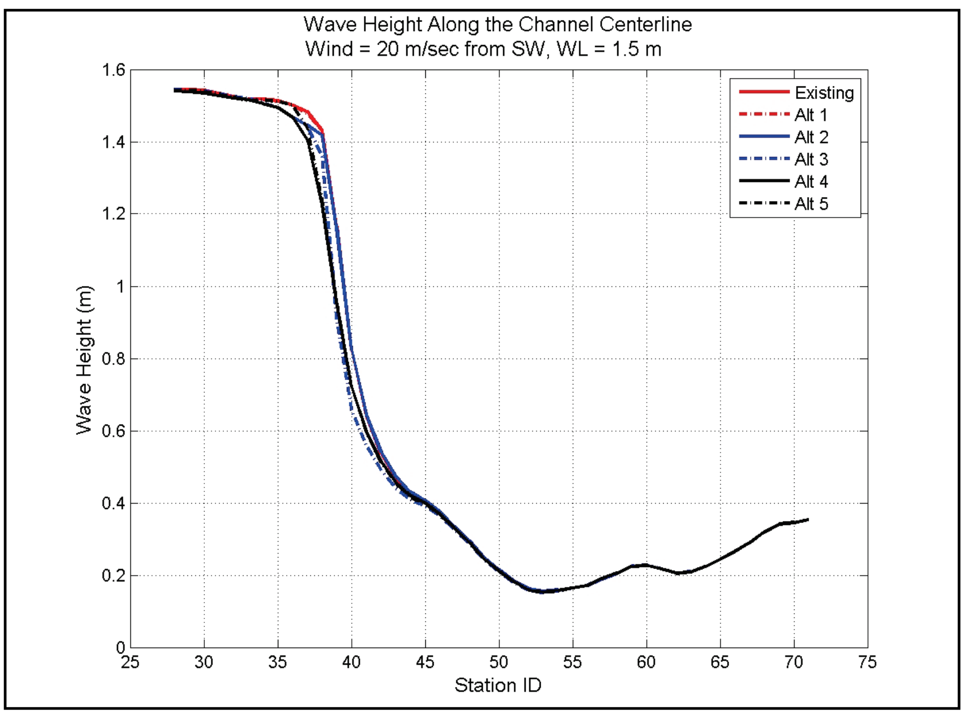
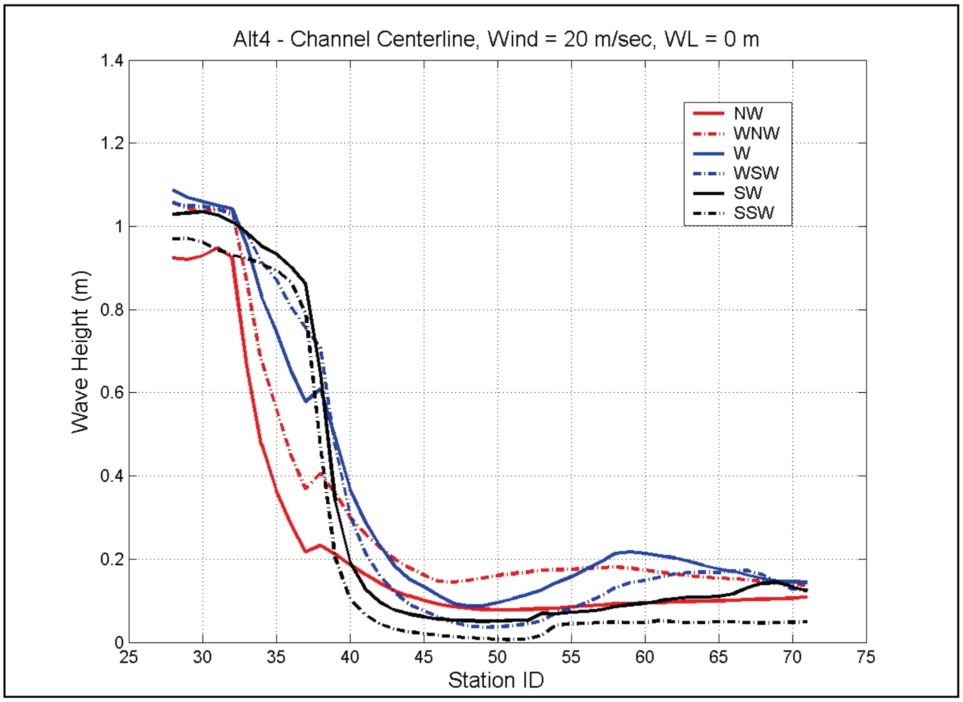


Figure 35. Calculated wave heights for Alt 4 along the west channel centerline for 50 yr design winds from six directions (NW, WNW, W, WSW, SW, and SSW) at water level of 0 m.



For all wind directions and two water levels investigated in this study, the analysis of wave-height reduction from five alternatives is based on the wave-height reduction factor calculated as the percentage of wave-height reduction to the wave heights in the existing channel without the project condition.

$$\left| \frac{\text{(Wave Height, Alternative) - (Wave Height, Existing Channel)}}{\text{(Wave Height, Existing Channel)}} \right| \times 100\%$$

For example, Figures 36 to 38 show the wave-height reduction factor along the channel centerline for Alternatives 1 to 5 and 50 yr design winds from directions of NW, W, SW, respectively, and WL = 0 m. Figures 39 to 41 show the wave-height reduction factor along the channel centerline for alternatives 1 to 5 and 50 yr design winds from NW, W, and SW, respectively, and WL = 1.5 m.

Figure 36. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds from NW at water level of 0 m.

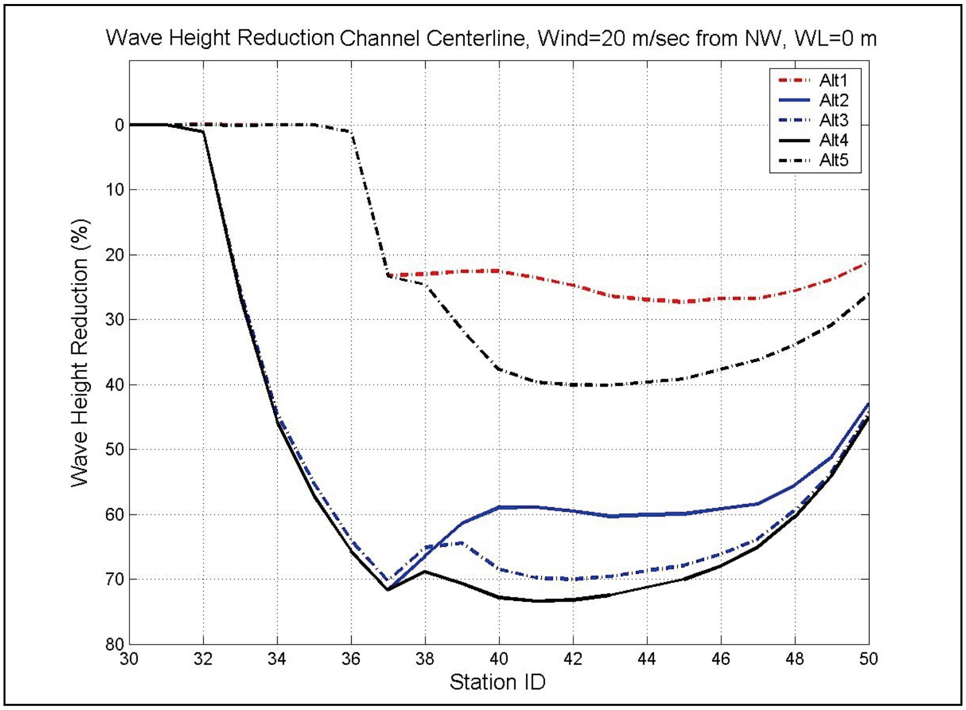


Figure 37. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds from W at water level of 0 m.

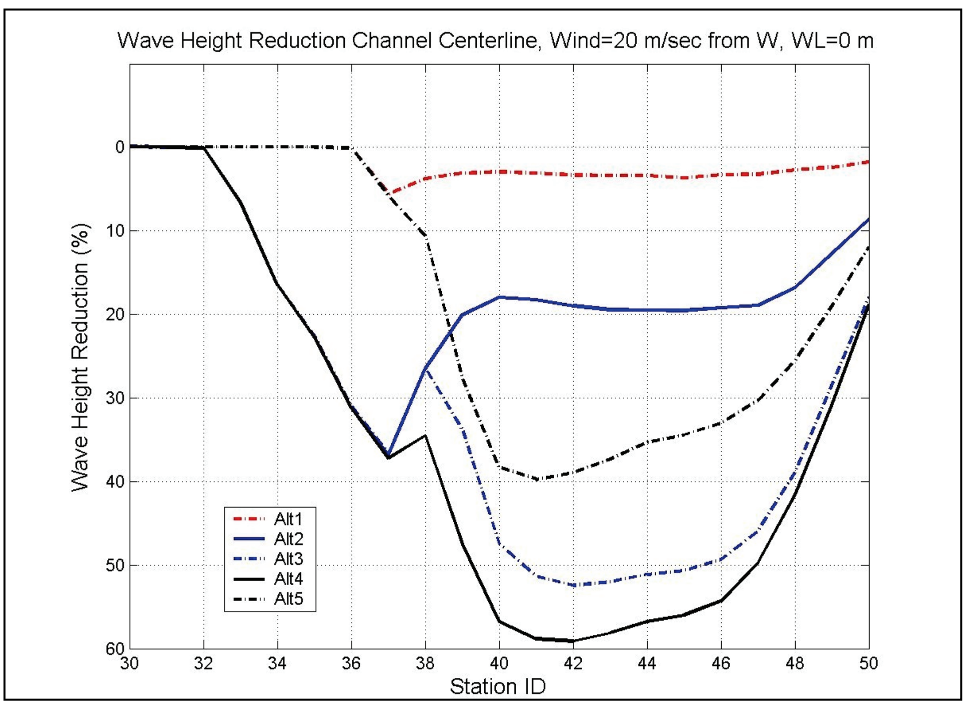


Figure 38. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds from SW at water level of 0 m.

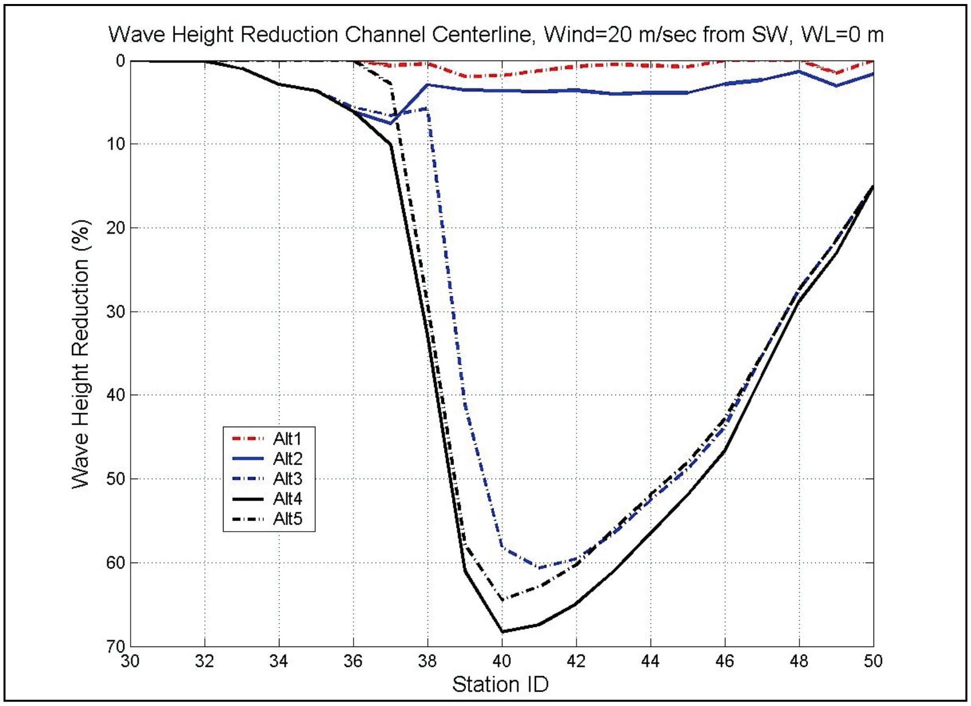


Figure 39. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds form NW at water level of 1.5 m.

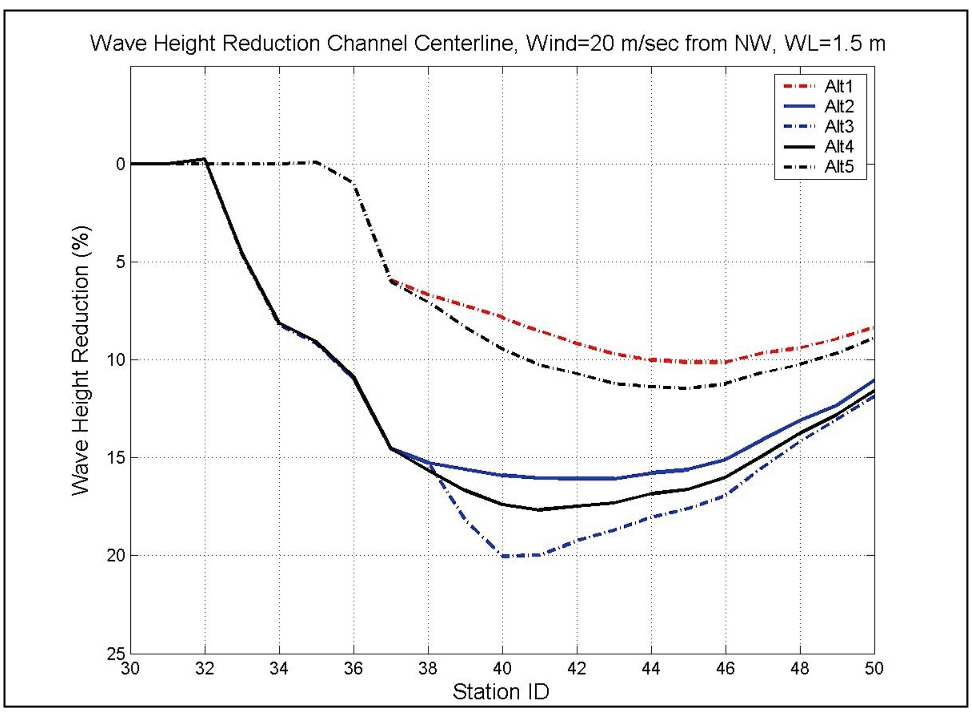


Figure 40. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds from W at water level of 1.5 m.

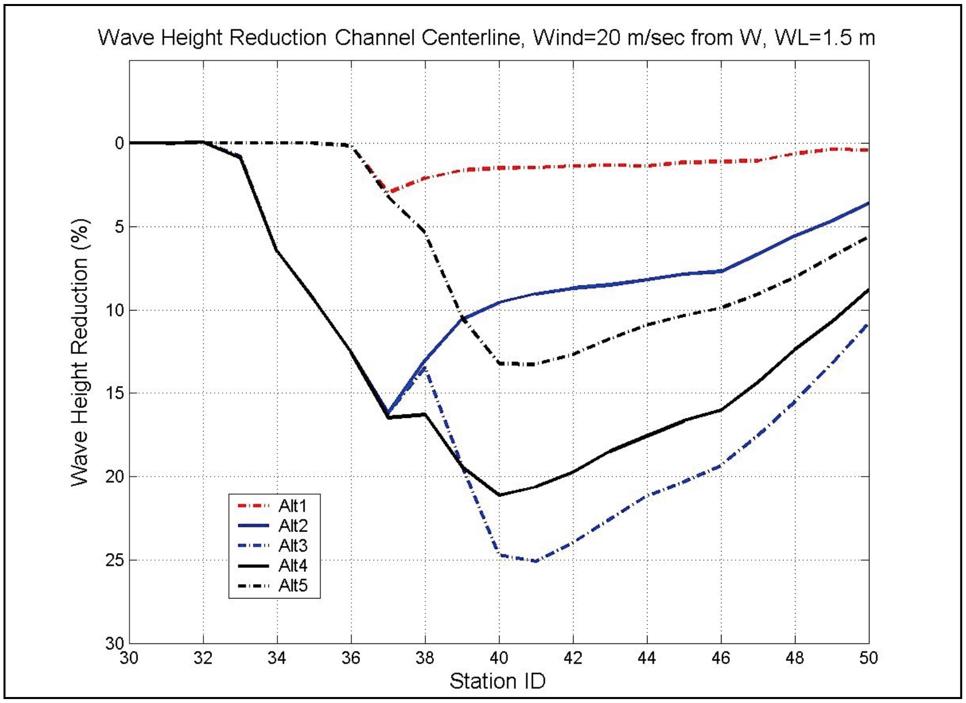
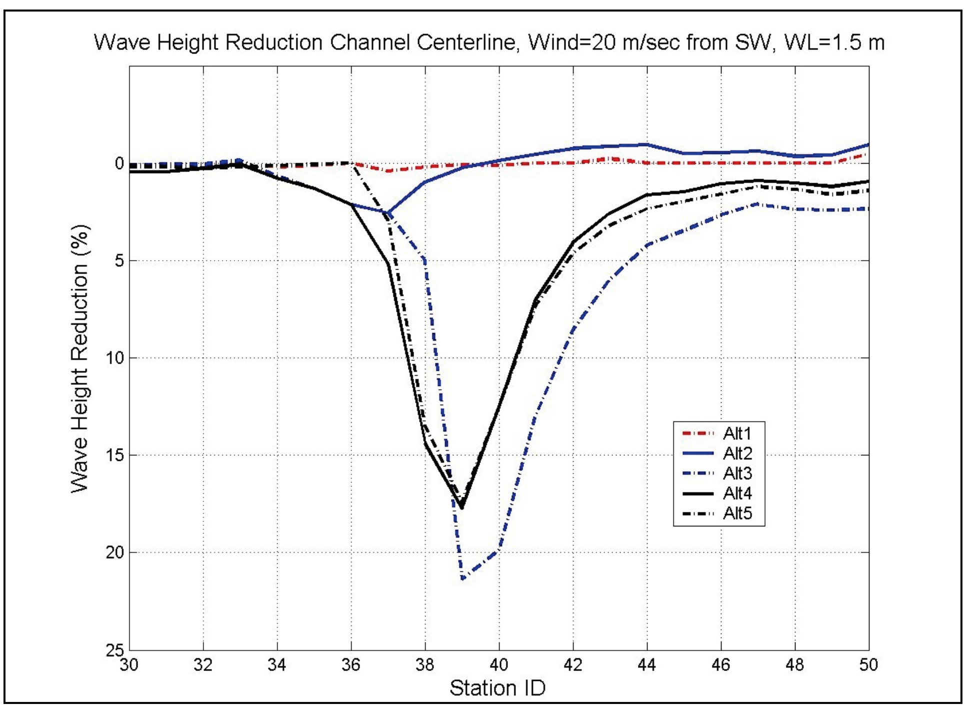


Figure 41. Calculated wave-height reduction for Alts 1-5 along the west channel centerline for 50 yr design winds from SW at water level of 1.5 m.



The corresponding wave-height variations along the north and south shorelines for the existing channel and five alternatives with design wind speeds from NW, W and SW at WL = 0 m are shown in Figures 42-47. Similarly, the wave-height variation along the north and south shorelines with design wind speeds from NW, W, and SW at WL = 1.5 m are shown in Figures 48-53. Among all alternatives, Alts 3 and 4 generally produced the largest wave-height reduction for WL = 0 m and 1.5 m, respectively, along the west channel centerline and along north and south shorelines. The high water (WL = 1.5 m) situation produces larger waves as compared to the lower water level (WL = 0 m). It must be emphasized that for high water level (WL=1.5 m), the structures used in the alternatives will be submerged, losing much of their effectiveness to intercept and reduce wave energy propagating into west and mid-sections of the channel. Under such extreme water level conditions, the wave-height reduction by alternatives cannot be used as a measure to rank the alternatives. Consequently, the ranking of alternatives is based on their performance (e.g., wave-height reduction factor) calculated for the WL = 0 m.

Figure 42. Calculated wave-heights along the north shoreline for 50 yr design winds from NW and water level of 0 m.

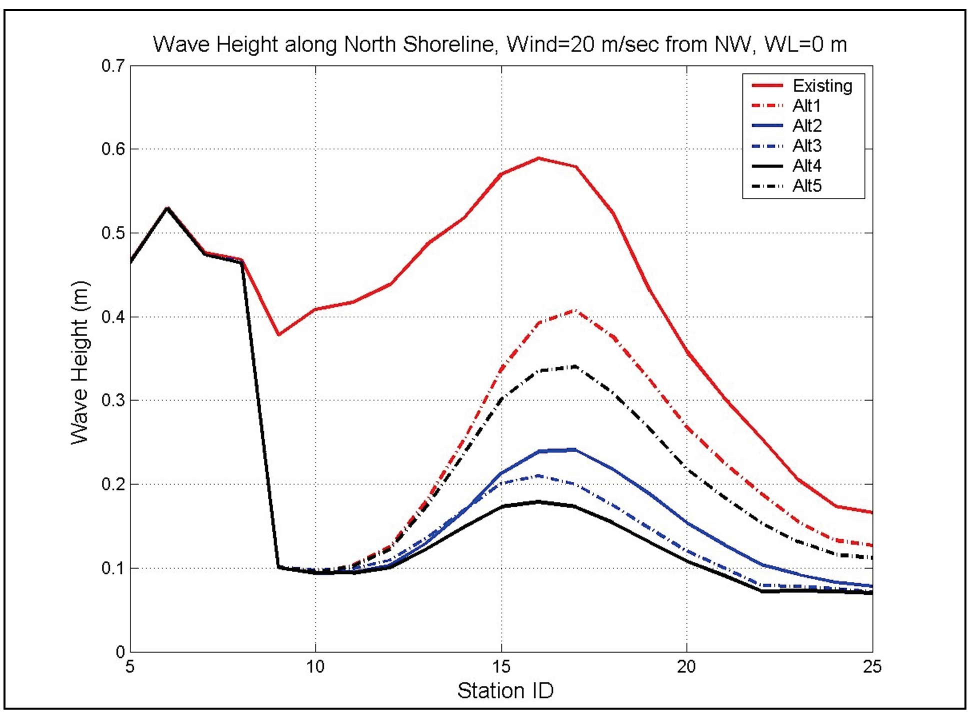


Figure 43. Calculated wave-heights along the north shoreline for 50 yr design winds from W and water level of 0 m.

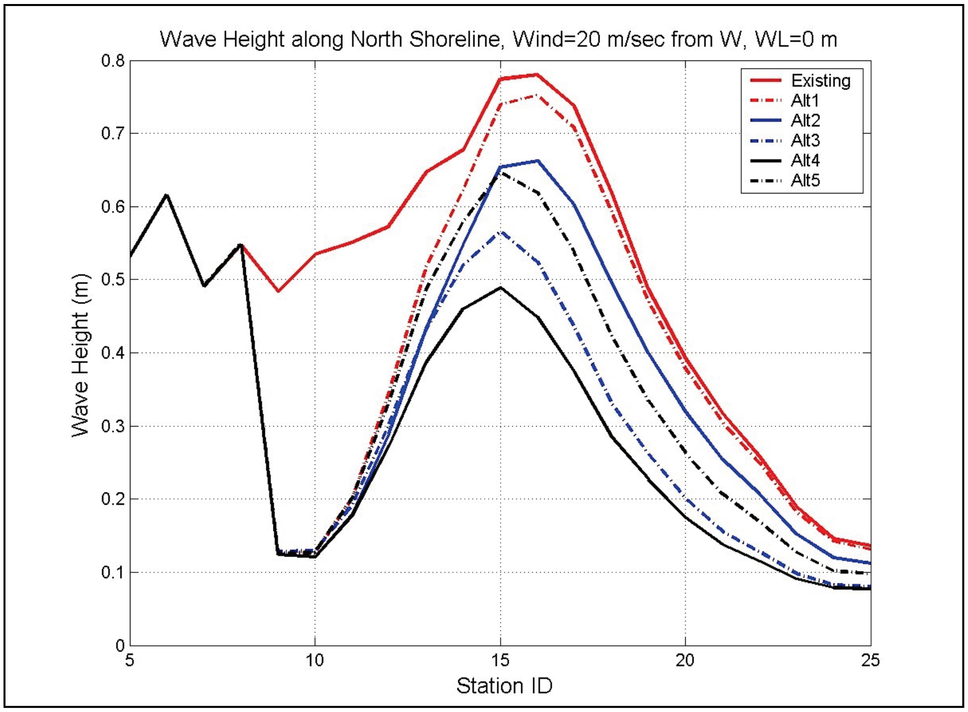


Figure 44. Calculated wave heights along the north shoreline for 50 yr design winds from SW and water level of 0 m.

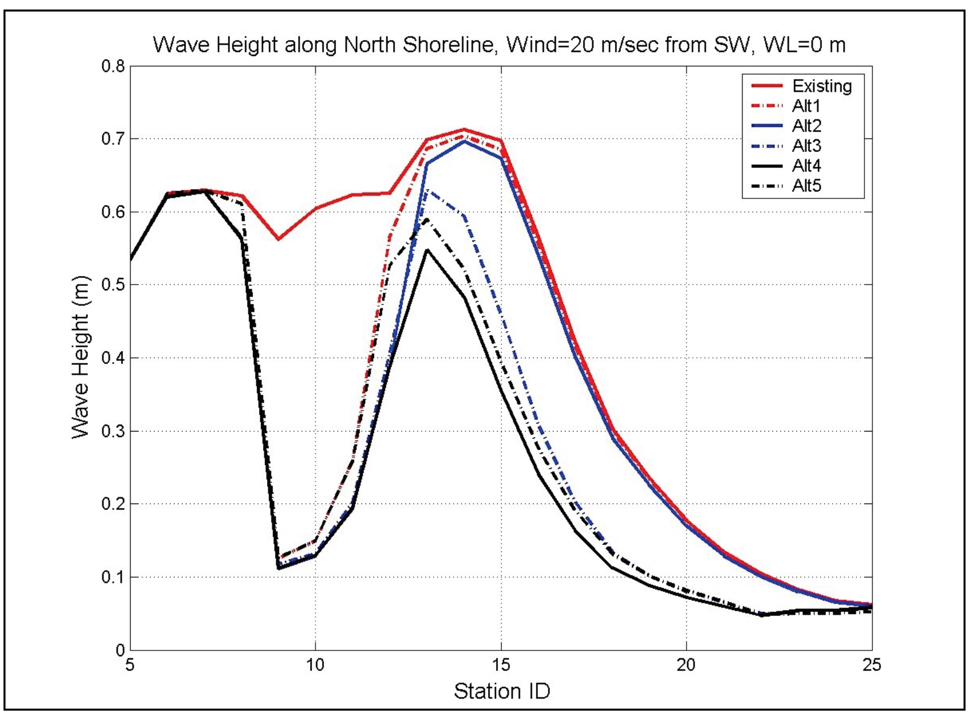


Figure 45. Calculated wave heights along the south shoreline for 50 yr design winds from NW and water level of 0 m.

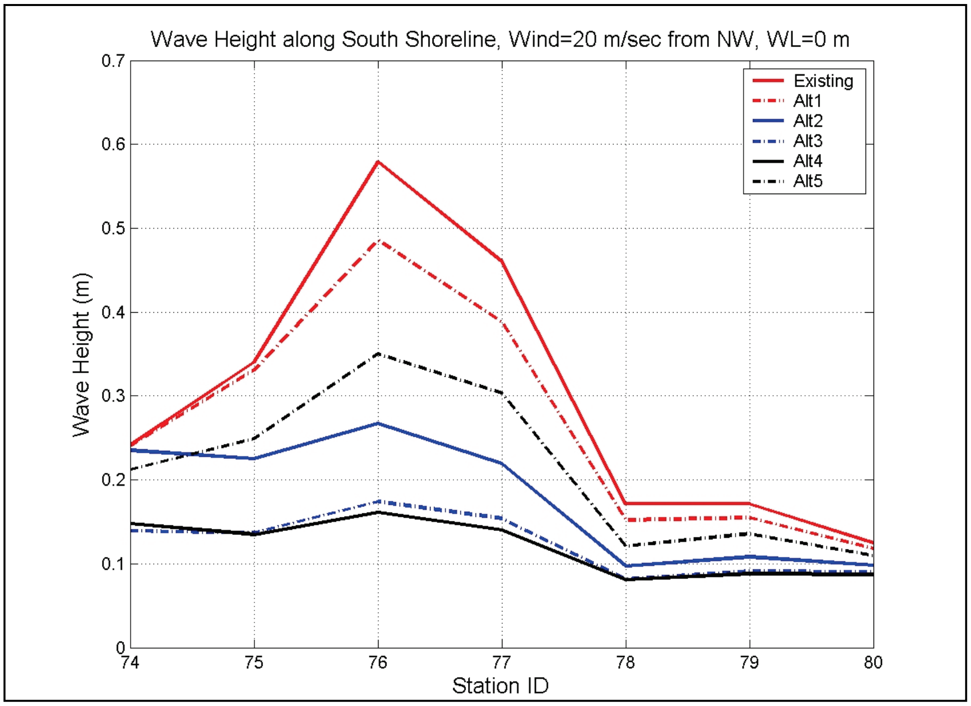


Figure 46. Calculated wave heights along the south shoreline for 50 yr design winds from W and water level of 0 m.

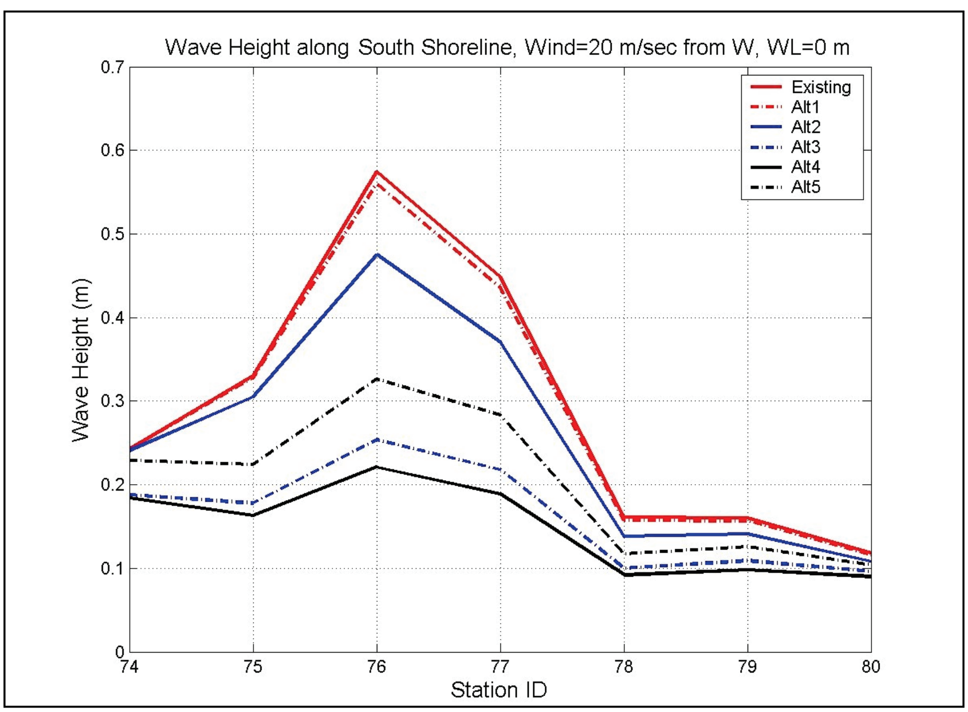


Figure 47. Calculated wave heights along the south shoreline for 50 yr design winds from SW and water level of 0 m.

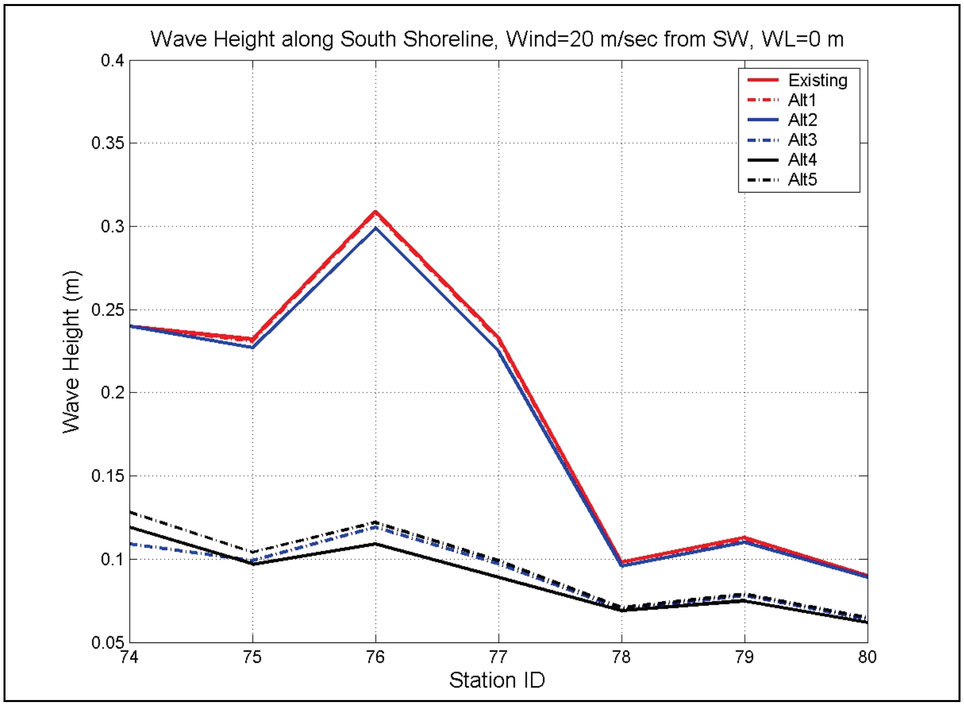


Figure 48. Calculated wave heights along the north shoreline for 50 yr design winds from NW and water level of 1.5 m.

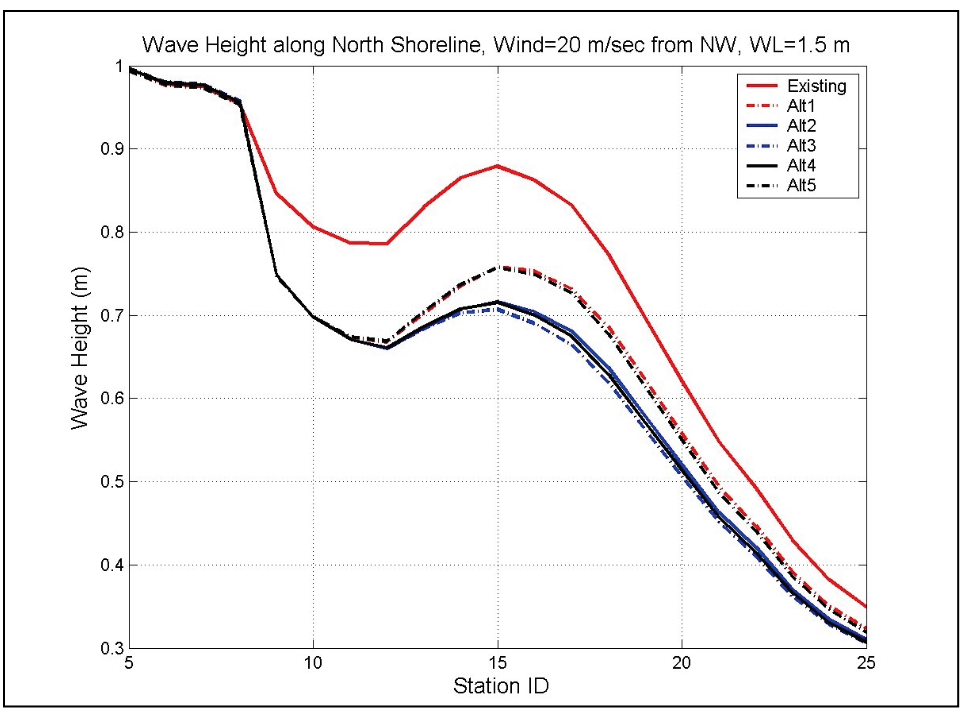


Figure 49. Calculated wave heights along the north shoreline for 50 yr design winds from W and water level of 1.5 m.

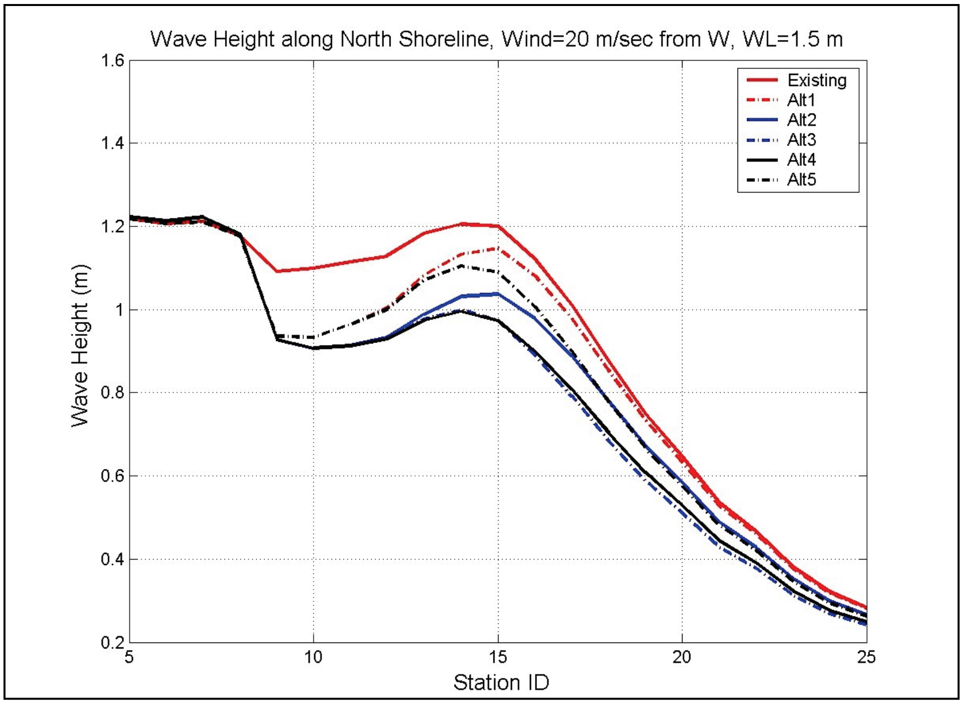


Figure 50. Calculated wave heights along the north shoreline for 50 yr design winds from SW and water level of 1.5 m.

