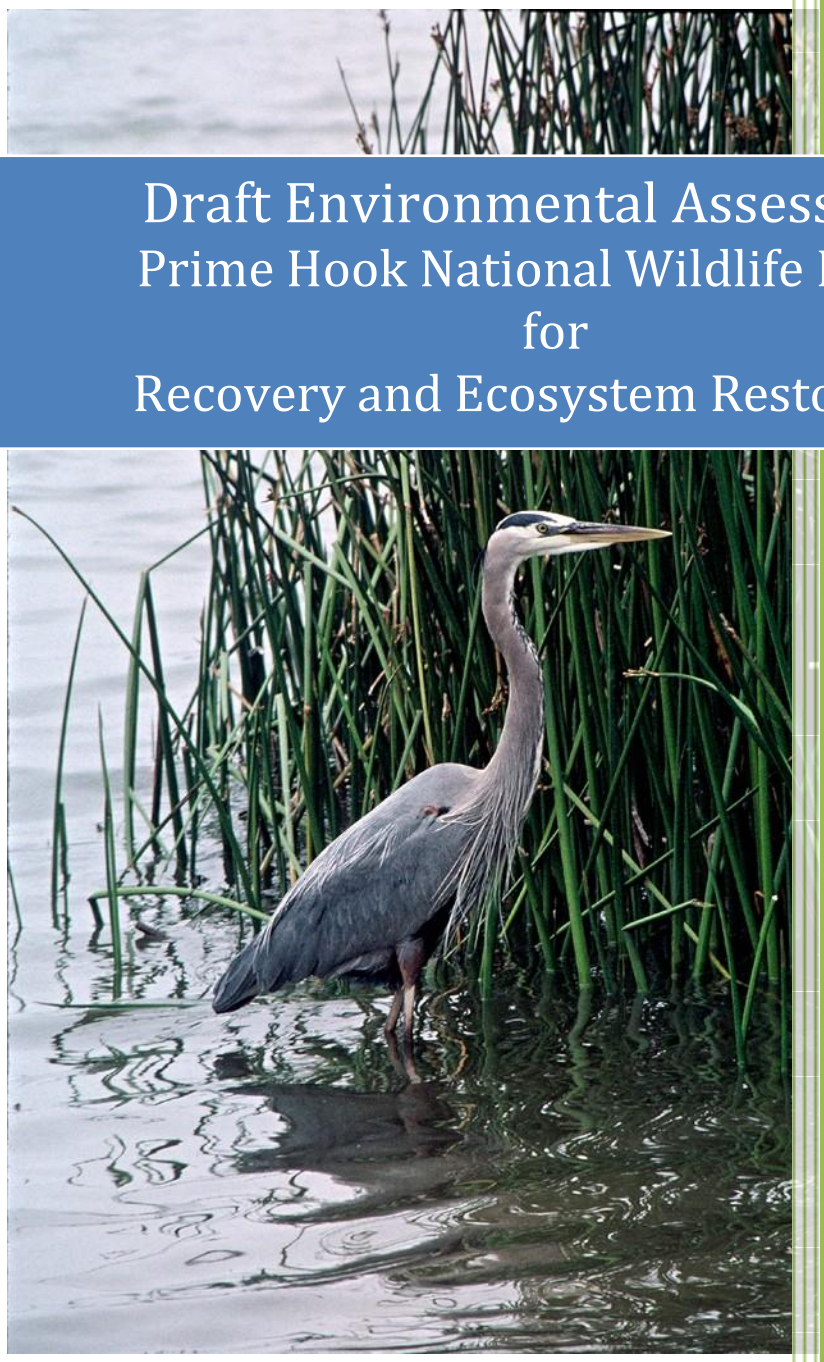
Draft Environmental Assessment
Prime Hook National Wildlife Refuge
for
Recovery and Ecosystem Restoration



U.S. Fish and Wildlife Service

February 2015

APPENDICES

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Prime Hook National Wildlife Refuge
For
Recovery and Ecosystem Restoration

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APPENDIX A

Atkins Water Levels Memorandum

Memo:
Prime Hook NWR Water Levels

To:	Bart Wilson, Al Rizzo (USFWS)		
From:	Jeff Tabar (Louis Berger), Todd DeMunda (Atkins)	**Email:**	jtabar@louisberger.com
Phone:	727-510-7619	**Date:**	Dec 5, 2014
Subject:	Prime Hook NWR - Water Level Comparisons		

Overview

This memo presents a brief comparison of peak water levels within Units II and III of Prime Hook National Wildlife Refuge (Refuge) adjacent to the Prime Hook Beach and Broadkill Beach communities as determined by an analysis of measured data as well as hydrodynamic model results for a variety of Refuge configurations. Peak water levels were compared for both normal tidal and inflow conditions and for conditions during Hurricane Sandy.

Locations and scenarios for comparison

The Refuge was modeled for three scenarios:

1. Existing conditions, which represents the best available elevations of the marsh and breach immediately post-Sandy and the removal of water control structures
2. Breach closure only, which represents a barrier between the Refuge and Delaware Bay at the breach location and removal of water control structures but otherwise leaves the marsh as-is
3. The final design, which builds upon the breach closure scenario by adding conveyance channels throughout Units II and III.

Measured water level data within the Refuge is available at a number of locations from 2010 to the present. This timeframe includes Hurricane Sandy (October 2012), and this data was directly compared to the model results. For comparing normal conditions, only the measured data from 2013 and 2014 was used, as this coincides with the breach configuration represented in the model. It should be noted that the measured 2013/2014 peaks include all surge and high-inflow events, whereas the modeled normal conditions do not. Figure 1 shows the locations of the measured water levels and the additional output points from the model. The locations *FowlerS*, *PrimeHookN*, *PrimeHookS*, and *HeadQ* are measured data locations within Units II and III, while *Unit II S Main, Unit III N Main, Unit III C S Main,* and *Unit III S Main* are model output points adjacent to the Prime Hook Beach and Broadkill Beach communities with no associated measured data.

Water levels – normal conditions

Due to the presence of low-frequency events in the 2013/2014 measured data, the most meaningful comparison between peak water levels for the different marsh configurations would be to compare the three modeled scenarios (refer to Table 1). By closing the breaches, peak water levels within Units II and III are lowered by approximately 45% and 21%, respectively. Adding the final design of conveyance channels further reduces the peak water level by about 7%. Figure 2 shows the range of modeled water levels in Unit II adjacent to Prime Hook Beach for each of the 3 scenarios.

Water levels – Hurricane Sandy

To evaluate the effects of the potential modifications during storm events, Hurricane Sandy was modeled and compared to measured data (refer to Table 2). In Unit II, peak water levels were reduced by approximately 25% when the breaches were closed with or without the final design channels. In Unit III, peak water levels were reduced by about 20% after breach closure. Figure 3 shows the water level time series during Sandy in Unit II.

Conclusions

The modeling effort demonstrates that closing the breaches, with or without adding the conveyance channels, will serve to reduce peak water levels within the Refuge, for both normal and storm conditions. Adding the conveyance channels further reduces water levels along the Prime Hook Beach and Broadkill Beach communities. It is not expected that the proposed design will increase flooding in vulnerable areas.

Memo:
Prime Hook NWR Water Levels

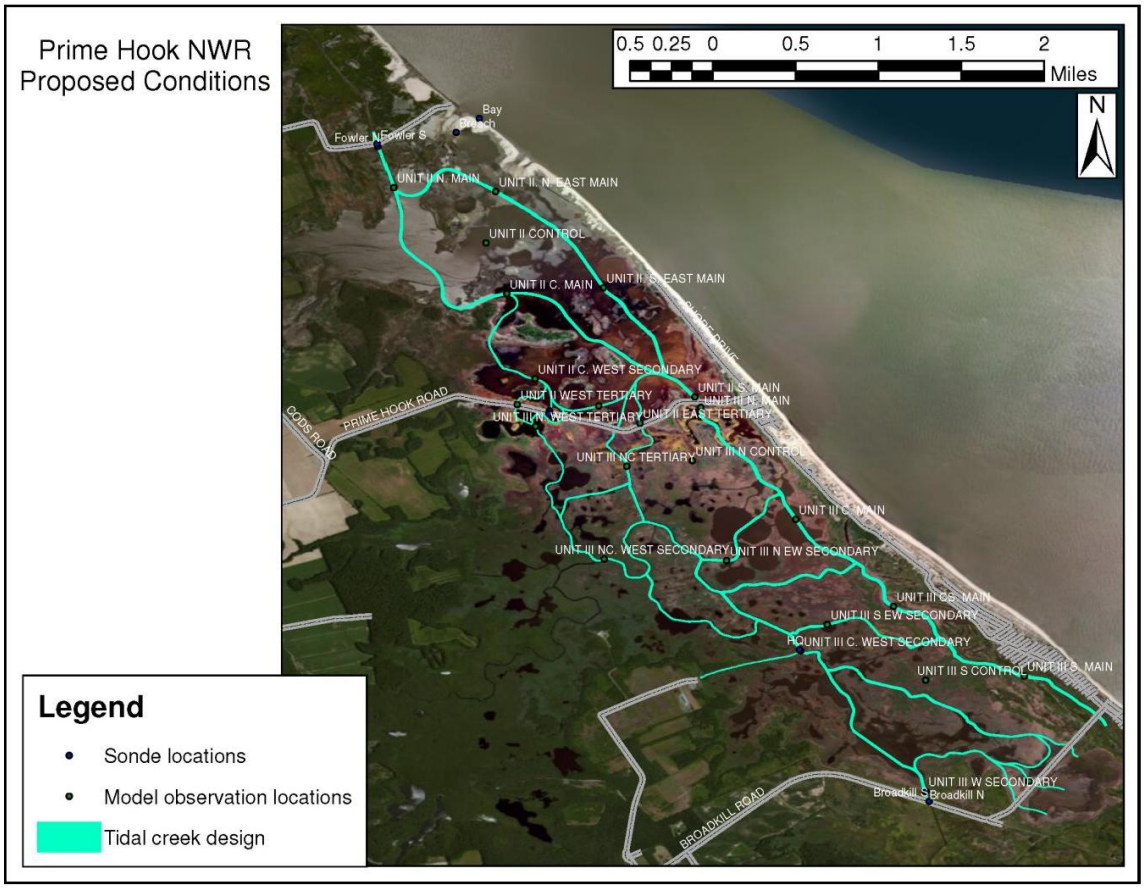

Figure 1. **Measured data and model output locations within Units II and III.**

Table 1. **Maximum water levels within the Refuge during "normal" conditions (ft NAVD88).**

Location	Station	Measured (2013/14)	Modeled		
			Existing conditions	Breach closure only	Final design
Unit II	FowlerS	4.5	2.8	1.5	1.4
	PrimeHookN	4.5	2.8	1.5	1.4
Unit III	PrimeHookS	4.2	2.1	1.4	1.3
	HeadQ	4.2	1.9	1.5	1.4
Prime Hook Beach	Unit II S Main	n/a	2.8	1.5	1.4
	Unit III N Main	n/a	1.9	1.5	1.4
Broadkill Beach	Unit III C S Main	n/a	1.9	1.5	1.4
	Unit III S Main	n/a	1.9	1.5	1.4

Table 2. Maximum water levels within the Refuge during Hurricane Sandy (ft NAVD88).

Location	Station	Measured	Modeled		
			Existing conditions	Breach closure only	Final design
Unit II	FowlerS	5.6	5.2	4.0	4.0
	PrimeHookN	5.0	5.0	3.9	3.9
Unit III	PrimeHookS	4.6	4.9	3.9	3.9
	HeadQ	5.5	4.8	3.9	3.9

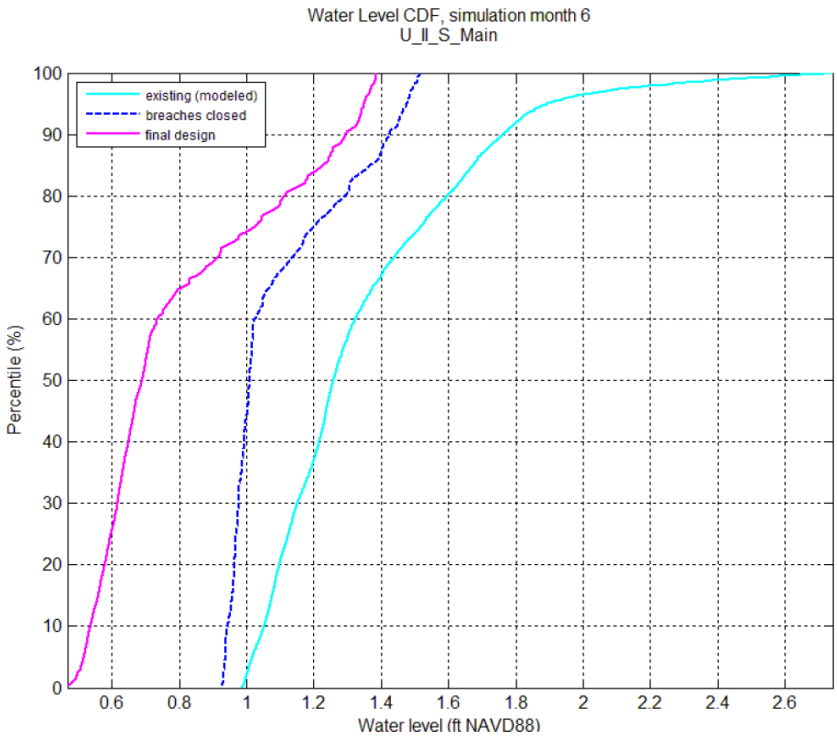

Figure 2. Modeled water level distributions for the 3 scenarios, Unit II at Prime Hook Beach.

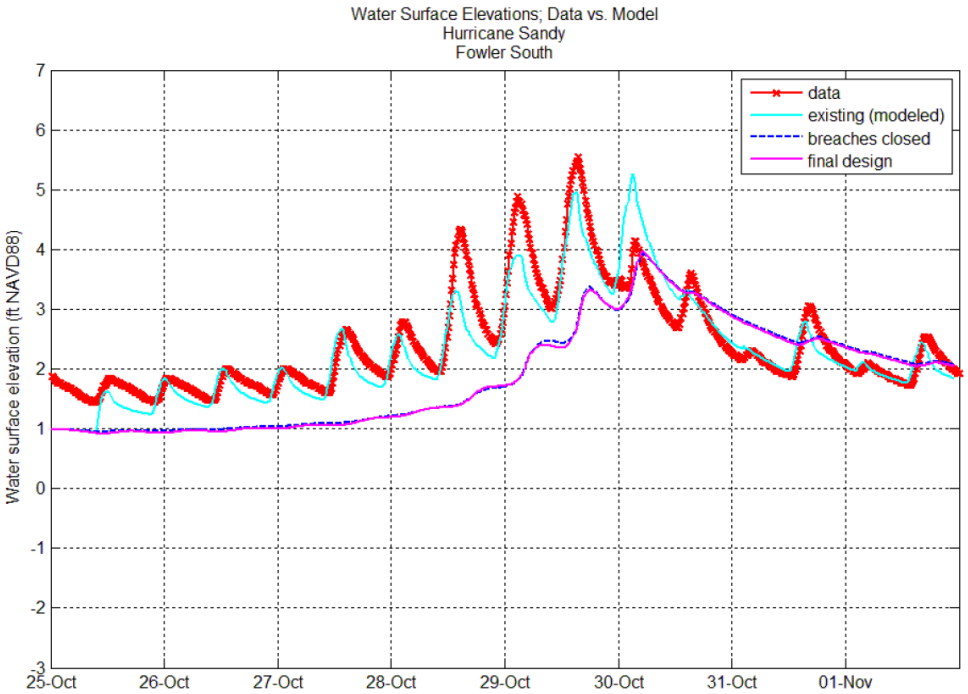

Figure 3. **Measured and modeled water levels during Hurricane Sandy in Unit II.**

Prime Hook National Wildlife Refuge Beach Restoration Project

Coastal Modeling Study

Submitted to:

US Army Corps of Engineers

November 25 2014

Contract No. W9128F-09-D-0041, Task Order No. CK01

Prepared by:

ATKINS

Louis Berger

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Executive summary

Prime Hook National Wildlife Refuge (Refuge) and its adjacent water bodies are important natural features along western Delaware Bay and throughout the region, providing critical stopover sites for migratory birds and habitat for many species of fish and wildlife. Over the past several years, large portions of the Refuge's managed impoundments have reverted to saline conditions, largely due to severe storm events that caused inland flooding, beach erosion, and several overwashes/breaches along the barrier island fronting the Refuge. Because of these breaches, the Refuge impoundments have been inundated with saltwater, resulting in loss of freshwater vegetation, oxidation of organic soils, and loss of sediments. Consequently, there has been a shift from freshwater marsh to a largely open saltwater embayment that has been slow to recover. Most recently, the slow recovery of marsh vegetation was exacerbated by Hurricane Sandy. Several new breaches have opened and the existing breaches have expanded and deepened.

The U.S. Army Corps of Engineers (USACE), Philadelphia District entered into a supportive agreement with the United States Fish and Wildlife Service (USFWS) to provide design services for the Refuge Breach Closure Project. As part of that agreement to provide design services, USACE requested coastal engineering support services from an A/E Consultant (Atkins and Louis Berger) to complete a coastal engineering analysis to design the breach closure. Recommendations regarding design dimensions utilized the Storm-induced BEAch CHange (SBEACH) numerical model for estimating the berm width and elevation sufficient to protect against the design storm impacts. A coupled hydrodynamic-wave model, Delft3D, was used to conduct an analysis of the alterations to the local wave field at the shoreline and potential borrow area due to the proposed dredging.

The SBEACH model was run based on the results of a storm surge and wave model of Hurricane Sandy, an approximately 30-year return period event in the project area. The results of the SBEACH modeling show that a 20-foot equilibrium storm berm width would be able to withstand a storm event of similar scale to Hurricane Sandy. This beach berm width would mostly erode away during the storm event, but the dunes would remain largely intact. While the 20-foot berm width would provide sufficient protection from the storm event, additional berm width is required to account for estimated historical loss rates of 3 to 5 feet per year. This results in a total equilibrium beach berm width of 110 to 170 feet for the 30-year design horizon.

The results of the wave modeling effort indicate that under a variety of wind and wave conditions, the wave characteristics at the shoreline adjacent to the borrow area are affected only to a small degree even for the maximum potential dredge cut. There are no indications that appreciable changes to wave energy or littoral transport, such as changes in transport direction or the creation of wave focusing "hot spots" would occur.

1. Introduction

Prime Hook National Wildlife Refuge (Refuge) and its adjacent water bodies are important natural features along western Delaware Bay and throughout the region, providing critical stopover sites for migratory birds and habitat for many species of fish and wildlife. The Refuge wetlands are divided into four management units, all of which have experienced major changes over the past decade in terms of habitat, sedimentation, and water circulation. Two of these management Units, II and III, were historically salt and brackish marsh habitats that were diked and managed as freshwater impoundments starting in the early 1980s. Over the past several years, portions of these impoundments have reverted to saline conditions, largely due to recent severe storm events that caused flooding, erosion, and several overwashes/breaches along the barrier island fronting the Refuge.

Because of these breaches, portions of the Refuge have been inundated with saltwater, resulting in loss of freshwater vegetation (due to toxic effects of salt) and oxidation and dispersal of organic soils (due to oxidation of organic sediments via sulfates in sea water), predominantly in Unit II. The subsequent effect in Unit II, and increasingly in Unit III, has been a shift from freshwater marsh to a largely open saltwater system that has been slow to become re-established as a saltmarsh under the altered conditions. Most recently, the Refuge (marsh and shoreline) underwent significant changes due to Hurricane Sandy. Several new breaches have opened and the existing breaches have expanded and deepened. Figure 1 presents the location of the Refuge on the coast of Delaware Bay, highlighting the four Unit designations from north to south.

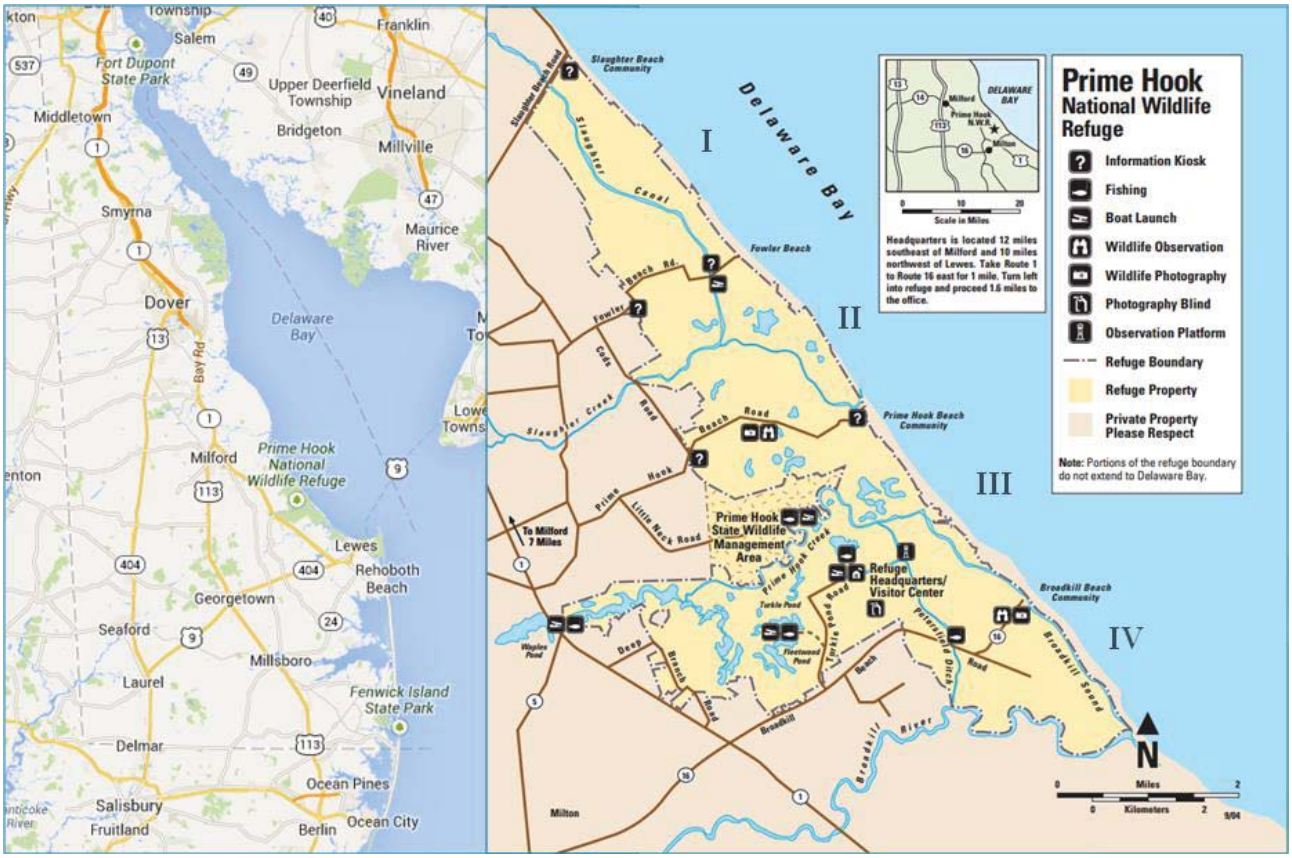

Figure 1. Location of Prime Hook NWR on Delaware Bay (left); map of the Refuge and the four management units (right).

In a 2009 study produced for the Delaware Department of Natural Resources and Environmental Control (DNREC), Atkins concluded, from data analysis and a study of previous work in the region, that the shoreline of Delaware Bay is a sediment-starved beach system. In the vicinity of Prime Hook NWR, net transport is from north to south; it is likely that the original breach opening in 2009 acted as sediment sink for migrating sand and thus starved the beaches immediately south. This was, likely a cause of the additional breaches opening during subsequent storms, as the beach did not have enough sediment volume to react without failure. In the same report, a wave and circulation modeling exercise concluded that, during a storm event, the area where the breaches now exist is somewhat of a 'hot spot' for higher current velocities due to the hydrodynamics of the Bay and Refuge. This is likely another contributing factor to the number and frequency of breach openings over the past few years.

2. Purpose

The U.S. Army Corps of Engineers (USACE), Philadelphia District entered into a supportive agreement with the United States Fish and Wildlife Service (USFWS) to provide design services for the Refuge Breach Closure Project per the terms and conditions of USACE – SERVICE 22 January 2003 Two-Way memorandum of Agreement (MOA). As part of that agreement to provide design services, USACE requested coastal engineering support services from an A/E Consultant (Atkins and Louis Berger) to assist with completing the work assignment. As a result, Contract No. W9128F-09-D-0041 was utilized to authorize Task Order CK01 for support coastal engineering services.

The purpose of this Task Order is to support the design of a protective dune system for the Refuge, specifically completing a coastal engineering analysis in support of the USACE to design the breach closure. Recommendations of design dimensions for building a protective dune system are provided herein. In addition to measured and estimated historical shoreline loss rates, the berm design utilized the Storm-induced BEAch CHange (SBEACH) numerical model for estimating the berm width and elevation sufficient to protect against the design storm impacts. In addition, a coupled hydrodynamic-wave model, Delft3D, which utilizes the spectral wave model SWAN, was used to conduct an analysis of the alterations to the local wave field at the shoreline and potential borrow area due to the proposed dredging.

This document presents recommendations for the Prime Hook NWR protective dune system, and includes guidance for implementing the proposed project goals and strategies. This document provides supporting information for the permitting and preparation of final design documents (to be prepared by USACE).

3. Existing Data

3.1. Topography and bathymetry

In order to develop a numerical model that represents real-world physical conditions as accurately as possible, a detailed and up-to-date elevation data set is crucial. To this end, a number of existing bathymetric and topographic data sets were used in the model creation:

- A Digital Elevation Model (DEM) for Delaware Bay, created for the updated ADCIRC model for FEMA Region III (Forte, 2011)
- The Sussex County, DE topographic DEM, developed by the Delaware Geological Survey (2005)
- Survey and LiDAR data of the breaches and surrounding areas, collected by VanDemark & Lynch, Inc. (VDM) as part of the Atkins hydrodynamic modeling effort for USFWS (Atkins 2014)
- Bathymetric survey data of the proposed borrow area collected during the geotechnical investigation by Gahagan & Bryant Associates, Inc. (GBA, 2014)

These sources were merged into a single elevation data set for use in the SBEACH and Delft3D models as well as for plan view and cross-section development.

3.2. Water levels

The hydrodynamic models incorporated extensive measurements of water level and salinity across a large expanse of the domain. Long-term tide gauge data pertinent to the modeling effort was available from ten NOAA gauge locations within the Atlantic Ocean, Delaware Bay, and the Delaware River, presented in Table 1.

Table 1. NOAA tide gauge stations with measured data within study area.

Station ID	Station Name	Longitude (° W)	Latitude (° N)	Data Start	Data End
8534720	Atlantic City, NJ	74.4180	39.3550	1911	present
8536110	Cape May, NJ	74.9600	38.9683	1965	present
8537121	Ship John Shoal, NJ	75.3750	39.3050	2002	present
8539094	Burlington, Delaware River, NJ	74.8683	40.0817	1979	present
8540433	Marcus Hook, PA	75.4100	39.8117	1981	present
8545240	Philadelphia, PA	75.1417	39.9333	1989	present
8551910	Reedy Point, DE	75.5733	39.5583	1996	present
8555889	Brandywine Shoal Light, DE	75.1133	38.9867	1984	present
8557380	Lewes, DE	75.1200	38.7817	1957	present
8570283	Ocean City Inlet, MD	75.0920	38.3280	1997	present

3.3. Wind, waves, and freshwater inflow

In addition to tides and storm surge, the models were also driven by wind, waves, and freshwater inflow. Measured hourly wind speed and direction is available at NOAA's NDBC station 44009, 26 nautical miles southeast of Cape May, NJ (38.461° N, 74.703° W), from 1984-present. This location also has measured wave parameters available from 1993-present.

For Delaware Bay as a whole, the two major freshwater influences are the Delaware River itself at Trenton, NJ, the upstream limit of tidal influence, and the Schuylkill River near Philadelphia, PA. The United States Geological Survey (USGS) maintains flow gauges for each of these rivers; Station 01463500 (Delaware River at Trenton, NJ) and Station 01474500 (Schuylkill River at Philadelphia, PA).