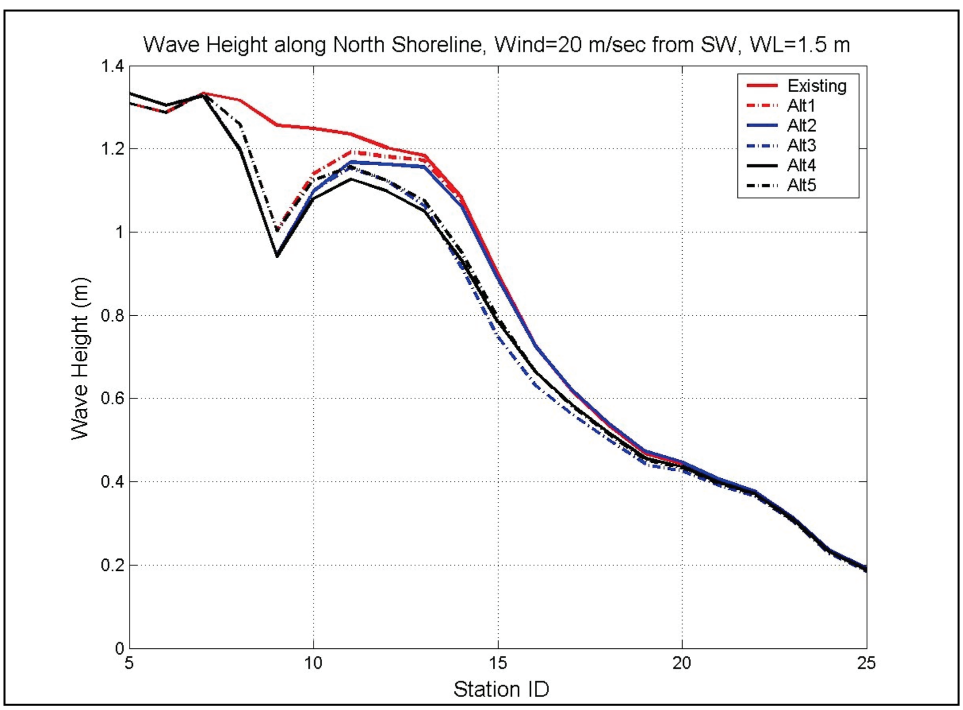


Figure 51. Calculated wave heights along the south shoreline for 50 yr design winds from NW and water level of 1.5 m.

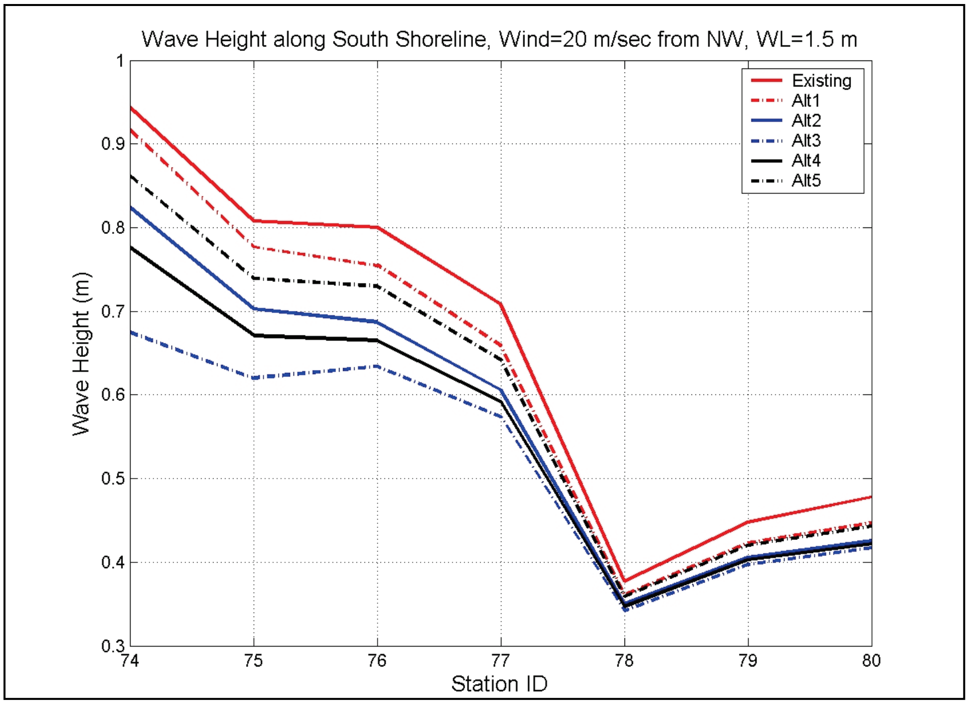


Figure 52. Calculated wave heights along the south shoreline for 50 yr design winds from W and water level of 1.5 m.

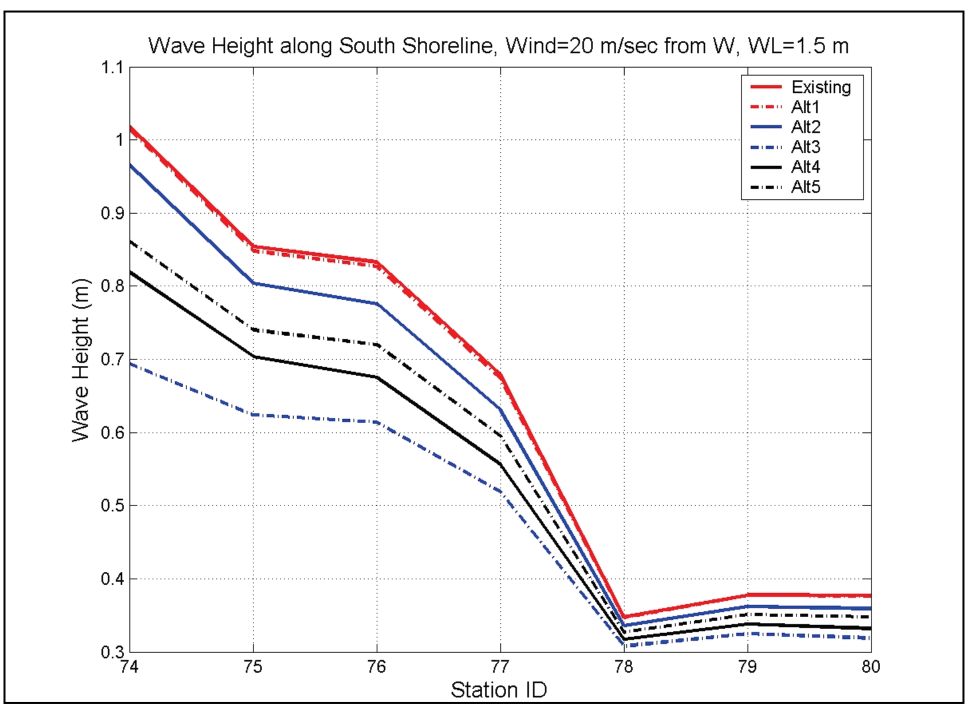
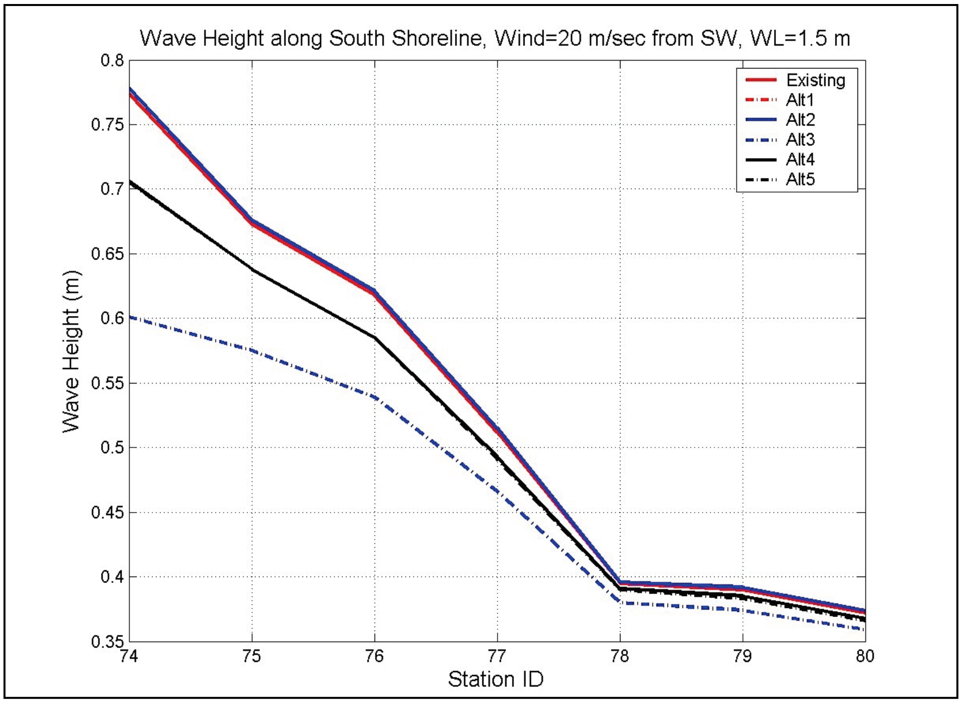


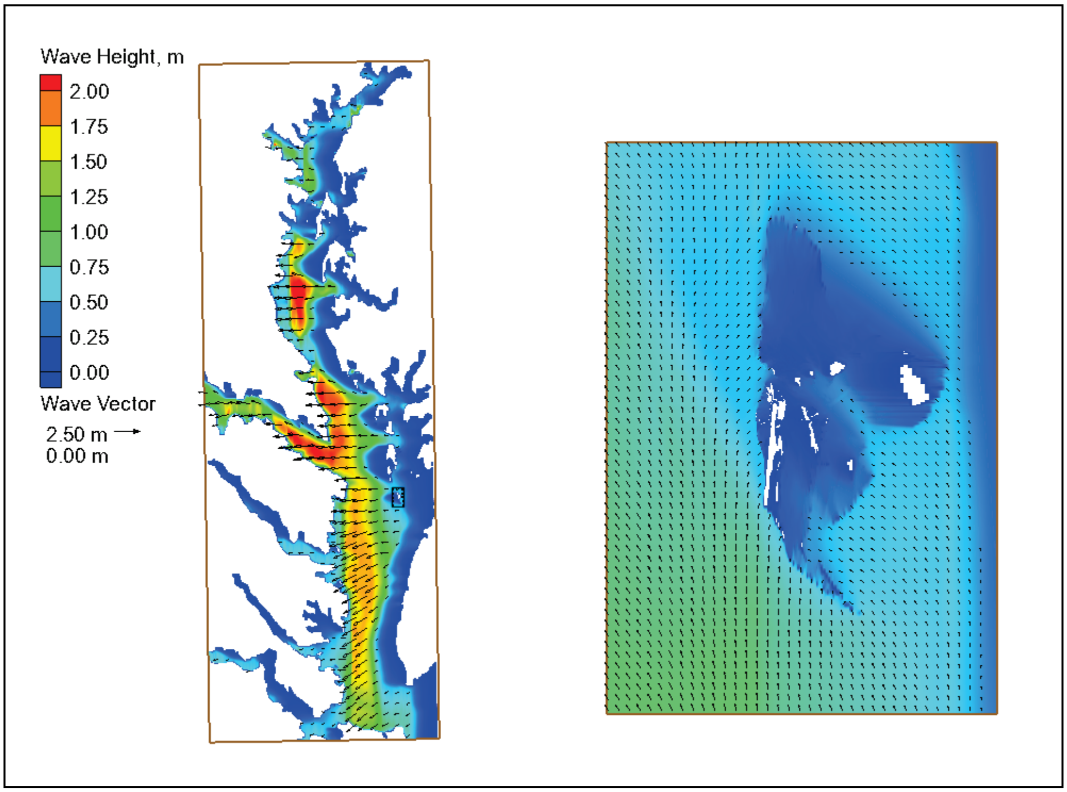
Figure 53. Calculated wave heights along the south shoreline for 50 yr design winds from SW and water level of 1.5 m.



2.10 Hurricane Isabel simulations (waves with current)

A similar analysis of waves was performed using Hurricane Isabel winds for six channel configurations (existing and five alternatives). This was done to determine wave and water level estimates for a 50 yr hurricane event. Because the winds for Hurricane Isabel approached Chesapeake Bay from the east side and winds rotate counter-clockwise around the center (eye) of the hurricane, significant over-land drag reduction of wind speeds occurred, affecting the water level close to the land-water boundaries. The strong east-to-west winds associated with Hurricane Isabel produced elevated water levels along the west side of the bay and lowered the water level in the mid and east side of bay. As a consequence, although lower water levels occurred at and around Tangier Island during Isabel, this event was considered as a 50 yr hurricane for the entire bay. The wind and water-level pattern associated with Hurricane Isabel was simulated for 17-20 September 2003. As expected, model results indicated comparatively lower waves and water levels at Tangier Island than in the western portion of the bay. Figure 54 shows an example of the calculated wave-height field in the Chesapeake Bay (regional grid) and at Tangier Island (local grid) for the existing channel configuration during Isabel.

Figure 54. Example of calculated wave-height fields during Hurricane Isabel.



2.11 Estimates for structure design

Based on results described in the two previous sections, the structural lay-out of Alt 4 overall is more effective at reducing wave-energy propagation into the canal than the other alternatives for all conditions evaluated. Consequently, Alt 4 is the recommended structural lay-out for achieving the project goals. This recommendation is based on the performance of alternatives for WL = 0 m, defined as the wave-height reduction factor achieved along the channel centerline. However, it is noted that at the extreme high water level (WL=1.5 m, 5 ft), the structures evaluated are partially or fully submerged, diminishing their effectiveness to intercept and reduce wave energy penetrating into the west and mid-sections of the channel. Under such extreme water level conditions, wave-height reduction cannot be used as a measure to rank the alternatives. For purposes of completeness and future records, the ranking of alternatives is provided in this report for both water levels.

The calculated wave-height, period, direction, and water-level estimates at ten locations on the windward side of the north and south structures of Alt 4 and along north shoreline are shown in Figure 46. These stations are marked in black squares in Figure 55 and are 4, 7, 10, 13, 85, 88, 99, 103, 118, and 121. Wave and water-level estimates at these stations are used in the structure design calculation and evaluation of wave effects to north shoreline. Calculated wave direction, height, and period estimates at these ten stations marked on Figure 55 are listed in Tables 3, 4, and 5 for two water levels (0 and 5 ft or 1.5 m). Wave direction is meteorological (e.g., direction waves coming from).

Figure 55. Ten selected locations (black squares) in Alt 4 where wave and water-level estimates are provided for design of structure and evaluation of wave effect to north shoreline.

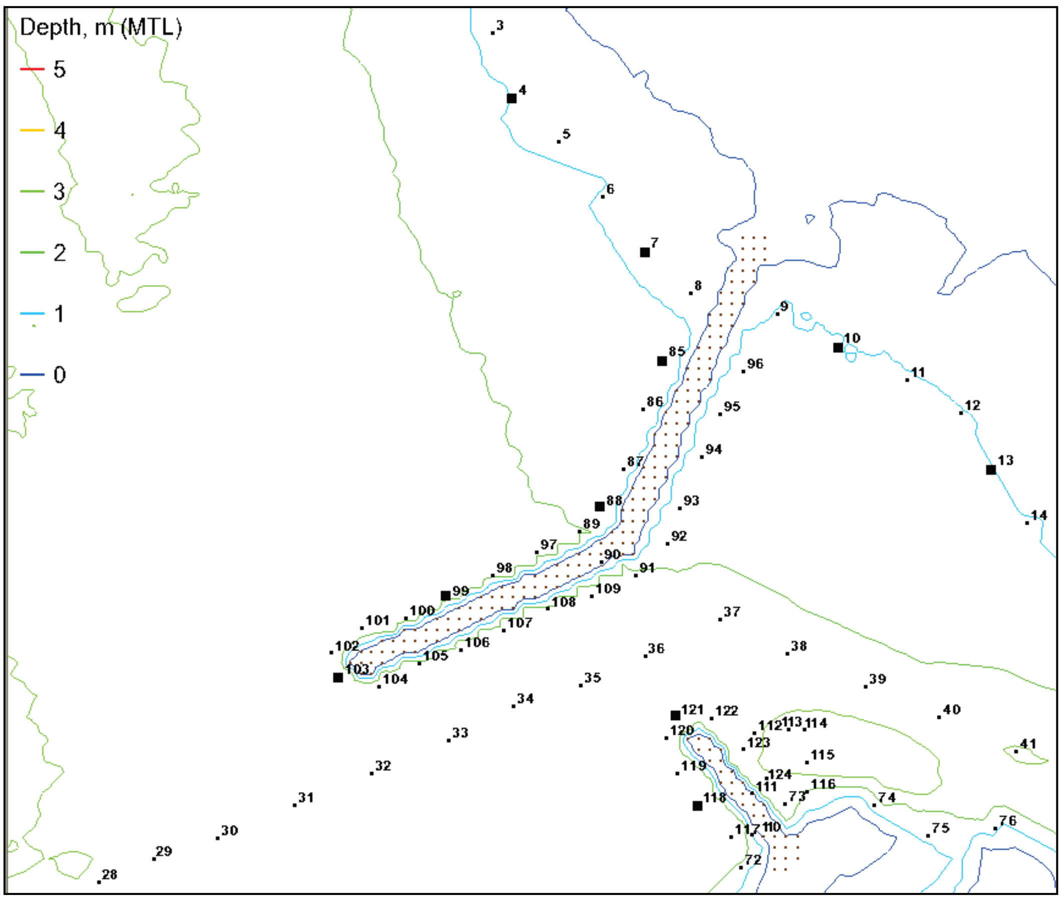


Table 3. Wave parameters for 50 yr design conditions (water level = 0 m).

Sta	Depth (m, MTL)	Wave Height (m)	Wave Period (sec)	Direction (deg)
4	0.93	0.81	5.4	250
7	0.7	0.63	5.4	237
10	1.0	0.26	5.4	259

Sta	Depth (m, MTL)	Wave Height (m)	Wave Period (sec)	Direction (deg)
13	1.0	0.64	5.4	233
85	1.27	0.7	5.4	266
88	1.88	0.9	5.4	285
99	2.35	1.02	5.4	288
103	2.64	1.06	5.4	287
118	2.65	0.98	5.4	233
121	2.56	0.97	5.4	232

Table 4. Wave parameters for 50 yr design conditions (water level = 1.5 m).

Sta	Depth (m, MTL)	Wave Height (m)	Wave Period (sec)	Direction (deg)
4	2.43	1.39	5.2	247
7	2.2	1.33	5.2	229
10	2.5	1.09	5.3	224
13	2.5	1.1	5.3	241
85	2.77	1.27	5.3	247
88	3.38	1.3	5.3	284
99	3.85	1.34	5.3	289
103	4.14	1.53	5.3	230
118	4.15	1.47	5.3	230
121	4.06	1.47	5.3	229

Table 5. Wave parameters for Hurricane Isabel.

Sta	Depth (m, MTL)	Wave Height (m)	Wave Period (sec)	Direction (deg)
4	0.93	0.47	2.6	36
7	0.7	0.41	2.7	25
10	1.0	0.27	2.7	42
13	1.0	0.28	2.7	32

Sta	Depth (m, MTL)	Wave Height (m)	Wave Period (sec)	Direction (deg)
85	1.27	0.38	2.7	16
88	1.88	0.32	2.7	6
99	2.35	0.32	2.7	3
103	2.64	0.6	2.4	44
118	2.65	0.44	2.7	29
121	2.56	0.41	2.7	43

Table 6 presents the average of wave-height reduction factors at WL = 0 m along the west channel centerline from Sta 30 to 50 for each of five alternatives. Tables 7 and 8 present the average wave-height reduction factors at WL = 0 m along the north shoreline (Sta 5 to 25) and along south shoreline (Sta 74 to 80), respectively for Alts 1 to 5. The average of wave-height reduction factor is provided for nine cases (wind directions from N, NNW, NW, WNW, W, WSW, SW, SSW, and S) and average of cases of all nine wind directions for each alternative. Overall, the wave reduction for Alt 4 was greater than other alternatives for WL = 0 m.

Tables 9 to 11 presents the average of wave-height reduction factor at WL = 1.5 m along the west channel centerline, north shoreline, and south shoreline, respectively. In this higher water-level scenario (WL = 5 ft or 1.5 m), the average wave reduction is less for all alternatives, about 25 percent less as compared to existing channel configuration (without project). The average wave reduction for Alt 3 was greater than other alternatives. However, as discussed earlier, ranking of alternatives is based on the low water results (WL = 0.0 m) because at high water the structures are underwater. Therefore, Alt 4 is the recommended alternative.

Table 6. Average of wave-height reduction factors along west channel centerline (Sta 30 to 50) for Alts 1-5 at WL = 0 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	20.3	53.9	57.4	56.5	27.3
NNW	21.5	51.9	55.0	56.7	28.6
NW	16.4	48.6	52.0	54.0	22.9

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
WNW	5.6	31.2	38.5	40.7	14.4
W	2.2	16.7	31.4	35.1	18.5
WSW	1.1	7.7	30.9	36.1	27.1
SW	0.5	2.9	26.0	30.4	27.4
SSW	0.1	2.8	38.2	43.9	38.4
S	0.2	2.1	25.7	30.6	28.1
Average	7.5	24.2	39.5	42.7	25.9

Table 7. Average of wave-height reduction factors along north shoreline (Sta 5 to 25) for Alts 1-5 at WL = 0 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	38.4	57.5	61.6	61.2	44.9
NNW	39.6	55.9	59.0	60.5	46.2
NW	34.2	51.3	54.6	56.9	40.4
WNW	23.0	40.3	47.2	50.4	31.4
W	15.3	24.8	37.8	42.3	29.3
WSW	12.3	17.3	35.6	40.6	34.4
SW	11.2	15.5	37.2	40.6	36.9
SSW	10.8	15.7	40.5	46.9	40.8
S	11.4	20.0	45.6	50.9	42.1
Average	21.8	33.1	46.6	50.0	38.5

Table 8. Average of wave-height reduction factors along south shoreline (Sta 74 to 80) for Alts 1-5 at WL = 0 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	18.3	56.3	74.0	63.6	35.8
NNW	16.6	48.4	65.7	65.6	35.3
NW	8.7	34.9	52.2	53.2	24.9

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
WNW	2.4	17.4	36.7	40.3	17.3
W	1.6	11.0	37.7	42.7	25.4
WSW	0.7	4.4	41.6	45.9	36.5
SW	0.3	2.1	45.7	47.1	43.6
SSW	0	2.1	65.1	68.6	61.1
S	0	1.2	59.6	63.6	59.5
Average	5.4	20.0	53.1	54.5	37.7

Table 9. Average of wave-height reduction factors along west channel centerline (Sta 30 to 50) for Alts 1-5 at WL = 1.5 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	1.9	8.0	8.9	8.9	2.8
NNW	5.8	11.0	12.2	11.7	6.4
NW	5.8	11.4	12.7	12.0	6.5
WNW	2.9	10.4	13.4	12.3	5.2
W	0.9	7.1	13.9	12.3	6.2
WSW	0.1	1.6	8.6	6.7	5.1
SW	0.1	0.1	4.8	3.7	3.5
SSW	0.7	0.1	3.9	2.6	2.9
S	0.0	0.2	1.6	2.1	2.0
Average	2.0	5.5	8.9	8.0	4.5

Table 10. Average of wave-height reduction factors along north shoreline (Sta 5 to 25) for Alts 1-5 at WL = 1.5 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	6.2	9.5	10.0	10.0	6.7
NNW	9.8	13.0	13.8	13.4	10.2
NW	9.5	12.6	13.6	13.0	10.0

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
WNW	7.3	12.0	14.1	13.4	8.9
W	4.4	9.7	15.0	13.9	8.6
WSW	2.5	4.4	10.5	9.2	7.0
SW	1.9	2.5	7.2	6.1	5.4
SSW	2.7	3.1	7.2	5.9	5.2
S	3.6	5.7	7.3	8.1	5.7
Average	5.3	8.1	11.0	10.3	7.5

Table 11. Average of wave-height reduction factors along south shoreline (Sta 74 to 80) for Alts 1-5 at WL = 1.5 m.

Wind Dir	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
N	0.7	8.9	13.0	12.4	4.2
NNW	4.7	11.8	16.3	14.0	7.1
NW	5.1	11.7	17.8	14.0	7.7
WNW	1.8	9.1	19.6	14.6	7.7
W	0.5	5.3	21.4	15.1	10.8
WSW	0.0	0.3	15.1	8.2	7.8
SW	0.0	0.0	10.0	3.8	4.0
SSW	0.5	0.0	8.0	2.2	2.6
S	0.0	0.0	2.0	1.5	1.5
Average	1.5	5.2	13.7	9.5	5.9

2.12 Single-parameter representative wave-reduction rating

Ranking of alternatives based on a single number is not recommended, but may be useful for preliminary analysis. As discussed earlier, alternatives are ranked based on the wave-reduction factors calculated at the low water level (WS = 0.0 m). The bottom line in Tables 6, 7, and 8 give the wave-reduction factor for each alternative averaged over the nine wind direction cases for the channel centerline, north shoreline, and south shoreline, respectively. By averaging the results for the centerline and north and south shoreline, we can obtain a single number on which to base a preliminary ranking of each alternative. By this method, we obtain the representative wave-reduction ratings given in Table 12. Again, Alt 4 has the highest representative wave reduction.

Table 12. Representative wave-reduction ratings for Alt 1-5.

Alternative	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Ave Wave Reduction (%)	11.6	25.8	46.4	49.1	34.0

2.13 Channel sedimentation issues

A detailed sediment-transport component was not deemed necessary in the scope of the modeling study. Consequently, changes in the sedimentation patterns caused by the construction of alternative 4 were not considered warranted for two reasons. First, the dogleg shape of the Alt 4 northern jetty is expected to trap the southward longshore transport moving along the western side of Tangier Island, blocking sediments from entering the channel. Second, both tidally driven and wave-driven currents in the channel are below the threshold for the initiation of sediment motion. Therefore, a detailed examination of sediment transport and local scouring potential along the structures was not considered in this study.

It is noted that the CMS development of sediment transport is continuing. Consequently, modeling estimates for flow and sediment transport if used in the final design should be validated either with field data or compared to estimates obtained from other two- or three-dimensional hydrodynamic models. Because of the absence of field data at Tangier Island, the flow and sediment modeling results presented in this report are qualitative and were not used in the relative comparison of alternatives.

However, the CENAO dredges the boat channel on a regular basis. The proposed construction may affect the overall sedimentation pattern in the vicinity of the structures and throughout the channel reaches of Tangier Island. This required modeling of sediment transport. The CMS was used to simulate the sediment transport for Hurricane Isabel. The purpose of the sediment simulation was to provide a quick view of potential shoaling and erosion areas from a 50 yr tropical storm (Hurricane Isabel). It was by no means to model long-term morphology evolution at Tangier Island and channel reaches. For this reason, a constant sediment median size of 0.15 mm was specified in the three-day simulation of Hurricane Isabel, because modeling of fines, mud, and cohesive sediments was not available in CMS at the time of this study.

Figure 56 shows the calculated spatially varying sediment accretion and erosion field for the existing west channel configuration (without project) in the 3-day simulation of Hurricane Isabel. There is apparent sediment deposition immediately outside the west entrance channel and bottom erosion inside the west entrance channel. Figures 57 to 61 show the calculated erosion and deposition fields for Alts 1 to 5, respectively, in the three-day simulation of Isabel. The result of calculated morphology change for Alts 1, 2, and 5 indicates sediment can be scoured in the channel near the tip of the jetty and trapped inside the west entrance channel during large storms. There is more bottom erosion between north jetty and south spur structure in Alts 3 and 4. The eroded sediment is carried by stronger currents into the bay. Accordingly, the sediment deposition is insignificant inside the west channel entrance.

Figure 56. Calculated sediment accretion and erosion field for the existing west channel configuration in three-day simulation of Hurricane Isabel.

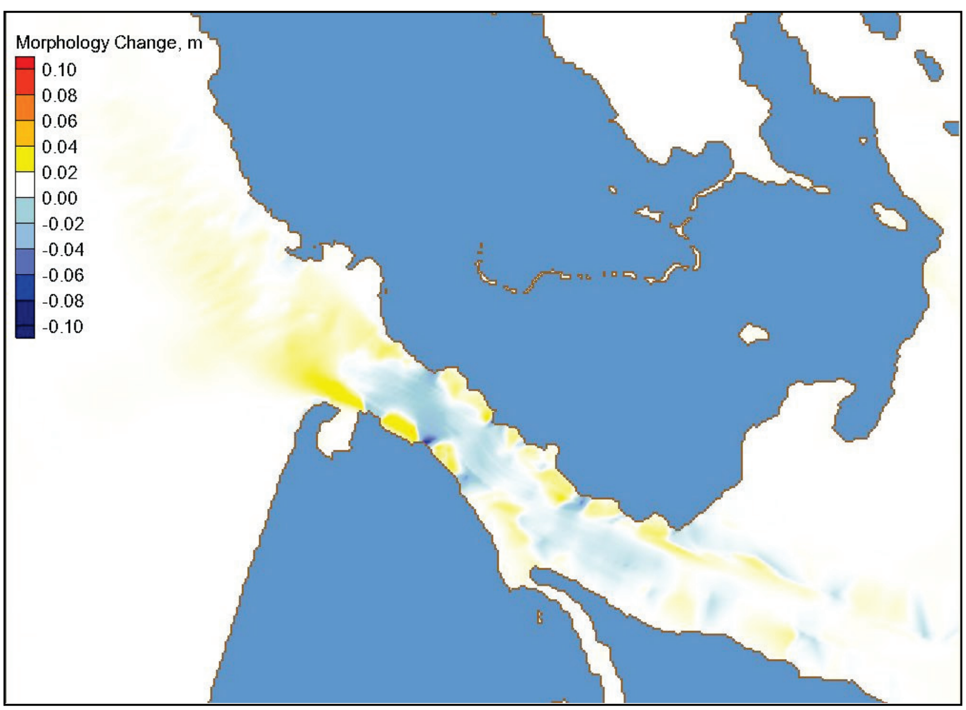


Figure 57. Calculated sediment accretion and erosion field for Alt 1 in three-day simulation of Hurricane Isabel.

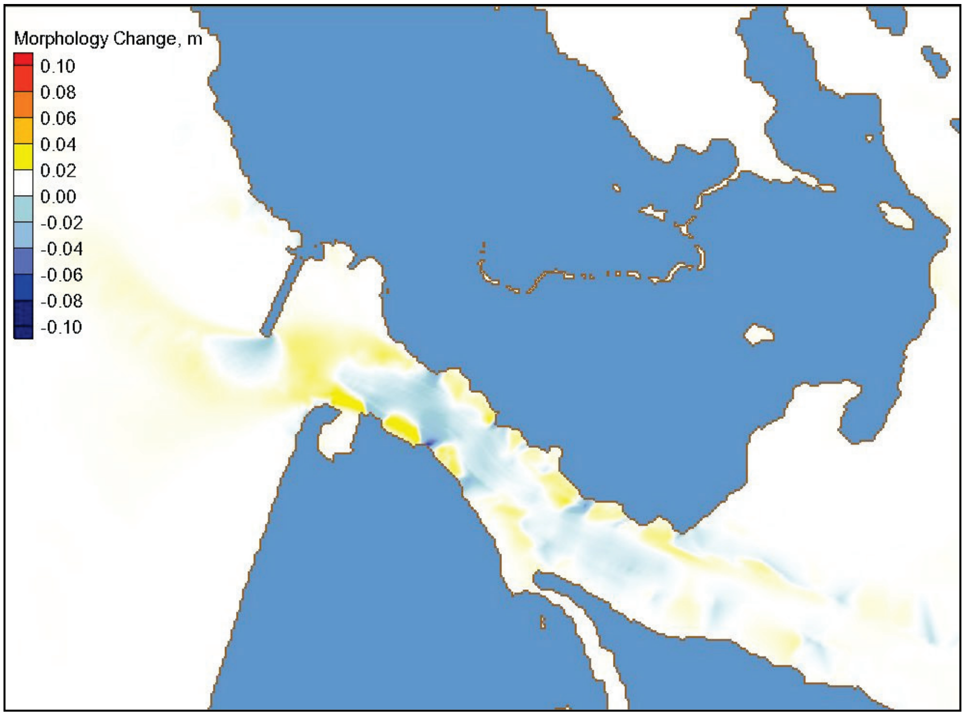


Figure 58. Calculated sediment accretion and erosion for Alt 2 in three-day simulation of Hurricane Isabel.

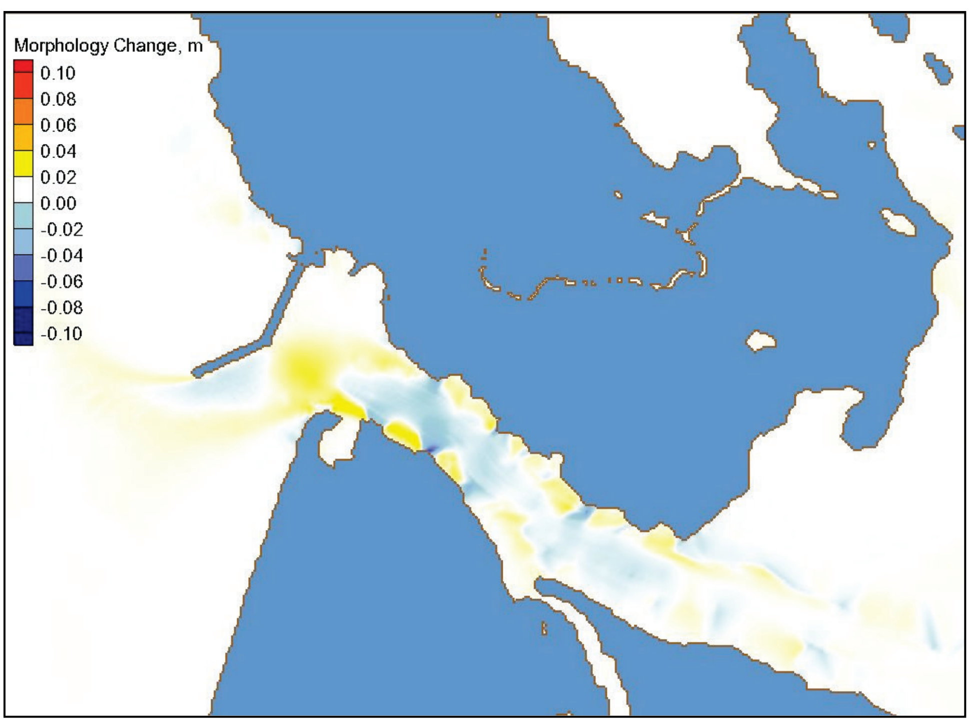


Figure 59. Calculated sediment accretion and erosion field for Alt 3 in three-day simulation of Hurricane Isabel.

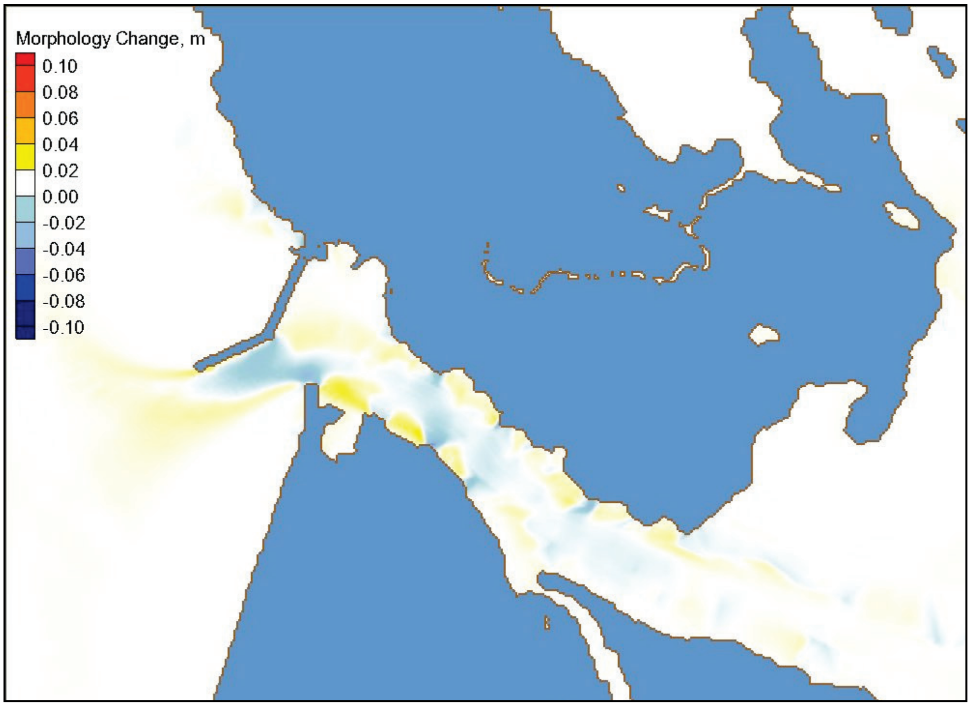


Figure 60. Calculated sediment accretion and erosion field for Alt 4 in three-day simulation of Hurricane Isabel.

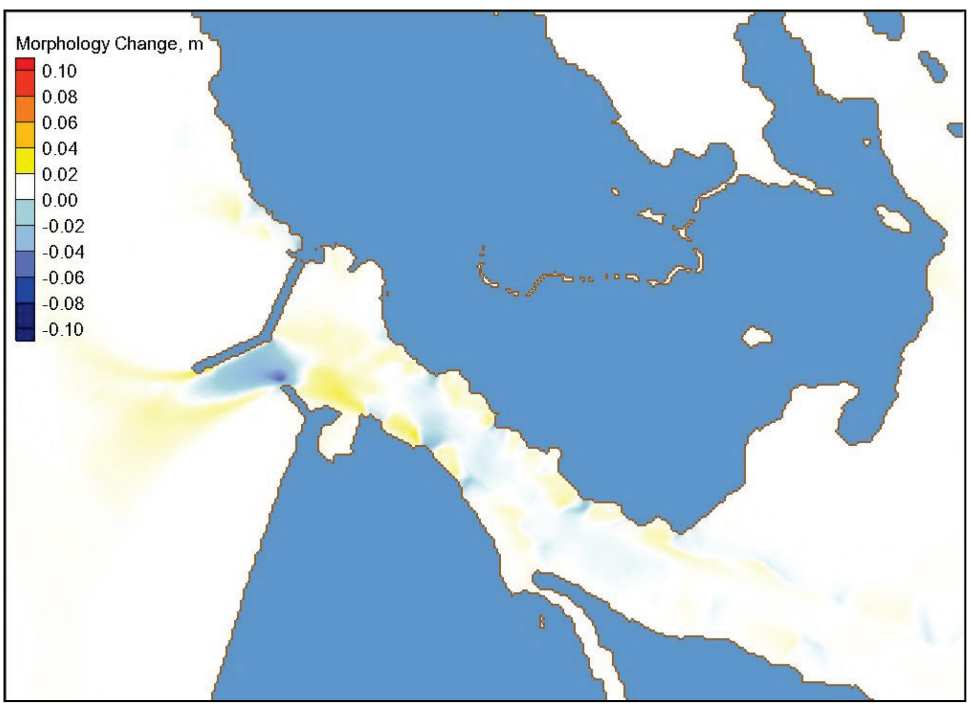
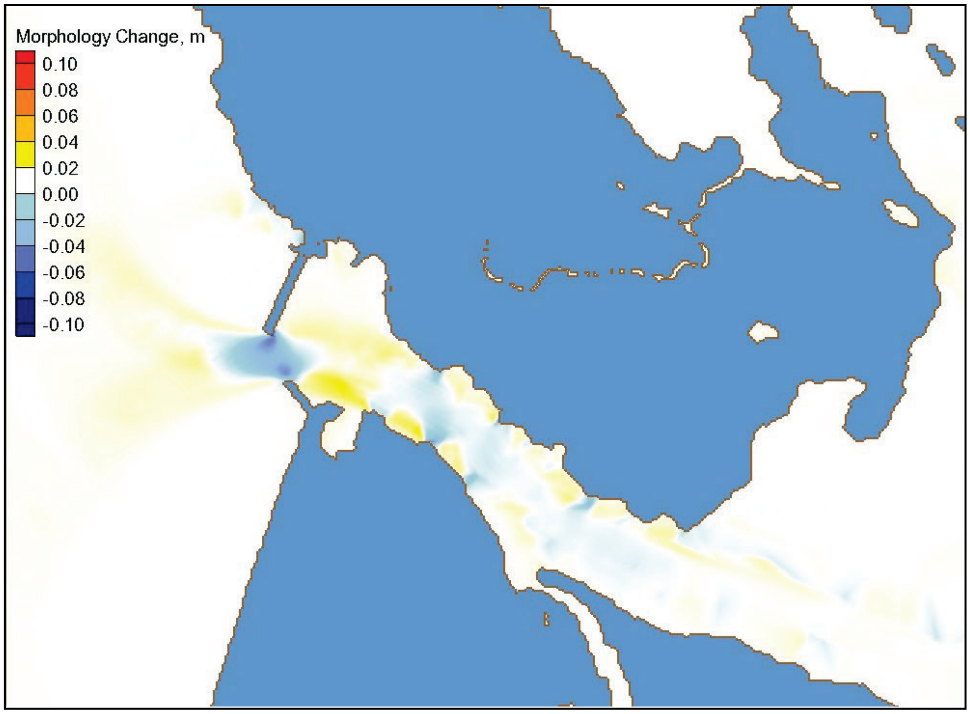


Figure 61. Calculated sediment accretion and erosion field for Alt 5 in three-day simulation of Hurricane Isabel.



Overall, sediment transport results for the existing channel configuration and all five alternatives were similar with an insignificant morphology change (magnitude of either erosion or deposition less than 2 in. or 0.05 m). As the structure is intended to reduce wave energy in the channel, the current could increase and scour channel near structures. Some additional settling of suspended sediments could occur away from the channel due to reduced wave currents. Based on model results for the 50-year, return-interval event, Hurricane Isabel (three-day simulation), the depth-averaged current magnitude is less than 3 ft/sec (1 m/sec) in the channel and the maximum channel depth change is less than 2 in. (0.05 m). No significant effect of structure on channel sedimentation and channel infilling was apparent for the Hurricane Isabel simulation.

3 Structural Design Calculations

3.1 Selection of design wave and water level

For design purposes, the storm with a statistical return period of 50 years was recommended by CHL and agreed to by CENAO. Wave heights and wave periods for the 50 yr event were presented in the preceding chapter. Although the tidal range is small in the area of Tangier Island, a significant storm surge is expected during the design event. As related in the previous chapter, a water-level rise of 1.5 m (5 ft) was selected to include tidal fluctuations, storm surge, and wave setup.

The basic design of the structures will therefore be based on the wave height and wave period of a storm with a return period of 50 yrs, with a still-water level of 1.5 m (5 ft). The recommended design will then be examined under the conditions presented during Hurricane Isabel, and examined again using the same wave heights and periods (50 yr storm) but with increased water levels due to sea level rise.

At the request of CENAO, all calculations have been converted to American Customary units in this section. A table of conversions is included at the beginning of this report to assist in conversion back to SI units if desired.

3.2 Stability equations

3.2.1 Stable seaside armor size

Stable armor stone size is computed here based on 50-year return period wave and water-level conditions given in the previous sections. The Hudson equation is well known and has been used for years to determine armor stability (Hudson 1959; Shore Protection Manual 1984). The equation in stability number form is given by

$$N_s = \frac{H_{1/10}}{\Delta D_{n50}} = (K_D \cot \theta)^{1/3} \tag{1}$$

In Equation 1, $H_{1/10}$ is the average height of the highest 10 percent of waves. $\Delta = S_r - 1$, where S_r is immersed specific gravity of the armor stone; that is: $S_r = \rho_r/\rho_w$, where ρ_r = density of armor stone and ρ_w = density of water at the project site. D_{n50} is nominal stone size defined as $D_{n50} = (M_{50}/\rho_r)^{1/3}$ where M_{50} = median mass of armor stone. K_D is an empirical coefficient and $\cot\theta$ is the structure's seaward slope. K_D takes into account all parameters not in the equation. The Hudson equation was originally developed for monochromatic waves, and use of the equation with irregular wave height statistics has been discussed by many authors. The most common application of the equation utilizes $H_{1/10}$ for depth-limited wave conditions with the depth-limited breaker height limited to 0.78*depth. Values published for K_D in the *Shore Protection Manual* (1984) are appropriate. The Hudson equation design assumes damage based on eroded volume of $D\%$ = 0 to 5.

In this report, seaside armor stability is computed based on more recent guidance published in Melby and Kobayashi (2011). The maximum wave-momentum flux is highly nonlinear for nonlinear waves (steep waves in shallow water). This corresponds to the case where armor stability is at its minimum. Melby and Hughes (2004) described a non-linear wave momentum flux using a numerical Fourier solution. The resulting approximate relation was found to be

$$\left(\frac{M_F}{\rho_w g h^2}\right)_{\max} = A_0\left(\frac{h}{gT_m^2}\right)^{-A_1}$$

$$A_0 = 0.639\left(\frac{H_{m0}}{h}\right)^{2.026} \qquad (2)$$

$$A_1 = 0.180\left(\frac{H_{m0}}{h}\right)^{-0.391}$$

where M_f is the momentum flux, g is acceleration of gravity, h is local water depth, T_m is mean wave period, and H_{mo} is wave height of the zeroth moment of the wave energy spectrum. A nonlinear approximation for momentum flux is important because stability is at its minimum when the incident wave is the most nonlinear.

Two stability equations resulted from the fit to data using Equation 2. The recommended equations for stability are

$$N_m = \frac{1}{a_m}\left(\frac{S}{K_s\sqrt{N_z}}\right)^{0.2} \tag{3}$$

and

$$N_m = \left(\frac{(M_F/\gamma_w h^2)_{\max}}{\Delta}\right)^{1/2}\frac{h}{D_{n50}} \tag{4}$$

where for plunging waves

$$a_m = \frac{1}{5P^{0.18}\sqrt{\cot\theta}} \qquad s_m \geq s_{mc} \tag{5}$$

and for surging waves

$$a_m = \frac{s_m^{P/3}}{5P^{0.18}(\cot\theta)^{0.5-P}s_m^{-P/3}} \quad s_m < s_{mc} \tag{6}$$

and

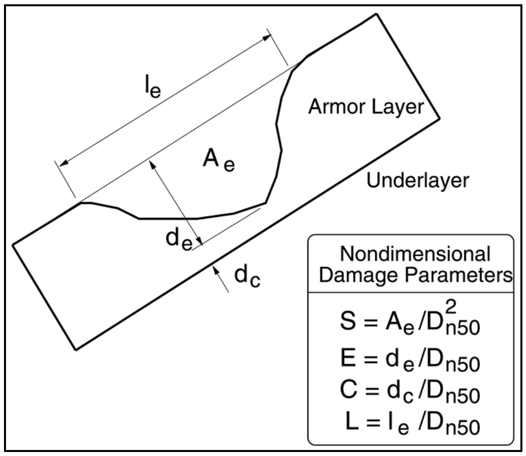
$$s_m = H_{m0}/L_{m,} \qquad s_{mc} = -0.0035\cot\theta + 0.028 \tag{7}$$

Solving for the stable stone size yields

$$D_{n50} = ha_m\left(\frac{S}{K_s\sqrt{N_z}}\right)^{-1/5}\left(\frac{(M_F/\gamma_w h^2)_{\max}}{\Delta}\right)^{1/2} \tag{8}$$

In Equations 3 through 8: Nm is the momentum flux stability number, P = notional permeability of the structure, S = Ae/(Dn50)2 = normalized eroded area, Ae = eroded area, and Nz = storm duration/Tm. S and Ae are illustrated in Figure 62. Ks = 1.3 is an empirical parameter to account for accelerated damage that occurs with constant wave conditions, γw is the specific weight of water, θ is the seaside structure slope, sm is the local wave steepness and smc is critical wave steepness. Damage levels given by S = 1 to 3 represent the start of damage and correspond to Hudson's D% = 0 to 5 percent.

Figure 62. Illustration of damage parameters.



For an impermeable dike, P = 0.1. For a traditional multi-layer breakwater, P = 0.4 – 0.6. For the Tangier Island jetty, a somewhat porous core would be desirable to allow some flow through the structure to improve leeside circulation (P = *0.6*), but may not be economically feasible. Use of small core material that effectively restricts transmission would give a permeability of P = *0.4*. In the absence of more detailed information, a value of P = *0.5* is selected for this study.

3.2.2 Stable leeside armor stone

Stability equations were given by Van Gent and Pozueta (2004) for leeside stability. Melby (2009) revised these equations to be in a similar form to the seaside equations as follows

$$D_{n50} = a_{ls}\left(\frac{S_{ls}}{K_{ls}\sqrt{N_z}}\right)^{-1/r}\left(\frac{u_{1\%}T_{m-1,0}}{125\sqrt{\Delta}}\right) \tag{9}$$

$$a_{ls} = (\cot\phi)^{-2.5/r}[1+10\cdot\exp(-R_{c-rear}/H_s)]^{1/r} \tag{10}$$

where S_{ls} is the leeside damage, K_{ls} and r are empirical fit parameters, with $r = 6$ for constant wave conditions, $u_{1\%}$ = maximum crest velocity exceeded by 1% of the waves, $T_{m-1,0} = m_{-1}/m_0$ of incident spectrum, $T_{m-1,0} \sim T_p/1.1$ for a JONSWAP incident wave spectrum, cot φ = leeside slope, R_{c-rear} = freeboard of leeside edge of crest, $H_s = H_{m0}$ of incident wave spectrum, and $(D_n)_{ls}$ and Δ_{ls} are the nominal stone size and density parameter for the leeside armor, respectively. A leeside stability number, N_{ls}, is introduced where

$$N_{ls} = \left(\frac{u_{1\%} T_{m-1,0}}{125(D_n \sqrt{\Delta})_{ls}} \right) = \frac{1}{a_{ls}} \left(\frac{S_{ls}}{K_{ls} \sqrt{N_z}} \right)^{1/r} \quad (11)$$

Then the single-storm leeside damage for constant wave conditions can be expressed as

$$S_{ls} = K_{ls} \sqrt{N_z} \left(a_{ls} N_{ls} \right)^r \quad (12)$$

The n^{th} moment of the incident wave-energy density spectrum is given by

$$m_n = \int_0^\infty f^n S(f) df \quad (13)$$

The crest velocity exceeded by 1 percent of the waves is given by

$$\frac{u_{1\%}}{\sqrt{gH_s}} = \frac{1.7(\gamma_{f-C})^{0.5} \left(\frac{z_{1\%} - R_c}{\gamma_f H_s} \right)^{0.5}}{\left(1 + 0.1 \frac{B_c}{H_s} \right)} \quad (14)$$

where γ_{f-C} = friction factor on crest, γ_f = friction factor on seaward slope, R_c = freeboard of seaside crest, B_c = jetty/breakwater crest width, and $z_{1\%}$ = run-up exceeded by 1 percent of waves. The friction coefficients and run-up can be computed by Equations 15 and 16, respectively.

$$\gamma_f = \gamma_{f-C} = \begin{cases} 0.55 & \xi_{s,-1} \le 2 \\ 0.05625 * (\xi_{s,-1} - 2) + 0.55 & 2 < \xi_{s,-1} < 10 \\ 1.0 & \xi_{s,-1} \ge 10 \end{cases} \quad (15)$$

$$\frac{z_{1\%}}{\gamma H_s} = \begin{cases} c_0 \xi_{s,-1} & for\ \xi_{s,-1} \le p \\ c_1 - c_2 / \xi_{s,-1} & for\ \xi_{s,-1} > p \end{cases}$$

$$\frac{z_{1\%}}{\gamma H_s} = \begin{cases} c_0 \xi_{s,-1} & for\ \xi_{s,-1} \le p \\ c_1 - c_2 / \xi_{s,-1} & for\ \xi_{s,-1} > p \end{cases} \quad (16)$$

Here $c_2 = 0.25\ c_1^2/c_0$, $p = 0.5\ c_1/c_0$, and $\gamma = \gamma_f \gamma_\beta$ = reduction factor for roughness and angular wave attack, with $\gamma_\beta = 1.0$ for normally incident waves. The Iribarren parameter based on the first negative moment wave period is

$$\xi_{s,-1} = \frac{\tan\theta}{\sqrt{\dfrac{H_s}{L_{m-1,0}}}} \qquad (17)$$

where

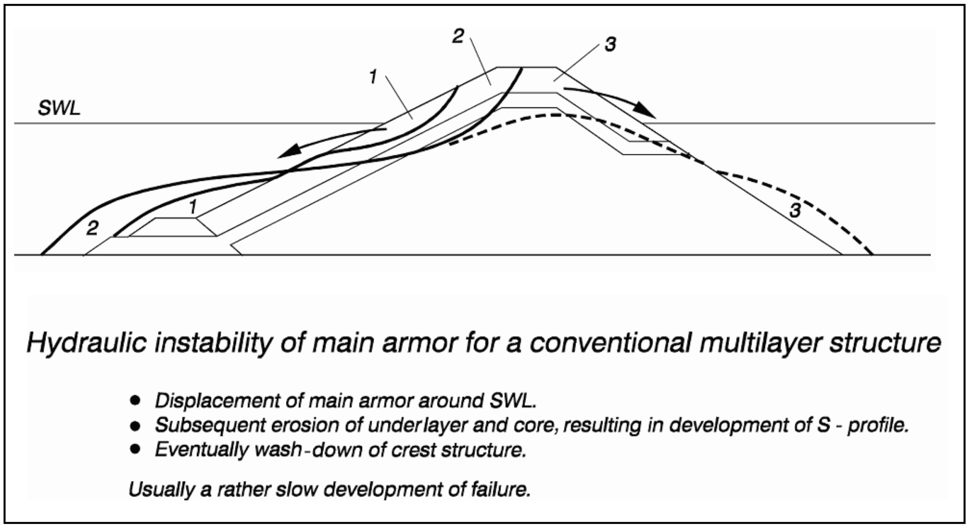
$$L_{m-1,0} = \frac{gT_{m-1,0}^2}{2\pi} \qquad (18)$$

and c_0 = 1.45 and c_1 = 5.1 for $z_{1\%}$. So, for the Tangier Island jetties, Equation 16 becomes

$$\frac{z_{1\%}}{H_s} = \begin{cases} 1.45\xi_{s,-1} & for\ \xi_{s,-1} \le 1.76 \\ 5.10 - 4.485/\xi_{s,-1} & for\ \xi_{s,-1} > 1.76 \end{cases} \qquad (19)$$

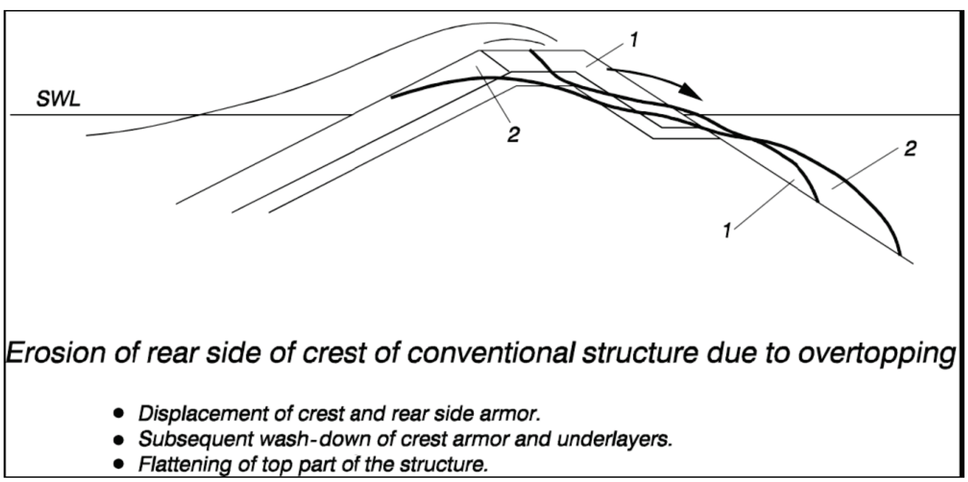
An illustration of seaside damage on a rubble mound structure is shown in Figure 63, indicated by numbers 1 and 2. Condition 1 illustrates damage initiation that occurs as armor is displaced near the still water line but has not extended into the filter layers. Condition 2 illustrates extensive damage over the entire active zone of the seaward side extending into the filter layers and even into the core and crest. Herein, we assume that once seaside damage reaches Condition 2, the structure has no capacity and will breach during the storm that caused it to be in Condition 2.

Figure 63. Illustration of damage on a rubble-mound structure (CEM).



Leeside damage is illustrated in Figure 64. Damage begins on the rear crest and erodes seaward through the crest.

Figure 64. Illustration of leeside erosion of a rubble-mound jetty cross-section (CEM).



3.3 Design structure

3.3.1 Assumptions

Incident-wave direction is not included in the stability equations; therefore, it is assumed that waves are approaching normal to the structure.

Because the wave climate is relatively mild, structure side slopes of 1:2 (vertical: horizontal) were selected. A crest width of three armor stones was chosen as a minimum structure size. As will be seen below, stable stone sizes have a nominal diameter of approximately 2 ft, so a crest width of 6 ft was used in the initial computations.

In the absence of detailed information on stone that will be used, a specific weight of 165 pcf was assumed for the calculations. Zero damage $S = 2$ was assumed.

3.3.2 Calculations

Wave run-up on a rubble-mound structure is typically on the order of 1.5 to 1.6 times the incident-wave height. Selecting a design height that includes storm surge plus a freeboard of 1.5 times the design wave height will yield some overtopping by the larger waves, but it will be minimal. Reducing the height of the structure to storm surge plus design wave height will obviously result in increased overtopping, but is probably justifiable because ships are not expected to be using the channel in the midst of a 50 yr storm. For the initial design calculations, structure heights of storm surge plus 0.5, 1.0, and 1.5 times the design wave height were considered.

Using the equations 1 through 19, above, and the assumptions given above in this section, stable armor stone sizes were calculated for each of the save points presented in Figure 55, above. Tables 13, 14, and 15 present the calculated stone weights and transmitted wave heights for freeboards of storm surge plus one-half wave height, storm surge plus one wave height, and storm surge plus 1.5 times the design wave height, respectively.

Table 13. Stable stone weights and transmitted wave height for crest elevation of storm surge plus one-half the design wave height.

Station	Storm Water Level, MTL (ft)	Depth, MTL (ft)	Design Wave Ht (ft)	Design Wave Period (sec)	Freeboard (ft)	Sea-side Armor Diam (ft)	Sea-side Armor Weight (tons)	Lee-side Armor Diam (ft)	Lee-side armor weight (tons)	Trans Coef	Trans Wave Height (ft)
85	5.00	4.17	4.17	5.3	2.08	1.49	0.27	2.12	0.78	0.24	1.00
88	5.00	6.17	4.27	5.3	2.13	1.53	0.30	2.14	0.81	0.24	1.03
99	5.00	7.71	4.40	5.3	2.20	1.58	0.33	2.16	0.84	0.24	1.06
103	5.00	8.66	5.02	5.3	2.51	1.77	0.46	2.28	0.98	0.25	1.24
118	5.00	8.69	4.82	5.3	2.41	1.71	0.42	2.25	0.93	0.25	1.18
121	5.00	8.40	4.82	5.3	2.41	1.71	0.41	2.25	0.93	0.25	1.18

Table 14. Stable stone weights and transmitted wave heights for crest elevation of storm surge plus one design wave height.

Station	Storm Water Level, MTL (ft)	Depth, MTL (ft)	Design Wave Ht (ft)	Design Wave Period (sec)	Free-board (ft)	Sea-side Armor Diam (ft)	Sea-side Armor Weight (tons)	Lee-side Armor Diam (ft)	Lee-side armor weight (tons)	Trans Coef	Trans Wave Height (ft)
85	5.00	4.17	4.17	5.3	4.17	1.49	0.27	1.50	0.28	0.00	0.00
88	5.00	6.17	4.27	5.3	4.27	1.53	0.30	1.51	0.29	0.00	0.00
99	5.00	7.71	4.40	5.3	4.40	1.58	0.33	1.52	0.29	0.00	0.00
103	5.00	8.66	5.02	5.3	5.02	1.77	0.46	1.57	0.32	0.00	0.00
118	5.00	8.69	4.82	5.3	4.82	1.71	0.42	1.56	0.31	0.00	0.00
121	5.00	8.40	4.82	5.3	4.82	1.71	0.41	1.56	0.31	0.00	0.00

Table 15. Stable stone weights and transmitted wave heights for crest elevation of storm surge plus 1.5 times the design wave height.

Station	Storm Water Level, MTL (ft)	Depth, MTL (ft)	Design Wave Ht (ft)	Design Wave Period (sec)	Free-board (ft)	Sea-side Armor Diam (ft)	Sea-side Armor Weight (tons)	Lee-side Armor Diam (ft)	Lee-side armor weight (tons)	Trans Coef	Trans Wave Height (ft)
85	5.00	4.17	4.17	5.3	6.25	1.49	0.27	0.73	0.03	0.00	0.00
88	5.00	6.17	4.27	5.3	6.40	1.53	0.30	0.72	0.03	0.00	0.00
99	5.00	7.71	4.40	5.3	6.59	1.58	0.33	0.70	0.03	0.00	0.00
103	5.00	8.66	5.02	5.3	7.53	1.77	0.46	0.59	0.02	0.00	0.00
118	5.00	8.69	4.82	5.3	7.23	1.71	0.42	0.63	0.02	0.00	0.00
121	5.00	8.40	4.82	5.3	7.23	1.71	0.41	0.63	0.02	0.00	0.00

3.3.3 Analysis

Changing the crest elevation does not change the stable armor stone size on the seaside of the structure, but it significantly affects the leeside armor stone. With the crest elevation at still water level (SWL=storm surge = +5 ft MTL) plus one-half wave height (Table 13), the armor stone on the lee side of the jetties are more than twice as large as on the sea side. With the crest at SWL plus a full wave height, stable armor stones on the sea side and lee side are roughly the same size.

Run-up calculations (not shown) indicate that if the crest is at SWL plus one wave height (Table 14), the run-up elevation will be higher than the crest so there will be some overtopping of the seaside of the jetty. However, there is essentially no transmission indicating that the volume of water overtopping the seaside crest is small. Because there is effectively zero transmission, a higher crest elevation is not needed.

During Hurricane Isabel, water piled up along the western shore of the bay, so water levels, wave heights, and wave periods were all lower than for the design 50 yr storm (Table 5). The hurricane is therefore discounted from the calculations.

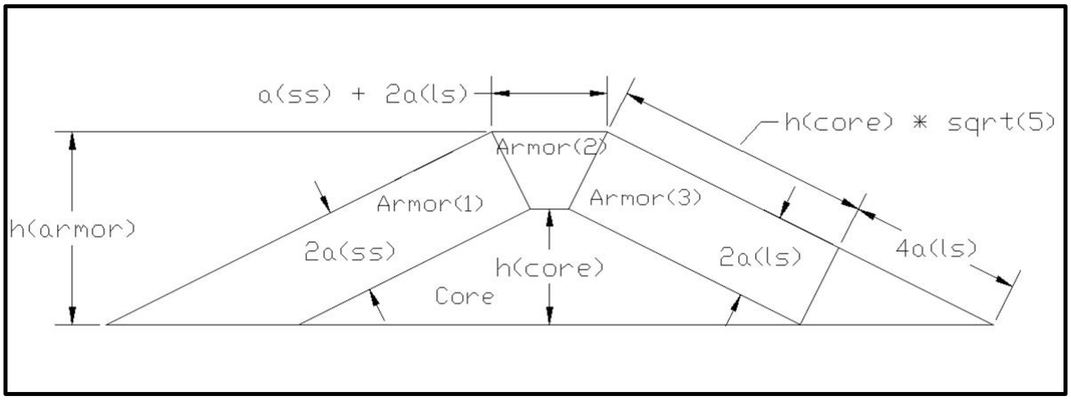
Selected options at this point are a structure with a crest elevation of SWL plus one-half wave height or a higher-crested structure with a crest elevation of SWL plus one wave height. The lower-crested structure has some transmission and requires armor stone on the leeside more than twice as large as the higher-crested structure. The higher-crested structure has no transmission and smaller armor stone, but is 2- to 2-1/2-ft higher.

There are three reaches of the jetties to be considered: the shore-attached reach of the main jetty, the dogleg extending to the head of the main jetty, and the spur jetty. Each of these reaches will be considered by examining a cross-section at save stations 85, 99, and 118, respectively.

The cross-section is considered based on a core plus underlayers, covered by two layers of armor stone. For simplicity, the volume of the underlayers will be included with the core volume. Crest width is three armor stones. If the leeside armor stones are different from the seaside armor stones, the crest width is based on one smaller stone and two larger stones, regardless of whether the larger stones are on the seaside or leeside.

In Figure 65, a(ss) and a(ls) are nominal diameters of the seaside armor stone and leeside armor stone, respectively. Armor(1) is the cross-sectional area of the seaside armor, Armor(3) is the cross-sectional area of the leeside armor, and the area of Armor(2) is divided into one-third seaside armor and two-thirds leeside armor.

Figure 65. Idealized cross-section of jetty.



The dogleg extending to the seaward end of the main jetty (represented by save station 99) is exposed to waves both from the north and south. Although the 50 yr design storm shows waves approaching from 289 deg, it is possible for either side of the jetty to be the seaside or leeside, depending on actual wave angle of approach. Therefore, both sides of the jetty must be armored with the larger of the seaside or leeside armor stone.

Cross-sectional areas for the seaside armor stone, leeside armor stone, and core are shown in Table 16 for each of the three sections of jetty and at the two different crest elevations.

Table 16. Cross-sectional areas of armor stone and core.

Sta	Jetty Height (ft)	Seaside Stone Diam (ft)	Leeside Stone Diam (ft)	Total Area Seaside Armor (ft^2)	Total Area Leeside Armor (ft^2)	Total Area Armor Stone (ft^2)	Area of Core + Underlayers (ft^2)
Crest elevation = SWL + 0.5*wave height							
88	11.3	1.53	2.14	62.4	95.4	157.8	70.6
99	14.9	2.16	2.16	126.7	132.6	259.3	150.7
118	16.1	1.71	2.25	106.0	148.2	254.3	172.2
Crest elevation = SWL + 1.0*wave height							

Sta	Jetty Height (ft)	Seaside Stone Diam (ft)	Leeside Stone Diam (ft)	Total Area Seaside Armor (ft^2)	Total Area Leeside Armor (ft^2)	Total Area Armor Stone (ft^2)	Area of Core + Underlayers (ft^2)
88	13.3	1.53	1.51	82.6	84.3	166.9	131.9
99	17.1	1.58	1.58	111.6	114.8	226.4	231.1
118	18.5	1.71	1.56	132.5	123.4	255.9	278.8

There is surprisingly little difference in total area of armor stone for either the low-crested structure or the higher-crested structure due to the difference in size of the armor stone. The low-crested structure requires a larger armor stone size on the leeward side which means the two layers of armor stone will be thicker, which offsets the greater height of the higher-crested structure. The real difference is in the area of the core, where the higher-crested structure is significantly larger.

Although the core stone is typically significantly less expensive than the armor stone, and less expensive to place, it appears that the low-crested structure will be the less expensive of the two options. For this preliminary design, the structure crest will therefore be placed at SWL with storm surge, plus one-half the incident wave height.

The stability equations of Melby and Kobayashi (2011) and Melby (2009) presented above for the seaside and leeside armor, respectively, do not consider the jetty heads. In the Hudson equation (Equation 1), the stability coefficient K_D for jetty trunks with breaking waves and two layers of armor stone is 2.0, while for jetty heads with a 1:2 slope the recommended coefficient (two layers of armor and breaking waves) is 1.6 (Shore Protection Manual 1984), resulting in a 25 percent increase in stone size. In the absence of other guidance, armor stone sizes on the jetty heads (Stations 103 and 121) will be calculated in the same manner as on the jetty trunks, and then increased by 25 percent.

The basic features of the preliminary design are listed below in Table 17. As a reference, stone weights as calculated by the Hudson equation (Equation 1) are also included.

Table 17. Crest elevation and armor stone size for preliminary structure design.

Station	Depth MTL (ft)	Crest Elev MTL (ft)	Weight Seaside Armor W(50) (tons)	Weight Leeside Armor W(50) (tons)	Hudson Eqn W(50) (tons)
85	4.17	7.08	0.27	0.78	0.78
88	6.17	7.13	0.30	0.81	0.83
99	7.71	7.20	0.33	0.84	0.91
103	8.66	7.51	0.57	1.22	1.70
118	8.69	7.41	0.42	0.93	1.21
121	8.40	7.41	0.52	1.17	1.51

In general, Table 17 calls for a crest elevation of 7.1 ft MTL on the first reach of the main jetty, with seaside armor stone of 0.30 tons and leeside armor stone of 0.81 tons. The dogleg of the main jetty has a crest elevation of 7.2 ft MTL. Because either side of the dogleg could be the leeside depending on the direction of the storm, both sides of the dogleg are armored with 0.84-ton armor stone. The head of the main jetty has a crest elevation of 7.5 ft MTL and is armored with 1.22-ton armor stone.

The spur jetty is built to a crest elevation of 7.4 ft MTL. The trunk of the spur is armored with 0.42-ton stone on the seaside and 0.93-ton stone on the leeside. The head of the spur is armored with 0.52-ton stone on the seaside and 1.17-ton stone on the lee side.

3.4 Low-crested jetty

The calculations presented in the preceding sections developed a design for a traditional jetty with minimal transmission (transmitted wave heights about 1 ft) with minimal damage during a 50 yr storm event. However, the design storm assumed a water level of + 5 ft MTL. At that water elevation, much of the island where the north jetty is located will be inundated and there is little point in having a jetty extend higher than the surrounding land mass. A low-crested structure is therefore considered.

In Chapter 2 of this report, a crest elevation of 1 m (3.3 ft) was assumed when calculating the amount of wave-energy reduction for the different alternatives. This section will therefore consider the design of the jetties with a crest elevation of 3.3 ft above MTL. Wave heights at the proposed structure locations for Alternative 4 were determined for water levels of 0.0 ft and 5.0 ft. For water levels between these two depths, a simple linear interpolation is used to estimate the wave heights.

The critical depth for design of the jetty is a water level near the crest of the jetty because the waves will be larger than at lower water levels and the overtopping will be directly impacting the jetty. At higher water levels, more of the energy passes over the structure. The equations presented above were therefore used to determine the required stone sizes for a water level of 3 ft. The results are given below in Table 18. As before, stone sizes on the jetty heads have been increased by 25 percent.

At the design flood level, this structure will be submerged and wave heights will be larger. Therefore, the armor stone weights were calculated for a submerged structure. As the water depth over a structure increases, the effects of waves on the structure decrease. However, in this case as the water level increases the wave heights increase. Therefore, two water levels were considered: the maximum design water level of +5 ft and a water level of +3.3 ft (crest elevation).

Table 18. Armor stone size for low-crested structure design.

Station	Depth MTL (ft)	Crest Elev MTL (ft)	Wave Height (ft)	Weight Seaside Armor W(50) (tons)	Weight Leeside Armor W(50) (tons)	Transmission Coefficient	Transmitted Wave Height (ft)
85	4.17	3.3	3.4	0.16	1.10	0.40	1.35
88	6.17	3.3	3.7	0.21	1.27	0.40	1.51
99	7.71	3.3	4.0	0.25	1.40	0.41	1.62
103	8.66	3.3	4.4	0.41	2.04	0.41	1.83
118	8.69	3.3	4.2	0.29	1.51	0.41	1.72
121	8.40	3.3	4.2	0.35	1.88	0.41	1.71

Unfortunately, there has been only limited research on armor layer stability of submerged structures. CIRIA et al (2007) presents results from Vidal et al. (1995) for stability of submerged structures. Nominal stone diameter, D_{n50}, is calculated by the equation

$$\frac{H_s}{\Delta D_{n50}} = A + B\frac{R_c}{D_{n50}} + C\left(\frac{R_c}{D_{n50}}\right)^2 \tag{20}$$

where R_c is the distance from the structure crest to still water level and is negative for submerged structures, and A, B, and C are coefficients that vary with the level of damage and the section of the structure. For the initiation of damage, the coefficients are given below in Table 19.

Table 19. Coefficients for initiation of damage in Equation 20 (from Vidal et al. 1995 as presented in CIRIA et al. 2007).

Segment	A	B	C
Front slope	1.831	-0.245	0.0119
Crest	1.652	0.0182	0.159
Back slope	2.575	-0.54	0.115
Total section	1.544	-0.23	0.053

The coefficients given in Table 19 were based on structures with seaside and leeside slopes of 1:1.5, but otherwise the proposed jetties generally fall within the range of parameters tested. Results of the calculations are shown below in Table 20 for a water level of 3.3 ft and Table 21 for a water level of 5.0 ft. As before, wave heights for the water level of 3.3 ft were determined by linear interpolation of the wave heights given for water levels of 0.0 and 5.0 ft, and stone sizes on the heads of the jetties were increased by 25 percent.

Table 20. Armor stone weights for submerged structures with water level at +3.3 ft and crest elevation at +3.3 ft.

Station	Wave Height H_s (ft)	Seaside Armor Wt (ton)	Crest Armor Wt (ton)	Leeside Armor Wt (ton)	Total Section Armor Wt (ton)
85	3.53	0.15	0.20	0.05	0.25
88	3.82	0.19	0.26	0.07	0.32
99	4.04	0.23	0.31	0.08	0.38
103	4.50	0.38	0.52	0.14	0.64
118	4.28	0.27	0.36	0.10	0.44
121	4.27	0.33	0.45	0.12	0.55

Table 21. Armor stone weights for submerged structures with water level at +5.0 ft and crest elevation at +3.3 ft.

Station	Wave Height H_s (ft)	Seaside Armor Wt (ton)	Crest Armor Wt (ton)	Leeside Armor Wt (ton)	Total Section Armor Wt (ton)
85	4.17	0.15	0.22	0.06	0.20
88	4.27	0.16	0.24	0.06	0.22
99	4.40	0.18	0.27	0.07	0.25
103	5.02	0.36	0.55	0.10	0.52
118	4.82	0.25	0.38	0.08	0.36
121	4.82	0.31	0.48	0.09	0.45

The results of the submerged structure analysis confirm that the armor stone weights presented in Table 18 for the low-crested jetty should be stable at all design water levels considered. However, the submerged structure analysis suggests that the leeside armor stone determined in the low-crested analysis are overly conservative. The design equations (Equations 1 through 19) were not developed for such low-crested structures. The crest elevation will not affect the seaside armor stone calculations, but the leeside armor weights do not appear reasonable. However, the leeside of the crest is the most vulnerable section of the armor for a heavily overtopped structure.

Obviously the low-crested structure will not provide the same level of protection during the design storm as would the higher-crested structure presented earlier. To illustrate the difference in levels of protection, Figures 66 and 67 show the wave fields during the design storm with water level at +5 ft for a structure with a crest elevation of 3.3 ft (Figure 66) and a structure high enough to block all overtopping (Figure 67). Waves in this example are from the southwest. There is little difference on the west side of the structures, but the higher structure clearly provides more protection on the lee side.

Figure 66. Wave field for structures with crest elevation of 3.3 ft, water level at 5.0 ft.

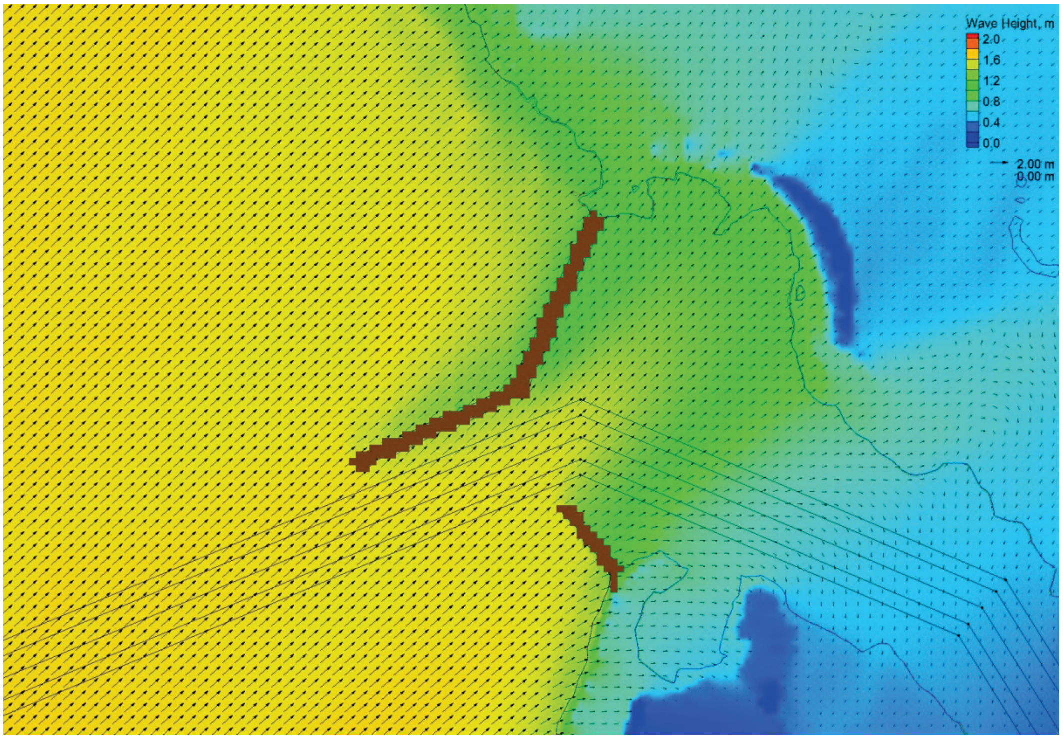
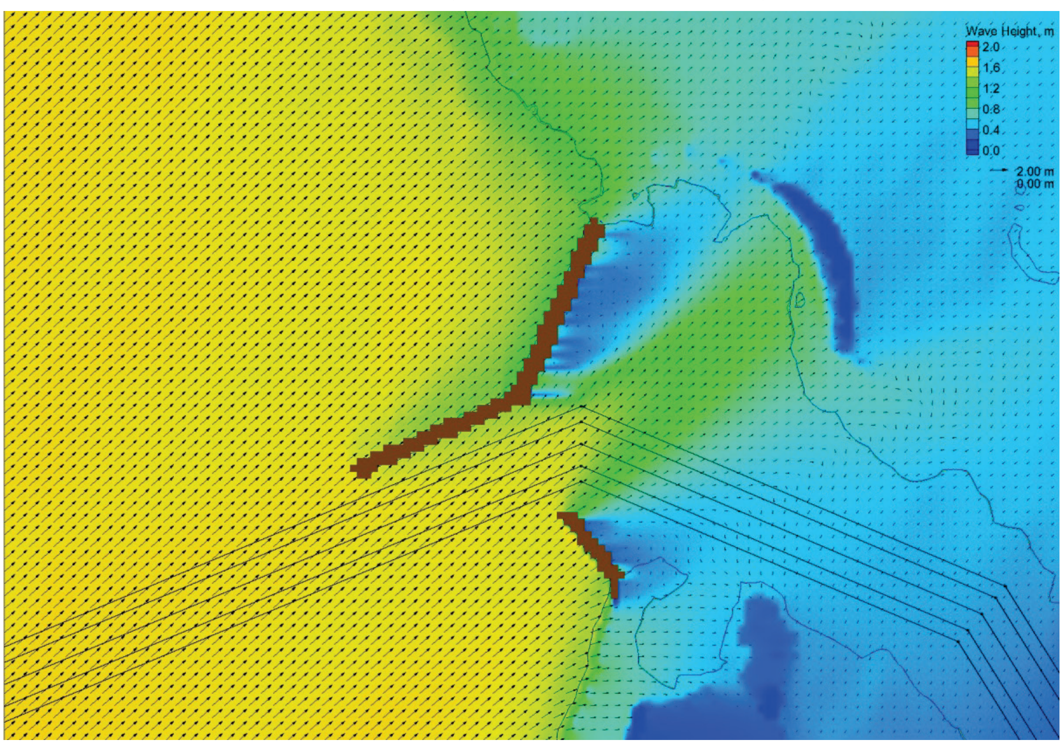


Figure 67. Wave field for structures with crest elevations sufficiently high to block all overtopping.