4. SBEACH Modeling and Berm Design

4.1. Model description

For this effort, the Storm-induced BEAch CHange (SBEACH) numerical model, developed by the USACE, was used for estimating the equilibrium storm berm width and elevation sufficient to protect against the design storm impacts. SBEACH is a 1-dimensional numerical model that evaluates beach profile morphology due to wind, wave, and storm surge effects along cross-shore (shore-perpendicular) transects. The design storm conditions are based on results of a numerical storm surge and wave model simulation of Hurricane Sandy, an approximate 30-year return period event in Delaware Bay (see Section 5 for details of the surge and wave model).

4.2. Model development

The development of the SBEACH model included transect selection, input profile creation, construction of the design storm boundary conditions, and a sensitivity analysis of the morphologic input parameters that affect sediment transport within the model.

4.2.1. Transect selection

Eight cross-shore transects were selected for SBEACH evaluation. These transects were based on the most recent elevation data for the breach area and offshore (January 2013 LiDAR survey, Atkins 2014) and the borrow area bathymetric survey (GBA 2014). Figure 2 shows the locations of the selected SBEACH analysis profiles/transects. SBEACH transects 1 through 5 are within the proposed breach fill project area, while transects 6 through 8 are south of the project area where the dune is somewhat intact. Transects 6 through 8 also aided in aligning the fill template with the existing dune line.

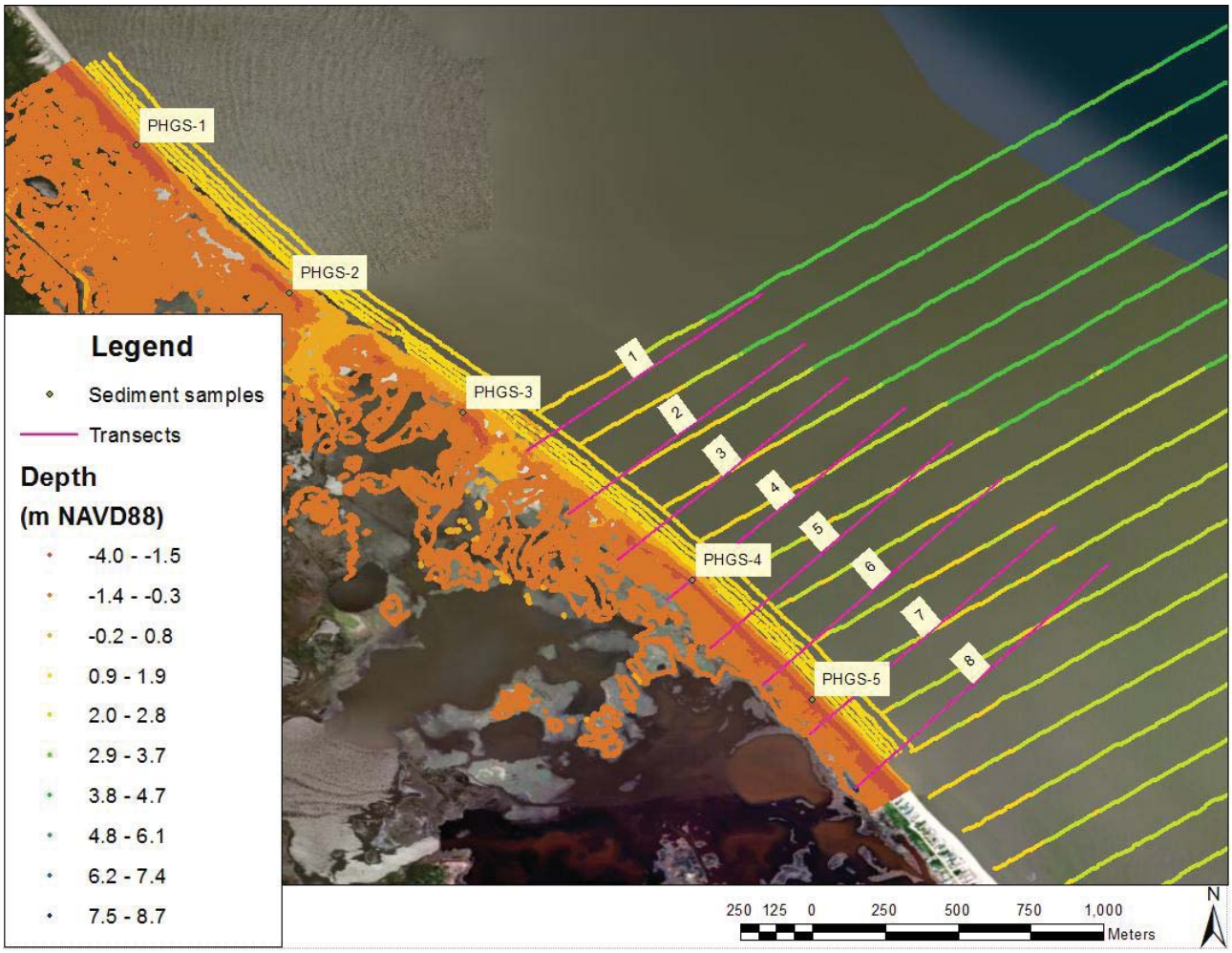

Figure 2. SBEACH transect locations, showing the most recent available elevation data.

4.2.2. SBEACH profile development

The beach fill template input into SBEACH includes a 40-foot wide dune at an elevation of +9.8 feet NAVD88 fronted by a 1V:3H slope down to the beach berm at an elevation of +7.2 feet NAVD88. These elevations were selected from a previous study aimed at the design of a beach nourishment project along the Prime Hook Beach community (Atkins, 2009). The tested storm berm widths varied from 15 feet to 110 feet. Beyond the berm, an equilibrium beach profile (Dean 2003) extended down from the seaward edge of the berm until the intersection with the offshore existing profile. Figure 3 illustrates a typical fill template with a 20-foot berm width.

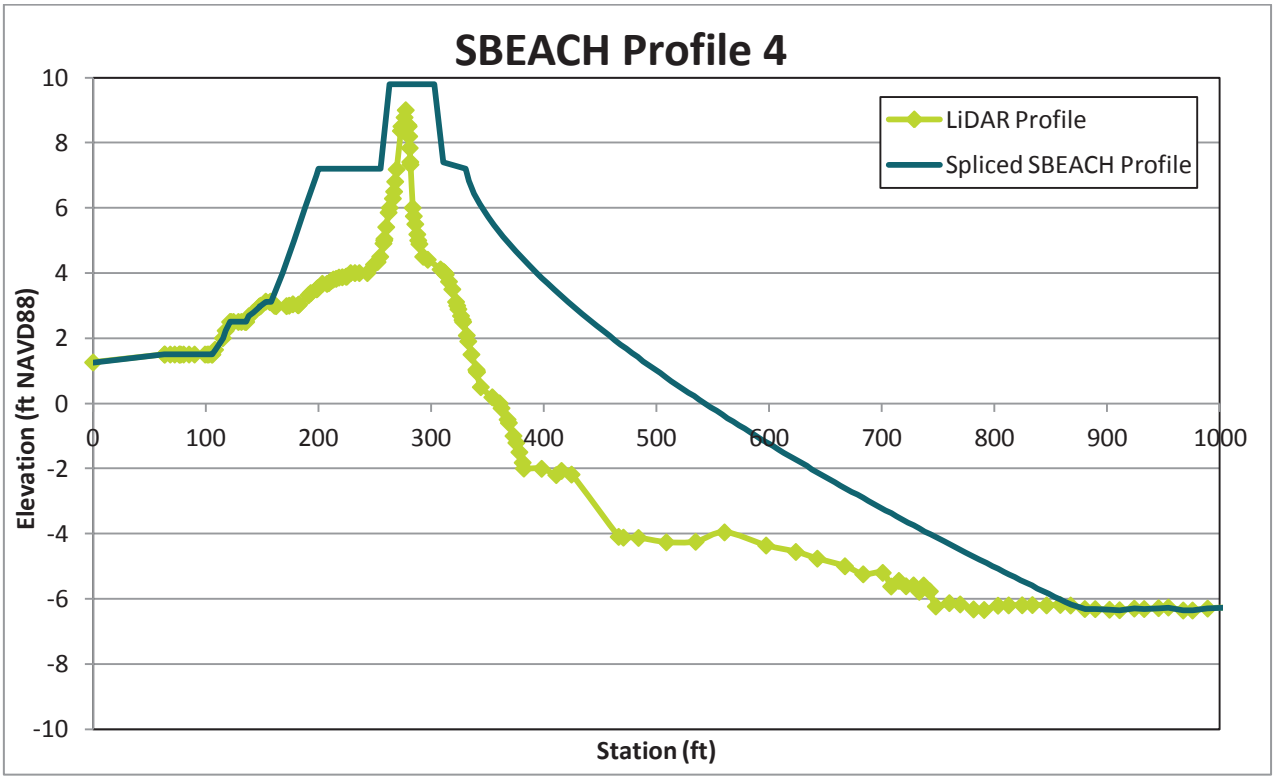

Figure 3. Typical fill template used in the SBEACH modeling.

The profile berm slope is an important factor for SBEACH stability. Perfectly flat profile segments usually result in model instability, so the flat top of the berm and dune crest were given a slight slope (1V:100H) when input into SBEACH.

SBEACH allows for a maximum of 1000 grid cells in the profile analysis. Due to this limitation and the length of the input profiles, a variable grid was selected. This allowed for 2-foot grid resolution for the first 1000 feet from the landward edge of the SBEACH profile. For all eight SBEACH transects, this was far enough offshore to reach the existing bathymetric profile (i.e. offshore of the merge point of the equilibrium profile and existing data). From 1000 feet offshore to the end of the profile, the grid spacing was increased to 5 feet, allowing for the full profile to be accounted for.

4.2.3. Storm event - water level and wave input

The design storm used for equilibrium storm berm width in SBEACH was Hurricane Sandy, an approximately 30-year return period event within Delaware Bay. Hydrodynamic and wave model results offshore of the transect endpoints were used for SBEACH input. Section 5 describes the wave and surge models, as well as the forcing conditions. Time series for water level, wave height, wave period, wind speed, and wind direction were translated from the model outputs into the SBEACH model for analysis. Model output was recorded at

15-minute intervals; however, model instabilities proved this to be too coarse of a timestep. The SBEACH boundary conditions were interpolated to a 5-minute time step, resulting in more stable and smoother morphological results. Figure 4 illustrates the modeled wave height, wave period and water level time series for Hurricane Sandy offshore of the project, while Figure 5 shows the time series for wind speed and wind direction.

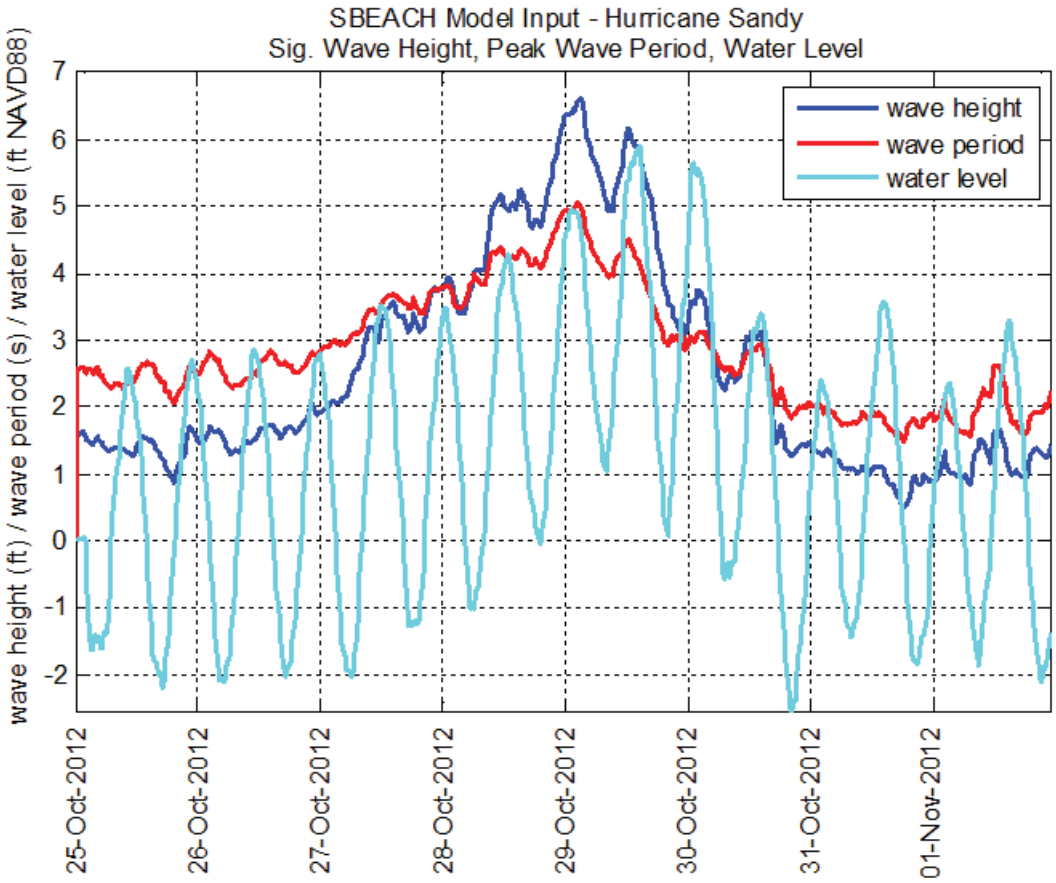

Figure 4. SBEACH forcing conditions; water level, wave height, and wave period.

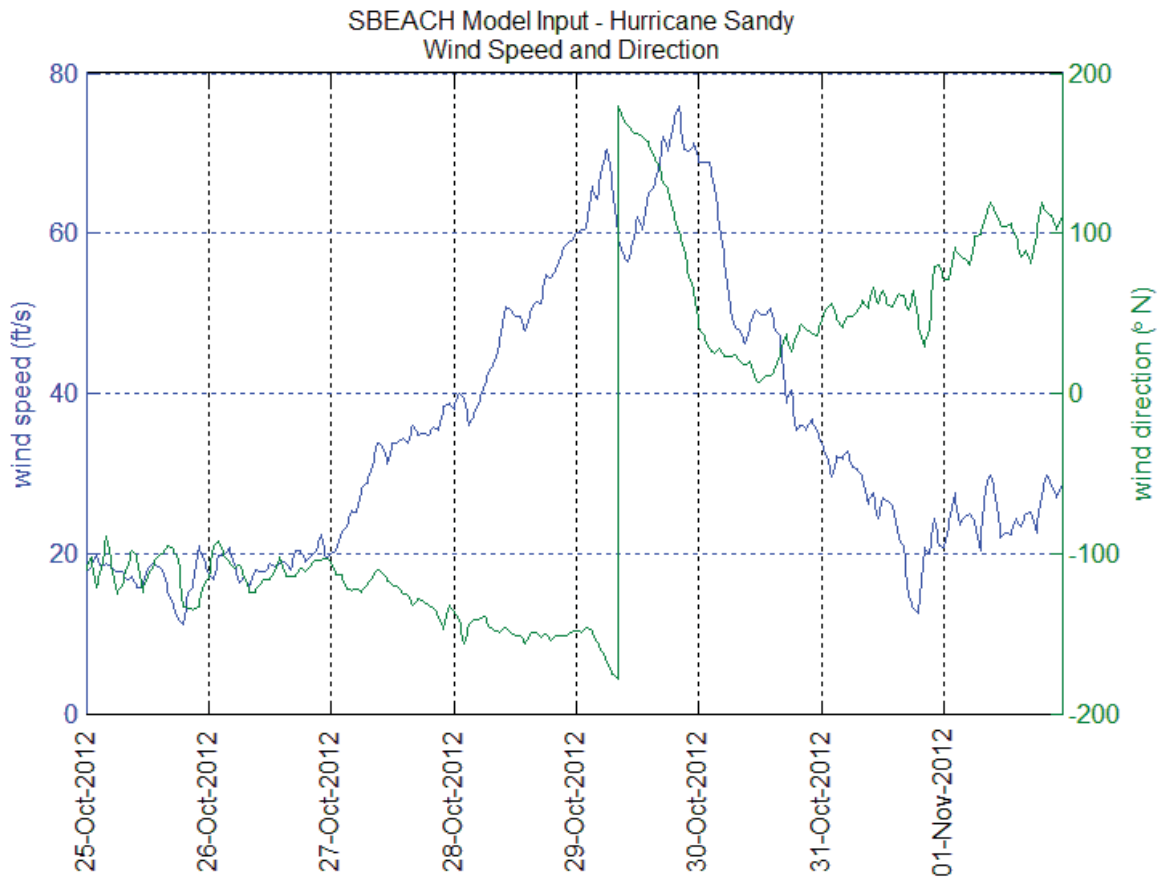

Figure 5. SBEACH forcing conditions; wind speed and wind direction.

4.2.4. SBEACH input parameters

In addition to the cross-shore profile and storm data, SBEACH requires morphological parameters to quantify the type of sediment representative of the transect, including effective grain size and maximum slope prior to avalanching. The effective grain size is the median grain size (mm) of the fill source. Prime Hook Borrow Area B is the proposed fill source for the beach berm placement. Based on the geotechnical report provided by Gahagan & Bryant Associates Inc. (Gahagan & Bryant 2014), the median grain size for the composite Prime Hook Borrow Area B (PHB-B Comp.) is 0.35 mm. The maximum slope prior to avalanching was tested for sensitivity, but the slopes of the eroded berm were not steep enough to be visibly influenced by this parameter. It was decided to keep this parameter at the default SBEACH value since the resultant profile was not affected.

The remaining SBEACH inputs are the sediment transport parameters, which govern the magnitude and distribution of erosion and deposition along the profile. These include the transport rate coefficient, overwash transport parameter, coefficient for slope-dependent term, transport rate decay coefficient multiplier, and water temperature. The water temperature was adjusted to 15°C based on the location of the project in southern Delaware Bay and the timeframe of late October for Hurricane Sandy. After sensitivity testing, the transport rate coefficient, overwash transport parameter and transport rate decay coefficient multiplier were left at their default values. The coefficient for slope-dependent term was adjusted to a value of 0.005 in order to induce the expected bar-trough erosion pattern, which is within the acceptable range for this value (0.001 to 0.005).

4.3. Model results

SBEACH results for storm berms of 15 feet and 20 feet in width are provided in this section, along with evaluation of historical erosion rates from existing documentation. A summary table is provided showing the resulting total equilibrium berm and its components.

4.3.1. SBEACH

SBEACH was run for storm berm widths of 15 feet and 20 feet. The SBEACH results for the 15-foot berm show that the erosion losses extended into the proposed dune feature. Figure 6 shows the resultant eroded SBEACH profile at Transect 4 with a 15-foot berm width. The SBEACH eroded profiles at the remaining 7 transects are provided in Appendix A.3, including the approximate extent shown below and a zoomed in version emphasizing the storm berm template. In these figures, the existing ground elevation is shown in yellow, the initial SBEACH profile is in dark blue, and the eroded profile is purple.

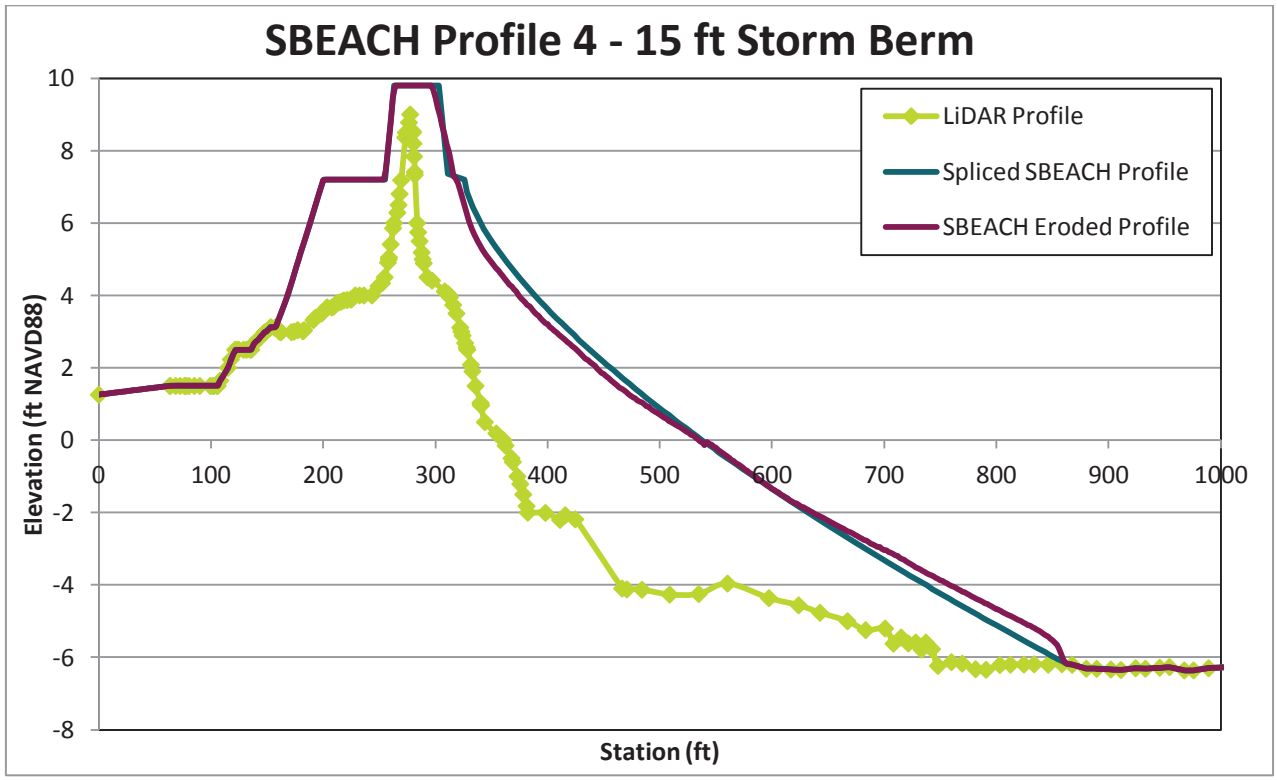

Figure 6. SBEACH results; Transect 4, 15-foot equilibrium berm width.

For the 20-foot equilibrium storm berm scenario, the majority of the berm erodes away, but the dune feature remains intact. Therefore, the 20-foot storm berm is recommended for this project. Figure 7 shows the resultant eroded SBEACH profile at Transect 4 with a 20-foot berm width. The SBEACH eroded profiles at the remaining 7 transects are provided in Appendix A.4, including the approximate scale shown below and a zoomed in version emphasizing the storm berm template.

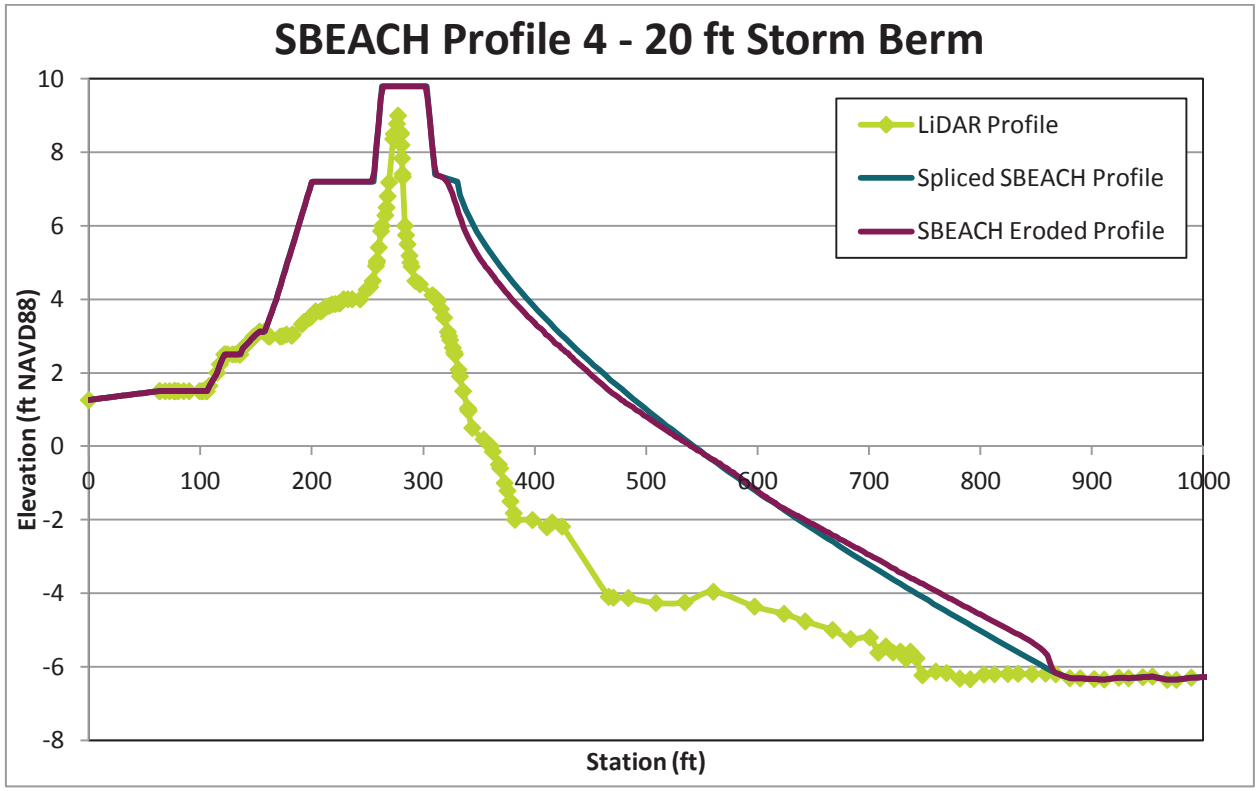

Figure 7. SBEACH results; Transect 4, 20-foot equilibrium berm width.

4.3.2. Historical erosion rates

In addition to modeled storm losses, the total berm design width recommendation accounts for historical shoreline erosion rates. Atkins (2009) conducted a thorough review of a variety of studies regarding measured and predicted shoreline erosion rates in Delaware Bay, and in the project vicinity (Prime Hook Beach), the historical loss rate is estimated to be between 3 and 5 feet per year. Accordingly, based on a 30-year design horizon, an additional berm width of 90 to 150 feet is required to account for historical shoreline recession rates.

4.3.3. Summary table

Table 2 and Table 3 present a summary of all design parameters and results of the SBEACH and historical erosion rate analyses. The recommended equilibrium storm berm width is 20 feet, based on the design event (Hurricane Sandy). An additional 90 to 150 feet of berm width accounts for historical loss rates based on a 30-year design life and shoreline recession rates of 3 to 5 feet per year. The resultant 30-year equilibrium berm width ranges from 110 to 170 feet, depending on the applied historical loss rate.

In addition to the berm widths, estimates of unit volume placements are also presented. These values were calculated using the method of Dean (1992), which accounts for the depth of closure, native and fill sediment diameters, berm height, and the desired equilibrium berm width (storm width plus advance fill for historical losses) after the fill template adjusts to local conditions. It must be emphasized that this volume placement accounts only for the volume necessary to extend the berm by the desired width, and does not include the volume needed to raise the berm from existing grade or construct the dune and back-bay features. Depending on the historical loss rate, the estimated volume necessary to extend the berm by 110 to 170 feet is 90 yd^3/ft to 136 yd^3/ft, respectively.

Table 2. Summary of design parameters for breach fill project.

SBEACH profile parameters	Dune width (ft)	40
	Dune elevation (ft NAVD88)	9.8
	Dune slope (v:h)	1:3
	Storm berm width range (ft)	15 to 20
	Berm elevation (ft NAVD88)	7.2
	Foreshore slope[1]	equilibrium
	Median grain size[1] (d_{50}, mm)	0.35
	A parameter for equilibrium profile[1] ($m^{1/3}$)	0.135
	A parameter for equilibrium profile[1] ($ft^{1/3}$)	0.2025
30-year storm parameters (Hurricane Sandy)	Maximum significant wave height (ft)	6.61
	Maximum peak wave period (s)	5.05
	Peak water surface elevation (ft NAVD88)	5.89
Net unit volume loss (above MLW[2]) from SBEACH erosion runs (yd^3/ft)	Profile 1	2.61
	Profile 2	2.61
	Profile 3	2.69
	Profile 4	2.71
	Profile 5	2.76
	Profile 6	2.77
	Profile 7	2.81
	Profile 8	2.74
Total equilibrium berm components (including storm and historical loss rate)[3]	Dune width (ft)	40
	Dune elevation (ft NAVD88)	9.8
	Dune slope (V:H)	1:3
	Storm berm width (ft)	20
	Berm elevation (ft NAVD88)	7.2
	Foreshore slope[1]	equilibrium
	Borrow area median grain size[1] (d_{50}, mm)	0.35
	A parameter for equilibrium profile[1] ($ft^{1/3}$)	0.2025
	Historical loss rate alternative 1 (ft/yr)	-3.0
	Historical loss rate alternative 2 (ft/yr)	-4.0
	Historical loss rate alternative 3 (ft/yr)	-5.0
30-year historical loss (ft)	Historical loss rate alternative 1	90
	Historical loss rate alternative 2	120
	Historical loss rate alternative 3	150

Notes:
1. Equilibrium profile determined by the composite median grain size (d50) from Prime Hook Borrow Area B.
2. Mean Low Water (MLW) is -2.5 ft NAVD88 (at Lewes, DE).
3. Total equilibrium berm is not the final construction template

Table 3. Total equilibrium berm width and unit volume placements (berm only).