3.5 Tangier Island revetment

A rock revetment protects the shoreline along the west side of Tangier Island, running from the vicinity of the proposed spur jetty south, along the airport's runway (Figure 68). The revetment has performed satisfactorily, although there is evidence that some of the stones have moved. A letter dated 29 July 1986 from Norfolk District chief of the engineering division (Jack Starr) to the Coastal Engineering Research Center (Thomas Richardson), discusses what appears to be the final design of the revetment. The document calls for armor stone ranging in weight from 600 to 1,000 lbs with 75 percent greater than 750 lbs. Although it cannot be positively stated that this document represents the design of the as-built structure, the design would yield a W_{50} of at least 800 lbs (0.4 tons). This weight is surprisingly consistent with the 0.42 ton seaside armor weight for the spur jetty (Sta. 118) given in Table 17.

Figure 68. North end of revetment along the west side of Tangier Island.

3.6 Jetty response with sea level rise

The effects of sea level rise (SLR) on the performance and stability of the jetties were considered using four different SLR trends (USACE 2011) as follows:

1. No SLR
2. NRC-I
3. NRC-II
4. NRC-III

SLR in meters is computed using the equation

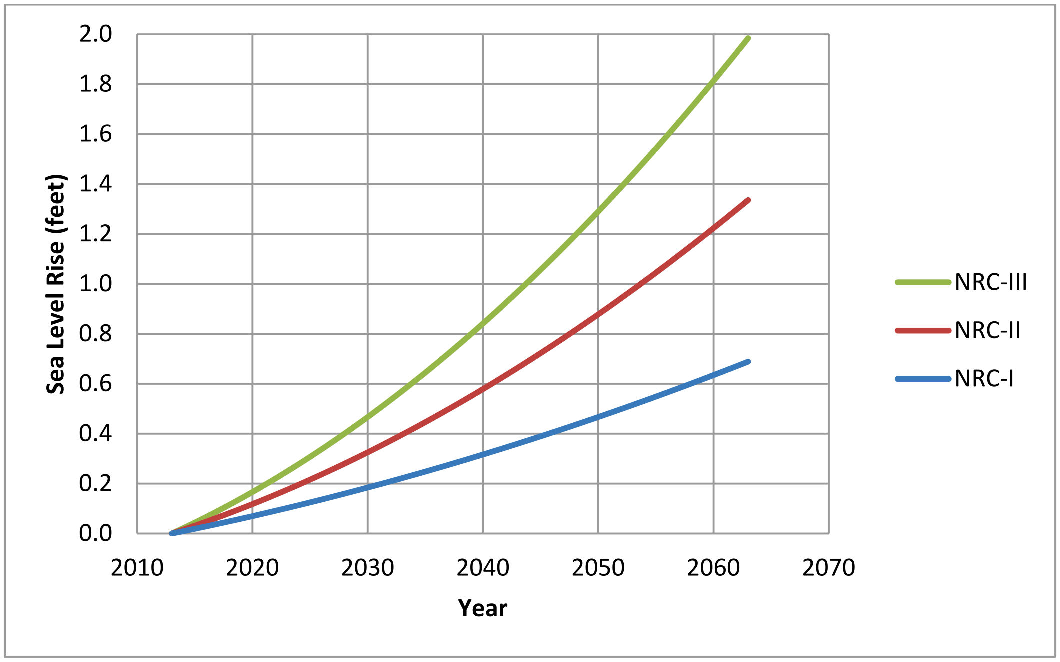
$$E(t_2)-E(t_1) = 0.0017(t_2-t_1)+b(t_2^2-t_1^2) \tag{21}$$

where t_2 and t_1 are times in years from a reference of 1992, t_2-t_1 is the time from 2013 and $E(t_2)$-$E(t_1)$ is the difference in water levels since 2013. The coefficient b is the only difference between the curves and is 2.71e-5, 7.00e-5, and 1.13e-4 for NRC-I, NRC-II, and NRC-III, respectively. The SLR rise scenarios, converted to feet, are shown in Figure 69.

Comparing Figure 60 to the results of Church and White (2011) and Houston (2012), the NRC-II prediction corresponds to a probability of occurrence of 0.05 while the NRC-I prediction is roughly a probability of excedance of 0.6. Boon et al. (2010) report that the current sea-level rise in the Chesapeake Bay area is about 1.8 mm/yr, which corresponds to a rise of 0.3 ft over 50 yrs. So the NRC-I prediction is a reasonable approximation of the most likely sea-level rise scenario and the NRC-II is reasonable as an upper bound at this time.

However, Boon et al. (2010) also report a subsidence in the Chesapeake Bay area of about -4 mm/yr, which corresponds to an increase in depth of 0.65 ft over 50 yrs.

Figure 69. Sea-level rise based on NRC-I, NRC-II, and NRC-III.



Although the design waves at the sites of the proposed Tangier Island jetties are not depth-limited, increased water depths will allow larger waves to reach the project site. However, the numerical models used in Chapter 2 of this report were not re-run with the higher water levels to determine the wave heights that would reach the structures. Instead, the design wave conditions presented in Table 4 were used with the structure freeboard reduced by the sea-level rise and the subsidence. Taking the NRC-I sea level rise as a most likely case, and adding 0.65 ft for subsidence, depth at the structure will increase by 1.34 ft in 50 yrs. Assuming the NRC-II as the upper bound of the expected sea-level rise, and adding 0.65 ft for subsidence, the depth at the structure could increase by as much as 2 ft in 50 yrs.

If depth at the structure increases, the jetty freeboard is reduced by the same amount. The seaside armor stone calculations are not affected by the freeboard, but the leeside armor stones will be unstable if the freeboard is reduced. Table 22 lists the stable leeside armor stone sizes at each of the save stations if the depth increases by 1.34 ft (NRC-I plus subsidence) or 2.0 ft (NRC-II plus subsidence). Jetty head stone weights have been increased by 25%.

The transmitted wave heights will increase if the freeboard decreases. Table 22 also lists the calculated transmitted wave heights for the design storm if the depth at the structure were to increase by 1.34 ft or 2.0 ft.

If the transmitted wave heights are considered unacceptable with the possibility of sea-level rise and subsidence, Table 23 lists leeside armor stone weights and transmitted wave heights for an initial crest elevation of one design wave height plus storm surge.

3.7 Local subsidence

The subsidence discussed above refers to the general subsidence of the Chesapeake Bay. It does not address local subsidence caused by the weight of the jetty compressing the underlying soil. Borings taken at the proposed jetty location indicate local subsidence should be expected. Design jetty crest elevation will need to be increased in order to have the desired crest elevation after the structure has settled. The geotechnical investigation necessary to determine the amount of local subsidence is being conducted at the same time as this study; thus, CENAO and CHL have agreed that CENAO will modify the final design to include local subsidence. Therefore, the design presented here is considered preliminary.

Table 22. Stable leeside armor stone required for crest elevation of storm surge plus one-half design wave height if depth increases by 1.34 ft (NRC-I plus subsidence) or 2.0 ft (NRC-II plus subsidence).

Station	Depth, MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)	Depth MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)	Depth, MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)
	No change in depth				Depth increases by 1.34 ft				Depth increases by 2.0 ft			
85	4.17	7.08	0.78	1.00	5.51	0.74	1.29	1.54	6.17	5.08	1.61	1.80
88	6.17	7.13	0.81	1.03	7.51	0.79	1.32	1.56	8.17	5.13	1.64	1.83
99	7.71	7.20	0.84	1.06	9.05	0.86	1.36	1.60	9.71	5.20	1.68	1.86
103	8.66	7.51	1.22	1.24	10.00	1.17	1.91	1.77	10.66	5.51	2.32	2.04
118	8.69	7.41	0.93	1.18	10.03	1.07	1.47	1.72	10.69	5.41	1.80	1.98
121	8.40	7.41	1.17	1.18	9.74	1.07	1.84	1.72	10.40	5.41	2.25	1.98

Table 23. Stable leeside armor stone required for crest elevation of storm surge plus design wave height if depth increases by 1.34 ft (NRC-I plus subsidence) or 2.0 ft (NRC-II plus subsidence).

Station	Depth, MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)	Depth, MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)	Depth, MTL (ft)	Free-board, MTL (ft)	Weight Leeside Armor W(50) (tons)	Trans Wave Ht (ft)
	No change in depth				Depth increases by 1.34 ft				Depth increases by 2.0 ft			
85	4.17	4.17	0.28	0.00	5.51	2.83	0.57	0.70	6.17	2.17	0.76	0.97
88	6.17	4.27	0.29	0.00	7.51	2.93	0.57	0.71	8.17	2.27	0.76	0.97
99	7.71	4.40	0.29	0.00	9.05	3.06	0.58	0.72	9.71	2.40	0.77	0.99
103	8.66	5.02	0.40	0.00	10.00	3.68	0.78	0.77	10.66	3.02	1.01	1.03
118	8.69	4.82	0.31	0.00	10.03	3.48	0.61	0.76	10.69	2.82	0.80	1.02
121	8.40	4.82	0.39	0.00	9.74	3.48	0.76	0.76	10.40	2.82	1.00	1.02

3.8 Site visit July 2013

The site for the root of the north jetty discussed in this report up to this point was selected during a site visit by CHL and District personnel in October 2012. The site was re-visited in July 2013, and it was found that the site had eroded significantly. In Figure 70, the "x" marks the location of the north jetty root that was selected in October 2012. At that time, the point was on the shoreline. The picture in Figure 70 was taken shortly before high tide and the depth between the shoreline and the point is about 6 in. There is concern that the site will continue to erode and ultimately flank the jetty.

If the shoreward segment of the north jetty were simply extended to the new shoreline, the jetty would be anchored in an area with an elevation that did not appear to be more than 1 ft above the water level (near high tide). The nearest point that appeared to be more resistive of erosion is marked in Figure 70 with an "o." The elevation there appeared to be close to 3 ft and the ground was held in place with a tangle of roots.

The location of the new point for the root of the north jetty is shown by the blue dot in Figure 71. If the offshore segment of the north jetty is left in place and the shoreward segment redirected straight to the new point, the length of the Alt 4 north jetty will be increased from 546 ft to 757 ft. The new jetty footprint with the modified landward terminus of the north jetty is expected to produce essentially the same wave-reduction benefits as the modeled footprints, so no changes are necessary in the jetty cross-sectional design.

Table 24 is an update of Table 1, and gives the state plane coordinates of key locations for the structures in each of the alternatives with the change in location of the north jetty root. In Table 24 all distance units have been converted from meters to feet.

Figure 70. Looking east towards original site of proposed north jetty root.

Figure 71. Location of key points on the north jetty.
The recommended revised location for the root is the blue dot.

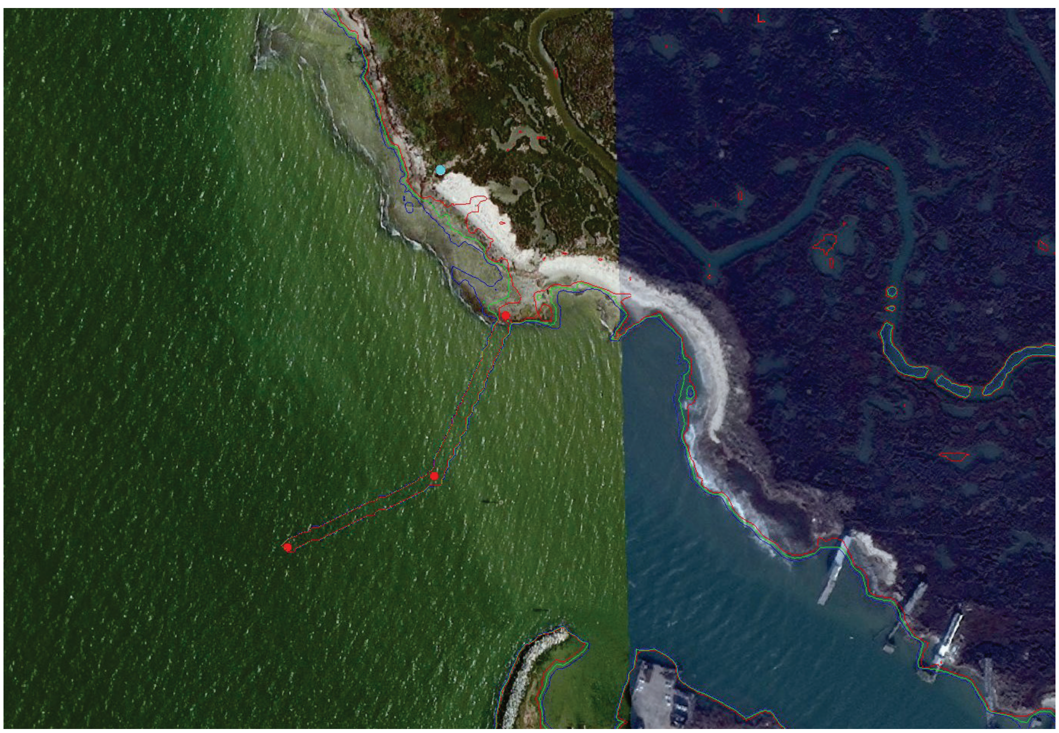


Table 24. Location (footprint) of alternatives in state plane coordinates, ft.

		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
North Jetty	Type	Straight	Dogleg	Dogleg	Dogleg	Straight
	Landward End Easting (ft)	12205238	12205238	12205238	12205238	12205238
	Landward End Northing (ft)	3836792	3836792	3836792	3836792	3836792
	Turning Point Easting (ft)		12205228	12205228	12205228	
	Turning Point Northing (ft)		3836298	3836298	3836298	
	Seaward End Easting (ft)	12205228	12204992	12204992	12204992	12205228
	Seaward End Northing (ft)	3836298	3836183	3836183	3836183	3836298
	Shore Seg-ment Length (ft)		494	494	494	
	Bay segment Length (ft)		263	263	263	
	Tot Length (ft)	494	757	757	757	494
South Spur Jetty	Type	None	None	Straight	Straight	Straight
	Landward End Easting (ft)			12205366	12205376	12205376
	Landward End Northing (ft)			3835980	3836016	3836016
	Seaward End Easting (ft)			12205366	12205294	12205294
	Seaward End Northing (ft)			3836111	3836118	3836118
	Length (ft)			131	131	131

4 Conclusions

This report documents numerical wave and flow modeling for evaluation of jetties on a shallow draft navigation channel on Tangier Island, VA, located in the south Chesapeake Bay. CENAO is considering the construction of structures to protect the western entrance of the channel and reduce the wave energy in the lee of the structures. Five alternatives and the existing channel geometry were investigated by numerical models. All five alternatives included a jetty system that connects to the north shoreline. Alternatives 3, 4, and 5 included an optional short structure (spur) joining to the south shoreline. A number of advances to CMS-Wave were necessary to address this project's special needs. The CIRP funded these developments to improve model's capabilities. These included development and testing of the full-plane and parent-child capability for hurricanes and northeasters in an estuary, and developing pre- and post-processing analysis codes for model setup and providing wave parameters for structural design calculations required at and around structures.

Structural designs were estimated based on numerical wave and hydrodynamic modeling conducted for 50 yr design wind speeds, waves, and water-level conditions. The 50 yr wind speed was considered as idealized condition and was based on a previous study by Basco and Shin (1993). Different structure alternatives were evaluated to determine an optimal design as determined by the level of wave-energy reduction in the navigation channel. The hydrodynamic modeling study results (e.g., wave height, period, direction, and water level) along the western side of the proposed structure footprint were used in the preliminary wave-control structural design calculations. These calculations included structural stability, run-up/overtopping, and transmission through and over the structure.

Overall, Alternative 4 performed better than other alternatives for the conditions evaluated, as shown in Figures 29, 31, 33, 36-38, and 42-47; and in Tables 6-8 and 12. Consequently, based upon the level of wave reduction shown in the modeling results, the modified footprint of Alternative 4, as provided in Table 24, is recommended for use as the design structure location. However, some of the other alternatives also provided considerable wave-reduction benefits. A comparison of the alternatives indicated that the three that included a south spur jetty (Alternatives 3, 4, and 5) outperformed the other two (Alternatives 1 and 2, with no south spur) in reducing wave energy in the channel. This is shown in the figures and tables listed above.

In addition, it should be noted that the geometry of the channel itself, even without any jetty structure, strongly dampens the propagating waves. For example, station 50 is approximately 300 m (1000 ft) down the channel from the western entrance. As shown by the red line (the without project line) in Figures 29, 31, and 33, by the time that waves have propagated this distance down the channel, their energy has dissipated to the extent that their height is only of the order of 10 to 20 percent of their former height in the bay. These three figures (and others) show that the greatest benefits to be accrued by any of the alternatives will occur in this westernmost 1000 ft (300 m) of the Tangier Island boat canal. Most of the docks and processing sheds that line both sides of the channel are to the east (further down the channel) of this position. Thus, while this report shows that Alternative 4 provides the greatest wave-reduction benefits of any of the alternatives, it is recognized that multiple criteria may be used in the selection process of the optimal alternative.

The following results are based upon the choice of Alternative 4 as the construction footprint. Stable armor stone sizes for both the seaside and leeside of a conventional multi-layer rubble-mound jetty are determined at each of six save stations on the proposed jetties. Three different crest elevations for the jetties were considered (Tables 13, 14, and 15): storm surge plus one-half design wave height, storm surge plus one design wave height, and storm surge plus 1.5 times the design wave height. Based on the size of the armor stones, cross-sectional areas were calculated for the seaside armor, leeside armor, and a combined core plus under-layers (Table 16). The lowest crest elevation (storm surge plus one-half design wave height) appears to offer sufficient protection while being the least costly.

Structures with low crest elevation are particularly susceptible to leeside damage by overtopping waves. Armor stone sizes for the seaside and leeside were therefore calculated separately for the different configurations considered (Table 17).

Transmitted wave heights were calculated at each save station for each of the crest elevations considered. Transmitted wave heights were also calculated for the expected freeboard after 50 yrs of the most likely sea-level rise (NRC-I) and also for the larger sea-level rise expected as an upper limit (NRC-II) (Tables 22 and 23). In both cases, a constant rate of subsidence for Chesapeake Bay was included. However, the larger wave heights that would result from the greater depths were not determined. Not included in the calculations was local settling caused by the weight of the structure on the in situ material.

The structures described above allow some overtopping with transmitted wave heights during the design storm event of about 1 ft. However, the proposed jetty crest elevation is considerably higher than the island to which the main jetty is attached. At the design water level, much of the island will be inundated leaving the jetty exposed as an island. A low-crested structure, with crest elevation approximating the highest land elevations in the vicinity of the structure root (crest elevation= 3.3 ft), was also examined. Although the low-crested structure will obviously have greater transmission, it will be less expensive to build and still provide a high level of energy reduction. The wave-height reduction factors in Tables 6 through 11 were based on a crest elevation of 3.3 ft.

A site visit to the island in July 2013 found that the point of land that had been selected as the anchor point of the north jetty had significantly eroded. At high tide, the point was completely surrounded by water and cut off from the main part of the island. Extending the jetty through the selected point and straight back to the island was not recommended as the island at that location was low-lying and additional erosion was expected. A new location for the jetty root was selected at the nearest point that offered at least some elevation and appeared more resistant to erosion.

The design was based on a design storm with a return period of 50 yrs. Not only is the design storm expected to occur during the life of the structure, but a more severe storm is obviously possible. The design equations assume a low level of damage during the design event. Because of the difficulty in obtaining repair and maintenance funds for coastal structures, it may be prudent to use a more extreme design storm or include a level of over-design to minimize any damage that may occur. As was noted in Chapter 2, the focus of this study was on wave modeling to develop means for wave-energy reduction in the navigation canal. If required for the final design, the modeling estimates for flow and sediment transport should be validated either with field data or compared to the estimates obtained from other two- or three-dimensional hydrodynamic models.

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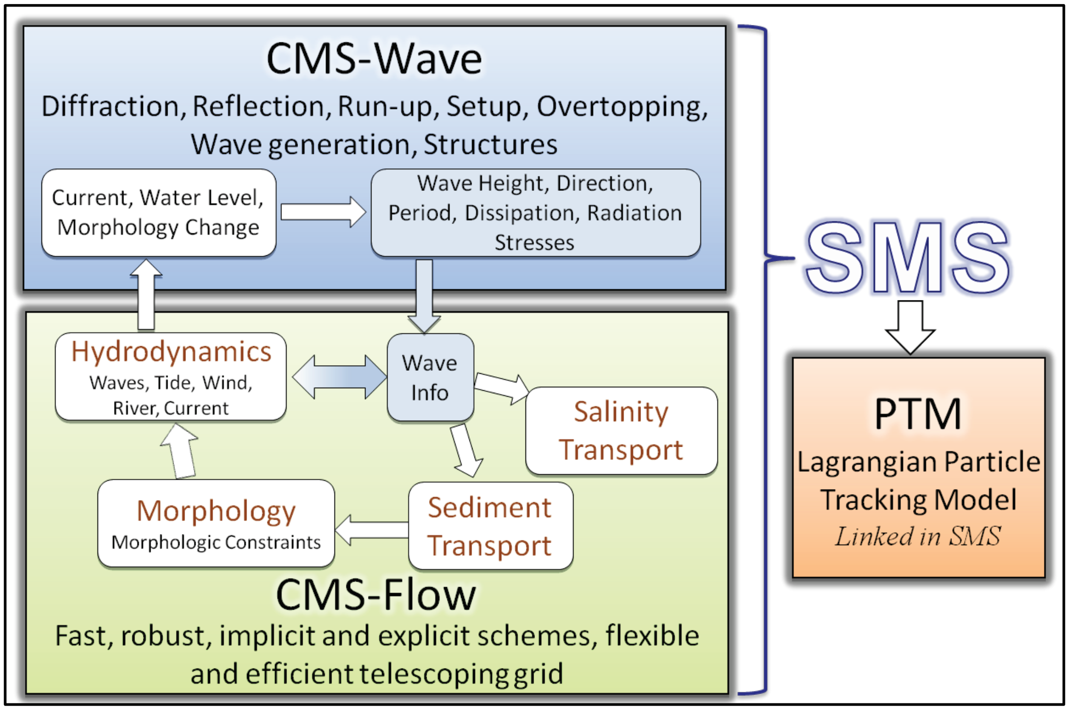
Appendix A: Description of CMS

The Coastal Modeling System (CMS) was used for the numerical modeling estimates of waves, currents, and sediment transport at Tangier Island. A brief description of the CMS is provided here for completeness.

As shown in Figure A-1, the CMS is an integrated suite of numerical models for waves, flows, and sediment transport and morphology change in coastal areas. This modeling system includes representation of relevant nearshore processes for practical applications of navigation channel performance, and sediment management at coastal inlets and adjacent beaches. The development and enhancement of CMS capabilities continues to evolve as a research and engineering tool for desk-top computers. CMS uses the Surface-water Modeling System (SMS) (Zundel 2006) interface for grid generation and model setup, as well as plotting and post-processing. The Verification and Validation (V&V) Report 1 (Demirbilek and Rosati 2011) and Report 2 (Lin et al. 2011) have detailed information about the CMS-Wave features, and evaluation of model's performance skills in a variety of applications. Report 3 and Report 4 by Sanchez et al. (2011a and 2011b) describe coupling of wave-flow models, and hydrodynamic and sediment transport and morphology change aspects of CMS-Flow. The performance of CMS for a number of applications is summarized in Report 1 and details are described in the three companion V&V Reports 2, 3, and 4.

Figure A- 1. The CMS framework and its components.



The CMS-Wave, a spectral wave model, is used in this study given the large extent of modeling domain over which wave estimates were required. Wind-wave generation and growth, diffraction, reflection, dissipation due to bottom friction, white-capping and breaking, wave-current interaction, wave run-up, wave setup, and wave transmission through structures are the main wave processes included in the CMS-Wave.

CMS-Wave model solves the steady-state wave-action balance equation on a non-uniform Cartesian grid to simulate steady-state spectral transformation of directional random waves. CMS-Wave is designed to simulate wave processes with ambient currents at coastal inlets and in navigation channels. The model can be used either in half-plane or full-plane mode for spectral wave transformation (Lin et al. 2008; Demirbilek et al. 2007). The half-plane mode is default because in this mode CMS-Wave can run more efficiently as waves are transformed primarily from the seaward boundary toward shore. See Lin et al. (2011 and 2008) for features of the model and step-by-step instructions with examples for application of CMS-Wave to a variety of coastal inlets, ports, structures, and other navigation problems. Publications listed in the V&V reports and this report provide additional information about the CMS-Wave and its engineering applications. Additional information about CMS-Wave is available from the CIRP website: http://cirp.usace.army.mil/wiki/CMS-Wave

The CMS-Flow, a two-dimensional shallow-water wave model, was used for hydrodynamic modeling (calculation of water level and current) in this study. The implicit solver of the flow model was used in this study. This circulation model provides estimates of water level and current given the tides, winds, and river flows as boundary conditions. CMS-Flow calculates hydrodynamic (depth-averaged circulation), sediment transport, and morphology change, and salinity due to tides, winds, and waves.

The hydrodynamic model solves the conservative form of the shallow-water equations that includes terms for the Coriolis force, wind stress, wave stress, bottom stress, vegetation-flow drag, bottom friction, wave roller, and turbulent diffusion. Governing equations are solved using the finite volume method on a non-uniform Cartesian grid. See the V&V Reports 3 & 4 by Sanchez et al. (2011a and 2011b) for the preparation of model at coastal inlet applications. Additional information about CMS-Flow is available from the CIRP website: http://cirp.usace.army.mil/wiki/CMS-Flow

CMS-Flow modeling task included specification of winds and water levels to the model. The effects of waves on the circulation were input to the CMS-Flow and have been included in the simulations performed for this study.

There are three sediment transport models available in CMS-Flow: a sediment mass balance model, an equilibrium advection-diffusion model, and a non-equilibrium advection-diffusion model. Depth-averaged salinity transport is simulated with the standard advection-diffusion model and includes evaporation and precipitation. The V&V Report 1, Report 3, and Report 4 describe the integrated wave-flow-sediment transport and morphology change aspects of CMS-Flow. The performance of CMS-Flow is described for a number of applications in the V&V reports.

Appendix B: Datums

Horizontal datums

The horizontal datum used for coordinate data input into the models was NAD83, State Plane Virginia, South (Federal Information Processing Standard state code: 4502) in meters.

Vertical datums

The vertical datum used in this study was MTL (mean tide level) in meters, based on NOAA benchmark at Bishops Head, Hoopers Strait, Maryland (Station 8571421). The station information is given as follows:

Station ID: 8571421 PUBLICATION DATE: 11/19/2012
Name: BISHOPS HEAD, HOOPERS STRAIT, MARYLAND

NOAA Chart: 12261 Latitude: 38° 13.2' N
USGS Quad: WINGATE Longitude: 76° 2.3' W

Tidal datums at BISHOPS HEAD, HOOPERS STRAIT based on:
LENGTH OF SERIES: 6 YEARS
TIME PERIOD: Sep 05 - Aug 09 & April 10 - March 12
TIDAL EPOCH: 1983-2001

CONTROL TIDE STATION: 8571892 CAMBRIDGE, CHOPTANK RIVER
Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in meters:

HIGHEST OBSERVED WATER LEVEL (10/30/2012)		= 1.309
MEAN HIGHER HIGH WATER	MHHW	= 0.624
MEAN HIGH WATER	MHW	= 0.575
North American Vertical Datum	NAVD88	=0.380
MEAN SEA LEVEL	MSL	= 0.307
MEAN TIDE LEVEL	MTL	= 0.307
MEAN LOW WATER	MLW	= 0.039
MEAN LOWER LOW WATER	MLLW	= 0.000
LOWEST OBSERVED WATER LEVEL (01/03/2008)		= -0.559

The data above were obtained from the website:
http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8571421%20Bishops%20Head,%20MD&type=Bench%20Mark%20Data%20Sheets

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14. ABSTRACT

This report documents numerical wave and flow modeling for evaluation of the jetties on a shallow draft navigation channel on Tangier Island, VA, located in Chesapeake Bay. Because it is heavily used by the local fishing fleet, the U.S. Army Engineer District, Norfolk (CENAO) maintains the Tangier Island boat canal. CENAO is considering the construction of structures to protect the western entrance of the channel and reduce the wave energy in the lee of the structures, and asked the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) to perform a numerical modeling study to investigate how waves and hydrodynamics would be affected by structures, to identify the optimal location for the structures, and to develop a preliminary structure design. The primary goal of the study was to develop a quantitative estimate of waves and wave reduction in the canal for a relative comparison of alternatives investigated and for the preliminary structural design calculations.

CMS-Wave, a spectral wave model, was used to estimate waves in Chesapeake Bay and propagate waves into the entrance channel and boat canal. The numerical modeling results indicated that maximum wave energy reduction inside the canal was obtained using a dog-leg jetty connecting to the north shoreline and a spur on the south shoreline.

15. SUBJECT TERMS
Numerical modeling, evaluation, hydrodynamics, wave reduction, Tangier Island, VA

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ATTACHMENT A-2

GEOTECHNICAL ENGINEERING DESIGN ANALYSIS REPORT

US Army Corps of Engineers ®
Norfolk District

TANGIER ISLAND JETTY SECTION 107 NAVIGATION PROJECT
Subsurface Exploration and Preliminary Geotechnical Evaluation

2013

PREPARED BY:
Geo Environmental Section, Norfolk District
U.S. Army Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, VA 23510

Table of Contents

1. **Purpose:** The purpose of this report is to summarize the results of the subsurface exploration, laboratory testing, and geotechnical engineering evaluation performed by the U.S. Army Corps of Engineers (USACE), Norfolk District, Geo-Environmental Section. This report presents our understanding of the project, reviews the exploration procedures, and presents our observation, evaluations and preliminary recommendations.

2. **Project Information**
   - 2.1. **Project Information and Scope of Work:** The project will encompass the feasibility phase of the Tangier Island Jetty Section 107 Navigation project. Tangier Island is divided by a federal navigation channel running east to west. The western side opens into the Chesapeake Bay. The channel configuration allows wave action from the west to enter the turning basin which is located at the relative center of the island. The wave action is causing damage to the docks, crabbing systems, as well as boats and shorelines. The intent of the project is to study the feasibility of installing a rock jetty across the opening of the channel to mitigate the wave action from entering the channel.
   - 2.2. **Historical Information:** The project has been studied since 1982 after the channel was installed west from the turning basin, dividing the island in two halves. In 1982 Waterway Surveys and Engineering, LTD submitted a report suggesting that the island install a jetty system enclosing the western opening of the federal channel. (Review of Project Channel, Tangier Island, VA; by Waterway Surveys & Engineering; 1982). Other historical information included design information of the existing seawall installed on the western coast along the airport property as well as proposed breakwaters, although not installed, along the western edge of the 'Uppards' which is the land mass north of the inhabited portion of Tangier Island. Additionally, Norfolk District completed a technical analysis of the shore protection required along the western shoreline of the island in 1980. All three reports included geotechnical data including soil borings. Information from these historical documents was used to assist with the geotechnical evaluation of the proposed jetty. The boring logs were not used for analysis as the shoreline has eroded significantly since the last investigation. Norfolk District instead chose to use more conservative numbers in the analysis for settlement. A listing of the documents is found in Appendix A.
   - 2.3. **Site Location and Description:** Tangier Island is located in the Chesapeake Bay approximately 13 miles southwest of Crisfield, MD and approximately 15 miles directly east of Reedville, VA. The project site is the entrance channel on the west side of Tangier Island, VA. The opening is approximately 500 feet wide with the channel exiting the opening and veering left as you approach open water of the Chesapeake Bay. The northern shore is remote due to the lack of infrastructure as well as the lack of inhabitants. The southern shore includes a small harbor as well as the northern tip of the seawall installed along the airport property mentioned above. The water depth in the area of the project site ranges from -9 feet MLLW to 2 feet MLLW according to recent

hydrographic surveys performed by the Survey Section, Operations Branch, Norfolk District**.**

2.4. Current Studies: The Coastal and Hydraulics Laboratory (CHL) at the Engineering Research Development Center (ERDC) was contracted by Norfolk District to perform hydraulic computer modeling considering the proposed stone jetty at the channel entrance. The final report from ERDC has not been completed at the time of this report. The information from the study will be used to determine the best configuration and size of jetty to mitigate the wave action and the ensuing damage.

3. Subsurface Exploration

3.1. General: The Geo-Environmental Section developed a subsurface exploration plan in order to obtain additional information in regards to the underlying soils in the general location of the proposed jetty. The subsurface exploration consisted of performing cone penetration testing (CPT) soundings, and soil sampling utilizing vibracore or direct push (macrocore) methods. All testing and sampling was performed overwater from the Norfolk Districts floating plant, MS Elizabeth. The program was to assist with a determining representative foundation soil conditions beneath the proposed jetty and their effect on the settlement and stability of the structure.

3.2. Locations: Boring locations were located in the field using a GPS mounted to the Monarch which is a skiff used as a service boat aboard the MS Elizabeth. The locations were marked using buoys and anchors in order for the Elizabeth to be piloted into location. The locations of the borings were placed in the general area of the proposed jetty. The Hydraulics/Hydrology Section of Norfolk District developed four alternative arrangements for the proposed jetty. See Appendix C for boring location plan.

3.3. Sampling and Testing:

3.3.1. Cone Penetration Testing: Cone Penetration Testing (CPT) was advanced in accordance with ASTM D 5778. Cone resistance, friction resistance, and pore pressure, among other data sets, were recorded at approximate 5 cm intervals. The data was collected by, Savannah District, U.S. Army Corps of Engineers using a track mounted portable rig (Geoprobe 66DT) to advance an electronic cone. Two locations were tested with this method. CPT's were accomplished between 21 May 2013 and 22 May 2013 and were designated as CPT-2 and CPT-3. Empirical correlations of the CPT data were performed by Savannah District to provide an estimated soil profile and soil strength parameters, such as friction angle and undrained shear strength. Additional CPT readings were anticipated for the project but due to equipment issues and unfavorable seas they were unable to be performed.

3.3.2. Soil Sampling Methods: Norfolk District utilized two methods to collect subsurface soil samples. A vibracore sampler was used to obtain soil samples at 3 locations (VC-2, VC-3 and VC-4). The vibracore samples were limited to the top 3-7 feet below the mud line, due to difficulty penetrating denser or firmer underlying soils. The Geoprobe 66DT which advanced the CPT probe was also capable of obtaining soil samples. Sampling was accomplished at one location, MC-4 (See appendix C) from 5 feet down to 30 feet below the mud line. For both methods samples were collected continuously in approximately 5 to 10 foot plastic tubes. The sample tubes were brought back to Norfolk District to visually classify and record soils. Representative samples of the soil were sent to a soil testing laboratory for soil index testing.

3.4. Geotechnical Laboratory Testing: The geotechnical laboratory testing program was performed on selected samples recovered from the test borings to determine the physical characteristics of the material. Soil index testing included 6 grain size distributions, 6 Atterberg Limits, 6 natural moisture contents, and 6 wet washes (ASTM D 422, D 4318, D 2216, and D 1140). The laboratory soil testing was performed by McCallum Testing Laboratories, Inc. in Chesapeake, VA. Laboratory test results are included in Appendix F.

4. Subsurface Conditions

4.1. Regional Geology: Tangier Island is located within the outer edge of the Coastal Plain physiographic province of Virginia. The Coastal Plain province generally consists of gently seaward dipping sediment layers of Cretaceous to recent geologic age. Sediments in the outer edge of the Coastal Plain province are generally of fluvial-estuarine and marine origin and were typically deposited in cyclical environments of advancing and retreating sea levels (Peebles, 1984). The soils at the project site are part of the Shirley Formation which in this part of the province overlay the older soils of the Yorktown Formation.

The Shirley Formation typically consists of interlayered fine- and coarse-grained soils. The fine-grained soils generally consist of clays and silt with various amounts of sand and are generally normally preconsolidated to slightly preconsolidated. The coarse-grained soils generally consist of poorly graded sands, silty sands and clayey sands and may contain gravel. Organic soil and peat are commonly found within this Formation.

The Yorktown Formation typically consists of bluish-gray to greenish-gray silty sands and clayey sands that are generally moderately preconsolidated. Significant amounts of shell material are frequently present. The soils of this Formation are sensitive to disturbance and often exhibit lower SPT N values than would other soils of comparable strength (Martin et al, 1987). These soils are typically the bearing stratum for deep foundations in the Tidewater area of Virginia.

4.2. Generalized Subsurface Stratigraphy: The subsurface conditions discussed in the following section and those shown on the boring logs represent an interpretation of the boring data using accepted geotechnical engineering judgment. The lines designating strata breaks on the boring logs and those indicated below represent approximate boundaries between soil types, as the transition may be gradual or may occur between samples.

The generalized subsurface stratigraphy is our interpretation of the soil stratigraphy and subsurface conditions near the proposed jetty. The interpretation necessarily assumes uniform subsurface conditions across the site, which is probably, but not necessarily, correct. The general description, below, should not be considered as a substitute for the borings logs and cone penetration data, that are included in Appendix E and F, respectively, of this report.

The marcro core (MC-4), vibracores (VC2, 3, and 4) and the CPT soundings generally show a soil profile consisting of an upper layer of silts and clays to a depth of approximately 3 to 7 feet below the mudline. This layer is generally followed by a layer of silty sands to a depth ranging between 15 to 17 feet below the mudline. Below the sand layer was generally a layer of clayey silts or silty clays which extends to approximate depths of 25 to 30 feet below the mudline. Both CPT soundings were terminated in dense sand at depths of 35 feet below the mudline.

For an evaluation of settlement, the subsurface soils were divided into eight different stratums based on similar soil strength properties from the CPT soundings.

5. Preliminary Evaluation

5.1. Cross Section: According to recent information from the Coastal Laboratory, the recommended height of the jetty should be 3.3 feet above mean sea level. (refer to Tangier Island Letter Report, dated, Table 10). The slopes were recommended to be 2Horizontal:1Vertical and the crest width 13 feet. A cross section was initially assumed for our settlement evaluation prior to this letter report being released. The assumed cross section for the analysis was 10 feet above MLLW with the same slopes and a 6 foot crest width. The difference in height assumed for the analysis is considered minor and should only provide some conservatism in the design. The rock jetty is to be constructed of large armor stone with a center core of smaller stone.

5.2. Soil Index Tests: The results of the soil index tests showed natural moisture contents between 17.5% and 25.2%. The liquid limit ranged from 25% to 32% for the sandy and silty clays (CL) material and 17% for the silty sand (SP-SM) found in the upper levels (5 to 10 feet) of TI-MC4. The plastic limit for the CL material ranged from 14% and 21%.

5.3. Jetty Configuration Alternatives: Four alternatives for the configuration of the jetty alignment were chosen by Norfolk District’s Hydraulics and Hydrology section as possible alignments to decrease wave action in the channel. The alternatives are shown in Appendix D.