30-year total equilibrium berm width[1] (ft)	Historical loss rate alternative 1	110
	Historical loss rate alternative 2	140
	Historical loss rate alternative 3	170
Total equilibrium berm (30-year) unit volume placement[2] (yd^3/ft)	Historical loss rate alternative 1	90
	Historical loss rate alternative 2	113
	Historical loss rate alternative 3	136

Notes:
1. SBEACH storm design berm plus historical loss rate scenarios
2. Unit volume placement only includes the total equilibrium berm volume. Dune and back bay volumes are not included in this value.

4.3.4. Final plan view and cross-sections

Plan view and cross-section drawings of the recommended 30-year breach fill and berm dimensions are provided in Appendix B.

5. Wave Transformation Modeling

5.1. Overview

Atkins' previous modeling effort for USFWS (Atkins 2014) included the development of a Delft3D hydrodynamic model calibrated for use in predicting water level fluctuations due to tides, winds, storm surge, and freshwater inflow in the vicinity of Prime Hook NWR. Please refer to this report for the full details of the model development.

For the wave transformation model in this effort, a modified version of the aforementioned Delft3D model was utilized for both hydrodynamics and waves, which excluded the inland Refuge portion of the previous grid and added a nested wave grid encompassing the project site and borrow area for detailed wave modeling. The model was driven, depending on the forcing scenario, by wind, offshore waves, measured offshore water levels, and freshwater inflow. A total of 11 scenarios were modeled: 10 'seasonal' wind and wave conditions, and Hurricane Sandy. Each condition was modeled both with and without the maximum dredge cut to the borrow area. Analysis of model results focused on examining the differences in wave height and energy transport magnitudes and directions in the nearshore and within the borrow area.

5.2. Model development

The hydrodynamic and wave model used in this effort was developed based on Atkins' previous work with USFWS (2014). The six subdomains of the main Delaware Bay grid were combined into a single grid, while the Refuge portion of the grid was removed and replaced with a continuation of the Bay domain to the shoreline at similar resolution to the main body. This was done because the Refuge grid for the USFWS study was highly detailed and extended significantly far inland, which was unnecessary and computationally inefficient for this effort. This grid was the primary model domain for hydrodynamics and wave transformation on which all boundary forcing conditions (wind, waves, water levels, and inflow) were applied.

In addition to the primary grid, a 'nested' model grid was developed in the vicinity of the project site and proposed borrow area. This grid had a spatial resolution of 40 m and incorporated the detailed survey and LiDAR data adjacent to the shoreline and proposed borrow area described in Section 3.1. The nested grid

was dynamically coupled with the primary grid in the Delft3D wave module and required no boundary conditions of its own. This grid was the domain in which the two borrow area scenarios (existing and full dredge cut) were applied to the bathymetry. Figure 8 illustrates the domain and bathymetry of the primary model domain, while Figure 9 shows the detail of the model domain in the project vicinity.

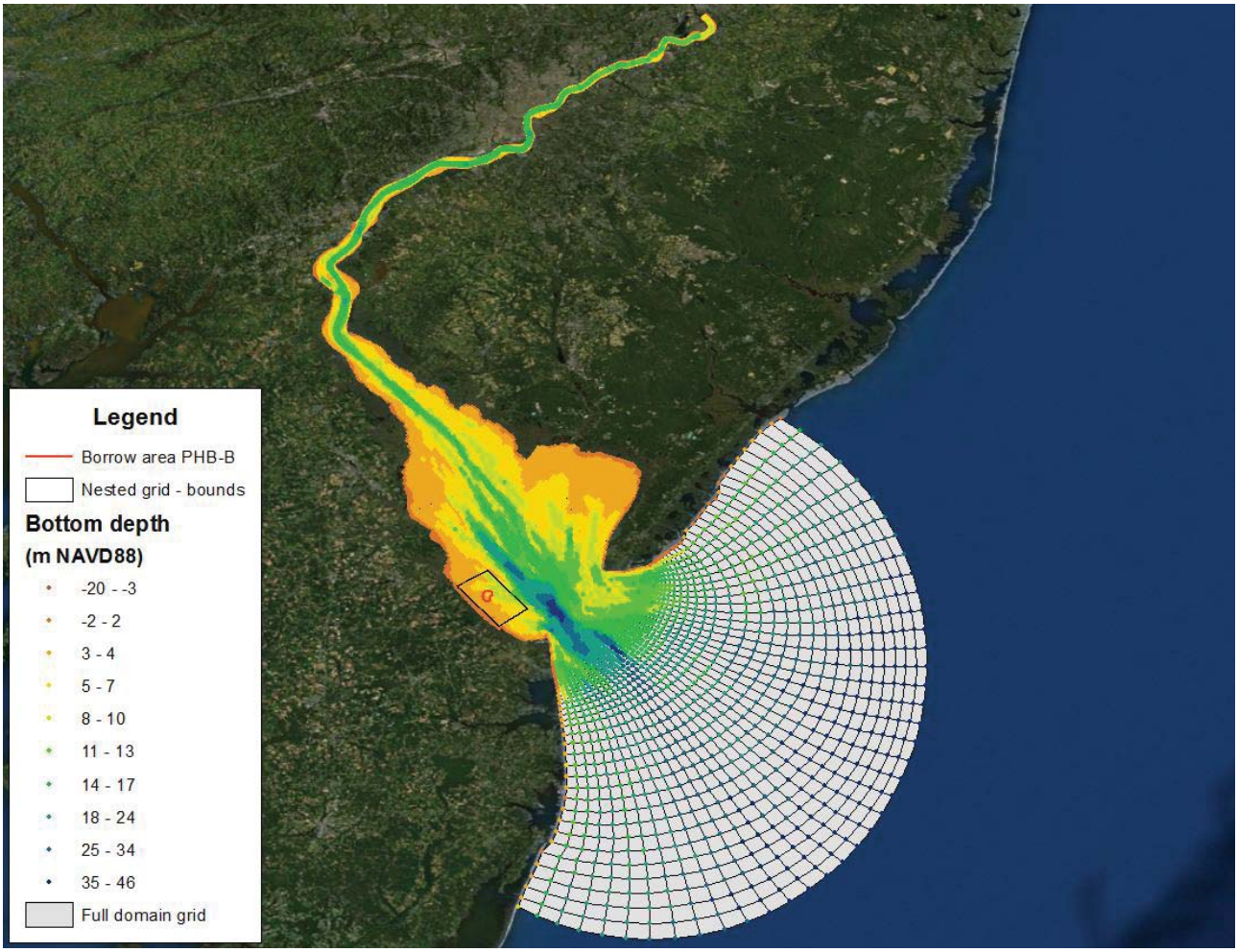

Figure 8. Primary Delaware Bay model domain for hydrodynamics and waves.

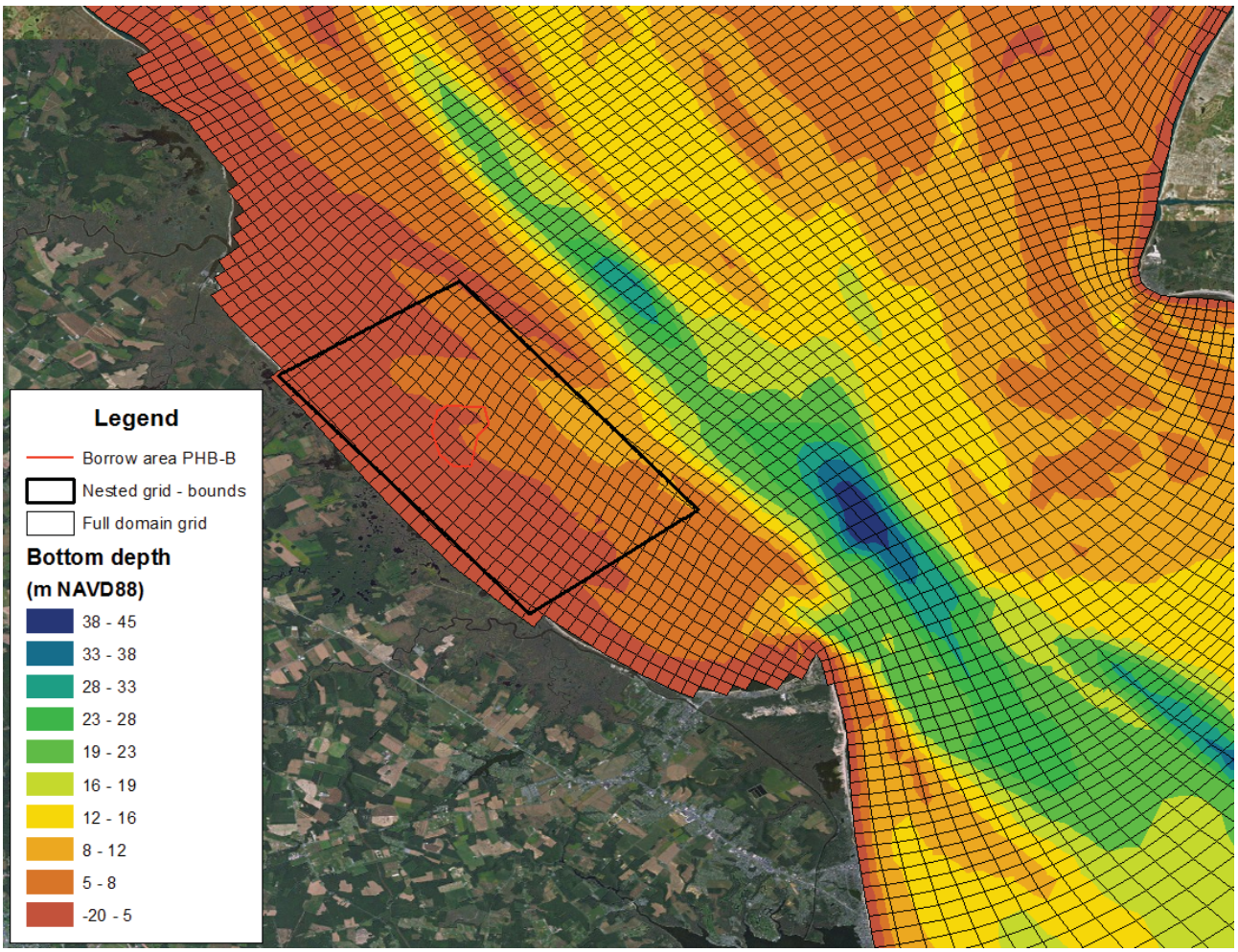

Figure 9. Primary model domain in the vicinity of the project, with nested wave grid boundary.

5.3. Potential borrow area

Based on the geotechnical analysis of the potential borrow sites (Gahagan & Bryant 2014), Prime Hook Borrow Area B (PHB-B) was selected for the modeling effort. The area was divided into three parts based on sand thickness, and the full dredge cut consists of three sections; two sections dredged to 5 ft (1.5 m) below existing grade, and one section cut to 3.5 ft (1.1 m) below existing grade. Figure 10 and Figure 11, respectively, illustrate the existing and fully-dredged bathymetry of the nested borrow area wave grid, along with the boundaries of each cut location.

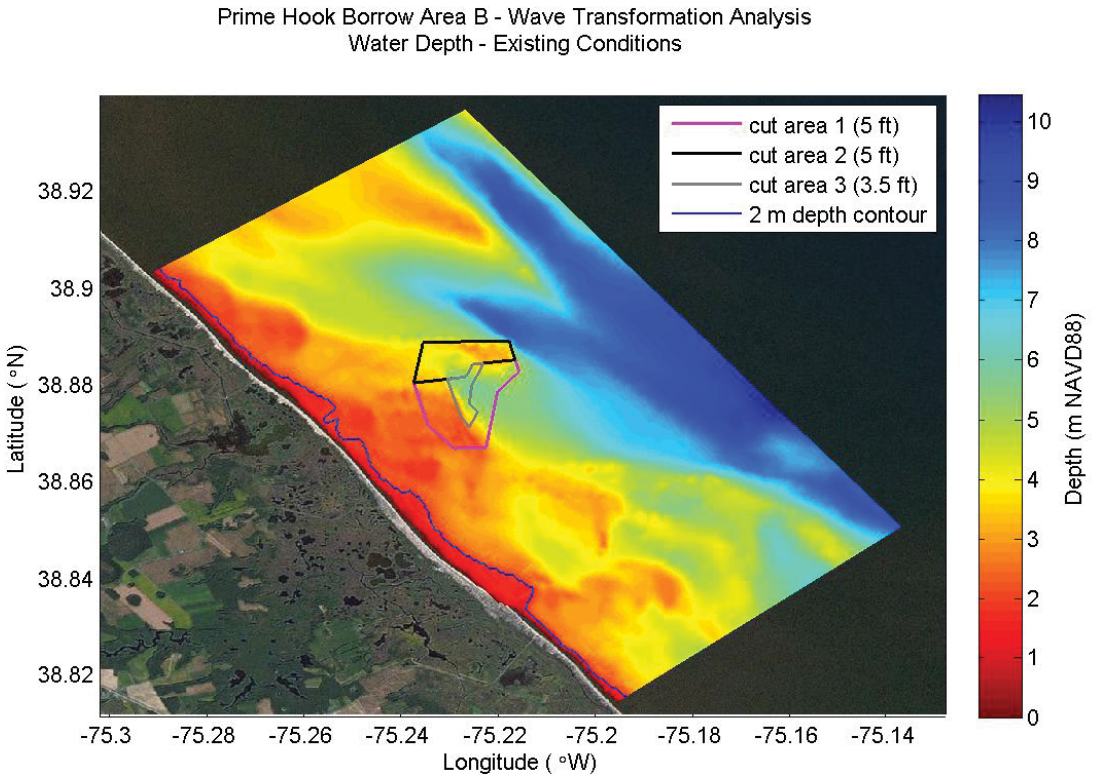

Figure 10. Existing bathymetry in the vicinity of the project site and borrow area.

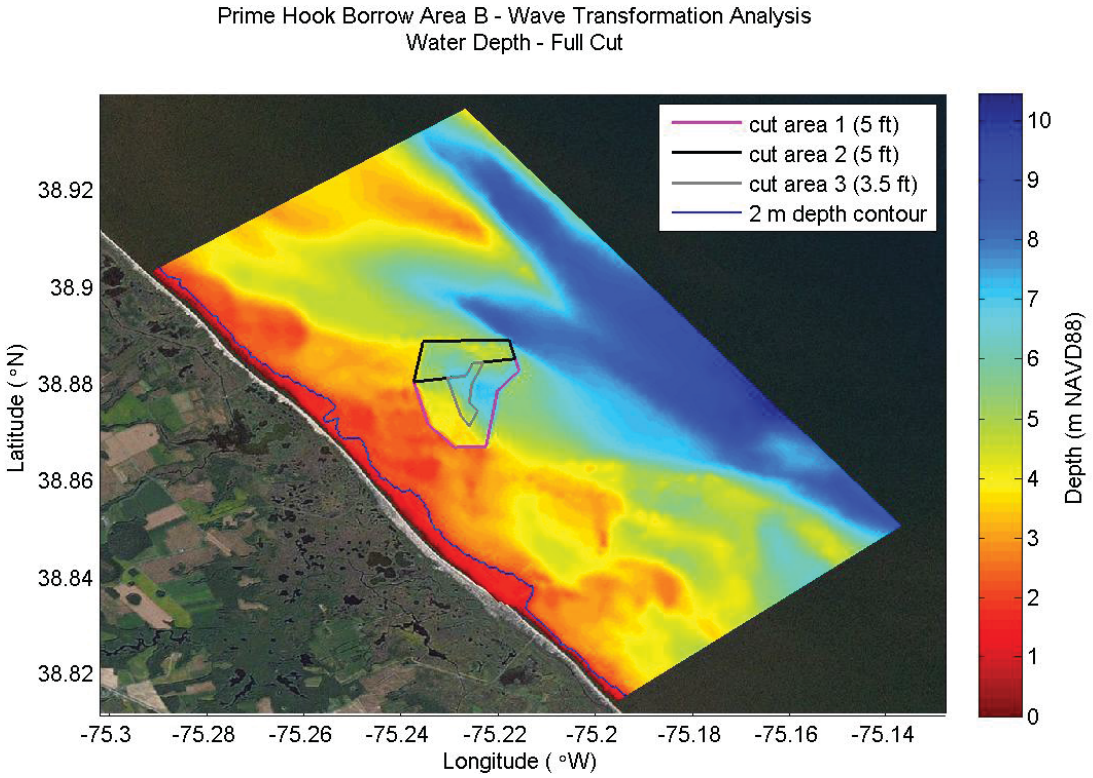

Figure 11. Fully-dredged bathymetry in the vicinity of the project site and borrow area.

5.4. Wave forcing conditions

The wave model was run using both the existing and fully-dredged bathymetries for a total of 11 conditions: annual, winter, spring, summer, and fall prevailing winds, both with and without seasonal average offshore waves included, as well as replicating the wind, wave, and storm surge characteristics of Hurricane Sandy. The seasonal wind conditions for the region were taken from the thesis of Maurmeyer (1978), which was examined in depth in Atkins' 2009 report for DNREC. The seasonal offshore wave conditions were developed from NOAA station 44009, which has measured directional wave data from 1993 through 1998 and spectral wave data from 1998 to the present, also examined in Atkins (2009). For Hurricane Sandy, measured water levels from the NOAA tide stations at Ocean City, MD and Atlantic City, NJ were used to drive the offshore tide boundary, while winds over the domain and waves at the offshore boundary came from NOAA station 44009. Freshwater inflows from USGS measured data were applied at the Delaware River (Trenton, NJ) and the Schuylkill River. For more details on the Hurricane Sandy boundary conditions, see Atkins (2014). A summary of the seasonal conditions is presented in Table 4.

Table 4. Wind and wave conditions for the 10 seasonal scenarios.

Offshore waves	Season	Sig. wave height (m)	Peak wave period (s)	Wave direction (deg N)	Wind speed (m/s)	Wind direction (deg N)
No	Annual	--	--	--	4.9	315 (NW)
	Winter	--	--	--	5.7	315 (NW)
	Spring	--	--	--	5.3	315 (NW)
	Summer	--	--	--	3.6	180 (S)
	Fall	--	--	--	4.7	45 (NE)
Yes	Annual	1.2	7.6	112.5 (ESE)	4.9	315 (NW)
	Winter	1.5	7.7	90 (E)	5.7	315 (NW)
	Spring	1.2	7.6	90 (E)	5.3	315 (NW)
	Summer	0.9	7.4	135 (SE)	3.6	180 (S)
	Fall	1.2	7.7	112.5 (ESE)	4.7	45 (NE)

5.5. Model simulations

For the 10 seasonal conditions, Delft3D-WAVE module was run in standalone mode, meaning the winds (and offshore waves, if applicable) were applied to the model and fully-developed wave conditions were computed. The result was a single set of wave conditions over the domain for each 'season'. For the Hurricane Sandy runs, waves and hydrodynamics were dynamically coupled within the Delft3D model, meaning that hydrodynamic results were utilized by the wave model and vice-versa and a time series of wave and water level conditions was produced for the duration of the event. In all cases, the results on the nested wave grid were used to make comparisons between existing and fully-dredged conditions. Waves and water levels from the Hurricane Sandy run were also extracted offshore of the project area for use in the SBEACH analysis (Section 4).

5.6. Model results

To estimate the effect of the maximum potential borrow area dredge on wave conditions both in the nearshore and at the borrow area, pre- and post-dredge comparisons of significant wave height, mean wave direction, energy transport, and energy transport direction were evaluated for each seasonal condition, the peak value at each model point of all seasons, and the highest value during Hurricane Sandy. The nearshore was defined by the -2.0 m NAVD88 elevation contour (shown in Figure 10 and Figure 11), which

is just offshore of the depth of closure and deep enough to avoid boundary and wave breaking effects in the model. In Delft3D, energy transport is defined as power per unit length (W/m), or equivalently force per unit time (N/s).

Figure 12 through Figure 19 illustrate the significant wave height and energy transport magnitudes and directions for pre- and post-dredge conditions, as well as the differences between the scenarios, for annual prevailing winds and offshore waves across the entire nested wave model domain. Figure 20 and Figure 21 show the maximum wave height and energy transport magnitudes and differences of all seasonal conditions for pre- and post-dredge conditions at the nearshore contour. Figure 22 and Figure 23 show the maximum wave height and energy transport magnitudes and differences during Hurricane Sandy for pre- and post-dredge conditions at the nearshore contour. A full set of figures for all conditions, including Hurricane Sandy, can be found in Appendix C.

Summaries of the changes in wave height, wave direction, energy transport, and energy transport direction are found in Table 5 through Table 16. In the nearshore, for all seasonal scenarios, the maximum change in wave height is 0.01 m (5%), the maximum change in wave direction is 3°, the maximum change in energy transport is 16 W/m (12%), and the maximum change in energy transport direction is 5°. In the borrow area, for all seasonal scenarios, the maximum change in wave height is 0.04 m (9%), the maximum change in wave direction is 16°, the maximum change in energy transport is 90 W/m (40%), and the maximum change in energy transport direction is 25°. In the nearshore, during Hurricane Sandy, the maximum change in wave height is 0.02 m (1%), the maximum change in wave direction is 5°, the maximum change in energy transport is 350 W/m (7%), and the maximum change in energy transport direction is 10°. In the borrow area, during Hurricane Sandy, the maximum change in wave height is 0.30 m (20%), the maximum change in wave direction is 15°, the maximum change in energy transport is 2800 W/m (60%), and the maximum change in energy transport direction is 10°. It is important to note that in the cases of Hurricane Sandy and the maximum of all seasons, the direction corresponding to the maximum change can be difficult to define precisely as the maximum value of energy transport or wave heights can occur at more than one instance.

5.7. Conclusions

Overall, during normal seasonal conditions, wave heights, wave energy, and direction in the nearshore and within the borrow area are minimally affected. During Hurricane Sandy, in the nearshore, the maximum wave height is increased by less than 5% and the maximum energy transport is increased by less than 10%. In the borrow area, the wave height is increased by 20% or less.

The results of the wave modeling effort indicate that under a variety of wind and wave conditions, the wave characteristics at the shoreline adjacent to the borrow area are affected only to a small degree even for the maximum potential dredge cut. There are no indications that appreciable changes to wave energy or littoral transport, such as changes in transport direction or the creation of wave focusing “hot spots” would occur based on the proposed dredge cut.

It should also be noted that based on preliminary design calculations provided by the USACE, a dredge volume of approximately 1.1 million cubic yards is expected for the proposed breach fill project. This quantity is significantly less than the maximum volume that the borrow area can yield. Therefore, the actual dredge cut would be shallower then what was modeled and the wave transformation analysis represents a worst-case scenario.

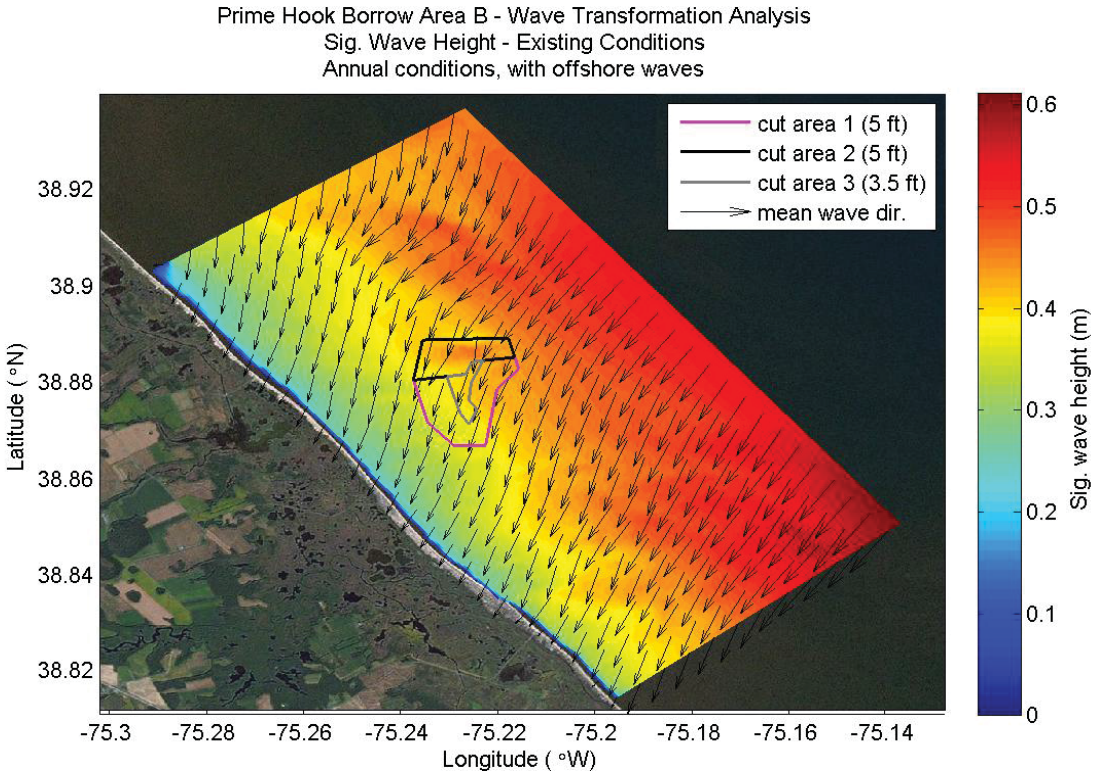

Figure 12. Significant wave height, existing conditions; annual winds with offshore waves.

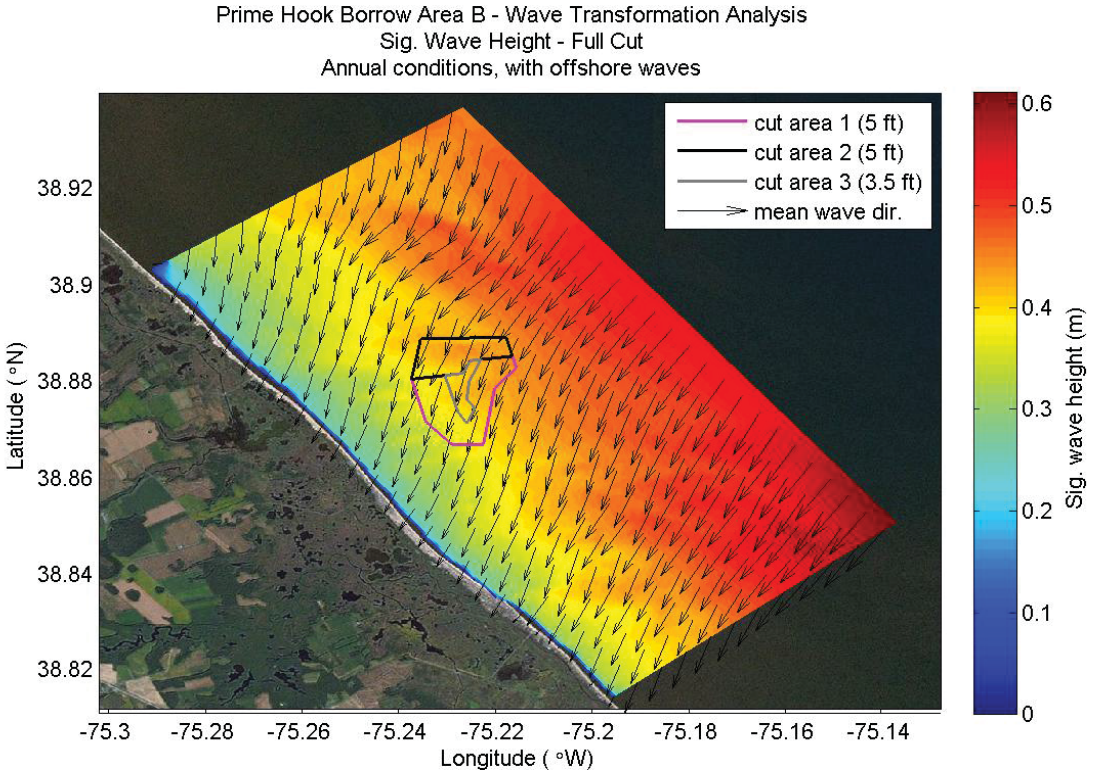

Figure 13. Significant wave height, post-dredge conditions; annual winds with offshore waves.