6. Geotechnical Evaluation:

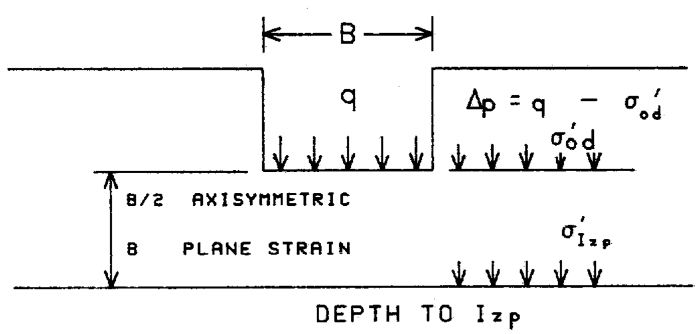
6.1. Settlement Evaluation: Placement of a large load or structure such as the rock jetty on the underlying foundation soils can cause to soils to compress and result in settlement of the structure. To estimate the amount of settlement the rock jetty may undergo, an analysis was performed considering the assumed jetty cross section, the generalized soil profile and the soil parameters from the CPT soundings. The increase in foundation stresses on the underlying soils from the rock jetty was based on an assumed unit weight for the stone equal to 165 pounds per cubic foot (pcf). No voids were assumed in the rock jetty. Core and armor stone were assumed to have the same properties. The settlement evaluation was performed utilizing methods presented in the Corps Engineering Manual, EM 1110-1-1904 and as described in reference "Engineering Design Using the Cone Penetration Test. Norfolk District utilized two methods of approximation due to the unfamiliar subsurface. Schmertmann's method and Janbu's approximation were both used and compared to ensure accuracy of the settlement magnitude.

Schmertmann's Method: The method used was Schmertmann's Approximation of settlement. The analysis assumes that the distribution of vertical strain is compatible with a linear elastic half space subjected to a uniform pressure.

The elastic modulus was estimated from the result of the CPT soundings utilizing the following equation:

$$E_{si} = 3.5 \cdot q_c$$

An influence factor was found for each stratum to find the stress increase each layer was subjected to under the loading (See figure 1 below).



Z = DEPTH BELOW FOOTING BOTTOM, FT
B = FOOTING WIDTH, FT
Iz = DEPTH INFLUENCE FACTOR
Izp = PEAK DEPTH INFLUENCE FACTOR

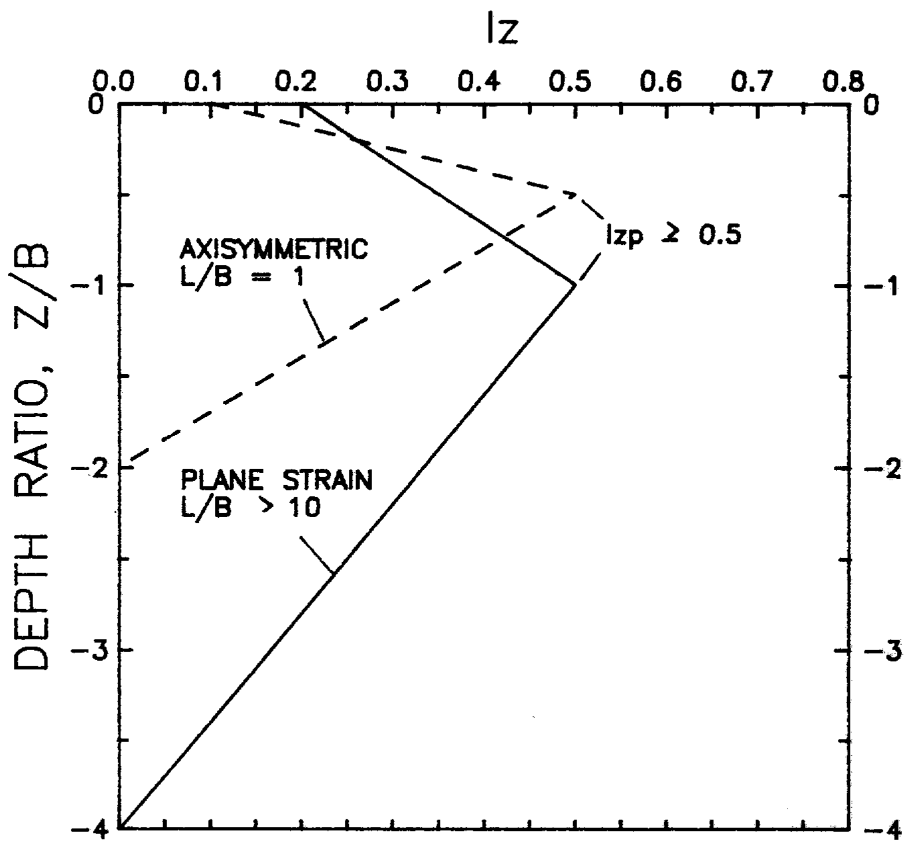


Figure 1 –EM1110-1-1904 Figure 3-4 Recommended strain influence factors for Schmertmann's Approximation.

The subsurface profile was divided into eight layers based on similar tip resistance results (See Appendix H). Settlement of each of these layers was calculated and was combined for the total estimated settlement. The settlement was calculated using an excel spreadsheet with the following equations

$$S = C_1 \times C_2 \times \Delta p \times \sum_{1}^{N} \left(\frac{I_{zi} \times \Delta z_i}{x \quad \times q_{ci}} \right)$$

$$C_1 = 1 - 0.58 \left(\frac{\sigma'_1}{\Delta p} \right)$$

$$C_2 = 1 + 0.20 log_{10} \left(\frac{t_{yr}}{0.1} \right)$$

S = Settlement
C_1 = correction factor for depth of embedment
C_2 = correction factor for creep settlement
Δp = net foundation pressure increase at base of foundation
σ'_1 = previous vertical effective stress at the elevation at the base of foundation
I_{zi} = strain influence factor a the center of the layer

N = numbers of sublayers
Δz_i = thickness of the sublayer
t_{yr} = time in years
q_{ci} = average value of cone tip resistance
x = modulus factor (2.5 for square and 3.5 for strip foundations)

The spreadsheet was checked with hand calculations also included in Appendix H. The maximum settlement for the rock jetty was estimated to be up to 15 inches.

Janbu's Approximation: In cohesive soils, immediate and long term consolidation will have an effect on the settlement included. Long term consolidation was not evaluated but expected to be included in the total settlement due to the conservative nature of the inputs. Janbu's Approximation uses equation 3-17 from EM 1110-1-1904 which is shown below:

$$\rho_i = \mu_0 \cdot u_1 \cdot \frac{q \cdot B}{E_s}$$

μ_0 = influence factor for depth D of foundation below ground surface,Figure 3-8
u_1 = influence factor for foundation shape, Figure 3-8
E_s = equivalent Young's modulus of the soil, tsf

Young's Modulus was estimated to be 75% of the average of the seven layers for TI-CPT-2 due to weaker nature of the material. This will provide more conservative numbers and minimize risk associated with the settlement.

7.0. Preliminary Geotechnical Recommendations

8.1. Subgrade Preparation: The entire subgrade for the proposed jetty should be prepared properly to minimize settling and ensure a proper base for the jetty structure. The subgrade preparation shall include the actual footprint of the structure plus an additional five (5) surrounding the jetty structure. It is recommended that two (2) feet of soil below the mudline across the entire footprint be excavated and removed prior to placement the structure.

8.2. Marine Mattress: To replace the excavated natural bottom soils, a marine mattress, consisting of two layers thick, shall be installed as an underlayment for the rock jetty. The marine mattress shall consist of rock filled containers constructed of high strength geogrids. Each marine mattress shall be no thicker than 12 inches and the bottom side of the lower mattress shall be covered with a high strength geo fabric. The mattress layer shall extend the 5 feet beyond the limits of the jetty structure. The rock for marine mattress shall be hard, angular to round, durable and of such quality that they shall not disintegrate on exposure to water or weathering during the life of the structure. Rock size for the mattress shall range between 2 in. and 8 in. Mattress sections shall be placed on the subgrade immediately after an area is excavated (removal of the upper two (2) feet of soil). This will prevent the redepositing of fluvial fine material brought in by the water currents or waves.

8.3. Rock Jetty: To account for anticipated settlement the rock jetty shall be constructed 15 inches higher than the proposed top of jetty.

Appendix A-References

References

EM1110-1-1904 - Engineering and Design - Settlement Analysis, September 1990

Foundation Engineering – Braja Das, Sixth Edition

Engineering Design Using the Cone Penetration Test – ConeTec, October 2009

Modeling of Tangier Jetties – CHL/ERDC – June 2013

ERDC/CHL CHETN-III-72 - Uses for Marine Mattresses in Coastal Engineering – February 2006

Historical Reports

Detailed Project Report, Norfolk District, 1965

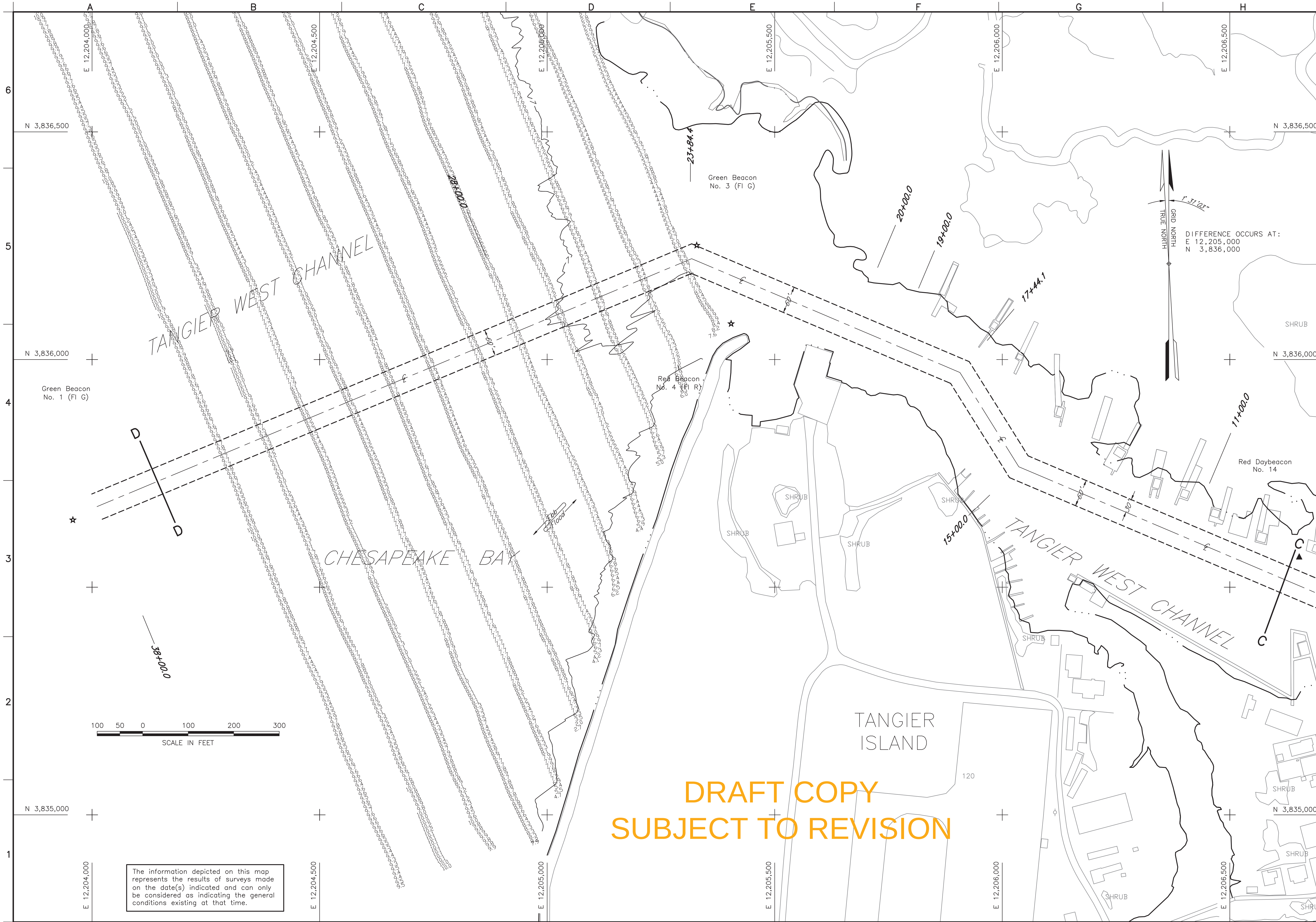
Boring Logs (No Report), Tangier Airport Fill, Norfolk District, 1976

Boring Logs (No Report), Tangier Island Shore Protection, Norfolk District, 1979

Review of Project Channel, Waterway Surveys & Engineering, LTD, 1982

Uppards West Coast Shoreline Breakwater Design, Norfolk District, 2004

Appendix B - Survey Data/Shoreline Erosion



US Army Corps of Engineers
Norfolk District

REV.	DATE	DESCRIPTION	BY	APP.

DESIGNED:
CHECKED: C.S.R.
DATE: 18 DEC 12
DRAWN: P.J.
SUBMITTED: K.L.G.
SCALE: AS SHOWN
NORFOLK DISTRICT FILE NO.: TNT.2012
DRAWING NO.: (5)
SURVEYED BY: W.S.&E.

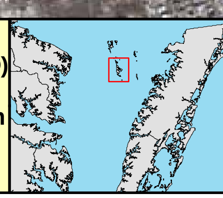
NORFOLK DISTRICT
CORPS OF ENGINEERS
NORFOLK, VIRGINIA

TANGIER CHANNELS JETTY
107 FISEABALITY STYDY
SURVEY OF DECEMBER 2012
TANGIER ISLAND, VIRGINIA

SHEET 5 OF 5

US Army Corps of Engineers
Norfolk District

EROSION HISTORY (UPDATED)
Uppards, Tangier Island, VA
Section 206 Aquatic Ecosystem Restoration Study



0 500 1,000 1,500 Feet

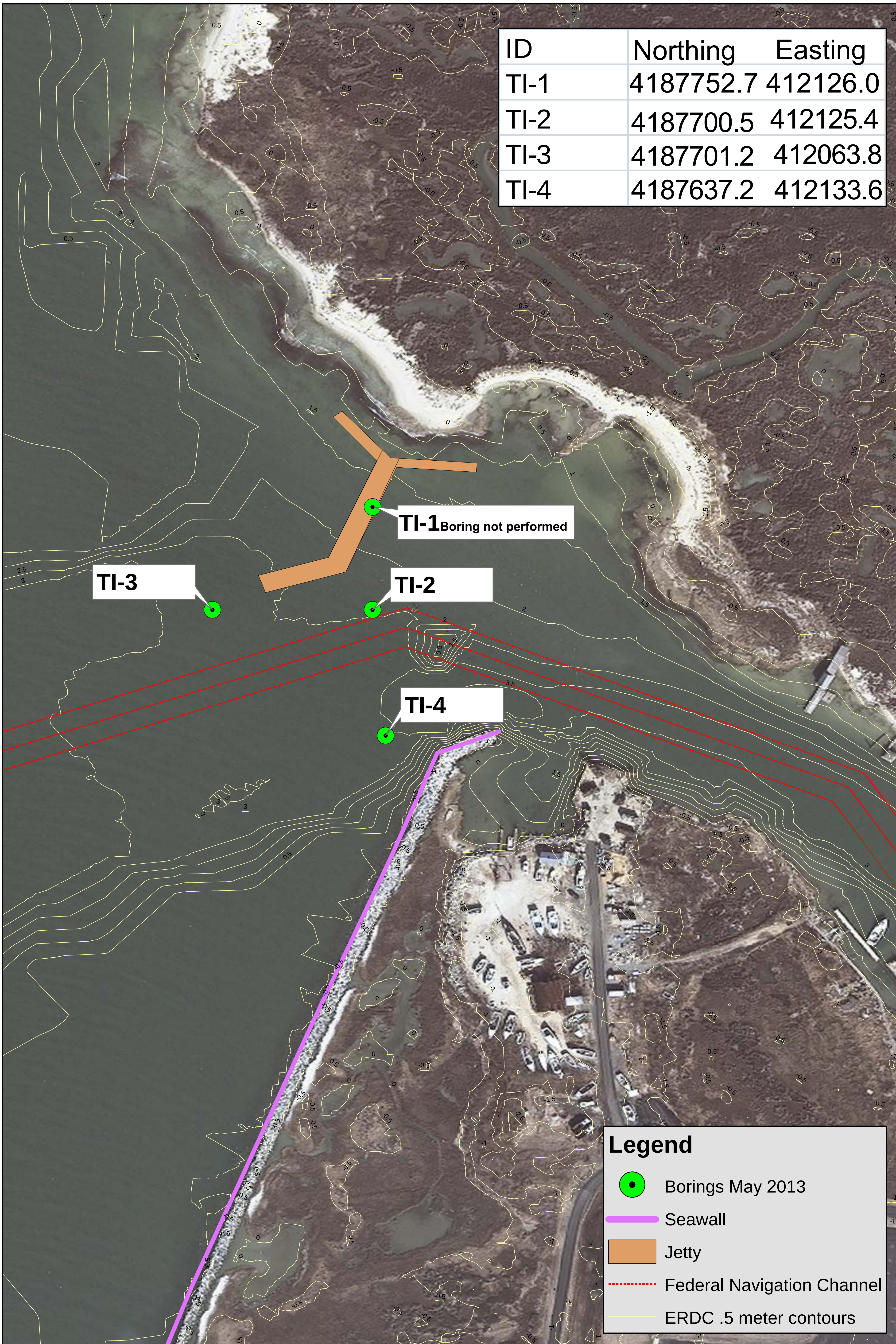
Map Date: Sept. 21, 2010

N W E S

Projection:
Virginia State Plane
South Zone - NAD 83
U.S. Survey Foot

Imagery: 20 May 2009

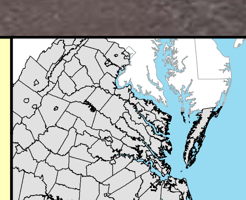
Appendix C – Boring Location Plan



ID	Northing	Easting
TI-1	4187752.7	412126.0
TI-2	4187700.5	412125.4
TI-3	4187701.2	412063.8
TI-4	4187637.2	412133.6

US Army Corps of Engineers
Norfolk District

Tangier Jetty
Boring Points
May 2013
Tangier Island
Accomack County, VA



0 50 100 200 Feet

Projection:
Virginia State Plane
South Zone - NAD 83
U.S. Survey Feet

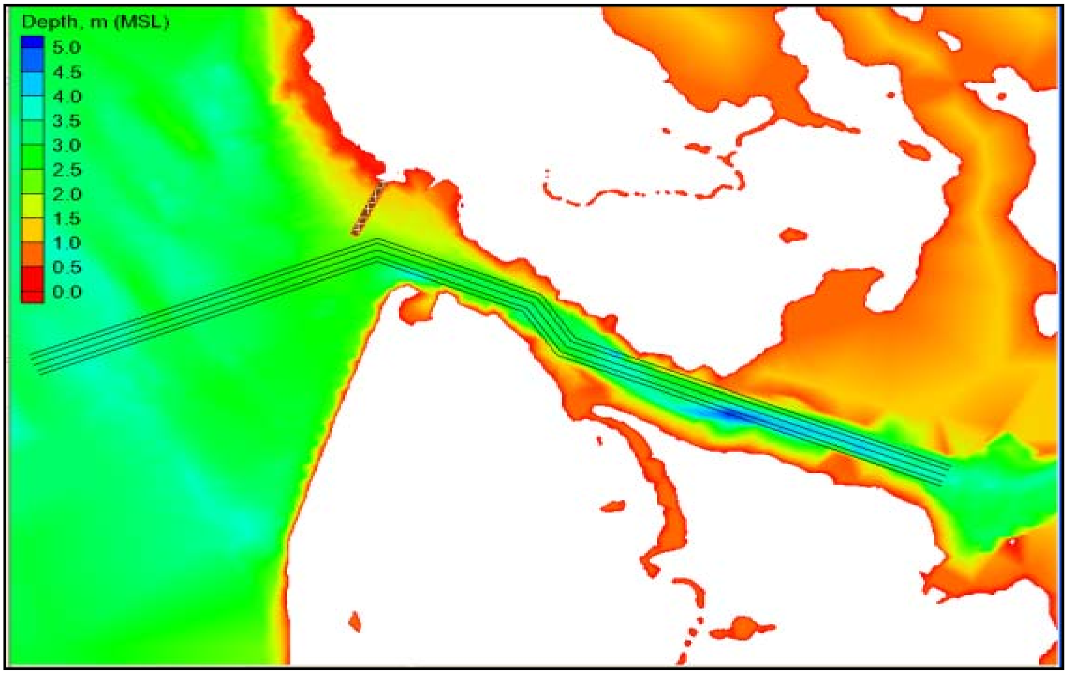
Base Imagery:
ESRI Online Maps

Project Manager: Larry Ives
E-mail: Lawrence.H.Ives@usace.army.mil
Phone: (757) 201-7769

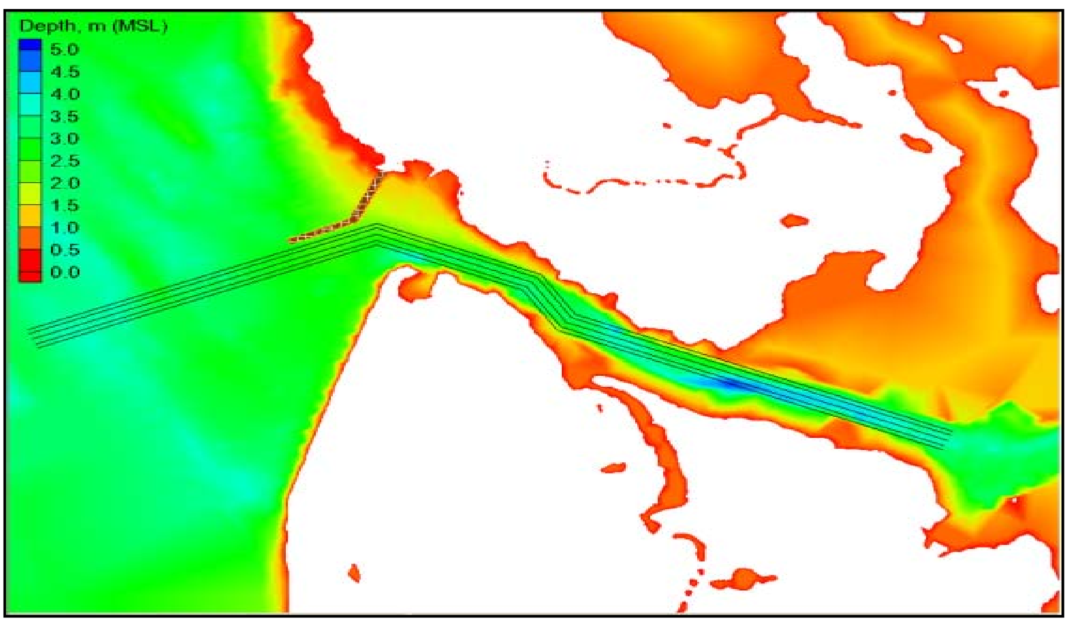
Prepared by: Karin Dridge
Geospatial Section

Map File: Boring_pts.mxd
Map Date: July 8, 2013

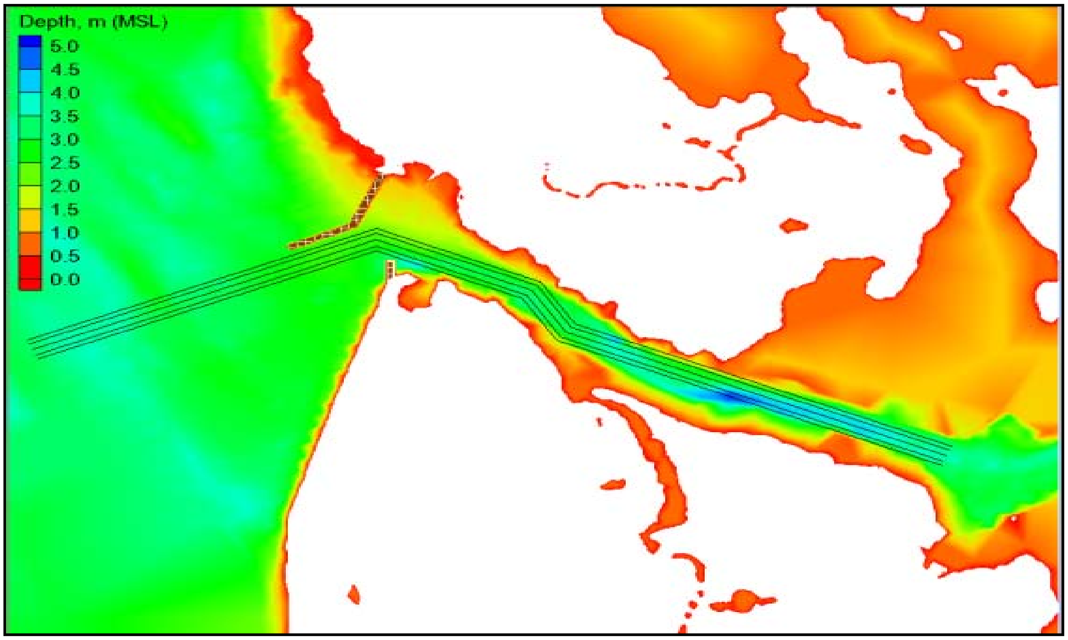
Appendix D – Configuration Alternatives



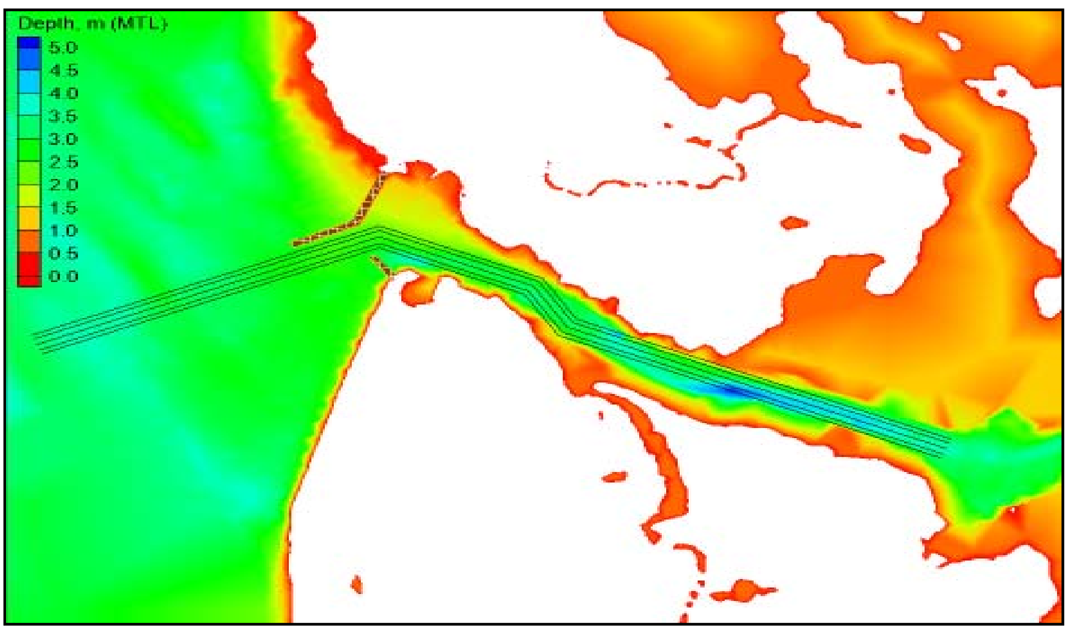
Alternative 1 with channel and structure configuration.



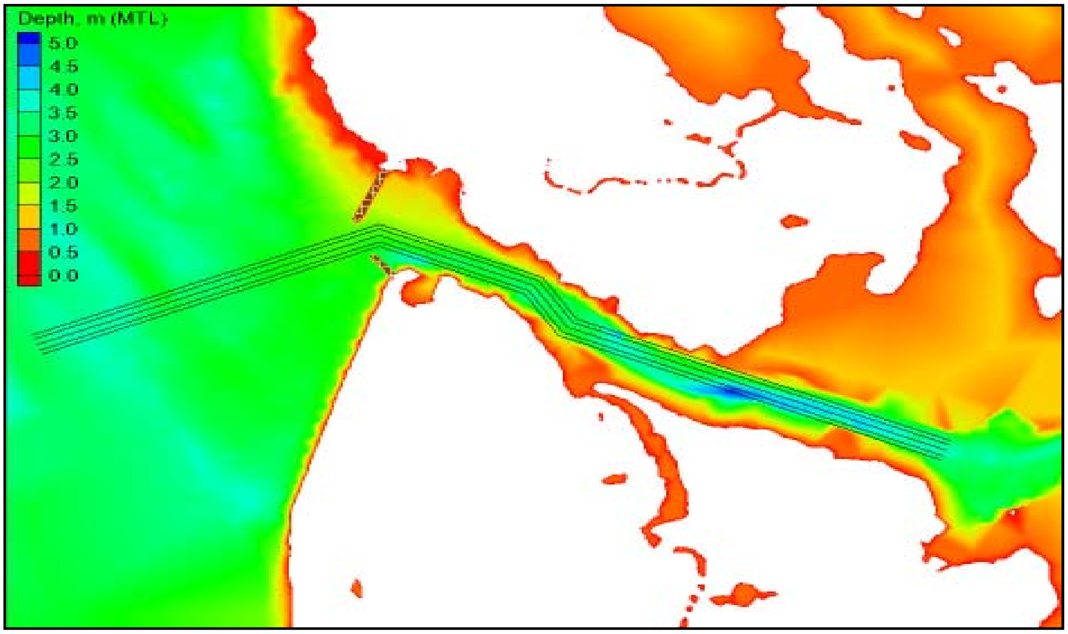
Alternative 2 with channel and structure modification.



Alternative 3 with channel and structure configuration.



Alternative 4 with channel and structure configuration.



Alternative 5 with channel and structure configuration.

Table 1. Location (Footprint) of Alternatives.

		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
North Jetty	Type	Straight	Dogleg	Dogleg	Dogleg	Straight
	Landward End Easting (m)	3720196	3720196	3720196	3720196	3720196
	Landward End Northing (m)	1169385	1169385	1169385	1169385	1169385
	Turning Point Easting (m)		3720161	3720161	3720161	
	Turning Point Northing (m)		1169306	1169306	1169306	
	Seaward End Easting (m)	3720161	3720089	3720089	3720089	3720161
	Seaward End Northing (m)	1169306	1169271	1169271	1169271	1169306
	Shore Segment Length (m)		86.4	86.4	86.4	
	Bay segment Length (m)		80.1	80.1	80.1	
	Tot Length (m)	86.4	166.5	166.5	166.5	86.4
South Spur Jetty	Type	None	None	Straight	Straight	Straight
	Landward End Easting (m)			3720203	3720206	3720206
	Landward End Northing (m)			1169209	1169220	1169220
	Seaward End Easting (m)			3720203	3720181	3720181
	Seaward End Northing (m)			1169249	1169251	1169251
	Length (m)			40	39.8	39.8

Appendix E – Boring Logs

Hole No. TI-MC-4

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Tangier Island Jetty Section 107 Navigation Project	10. SIZE AND TYPE OF BIT NA
2. LOCATION (Coordinates or Station) Tangier Island, VA N 4,187,637.2 E 412,133.6	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY US Army Corps of Engineers, Savannah District	12. MANUFACTURER'S DESIGNATION OF DRILL 66DT
4. HOLE NO. *(As shown on drawing title and file number)* TI-MC-4	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER G. Johnston	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE STARTED 5/22/2013 COMPLETED 5/22/2013
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE MSL ±
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 30.0	19. GEOLOGIST Jeremy Pianalto

ELEVATION (feet) a	DEPTH (feet) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	SAMPLE DEPTH (feet) e	SAMPLE BLOWS f	REMARKS *(Drilling time, water loss, dept weathering, etc., if significant)* g
	0.0		No Recovery			
	5.0		Dark Grey fine SAND with some silt [SM]			
	10.0		Tan-Grey fine to medium SAND with trace clay [SC]			2" Recovery
	15.0		Dark Grey CLAY with little fine sand [CL]			Mottled light brown seam
	22.0		Dark Grey CLAY with some fine sand [CL]			
	25.0		Grey fine sandy CLAY [CL]			
	30.0		End of Boring at 30'			

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Tangier Island Jetty Section 107 Navigation Project	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Tangier Island, VA N 4,187,700.5 E 412,125.4	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY MS Elizabeth	12. MANUFACTURER'S DESIGNATION OF DRILL BH-5
4. HOLE NO. *(As shown on drawing title and file number)* TI-VC-2	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER D. Barnes	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE STARTED 5/21/2013 COMPLETED 5/21/2013
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE MSL ±
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 3.4	19. GEOLOGIST Jeremy Pianalto

ELEVATION (feet) a	DEPTH (feet) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	SAMPLE DEPTH (feet) e	SAMPLE BLOWS f	REMARKS *(Drilling time, water loss, dept weathering, etc., if significant)* g
			Dark Grey fine SAND with some silt [SM]			
	0.4		Grey mottled tan CLAY with little fine sand [CL]			
	1.7		Grey mottled tan clayey fine SAND [SC]			
	3.4		End of Boring at 3.4'			

Hole No. TI-VC-3

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Tangier Island Jetty Section 107 Navigation Project	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Tangier Island, VA N 4,187,701.2 E 412,063.8	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY MS Elizabeth	12. MANUFACTURER'S DESIGNATION OF DRILL BH-5
4. HOLE NO. *(As shown on drawing title and file number)* TI-VC-3	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED:
5. NAME OF DRILLER D. Barnes	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE STARTED 5/21/2013 COMPLETED 5/21/2013
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE MSL ±
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 7.0	19. GEOLOGIST Jeremy Pianalto

ELEVATION (feet) a	DEPTH (feet) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	SAMPLE DEPTH (feet) e	SAMPLE BLOWS f	REMARKS *(Drilling time, water loss, dept weathering, etc., if significant)* g
			Dark grey fine sandy SILT [ML]			
	1.5		Grey mottled light brown fine sand CLAY [CL]			
	4.0		Grey mottled tan CLAY with some fine sand [CL]			1 TSF TV; 1.25 TSF PP
	6.0		Dark Grey mottled brown CLAY with little fine sand [CL]			1 TSF TV
	7.0		End of Boring at 7'			

DRILLING LOG

DRILLING LOG	DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Tangier Island Jetty Section 107 Navigation Project	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Tangier Island, VA N 4,187,637.2 E 412,133.6	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY MS Elizabeth	12. MANUFACTURER'S DESIGNATION OF DRILL BH-5
4. HOLE NO. *(As shown on drawing title and file number)* TI-VC-4	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED:
5. NAME OF DRILLER D. Barnes	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER NA
	16. DATE HOLE: STARTED 5/22/2013; COMPLETED 5/22/2013
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE MSL ±
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 3.7	19. GEOLOGIST Jeremy Pianalto

ELEVATION (feet) a	DEPTH (feet) b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	SAMPLE DEPTH (feet) e	SAMPLE BLOWS f	REMARKS *(Drilling time, water loss, dept weathering, etc., if significant)* g
			Dark grey fine SAND with some silt [SM]			
	1.3		Grey mottled light tan CLAY with little fine sand [CL]			
	2.5		Grey clayey fine SAND [SC]			
	3.7		End of Boring at 3.7'			

Appendix F – CPT Data

Tangier Island
(Tangier Island,Virginia)
Project No: FY 2013

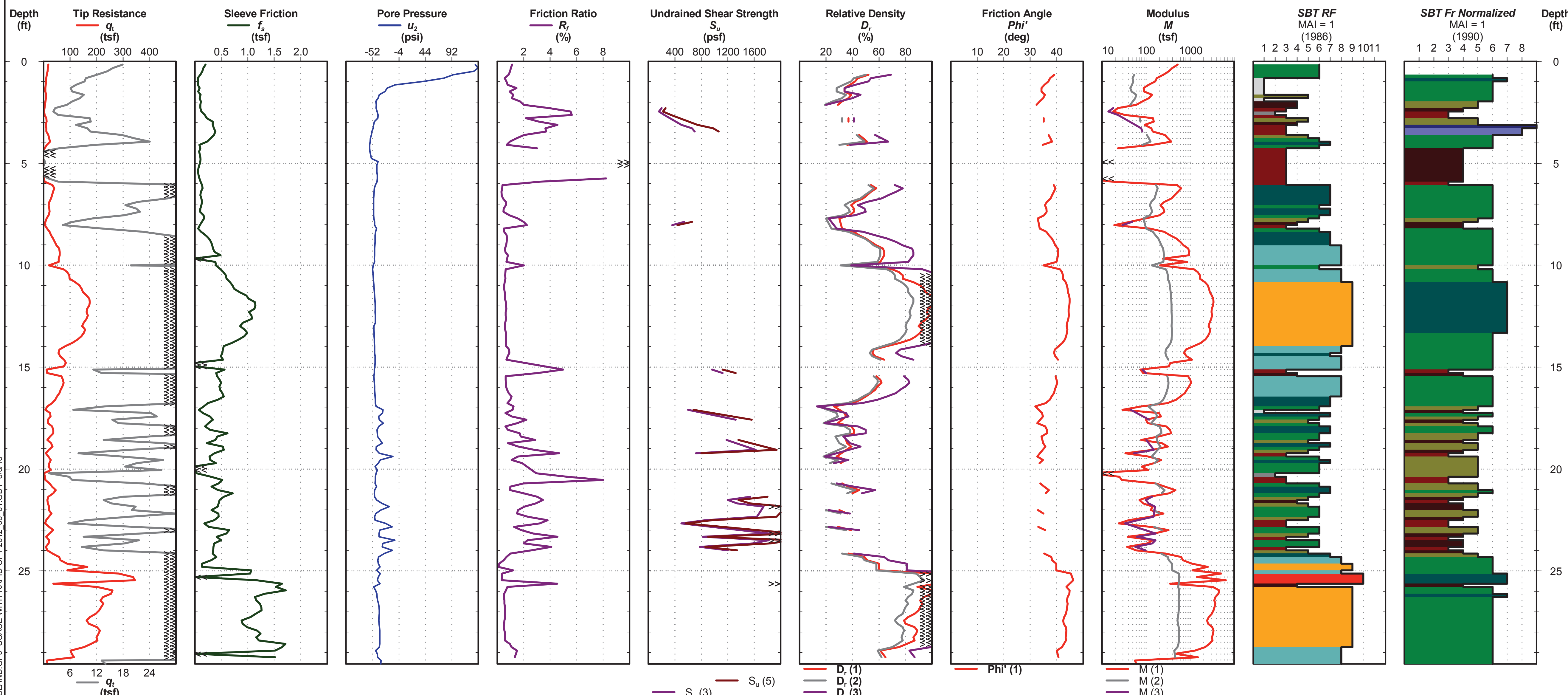
Cone Penetration Test

TI-CPT-3

Date: May. 21, 2013
Operator: Johnston
Drilling Agency: USACE, Savannah District

Northing:
Easting:
Probe ID/Net Area Ratio: DDG1069 / 0.8

Elevation:
Water Depth: -10
Total Depth: 29.6 ft



CPT REPORT - DYNAMIC 11X17 WITH RAPID CPT 2012_09_01.GDT 6/5/13 USACE TANGIER ISLAND.GPJ TANGIER ISLAND.GPJ

Electronic Filename: TI-CPT-3b.cpt

Tangier Island
(Tangier Island,Virginia)
Project No: FY 2013

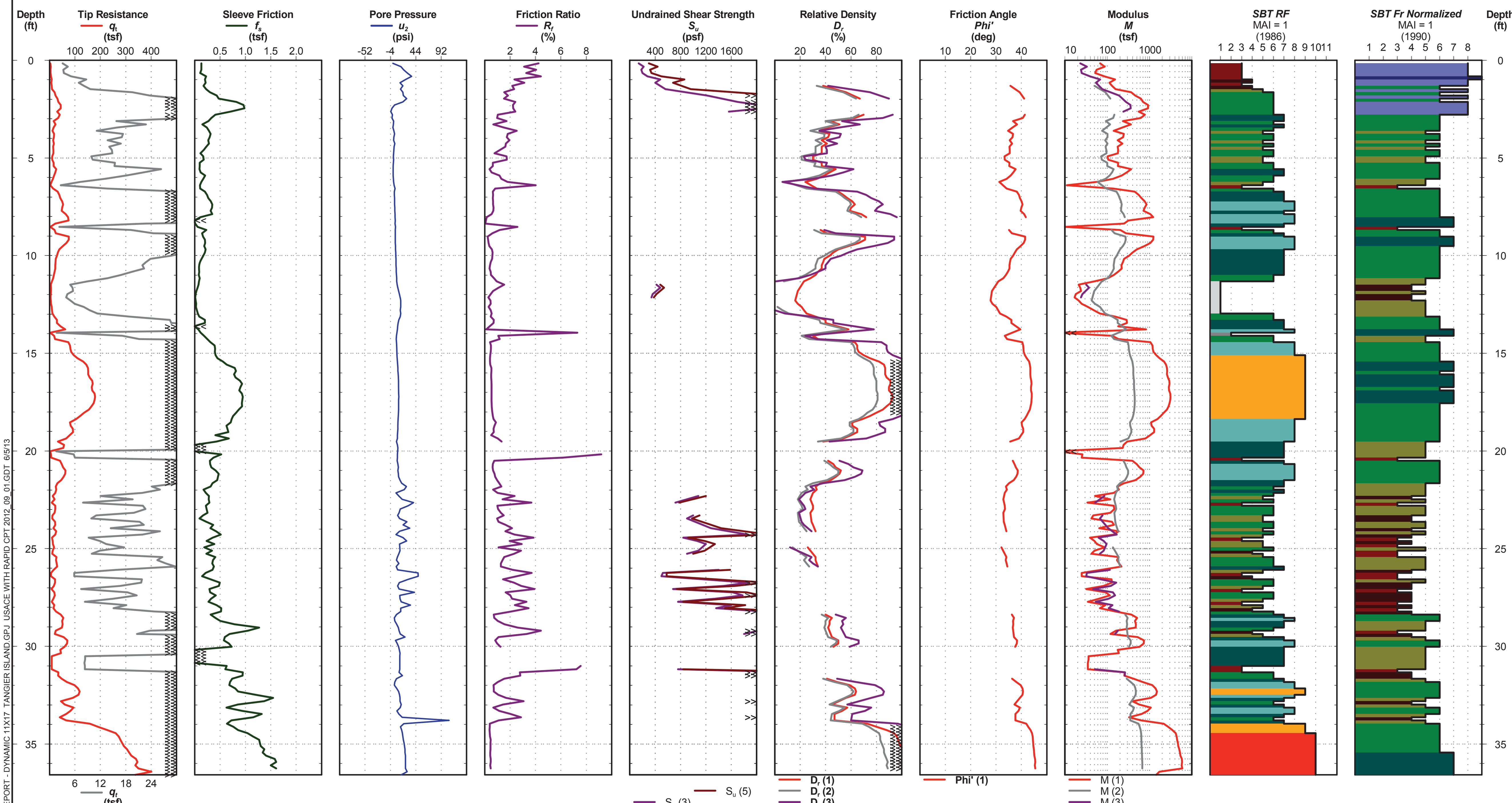
Cone Penetration Test

TI-CPT-2

Date: May. 21, 2013
Operator: Johnston
Drilling Agency: USACE, Savannah District

Northing:
Easting:
Probe ID/Net Area Ratio: DDG1069 / 0.8

Elevation:
Water Depth: -10
Total Depth: 36.6 ft



Electronic Filename: TI-CPT-2a.cpt

CPT Correlations

References are in parenthesis next to the appropriate equation.

General

p_a=atmospheric pressure (for unit normalization)
q_t=corrected cone tip resistance (tsf)
f_s=friction sleeve resistance (tsf)
$R_f = 100\% \cdot (f_s/q_t)$
u_2=pore pressure behind cone tip (tsf)
u_0=hydrostatic pressure

$B_q = (u_2 - u_0)/(q_t - \sigma_{vo})$
$Q_t = (q_t - \sigma_{vo})/\sigma'_{vo}$
$F_r = 100\% \cdot f_s/(q_t - \sigma_{vo})$
$I_c = ((3.47 - \log Q_t)^2 + (\log F_r + 1.22)^2)^{0.5}$

K_o

K_0 (1)	$K_o = (1-\sin\varphi)OCR^{\sin\varphi}$	
K_0 (2)	$K_o = 0.1(Q_t)$	1

Stress History

$OCR = \sigma_p'/\sigma_{vo}$

(OCR 1)	$\sigma_p' = 0.33(q_t - \sigma_{vo})$	8
(OCR 2)	$\sigma_p' = 0.53(u_2 - u_o)$	9
(OCR 3)	$\sigma_p' = 0.60(q_t - u_2)$	9

N-Value

$N_{60} = (q_t/p_a)/[8.5(1 - I_c/4.6)]$ 6

Undrained Shear Strength

S_u (1)	$S_u = (u_2 - u_o)/N_u$	where $7 \le N_u \le 9$	10
S_u (2)	$S_u = (q_t - \sigma_{vo})/N_{kT}$	where $15 \le N_{kT} \le 20$	11
S_u (3)	$S_u = 0.091 * ((\sigma'_{vo}{}^{0.2}) * (q_t - \sigma_{vo})^{0.8}$		
S_u (4)	$S_u = (q_c - \sigma_{vo})/N_k$	where $15 \le N_k \le 20$	
S_u (5)	$S_u = q_t/N_c$	where XXX $\le N_c \le$ YYY	

Drained Friction Angle

φ' (1)	$\varphi' = 17.6 + 11.0\text{Log}[q_t/(\sigma_{vo}')^{0.5}]$	1
φ' (2)	$\varphi' = \arctan[0.1 + 0.38\text{Log}(q_t/\sigma_{vo}')]$	13
φ' (3)	$\varphi' = 30.8\text{Log}[(f_s/\sigma_{vo}') + 1.26]$ (for clays or sands)	14

Unit Weight

$\rho = \gamma/\gamma_w$
$\rho = 0.8\text{Log}(V_s)$ V_s in m/sec 17

Relative Density and Void Ratio

D_R (1)	$D_R = 100(q_{c1}/305)^{1/2}$	where, $q_{c1} = q_c/(\sigma_{vo}')^{1/2}$	1
D_R (2)	$D_R = -1.292 + 0.268\ln(q_c \cdot (\sigma_{vo}'^{-0.5}))$		18

D_R (3) $D_R = (1/2.41) \cdot \ln(q_{c1}/15.7)$ 3

$e_o = 1.099 - 0.204\log(q_{c1})$ 1

$E_D = 5\ q_t$ $I_D = 2.0 - 0.14(R_f)$ $K_D = E_D/(34.7 \cdot I_D \cdot \sigma_{vo}')$

Compressibility

M (1) = $R_m\ E_D$ where R_m= function(I_D, K_D) see the following table

$I_D <= 0.6$	$R_M = 0.14 + 2.36 \log K_D$
$I_D >= 3$	$R_M = 0.5 + 2 \log K_D$
$0.6 < I_D < 3$	$R_M = R_{M,D} + (2.5 - R_{M,D})\log K_D$
	$R_{M,D} = 0.14 + 0.15(I_D - 0.6)$
$K_D > 10$	$R_M = 0.32 + 2.18 \log K_D$
$R_M < 0.85$	$R_M = 0.85$

M (2) $M = q_c \cdot 10^{(1.09-0.0075D_R)}$ *sands*

M (3) $M = 8.25\ (q_t - \sigma_{vo})$ *clays*

Sensitivity

S_t (1) $S_t = 7.5/R_f$ 2

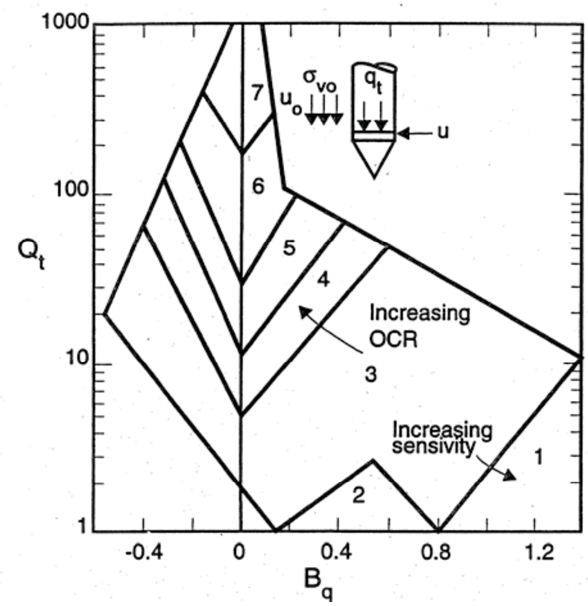
S_t (2) $S_t = (q_t - \sigma_{vo})/(15 \cdot f_s)$ 2

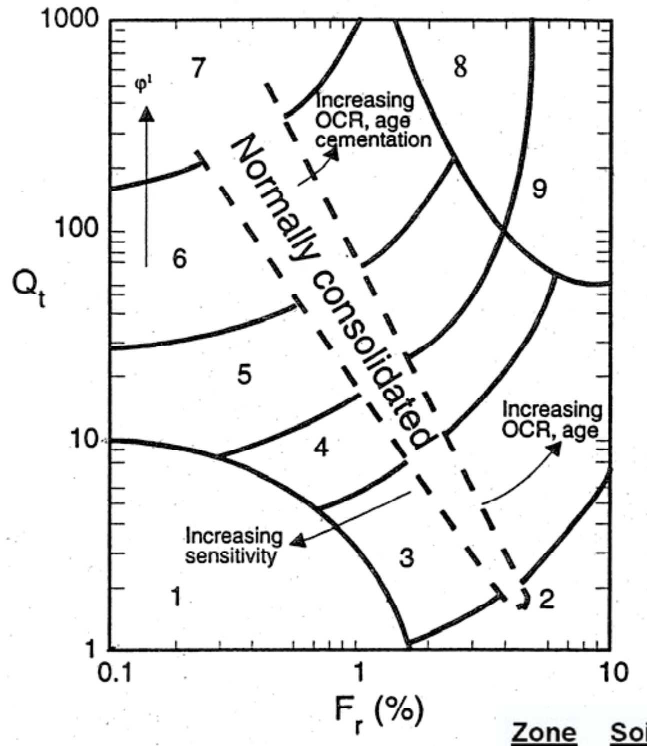
Fines Content

$FC = [(3.58\text{-}\log(q_t))^2+(1.43+\log(R_f))^2]^{1.8}$ 4

$FC = [5.31(I_{cfs})^{2.31}]+9.61$, where $I_{cfs} = [(1.95\text{-}\mathrm{Log}Q_t)^2+(\log F_r+1.78)^2]^{0.5}$ 4

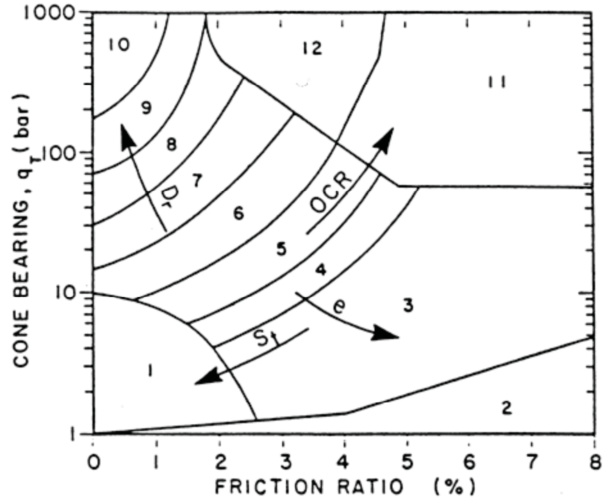
Normalized Soil Behavior Types - Robertson & Campanella (1990)

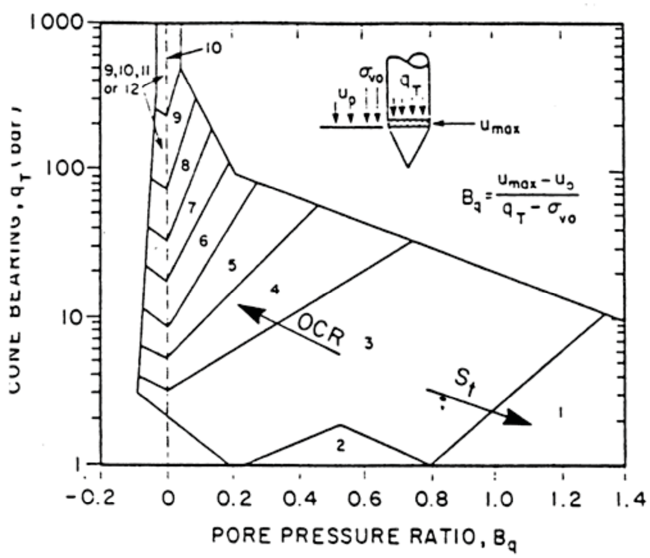




Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils-peats
3	Clays-clay to silty clay
4	Silt mixtures; clayey silt to silty clay
5	Sand mixtures; silty sand to sandy silt
6	Sands; clean sands to silty sands
7	Gravelly sand to sand
8	Very stiff sand to clayey sand
9	very stiff fine grained

Non-Normalized Soil Behavior Types – Robertson & Campanella (1986)





Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils-peats
3	Clay
4	Silty clay to clay
5	Clayey silt to silty clay
6	Sandy silt to clayey silt
7	Silty sand to sandy silt
8	Sand to silty sand
9	Sand
10	Gravelly sand to sand
11	Very stiff fine grained*
12	Sand to clayey sand*

*Overconsolidated or cemented

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Appendix G – Laboratory Data

CHESAPEAKE, VIRGINIA

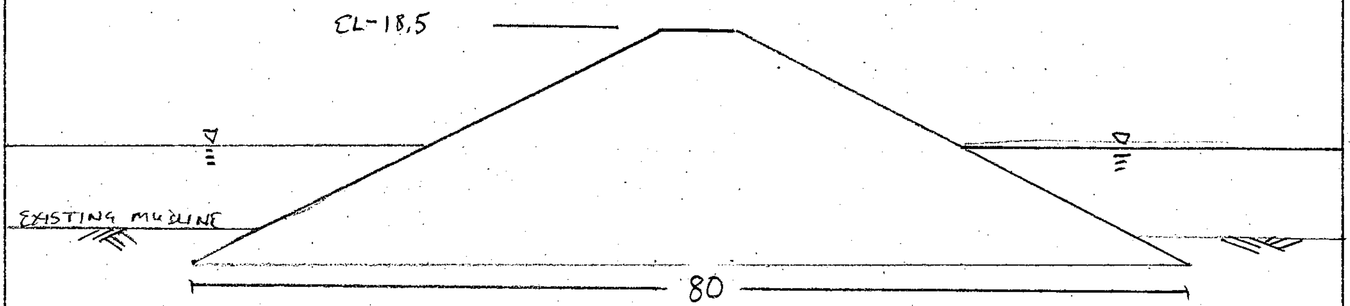
TANGIER ISLAND SOIL ANALYSIS
TANGIER ISLAND, VIRGINIA
MTL PROJECT #13-14961

LABORATORY TEST RESULTS

SAMPLE NUMBER	TI-VC2	TI-VC3	TI-VC3	TI-VC4	TI-MC4	TI-MC4
DEPTH (FT)	0.4 - 1.7	1.5 - 4.0	4.0 - 6.0	1.3 - 2.5	5.0 - 10.0	15.0 - 20.0
NATURAL PERCENT MOISTURE (ASTM D 2216)						
MOISTURE CONTENT (%)	19.1	19.9	20.6	22.6	17.5	25.2
PARTICLE SIZE ANALYSIS (ASTM C 117 & C 136)						
SIEVE SIZES	PERCENT PASSING					
#4 (4.75 mm)	100	100	100	100	100	100
#8 (2.38 mm)	99.8	99.8	100	99.9	98.9	100
#10 (2.00 mm)	99.8	99.8	100	99.9	98.5	99.9
#16 (1.19 mm)	99.7	99.7	100	99.9	96.3	99.7
#30 (0.600 mm)	99.6	99.5	99.8	99.7	75.1	99.6
#40 (0.425 mm)	99.3	99.0	99.5	99.4	58.2	99.3
#50 (0.300 mm)	98.8	98.2	99.1	98.8	33.6	98.4
#80 (0.180 mm)	96.6	94.4	97.5	96.2	14.2	96.2
#100 (0.150 mm)	94.5	90.9	96.5	95.0	13.3	95.9
#200 (0.075 mm)	78.6	72.2	81.9	87.1	11.0	92.2
ATTERBERG LIMITS TEST (ASTM D 4318)						
LIQUID LIMIT	25	28	28	30	17	32
PLASTIC LIMIT	15	14	17	21	NP[1]	17
PLASTICITY INDEX	10	14	11	9	NP[1]	15
SOIL CLASSIFICATION (ASTM D 2487)						
UNIFIED SOIL CLASSIFICATION	CL	CL	CL	CL	SP-SM	CL

1808 HAYWARD AVENUE, CHESAPEAKE, VA. 23320 • P. O. BOX 13337, CHESAPEAKE, VA. 23325-0337
PHONE (757) 420-2520 • FAX (757) 424-2874

Appendix H – Cross Section and Calculations



$\gamma_w = 62.4$ pcf
$\gamma_{ARMOR + CORE} = 165$ pcf
ASSUME MLLW FOR CONSERVATIVE (LESS BUOYANCY)

BELOW MLLW $= 2[\frac{1}{2}(9 \cdot 18)] + (42 \cdot 9) = 540$ SQFT/LF

540 ft²/LF $(165 - 62.4) = 55404$ #/LF

ABOVE MLLW $= 2[\frac{1}{2}(18 \cdot 9.5)] + (6 \cdot 9.5) = 228$ ft²/LF

228 ft²/LF $(165) = 37620$ PSF/LF

TOTAL $= \dfrac{93024 \text{ PSF/LF}}{43' \times 1'} = 2164$ PSF

SAY 2500 PSF

ASSUME COLUMN OF ROCK

$18.5' \times 1' \times 1' \times 165$ FT³ $= 3052$ PSF **USE 1.5 TSF**

I_z WAS FOUND USING EXCEL SPREADSHEET CONFIRMED BY FIGURE 5.11 IN DAS

$E_s = 3.5 q_c$ (3-10b EM 1110-1-1904)

T1 - CPT - 3

	q_t tsf	E_s	Δz	I_z	$\frac{I_z}{E_s}\Delta z$
L_1	50	175	6	0.98	0.034
L_2	100	350	5	0.92	0.013
L_3	50	175	2	0.87	0.010
L_4	30	105	8	0.79	0.061
L_5	100	350	5	0.71	0.010
L_6	75	263	32	0.52	0.063
L_7	75	263	32	0.34	0.041
L_8	75	263	32	0.25	0.030

$$\sum \frac{I_z}{E_s}\Delta z = 0.263$$

$$C_1 = 1 - 0.5\left(\frac{q}{\bar{q}-q}\right) = 1 - 0.5\left(\frac{0}{3000-0}\right) = 1$$

$$C_2 = 1 + 0.2\log\left(\frac{10}{0.1}\right) = 1.4$$

$$S_c = C_1 C_2 (\bar{q} - q) \sum \frac{I_z}{E_s}\Delta z$$

$$S_c = 1(1.4)(3000\,psf / 144\,in/ft^2)(0.263) = 7.656$$

SAY 8 inches

	q_t tsf	E_s	Δz	I_z	$\frac{I_z}{E_s}\Delta z$
L_1	25	87.5	10	0.968	0.111
L_2	70	245	6	0.853	0.021
L_3	25	87.5	10	0.741	0.085
L_4	50	175	6	0.644	0.022
L_5	37.5	131.25	32	0.475	0.116
L_6	37.5	131.25	32	0.317	0.077
L_7	37.5	131.25	32	0.235	0.057
					0.489

$C_1 = 1$

$C_2 = 1.4$

SEE T1-CPT-3

$$S_c = 1(1.4)(3000\,psf / 144\,in/ft^2)(0.489) = 14.86\ in$$

SAY 15 inches

TOPS 35500

TI-CPT-3

	qt (tsf)	Es (tsf)	Δ z	z	B1/z	B2/z	α1	α2	Iz	Σiz/Es(Δz)
L1	50	175	6	3	1	12.33333	0.710538	0.785398	0.989019	0.0339092
L2	100	350	5	8.5	0.352941	4.352941	1.022118	0.339293	0.919461	0.0131352
L3	50	175	2	12	0.25	3.083333	1.034361	0.244979	0.867844	0.0099182
L4	30	105	8	17	0.176471	2.176471	0.994253	0.174672	0.795482	0.0606082
L5	100	350	5	23.5	0.12766	1.574468	0.912646	0.126973	0.708951	0.0101279
L6	75	262.5	32	42	0.071429	0.880952	0.689705	0.071307	0.520077	0.0633998
L7	75	262.5	32	74	0.040541	0.5	0.455033	0.040518	0.338966	0.0413215
L8	75	262.5	32	106	0.028302	0.349057	0.332542	0.028294	0.246881	0.030096
										0.262516

TI-CPT-2

	qt (tsf)	Es (tsf)	Δ z	z	B1/z	B2/z	α1	α2	Iz	Σiz/Es(Δz)
L1	25	87.5	10	5	0.6	7.4	0.906022	0.54042	0.9676	0.1105829
L2	70	245	6	13	0.230769	2.846154	1.029766	0.226799	0.853108	0.0208924
L3	25	87.5	10	21	0.142857	1.761905	0.945452	0.141897	0.74103	0.0846892
L4	50	175	6	29	0.103448	1.275862	0.840407	0.103082	0.644023	0.0220808
L5	37.5	131.25	32	48	0.0625	0.770833	0.632319	0.062419	0.474923	0.1157908
L6	37.5	131.25	32	80	0.0375	0.4625	0.426165	0.037482	0.317165	0.0773278
L7	37.5	131.25	32	112	0.026786	0.330357	0.316245	0.026779	0.2347	0.057222
										0.4885859

B1	3	
B2	37	

See Das Figure 5.10

Overburden	0	
Delta	1.50	tsf
Time	20	

C1	C2
1	1.460206

Settlement

7.99	inches	CPT-3
14.86	inches	CPT-2

ATTACHMENT A-3

DETAILED COST ESTIMATES

COST ESTIMATES

Cost Estimate for Selected Plan

Introduction: Tangier Island is located in the Chesapeake Bay approximately 65 miles north of Norfolk, Virginia and lies entirely within the political boundaries of Accomack County on Virginia's Eastern Shore. The shore adjacent to the North Channel is developed with boat repair facilities, crab processing houses, marinas, fuel facilities, docks, retail businesses, and bait and ice houses. The section of the island that provided shelter to the navigation channel and harbor has eroded considerably in recent years. This erosion has resulted in a longer fetch, stronger currents, and more wave energy, which has resulted in damage to structures within the harbor and infrastructure related to the fishing industry. To prevent further damage, construction of a stone jetty was proposed to protect the western portion of the navigation channel, the harbor for the town of Tangier, and its associated seafood industry infrastructure.

1. Project Description

    a. General: The proposed Tangier Island Jetty CAP Section 107 Navigation Study examines the feasibility and environmental effects of implementing measures to protect the navigation channel and harbor located on Tangier Island in Accomack County, Virginia.

    b. Purpose: The purpose of this study is to evaluate the problems at the navigation channel located on the western shore of Tangier Island and to identify the most cost effective plan for navigation improvements. The study also considered solutions that would reduce wave energy to the existing Federal navigation channel. The findings are based on an evaluation of the most cost-effective plan and a determination of the potential solutions' compliance with current policies and within CAP Section 107 project funding limits.

    c. Design Features: Alternatives under consideration external to the do-nothing approach included the following: Alternative 1: Straight North Jetty alone; Alternative 2: Dogleg North Jetty alone; Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north; Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW; Alternative 5: Straight North Jetty with South Spur Jetty pointing NW. The navigation project was investigated economically through the use of Benefit to Cost Ratio Analysis for each of the aforementioned alternatives. Alternative 1 had the only positive net remaining benefit with an average wave height reduction of 11.6%, which does not provide the highest of level of wave reduction. However, it does provide the greatest net benefit relative to the economic analysis performed.

2. Basis of Estimate

   a. Basis of Design: Plans for Tangier Island Jetty Feasibility Phase, Section 107- Navigation Project, Accomack County, Virginia.

   b. Basis of quantities: The estimate development is from quotes, calculations, and unit prices. Unit prices are primarily developed with labor, equipment, and material components. Backup for these unit prices include production rates and crew output calculations - shown on other sheets. The estimate quantities are from plan takeoffs. Designers provided other information when needed. This project is normal jetty construction except for its location at Tangier Island, which is in the middle of the Chesapeake Bay. The design contains all the information necessary to complete a feasibility level cost estimate.

   c. Quotes: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks, 2” to 6” in diameter. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long. Quote information is from Jeff Fiske: Coastal & Waterway Industry Manager, Tensar International Corporation (770) 344-2123. Armor stone and core stone cost information is from Rob Flanagan of Vulcan Materials; Havre-de-Grace, Maryland (717) 515-4967.

   d. Estimate Development: The estimate employed the Mii estimating software for all work items. The first aspect of the project includes 5 different alternatives to provide channel protection. Based on the results of an economic analysis alternative 1 is the chosen plan. To simplify the presentation we created 2 estimates. The first estimate is for alternative 1. The second estimate contains the information for alternatives 2 through 5. Each alternative cost estimate has a separate mobilization and a different layout of jetties. The pricing basis is the 2012 Corps of Engineers Cost Book, 2014 Corps of Engineers Equipment database (Region 2) updated with current factors, and a labor database for the Tangier/Accomack Co area updated to 2015. The labor database includes marine rates comparable to rates in the CEDEP (Corps of Engineers Dredge Estimating Program) database.

   e. Cost Development: This job consists mostly of marine crews handling or transporting large stone to place in jetty structures. The estimate consists of several assemblies created for different tasks such as mobilization of equipment to the jobsite, transporting marine mattresses, installing mattresses, moving armor/core stone, placing armor/core stone, etc. These assemblies typically involve a barge, a piece of equipment, several deckhands, and possibly a tug with operators.

f. Armor Stone/Core Stone: The main component of the jetty structure is large armor stone- approximately 2500 lb/each. This surrounds a “core” of smaller stone weighing 1000 lb/each. The structure rises from the bottom mud line to an elevation of roughly 4-feet.

g. Marine Mattress: The armor/core stone rests on a marine mattress foundation. The stone filled marine mattress alleviates the soft bottom conditions for the placement of heavier armor and core stone on top of it. The estimator assumes that the contractor would have a marine mattress fabrication “yard” on the Eastern Shore of Virginia. Mattress stone delivered to the yard is by barge or rail and truck. The operation consists of a mattress jig, an empty mattress placed in the jig, and stone placed inside the mattress. Once complete and tied off, the contractor stockpiles the mattresses using a small crane. When a barge is ready a small crane loads the barge and a tug moves the barge to Tangier. A separate crew places the mattress in the correct location. Movement of the mattresses requires a determination of cycle times and creation of crews in the assembly. Assumptions include the use of small 2 to 5 man crews for water based operations and shallow draft barges. To optimize the work we used a two or three barge system for loading, transporting, and placing the mattresses.

h. Site Access: Site access is by water from the southern end of the channel through Tangier Island. The contractor has access to the site throughout the year. Access to the very shallow water and marsh could be by a barge and ramp system. There may be times where boat traffic in the channel creates problems.

i. Mobilization: Mobilization on land is for a crane, hydraulic excavators, and smaller equipment. Water-based mobilization is for several types of barges and the tugs that will move them.

j. Overtime: The cost estimate includes a 6-day work week and a 10-hour work day.

k. Estimate Structure: Alternative 1 is the chosen alternative. There is a separate standalone Mii estimate for alternative 1. Alternatives 2 through 5 are in a second Mii estimate file. This reduces the total number of Mii files and allows the alternative 1 file to be evaluated separately for current and future submissions.

l. Contractors: The basis of these estimates is that the prime contractor will do all the work. The marine mattress fabrication could be done by a subcontractor. However, experience at Norfolk District on similar jobs shows that the prime contractor builds his own mattresses.

m. Markups: The job office overhead (JOOH) calculation for alternative 1, the chosen alternative, comes from a detailed breakout of general condition items. This equals approximately 15.99%. In alternative 1 the Profit calculation is by the weighted guidelines method and is 9.3%. The bond in alternative 1 is from the bond table at 1.15%. Alternatives 2 through 5 use the same percentages as listed above. However the estimate shows them applied as running percentage markups instead of calculations from detail items or tables. Home office overhead (HOOH) is a 9% running calculation in both estimates.

n. Cost and Schedule Risk Analysis – CSRA: Civil Works projects require an analysis of schedule and costs risks. Costs from the Mii estimate are used in the analysis. The abbreviated CSRA method calculates a contingency for this project of 19.16%. See the Cost and Schedule Risk Analysis for additional information.

o. TPCS (Total Project Cost Summary): The TPCS summarizes the main features of the project. The main feature in this project is jetty construction - CWWBS Category 10 Breakwater & Seawalls. Other items in the TPCS include Lands & Damages; Planning, Engineering and Design (PED); and Construction Management. The PED cost and the Construction management cost are percentages of the construction cost. The basis of these percentages is discussions with the project manager and PDT members. The TPCS estimate shows the original price level as 01 October 2015 (FY2016-Quarter 1). Work begins in FY 2017 and is complete in the same year. See the project schedule for detailed items. The TPCS shows escalated construction and project costs to the fully funded midpoint of construction.

3. Construction Schedule: The construction schedule provided to the PDT covers the current stage of design through construction completion – see separate attachment. The contract award is in mid-December 2016, which we rounded to 1 Jan 2017. The first two months consist of contractor submittals and home office preparation. For Alternative 1 mobilization begins on 01 March 2017 and demobilization is complete by 01 December 2017. This gives a midpoint of construction of 01 Aug 2017

4. Acquisition Strategy: The project plan is to award a competitive Firm Fixed Price contract. The solicitation will be a small business set-aside contract.

5. Non-construction features:
   a. The basis for Planning Engineering and Design (E&D – Feature 30) costs are discussions with the project manager and established rates used on other jobs.
   b. The basis for Construction Management and Design (E&D – Feature 31) costs are discussions with the project manager, in-house construction personnel, and established rates used on other jobs.
   c. The cost for Lands & Damages (Feature 01) is from detailed reports submitted by Real Estate

6. Other Project Mark-ups

   a. Escalation: The estimate price level is 01 October 2015. The Program Year is 2017. Work begins in FY 2017 and will be complete in the same year. See the project schedule for more detail. The project construction can be completed in 3 to 4 months. A conservative project schedule allows a 6-month construction period.

Mii

Cost Estimates

Tangier Jetty Mii Est Update Oct 2015_ALT 1-rev6

The proposed Tangier Island Jetty CAP Section 107 Navigation Study examines the feasibility and environmental effects of implementing measures to protect the navigation channel and harbor located on Tangier Island in Accomack County, Virginia.

Estimated by	CENAO-ECE-E
Designed by	CENAO-ECE-H
Prepared by	CENAO-ECE-E, MIchael Hall
Preparation Date	10/1/2015
Effective Date of Pricing	10/1/2015
Estimated Construction Time	335 Days

Designed by	
CENAO-ECE-H	
Estimated by	
CENAO-ECE-E	
Prepared by	
CENAO-ECE-E, MIchael Hall	

Design Document	Feasibility Phase Drawings
Document Date	10/1/2015
District	Norfolk District
Contact	
Budget Year	2017
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost
UserCost1

Timeline/Currency

Preparation Date	10/1/2015
Escalation Date	10/16/2015
Eff. Pricing Date	10/1/2015
Estimated Duration	335 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB12EB-b: MII English Cost Book 2012-b

Labor Tang-2015: Local Labor Library - Tangier Island 2015

to the laborers are taxable. In a non-union job the whole fringes are taxable. This database includes pay rates omparable to CEDP rates for marine type labor. Not all labor update

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP14R02: MII Equipment 2014 Region 02-Local
Note: Changes for Local Area

02 MIDEAST

Sales Tax	6.00
Working Hours per Year	1,450
Labor Adjustment Factor	1.02
Cost of Money	2.13
Cost of Money Discount	25.00
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.095
Gas	3.000
Diesel Off-Road	2.950
Diesel On-Road	3.500

Shipping Rates

Over 0 CWT	10.54
Over 240 CWT	9.81
Over 300 CWT	8.84
Over 400 CWT	7.94
Over 500 CWT	5.17
Over 700 CWT	5.17
Over 800 CWT	8.64

Date	Author	Note
8/3/2015	mkh	Introduction: Tangier Island is located in the Chesapeake Bay approximately 65 miles north of Norfolk, Virginia and lies entirely within the political boundaries of Accomack County on Virginia's Eastern Shore. The section of the island that provided shelter to the navigation channel and harbor has eroded considerably in recent years. This erosion has resulted in a longer fetch, stronger currents, and more wave energy, which has resulted in damage to structures within the harbor and infrastructure related to the fishing industry. To prevent further damage, construction of a stone jetty was proposed to protect the western portion of the navigation channel, the harbor for the town of Tangier, and its associated seafood industry infrastructure.
8/3/2015	mkh	1.Project Description a.General: The proposed Tangier Island Jetty CAP Section 107 Navigation Study examines the feasibility and environmental effects of implementing measures to protect the navigation channel and harbor located on Tangier Island in Accomack County, Virginia.
8/3/2015	mkh	b.Purpose: The purpose of this study is to evaluate the problems at the navigation channel located on the western shore of Tangier Island and to identify the most cost effective plan for navigation improvements. The study also considered solutions that would reduce wave energy to the existing Federal navigation channel. The findings are based on an evaluation of the most cost-effective plan and a determination of the potential solutions' compliance with current policies and within CAP Section 107 project funding limits.
8/3/2015	mkh	c.Design Features: Alternatives under consideration external to the do-nothing approach included the following: Alternative 1: Straight North Jetty alone; Alternative 2: Dogleg North Jetty alone; Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north; Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW; Alternative 5: Straight North Jetty with South Spur Jetty pointing NW. The navigation project was investigated economically through the use of Benefit to Cost Ratio Analysis for each of the aforementioned alternatives. Alternative 1 had the only positive net remaining benefit with an average wave height reduction of 11.6%, which does not provide the highest of level of wave reduction. However, it does provide the greatest net benefit relative to the economic analysis performed.
8/3/2015	mkh	d. This estimate is a feasibility level estimate for the chosen alternative 1.

Direct Cost Markups		**Category**		**Method**		
Productivity		Productivity		Productivity		
Overtime-Dredging		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*1.00*	*8.00*	*8.00*	*8.00*
Actual	*6.00*	*8.00*	*1.00*	*10.00*	*8.00*	*8.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*0.00*	*0.00*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*1.50*	*No*		

Overtime-Jetty		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*1.00*	*8.00*	*0.00*	*0.00*
Actual	*6.00*	*8.00*	*1.00*	*10.00*	*0.00*	*0.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*16.67*	*(33.33)*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*2.00*	*No*		

Overtime-other		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*2.00*	*8.00*	*8.00*	*0.00*
Actual	*7.00*	*8.00*	*2.00*	*12.00*	*12.00*	*0.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*26.19*	*(76.19)*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*1.50*	*Yes*		

Sales Tax	TaxAdj	Running % on Selected Costs
MatlCost		

Contractor Markups	**Category**	**Method**

JOOH-Calculated (Small Tools)	JOOH	% of Labor
JOOH-Calculated	JOOH	JOOH (Calculated)
JOOH-running	JOOH	Running %
HOOH	HOOH	Running %
Profit	Profit	Profit Weighted Guidelines

Guideline	*Value*	*Weight*	*Percentage*
Risk	*0.090*	*20*	*1.80*
Difficulty	*0.080*	*15*	*1.20*
Size	*0.100*	*15*	*1.50*
Period	*0.050*	*15*	*0.75*
Invest (Contractor's)	*0.090*	*5*	*0.45*
Assist (Assistance by)	*0.120*	*5*	*0.60*
SubContracting	*0.120*	*25*	*3.00*
Total		*100*	*9.30*

Bond	Bond	Bond Table

Class B, Tiered, 24 months, 1.00% Surcharge

Contract Price	*Bond Rate*
500,000	*15.84*
2,000,000	*9.57*
2,500,000	*7.59*
2,500,000	*6.93*
7,500,000	*6.34*

Owner Markups	**Category**	**Method**
Escalation	Escalation	Escalation

StartDate	*StartIndex*	*EndDate*	*EndIndex*	*Escalation*
6/30/2015	*0.00*	*6/30/2015*	*0.00*	*0.00*

Contingency	Contingency	Running %
SIOH	SIOH	Running %

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	MiscOwner	ProjectCost	C/O
Project Cost Summary Report			**1,627,781**	**0**	**0**	**0**	**0**	**1,627,781**	
			1,627,780.69					*1,627,780.69*	
Jetty Construction	**1.00**	**EA**	**1,627,781**	**0**	**0**	**0**	**0**	**1,627,781**	
			1,627,780.69					*1,627,780.69*	
Alternative 1	**1.00**	**EA**	**1,627,781**	**0**	**0**	**0**	**0**	**1,627,781**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
Contract Cost Summary Report				**1,164,587**	**0**	**1,164,587**	**463,194**	**1,627,781**	
				1,164,586.91		*1,164,586.91*		*1,627,780.69*	
Jetty Construction	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,194**	**1,627,781**	
				1,164,586.91		*1,164,586.91*		*1,627,780.69*	
Alternative 1	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,194**	**1,627,781**	
				1,164,586.91		*1,164,586.91*		*1,627,780.69*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,194**	**1,627,781**	
				1,164,586.91		*1,164,586.91*		*1,627,780.69*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,194**	**1,627,781**	

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
Project Direct Costs Report			**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
Jetty Construction	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
(Note: The purpose of this study is to evaluate the problems at the navigation channel located on the western shore of Tangier Island and to identify the most cost effective plan for navigation improvements. Alternatives under consideration external to the do-nothing approach include 5 Different alternatives. This estaimate is for Alternative 1: Straight North Jetty alone. The other alternatives in a different Mii estiamte include: Alternative 2: Dogleg North Jetty alone; Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north; Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW; Alternative 5: Straight North Jetty with South Spur Jetty pointing NW.)							
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
Alternative 1	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
(Note: Alternatives under consideration external to the do-nothing approach included the following: Alternative 1: Straight North Jetty alone;)							
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
Jetty X-Section A-A'	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			249,074.48	*177,292.28*	*659,201.61*	*0.00*	*1,085,568.38*
100046 Breakwater	**1.00**	**EA**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							

Tangier Jetty -ALL-NEW-Mii Oct 2015rev6

The proposed Tangier Island Jetty CAP Section 107 Navigation Study examines the feasibility and environmental effects of implementing measures to protect the navigation channel and harbor located on Tangier Island in Accomack County, Virginia.