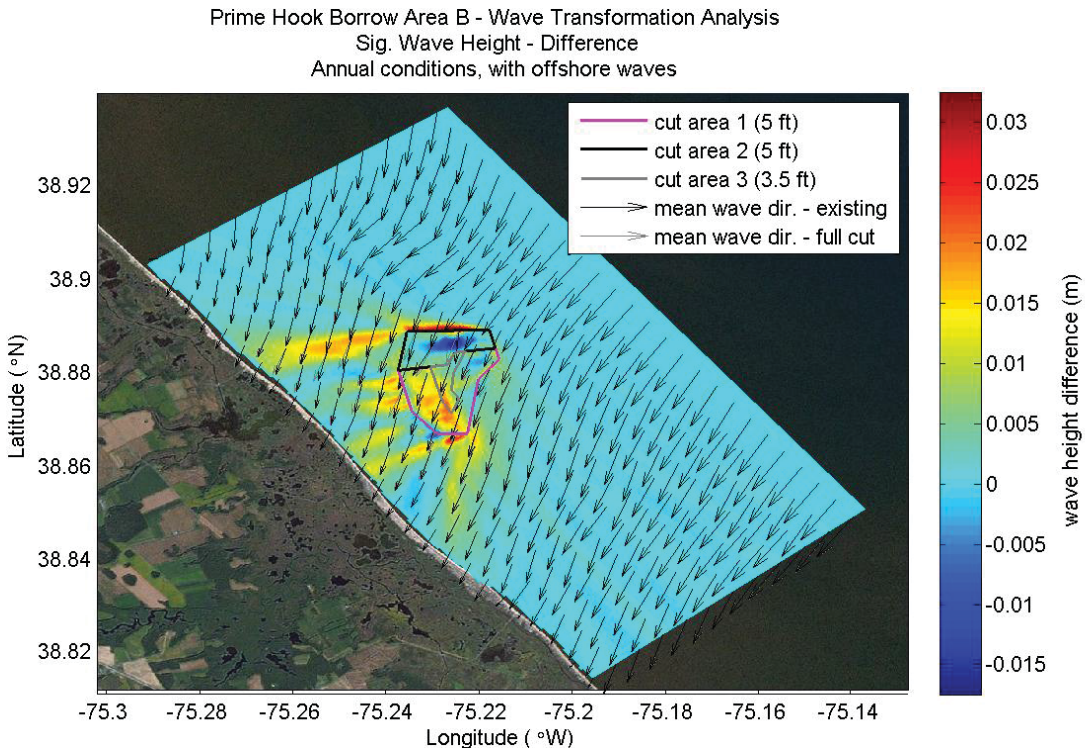

Figure 14. Significant wave height difference (magnitude), pre- vs. post-dredge; annual conditions with offshore waves.

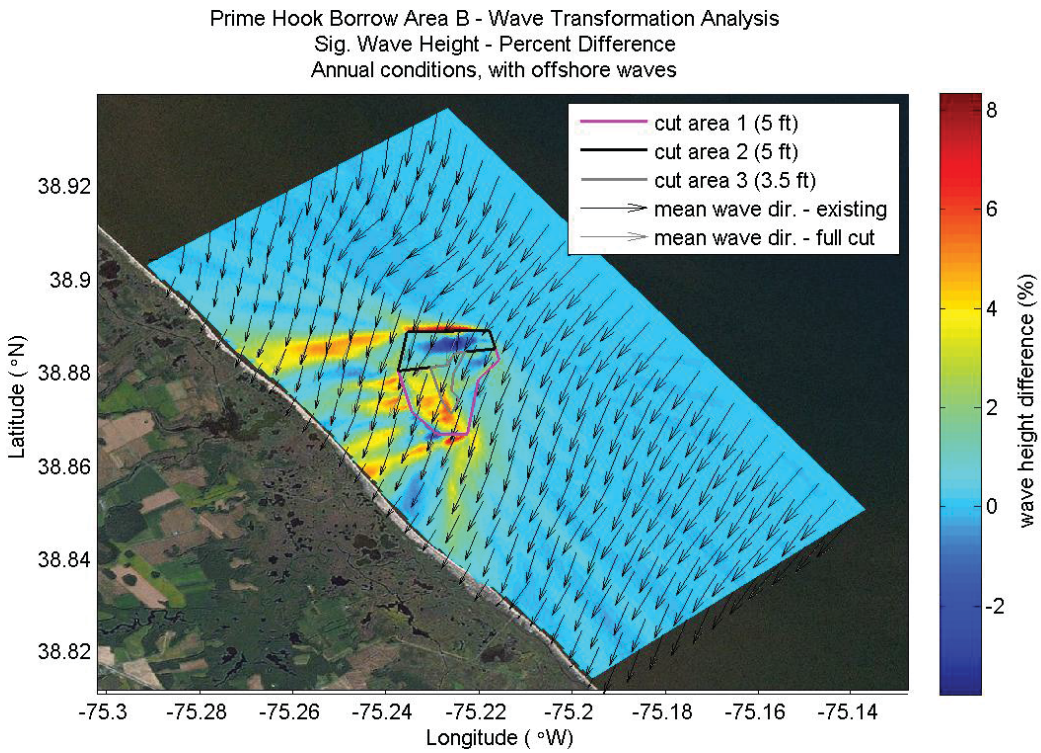

Figure 15. Significant wave height difference (percent), pre- vs. post-dredge; annual conditions with offshore waves.

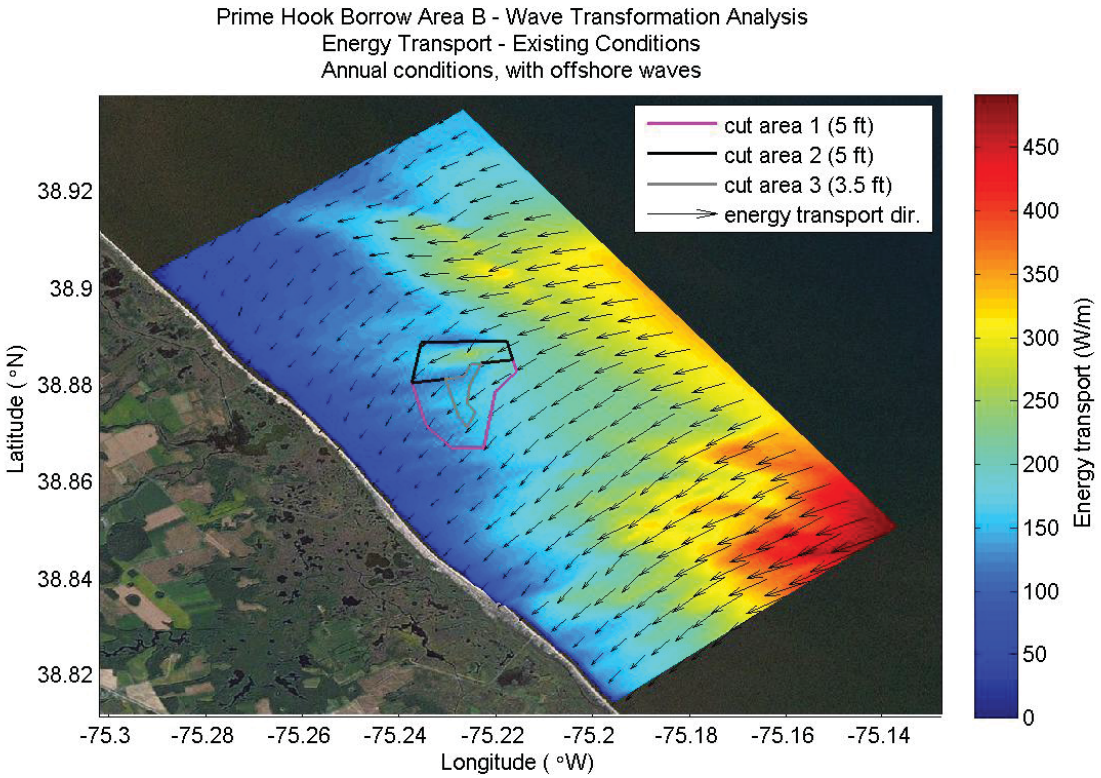

Figure 16. Energy transport, existing conditions; annual winds with offshore waves.

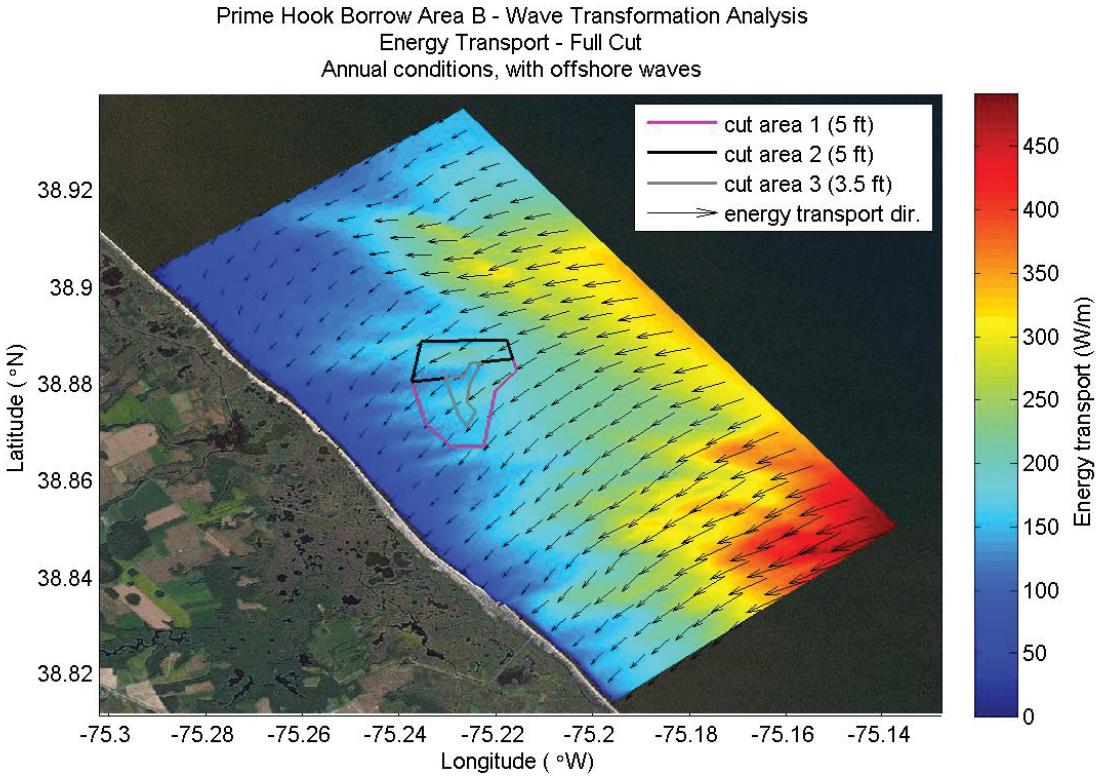

Figure 17. Energy transport, post-dredge conditions; annual winds with offshore waves.

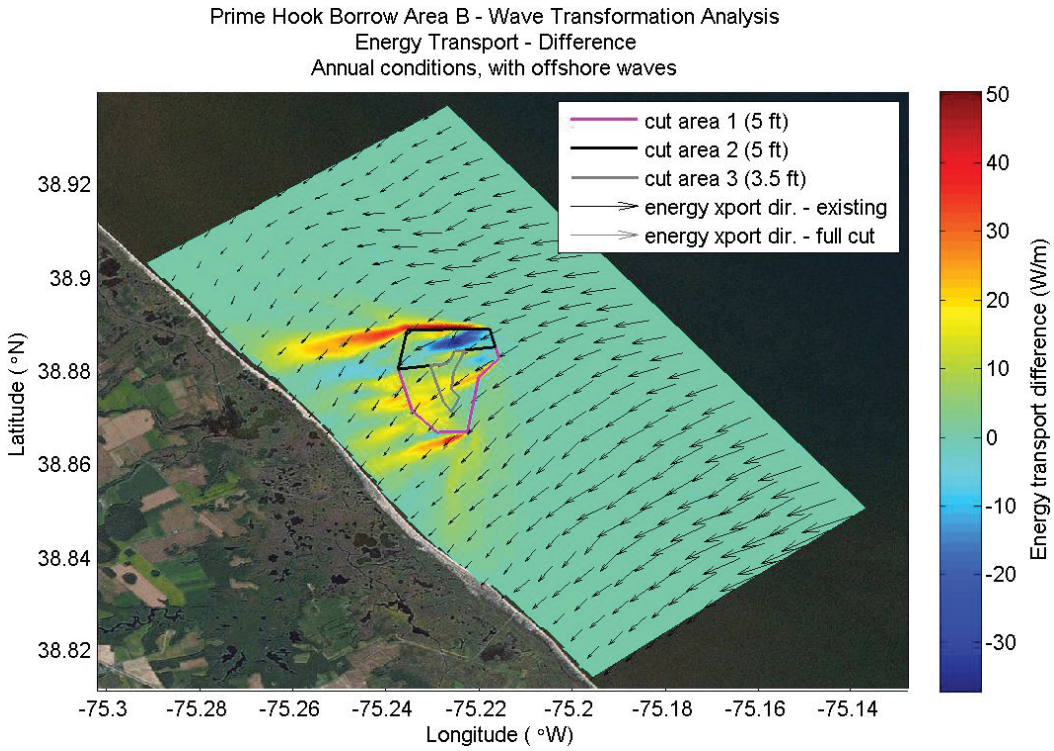

Figure 18. Energy transport difference (magnitude), pre- vs. post-dredge; annual conditions with offshore waves.

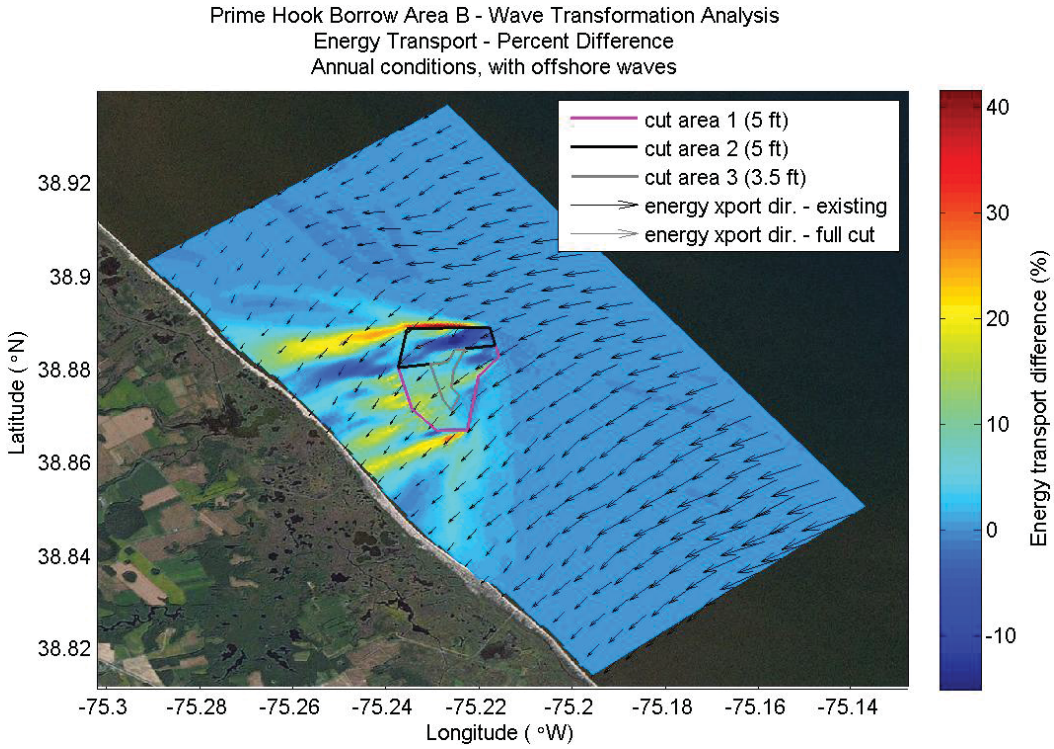

Figure 19. Energy transport difference (percent), pre- vs. post-dredge; annual conditions with offshore waves.

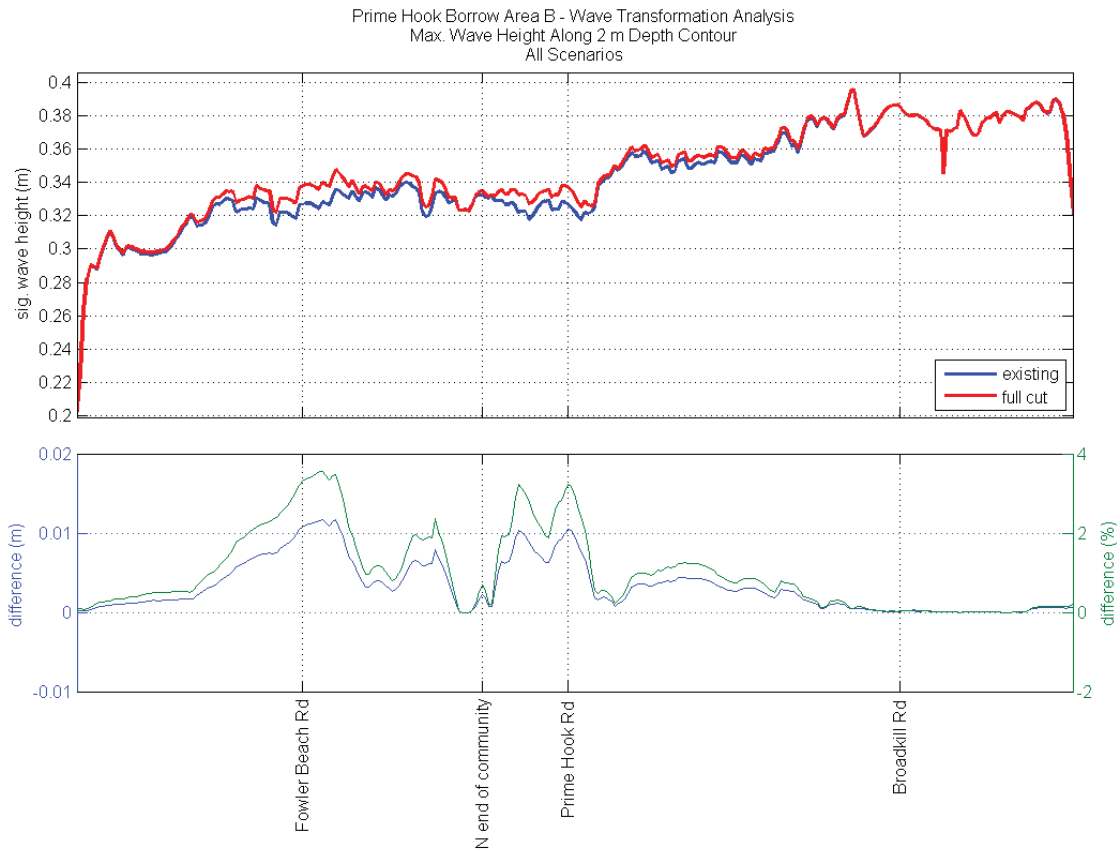

Figure 20. Significant wave height pre- and post-dredge at nearshore contour, maximum of all seasonal conditions.

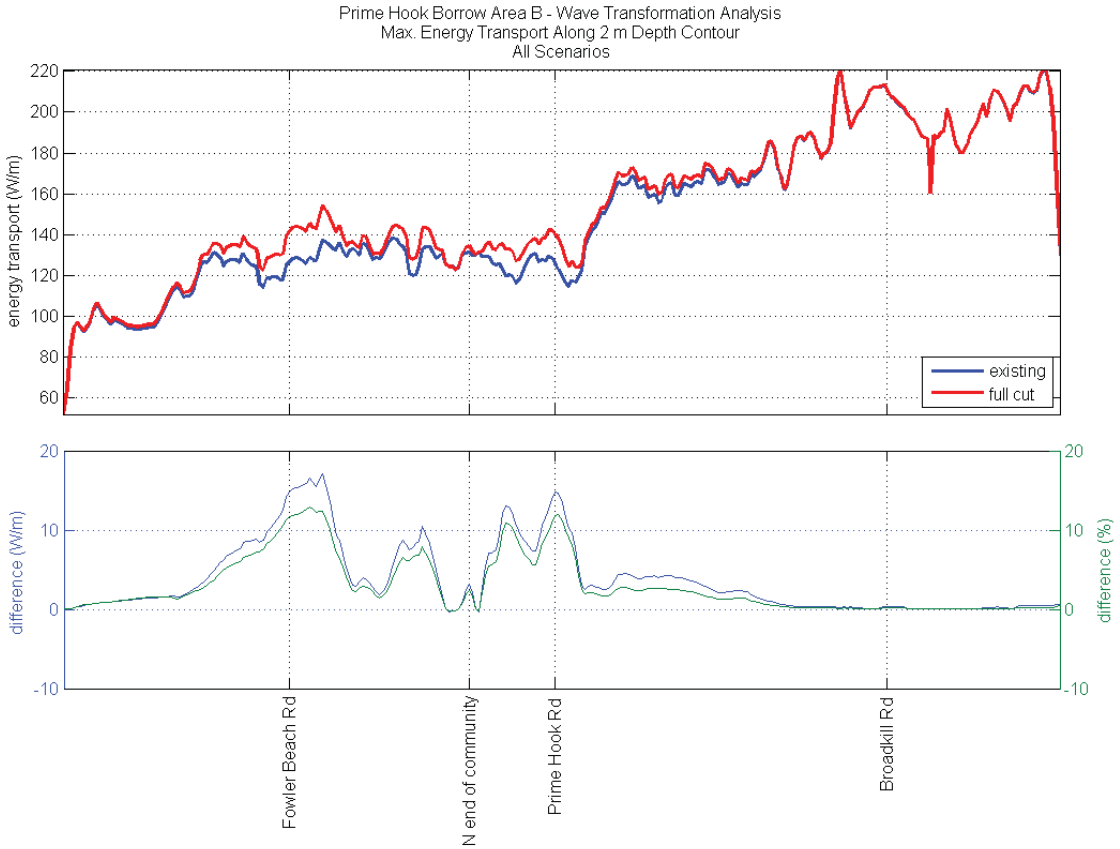

Figure 21. Energy transport magnitude pre- and post-dredge at nearshore contour, maximum of all seasonal conditions.

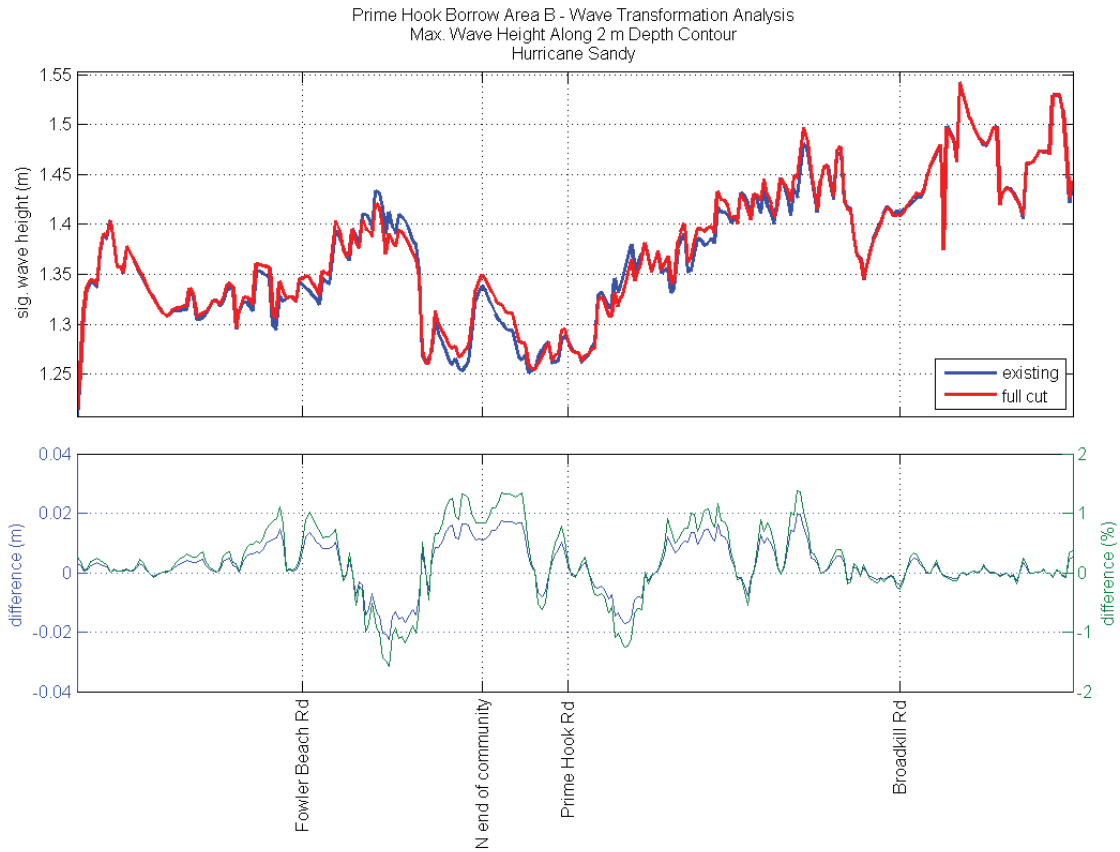

Figure 22. Significant wave height pre- and post-dredge at nearshore contour, Hurricane Sandy.

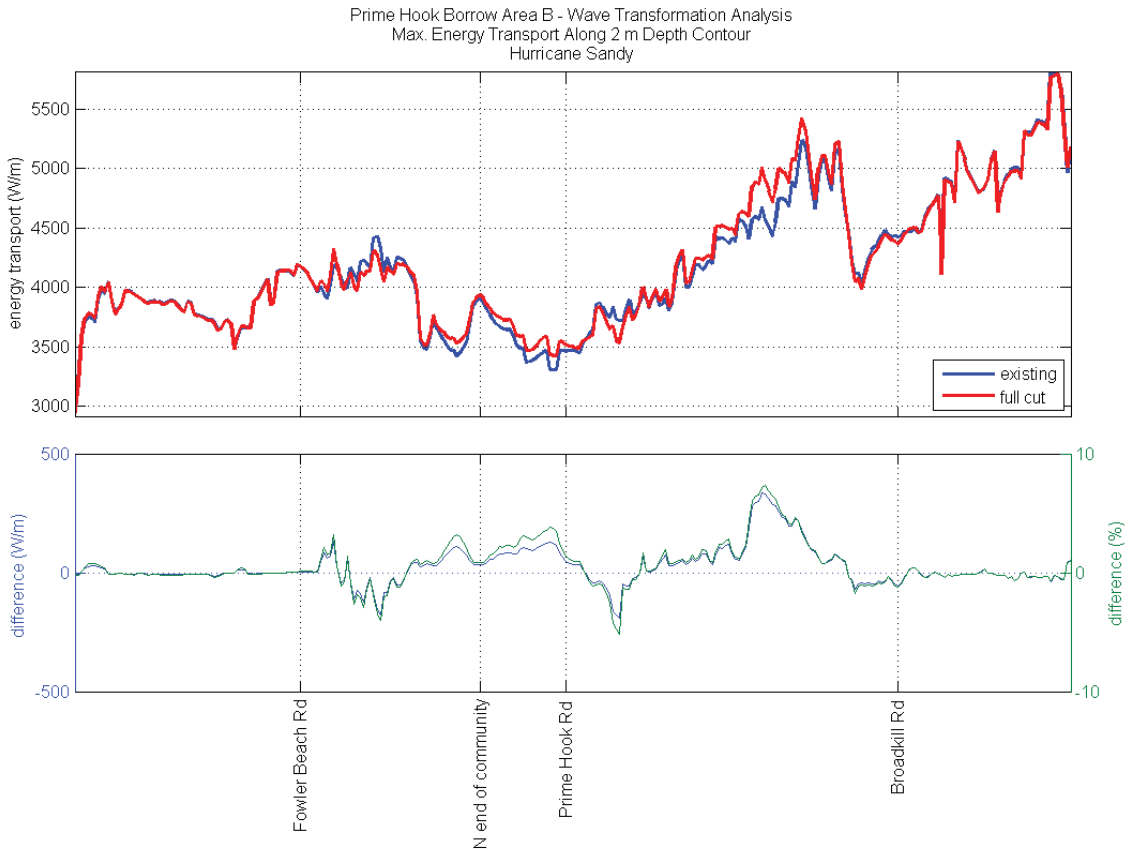

Figure 23. Energy transport magnitude pre- and post-dredge at nearshore contour, Hurricane Sandy.