Estimated by	
Designed by	
Prepared by	mh
Preparation Date	7/30/2015
Effective Date of Pricing	7/30/2015
Estimated Construction Time	Days

Designed by

Estimated by

Prepared by
mh

Design Document	
Document Date	7/30/2015
District	Norfolk District
Contact	
Budget Year	2017
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost
UserCost1

Timeline/Currency

Preparation Date	7/30/2015
Escalation Date	10/1/2014
Eff. Pricing Date	7/30/2015
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB12EB-b: MII English Cost Book 2012-b

Labor Tang-2015: Local Labor Library - Tangier Island 2015
to the laborers are taxable. In a non-union job the whole fringes are taxable. This database includes pay rates omparable to CEDP rates for marine type labor. Not all labor update

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP14R02: MII Equipment 2014 Region 02-Local
Note: Changes for Local Area

02 MIDEAST

Sales Tax	6.00
Working Hours per Year	1,450
Labor Adjustment Factor	1.02
Cost of Money	2.13
Cost of Money Discount	25.00
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.095
Gas	3.000
Diesel Off-Road	2.950
Diesel On-Road	3.500

Shipping Rates

Over 0 CWT	10.54
Over 240 CWT	9.81
Over 300 CWT	8.84
Over 400 CWT	7.94
Over 500 CWT	5.17
Over 700 CWT	5.17
Over 800 CWT	8.64

Date	Author	Note
8/3/2015	mkh	Introduction: Tangier Island is located in the Chesapeake Bay approximately 65 miles north of Norfolk, Virginia and lies entirely within the political boundaries of Accomack County on Virginia's Eastern Shore. The section of the island that provided shelter to the navigation channel and harbor has eroded considerably in recent years. This erosion has resulted in a longer fetch, stronger currents, and more wave energy, which has resulted in damage to structures within the harbor and infrastructure related to the fishing industry. To prevent further damage, construction of a stone jetty was proposed to protect the western portion of the navigation channel, the harbor for the town of Tangier, and its associated seafood industry infrastructure.
8/3/2015	mkh	1.Project Description a.General: The proposed Tangier Island Jetty CAP Section 107 Navigation Study examines the feasibility and environmental effects of implementing measures to protect the navigation channel and harbor located on Tangier Island in Accomack County, Virginia.
8/3/2015	mkh	b.Purpose: The purpose of this study is to evaluate the problems at the navigation channel located on the western shore of Tangier Island and to identify the most cost effective plan for navigation improvements. The study also considered solutions that would reduce wave energy to the existing Federal navigation channel. The findings are based on an evaluation of the most cost-effective plan and a determination of the potential solutions' compliance with current policies and within CAP Section 107 project funding limits.
8/3/2015	mkh	c.Design Features: Alternatives under consideration external to the do-nothing approach included the following: Alternative 1: Straight North Jetty alone; Alternative 2: Dogleg North Jetty alone; Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north; Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW; Alternative 5: Straight North Jetty with South Spur Jetty pointing NW. The navigation project was investigated economically through the use of Benefit to Cost Ratio Analysis for each of the aforementioned alternatives. Alternative 1 had the only positive net remaining benefit with an average wave height reduction of 11.6%, which does not provide the highest of level of wave reduction. However, it does provide the greatest net benefit relative to the economic analysis performed.
8/3/2015	mkh	d. This estimate is a feasibility level estimate for the chosen alternative 1.

Direct Cost Markups		**Category**		**Method**		
Productivity		Productivity		Productivity		
Overtime-Dredging		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*1.00*	*8.00*	*8.00*	*8.00*
Actual	*6.00*	*8.00*	*1.00*	*10.00*	*8.00*	*8.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*0.00*	*0.00*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*1.50*	*No*		

Overtime-Jetty		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*1.00*	*8.00*	*0.00*	*0.00*
Actual	*6.00*	*8.00*	*1.00*	*10.00*	*0.00*	*0.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*16.67*	*(33.33)*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*2.00*	*No*		

Overtime-other		Overtime		Overtime		
	Days/Week	*Hours/Shift*	*Shifts/Day*	*1st Shift*	*2nd Shift*	*3rd Shift*
Standard	*5.00*	*8.00*	*2.00*	*8.00*	*8.00*	*0.00*
Actual	*7.00*	*8.00*	*2.00*	*12.00*	*12.00*	*0.00*

Day	*OT Factor*	*Working*	*OT Percent*	*FCCM Percent*
Monday	*1.50*	*Yes*	*26.19*	*(76.19)*
Tuesday	*1.50*	*Yes*		
Wednesday	*1.50*	*Yes*		
Thursday	*1.50*	*Yes*		
Friday	*1.50*	*Yes*		
Saturday	*1.50*	*Yes*		
Sunday	*1.50*	*Yes*		

Sales Tax	TaxAdj	Running % on Selected Costs
MatlCost		

Contractor Markups	**Category**	**Method**

JOOH-running	JOOH	Running %
HOOH	HOOH	Running %
Profit	Profit	Running %
Bond	Bond	Running %

Owner Markups	**Category**	**Method**
Escalation	Escalation	Escalation

StartDate	*StartIndex*	*EndDate*	*EndIndex*	*Escalation*
6/30/2015	*0.00*	*6/30/2015*	*0.00*	*0.00*

Contingency	Contingency	Running %
SIOH	SIOH	Running %

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	MiscOwner	ProjectCost	C/O
Project Cost Summary Report			**14,102,325**	**0**	**0**	**0**	**0**	**14,102,325**	
			14,102,324.83					*14,102,324.83*	
Jetty Construction	**1.00**	**EA**	**14,102,325**	**0**	**0**	**0**	**0**	**14,102,325**	
			1,627,975.76					*1,627,975.76*	
Alternative 1	**1.00**	**EA**	**1,627,976**	**0**	**0**	**0**	**0**	**1,627,976**	
			2,845,429.94					*2,845,429.94*	
Alternative 2	**1.00**	**EA**	**2,845,430**	**0**	**0**	**0**	**0**	**2,845,430**	
			3,584,667.05					*3,584,667.05*	
Alternative 3	**1.00**	**EA**	**3,584,667**	**0**	**0**	**0**	**0**	**3,584,667**	
			3,630,853.13					*3,630,853.13*	
Alternative 4	**1.00**	**EA**	**3,630,853**	**0**	**0**	**0**	**0**	**3,630,853**	
			2,413,398.96					*2,413,398.96*	
Alternative 5	**1.00**	**EA**	**2,413,399**	**0**	**0**	**0**	**0**	**2,413,399**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
Contract Cost Summary Report				**10,088,223**	**0**	**10,088,223**	**4,014,102**	**14,102,325**	
				10,088,223.26		*10,088,223.26*		*14,102,324.83*	
Jetty Construction	**1.00**	**EA**	**Prime**	**10,088,223**	**0**	**10,088,223**	**4,014,102**	**14,102,325**	
				1,164,586.91		*1,164,586.91*		*1,627,975.76*	
Alternative 1	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,389**	**1,627,976**	
				1,164,586.91		*1,164,586.91*		*1,627,975.76*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,389**	**1,627,976**	
				1,164,586.91		*1,164,586.91*		*1,627,975.76*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**1,164,587**	**0**	**1,164,587**	**463,389**	**1,627,976**	
				2,035,503.57		*2,035,503.57*		*2,845,429.94*	
Alternative 2	**1.00**	**EA**	**Prime**	**2,035,504**	**0**	**2,035,504**	**809,926**	**2,845,430**	
				2,035,503.57		*2,035,503.57*		*2,845,429.94*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**2,035,504**	**0**	**2,035,504**	**809,926**	**2,845,430**	
				2,035,503.57		*2,035,503.57*		*2,845,429.94*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**2,035,504**	**0**	**2,035,504**	**809,926**	**2,845,430**	
				2,564,323.40		*2,564,323.40*		*3,584,667.05*	
Alternative 3	**1.00**	**EA**	**Prime**	**2,564,323**	**0**	**2,564,323**	**1,020,344**	**3,584,667**	
				2,564,323.40		*2,564,323.40*		*3,584,667.05*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**2,564,323**	**0**	**2,564,323**	**1,020,344**	**3,584,667**	
				2,564,323.40		*2,564,323.40*		*3,584,667.05*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**2,564,323**	**0**	**2,564,323**	**1,020,344**	**3,584,667**	
				2,597,363.02		*2,597,363.02*		*3,630,853.13*	
Alternative 4	**1.00**	**EA**	**Prime**	**2,597,363**	**0**	**2,597,363**	**1,033,490**	**3,630,853**	
				2,597,363.02		*2,597,363.02*		*3,630,853.13*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**2,597,363**	**0**	**2,597,363**	**1,033,490**	**3,630,853**	
				2,597,363.02		*2,597,363.02*		*3,630,853.13*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**2,597,363**	**0**	**2,597,363**	**1,033,490**	**3,630,853**	
				1,726,446.37		*1,726,446.37*		*2,413,398.96*	
Alternative 5	**1.00**	**EA**	**Prime**	**1,726,446**	**0**	**1,726,446**	**686,953**	**2,413,399**	
				1,726,446.37		*1,726,446.37*		*2,413,398.96*	
Jetty X-Section A-A'	**1.00**	**EA**	**Prime**	**1,726,446**	**0**	**1,726,446**	**686,953**	**2,413,399**	
				1,726,446.37		*1,726,446.37*		*2,413,398.96*	
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**Prime**	**1,726,446**	**0**	**1,726,446**	**686,953**	**2,413,399**	

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
Project Direct Costs Report			**2,348,088**	**1,654,474**	**6,085,662**	**0**	**10,088,223**
			2,348,087.50	*1,654,473.80*	*6,085,661.96*	*0.00*	*10,088,223.26*
Jetty Construction	**1.00**	**EA**	**2,348,088**	**1,654,474**	**6,085,662**	**0**	**10,088,223**
(Note: The purpose of this study is to evaluate the problems at the navigation channel located on the western shore of Tangier Island and to identify the most cost effective plan for navigation improvements. Alternatives under consideration external to the do-nothing approach include 5 Different alternatives. This estaimate is for Alternative 1: Straight North Jetty alone. The other alternatives in a different Mii estiamte include: Alternative 2: Dogleg North Jetty alone; Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north; Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW; Alternative 5: Straight North Jetty with South Spur Jetty pointing NW.)							
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
Alternative 1	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
(Note: Alternatives under consideration external to the do-nothing approach included the following: Alternative 1: Straight North Jetty alone;)							
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
Jetty X-Section A-A'	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
			283,990.10	*211,392.76*	*669,204.06*	*0.00*	*1,164,586.91*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**283,990**	**211,393**	**669,204**	**0**	**1,164,587**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			249,074.48	*177,292.28*	*659,201.61*	*0.00*	*1,085,568.38*
100046 Breakwater	**1.00**	**EA**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			473,151.13	*332,676.49*	*1,229,675.94*	*0.00*	*2,035,503.57*
Alternative 2	**1.00**	**EA**	**473,151**	**332,676**	**1,229,676**	**0**	**2,035,504**
(Note: Alternative 2: Dogleg North Jetty alone;)							
			473,151.13	*332,676.49*	*1,229,675.94*	*0.00*	*2,035,503.57*
Jetty X-Section A-A'	**1.00**	**EA**	**473,151**	**332,676**	**1,229,676**	**0**	**2,035,504**
			473,151.13	*332,676.49*	*1,229,675.94*	*0.00*	*2,035,503.57*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**473,151**	**332,676**	**1,229,676**	**0**	**2,035,504**
			473,151.13	*332,676.49*	*1,229,675.94*	*0.00*	*2,035,503.57*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**473,151**	**332,676**	**1,229,676**	**0**	**2,035,504**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			438,235.51	*298,576.02*	*1,219,673.49*	*0.00*	*1,956,485.03*
100046 Breakwater	**1.00**	**EA**	**438,236**	**298,576**	**1,219,673**	**0**	**1,956,485**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			654.54	*419.67*	*1,939.35*	*0.00*	*3,013.55*
Sitework Jetty X-Section B-B'	**289.00**	**LF**	**189,161**	**121,284**	**560,472**	**0**	**870,917**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**594.44**	**CY**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	16,050.00	SF	0	0	84,503	0	84,503
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	882.75	TON	0	0	72,504	0	72,504
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	16,050.00	SF	27,834	53,115	0	0	80,948
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	16,050.00	SF	45,122	14,772	0	0	59,894
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**2,290.00**	**TON**	**33,030**	**15,177**	**109,717**	**0**	**157,925**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,347.06**	**CY**	**33,030**	**15,177**	**109,717**	**0**	**157,925**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	2,290.00	TON	17,629	9,842	0	0	27,471
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	2,290.00	TON	15,401	5,335	0	0	20,736
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	2,290.00	TON	0	0	109,717	0	109,717
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,325.00**	**TON**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,544.12**	**CY**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,325.00	TON	44,394	24,784	0	0	69,178
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,325.00	TON	38,782	13,436	0	0	52,218
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,325.00	TON	0	0	293,748	0	293,748
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			588,536.06	*407,344.24*	*1,568,443.09*	*0.00*	*2,564,323.40*
Alternative 3	**1.00**	**EA**	**588,536**	**407,344**	**1,568,443**	**0**	**2,564,323**
(Note: Alternative 3: Dogleg North Jetty with South Spur Jetty pointing due north;)							
			588,536.06	*407,344.24*	*1,568,443.09*	*0.00*	*2,564,323.40*
Jetty X-Section A-A'	**1.00**	**EA**	**588,536**	**407,344**	**1,568,443**	**0**	**2,564,323**
			588,536.06	*407,344.24*	*1,568,443.09*	*0.00*	*2,564,323.40*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**588,536**	**407,344**	**1,568,443**	**0**	**2,564,323**
			588,536.06	*407,344.24*	*1,568,443.09*	*0.00*	*2,564,323.40*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**588,536**	**407,344**	**1,568,443**	**0**	**2,564,323**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			553,620.45	*373,243.77*	*1,558,440.64*	*0.00*	*2,485,304.86*
100046 Breakwater	**1.00**	**EA**	**553,620**	**373,244**	**1,558,441**	**0**	**2,485,305**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			654.54	*419.67*	*1,939.35*	*0.00*	*3,013.55*
Sitework Jetty X-Section B-B'	**289.00**	**LF**	**189,161**	**121,284**	**560,472**	**0**	**870,917**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**594.44**	**CY**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	16,050.00	SF	0	0	84,503	0	84,503
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	882.75	TON	0	0	72,504	0	72,504
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	16,050.00	SF	27,834	53,115	0	0	80,948
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	16,050.00	SF	45,122	14,772	0	0	59,894
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**2,290.00**	**TON**	**33,030**	**15,177**	**109,717**	**0**	**157,925**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,347.06**	**CY**	**33,030**	**15,177**	**109,717**	**0**	**157,925**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	2,290.00	TON	17,629	9,842	0	0	27,471
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	2,290.00	TON	15,401	5,335	0	0	20,736
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	2,290.00	TON	0	0	109,717	0	109,717
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,325.00**	**TON**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,544.12**	**CY**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,325.00	TON	44,394	24,784	0	0	69,178
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,325.00	TON	38,782	13,436	0	0	52,218
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,325.00	TON	0	0	293,748	0	293,748
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			508.30	*328.93*	*1,492.37*	*0.00*	*2,329.60*
Sitework Jetty X-Section C-C'	**227.00**	**LF**	**115,385**	**74,668**	**338,767**	**0**	**528,820**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**10,111.00**	**SF**	**45,960**	**42,766**	**98,910**	**0**	**187,636**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**374.48**	**CY**	**45,960**	**42,766**	**98,910**	**0**	**187,636**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**10,111.00**	**SF**	**45,960**	**42,766**	**98,910**	**0**	**187,636**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	10,111.00	SF	0	0	53,234	0	53,234

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	556.11	TON	0	0	45,675	0	45,675
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	10,111.00	SF	17,534	33,461	0	0	50,995
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	10,111.00	SF	28,425	9,306	0	0	37,731
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,760.00**	**TON**	**25,385**	**11,665**	**84,324**	**0**	**121,374**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,035.29**	**CY**	**25,385**	**11,665**	**84,324**	**0**	**121,374**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,760.00	TON	13,549	7,564	0	0	21,113
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,760.00	TON	11,836	4,101	0	0	15,937
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,760.00	TON	0	0	84,324	0	84,324
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**2,290.00**	**TON**	**44,040**	**20,237**	**155,533**	**0**	**219,810**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**1,347.06**	**CY**	**44,040**	**20,237**	**155,533**	**0**	**219,810**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	2,290.00	TON	23,506	13,123	0	0	36,628
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	2,290.00	TON	20,534	7,114	0	0	27,648
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	2,290.00	TON	0	0	155,533	0	155,533

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			595,785.62	*412,172.02*	*1,589,405.38*	*0.00*	*2,597,363.02*
Alternative 4	**1.00**	**EA**	**595,786**	**412,172**	**1,589,405**	**0**	**2,597,363**
(Note: Alternative 4: Dogleg North Jetty with South Spur Jetty pointing NW;)							
			595,785.62	*412,172.02*	*1,589,405.38*	*0.00*	*2,597,363.02*
Jetty X-Section A-A'	**1.00**	**EA**	**595,786**	**412,172**	**1,589,405**	**0**	**2,597,363**
			595,785.62	*412,172.02*	*1,589,405.38*	*0.00*	*2,597,363.02*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**595,786**	**412,172**	**1,589,405**	**0**	**2,597,363**
			595,785.62	*412,172.02*	*1,589,405.38*	*0.00*	*2,597,363.02*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**595,786**	**412,172**	**1,589,405**	**0**	**2,597,363**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			560,870.00	*378,071.55*	*1,579,402.93*	*0.00*	*2,518,344.49*
100046 Breakwater	**1.00**	**EA**	**560,870**	**378,072**	**1,579,403**	**0**	**2,518,344**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			654.54	*419.67*	*1,939.35*	*0.00*	*3,013.55*
Sitework Jetty X-Section B-B'	**289.00**	**LF**	**189,161**	**121,284**	**560,472**	**0**	**870,917**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**594.44**	**CY**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**16,050.00**	**SF**	**72,956**	**67,886**	**157,007**	**0**	**297,849**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	16,050.00	SF	0	0	84,503	0	84,503
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	882.75	TON	0	0	72,504	0	72,504
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	16,050.00	SF	27,834	53,115	0	0	80,948
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	16,050.00	SF	45,122	14,772	0	0	59,894
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**2,290.00**	**TON**	**33,030**	**15,177**	**109,717**	**0**	**157,925**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,347.06**	**CY**	**33,030**	**15,177**	**109,717**	**0**	**157,925**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	2,290.00	TON	17,629	9,842	0	0	27,471
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	2,290.00	TON	15,401	5,335	0	0	20,736
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	2,290.00	TON	0	0	109,717	0	109,717
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,325.00**	**TON**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,544.12**	**CY**	**83,175**	**38,220**	**293,748**	**0**	**415,143**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,325.00	TON	44,394	24,784	0	0	69,178
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,325.00	TON	38,782	13,436	0	0	52,218
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,325.00	TON	0	0	293,748	0	293,748
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			817.56	*529.97*	*2,398.20*	*0.00*	*3,745.73*
Sitework Jetty X-Section D-D'	**150.00**	**LF**	**122,634**	**79,496**	**359,729**	**0**	**561,859**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**10,810.00**	**SF**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**400.37**	**CY**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**10,810.00**	**SF**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	10,810.00	SF	0	0	56,915	0	56,915

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	594.55	TON	0	0	48,833	0	48,833
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	10,810.00	SF	18,747	35,774	0	0	54,520
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	10,810.00	SF	30,391	9,949	0	0	40,340
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,845.00**	**TON**	**26,611**	**12,228**	**88,397**	**0**	**127,236**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,085.29**	**CY**	**26,611**	**12,228**	**88,397**	**0**	**127,236**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,845.00	TON	14,203	7,929	0	0	22,133
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,845.00	TON	12,408	4,299	0	0	16,707
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,845.00	TON	0	0	88,397	0	88,397
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**2,438.00**	**TON**	**46,886**	**21,544**	**165,585**	**0**	**234,016**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**1,434.12**	**CY**	**46,886**	**21,544**	**165,585**	**0**	**234,016**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	2,438.00	TON	25,025	13,971	0	0	38,995
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	2,438.00	TON	21,861	7,574	0	0	29,435
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	2,438.00	TON	0	0	165,585	0	165,585

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			406,624.59	*290,888.28*	*1,028,933.50*	*0.00*	*1,726,446.37*
Alternative 5	**1.00**	**EA**	**406,625**	**290,888**	**1,028,933**	**0**	**1,726,446**
(Note: Alternative 5: Straight North Jetty with South Spur Jetty pointing NW.)							
			406,624.59	*290,888.28*	*1,028,933.50*	*0.00*	*1,726,446.37*
Jetty X-Section A-A'	**1.00**	**EA**	**406,625**	**290,888**	**1,028,933**	**0**	**1,726,446**
			406,624.59	*290,888.28*	*1,028,933.50*	*0.00*	*1,726,446.37*
10 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**406,625**	**290,888**	**1,028,933**	**0**	**1,726,446**
			406,624.59	*290,888.28*	*1,028,933.50*	*0.00*	*1,726,446.37*
1000 BREAKWATERS AND SEAWALLS	**1.00**	**EA**	**406,625**	**290,888**	**1,028,933**	**0**	**1,726,446**
(Note: The jetty cost consists of a mobilization item and jetty construction itself.)							
			34,915.62	*34,100.47*	*10,002.45*	*0.00*	*79,018.54*
100001 Mobilization, Demob, and Prep Work	**1.00**	**EA**	**34,916**	**34,100**	**10,002**	**0**	**79,019**
			2,311.60	*10,216.66*	*0.00*	*0.00*	*12,528.27*
Land Equip Mob over Land	**1.00**	**EA**	**2,312**	**10,217**	**0**	**0**	**12,528**
(Note: Mob/Demob of equipment associated with material movement between barges and placement in jetty. Mobilization: Assume 3-ea hyd excavator . 8 hr/ ea mob x 3 ea pieces of equip = 24 hours. DeMobilization: same as mob. Trucking: 1-ea truck and lo-boy per piece of equipment. Total = 16 hrs x 3 ea excav + 16 hr (Suburban) = 64 hrs)							
			0.00	*9.29*	*0.00*	*0.00*	*9.29*
EP T45XX014 TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)	64.00	HR	0	594	0	0	594
			0.00	*62.32*	*0.00*	*0.00*	*62.32*
MAP T50XX030 TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6X6 (CHASSIS ONLY-ADD OPTIONS)	64.00	HR	0	3,989	0	0	3,989
			36.12	*0.00*	*0.00*	*0.00*	*36.12*
RSM X-TRKDVRHV Outside Truck Drivers, Heavy	64.00	HR	2,312	0	0	0	2,312
(Note: add 16 hr for driver of Suburban on call at land site.)							
			0.00	*48.92*	*0.00*	*0.00*	*48.92*
EP H25CA022 HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75' MAX DIGGING DEPTH	32.00	HR	0	1,565	0	0	1,565
			0.00	*64.42*	*0.00*	*0.00*	*64.42*
MAP H25KC021 HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08' MAX DIGGING DEPTH	16.00	HR	0	1,031	0	0	1,031
			0.00	*25.01*	*0.00*	*0.00*	*25.01*
EP T50GM005 TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	16.00	HR	0	400	0	0	400

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*164.84*	*0.00*	*0.00*	*164.84*
EP C75GV025 CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON, 110' BOOM 4X4	16.00	HR	0	2,637	0	0	2,637
			25,129.44	*15,022.71*	*0.00*	*0.00*	*40,152.15*
Mob over Sea	**1.00**	**EA**	**25,129**	**15,023**	**0**	**0**	**40,152**
			5,179.62	*3,444.30*	*0.00*	*0.00*	*8,623.92*
USR Mob 40' Barges & Hyd Excavators	2.00	DAY	10,359	6,889	0	0	17,248
(Note: Asume it will take 1 day to deliver and 1 day to demob barges and eqipment. There are 2-ea 40' barges. Assume 1-ea hyd excav (43,800-lb) is on each 40' barge (3 sections per barge). One large tug and one small tug will assist moving the barges. Assume work boat travels on its own with 1 deckhand operating it.)							
			3,267.99	*1,928.64*	*0.00*	*0.00*	*5,196.63*
USR Mob 60' Barges & Hyd Excavator	2.00	DAY	6,536	3,857	0	0	10,393
(Note: Asume it will take 1 day to deliver and 1 day to demob barge. There will be 2 ea 60' barges (2 sections per barge). Assume 1-ea hyd excav (55,100-lb) is on only one of the 60' barges. One large tug and will assist moving the barges. Include extra time for the large tug to return to shore-see next ssembly.)							
			343.09	*178.20*	*0.00*	*0.00*	*521.29*
USR Mob 40' Tugs back to Shore	24.00	HR	8,234	4,277	0	0	12,511
(Note: These large tugs move the 40' and 60' barges to Tangier. They only use is for mob/demob. 12 hr-mob, 12-hr demob. Total = 24 hr.)							
			6,535.98	*8,861.10*	*0.00*	*0.00*	*15,397.08*
Mob Marine Mattress Barges	**1.00**	**EA**	**6,536**	**8,861**	**0**	**0**	**15,397**
(Note: Mob 2 barges w/one tug. Assume 12 hr mob for barge. 12 hr x 2 ea (mob/demob) = 24 hr.)							
			272.33	*369.21*	*0.00*	*0.00*	*641.54*
USR Mob 400 ton Barges for Marine Mattresses & Tugs	24.00	HR	6,536	8,861	0	0	15,397
			938.59	*0.00*	*10,002.45*	*0.00*	*10,941.04*
Setup Steel Jig to Assemble Mattress	**1.00**	**EA**	**939**	**0**	**10,002**	**0**	**10,941**
(Note: Setup jig on land near the departure point to Tangier. Set marine mattress stone in stockpile near the jig. Use jig to assemble mattresses. After assmbly assume mattresses will be sotckpiled and ready for loading into barges.)							
			0.53	*0.00*	*0.74*	*0.00*	*1.27*
RSM 061636100805 Sheathing, plywood on walls, CDX, 3/4" thick, pneumatic nailed	494.00	SF	261	0	364	0	626
			0.40	*0.00*	*5.11*	*0.00*	*5.51*
RSM 051223401200 Continuous slotted channel framing system, field fabricated, incl cutting & welding, maximum	1,700.00	LB	677	0	8,682	0	9,359
			0.00	*0.00*	*1.45*	*0.00*	*1.45*
RSM 051223401250 Plate & bar stock, for reinforcing structural beams and trusses, for field fabrication, incl cutting & welding	140.00	LB	0	0	203	0	203
(Note: misc steel work)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*57.92*	*0.00*	*57.92*
RSM 335113207102 Gas Piping, 4" diameter, schedule 80,	13.00	LF	0	0	753	0	753
(Note: use for lifting rig.)							
			371,708.98	*256,787.81*	*1,018,931.05*	*0.00*	*1,647,427.83*
100046 Breakwater	**1.00**	**EA**	**371,709**	**256,788**	**1,018,931**	**0**	**1,647,428**
(Note: Jetty construction includes a marine mattress base and a rock structure on top of the base. Armor stone forms the exterior of the structure with the smaller core stone in the interior of the structure.)							
			473.53	*337.06*	*1,253.23*	*0.00*	*2,063.82*
Sitework Jetty X-Section A-A'	**526.00**	**LF**	**249,074**	**177,292**	**659,202**	**0**	**1,085,568**
			5.10	*4.75*	*9.78*	*0.00*	*19.63*
Marine Mattress w/GeoFabric Attached	**26,148.00**	**SF**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			137.76	*128.19*	*264.12*	*0.00*	*530.08*
Marine Mattress CY	**968.44**	**CY**	**133,417**	**124,147**	**255,789**	**0**	**513,354**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**17,432.00**	**SF**	**79,238**	**73,732**	**170,526**	**0**	**323,496**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	17,432.00	SF	0	0	91,779	0	91,779
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	958.76	TON	0	0	78,747	0	78,747
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	17,432.00	SF	30,230	57,688	0	0	87,919
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	17,432.00	SF	49,007	16,044	0	0	65,051
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			6.22	*5.78*	*9.78*	*0.00*	*21.78*
Install Marine Mattress in Marsh/Shallow Water	**8,716.00**	**SF**	**54,180**	**50,415**	**85,263**	**0**	**189,858**
(Note: This work is for the installation of the structure in very shallow water. The only difference is the rate of production and the use of barges that may rest on the mud instead of floating.)							

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	8,716.00	SF	0	0	45,890	0	45,890
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	479.38	TON	0	0	39,373	0	39,373
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			2.37	*4.53*	*0.00*	*0.00*	*6.90*
USR Load Mattresses on Small Barge, Sail to Jetty and Return (shallow)	8,716.00	SF	20,670	39,445	0	0	60,115
			3.84	*1.26*	*0.00*	*0.00*	*5.10*
USR Install Mattress in Marsh / Shallow Water	8,716.00	SF	33,509	10,970	0	0	44,479
(Note: Assume work will only be done at high tide. Cut the output in half Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,668.00**	**TON**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**981.18**	**CY**	**24,058**	**11,055**	**79,916**	**0**	**115,030**
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,668.00	TON	12,841	7,169	0	0	20,010
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,668.00	TON	11,218	3,886	0	0	15,104
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,668.00	TON	0	0	79,916	0	79,916
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**4,763.00**	**TON**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**2,801.76**	**CY**	**91,599**	**42,090**	**323,496**	**0**	**457,185**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	4,763.00	TON	48,889	27,294	0	0	76,183

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	4,763.00	TON	42,709	14,796	0	0	57,506
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	4,763.00	TON	0	0	323,496	0	323,496
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			817.56	*529.97*	*2,398.20*	*0.00*	*3,745.73*
Sitework Jetty X-Section D-D'	**150.00**	**LF**	**122,634**	**79,496**	**359,729**	**0**	**561,859**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Marine Mattress w/GeoFabric Attached	**10,810.00**	**SF**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
(Note: Marine mattress material consists of a webbed plastic container strong enough to hold gabion sized rocks. The mattress includes a geofabric attached to the bottom. The mattress is 1-foot thick, 5-feet wide, and 20-feet long filled with 2" to 6" stone. The complete mattress has a geofabric attached to the bottom of the mattress.)							
			122.73	*114.20*	*264.12*	*0.00*	*501.05*
Marine Mattress CY	**400.37**	**CY**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
			4.55	*4.23*	*9.78*	*0.00*	*18.56*
Install Mattress in Normal conditions	**10,810.00**	**SF**	**49,137**	**45,723**	**105,747**	**0**	**200,608**
			0.00	*0.00*	*5.27*	*0.00*	*5.27*
USR Marine Mattress, 1-foot thick; includes geofabric attached to bottom.	10,810.00	SF	0	0	56,915	0	56,915
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			0.00	*0.00*	*82.13*	*0.00*	*82.13*
USR Marine Mattress Stone Material	594.55	TON	0	0	48,833	0	48,833
(Note: Material Quote: Tensar Int Corp; Jeff Fiske - 770-344-2123)							
			1.73	*3.31*	*0.00*	*0.00*	*5.04*
USR Load Mattresses on Small Barge, Sail to Jetty and Return	10,810.00	SF	18,747	35,774	0	0	54,520
			2.81	*0.92*	*0.00*	*0.00*	*3.73*
USR Install Mattress in Jetty-Normal Conditions	10,810.00	SF	30,391	9,949	0	0	40,340
(Note: Assume there will be 1- tug to move barges around. Use a workboat to help position the mattresses before lowering in water.)							
			14.42	*6.63*	*47.91*	*0.00*	*68.96*
Core Stone	**1,845.00**	**TON**	**26,611**	**12,228**	**88,397**	**0**	**127,236**
(Note: Core stone material is a riprap type stone 600 lb to 1500 lb. It rests on the marine matress and is surrounding by the larger armor stone.)							
			24.52	*11.27*	*81.45*	*0.00*	*117.24*
Core Stone	**1,085.29**	**CY**	**26,611**	**12,228**	**88,397**	**0**	**127,236**

Description	Quantity	UOM	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectCost
			7.70	*4.30*	*0.00*	*0.00*	*12.00*
USR Load and Transport Core Stone from Big Barge to Jetty & Return	1,845.00	TON	14,203	7,929	0	0	22,133
			6.73	*2.33*	*0.00*	*0.00*	*9.06*
USR Place Stone from Small Barge in Jetty	1,845.00	TON	12,408	4,299	0	0	16,707
			0.00	*0.00*	*47.91*	*0.00*	*47.91*
USR Core Stone Material	1,845.00	TON	0	0	88,397	0	88,397
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							
			19.23	*8.84*	*67.92*	*0.00*	*95.99*
Armor Stone	**2,438.00**	**TON**	**46,886**	**21,544**	**165,585**	**0**	**234,016**
(Note: Armor stone is a riprap type stone that is 1500 lb to 3500 lb stone. The is the primary component of the structure and rests on the marine mattress and the core stone. The armor stone completely surrounds the core stone.)							
			32.69	*15.02*	*115.46*	*0.00*	*163.18*
Armor Stone	**1,434.12**	**CY**	**46,886**	**21,544**	**165,585**	**0**	**234,016**
			10.26	*5.73*	*0.00*	*0.00*	*15.99*
USR Load and Transport Armor Stone from Big Barge to Jetty & Return	2,438.00	TON	25,025	13,971	0	0	38,995
			8.97	*3.11*	*0.00*	*0.00*	*12.07*
USR Place Stone from Small Barge in Jetty	2,438.00	TON	21,861	7,574	0	0	29,435
			0.00	*0.00*	*67.92*	*0.00*	*67.92*
USR Armor Stone Material-New	2,438.00	TON	0	0	165,585	0	165,585
(Note: Quote: Vulcan Materials, Havre-de-Grace, MD; Rob Flanagan 717-515-4967)							

Total Project Cost Summary (TPCS) Spreadsheets

PROJECT: **Tangier Island Jetty - CAP Section 107** DISTRICT: **NAO - Norfolk District** PREPARED: **10/15/2015**
PROJECT NO: **P2**
LOCATION: **Tangier Island, VA** POC: **CHIEF, COST ENGINEERING**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 1

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
							Program Year (Budget EC):			2017					
							Effective Price Level Date:			1-Oct- 16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: 10/1/2015 ($K)	**TOTAL FIRST COST ($K)**	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
10	BREAKWATER & SEAWALLS	$1,628	$312	19.16%	$1,940	1.8%	$1,657	$317	$1,974		$1,974	1.4%	$1,679	$322	$2,001
			-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$1,628	$312		$1,940	1.8%	$1,657	$317	$1,974		$1,974	1.4%	$1,679	$322	$2,001
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31		$31	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN	$195	$37	19.16%	$233	3.6%	$202	$39	$241		$241	1.4%	$205	$39	$245
31	CONSTRUCTION MANAGEMENT	$130	$25	19.16%	$155	3.6%	$135	$26	$161		$161	3.0%	$139	$27	$166
	PROJECT COST TOTALS:	$1,979	$379	19.16%	$2,358		$2,020	$387	$2,407		**$2,407**	1.5%	$2,049	$393	$2,442

________________ CHIEF, COST ENGINEERING

________________ PROJECT MANAGER

________________ CHIEF, REAL ESTATE

________________ CHIEF, PLANNING and POLICY

________________ CHIEF, WATER RESOURCES DIVISION

________________ CHIEF, ENGINEERING

________________ CHIEF, CONSTRUCTION

________________ CHIEF, ENGINEERING and CONSTRUCTION

________________ CHIEF, PPMD

ESTIMATED TOTAL PROJECT COST:		**$2,442**
ESTIMATED FEDERAL COST:	65%	$1,587
ESTIMATED NON-FEDERAL COST:	**35%**	$855
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$1,752**

**** CONTRACT COST SUMMARY ****

PROJECT: Tangier Island Jetty - CAP Section 107
LOCATION: Tangier Island, VA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 1

DISTRICT: NAO - Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 10/15/2015

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			10/15/2015	Program Year (Budget EC):			2017					
		Estimate Price Level:			01-Oct-15	Effective Price Level Date:			1 -Oct-16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$1,628	$312	19.16%	$1,940	1.8%	$1,657	$317	$1,974	2017Q4	1.4%	$1,679	$322	$2,001
	CONSTRUCTION ESTIMATE TOTALS:	$1,628	$312	19.16%	**$1,940**		$1,657	$317	$1,974			$1,679	$322	$2,001
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31	2017Q2	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN													
0.01	Project Management	$16	$3	19.16%	$19	3.6%	$17	$3	$20	2017Q2	1.0%	$17	$3	$20
0.01	Planning & Environmental Compliance	$16	$3	19.16%	$19	3.6%	$17	$3	$20	2017Q2	1.0%	$17	$3	$20
0.06	Engineering & Design	$98	$19	19.16%	$116	3.6%	$101	$19	$121	2017Q2	1.0%	$102	$20	$122
0.005	Engineering Tech Review ITR & VE	$8	$2	19.16%	$10	3.6%	$8	$2	$10	2017Q2	1.0%	$9	$2	$10
0.005	Contracting & Reprographics	$8	$2	19.16%	$10	3.6%	$8	$2	$10	2017Q2	1.0%	$9	$2	$10
0.015	Engineering During Construction	$24	$5	19.16%	$29	3.6%	$25	$5	$30	2017Q4	3.0%	$26	$5	$31
0.01	Planning During Construction	$16	$3	19.16%	$19	3.6%	$17	$3	$20	2017Q4	3.0%	$17	$3	$21
0.005	Project Operations	$8	$2	19.16%	$10	3.6%	$8	$2	$10	2017Q2	1.0%	$9	$2	$10
31	CONSTRUCTION MANAGEMENT													
0.055	Construction Management	$90	$17	19.16%	$107	3.6%	$93	$18	$111	2017Q4	3.0%	$96	$18	$114
0.01	Project Operation:	$16	$3	19.16%	$19	3.6%	$17	$3	$20	2017Q4	3.0%	$17	$3	$21
0.015	Project Management	$24	$5	19.16%	$29	3.6%	$25	$5	$30	2017Q4	3.0%	$26	$5	$31
	CONTRACT COST TOTALS:	$1,979	$379		**$2,358**		$2,020	$387	$2,407			$2,049	$393	**$2,442**

PROJECT: **Tangier Island Jetty - CAP Section 107** DISTRICT: **NAO - Norfolk District** PREPARED: **10/15/2015**
PROJECT NO: **P2**
LOCATION: **Tangier Island, VA** POC: **CHIEF, COST ENGINEERING**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 2

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC):				2017					
						Effective Price Level Date:				1-Oct- 16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: **10/1/2015** ($K)	**TOTAL FIRST COST** ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
09	CHANNELS & CANALS	$2,845	$545	19.16%	$3,391	1.8%	$2,896	$555	$3,451		$3,451	1.9%	$2,950	$565	$3,515
			-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$2,845	$545		$3,391	1.8%	$2,896	$555	$3,451		$3,451	1.9%	$2,950	$565	$3,515
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31		$31	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN	$340	$65	19.16%	$405	3.6%	$352	$67	$420		$420	1.6%	$358	$69	$426
31	CONSTRUCTION MANAGEMENT	$227	$43	19.16%	$270	3.6%	$235	$45	$280		$280	4.0%	$245	$47	$291
	PROJECT COST TOTALS:	$3,438	$659	19.16%	$4,096		$3,509	$672	$4,181		**$4,181**	2.0%	$3,578	$686	$4,264

_______________ CHIEF, COST ENGINEERING

_______________ PROJECT MANAGER

_______________ CHIEF, REAL ESTATE

_______________ CHIEF, PLANNING and POLICY

_______________ CHIEF, WATER RESOURCES DIVISION

_______________ CHIEF, ENGINEERING

_______________ CHIEF, CONSTRUCTION

_______________ CHIEF, ENGINEERING and CONSTRUCTION

_______________ CHIEF, PPMD

ESTIMATED TOTAL PROJECT COST:		**$4,264**
ESTIMATED FEDERAL COST:	65%	$2,771
ESTIMATED NON-FEDERAL COST:	**35%**	$1,492
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$2,936**

****** CONTRACT COST SUMMARY ******

PROJECT: Tangier Island Jetty - CAP Section 107
LOCATION: Tangier Island, VA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 2