Table 5. Summary of wave and energy transport changes; maximum of seasonal conditions.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	5	0.04	9
Mean wave direction (deg N)	3	--	16	--
Energy transport (W/m)	16	12	90	40
Energy transport direction (deg N)	5	--	20	--

Table 6. Summary of wave and energy transport changes; Hurricane Sandy.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.02	1	0.30	20
Mean wave direction (deg N)	5	--	10	--
Energy transport (W/m)	350	7	2800	60
Energy transport direction (deg N)	10	--	10	--

Table 7. Summary of wave and energy transport changes; annual winds, no offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	< 0.01	2	0.02	7
Mean wave direction (deg N)	1	--	3.5	--
Energy transport (W/m)	3	8	9	17
Energy transport direction (deg N)	2	--	20	--

Table 8. Summary of wave and energy transport changes; annual winds and offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	4	0.03	8
Mean wave direction (deg N)	4	--	15	--
Energy transport (W/m)	12	18	50	40
Energy transport direction (deg N)	5	--	25	--

Table 9. Summary of wave and energy transport changes; winter winds, no offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	5	0.03	10
Mean wave direction (deg N)	1	--	3	--
Energy transport (W/m)	5	11	17	23
Energy transport direction (deg N)	2	--	5	--

Table 10. Summary of wave and energy transport changes; winter winds and offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	4	0.04	8
Mean wave direction (deg N)	4	--	16	--
Energy transport (W/m)	17	18	70	40
Energy transport direction (deg N)	5	--	25	--

Table 11. Summary of wave and energy transport changes; spring winds, no offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	< 0.01	3	0.02	7
Mean wave direction (deg N)	1	--	4	--
Energy transport (W/m)	3	8	11	18
Energy transport direction (deg N)	2	--	5	--

Table 12. Summary of wave and energy transport changes; spring winds and offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	4	0.03	8
Mean wave direction (deg N)	4	--	13	--
Energy transport (W/m)	12	16	45	32
Energy transport direction (deg N)	5	--	25	--

Table 13. Summary of wave and energy transport changes; summer winds, no offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	1	< 0.01	3
Mean wave direction (deg N)	1	--	2	--
Energy transport (W/m)	< 1	3	1	7
Energy transport direction (deg N)	1	--	2	--

Table 14. Summary of wave and energy transport changes; summer winds and offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	5	0.03	10
Mean wave direction (deg N)	3	--	6	--
Energy transport (W/m)	5	15	40	52
Energy transport direction (deg N)	4	--	9	--

Table 15. Summary of wave and energy transport changes; fall winds, no offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	< 0.01	2	0.02	7
Mean wave direction (deg N)	1	--	3	--
Energy transport (W/m)	3	5	10	14
Energy transport direction (deg N)	1	--	4	--

Table 16. Summary of wave and energy transport changes; fall winds and offshore waves.

Parameter	Nearshore (2 m depth contour)		Borrow Area	
	Max. Change	Max. Change (%)	Max. Change	Max. Change (%)
Sig. wave height (m)	0.01	3	0.05	10
Mean wave direction (deg N)	2	--	8	--
Energy transport (W/m)	17	12	90	40
Energy transport direction (deg N)	3	--	11	--

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APPENDIX B

Public Involvement and Agency Coordination

AGENCY COORDINATION MEETINGS POST-CCP/EIS, 2012

U.S. FISH AND WILDLIFE SERVICE

PRIME HOOK NATIONAL WILDLIFE REFUGE

11/07/2013	U.S. Corps of Engineers, Philadelphia District, PA
11/13/2013	Public Meeting - Marsh Restoration Plans, Milford, DE
12/18/2013	DelDOT Bridge Design Team
02/20/2014	DNREC Coastal Program - Monitoring
03/13/2014	DNREC Coastal Program - Monitoring
03/27/2014	U.S. Corps of Engineers, Philadelphia District, PA
06/14/2014	Marsh Restoration Meeting for Prime Hook Beach Association
07/01/2014	DNREC Coastal Program and University of DE - Monitoring
07/26/2014	Marsh Restoration Update at Broadkill Beach Association Annual Meeting
07/31/2014	DNREC - Potential Borrow Areas
09/15/2014	Senator Carper, State Senator Simpson, Representative Kenton
07/01/2014	DNREC Coastal Program and University of DE - Monitoring
11/07/2014	DNREC Coastal Program and University of DE - Monitoring
11/20/2014	Marsh Restoration Meeting for Regulatory Agencies

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
2591 Whitehall Neck Rd, Smyrna, DE 19977
(302) 653-9345

April 9, 2014

Mr. Frank Cianfrani
U.S. Army Corps of Engineers
Chief, Regulatory Branch
100 Penn Square East
Wanamaker Building
Philadelphia, PA 19107

Dear Mr. Cianfrani:

This letter is to formally request the participation of the Army Corps of Engineers, Philadelphia District, Regulatory Branch in the capacity of a cooperating agency as defined by the NEPA EIS/supplement process. As we discussed at the March 14, 2014 meeting with you and your staff at the District office, the U.S. Fish and Wildlife Service (Service) is proposing to restore the damage incurred by Super Storm Sandy to Prime Hook National Wildlife Refuge located in Sussex County, Delaware. The proposed restoration entails replacement of the fore-beach, dune and a back-barrier marsh platform that will be planted to *Spartina alternifilfora*. Additionally, the marsh restoration component will involve removing water control structures to re-establish tidal channels and pools, along with supplemental thin layer sediment applications to promote *Spartina alterniflora* colonization. These alternatives were developed and discussed during the original EIS that was crafted along with the Comprehensive Conservation Plan. A Record of Decision was signed March 29, 2013.

Subsequent to the ROD, a hydrodynamic modeling exercise was conducted by Atkins North America that validated our preferred alternative. We are currently in the initial stages of developing plans and specifications for the preferred alternative, restoration concept. Due to the size and scope of the proposed project, the Service has opted to draft a supplement to the original EIS to discuss the potential additional effects on the human environment including the proposed subaqueous, sand borrow area, and proposed methods to avoid and mitigate negative environmental impacts.

To clarify roles and responsibilities, the Service will be the Clean Water Act permit applicant. However, the Service has engaged elements of the Army Corps of Engineers, Philadelphia District Planning and Civil Works Divisions through an interagency agreement to assist in the design of the beach/dune complex and development of the EIS supplement.

The timing of the project is contingent on a number of factors including sand resource assessments, other federal agency review, State subaqueous and beach construction permits, contracting and weather. Anticipated completion of the marsh and beach/dune complex designs is August, 2014. The Service is anticipating publishing a draft supplement at the end of July, 2014 contingent on validation of the quantities, quality and location of the sand resources necessary to construct the project.

If you have any immediate concerns, please contact me at your convenience.

Sincerely,

Al Rizzo
Project Leader
Coastal Delaware National Wildlife Refuge Complex

Cc: Anne Sittauer

DEPARTMENT OF THE ARMY

PHILADELPHIA DISTRICT CORPS OF ENGINEERS
WANAMAKER BUILDING, 100 PENN SQUARE EAST
PHILADELPHIA. PENNSYLVANIA 19107-3390

REPLY TO
ATTENTION OF

APR 22 2014

Regulatory Branch
Applications Section I

SUBJECT: CENAP-OP-R-2013-1009-23
Prime Hook National Wildlife Refuge

Mr. Al Rizzo, Project Leader
United States Department of the Interior
Fish and Wildlife Service
Coastal Delaware National Wildlife Refuge
2591 Whitehall Neck Road
Smyrna, Delaware 19977

Dear Mr. Rizzo:

This is in response to your letter dated April 9, 2014, inviting the United States Army Corps of Engineers (Corps), Philadelphia District, to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS)/Supplement associated with the proposal of the United States Fish and Wildlife Service (USFWS) to restore the Prime Hook National Wildlife Refuge from damage incurred from Super Storm Sandy in 2012, along the Delaware River, in Sussex County, Delaware.

The Philadelphia District is accepting your invitation to serve as a cooperating agency in the development of the EIS/Supplement. By participating as a cooperating agency, the Corps can work with the USFWS to ensure that sufficient information is included in the EIS/Supplement for the Corps to adopt the environmental document, conduct a timely review of the USFWS application, and make a final decision and/or determine project compliance with Section 404 of the Clean Water Act and Section 10 of the River and Harbor Act of 1899.

We are looking forward to working with you as a cooperating agency. If you have any questions regarding this matter, please contact Mr. John Brundage (609) 217-8527.

Sincerely,

Frank J. Cianfrani
Chief, Regulatory Branch

Copy Furnished:

NMFS (Oxford MD)
NMFS (Gloucester, MA)
USEPA Region III (Phila, PA)-Mansolino
USFWS (Annapolis, MD)

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
2591 Whitehall Neck Rd, Smyrna, DE 19977
(302) 653-9345

April 21, 2014

Louis Chiarella
Assistant Regional Administrator
for Habitat Conservation
NOAA/National Marine Fisheries Service
Greater Atlantic Regional Fisheries Office
55 Great Republic Drive
Gloucester, MA 01930

Dear Mr. Chiarella:

This letter is to formally request the participation of the NOAA/National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office in the capacity of a cooperating agency as defined by NEPA EIS/supplement process. The U.S. Fish and Wildlife Service (Service) is proposing to restore the damage incurred by Super Storm Sandy to Prime Hook National Wildlife Refuge located in Sussex County, Delaware. The proposed restoration entails replacement of the fore-beach, dune and a back-barrier marsh platform that will be planted to *Spartina alterniflora*. Additionally, the marsh restoration component will involve removing water control structures to re-establish tidal channels and pools, along with supplemental thin layer sediment applications to promote *Spartina alterniflora* colonization. These alternatives were developed and discussed during the original EIS that was crafted along with the refuge's Comprehensive Conservation Plan. A Record of Decision was signed March 29, 2013.

Subsequent to the ROD, a hydrodynamic modeling exercise was conducted by Atkins North America that validated our preferred alternative. We are currently in the initial stages of developing plans and specifications for the preferred alternative, restoration concept. Due to the size and scope of the proposed project, the Service has opted to draft a supplement to the original EIS to discuss the potential additional effects on the human environment including the proposed subaqueous, sand borrow area, and proposed methods to avoid and mitigate negative environmental impacts.

To clarify roles and responsibilities, the Service will be the Clean Water Act permit applicant. However, to be clear, the Service has engaged elements of the Army Corps of Engineers, Philadelphia District Planning and Civil works Divisions through an interagency agreement to assist in the design of the beach/dune complex and development of the EIS supplement.

The timing of the project is contingent on a number of factors including sand resource assessments, other federal agency review, State subaqueous and beach construction permits, contracting and weather. Anticipated completion of the marsh and beach/dune complex designs is August, 2014. The Service is anticipating publishing a draft supplement at the end of July, 2014 contingent on validation of the quantities, quality and location of the sand resources necessary to construct the project.

We thank you and the Army Corps of Engineers staff for their assistance and guidance in this matter. If you have any immediate concerns, please contact me at your convenience.

Sincerely,

Al Rizzo
Project Leader
Coastal Delaware National Wildlife
Refuge Complex

Cc: Anne Sittauer

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
55 Great Republic Drive
Gloucester, MA 01930-2276

JUL 14 2014

Mr. Al Rizzo
Coastal Delaware National Wildlife Refuge Complex
2591 Whitehall Neck Road
Smyrna, DE 19977

Re: Prime Hook National Wildlife Refuge, Request for Participation as a Cooperating Agency

Dear Mr. Rizzo,

Your letter dated April 21, 2014, requested that NOAA Fisheries participate as a cooperating agency in the preparation of an Environmental Impact Statement (EIS) supplement associated with the proposed Prime Hook National Wildlife Refuge restoration. We agree to participate as a cooperating agency to help advance effective interagency coordination on this project.

Our role and degree of involvement as a cooperating agency is dependent on existing staff and fiscal resources. Our contributions will be limited to providing written comments in response to your documents prepared as part of the NEPA process. You can expect our comments to provide technical information identifying species and habitats of concern, identification of issues and topics that need consideration and evaluation in your NEPA process, and guidance on evaluating, minimizing and avoiding effects to our trust resources. We are not in a position to undertake data collection to conduct EIS analyses, or to prepare sections of the draft or final EIS as staff and resources are fully tasked in other obligatory NOAA Fisheries programs.

Thank you for the opportunity to participate as a cooperating agency on this project. We look forward to working with you. If you have any questions regarding this matter, please contact Michelle Magliocca at (410) 573-4559.

Sincerely,

John K. Bullard
Regional Administrator

US ARMY
CORPS OF ENGINEERS

14 July 2014

Environmental Resources Branch
U.S. Army Corps of Engineers
100 Penn Square East
Philadelphia, PA 19107

[addressee list attached]
Dear :

In accordance with the National Environmental Policy Act of 1969, as amended, the U.S. Army Corps of Engineers (USACE) Philadelphia District, in partnership with the U.S. Fish & Wildlife Service (Service), is preparing a Supplemental Environmental Impact Statement (SEIS) for the Prime Hook National Wildlife Refuge to evaluate impacts of changes to the physical environment and changes to the proposed project since completion of the previous Environmental Impact Statement in 2012. The Service proposes to restore coastal habitat that has been decimated through storm-generated beach breaches and flooding of impoundments.

This letter serves to initiate the scoping phase of the proposed plan and to solicit your input on any concerns you may have, as outlined in 33 CFR Part 230.12. The Service's combination Comprehensive Conservation Plan (CCP) and EIS (2012) can be accessed at http://www.fws.gov/refuge/Prime_Hook/what_we_do/conservation.html.

As described in the EIS (2012), the focus of the project is to restore saltmarsh habitat on two of the refuge's four management units (see attached Map 1-1). Unit 2 and Unit 3 have incurred the most damage due to the loss of vegetation resulting from saltmarsh intrusion into freshwater impoundments and tidal flooding. Breach closure and the re-establishment of saltmarsh will provide better protection against future storm events, as saltmarsh vegetation naturally withstands tidal flooding and overwashes. The project will also include construction of a north-south channel meander through the refuge from the Mispillion River to Broadkill, removal of the easternmost section of Fowler Beach Road, and some water-control structures to re-introduce tidal circulation within the units.

By this letter, we are inviting your agency to participate in the scoping of this study. Please provide any relevant information within your agency's purview, and any comments or concerns that may have an impact on this study by 1 August 2014. For further information, please contact Ms. Barbara Conlin of the Environmental Resources Branch at (215) 656-6557 or by e-mail at Barbara.E.Conlin@usace.army.mil.

Sincerely,

Peter R. Blum, Chief
Planning Division

Enclosure

SCOPING LETTER RECIPIENTS

John Pomponio
U.S. Environmental Protection Agency Region III
Environmental Assessment and Innovation Division
1650 Arch Street
Philadelphia, PA 19103

Mary A. Colligan
Assistant Regional Administrator for Protected Resources
National Marine Fisheries Service
Northeast Region
One Blackburn Drive
Gloucester, MA 01930-2298

Karen Green
National Marine Fisheries Service
Habitat Conservation Division
James J. Howard Marine Sciences Laboratory
74 Magruder Road
Highlands, New Jersey 07732

Dave Saveikis
Director
Delaware Department of Natural Resources and Environmental Control
Division of Fish and Wildlife
89 Kings Highway
Dover, DE 19901

Sarah Cooksey
Environmental Program Administrator
Delaware Coastal Management Program
5 E Reed Street, Suite 201
Dover, DE 19901

Blair Fink
Delaware Tribe Historic Preservation Representative
Department of Anthropology
Gladfelter Hall
Temple University
1115 W. Polett Walk
Philadelphia, PA 19122

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

JUL 31 2014

Peter R. Blum
U.S. Army Corps of Engineers
Philadelphia District
Wanamaker Building
100 Penn Square East
Philadelphia, Pennsylvania 19107-3390
Attn: Environmental Resources Branch

Re: Supplemental EIS for the Prime Hook National Wildlife Refuge

Dear Mr. Blum:

We received your July 16, 2014 letter requesting comments on the Comprehensive Conservation Plan (CCP) and Environmental Impact Statement (2012) to assist in your preparation of a Supplemental Environmental Impact Statement (EIS). Although not specifically outlined in the CCP/EIS, Barbara Conlin of your office shared information regarding the preferred plan's details. Specifically, the preferred plan is currently thought to entail:

- Dredging of approximately 800,000 cubic yards from a borrow area located about 2 miles offshore of the refuge (an 840-acre site called PHB-B) to nourish the beach, though placement information has not been provided.
- The creation of tidal circulation channels within the interior of the refuge property (currently, no design is available for review).
- The creation of a 300 foot wide or deep (details unclear) platform made from dredge material that will be placed behind the nourished beach.

Within the 2012 CCP/EIS, there is no mention of listed species under NMFS jurisdiction that may occur in the project area. The following Endangered Species Act (ESA)-listed species under our jurisdiction may occur within the waters of Delaware Bay:

Species	Status
Gulf of Maine Distinct Population Segment (DPS) of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)	Threatened

New York Bight DPS of Atlantic sturgeon	Endangered
Chesapeake Bay DPS of Atlantic sturgeon	Endangered
Carolina DPS of Atlantic sturgeon	Endangered
South Atlantic DPS of Atlantic sturgeon	Endangered
Northwest Atlantic Ocean DPS of loggerhead sea turtle (*Caretta caretta*)	Threatened
Kemp's ridley sea turtle (*Lepidochelys kempi*)	Endangered
Green sea turtle (*Chelonia mydas*)	Endangered
Leatherback sea turtle (*Dermochelys coriacea*)	Endangered
Shortnose sturgeon (*Acipenser brevirostrum*)	Endangered

Within the SEIS, analysis will be needed on the direct and indirect effects of the proposed action on ESA-listed species under NMFS jurisdiction. The direct and indirect effects of dredging and beach nourishment may include, but are not limited to: impingement or entrainment in the dredge, the potential for interaction with the dredge and transport vessels, elevated levels of suspended sediment caused by dredging and beach nourishment on foraging and migration, and temporary or permanent removal of prey from the benthic environment. The direct and indirect effects of construction of tidal channels and creation of a platform constructed of dredge material may include, but are not limited to: noise (depending on how the platform is constructed), sediment disturbance, introduction of pollution or contaminants, changes to habitat, and the potential for vessel interactions.

As project plans develop, we recommend you consider the following mitigation/minimization measures for all of the proposed project's activities that might affect sea turtles, sturgeon or whales.

Dredging: Consider using small cutterhead dredge, specialized hopper dredge such as the Currituck, or a mechanical bucket dredge to reduce the risks of entrainment or impingement.

Interaction with vessels: Impose speed restrictions (less than 7 knots) for all vessel traffic associated with the project.

Turbidity: Consider the use of turbidity curtains, where appropriate and conditions allow.

Noise: If any piles are to driven into the substrate, consider the use of cushion blocks or bubble curtains to reduce noise levels to below the behavioral and injury thresholds for sturgeon and sea turtles, as noted in the table below.

Organism	Injury*	Behavioral Modification
Sturgeon	206 dB re 1 μPa_{Peak} and 187 dB_{cSEL}	150 dB re 1μPa_{RMS}
Sea Turtles	180 dB re 1μPa_{RMS}	166 dB re 1μPa_{RMS}

Conclusion

As the proposed action has the potential to affect ESA-listed species of sea turtles and sturgeon, we encourage you to consider further the effects of the proposed action on the ESA-listed species noted above in the SEIS. As you may know, any discretionary federal action, such as the approval or funding of a project by a Federal agency, that may affect a listed species must undergo consultation pursuant to Section 7 of the ESA. The U.S. Army Corps of Engineers will be responsible for determining whether the proposed action is likely to affect listed species. When project plans are complete, the Corps should submit their determination of effects, along with justification for the determination, and a request for concurrence to the attention of the Section 7 Coordinator, NMFS, Northeast Regional Office, Protected Resources Division, 55 Great Republic Drive, Gloucester, MA 01930. After reviewing this information, NMFS would then be able to conduct a consultation under section 7 of the ESA.

Should you have any questions regarding these comments, please contact Jennifer Goebel of my staff at 978-281-9373 or Jennifer.Goebel@noaa.gov.

NMFS Habitat Conservation Division (HCD) is responsible for overseeing programs related to Essential Fish Habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act and other NOAA trust resources under the Fish and Wildlife Coordination Act. Michelle Magliocca (michelle.magliocca@noaa.gov; 410-563-4559) provided comments via email on July 30, 2014. Please contact her to discuss any further EFH and conservation recommendations for this project.

Sincerely,

for David Gouveia
Acting Assistant Regional Administrator
for Protected Resources

EC: Goebel, NMFS/PRD
Magliocca, NMFS/HCD
Conlin, ACOE

File Code: Sec 7 technical assistance 2014– ACOE Prime Hook NWF comments

Conlin, Barbara E NAP

From: Saveikis, David (DNREC) [David.Saveikis@state.de.us]
Sent: Friday, August 01, 2014 1:42 PM
To: Conlin, Barbara E NAP
Cc: Meredith, William H. (DNREC); Hossler, Robert (DNREC)
Subject: [EXTERNAL] Prime Hook NWR SEIS

Dear Ms. Conlin:

The Delaware Division of Fish and Wildlife (Division) is in receipt of U.S. Army Corps of Engineers correspondence dated July 14, 2014, regarding preparation of a Supplemental Environmental Impact Statement (SEIS) for the Prime Hook National Wildlife Refuge to evaluate impacts of changes to the physical environment and changes to the proposed project since completion of the previous Environmental Impact Statement in 2012.

The Division offers the following general comments:

- The restoration design and implementation should ensure the maximum practicable use of freshwater input in Unit III from Primehook Creek to ensure establishment/restoration of a diversity of wetland habitats, including brackish/freshwater wetlands along the western portion of Unit III. To help achieve such, tidal exchange and tidal circulation channels in Unit III should be designed and installed in the far eastern portion of Unit III.

- The restoration design and implementation should minimize establishment of mosquito producing habitats within Units II and III to the extent practicable consistent with marsh habitat restoration goals. The Division is available to work with the U.S. Fish and Wildlife Service to achieve such outcome, both in the design phase to minimize establishing avoidable mosquito habitat and during and after the restoration phase to implement water management practices/alterations to reduce unavoidable mosquito larvae habitat and production.

David E. Saveikis

Director

Delaware Division of Fish and Wildlife

(302) 739-9910

f&wlogo20

Delaware Division of Fish & Wildlife

State of Delaware
Historical and Cultural Affairs

21 The Green
Dover, DE 19901-3611

Phone: (302) 736.7400 Fax: (302) 739.5660

August 30, 2013 ER 2013.08.07.02

Arthur J. Coppola
Refuge Manger
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Project Proposed Wetland Restoration
Prime Hook National Wildlife Refuge, Sussex County, Delaware.

Dear Mr. Coppola,

The above referenced project was reviewed for potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended. The undertaking will occur in wet areas with low archaeological probability. In addition there are no recorded historic properties in the area to be impacted. The upland staging areas appear to have been disturbed, and would be very unlikely to contain intact archaeological resources. It is the conclusion of the reviewer that no archaeological survey should be required. Also, given the limited nature of construction associated with this project, no architectural historic properties can be affected by this project.

If you have any questions, please contact me at craig.lukezic@state.de.us.

Sincerely,

Craig Lukezic
Archaeologist, Division of Historical and Cultural Affairs

Cc Gwen Davis, Deputy State Historic Preservation Officer

Delaware Tribe Historic Preservation Representatives
Department of Anthropology
Gladfelter Hall
Temple University
1115 W. Polett Walk
Philadelphia, PA 19122
temple@delawaretribe.org

November 24, 2014

United States Department of the Interior
Fish and Wildlife Service
Attn: Arthur J. Coppola
Refuge Manager
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Re: Wetland Restoration Project at the Prime Hook National Wildlife Refuge in Milton

Dear Arthur J. Coppola,

Thank you for informing the Delaware Tribe regarding the above referenced project. The Delaware Tribe is committed to protecting historic sites important to our tribal heritage, culture and religion.

We are interested in learning more about the marine archaeological study conducted as part of the above project and look forward receiving the results of the study. We would also like to continue as a consulting party on this project. We appreciate your cooperation and look forward to working together on our shared interests in preserving Delaware cultural heritage.

If you have any questions, feel free to contact this office by phone at (609) 220-1047 or by e-mail at temple@delawaretribe.org.

Sincerely,

Blair Fink

Blair Fink
Delaware Tribe Historic Preservation Representatives
Department of Anthropology
Gladfelter Hall
Temple University
1115 W. Polett Walk
Philadelphia, PA 19122

COPY

INTRA-SERVICE SECTION 7 BIOLOGICAL EVALUATION FORM

Originating Person
Arthur J. Coppola
Telephone Number:
(302) 684-8419
Date: September 30, 2014

I. Region: Northeast – Region 5

II. Service Activity (Program): USFWS - Prime Hook National Wildlife Refuge of The Delaware Coastal NWR Complex

III. Pertinent Species and Habitat:

A. **Listed species and/or their critical habitat near the action area:** DFS = Delmarva Fox Squirrel *(Sciurus niger* cinereus*) are year-round residents located near the proposed wetland restoration site(s) and, migrating and feeding piping plovers (Charadrius melodus) in spring, summer and fall in wetland impoundments*

B. **Proposed Threatened Species within the action area:** *migrating and feeding red knot (Calidris canutus rufa) in spring and fall, primarily along the refuge coast but may also use the impoundments.*

III. Geographic area or station name and action: ***Prime Hook National Wildlife Refuge, Milton, Delaware***

IV. *Propose to construct and repair forebeach, dune and back barrier marsh on a 0.5 mile stretch of shoreline within Unit II and restore approximately 2,000 acres of salt marsh habitats immediately behind repaired dunelines).* {See Attached Map}

V. Location (attach map):

A. Ecoregion Number and Name: ***Ecosystem No. 36 Delaware River/Delmarva Coastal Ecosystem***

B. Distance (miles) and direction to nearest town: ***Project site is 5 miles east of Milton, DE.***

VI. **Description of proposed action:** *Dates for this proposed restoration is July 1st 2015 to April 1st 2016. The proposed undertaking will entail the restoration of the forebeach, associated dune and back barrier marsh that was destroyed by a series of winter storms over the past 8 years. Superstorm Sandy alone destroyed over 1800 linear feet of barrier beach and dune which resulted in the loss of 2000 acres of marsh. The Service proposed to repair the breached barrier beach and back barrier*

marsh by placing approximately 800,000 to 1.15 million cubic yards of sand that will be excavated approximately 1.5 miles off-shore in the Delaware Bay. The clean fill material that will be discharged into Unit II originates from the aforementioned offshore borrow area and will be displaced onto the foreshore, dune-line and back barrier marsh using a cutter suction dredge along approximately 3,000 linear foot stretch on the east side of Unit II. The Service also plans to cut meandering channels within Units II & III (attachment) for the purpose of distributing the diurnal tide cycles to allow for the necessary hydrology to support a Spartina alterniflora dominated salt marsh.

VII. Determination of effects:

A. Explanation of the action on listed and proposed species.

Delmarva Fox Squirrel populations are not located near the proposed restoration sites, where the nearest population ranges from 1 to 2 ½ miles away from actual areas of beach and marsh restoration work. Beneficial effects to DFS habitats will likely occur with contemporaneous positive outcomes to adjacent forested wetlands and upland patches because of significant reduction of salinity intrusion into refuge forested habitats once breaches are repaired. Therefore it is our biological opinion that the proposed marsh restoration may affect, but is not likely to adversely affect the Delmarva Fox Squirrel.

Piping Plover use has generally been restricted to foraging activities on overwash and beach areas of the refuge, with occasionally foraging birds moving inland to impounded areas. Benefits of proposed restoration actions will include creating larger potential breeding areas for piping plovers to encourage the birds to establish breeding territories. The proposed barrier island and back-barrier wetland restoration in Unit II will restore natural coastal formation processes that maintain and perpetuate high quality piping plover breeding habitats. Restoration actions will also benefit other rare state endangered species (American oystercatcher, black skimmer, common and least terns) co-occurring with piping plovers by enhancing and expanding potential breeding and feeding sites for all these species. Sandy beach habitat rehabilitation and overwash creation on backdunes will also generally benefit piping plover in the short term while ephemeral pools, mudflat and natural overwash habitats will continue to be available in Unit I that lies outside the action area. Therefore it is our biological opinion that the shoreline/marsh restoration project may affect, but is not likely to adversely affect piping plovers.

Red Knots (REKN) are a proposed threatened species which uses the refuge during the spring and fall migrations. Survey data on the chronology of use by Red Knots within the action area indicate that the bulk of usage occurs during the last two weeks of May and first week of June. Refuge ***IWMM (Integrated Waterbird Management and Monitoring)*** *survey data for the last four years show peak numbers range from 550 to 1900 birds: 2011 (1400*

A. Explanation of the action on listed and proposed species.

Delmarva Fox Squirrel populations are not located near the proposed restoration sites, where the nearest population ranges from 1 to 2 ½ miles away from actual areas of beach and marsh restoration work. Beneficial effects to DFS habitats will likely occur with contemporaneous positive outcomes to adjacent forested wetlands and upland patches because of significant reduction of salinity intrusion into refuge forested habitats once breaches are repaired. Therefore it is our biological opinion that the proposed marsh restoration may affect, but is not likely to adversely affect the Delmarva Fox Squirrel.

Piping Plover use has generally been restricted to foraging activities on overwash and beach areas of the refuge, with occasionally foraging birds moving inland to impounded areas. "Refuge IWMM survey data for the last 4 years showed no PIPL use in proposed project area during 2011 and 2012. In 2013, two PIPL were observed using the area between April12 and 26. In 2014, three PIPL were observed in the project area between March 7th and April 4 (See Migration Chronology Use Graphs for project area referred to as (DE-002F).

Benefits of proposed restoration actions will include creating larger potential breeding areas for piping plovers to encourage the birds to establish breeding territories. The proposed barrier island and back-barrier wetland restoration in Unit II will restore natural coastal formation processes that maintain and perpetuate high quality piping plover breeding habitats. Restoration actions will also benefit other rare state endangered species (American oystercatcher, black skimmer, common and least terns) co-occurring with piping plovers by enhancing and expanding potential breeding and feeding sites for all these species. Sandy beach habitat rehabilitation and overwash creation on backdunes will also generally benefit piping plover in the short term while ephemeral pools, mudflat and natural overwash habitats will continue to be available in Unit I that lies outside the action area. Therefore it is our biological opinion that the shoreline/marsh restoration project may affect, but is not likely to adversely affect piping plovers.

Red Knots (REKN) are a proposed threatened species which uses the refuge during the spring and fall migrations. Survey data on the chronology of use by Red Knots within the action area indicate that the bulk of usage occurs during the last two weeks of May and first week of June. Refuge ***IWMM (Integrated Waterbird Management and Monitoring)*** *survey data for the last four years show peak numbers range from 550 to 1900 birds: 2011 (1400 REKN), 2012 (550 REKN), 2013 (1900 REKN) and 2014 (1200 REKN) within the action area. (See Migration Chronology Use Charts for action area* ***(DE-002F)*** *enclosed depicting this information). Most of these birds feed and rest on the unique sand bar habitats naturally created in Unit II. Adverse effects to REKN are expected to be discountable and unlikely to occur since restoration construction will happen outside of the window of peak migratory use by Red Knots. Also barrier island restoration design and construction in Unit II will preserve and enhance the current sand bar habitat features that are preferred by these birds providing added positive effects. Therefore it is our biological opinion that the barrier island*

*REKN), 2012 (550 REKN), 2013 (1900 REKN) and 2014 (1200 REKN) within the action area. (See Migration Chronology Use Charts for action area **(DE-002F)** enclosed depicting this information). Most of these birds feed and rest on the unique sand bar habitats naturally created in Unit II. Adverse effects to REKN are expected to be discountable and unlikely to occur since restoration construction will happen outside of the window of peak migratory use by Red Knots. Also barrier island restoration design and construction in Unit II will preserve and enhance the current sand bar habitat features that are preferred by these birds providing added positive effects. Therefore it is our biological opinion that the barrier island shoreline/back-barrier marsh restoration project may affect, but is not likely to adversely affect red knots.*

VIII. Effect determination and response requested on listed and proposed species:

Determination	**Response requested**
no effect/no adverse modification (species:_____)	**____Concurrence**
may affect, but is not likely to adversely affect species/adversely modify critical habitat (species: Delmarva Fox Squirrel, Piping Plover, Red Knot)	**_XX_ Concurrence**
may affect, and is likely to adversely affect species/adversely modify critical habitat (species:	**____Formal Consultation**

Arthur J. Coppola, Refuge Manager 9/30/14 **Date**
Prime Hook NWR

IX. Reviewing ESO Evaluation:

A. Concurrence ✓ **Non-concurrence _____**

B. Formal consultation required _____

C. Conference required _____

D. Informal conference required _____

E. Remarks (attach additional pages as needed):

_____ 11/20/14

signature **date**

[Title/office of reviewing official]

Field Supervisor
Chesapeake Bay Field Office

APPENDIX C

Air Quality Emissions Calculations

							NOX		VOC	
PRIME HOOK NWR - USFWS										
PROJECT EMISSION SOURCES AND ESTIMATED POWER (TIDAL CHANNEL EXCAVATION)							**Emission**	**Emissions**	**Emission**	**Emissions**
	# of		**Load**		**days of**		**Factors**	**(tons)**	**Factors**	**(tons)**
	Engines	**HP**	**Factor (LF)**	**Hrs/Day**	**operation***	**hp-hr**	**(g/hp-hr)**	907,200	**(g/hp-hr)**	-
Mobilization, Demobilization Preparatory Work, Excavation										
TRUCK, HIGHWAY, CONVENTIONAL	1	135	0.57	8	175	107,730	10.33	1.227	0.54	0.064
12-INCH LOW DRAFT CUTTER SUCTION DREDGE	1	540	0.64	16	175	967,680	9.70	10.347	0.20	0.213
12-INCH LOW DRAFT CUTTER SUCTION DREDGE	1	540	0.64	16	175	967,680	9.70	10.347	0.20	0.213
12-INCH LOW DRAFT CUTTER SUCTION DREDGE	1	540	0.64	16	175	967,680	9.70	10.347	0.20	0.213
PONTOON BACKHOE	1	78	0.59	8	20	7,363	9.50	0.077	0.19	0.002
PONTOON BACKHOE	1	78	0.59	8	20	7,363	9.50	0.077	0.19	0.002
TOTALS						**3,025,496**		**32.42**		**0.71**

							NOX		VOC	
PRIME HOOK NWR - USACE										
PROJECT EMISSION SOURCES AND ESTIMATED POWER							**Emission**	**Emissions**	**Emission**	**Emissions**
	# of		**Load**		**days of**		**Factors**	**(tons)**	**Factors**	**(tons)**
BEACH REPLENISHMENT, WETLAND PLATFORM	**Engines**	**HP**	**Factor (LF)**	**Hrs/Day**	**operation***	**hp-hr**	**(g/hp-hr)**	907,200	**(g/hp-hr)**	-
INITIAL NOURISHMENT										
170001 Mobilization, Demobilization Preparatory Work										
TRUCK, HIGHWAY, CONVENTIONAL, 8,600 LBS (3,901KG) GVW, 4X2, 2 AXLE, 3/4 TON -PICKUP	1		0.57	8	9	5,335	10.33	0.061	0.54	0.003
TRUCK, HIGHWAY, 55,000 LBS (24,948KG) GVW, 6X4, 3 AXLE, (ADD ACCESSORIES)	1	310	0.57	8	8	11,309	10.33	0.129	0.54	0.007
TRUCK, HIGHWAY, CONVENTIONAL, 8,600 LBS (3,901KG)GVW, 4X2, 2 AXLE, 3/4 TON -PICKUP	1	135	0.57	8	4	2,462	10.33	0.028	0.54	0.001
TRUCK, HIGHWAY, 55,000 LBS (24,948KG) GVW, 6X4, 3 AXLE, (ADD ACCESSORIES)	1	310	0.57	8	4	5,654	10.33	0.064	0.54	0.003
PIPELINE DREDGE, ELECTRIC GENERATOR	1	830	0.43	24	7	59,959	7.50	0.496	0.20	0.013
WORK TUG, PRIMARY	1	4,000	0.69	24	7	463,680	9.70	4.958	0.37	0.189
WORK TUG, SECONDARY Electric	1	50	0.40	24	7	3,360	7.50	0.028	0.20	0.001
SUVEY BOAT, SHORE	1	100	0.50	24	7	8,400	9.70	0.090	0.37	0.003
SUVEY BOAT, SHORE, SECONDARY Electric	1	40	0.40	24	7	2,688	7.50	0.022	0.20	0.001
DERRICK, PRIMARY	1	150	0.40	24	7	10,080	7.50	0.083	0.20	0.002
DERRICK, SECONDARY Electric	1	25	0.40	24	7	1,680	7.50	0.014	0.20	0.000
SUVEY BOAT, OFFSHORE	1	500	0.50	24	7	42,000	9.70	0.449	0.37	0.017
SUVEY BOAT, OFFSHORE, SECONDARY Electric	1	40	0.40	24	7	2,688	7.50	0.022	0.20	0.001
170017 Dredging										
TRUCK, HIGHWAY, 8,600 GVW, 4X4 (SUBURBAN)	1	135	0.57	14	40.6	43,738	10.33	0.498	0.54	0.026
TRACTOR, CRAWLER (DOZER), 410 HP, POWERSHIFT, W/17.7 CY SEMI-U BLADE (ADD ATTACHMENTS)	1	410	0.59	14	195	660,387	9.50	6.915	0.19	0.138

LOADER, FRONT END, WHEEL, INTEGRATED TOOL CARRIER, 1.75 CY (1.3 M3) LOADER; 6,303 LB (2,859 KG) @ 12.17' (3.7 M) HIGH, FORK LIFT, OR 1,841 LB (835 KG) @ 22.42' (6.8 M) HIGH, MATERIAL HANDLING ARM	1	90	0.59	14	40.6	30,182	9.50	0.316	0.19	0.006
170099 Associated General Items										
LOADER/BACKHOE, WHEEL, 0.80 CY (0.6 M3) FRONT END BUCKET, 9.8' (3.0 M) DEPTH OF HOE, 24" (0.61 M) DIPPER, 4X4	1	78	0.59	8	1.3	479	9.50	0.005	0.19	0.000
TRUCK, HIGHWAY, CONVENTIONAL, 8,800 LB (3,992 KG) GVW, 4X4, 2 AXLE, 3/4 TON (0.68 MT) - PICKUP	1	135	0.57	8	38.1	23,454	10.33	0.267	0.54	0.014
170017 Dredging										
PIPELINE DREDGE, PRIME ENGINE	1	5,000	0.43	14	99.7	3,000,970	7.50	24.810	0.20	0.652
PIPELINE DREDGE, ELECTRIC GENERATOR	1	830	0.43	14	99.7	498,161	7.50	4.118	0.20	0.110
PIPELINE DREDGE, DREDGE PUMP	1	0	0.80	14	99.7	0	9.70	0.000	0.20	0.000
WORK TUG, PRIMARY	1	1,000	0.69	14	99.7	963,102	9.70	10.298	0.37	0.393
WORK TUG, SECONDARY Electric	1	50	0.40	14	99.7	27,916	7.50	0.231	0.20	0.006
SUVEY BOAT, SHORE	1	100	0.50	14	99.7	69,790	9.70	0.746	0.37	0.028
SUVEY BOAT, SHORE, SECONDARY Electric	1	40	0.40	14	99.7	22,333	7.50	0.185	0.20	0.005
DERRICK, PRIMARY	1	150	0.40	14	99.7	83,748	7.50	0.692	0.20	0.018
DERRICK, SECONDARY Electric	1	25	0.40	14	99.7	13,958	7.50	0.115	0.20	0.003
FLOATING BOOSTER, PRIMARY	1	4,000	0.43	14	99.7	2,400,776	9.50	25.140	0.20	0.529
FLOATING BOOSTER, SECONDARY	1	200	0.43	14	99.7	120,039	9.50	1.257	0.20	0.026
SUVEY BOAT, OFFSHORE	1	500	0.50	14	99.7	348,950	9.70	3.731	0.37	0.142
SUVEY BOAT, OFFSHORE, SECONDARY Electric	1	40	0.40	14	99.7	22,333	7.50	0.185	0.20	0.005
TOTALS						**8,949,612**		**85.95**		**2.34**

APPENDIX D

Cultural Resources

PHASE I
UNDERWATER ARCHAEOLOGICAL PROJECT
PRIME HOOK NATIONAL WILDLIFE REFUGE
DUNE BREACH REPAIR PROJECT
LOWER DELAWARE BAY
SUSSEX COUNTY, DELAWARE

FINAL REPORT

Submitted to:
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Submitted by:
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December 2014

ABSTRACT

In conjunction with the planned harvesting of sand in Delaware Bay for the Prime Hook National Wildlife Refuge Dune Breach Repair Project, an Underwater Archaeological Remote Sensing Investigation was conducted to assess the potential presence or absence of potential submerged cultural resources within three borrow areas in Delaware Bay, Sussex County, Delaware. The three borrow areas were designated as PHB-A (351 acres), PHB-B (880 acres), and PHB-C (599 acres). Comprehensive magnetic and acoustic and remote sensing surveys and target analysis were conducted across the borrow areas to identify targets suggestive of submerged cultural resources that might be impacted by the sand harvesting activities.

Comprehensive remote sensing survey of the borrow area using magnetic and acoustic instrumentation resulted in the identification of no potentially significant remote sensing targets. No additional underwater archaeological investigations are recommended in the three offshore borrow areas; PHB-A, PHB-B, and PHB-C.

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1.0 INTRODUCTION

A Phase I Underwater Archaeological Project was completed in Delaware Bay as part of the Prime Hook National Wildlife Refuge Dune Breach Repair Project. In conjunction with the planned harvesting of sand in Delaware Bay to replenish the lower Delaware Bay coastline that has incurred erosion from recent storms and tidal flooding, a comprehensive remote sensing investigation was conducted to assess the presence or absence of potential submerged cultural resources within three proposed offshore borrow areas in lower Delaware Bay, Sussex County, Delaware. The three borrow areas are identified as PHB-A (351 acres), PHB-B (880 acres), and PHB-C (599 acres).

This underwater archaeological project was completed for the U.S. Fish and Wildlife Service under a subcontract agreement between Versar, Inc. and Dolan Research, Inc.

The investigation included limited background documentary research, and magnetic and acoustic remote sensing to determine the presence or absence of submerged cultural resources potentially eligible for the National Register of Historic Places that might be affected by the proposed sand harvesting project. The underwater archaeological investigation will assist in compliance with: Section 106 of the National Historic Preservation Act of 1966, as amended; the regulations of the Advisory Council on Historic Preservation (30 CFR Part 800); the National Environmental Policy Act of 1969, as amended; other applicable federal and state mandates; and Corps of Engineers regulations (33 CFR Part 325, Appendix C). This investigation was conducted in accordance with the instructions and intents of the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (48 FR 44716) and Guidelines for Architectural and Archaeological Surveys in Delaware (1993). In addition, the survey will comply with the Bureau of Ocean Energy Management's standards, dated 9 November 2012, Guidelines for Providing Geological and Geophysical Hazards, and Archaeological Information Pursuant to 30 CFR Part 585.

Previous to fieldwork activities, limited documentary research was undertaken to determine the likelihood and nature of potentially significant submerged archaeological and historical resources within the project areas. Historical data were integrated with Delaware state preservation plans established in the Delaware Comprehensive Historic Preservation Plan (Ames, *et. al*. 1989). Of particular relevance to the current study is the recently developed historic archaeological context on the Maritime Theme in Delaware with the Sub-Theme Shipwrecks, Coastal Zone (Koski-Karell 1995).

Gathered documentary data were used to provide a framework for identifying historic and prehistoric archaeological resources that may have been deposited within the project areas, and to determine the extent of subsequent activities that may have removed or disturbed such material. Background research on the historic period established a generalized context for ultimate evaluation of any historic submerged sites that might be identified.

Fieldwork investigations were completed in Delaware Bay, from 02 -12 September, 2014. The project goal was to identify remote sensing targets of potential historical significance from gathered remote sensing data. After target signature analysis, recommendations were compiled for the need of additional archaeological investigation at each individual target location.

However, analysis of fieldwork data confirms the presence of no remote sensing targets that are suggestive of submerged cultural resources. No potentially significant magnetic anomalies or sonar contacts were identified during the survey. Since no potentially significant remote sensing

targets were identified, no additional underwater archaeological investigations are recommended in Borrow Areas PHB-A, PHB-B, or PHB-C.

2.0 PROJECT LOCATION AND DESCRIPTION

Three borrow areas in lower Delaware Bay, totaling 1,830 acres in size, were surveyed. All three of the irregular-shaped areas are located in Delaware Bay between three and five nautical miles north of Roosevelt Inlet, Sussex County, Delaware. The borrow areas are designated PHB-A, PHB-B, and PHB-C; each is located slightly more than one nautical mile offshore Prime Hook National Wildlife Refuge or Broadkill Beach. Coordinates for the 20 corners of the three project areas were supplied by the U.S. Fish and Wildlife Service.

Water depths were generally very shallow across all of the areas; generally varying between five and 12 feet deep, mean low water.

Coordinates (expressed in Delaware State Plane, NAD 83) for the corners of the three different project areas are:

Area PHB-A (351 acres)

Point	Easting	Northing
1	714141	313901
2	718619	312813
3	719942	312401
4	718449	308230
5	717591	308723
6	716938	311230
7	713537	312213

Area PHB-B (880 acres)

Point	Easting	Northing
1	709044	325010
2	713332	324243
3	713386	321501
4	712115	319979
5	712099	315734
6	709604	315713
7	708921	317064
8	708098	319558
9	707825	323414

Area PHB-C (599 acres)

Point	Easting	Northing
1	718909	308384
2	724620	311691
3	727684	309613
4	722357	305420

The locations of the three project areas are presented in Figure 1.

3.0 HISTORICAL BACKGROUND

3.1 Methodology

In addition to producing a generalized historical overview of activity in and around lower Delaware Bay, specific research was conducted on maritime themes; including shipping and navigational improvements. Both primary and secondary source material were consulted to provide data on local and regional historical developments. Specifically, data from the background research were used to generate a list of shipwrecks and ship losses near the mouth of Delaware Bay. Research was conducted at national and local venues. Repositories in Washington D.C.; Alexandria, Virginia; Dover, Delaware; and Philadelphia, Pennsylvania, were visited by project personnel while compiling information for inclusion in the historical background.

Historical research was designed to determine the potential presence of submerged cultural resources in lower Delaware Bay. The background research included a records check for known sites and National Register properties within the project vicinity, and review of state archaeological site and historic structure files in Delaware, as well as an examination of prior technical reports and preservation planning tools. Additionally, the background research portion of the project includes the development of generalized prehistoric overview for the borrow areas' region.

A prehistoric overview was included to supplement the historical background research and to evaluate the potential presence and corresponding significance of unrecorded inundated terrestrial sites near the borrow areas. Environmental parameters affecting settlement patterns in the project vicinity were identified and used to establish a probability for locating inundated terrestrial archaeological resources.

Background research on the historic period established a generalized context for ultimate evaluation of historic submerged sites identified. Submerged historic resources were considered with reference to the Delaware Comprehensive Historic Preservation Plan (Ames et. al. 1989) and the ongoing state preservation planning process. Also, data contained within the historic archaeological context on the Maritime Theme in Delaware with the Sub-Theme Shipwrecks, Coastal Zone (Koski-Karell 1995) were referenced by project staff while formulating the historic background. In addition, data from the historical research were used to generate a list of shipwrecks and ship losses near the mouth of Delaware Bay (Appendix I).

The specific context of shipwrecks relates to the following themes identified in the Delaware Comprehensive Historic Preservation Plan: Fishing and Oystering, and Transportation and Communication. Shipwreck episodes in/near mouth of Delaware Bay occurred during all five chronological periods established in the Delaware Plan (1630-1940). The context of regional shipping activities in and around Delaware Bay relates to the following themes identified in the Delaware Plan: Agriculture; Fishing and Oystering; Retailing and Wholesaling; and Transportation and Communication. Regional shipping patterns in Delaware Bay were an important feature of commerce during all five chronological periods established in the Delaware Plan (1630-1940).

3.2 Prehistoric Synopsis

For the purposes of completing a prehistoric overview of the project areas, various publications by Jay Custer of the University of Delaware's Center for Archaeological Research (1984, 1989) have provided a suitable general context.

The prehistory of the Delaware River Valley is divided into chronological time periods. Each period groups similar sets of cultural adaptations to environmental, and inferred social stresses as interpreted from archaeological data. Cultural adaptations including, settlement/subsistence patterns, resource utilization and exchange/trade networks, change through time and often by region. Symptoms of cultural adaptations are manifest as artifacts, food debris, burials, and features. Periods, therefore, are further divided into complexes that specifically describe adaptations through time or between physiographic zones.

Several specific historical Maritime themes of Delaware Bay are discussed in detail in the following sections. There are four cultural periods generally recognized by Custer (1984) for the Delaware River Valley; Paleo-Indian (c. 14,000 B.P. - 8,500 B.P.), Archaic (c. 8,500 B.P. - 5,000 B.P.), Woodland I (c. 5,000 B.P. - A.D. 1,000), and Woodland II (c. A.D. 1,000 - A.D 1,600). Each period corresponds to environmental episodes that were marked by broad climatic changes, thereby affecting the productivity and distribution of environmental resources available to people over time.

The Paleo-Indian Period corresponds to three environmental episodes. The Late Glacial Episode (c. 17,000 B.P. - 8,000 B.P.) marks the end of the Pleistocene. Glacial waters melting from the Laurentinde Ice Sheet poured into the Delaware River Valley creating a rive channel that extended 50 kilometers beyond the present mouth of the Delaware River Bay (Custer 1984). Changing salinity levels caused by rapid sea level rises made unstable conditions for estuary species. Fluctuations in precipitation and air temperature encouraged a mosaic development of plant and animal communities ranging from tundra to grassland to deciduous forest. The transition between the ends of the PreBoreal/Boreal Episode (8,000 B.P. - 6,500 B.P.) is noted for the growth of closed Boreal forests and a decline in grasslands. The spread of coniferous forests at this time would have forced browsing game to fresh water sources. Rapid sea level rise continued, meaning impoverished estuarine resources (Custer 1984).

Paleo-Indians were hunter/gatherers who traveled in flexible small bands. As a highly mobile people focused primarily on hunting, their technology is characterized by large fluted bifaces, knives, and projectile points. Few if any plant processing tools are associated with Paleo-Indian sites. Given the importance of high quality crystalline for the manufacturing of multipurpose biface tools, Paleo-Indian settlement systems often were centered on quarry sites. Types of sites associated with Paleo-Indian settlement/subsistence systems include: quarry, quarry reduction, base camp, base camp maintenance stations, outlying hunting stations, and isolated point finds. Except for quarry sites, Paleo-Indian sites are typically found near poorly drained sinkholes, swampy settings, headlands overlooking ancestral confluences of major drainages, and within the mid-peninsular divide (Custer 1984).

The Archaic Period (c. 8,500 B.P. - 5,000 B.P.) is associated with the Atlantic Environmental Episode. Mesil forest growth responded to general warming trends and increased precipitation. Rapid sea level rise caused poor estuary stability. Increased seasonality led to the development of a variety of resources exploited during the Archaic Period. There is an associated decrease in the importance of high quality lithic material and an increase in tool types including plant-processing tools. The settlement system was serial as people moved from area to area as resources were needed or depleted. Archaic sites include macroband base camps, microband base camps, and

procurement sites. It is probable that fusion and fission of social groups occurred as resources were exploited. Macroband base camps could reach 20 - 30 nuclear families at one time. Interior swamps, floodplains of major drainages, and medium range terraces were the most likely archaic site locations. Custer speculates that, "from the town of New Castle south, similar sites probably existed but are now inundated by sea level rise and are now buried below fairly recent sediments or have been destroyed by dredging" (Custer 1984, 71). Paleo-Indian and Archaic Sites often coincide in the same areas.

The Woodland I Period (c. 5,000 B.P. - A.D. 1,000) is associated with two environmental episodes; Sub-Boreal and Sub-Atlantic. Early in the Sub-Boreal Episode a marked dry and warm period occurred that eventually was ameliorated by wetter and cooler conditions during the Sub-Atlantic Episode. The mid-post glacial xerothermic caused shrinkage in available standing water sources. Coincidentally, sea level rises slowed causing stable environments for shellfish bed development. Hydrological fluctuations allowed anadromous fish greater inland penetration. Cultural adaptations vary widely throughout the Woodland I period, but in general people adopted a semi-sedentary lifestyle characterized by extensive trade networks, mortuary practices, and population growth. Ceramics, storage features, and caches were developed indicating periodic surplus. Pithouse features reflect longer site usage compared to archaic site use. Tool kits show an increase in the variety of ground stone tools reflecting the increased importance of plant food processing. Adzes, celts, gouges, and axes may have been used for canoe manufacturing. Exotic material used in the manufacturing of tools added to graves infers the possibility of ranked society (Custer 1984).

Woodland I sites include macroband base camps, microband base, procurement sites, and cemeteries. Macroband base camps were marked by a decrease in the variety of site locations. They were generally located near interior swamps and stream confluences along interior drainages. Woodland I sites tend to follow the interface between freshwater and saltwater up major drainages. By the end of the Woodland I Period environments were less circumscribed. Plant and animal communities expanded as the climate became more wet and cool. Sea level rises dramatically slowed allowing the expansion of productive estuaries. Large groups seemed to have fissioned, extensive trade networks collapsed and cemetery use was abandoned (Custer 1984).

The Woodland II Period (c. A.D. 1,000 - A.D. 1,600) is associated with historic environments. This period is characterized by a breakdown in extensive trade networks but increased sedentism. Use of grave goods made from exotic material ends but a development of ossuaries, or secondary reburial sites, grows. Some agriculture as a secondary subsistence strategy to hunting and gathering is noted. Shell beds, near Woodland I period shell beds, are located on the outer coast. Ceramics, storage features, and pithouse features are regularly associated with macroband base camps. Triangular projectile points are exclusively manufactured, possible due to the development of the bow and arrow. Large sites are often located in marginally productive environmental zones, including the floodplains of major drainages. A noticeable divergence in adaptations occurs between the upper and lower Delaware River Valley. While people on the lower Delaware River Valley became more sedentary, people from the upper portions of the valley adopted a semi-sedentary lifestyle. The people from the upper valley reverted to settlement systems used during the Woodland I period. When Europeans arrived in the Delaware Valley in the 17th century, they encountered Native Americans who for the most part were semi-sedentary.

Features characteristic of the inception of the Woodland Period include: the introduction of ceramic technology, the onset of elaborate burial mound construction, the participation in

exchange networks that transport materials, as well as artifacts, across large areas, and evidence indicating the domestication of plant foods. In contrast to the mobile lifestyle of the Paleo and Archaic, Woodland lifestyles were more sedentary and focused on productive estuaries. Custer mentioned that Early Woodland people in the region often established their base camps along brackish rivers. Small bands would then seasonally migrate from these basecamps to bayside marshes. By the late Woodland period, there is evidence of a further sedentary lifestyle with an increasing reliance on agriculture. Woodland sites have been identified on both the coastal marshes and in the mid-drainage areas in the region.

3.3 Historical Synopsis

Historic activity in Delaware Bay dates to 1609 when Henry Hudson first discovered the bay while surveying the northeast coast of North America for the Dutch East India Company. Hudson noted the entrance of Delaware Bay, but did not explore up into the upper bay and river. His observations of Delaware Bay were recorded and eventually stimulated a significant interest in additional exploration, trade, and colonization of the region. In 1614 the State General of Holland granted the merchants of Amsterdam and Hoorn exclusive privileges to trade between 40 and 45 degrees of latitude in an area identified as the territory "New Netherland." The first Dutch explorers came to Delaware Bay from New Amsterdam (New York City) in October 1614. By decree from The Hague, October 11, 1614, the owners of five Dutch ships were authorized to establish the United Company of Merchants with the exclusive rights to explore the area between New France in the north and Virginia to the south. Captain Cornelius Hendrickson then became one of the first to explore the bay aboard the Onrust (Restless). Captain Hendrickson produced the first chart of Delaware Bay and River in 1615. Included in a brief report submitted to the Dutch merchants, Hendrickson claimed to have found "certain lands, a bay and three rivers situated between 38 degrees and 40 degrees" (Weslager 1961, 45). Soon the Dutch merchants set up trading stations and settlements at various locations along the banks of Delaware Bay and River. In 1623, the Dutch East India Company constructed the first of several fortifications on the east shore of the bay.