DISTRICT: NAO - Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 10/15/2015

WBS Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			**10/15/2015**	Program Year (Budget EC):			2017					
		Estimate Price Level:			01-Oct-15	Effective Price Level Date:			1 -Oct-16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$2,845	$545	19.16%	$3,391	1.8%	$2,896	$555	$3,451	2018Q1	1.9%	$2,950	$565	$3,515
	CONSTRUCTION ESTIMATE TOTALS:	$2,845	$545	19.16%	**$3,391**		$2,896	$555	$3,451			$2,950	$565	$3,515
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31	2017Q2	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN													
0.01	Project Management	$28	$5	19.16%	$33	3.6%	$29	$6	$35	2017Q2	1.0%	$29	$6	$35
0.01	Planning & Environmental Compliance	$28	$5	19.16%	$33	3.6%	$29	$6	$35	2017Q2	1.0%	$29	$6	$35
0.06	Engineering & Design	$171	$33	19.16%	$204	3.6%	$177	$34	$211	2017Q2	1.0%	$179	$34	$213
0.005	Engineering Tech Review ITR & VE	$14	$3	19.16%	$17	3.6%	$15	$3	$17	2017Q2	1.0%	$15	$3	$17
0.005	Contracting & Reprographics	$14	$3	19.16%	$17	3.6%	$15	$3	$17	2017Q2	1.0%	$15	$3	$17
0.015	Engineering During Construction	$43	$8	19.16%	$51	3.6%	$45	$9	$53	2018Q1	4.0%	$46	$9	$55
0.01	Planning During Construction	$28	$5	19.16%	$33	3.6%	$29	$6	$35	2018Q1	4.0%	$30	$6	$36
0.005	Project Operations	$14	$3	19.16%	$17	3.6%	$15	$3	$17	2017Q2	1.0%	$15	$3	$17
31	CONSTRUCTION MANAGEMENT													
0.055	Construction Management	$156	$30	19.16%	$186	3.6%	$162	$31	$193	2018Q1	4.0%	$168	$32	$200
0.01	Project Operation:	$28	$5	19.16%	$33	3.6%	$29	$6	$35	2018Q1	4.0%	$30	$6	$36
0.015	Project Management	$43	$8	19.16%	$51	3.6%	$45	$9	$53	2018Q1	4.0%	$46	$9	$55
	CONTRACT COST TOTALS:	$3,438	$659		**$4,096**		$3,509	$672	$4,181			$3,578	$686	**$4,264**

PROJECT: **Tangier Island Jetty - CAP Section 107**
PROJECT NO: **P2**
LOCATION: **Tangier Island, VA**

DISTRICT: **NAO - Norfolk District** PREPARED: **10/15/2015**
POC: **CHIEF, COST ENGINEERING**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 3

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
								Program Year (Budget EC):		2017					
								Effective Price Level Date:		1-Oct- 16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: 10/1/2015 ($K)	**TOTAL FIRST COST** ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
09	CHANNELS & CANALS	$3,585	$687	19.16%	$4,271	1.8%	$3,648	$699	$4,347		$4,347	1.9%	$3,716	$712	$4,428
			-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$3,585	$687		$4,271	1.8%	$3,648	$699	$4,347		$4,347	1.9%	$3,716	$712	$4,428
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31		$31	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN	$431	$83	19.16%	$514	3.6%	$447	$86	$532		$532	1.6%	$454	$87	$541
31	CONSTRUCTION MANAGEMENT	$287	$55	19.16%	$342	1.8%	$292	$56	$348		$348	1.9%	$298	$57	$355
	PROJECT COST TOTALS:	$4,328	$829	19.16%	$5,157		$4,413	$845	$5,258		**$5,258**	1.8%	$4,493	$861	$5,354

__________________ CHIEF, COST ENGINEERING

__________________ PROJECT MANAGER

__________________ CHIEF, REAL ESTATE

__________________ CHIEF, PLANNING and POLICY

__________________ CHIEF, WATER RESOURCES DIVISION

__________________ CHIEF, ENGINEERING

__________________ CHIEF, CONSTRUCTION

__________________ CHIEF, ENGINEERING and CONSTRUCTION

__________________ CHIEF, PPMD

ESTIMATED TOTAL PROJECT COST:		**$5,354**
ESTIMATED FEDERAL COST:	65%	$3,480
ESTIMATED NON-FEDERAL COST:	**35%**	$1,874
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$3,645**

****** CONTRACT COST SUMMARY ******

PROJECT: Tangier Island Jetty - CAP Section 107
LOCATION: Tangier Island, VA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 3

DISTRICT: NAO - Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 10/15/2015

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			10/15/2015	Program Year (Budget EC):			2017					
		Estimate Price Level:			01-Oct-15	Effective Price Level Date:			1 -Oct-16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$3,585	$687	19.16%	$4,271	1.8%	$3,648	$699	$4,347	2018Q1	1.9%	$3,716	$712	$4,428
	CONSTRUCTION ESTIMATE TOTALS:	$3,585	$687	19.16%	**$4,271**		$3,648	$699	$4,347			$3,716	$712	$4,428
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31	2017Q2	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN													
0.01	Project Management	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2017Q2	1.0%	$38	$7	$45
0.01	Planning & Environmental Compliance	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2017Q2	1.0%	$38	$7	$45
0.06	Engineering & Design	$215	$41	19.16%	$256	3.6%	$223	$43	$265	2017Q2	1.0%	$225	$43	$268
0.005	Engineering Tech Review ITR & VE	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
0.005	Contracting & Reprographics	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
0.015	Engineering During Construction	$54	$10	19.16%	$64	3.6%	$56	$11	$67	2018Q1	4.0%	$58	$11	$69
0.01	Planning During Construction	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2018Q1	4.0%	$39	$7	$46
0.005	Project Operations	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
31	CONSTRUCTION MANAGEMENT													
0.055	Construction Management	$197	$38	19.16%	$235	1.8%	$201	$38	$239	2018Q1	1.9%	$204	$39	$244
0.01	Project Operation:	$36	$7	19.16%	$43	1.8%	$37	$7	$44	2018Q1	1.9%	$37	$7	$44
0.015	Project Management	$54	$10	19.16%	$64	1.8%	$55	$11	$66	2018Q1	1.9%	$56	$11	$67
	CONTRACT COST TOTALS:	$4,328	$829		**$5,157**		$4,413	$845	$5,258			$4,493	$861	**$5,354**

PROJECT: **Tangier Island Jetty - CAP Section 107**
PROJECT NO: **P2**
LOCATION: **Tangier Island, VA**

DISTRICT: **NAO - Norfolk District** PREPARED: **10/15/2015**

POC: **CHIEF, COST ENGINEERING**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 4

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
							Program Year (Budget EC):			2017					
							Effective Price Level Date:			1-Oct- 16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: 10/1/2015 ($K)	**TOTAL FIRST COST ($K)**	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
09	CHANNELS & CANALS	$3,631	$696	19.16%	$4,327	1.8%	$3,695	$708	$4,403		$4,403	1.9%	$3,764	$721	$4,485
			-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$3,631	$696		$4,327	1.8%	$3,695	$708	$4,403		$4,403	1.9%	$3,764	$721	$4,485
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31		$31	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN	$434	$83	19.16%	$517	3.6%	$450	$86	$536		$536	1.6%	$457	$88	$544
31	CONSTRUCTION MANAGEMENT	$290	$56	19.16%	$346	1.8%	$295	$57	$352		$352	1.9%	$301	$58	$358
	PROJECT COST TOTALS:	$4,380	$839	19.16%	$5,219		$4,466	$856	$5,321		**$5,321**	1.8%	$4,548	$871	$5,419

______________________ CHIEF, COST ENGINEERING

______________________ PROJECT MANAGER

______________________ CHIEF, REAL ESTATE

______________________ CHIEF, PLANNING and POLICY

______________________ CHIEF, WATER RESOURCES DIVISION

______________________ CHIEF, ENGINEERING

______________________ CHIEF, CONSTRUCTION

______________________ CHIEF, ENGINEERING and CONSTRUCTION

______________________ CHIEF, PPMD

ESTIMATED TOTAL PROJECT COST:		**$5,419**
ESTIMATED FEDERAL COST:	65%	$3,522
ESTIMATED NON-FEDERAL COST:	**35%**	$1,897
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$3,687**

****** CONTRACT COST SUMMARY ******

PROJECT: Tangier Island Jetty - CAP Section 107
LOCATION: Tangier Island, VA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 4

DISTRICT: NAO - Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 10/15/2015

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			10/15/2015	Program Year (Budget EC):			2017					
		Estimate Price Level:			01-Oct-15	Effective Price Level Date:			1 -Oct-16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$3,631	$696	19.16%	$4,327	1.8%	$3,695	$708	$4,403	2018Q1	1.9%	$3,764	$721	$4,485
	CONSTRUCTION ESTIMATE TOTALS:	$3,631	$696	19.16%	**$4,327**		$3,695	$708	$4,403			$3,764	$721	$4,485
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31	2017Q2	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN													
0.01	Project Management	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2017Q2	1.0%	$38	$7	$45
0.01	Planning & Environmental Compliance	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2017Q2	1.0%	$38	$7	$45
0.06	Engineering & Design	$218	$42	19.16%	$260	3.6%	$226	$43	$269	2017Q2	1.0%	$228	$44	$272
0.005	Engineering Tech Review ITR & VE	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
0.005	Contracting & Reprographics	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
0.015	Engineering During Construction	$54	$10	19.16%	$64	3.6%	$56	$11	$67	2018Q1	4.0%	$58	$11	$69
0.01	Planning During Construction	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2018Q1	4.0%	$39	$7	$46
0.005	Project Operations	$18	$3	19.16%	$21	3.6%	$19	$4	$22	2017Q2	1.0%	$19	$4	$22
31	CONSTRUCTION MANAGEMENT													
0.055	Construction Management	$200	$38	19.16%	$238	1.8%	$204	$39	$243	2018Q1	1.9%	$207	$40	$247
0.01	Project Operation:	$36	$7	19.16%	$43	1.8%	$37	$7	$44	2018Q1	1.9%	$37	$7	$44
0.015	Project Management	$54	$10	19.16%	$64	1.8%	$55	$11	$66	2018Q1	1.9%	$56	$11	$67
	CONTRACT COST TOTALS:	$4,380	$839		**$5,219**		$4,466	$856	$5,321			$4,548	$871	**$5,419**

PROJECT: **Tangier Island Jetty - CAP Section 107** DISTRICT: **NAO - Norfolk District** PREPARED: **10/15/2015**
PROJECT NO: **P2**
LOCATION: **Tangier Island, VA** POC: **CHIEF, COST ENGINEERING**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 5

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
								Program Year (Budget EC):		2017					
								Effective Price Level Date:		1-Oct- 16					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: 10/1/2015 ($K)	**TOTAL FIRST COST ($K)**	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
09	CHANNELS & CANALS	$2,413	$462	19.16%	$2,876	1.8%	$2,456	$471	$2,927		$2,927	1.4%	$2,490	$477	$2,967
			-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$2,413	$462		$2,876	1.8%	$2,456	$471	$2,927		$2,927	1.4%	$2,490	$477	$2,967
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31		$31	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN	$289	$55	19.16%	$344	3.6%	$299	$57	$357		$357	1.4%	$304	$58	$362
31	CONSTRUCTION MANAGEMENT	$193	$37	19.16%	$230	1.8%	$196	$38	$234		$234	1.4%	$199	$38	$237
	PROJECT COST TOTALS:	$2,921	$560	19.16%	$3,480		$2,978	$571	$3,548		**$3,548**	1.4%	$3,018	$578	$3,597

________________ CHIEF, COST ENGINEERING

________________ PROJECT MANAGER

________________ CHIEF, REAL ESTATE

________________ CHIEF, PLANNING and POLICY

________________ CHIEF, WATER RESOURCES DIVISION

________________ CHIEF, ENGINEERING

________________ CHIEF, CONSTRUCTION

________________ CHIEF, ENGINEERING and CONSTRUCTION

________________ CHIEF, PPMD

ESTIMATED TOTAL PROJECT COST:		**$3,597**
ESTIMATED FEDERAL COST:	65%	$2,338
ESTIMATED NON-FEDERAL COST:	35%	$1,259
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$2,503**

**** CONTRACT COST SUMMARY ****

PROJECT: Tangier Island Jetty - CAP Section 107
LOCATION: Tangier Island, VA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - TANGIER ISLAND JETTY / Alternative 5

DISTRICT: NAO - Norfolk District
POC: CHIEF, COST ENGINEERING

PREPARED: 10/15/2015

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 10/15/2015 Estimate Price Level: 01-Oct-15				Program Year (Budget EC): 2017 Effective Price Level Date: 1 -Oct-16								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$2,413	$462	19.16%	$2,876	1.8%	$2,456	$471	$2,927	2017Q4	1.4%	$2,490	$477	$2,967
	CONSTRUCTION ESTIMATE TOTALS:	$2,413	$462	19.16%	**$2,876**		$2,456	$471	$2,927			$2,490	$477	$2,967
01	LANDS AND DAMAGES	$25	$5	19.16%	$30	1.8%	$26	$5	$31	2017Q2	0.5%	$26	$5	$31
30	PLANNING, ENGINEERING & DESIGN													
0.01	Project Management	$24	$5	19.16%	$29	3.6%	$25	$5	$30	2017Q2	1.0%	$25	$5	$30
0.01	Planning & Environmental Compliance	$24	$5	19.16%	$29	3.6%	$25	$5	$30	2017Q2	1.0%	$25	$5	$30
0.06	Engineering & Design	$145	$28	19.16%	$173	3.6%	$150	$29	$179	2017Q2	1.0%	$152	$29	$181
0.005	Engineering Tech Review ITR & VE	$12	$2	19.16%	$14	3.6%	$12	$2	$15	2017Q2	1.0%	$13	$2	$15
0.005	Contracting & Reprographics	$12	$2	19.16%	$14	3.6%	$12	$2	$15	2017Q2	1.0%	$13	$2	$15
0.015	Engineering During Construction	$36	$7	19.16%	$43	3.6%	$37	$7	$44	2017Q4	3.0%	$38	$7	$46
0.01	Planning During Construction	$24	$5	19.16%	$29	3.6%	$25	$5	$30	2017Q4	3.0%	$26	$5	$31
0.005	Project Operations	$12	$2	19.16%	$14	3.6%	$12	$2	$15	2017Q2	1.0%	$13	$2	$15
31	CONSTRUCTION MANAGEMENT													
0.055	Construction Management	$133	$25	19.16%	$158	1.8%	$135	$26	$161	2017Q4	1.4%	$137	$26	$164
0.01	Project Operation:	$24	$5	19.16%	$29	1.8%	$24	$5	$29	2017Q4	1.4%	$25	$5	$30
0.015	Project Management	$36	$7	19.16%	$43	1.8%	$37	$7	$44	2017Q4	1.4%	$37	$7	$44
	CONTRACT COST TOTALS:	$2,921	$560		**$3,480**		$2,978	$571	$3,548			$3,018	$578	**$3,597**

Cost and Schedule Risk Analysis Report

Contingency Summary: Current regulations require a formal analysis of schedule and costs risks. An abbreviated Cost and Schedule Risk Analysis or CSRA provides a contingency calculation for projects that are under $40 million dollars. This project is well under this dollar amount. The contingency calculation for this project is 19.16%.

Project Description: The proposed Tangier Island Jetty Navigation Study Project examines measures designed to improve and protect the navigation channel located on Tangier Island. The study evaluates five alternatives for cost effectiveness. These measures also reduce wave energy in the channel. The study alternatives include several different combinations of jetties on the north and south side of the channel. The task for this report is to find the cost risk associated with implementing the selected plan.

Background: The evaluation of the five alternatives occurred using a benefit to cost ratio analysis by the economist in the Planning Section. Alternative 1 was the selected plan. The PDT supplied a construction schedule for the chosen alternative from cost estimate price level through the end of the project.

Contingency Method: A contingency calculation is the result of the abbreviated CSRA (Cost and Schedule Risk Analysis). The Army Corps of Engineers abbreviated CSRA spreadsheet is the tool used to provide the team with a contingency percentage. This project risk category is "Low Risk: Typical Construction, Simple". There are no life safety risks associated with this project.

For the risk analysis the construction cost estimate breakout consists of the following: mobilization, marine mattress fabric including stone, core and armor stone, mattress delivery and installation, and core/armor stone installation. Each of these items is subject to different risks.

Risk Items/Features: Mobilization is subject to weather and topography risks but not quantity risk. Mobilization of the marine mattress jig is an important element of the project. The jig must be setup correctly and able to withstand continuous use. Water-based equipment such as barges must be transported to the jobsite and available for immediate use. Because of the importance of the jig and water-based equipment to the project, we assigned higher risks to this item.

The mattress fabric supplier can easily deliver his material because it is not bulky. The mattress stone delivery is also easy because of its assumed destination on the Eastern Shore. Overall the risks for mattress fabric/stone materials were low.

The core and armor stone is best delivered by a large barge to the jobsite. The open water of the jobsite makes weather and sea conditions more of a factor than on land. In addition potential topography changes could increase or decrease the stone quantity. These concerns create more risk for the core/armor stone.

Shallow water complicates the placement of the core and armor stone. Also weather may impact and slow down stone placement. These factors create an overall moderate impact on the project contingency.

Marine mattress delivery and installation is one of the most risky processes in the project, because it requires several steps. First the mattresses must be delivered by barge to the jobsite. Then the same issues with stone placement now face mattress installation. This risk is primarily moderate and could possibly occur. Weather problems though are more likely to occur.

Risk Elements: Based on the current design this project scope is well-set. Some site investigations are 2-years old, which could cause quantity changes in the field. It is unlikely that these changes will be significant though. The project should meet its stated intent even with quantity changes. A single contractor could perform 90% of the work in this job. The work schedule is not accelerated and will not begin until after the winter months. Quantity changes could possibly affect the armor/core stone quantities but only by a moderate amount.

Because of the project size, we expect a competitive small business type contract. Open competition reduces the cost risk associated with a sole source type contract. At this time we do not expect a sole source type contract. Because of the project location in Virginia's northern end of the Chesapeake Bay, the number of potential bidders is higher. At the same time the island location (15 miles or more away from the mainland) will lower the number of potential bidders. Overall we expect 3 to 4 bidders.

Shallow water is the main concern for the actual construction of the jetty. This causes double handling of the stone. A barge/pier system resting on the mud will help with jetty construction in the shallowest parts of the site. Shallow water problems and weather delays are possible and will create moderate impacts.

Quantities for the contract have been determined by the cost engineer based on plans and information provided by the PDT. Subsidence of the structure and material waste due to contractor inexperience are the primary reasons why quantities might increase. A quantity take-off showing the significant quantities is included with the package for cost certification. These issues are a possibility but their effect is only marginal to moderate.

The marine mattress fabrication is probably the item with the most unknowns. The materials to construct the mattress are not a problem. As stated earlier the jig must be setup correctly and several test mattresses may be necessary before acceptable and reliable production begins. This item combined with delivery of the mattress to the jobsite yields a moderate impact that could possibly occur.

The assumptions in the cost estimate are not unusual based on the small number of components in the job. The job consists primarily of stone filled marine mattresses with core and armor stone placed over them. The fabric and stone material costs are over 50% of the total cost of the job. Quotes for these items are in the estimate. These costs are higher than the costs in comparable jobs opened within the last two years. The estimate includes a productivity reduction from 100% to 90% to account for uncertainties with water-based construction. Crews are liberally sized to provide extra margin for the unknowns at the site. The basis of overtime in the estimate is a 6-day work week with a 10-hour work day. The biggest uncertainty is the location of the mattress fabrication site. The contractor could elect to construct mattresses on Tangier Island or at a different location on the mainland. This is a moderate risk which is likely to occur.

Other Contingencies: Real Estate assigned a 15% contingency to the Lands and Damages costs in the estimate. The simple construction components allow a 5% contingency for PED (Planning Engineering & Design) and Construction Management.

Summary: The spreadsheet calculates a weighted average of all the construction and non-construction contingencies. For this job the average is 19.16%. We applied the 19.16% to each of the items in the TPCS (Total Project Cost Summary) as follows: Construction Cost, Lands & Damages, PED, and Construction Management.

The abbreviated CSRA is presented as an attachment.

Michael Hall, P.E.
Acting Chief, Cost Engineering Section

Abbreviated Risk Analysis

Project (less than $40M): **Tangier Island Jetty Section 107, Accomack Co, VA**

Alternative: Alt 1

Project Development Stage/Alternative: **Feasibility (Recommended Plan)**

Risk Category: **Low Risk: Typical Construction, Simple**

Meeting Date: 6/9/2015

Total Estimated Construction Contract Cost = $ 1,627,781

CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
01 LANDS AND DAMAGES	Real Estate	$ 25,250		15.00%	$ 3,788	$ 29,038
09 01 CHANNELS	Mob	$ 110,447		21.71%	$ 23,982	$ 134,429
09 01 CHANNELS	Marine Mattress Material-Fabric & Stone	$ 357,525		16.33%	$ 58,381	$ 415,906
09 01 CHANNELS	Core and Armor Stone Material	$ 563,863		21.34%	$ 120,332	$ 684,195
09 01 CHANNELS	Marine Mattresses Delivery & Install	$ 360,005		28.48%	$ 102,543	$ 462,548
09 01 CHANNELS	Core and Armor Stone Installation	$ 235,941		22.83%	$ 53,876	$ 289,817
		$ -		0.00%	$ -	$ -
		$ -		0.00%	$ -	$ -
		$ -		0.00%	$ -	$ -
		$ -		0.00%	$ -	$ -
		$ -		0.00%	$ -	$ -
		$ -		0.00%	$ -	$ -
All Other	**Remaining Construction Items**	$ -	0.0%	0.00%	$ -	$ -
30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 195,334		5.00%	$ 9,767	$ 205,100
31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 130,222		5.00%	$ 6,511	$ 136,734
FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals	Contract Cost	% Contingency	$ Contingency	Total
Real Estate	$ 25,250	15.00%	$ 3,788	$ 29,037.50
Total Construction Estimate	$ 1,627,781	22.06%	$ 359,114	$ 1,986,895
Total Planning, Engineering & Design	$ 195,334	5.00%	$ 9,767	$ 205,100
Total Construction Management	$ 130,222	5.00%	$ 6,511	$ 136,734
Total	**$ 1,978,587**	**19.16%**	**$ 379,179**	**$ 2,357,766**

	Base	50%	80%
Range Estimate ($000's)	$1,979k	$2,206k	$2,358k

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.	

Tangier Island Jetty Section 107, Accomack Co, VA Alt 1

Feasibility (Recommended Plan)

Abbreviated Risk Analysis

Meeting Date: 9-Jun-15

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Register

Risk Element	Feature of Work	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Scope Growth					Maximum Project Growth	40%
PS-1	Mob	None	N/A	Negligible	Possible	0
PS-2	Marine Mattress Material-Fabric & Stone	Quantities are based on 2 year old survey, Qty's most likely are locked in. Some changes in topography may have occurred since the last survey 2 years ago. Have existing borings going full length.	This item involves the farication of the marine matresses on land which includes the mattress fabric and the stone. The borings are reliable for design purposes. The worst case would be the structural foundation is placed at deeper water levels. Additionally, the area of marine mattresses could increase, due to changes in topography.	Marginal	Possible	1
PS-3	Core and Armor Stone Material	Quantities are based on 2 year old survey, Qty's most likely are locked in. Some changes in topography may have occurred since the last survey 2 years ago. Have existing borings going full length.	If topograhy changes, the volume of armor and core stone needed to construct the structure may increase or decrease.	Moderate	Possible	2
PS-4	Marine Mattresses Delivery & Install	Quantities are based on 2 year old survey, Qty's most likely are locked in. Some changes in topography may have occurred since the last survey 2 years ago. Have existing borings going full length.	This item involes the delivery of complete matresses delivered to the jobsite and installed. Material could be lost during transport and construction, thus, requiring additional purchase of material if not found within constraints of the Variation in Estimated Quantity Clause (FAR 52.211-18).	Marginal	Possible	1
PS-5	Core and Armor Stone Installation	Quantities are based on 2 year old survey, Qty's most likely are locked in. Some changes in topography may have occurred since the last survey 2 years ago. Have existing borings going full length.	The site topography may have changed, which would cause design changes. The borings are reliable for design purposes. Material could be lost during transport and construction, thus, requiring additional purchase of material if not found within constraints of the quanitities clause.	Moderate	Possible	2
PS-6	0			Negligible	Unlikely	0
PS-7	0			Negligible	Unlikely	0
PS-8	0			Negligible	Unlikely	0
PS-9	0			Negligible	Unlikely	0

PS-10	0			Negligible	Unlikely	0
PS-11	0			Negligible	Unlikely	0
PS-12	Remaining Construction Items			Negligible	Unlikely	0
PS-13	Planning, Engineering, & Design			Negligible	Unlikely	0
PS-14	Construction Management			Negligible	Unlikely	0
Acquisition Strategy				**Maximum Project Growth**		**30%**
AS-1	Mob	Contracting Plan has not been firmly established. Limited competition. Construction schedule.	The impact of these items on mob will be slight.	Marginal	Unlikely	0
AS-2	Marine Mattress Material-Fabric & Stone	Contracting Plan has not been firmly established. Limited competition. Construction schedule.	The Norfolk District has extensive experience with projects involving marine mattress installation. Bid Competition has not been a concern for previous projects of similar scope in the Norfolk District. The bid schedule should be simple consisting of 1 or 2 bid items.	Marginal	Possible	1
AS-3	Core and Armor Stone Material	Contracting Plan has not been firmly established. Limited competition. Construction schedule.	The Norfolk District has extensive experience with projects involving rock placement . The bid competition for the job may be slightly reduced because of the uncertainity of the demand for stone near the project location. The bid schedule should be simple consisting of 1 or 2 bid items.	Marginal	Possible	1
AS-4	Marine Mattresses Delivery & Install	Contracting Plan has not been firmly established. Limited competition. Construction schedule.	This item involes the delivery of complete matresses delivered to the jobsite and installed. The bid competition for the job may be slightly reduced because of the project location. Bid Competition has not been a concern for previous projects of similar scope in the Norfolk District. The geotextile material delivery schedule could be out of sync with stone delivery, causing a delay for fabrication of matresses. Possiblity of the use of subconstractors for on site fabrication.	Moderate	Possible	2
AS-5	Core and Armor Stone Installation	Contracting Plan has not been firmly established. Limited competition. Construction schedule.	Uncomplicated project and the Norfolk District has extensive experience with projects involving rock placement . The bid competition for the job may be slightly reduced because of the project location. Bid Competition has not been a concern for previous projects of similar scope in the Norfolk District. The bid schedule should be simple consisting of 1 or 2 bid items.	Marginal	Possible	1
AS-6	0			Negligible	Unlikely	0
AS-7	0			Negligible	Unlikely	0

AS-8	0			Negligible	Unlikely	0
AS-9	0			Negligible	Unlikely	0
AS-10	0			Negligible	Unlikely	0
AS-11	0			Negligible	Unlikely	0
AS-12	Remaining Construction Items			Negligible	Unlikely	0
AS-13	Planning, Engineering, & Design			Negligible	Unlikely	0
AS-14	Construction Management			Negligible	Unlikely	0
Construction Elements				**Maximum Project Growth**		**15%**
CE-1	Mob	Harsh Weather. Shallow water at project site. Work site access is only by water.	Harsh weather may cause mobilization time delays.	Marginal	Possible	1
CE-2	Marine Mattress Material-Fabric & Stone	Harsh Weather. Shallow water at project site. Work site access is only by water. Unexpected site conditions	Assumption: mattress fabrication takes place on the Eastern Shore (Chesapeake Bay side) of VA. Because this site is on the mainland, stone delivery by barge or truck will not be affected by shallow water. The effect of weather on land-based stone delivery is small.	Marginal	Possible	1
CE-3	Core and Armor Stone Material	Harsh Weather. Shallow water at project site. Work site access is only by water. Unexpected site conditions	The big barges that deliver stone can anchor in deeper water and will not be affected by shallow water or site conditions at Tangier Island. The weather may affect barge delivery of stone, but not significantly because of the plant size..	Moderate	Possible	2
CE-4	Marine Mattresses Delivery & Install	Harsh Weather. Shallow water at project site. Work site access is only by water. Unexpected site conditions	The shallow water in some places requires extra handling of materials. This slows down construction and/or adds extra steps to the process. The site survey alleviates some of the concern about unexpected site conditions. But the site condition unkowns increase the risk.	Moderate	Possible	2
CE-5	Core and Armor Stone Installation	Harsh Weather. Shallow water at project site. Work site access is only by water. Unexpected site conditions	The shallow water may slow down construction and/or add extra steps to the process. The site survey alleviates some of the concern about unexpected site conditions, but there are still unknowns.	Moderate	Possible	2
CE-6	0			Negligible	Unlikely	0
CE-7	0			Negligible	Unlikely	0
CE-8	0			Negligible	Unlikely	0

CE-9	0			Negligible	Unlikely	0
CE-10	0			Negligible	Unlikely	0
CE-11	0			Negligible	Unlikely	0
CE-12	Remaining Construction Items			Negligible	Unlikely	0
CE-13	Planning, Engineering, & Design			Negligible	Unlikely	0
CE-14	Construction Management			Negligible	Unlikely	0
Quantities for Current Scope				**Maximum Project Growth**		**20%**
Q-1	Mob			Negligible	Unlikely	0
Q-2	Marine Mattress Material-Fabric & Stone	Possible subsidence of materials place on the site. The design basis is a 2-year old site survey.	It is possible that subsidence will occur. The mattress footprint would still be approximately the same for small displacements. A design based on 2-year old site survey could contain quantity errors.	Marginal	Possible	1
Q-3	Core and Armor Stone Material	Possible subsidence of materials place on the site. The design basis is a 2-year old site survey.	Norfolk District has a lot of experience designing marine rock structures and these designs have proven effective. Subsidence will affect the stone quantities more the mattress quantities, which increases the risk.	Moderate	Possible	2
Q-4	Marine Mattresses Delivery & Install	Subsidence and material loss. Contractor negligence and wasteful material placement.	Contractor inexperience could lead to wasteful efforts in placement of mattresses and material lost during delivery.	Marginal	Possible	1
Q-5	Core and Armor Stone Installation	Subsidence and material loss. Contractor negligence and wasteful material placement.	Contractor inexperience could lead to wasteful efforts in stone placement.	Moderate	Possible	2
Q-6	0			Negligible	Unlikely	0
Q-7	0			Negligible	Unlikely	0
Q-8	0			Negligible	Unlikely	0
Q-9	0			Negligible	Unlikely	0
Q-10	0			Negligible	Unlikely	0
Q-11	0			Negligible	Unlikely	0

Q-12	Remaining Construction Items			Negligible	Unlikely	0
Q-13	Planning, Engineering, & Design			Negligible	Unlikely	0
Q-14	Construction Management			Negligible	Unlikely	0
Specialty Fabrication or Equipment				**Maximum Project Growth**		**50%**
FE-1	Mob	Unusual equipment. Transportation with marine mattress issues. Suppliers ability to provide stone. Marine mattress construction. Mobilization of effective mattress making equipment.	The marine mattress making equipment is simple but has not been used a lot compared to direct stone placement on a surface. The mattress making equipment needs to be assembled and functioning before proceeding with the rest of the job. Testing and retesting may be necessary.	Moderate	Possible	2
FE-2	Marine Mattress Material-Fabric & Stone	Suppliers ability to provide stone for Marine mattress construction.	The marine mattress fabric supplier can easily deliver the material in a timely way. The rock supplier should not have any difficulty supplying stone for mattress fabrication. Several suppliers are available.	Marginal	Unlikely	0
FE-3	Core and Armor Stone Material	Suppliers ability to provide stone .	The rock supplier should not have any difficulty supplying stone . Several suppliers are available.	Marginal	Unlikely	0
FE-4	Marine Mattresses Delivery & Install	Unusual equipment. Transportation with marine mattress issues. Problems with the placement of marine mattresses.	Problems with delivery, and installation of the mattress will create significant impacts to the job. Delays, slow production, or failures impact the project because the core/armor stone rests on the mattress foundation.	Moderate	Possible	2
FE-5	Core and Armor Stone Installation	Loading, transportation, and installation of stone.	The estimate uses standard water-based crews. The transportation distance is short after loading the placement barges. The crew places the rock in waters less than 20' deep.	Marginal	Unlikely	0
FE-6	0			Negligible	Unlikely	0
FE-7	0			Negligible	Unlikely	0
FE-8	0			Negligible	Unlikely	0
FE-9	0			Negligible	Unlikely	0
FE-10	0			Negligible	Unlikely	0
FE-11	0			Negligible	Unlikely	0
FE-12	Remaining Construction Items			Negligible	Unlikely	0
FE-13	Planning, Engineering, & Design			Negligible	Unlikely	0
FE-14	Construction Management			Negligible	Unlikely	0
Cost Estimate Assumptions				**Maximum Project Growth**		**25%**

CT-1	Mob	Location of mattress fabrication site. Productivity of mob crews. Location of stone delivery points. Unknown Mob distances.	Some contractors may have to mobilize longer distances than others. Equipment used and priced in the cost estimate may be different from what the contractor uses. We expect the mattress fabrication to take place on the Eastern shore, but the final location may be different.	Moderate	Likely	**3**
CT-2	Marine Mattress Material-Fabric & Stone	Location of mattress fabrication site. Location of stone delivery point.	The final location of the stone supplier's delivery point, whether on land or water, will affect the cost. Several suppliers can supply stone for the mattresses.	Marginal	Possible	**1**
CT-3	Core and Armor Stone Material	Location of stone delivery point.	The final location of the stone supplier's delivery point whether on land or water will affect the cost. Competition betwenn suppliers reduces this risk.	Marginal	Possible	**1**
CT-4	Marine Mattresses Delivery & Install	Long transport over water to bring marine mattresses to job site. Shallow water at project site causing crew changes. Productivity of crews.	The estimate assumes a standard water-based crew for tranportation of mattresses over the water. The estimate has separate crews for shallow and deep water mattress placement. Overall productivity is lower because construction takes place from barges.	Marginal	Possible	**1**
CT-5	Core and Armor Stone Installation	Moving stone from big barge to small barge due to shallow water. Reduced productivity of crews.	The contractor will have to move stone from the supply barge to a small barge for installation. This is a normal procedure for construction over water. The estimate has separate crews for shallow and deep water placement. Productivity is lower because of water-based installation.	Marginal	Possible	**1**
CT-6	0			Negligible	Unlikely	**0**
CT-7	0			Negligible	Unlikely	**0**
CT-8	0			Negligible	Unlikely	**0**
CT-9	0			Negligible	Unlikely	**0**
CT-10	0			Negligible	Unlikely	**0**
CT-11	0			Negligible	Unlikely	**0**
CT-12	Remaining Construction Items			Negligible	Unlikely	**0**
CT-13	Planning, Engineering, & Design			Negligible	Unlikely	**0**
CT-14	Construction Management			Negligible	Unlikely	**0**
External Project Risks				**Maximum Project Growth**		**20%**

EX-1	Mob	Potential Impacts due to the use of existing Channel. Potential delays due to adverse weather conditions. Unknown Fuel and Commodity costs. Lack of local support.	Blockage of the existing channel because of other marine traffic will cause delays in construction. Severe weather increases construction risk and delays complete mobilization. Fuel cost fluctuations impact equipment costs. The possiblity of a lack of local support may affect the start date of the project, which leads to cost growth and total project cost increases. Some of these effects may be small, but the combination of them produces greater risk.	Moderate	Possible	**2**
EX-2	Marine Mattress Material-Fabric & Stone	Potential delays due to adverse weather conditions. Unknown Fuel and Commodity costs.	Weather will not affect this item very much because stone delivery and fabrication can be done at most times except in extreme weather. The contractor can stockpile the mattresses for use when he needs them.	Marginal	Possible	**1**
EX-3	Core and Armor Stone Material	Potential Impacts due to the use of existing Channel. Potential delays due to adverse weather conditions. Unknown Fuel and Commodity costs.	Stone material transport is not a problem because of the large delivery barges and tugs that can withstand the local weather conditions. These large barges will be anchored outside of the main channel, which allows boat traffic in the channel. will The possiblity of lack of local support may affect the start date of the project, which leads to cost growth and total project cost increases. Some of these effects may be small, but the combination of them produces greater risk.	Marginal	Possible	**1**
EX-4	Marine Mattresses Delivery & Install	Potential Impacts due to the use of existing Channel. Potential delays due to adverse weather conditions. Unknown Fuel and Commodity and costs. Lack of local support.	Blockage of the existing channel because of other marine traffic will cause delays in construction. This item is most subject to weather delays, because of the time it takes to transport mattresses to the site and place them in the water. Fuel cost fluctations impact equipment and transportation costs. The possiblity of a lack of local support may affect the start date of the project, which leads to cost growth and total project cost increases. Some of these effects may be small, but the combination of them produces greater risk.	Moderate	Likely	**3**
EX-5	Core and Armor Stone Installation	Potential Impacts due to the use of existing Channel. Potential delays due to adverse weather conditions. Unknown Fuel and Commodity and costs. Lack of local support.	Blockage of the existing channel because of other marine traffic will cause delays in construction. Weather impacts the armor stone insta risk item but not as greatly as the mattress risk item. Changes in fuel prices affect the equipment costs.	Moderate	Possible	**2**
EX-6	0			Negligible	Unlikely	**0**
EX-7	0			Negligible	Unlikely	**0**
EX-8	0			Negligible	Unlikely	**0**
EX-9	0			Negligible	Unlikely	**0**
EX-10	0			Negligible	Unlikely	**0**
EX-11	0			Negligible	Unlikely	**0**
EX-12	Remaining Construction Items			Negligible	Unlikely	**0**

EX-13	Planning, Engineering, & Design			Negligible	Unlikely	**0**
EX-14	Construction Management			Marginal	Unlikely	**0**

Tangier Island Jetty Section 107, Accomack Co, VA Alt 1
Feasibility (Recommended Plan)
Abbreviated Risk Analysis

Risk Evaluation

WBS	Potential Risk Areas	Project Scope Growth	Acquisition Strategy	Construction Elements	Quantities for Current Scope	Specialty Fabrication or Equipment	Cost Estimate Assumptions	External Project Risks	Cost in Thousands
01 LANDS AND DAMAGES	**Real Estate**								$25
09 01 CHANNELS	**Mob**	0	0	1	0	2	3	2	$110
09 01 CHANNELS	Marine Mattress Material-Fabric & Stone	1	1	1	1	0	1	1	$358
09 01 CHANNELS	Core and Armor Stone Material	2	1	2	2	0	1	1	$564
09 01 CHANNELS	Marine Mattresses Delivery & Install	1	2	2	1	2	1	3	$360
09 01 CHANNELS	Core and Armor Stone Installation	2	1	2	2	0	1	2	$236
0	0	0	0	0	0	0	0	0	$0
0	0	0	0	0	0	0	0	0	$0
0	0	0	0	0	0	0	0	0	$0
0	0	0	0	0	0	0	0	0	$0
0	0	0	0	0	0	0	0	0	$0
0	0	0	0	0	0	0	0	0	$0
All Other	Remaining Construction Items	0	0	0	0	0	0	0	$0
30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	0	0	0	0	0	0	0	$195
31 CONSTRUCTION MANAGEMENT	Construction Management	0	0	0	0	0	0	0	$130
									$1,979
Risk		$ 50	$ 37	$ 140	$ 40	$ 22	$ 37	$ 50	**$375**
Fixed Dollar Risk Allocation		$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$0**
	Risk	$ 50	$ 37	$ 140	$ 40	$ 22	$ 37	$ 50	**$375**
								Total	**$2,354**