Swedish explorers were also active in the Delaware Bay region. In 1629 the Swedish West Indian Company purchased from the Indians a two-mile wide tract of land on the west side of the bay which extended 32 miles from Cape Henlopen north to a location above present Bowers Beach, Delaware. Although the purchase was ratified in 1630, it was not until Peter Minuit arrived with an expedition in 1638 that the Swedish attempted to settle the region (Hazard 1850). The Swedes eventually settled further upriver at a more suitable landing site on the west shore, near present Wilmington, Delaware.

For the next three decades the Swedes and Dutch co-existed in the Delaware Valley until 1664 when the British, under the command of Sir Robert Carr, assumed command of the region. When King Charles II made a grant of lands in the Delaware Valley to his brother James, Duke of York, the Duke sent a flotilla of warships under Carr's direction to subjugate the Dutch and Swedes and institute British control in the area. After several years of limited interest on the part of the Duke of York, King Charles II deeded a substantial portion of the territory to William Penn in 1682. Penn subsequently established an English colony, Pennsylvania, on the Delaware River with Philadelphia as its capital (Weslager 1961).

In 1684, Penn also acquired the "three lower counties" (present-day Delaware) from the Duke of York to add to his Pennsylvania holdings. With Penn's involvement the colonization process and economic growth in Delaware became tied more closely to Philadelphia and Pennsylvania. Throughout the colonial period, settlement in the lower Delaware Valley consolidated in regions

where solid banks came to the Delaware's edge; for most of the waterfront was marshland and unhealthy for habitation. New Castle, and Wilmington, Delaware, Burlington, and Bordentown, New Jersey, and Philadelphia, Pennsylvania developed at locations of this type. In the lower portion of the Delaware Valley, population centers were, again, on high land. The high land was often some distance up a creek navigable only by shallow-draft vessels. Dover, Delaware, and Salem, New Jersey, were examples of this. Some towns, which appeared during the colonial period, developed because they were stopping points along the 60-mile stretch of river on the much-traveled route from New York to Baltimore. This applies to Trenton and Bordentown, New Jersey, near the northeast bend of the river, and to New Castle and Wilmington, Delaware, near the southwest bend. Philadelphia, in the middle of this line of travel, was not merely a stop on the line but developed into a trade and travel center itself (Tyler 1955).

Wheat, rye, barley and tobacco were the principle colonial products of Delaware Valley inhabitants. After being hauled by wagon to mills established along the banks of the Schuylkill River, Brandywine Creek, and other swift-water tributaries of the Delaware, the flour was placed aboard shallops and taken up the Delaware River to Philadelphia for consumption or further shipment. For the duration of the colonial period, the Delaware Valley region remained predominantly agricultural. The agricultural landscape that developed in response emphasized the importance of river and coastal transportation routes over roads. The system of agricultural production and transportation routes facilitated the rise of Philadelphia as one of the most important ports in the British Empire at the onset of the Revolutionary War.

The Revolutionary War disrupted the economic development of the region, as the British blockaded shipping and conducted raids along the shores of Delaware Bay (DeCunzo and Catts 1990). Following the conclusion of the war, Delaware Valley merchants, now freed from the restrictions of the Navigation Acts, again prospered. Philadelphia became the most active port in North America, with its ships reaching new markets in the East Indies and across the world. By 1800 there were 40 Philadelphia vessels in the China trade, about as many more trading in South America, and a considerable number still trading in Europe. The War of 1812 caused a second disruption to the social and economic life of Delaware Valley residents, but shortly thereafter, local inhabitants began to focus again on industry and agriculture.

A water link between Delaware Bay and Chesapeake Bay was forged when the Chesapeake and Delaware Canal was opened in 1829. Traffic across the peninsula between the two bays was so heavy that it supported the canal, a previously constructed turnpike, and within a few years, the New Castle and Frenchtown Railroad, one of the first railroads in America (Tyler 1955). Manufacturing came to the upper Delaware Valley in the first half of the 19th century. By 1850 Wilmington had became a leading manufacturer of railroad cars, heavy machinery, gunpowder, textiles, flour, and iron ships (Weslager and Heite 1988).

There was little or no industrial development along the shores of lower Delaware Bay. The slow-moving tidal tributaries lacked the force to power a large industrial plant. The tidal rivers themselves were too shallow for most sea-going vessels to navigate. In addition to farming, fishing and oystering became major industries of lower Delaware Bay during the 19th century. For nearly a century after the Civil War, oystering was the primary industry in many towns along the lower estuary in both New Jersey and Delaware (Weslager and Heite 1988). Fishing industries processing sturgeon and menhaden caught in Delaware Bay also peaked during the second half of the 19th century.

The introduction of steam technology had a dramatic effect on industries throughout the Delaware Valley. Regional companies became leaders in the production of steam engines for

railroad locomotives and steamships. Several local companies also made railroad cars and car wheels, before expanding into the production of iron-hulled steamships. Delaware River shipyards gained an international reputation for producing quality iron-hulled steam vessels. Coal fuel was needed to power steam engines. Extensive anthracite coal reserves along the Lehigh and Schuylkill rivers were developed. Coal became a leading export for Delaware River ports during the 19th and 20th centuries. Related industries of iron and steel, initially founded in the Delaware Valley since the colonial period, expanded after the 19th century.

The large chemical industry of the Delaware Estuary began with the development of several small tanneries in and around New Castle County, Delaware, during the 19th century. Native black oak trees provided tanbark and local livestock production provided skins for the tanners. By the middle of the 19th century, Wilmington became a major producer of leather merchandise. Experiments were conducted in the tanning process that would revolutionize the leather making process. Prosperity gained from gunpowder production during the Civil War, allowed the local DuPont Company to expand over the next 30 years into one of the world's largest producer of chemicals and munitions. Petroleum-related industries and refineries were also established shortly after the discovery of oil in central and northwestern Pennsylvania in the 19th century. Philadelphia refineries are among the oldest in the world still producing refined oil products (Weslager and Heite 1988).

3.3.1 Overview of the Colonial Maritime History of Lewes, Delaware

While the initial colonization of the Sussex County was a short-lived whale-fishing camp established by the West India Company at Zwaanenael, now Lewes in 1631, the origins of present-day Lewes (historically known as Lewestown) as a merchant port date to the late 17th century. At this time the territory of present-day Delaware then known as the "three lower counties" was part of Pennsylvania and under the control of William Penn. Penn acquired these lands from the Duke of York in 1684. By the turn of the 17th century, shipbuilding had become a small, but growing industry in Lewestown (Pusey 1903:20-21; Brittingham 1998:12; Cohen 2004:116).

After Penn's arrival a number of immigrants from Scotland and Ireland, who belonged to the religious sect known as the "Independents" settled in Lewestown. The first courthouse was built in 1682. In 1725, the community consisted of 58 families. The first church (Presbyterian) was erected in 1728 and around 1740, Lewestown had a formal courthouse erected, being the seat of government for Sussex County until 1791. By virtue of the King's authority and later by express grant by the heirs of William Penn the tract of sandy level land and marsh lying between Lewestown and the Delaware Bay was established as a public commons for the people's benefit (Pusey 1903:21-23; Lewes Historical Society 1985:122-123; Brittingham 1998:12; Cohen 2004:115).

Historically, the Delaware Bay afforded the most ideal place of refuge within the 300 hundred miles extending from New York to the Chesapeake. It is of local tradition that the earliest lighthouse on Cape Henlopen was a crude whale oil light first erected around 1725. It was built to warn incoming mariners of their approach to the Hen and Chickens Shoals, located just off the Cape, and to guide their way into the shelter of the Bay. A more formal lighthouse was constructed in 1765, by the British government on the Atlantic side of the Cape (Pusey 1903:30-31; Cohen 2004:118).

During the Colonial period and into the 19th century, Lewestown was home to the pilots that shipmasters relied upon to assist with navigating around the hazards of the Delaware Bay and River. Many of these Pilots lived within Lewestown, but as early as 1756, it appears as though

some families associated with this trade established their own community, "Pilot-Town," located immediately to the south of Lewestown. Being the first port upon entering the Bay, sailing ships regularly stopped at Lewestown for pilots and provisions (Lewes Historical Society 1985:123; Knopp 1996:1-2).

The earliest Lewestown pilots made use of two-masted schooners owned by small groups or clans and consisting of about eight pilots each. There was strong competition between the groups each trying to be the first to reach an incoming ship in hopes to land the job of piloting the vessel up the Delaware to northern ports. Some started apprenticeship as early as 15 years of age learning the navigation of the Delaware Bay and River from other experienced Pilots. An apprentice was required to have six years of training before he was issued a license. A formal Pilots Association, established to better regulate the trade, was not formed until 1896 (Cullen 1956:37; Knopp 1996:5; Cohen 2004:129).

The first detailed chart of the Delaware Bay and River was drafted in 1756 by Joshua Fisher, a native of Lewestown. The documentary evidence is conflicting as to Fisher's occupation, but it is more than likely that he was associated with the pilot industry to have had the knowledge to create the chart (Lewes Historical Society 1981:61; 1985:176). The chart was published by an Act of Parliament and was signed by 22 licensed Pilots and 20 Masters, vouching for its authenticity. Fisher's chart indicates that the area today known as Lewes Beach was an ideal spot for anchoring vessels. Soundings were taken throughout the Bay at low tide and indicated on the map in fathoms. The water depth near Lewes Beach at this time was 18 feet. The chart shows that the main ship channel was located roughly four miles off the coast of Lewestown. The westernmost channel, indicated as being "used only by Shallops," is shown as commencing at the mouth of Lewes Creek. Historically Lewes Creek and the Broad Kill River came to a confluence before emptying into the Bay near the northwestern terminus of present-day Beach Plum Island. Present-day Cape Henlopen is labeled "Cape James" (Fisher 1756).

Throughout the remainder of the Colonial period, Lewestown's economy appears to have been closely tied to its maritime industries. The town remained the seat of county government beyond the Revolutionary War and shipbuilding appears to have continued on a small scale. The town was undoubtedly an important port throughout this period for supplying ships with pilots and other provisions. The port was also likely of local importance to the colonists of Sussex County for trading and shipping agricultural and other goods overseas and to the Wilmington and Philadelphia regions.

Over the years, the mouth of Lewes Creek became filled with sandbars and was virtually impassable at low tide. This is likely to have been a re-occurring problem throughout the 19th century and into the 20th century. In 1937, present-day Roosevelt Inlet was constructed to assist with alleviating this issue. The new inlet was constructed roughly two miles to the southeast of the original inlet. Shortly thereafter, Lewes Creek was deepened through dredging and the waterway became known as the Lewes-Rehoboth Canal (Cullen 1956:38).

3.3.2 Overview of Delaware Bay Navigational Improvements

Although the Delaware Bay was visited by Henry Hudson in 1609 and explored by others within the next decade, the first comprehensive navigational chart of the Delaware Coast vicinity was not completed until 1756. In that year Joshua Fisher charted the waters of the Delaware Bay and provided the first bottom contours based on soundings. In the first half of the 19th century several other maps and charts of the vicinity were privately published, but standardized charting of the coast was not initiated until the first United States Coast Survey was completed in the middle of

the 19th century. In 1878, this agency was reconstituted as the United States Coast and Geodetic Survey and, from this time on, has periodically updated the chart of the vicinity with increasingly detailed and more accurate hydrographic information.

As the Delaware Bay affords the only suitable deepwater inlet along the 295-mile stretch of the Atlantic Coast between Chesapeake Bay and New York Bay, mariners frequently sought refuge in the mouth of the bay during periods of inclement weather. Lewes became a harbor of refuge for ships heading along the Atlantic Coast and up Delaware Bay, alike. The earliest known aid to navigation in Delaware was the Cape Henlopen Light which was erected in 1767. The light helped to guide vessels into the bay and also served as a warning that the cape was nearby. The lighthouse continued to aid vessels entering and exiting Delaware Bay until it was destroyed by erosion in 1926. A second lighthouse was constructed on Fenwick Island in 1858 to further aid mariners traversing the Delaware coastal waters.

A major aid to navigation in the area was the construction of a pair of breakwaters inside Cape Henlopen and the creation of a Harbor of Refuge, thereby providing protection to vessels from storms and ice at the mouth of the Delaware Bay. Before the construction of these breakwaters, conditions at the mouth of the Delaware Bay were often more perilous than in the open ocean. Mariners, shipping companies, port officials, and insurers all raised the issue of the need for a protective breakwater near the mouth of Delaware Bay to protect shipping. In a plea made to Washington, D.C in 1826, Alex Stewart encouraged officials to:

> "... place a shelter at the entrance of the bay [because] the commerce of the Delaware will not alone be protected and preserved by it, but that of the whole coast, daily passing and repassing its capes, together with foreign vessels who resort there when overtaken by accident at sea. All will find a haven where their crews can be recruited; damages repaired, and their wants fully supplied secure from mishap or danger, thereby the interests of merchants, and the lives of hundreds of individuals will be saved from jeopardy or untimely death" (cited in Hazard 1828:70).

In 1822 an Act of Congress was approved which appropriated over $22,000 for a survey calling attention to the suitability of the Delaware Bay as a Harbor of Refuge. After numerous delays, this survey led to the construction of the original or inner breakwater, which was eventually finished in 1869. This structure was 2,558 feet long and had a detached ice breaker that was 1,359 feet long and separated by a gap of 1,390 feet. In 1882 a project was adopted which involved closing the gap between ice breaker and the breakwater, a task that was accomplished by 1898. However, even before this project was completed, the need for a more inclusive breakwater was evident. An outer breakwater was thus authorized by a Congressional Act in 1896. The resulting 8,040-foot-long breakwater was finished in 1901, providing the community of Lewes with the Harbor of Refuge that still remains in existence today (Department of the Army, Corps of Engineers 1916).

The Lewes and Rehoboth Canal constructed in 1913, runs along the former course of Lewes Creek, which in the late 17th century was known as Whorekil Creek. When it was initially constructed, the canal extended for 12 miles between Broadkill Jetty to Rehoboth Bay. It measured roughly six feet deep and was approximately 45 feet wide. The Lewes and Rehoboth Canal was expected to carry large numbers of vessels but never fulfilled its potential. The canal

presently meets Broadkill River at Roosevelt Inlet before flowing into Delaware Bay. Roosevelt Inlet was constructed in the mid-1930s and finished in 1938.

4.0 POTENTIAL SUBMERGED CULTURAL RESOURCE TYPES

4.1 National Register of Historic Places Nomination Process

To qualify for the National Register of Historic Places, a site "must be significant in American history, architecture, archaeology, engineering, or culture, and possess integrity of location, design, setting, materials, workmanship, feeling, and association." To be considered significant the site must meet one or more of four National Register criteria. These criteria include:

A. Association with events that have made a significant contribution to the broad patterns of our history;

B. Association with the lives of persons significant in our past;

C. Embodiment of the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction;

D. Sites that have yielded, or may be likely to yield, information important in prehistory or history.

National Register Bulletin 20 clarifies the National Register process for shipwrecks and other submerged cultural resources. Shipwrecks must meet at least one of the above criteria and retain integrity of location, design, settings, materials, workmanship, feelings and association. Determining the significance of a historic vessel depends on establishing whether the vessel is:

1. the sole, best, or a good representative of a specific vessel type; or

2. is associated with a significant designer or builder; or

3. was involved in important maritime trade, naval recreational, government, or commercial activities.

Properties which qualify for the National Register, must have significance in one or more "Areas of Significance" that are listed in National Register Bulletin 16A. Although 29 specific categories are listed, only some are relevant to the submerged cultural resources in lower Delaware Bay. Architecture, commerce, engineering, industry, invention, maritime history, and transportation are potentially applicable data categories for the type of submerged cultural resources that may be expected in the project areas.

4.2 Potential Inundated Terrestrial Sites

4.2.1 Potential Site Integrity

Although only a few inundated prehistoric terrestrial cultural resource sites have been identified along the Mid-Atlantic Continental Shelf, the potential for inundated sites has been recognized. Patterns of prehistoric human activity on the Atlantic Continental Shelf were tied to dramatically changing environmental conditions. At the onset of the Wisconsin Stage of the Pleistocene Epoch a general cooling of the earth occurred. The dramatic expansion of vast polar ice caps created a significant reduction in sea level. Landforms exposed by receding water reshaped the continent. A terrestrial ecology associated with cold-adapted boreal forests and or tundra and upland geomorphology developed (Vokes 1957). A warming trend, initiated at the end of the Wisconsin Stage of the Pleistocene Epoch, approximately 15,000 B.P., began to reverse the process of severe weather patterns. Melting glacial ice and post-glacial rebounding of the tectonic plates produced an erratic but rising sea level. Since the inception of the Pleistocene, the Atlantic Continental Shelf has been inundated several times. While short term rates of post-Pleistocene sea-level rise vary, most researchers support the concept of a rapid rise in sea level prior to 5,000 years ago. Since that time, local rise in sea level is generally estimated to be approximately six-inches per century. As a result of this sea-level rise, the Atlantic Coast has been migrating to the west. It is not uncommon to see evidence of a migration of several hundred feet in some localized areas during recorded history (Vokes 1957). During periods of lower sea level the prehistoric populations of the Delmarva Peninsula are assumed to have exploited the exposed Continental Shelf.

Examination of the study area geomorphology and environment provides some insight into the nature and condition of submerged cultural resources that might exist along the Delaware Coast. It is possible that the inundation of prehistoric archaeological sites would have resulted in extensive resorting of the archaeological record. While artifacts preserved in the bottom sediments could exist in an excellent state of preservation, the associated context of human activity may have been destroyed. The high-energy environment that is present along the coastline would lessen the likelihood that fragile evidence of prehistoric populations would survive. However, there are examples where terrestrial archaeological sites have survived the inundation process. Evidence from inundated Karst formation sites in Sarasota County, Florida (Clausen 1975) and in the Gulf of Mexico off Fort Myers (Ruppe 1979) indicate that the archaeological record associated with prehistoric sites is not always destroyed. However, much depends on the local conditions and insufficient evidence has been generated to support broad generalizations.

4.2.2 Anticipated Property Types

Perhaps the most comprehensive treatment of the subject is "A Summary and Analysis of Cultural Resource Information on the Continental Shelf form the Bay of Fundy to Cape Hatteras." Volume II of the study treats archaeology and paleontology. Although the potential for earlier sites was assessed as low, the potential for archaic sites was defined as medium to high. Although the location and identification of submerged archaic sites would be difficult, their association with detectable shell middens should enhance the possibilities. Investigations in the Gulf of Mexico off the west coast of Florida (Ruppe 1979) has confirmed both the association of prehistoric material with submerged middens and their detectability using side scan sonar remote sensing.

4.3 Potential Shipwreck Types in Project Area

4.3.1 Potential Site Integrity

The effect of geomorphology and environment on shipwreck material can be quite different. In most cases the remains of shipwrecks are not subjected to the processes of inundation. Shipwreck material deposited in even the shallowest environment can settle rapidly into the bottom with its associated archaeological record intact. The wreck of the DeBraak (1798), discovered at the mouth of Delaware Bay provides a classic example. A good portion of the lower hull survived intact, along with an extensive associated artifact assemblage. A second local example if site integrity comes from the wreck of the Roosevelt Inlet wreck (ca. 1783). Located in 2005 at the mouth of Delaware Bay near Roosevelt Inlet, this site had had very little surviving hull structure but contained a large volume of well preserved cultural material from the vessel's cargo. These two examples at the mouth of Delaware Bay confirm that even in extremely high-energy environments, archaeological evidence of historic wreck sites almost inevitably survives. Numerous other archaeological investigations off the coasts of the states Maine, Massachusetts, New Jersey, Virginia, Maryland, New York, North Carolina, Florida, and Texas, and the countries of England, Greece, Italy, Israel and Turkey, offer examples that ship remains survived to preserve valuable archaeological data.

At many of the shipwreck sites sand and light mud similar to the bottom sediments in portions of the study area provided an excellent environment for preservation. Given the level of maritime activity in Delaware Bay, the extent of vessel losses in the vicinity of the study areas, and the level of preservation at shipwreck sites in other similar environments, it is probable that well-preserved shipwreck sites exist in the vicinity of the study areas.

4.3.2 Anticipated Property Types

In conjunction with exploration, colonization and the expansion of coastal commerce, Delaware Bay has become a likely repository for a wide range of submerged cultural resources. Many coastal vessels attempting to reach the Harbor of Refuge at the mouth of the Delaware Bay have instead wrecked in the bay and along the Atlantic coast of Delaware. Strong coastal storms often with treacherous northeast winds and the presence of swift longshore tidal currents, all coupled with historically heavy coastal traffic, the mouth of Delaware Bay has become the final resting place for dozens of documented sailing vessels, steamships, barges, tugs and large modern ships that have perished since World War II.

Although there are no documented submerged historical sites within the boundaries of the three borrow areas, secondary and primary historical sources suggest that numerous vessels from a wide range of historical eras have been deposited in the general vicinity of these areas. The potential does exist for the borrow areas to contain National Register eligible submerged cultural resources.

A listing of shipwrecks and all types of ship losses along Delaware's Atlantic Coast and the mouth of Delaware Bay was gathered during background historical research (Appendix I). Drawing from a variety of primary and secondary sources, the extensive shipwreck list, while far from comprehensive, nonetheless gives an indication into the wide variety of shipwrecks that have been lost near the project vicinities over the last 350 years. More than 300 shipwrecks and ship losses were documented in/near the mouth of Delaware Bay since the first reported loss in 1641. Numerous ships were lost off the Delaware Atlantic Coast during World War II naval operations. Many known wrecks sites in the project vicinity are popular dive locations.

Potential submerged cultural resource types in the project vicinities may include a variety of material dating from the first half of the 17th century through the Second World War. Several recent shipping disasters that occurred within the last 60 years are also listed. To discuss the types of vessels potentially present, it is necessary to include vessels from all phases of the commercial and naval activity in and out of Delaware Bay and along the Delaware portion of the Atlantic coast. Wood-hulled ships, ranging from small fishing sloops, shallops, recreational sailing and motor craft, and coastal schooners, to ship-rigged warships, have been lost near the mouth of Delaware Bay. Iron-hulled vessels, including paddle wheel steamboats and World War II-era merchant ships sunk by German submarines, have also been lost in the project vicinity. Large 20th century steamships and freighters are among the listed losses in the region. Many of these types of vessels would potentially lend historic insights into a wide range of maritime related topics, including the contexts of naval activity, shipbuilding, regional shipping, and industry patterns. A Bureau of Land Management "Summary and Analysis of Cultural Resource Information on the Continental Shelf from the Bay of Fundy to Cape Hatteras," (Bourque, *et. al.* 1979) identifies the Delaware Coastal Zone as an area of "moderately heavy" predicted shipwreck density and acknowledges the potential for inundated prehistoric archaeological sites.

5.0 PREVIOUS UNDERWATER ARCHAEOLOGICAL PROJECTS

Numerous submerged cultural resource investigations have been conducted in the Delaware portion of lower Delaware Bay and in the Atlantic Ocean offshore from Delaware. In addition to these submerged cultural resource projects, one historic shipwreck, the DeBraak, was salvaged near the mouth of Delaware Bay.

In June, 1982, Historic Sites Research submitted the report, "Cape May Project Study Phase II Cultural Resources Survey Relocation, Testing and Evaluation of Submerged Magnetic Anomalies," (Historic Sites Research 1982) to Army Corps of Engineers, Philadelphia District. A magnetometer survey was conducted 1.25 miles offshore from Cape May to located magnetic targets in a proposed borrow area 6,000 feet long by 1,650 feet wide. Nine anomalies were identified and avoidance was recommended. Karell Archaeological Service submitted the report, "Underwater Cultural Resources, Background Study and Field Survey of the Delaware Inner Continental Shelf," (Koski-Karell 1984) to the Delaware Division of Soil and Water Conservation in June 1984. The study consisted of a literature search and a magnetic remote sensing survey of two proposed borrow areas near Indian River Inlet. One potentially significant magnetic target was located and avoidance was recommended.

Tidewater Atlantic Research submitted the report, "An Archaeological Reconnaissance of Proposed Offshore Borrow Sites Near Ocean City, Maryland," (Watts 1986) to the Maryland Geological Survey in November 1986. A magnetometer and side scan sonar survey was conducted at four borrow areas offshore of Ocean City. Of the 19 targets identified during the fieldwork, five were determined to have signature characteristics that could correspond with historically significant submerged cultural resources and were further investigated. On-site investigation confirmed that the remains of a barge and clam dredge were responsible for two of the signatures and debris from a third modern wreck was responsible for an additional target signature. A modern dredge pipe was responsible for the fourth signature. No evidence was found of the fifth target location, although it was believed to be associated with the remains of a modern commercial vessel.

In 1993, Dolan Research completed a remote sensing survey of two offshore sand borrow areas between Dewey Beach and Cape Henlopen, Delaware. The report submitted to the U.S. Army Corps of Engineers, Philadelphia District (COE), entitled "Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island" (Cox 1995) confirmed the presence of three targets that were classified as high probability targets. Additional investigation or avoidance of the three target locations was the recommended action.

In 2000, Dolan Research conducted two different Phase I Submerged Cultural Resources Investigations in the Atlantic Ocean for the COE. The first survey was completed at the Fenwick Island offshore sand borrow area (2,542 acres) in the Atlantic Ocean, approximately 1.50 miles offshore of Fenwick Island, Sussex County, Delaware (Cox 2001). Of the 22 targets identified during the project, four possessed signature characteristics suggestive of submerged cultural resources. These four were designated as high probability targets, where additional archaeological investigation or avoidance was recommended.

The second Dolan Research project in 2000 was conducted at three offshore borrow areas in the Atlantic Ocean; designated Borrow Area B, Borrow Area G, and the Indian River Inlet Borrow Area. The comprehensive magnetic and acoustic remote sensing survey identified eight remote sensing targets (Cox 2001a). However, only one target was classified as a high probability target Additional underwater archaeological investigation, or avoidance, of the target site (located in Borrow Area G) was recommended.

In 2004 Eviroscan, Inc. and Dolan Research, Inc., jointly conducted Phase I underwater archaeological investigations at three potential artificial reef locations in the Atlantic Ocean and the Delaware River for the Delaware Reef Program, State of Delaware, Division of Fish and Game (Cox and Capone 2004). The two artificial reef locations located well offshore of the Delaware Coast in the Atlantic Ocean were referred to as DELJERSEY Inshore and DELJERSEY Offshore. One potentially significant magnetic target was identified in the DELJERSEY Inshore reef and avoidance was the recommended action.

In 2005, Dolan Research completed Phase I and Phase II Underwater Archaeological Investigations at Lewes Beach and Roosevelt Inlet Borrow Areas, Delaware Bay, Sussex County, Delaware (Cox 2005). In addition to three potentially significant targets found in Borrow Area 2, the site of an 18th century shipwreck was identified (7S-D-91A) and documented at a Phase 2 level. The site was later nominated to the National Register of Historic Places. At Borrow Area 1, avoidance was recommended at two remote sensing target locations. In 2011, Dolan Research conducted a Phase I Underwater Archaeological Investigation at the Delaware Coast Expanded Borrow Area B, a 1,454 acre site located 2.5 miles northeast of Indian River Inlet, Sussex County, Delaware (Cox 2012). The remote sensing survey identified 16 magnetic and sonar targets. However, none of these 16 targets generated remote sensing signatures suggestive of potentially significant submerged cultural resources and no additional underwater investigations were recommended.

6.0 FIELDWORK INVESTIGATIONS

The purpose of remote sensing investigation was to locate, identify, and preliminarily assess the significance of remote sensing targets that might be impacted by harvesting sand in the three borrow areas in Delaware Bay. The remote sensing survey was designed to generate sufficient magnetic and acoustic remote sensing data to identify anomalies and bottom features typically associated with submerged cultural resources. Analysis of the remote sensing data aimed to identify targets of potential historical significance that might require further investigation or avoidance.

6.1 Summary of Equipment and Methods

Sonar and magnetic survey operations were conducted simultaneously from a 25-foot fiberglass survey vessel. Both sensors were towed from of the survey vessel. Sonar data were gathered with a *Marine Sonic HDS* two channel digital side scan sonar unit with a dual frequency 600/1200kHz side scan sensor. The sonar sensor was towed under the starboard side feet of the survey vessel and operated at a range of 120 feet in either channel which created a swath of acoustic coverage 240 feet wide on each survey lane. *Marine Sonic* data acquisition software was used to merge the acoustic data with real-time positioning data.

Magnetic data were collected with a *Geometrics 881* cesium marine magnetometer, capable of +/- 1/10 gamma resolution. A ½ -second sampling rate by the magnetometer's towed sensor, coupled with a four-knot vessel speed generated a magnetic sample every two feet. The magnetometer sensor was 50 feet aft of the port side of the survey vessel to provide optimal conditions for collecting magnetic data in a shallow water environment.

Hypack, a laptop PC-based software package in conjunction with a Differential Global Positioning System (DGPS) onboard the survey vessel provided positioning accuracy for the survey areas of +/- two (2) feet. The computer converted positioning data from the DGPS to Delaware State Plane Coordinates in real time. These X,Y coordinates were used to guide the survey vessel precisely along predetermined track lines that had been established at 75-foot offsets in the survey area (Figures 4-6). While surveying, vessel positions were continually updated on the computer monitor to assist the vessel operator, and the processed X,Y data were continually logged on computer disk for post-processing and plotting.

All project horizontal reference is the Delaware State Plane Coordinate System, NAD 83, in feet.

6.2 Data Products - Magnetometer

The magnetometer collected data on the ambient magnetic field strength by measuring the variation in cesium electron energy states. As the sensor passed over objects containing ferrous metal, a fluctuation in the earth's magnetic field was recorded. The fluctuation was measured in gammas and is proportional to the amount of ferrous metal contained in the sensed object.

Magnetic data were edited for detailed analysis of all anomalies. During the editing process background noise and diurnal change were removed and magnetic contour maps were created with five-gamma intervals for the three project areas (Figures 7-9, 11-13, & 15-16). Magnetic data editing consisted of using Hypack's single-beam editing program to review raw data (of individual survey lines) and to delete any artificially induced noise or data spikes. Once all survey lines for an area were edited, the edited data were converted to an XYZ file also using Hypack (easting, and northing coordinates, and magnetometer data – measured in gammas). Next, the XYZ files were imported into a Triangular Irregular Network (TIN) modeling program in Hypack) that was used to contour the data in ten-gamma intervals. A second major analytical

technique employed included the subtraction of general background from each successive data sample to develop the actual field gradient. The gradient is the vertical difference (z) between samples. By subtracting successive data samples one from the other the effects of diurnal change is completely eliminated. The resulting data represents only the localized changes in the magnetic background created by ferrous objects (i.e. anomalies) or geological features. When graphically represented by contouring, only the intensity of variation is represented.

6.3 Data Products - Side Scan Sonar

The side scan sonar derives its information from reflected acoustic energy. Side looking sonar, which transmits and receives swept high frequency bandwidth signals from transducers mounted on a sensor that is towed from a survey vessel. Two sets of transducers mounted in an array along both sides of the tow fish generate the short duration acoustic pulses required for high resolution images. The pulses are emitted in a thin, fan-shaped pattern that spreads downward to either side of the tow fish in a plane perpendicular to its path. As the fish is towed along the survey track line this acoustic beam sequentially scans the bottom from a point beneath the fish outward to each side of the track line.

Acoustic energy reflected from any bottom discontinuities (exposed pipelines, rocks, or other obstructions) is received by the set of transducers, amplified and transmitted to the survey vessel via a tow cable. The digital output from state of the art units is essentially analogous to a high angle oblique photograph provided detailed representations of bottom features and characteristics. Sonar allows display of positive relief (features extending above the bottom) and negative relief (such as depressions) in either light or dark opposing contrast modes on a video monitor. Examination of the images thus allows a determination of significant features and objects present on the bottom within a survey area.

Raw sonar records were inspected for potential man-made features and obstructions present on the bottom surface. Sonar data were saved in separate files for each survey lane. Individual acoustic data files were initially examined using SeaScan™ acoustic data review software to identify any unnatural or man-made features in the records. Once identified, acoustic features were described using visible length, width, and height from the bottom surface. Acoustic targets are normally defined according to their spatial extent, configuration, location and environmental context. As a last step, edited acoustic data were merged into geo-referenced sonar mosaics that were overlaid onto aerial photographs of the project areas (Figures 10, 14, & 17).

6.4 Evaluation of Remote Sensing Targets

Target signatures were evaluated using the National Register of Historic Places criteria as a basis for the assessment. For example, although an historic object might produce a remote sensing target signature, it is unlikely that a single object (such as a historic anchor or cannon ball) has the potential to meet the criteria for nomination to the National Register of Historic Places.

Target assessment was based primarily on the nature and characteristics of the acoustic and magnetic signatures. Shipwrecks – large or small – often have distinctive acoustic signatures, which are characterized by geometrical features typically found only in a floating craft. Most geometrical features identified on the bottom (in open water) are manmade objects. Often an acoustic signature will have an associated magnetic signature. Generally, if the acoustic signature demonstrates geometric forms or intersecting lines with some relief above the bottom surface and have a magnetic signature of any sort; it can be categorized as a potentially significant target. Often, modern debris near docks, bridges, or an anchorage is easily identified solely based on the characteristics of its acoustic signature. However, it is more common to find material partially exposed. Frequently, these objects produce a record that obviously indicates a man-made object,

but the object is impossible to identify or date. Also in making an archaeological assessment of any sonar target, the history and modern use of the waterway must be taken into consideration. Naturally, historically active areas tend to have greater potential for submerged cultural resources. The assessment process prioritizes targets for further underwater archaeological investigations.

Magnetic target signatures alone are more difficult to assess. Without any supporting acoustic records, the type of the bottom sediments and the water currents become more important to the assessment process. A small, single-source magnetic signature has the least potential to be a significant cultural resource. Although it might represent a single historic object, this type of signature has limited potential to meet National Register criteria.

A more complex magnetic anomaly, represented by a broad monopolar or dipolar type signature, has a greater potential to be a significant cultural resource, depending on bottom type. Shipwrecks that occur in regions with hard bottoms, with little migrating sand, tend to remain exposed and are often visible on sonar records. A magnetic anomaly that is identified in a hard bottom area and has no associated acoustic signature frequently can be discounted as being a historic shipwreck. Most likely, such an anomaly is modern debris, such as wire rope, chain, or other ferrous material.

Soft migrating sand or mud can bury large wrecks, leaving little or no indication of their presence on the bottom surface (via sonar data). The types of magnetic signatures that a boat or ship might produce are infinite, because of the large number of variables including location, position, chemical environment, other metals, vessel type, cargo, sea state, etc. These variables are what determine the characteristics of every magnetic target signature. Since shipwrecks occur in a dynamic environment, many of the variables are subject to constant change. Thus, in making an assessment of a magnetic anomalies potential to represent a significant cultural resource, investigators must be circumspect in their predictions.

Broad, multi-component signatures (again, depending on bottom characteristics and other factors) often have the greatest potential to represent a shipwreck. On the other hand, high-intensity, multi-component, magnetic signatures (without an accompanying acoustic signature) in areas of relatively high velocity currents can be discounted as a historic resource. Eddies created by the high-velocity currents almost always keep some portion of a wreck exposed. Generally, wire rope or some other low-profile ferrous debris produces this type of signature in these circumstances. Many types of magnetic anomalies display characteristics that are not easily interpreted. The only definitive method of determining the nature of the object creating these anomalies is by physical examination.

6.5 Remote Sensing Findings

Inspection of the remote sensing data has confirmed the presence of no potentially significant remote sensing targets in the surveys areas; PHB-A, PHB-B, or PHB-C. After processing and contouring the magnetic data sets, 15 small, single-source anomalies and two noisy multi-component anomalies were identified in the three survey areas (17 in total): five (5) in Area PHA, eleven (11) in Area PHB, and one (1) in Area PHC. No corresponding sonar imaging was associated with locations suggesting that the sources of the anomalies were buried. All anomalies that generated a signature that exceeded 10 gammas in intensity and extended for at least three sample intervals have been included in the target list. All the qualifying magnetic targets are listed and described in Table 1, below.

Other than the isolated magnetic anomalies identified in Table 1, there was very little/no magnetic variation and very few distinctive bottom features exposed on the bottom surface across

all three survey areas. In the opinion of the Principal Investigator, it is not likely that any of these magnetic signatures are suggestive of potential submerged cultural resources.

The evaluation of the sonar records confirms the lack of any potentially significant acoustic targets that are suggestive of submerged cultural resources. Sonar data indicate generally featureless bottom conditions across the majority of the three survey areas. Several small isolated features were identified but these objects appear to be suspected abandoned crab traps and some linear debris. Nine of these sonar anomalies, typical of the small features found across the three borrow areas hqave been included in the sonar target list: one (1) in Area PHA, five (5) in Area PHB, and three (3) in Area PHC. However, none of these nine features are considered potentially historically significant.. These nine sonar features are listed and described in Table 2, below.

Since not potentially significant remote sensing targets were identified during the remote sensing survey, no additional underwater archaeological investigations are recommended Borrow Areas PHB-A, PHB-B, and PHB-C.

Table 1 Magnetic Targets in Borrow Areas: PHB-A, PHB-B, and PHB-C

Notes:
1) Coordinates are expressed in the Delaware State Plane Coordinate System, NAD83.
2) A# targets are located in area PHB-A, B# targets in PHB-B and C# targets are in PHB-C

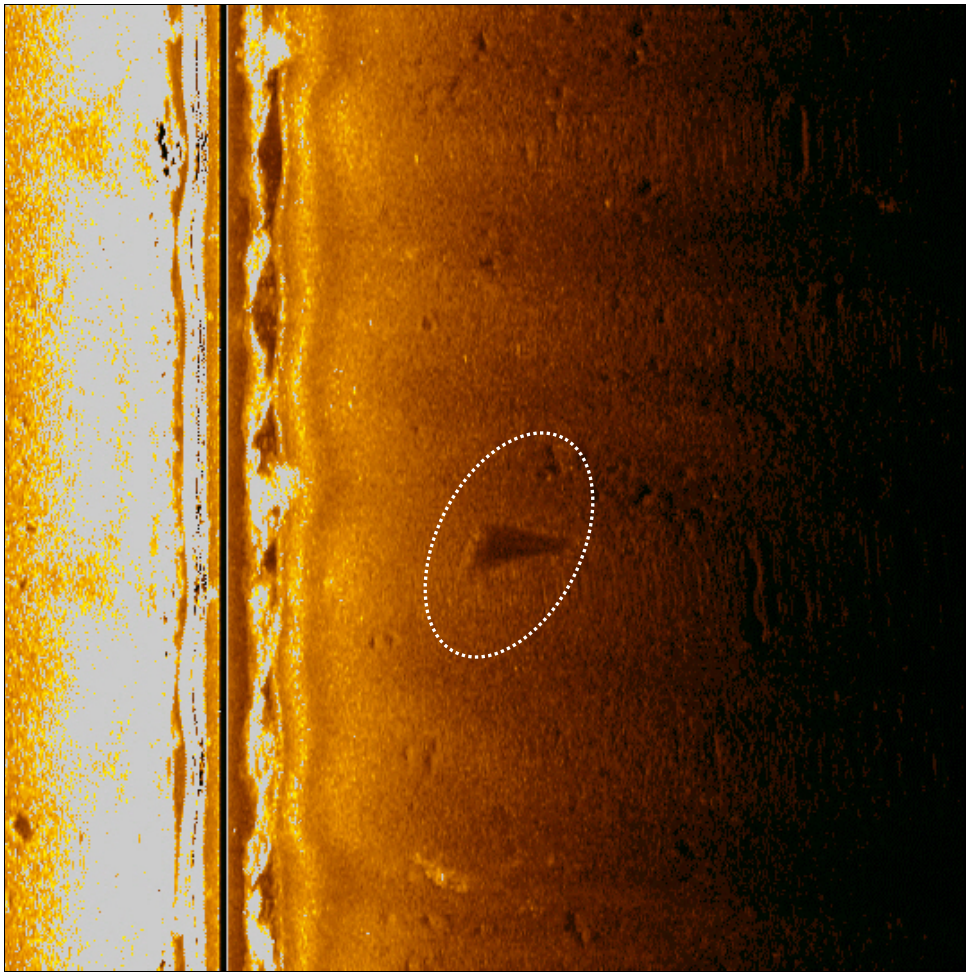
Anomaly #	Easting (X)	Northing (Y)	Characteristics
A1	717,850	309,816	14 gamma, negative monopolar signature that extended 21' across bottom. Small, single source anomaly. No further archaeological investigations are recommended at this location (NFI).
A2	718,815	312,515	18 gamma, negative, monopolar signature that extended 18' across bottom. Small, single source anomaly (NFI).
A3	717,547	312,592	46 gamma, positive, monopolar signature that extended 26' across bottom. Small, single source anomaly (NFI).
A4	716,658	312,735	21 gamma, negative, monopolar signature that extended 12' across the bottom. Small, single source anomaly (NFI).
A5	715,786	312,720	235 gamma, dipolar signature that extended 17' across the bottom. Single source anomaly with no signal duration (NFI).
B1	710,475	316,618	37 gamma, multi-component signature that extended 98' across the bottom. Noisy, irregular signature with linear orientation – very suggestive of wire rope (NFI).
B2	710,101	316,729	52 gamma, positive, monopolar signature that extended 12' across the bottom. Small, single source anomaly (NFI).
B3	709,361	316,969	26 gamma, positive, monopolar signature that extended 16' across the bottom. Small, single source anomaly (NFI).
B4	709,501	317,579.	14 gamma, positive, monopolar signature that extended 15' across the bottom. Small, single source anomaly (NFI).
B5	709,126	319,015	26 gamma, negative, monopolar signature that extended 16' across the bottom. Small, single source anomaly (NFI).
B6	709,352	319,588	14 gamma, positive, monopolar signature that extended 12' across the bottom. Small, single source anomaly (NFI).
B7	708,448	319,177	19 gamma, multi-component signature that extended 118' across the bottom. Noisy, irregular signature with linear orientation – very suggestive of wire rope (NFI).
B8	708,191	319,544	26 gamma, negative, monopolar signature that extended 16' across the bottom. Small, single source anomaly (NFI).
B9	708,145	320,101	62 gamma, positive, monopolar signature that extended 17' across the bottom. Small, single source anomaly (NFI).
B10	710,778	320,731	26 gamma, negative, monopolar signature that extended 15' across the bottom. Small, single source anomaly (NFI).

Anomaly #	Easting (X)	Northing (Y)	Characteristics
B11	710,777	323,376	19 gamma, positive, monopolar signature that extended 13' across the bottom. Small, single source anomaly (NFI).
C1	720,487	307,433	45 gamma, negative, monopolar signature that extended 14' across the bottom. Small, single source anomaly (NFI).

Table 2. Typical Sonar Targets in Borrow Areas: PHB-A, PHB-B, and PHB-C

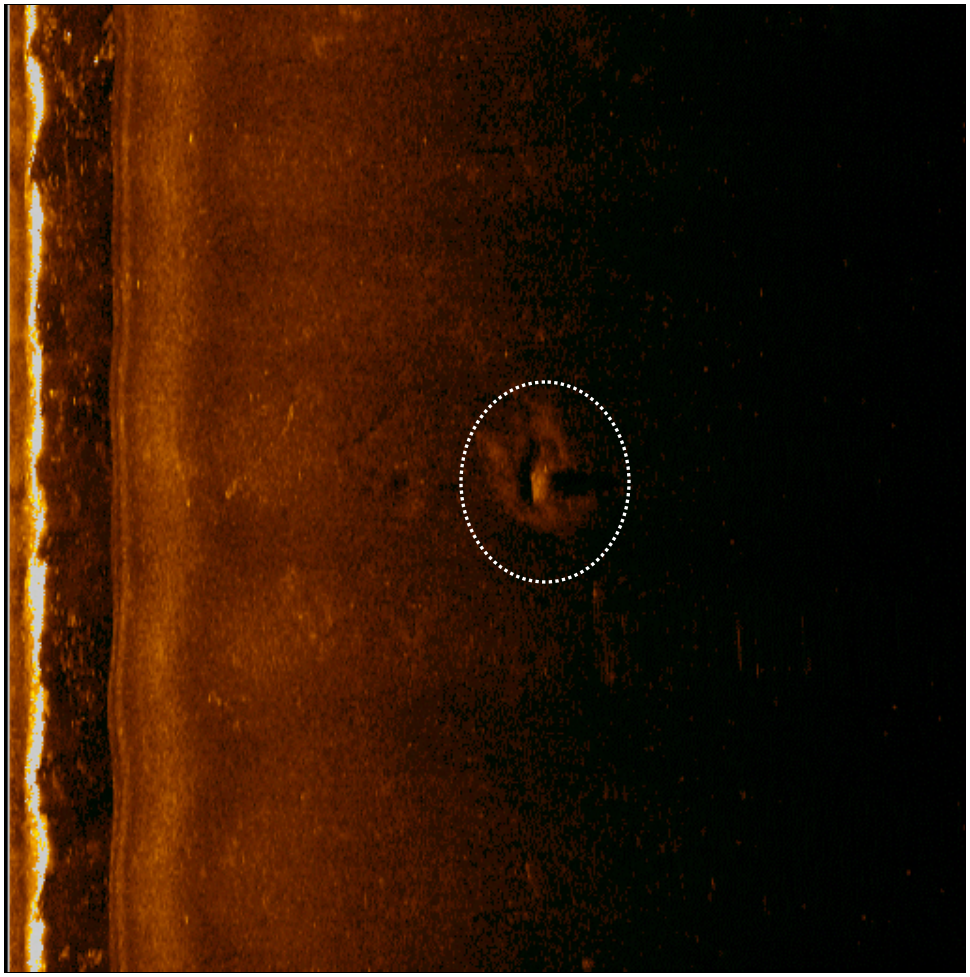
Note: Coordinates are expressed in the Delaware State Plane Coordinate System, NAD83.

S-A1



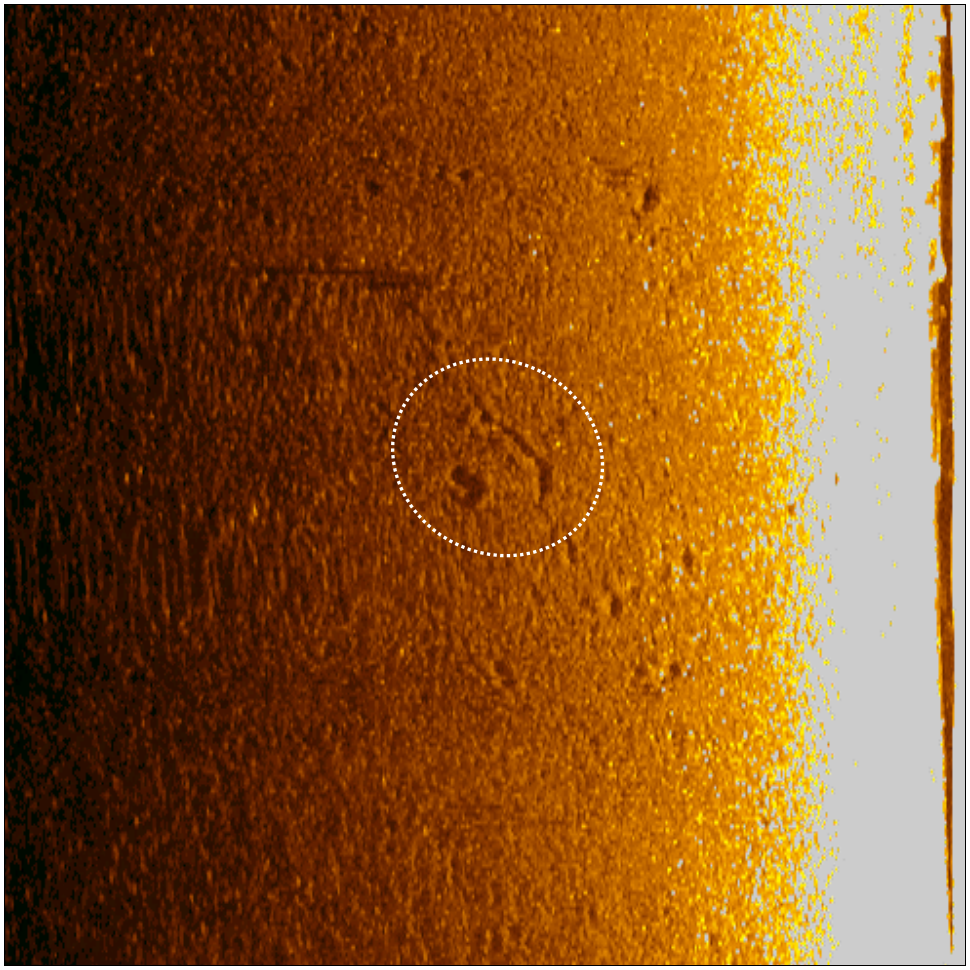
Contact Info: S-A1	Comments
• Sonar Time at Target: 09/03/2014 15:56:15 • Click Position (Lat/Lon Coordinates) 38° 51.55082' N 075° 12.63885' W (WGS84) • Click Position (Projected Coordinates) (X) 714834.38 (Y) 312967.50 • Map Proj: DE83F • Acoustic Source File: I:\Sonar Data\Primehook 14\20140903-02\2014SEP03_0026.sds • Ping Number: 161625 • Range to Target: 3.11 US Feet • Line Name: 2014SEP03_0026	Target Height >= 1.8 US Feet Target Length: 6.2 US Feet Target Shadow: 2.0 US Feet Target Width:1.8 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-A**. A 5' long linear feature; isolated on an otherwise featureless bottom. (NFI).

S-B1



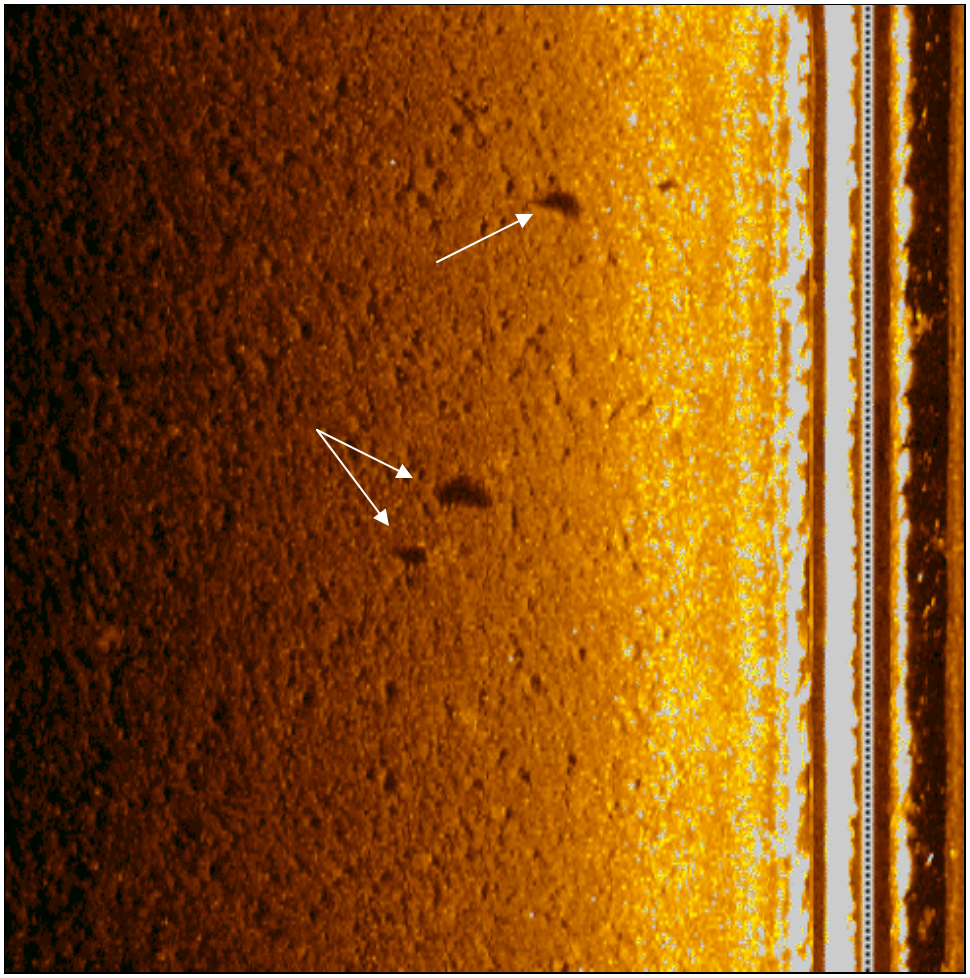
Contact Info: S-B1	Comments
• Sonar Time at Target: 09/05/2014 11:18:57 • Click Position (Lat/Lon Coordinates) 38° 52.39929' N 075° 13.43032' W (WGS84) • Click Position (Projected Coordinates) (X) 711067.06 (Y) 318109.78 • Map Proj: DE83F • Acoustic Source File: I:\Sonar Data\Primehook 14\20140905\2014SEP05_0002.sds • Ping Number: 7562 • Range to Target: 20.65 US Feet • Line Name: 2014SEP05_0002	Target Height >= 1.3 US Feet Target Length: 3.3 US Feet Target Shadow: 4.0 US Feet Target Width: 1.6 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-B.** A 3' x 2' square object with an associated scour in the bottom. (NFI).

S-B2



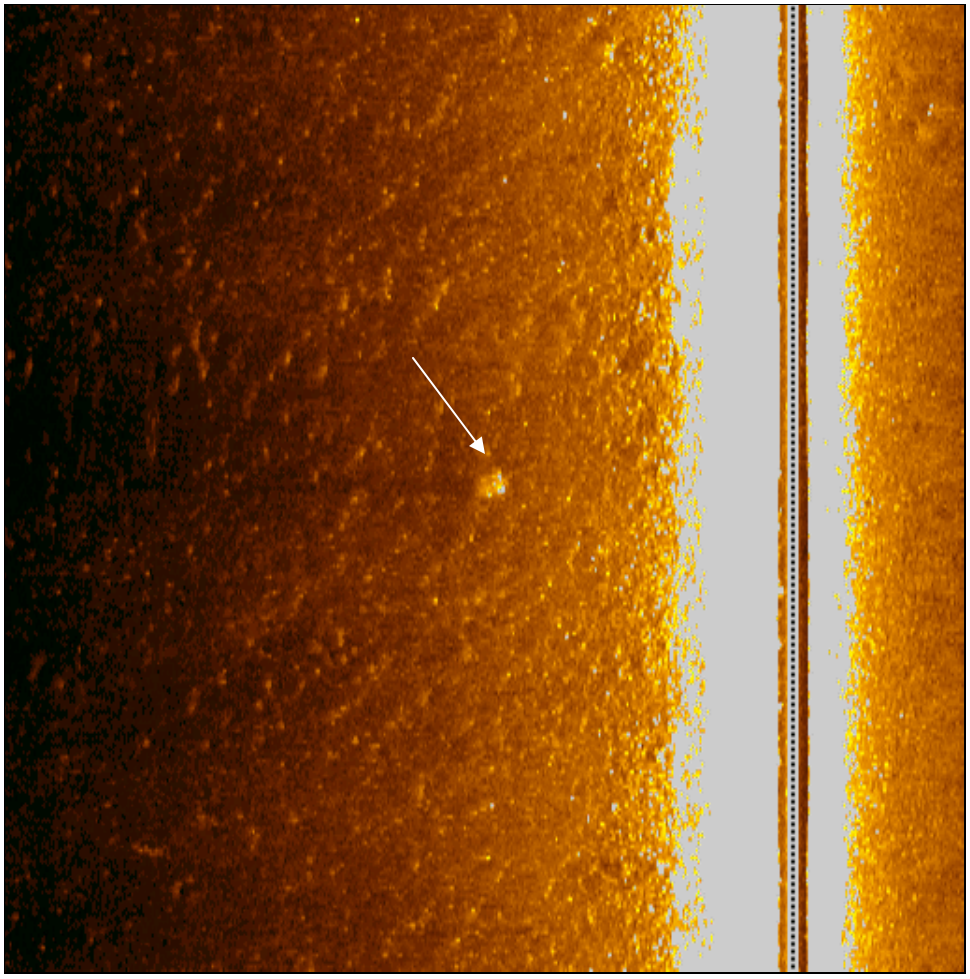
Contact Info: S-B2	Comments
• Sonar Time at Target: 09/05/2014 15:08:32 • Click Position (Lat/Lon Coordinates) 38° 53.31848' N 075° 13.64364' W (WGS84) • Click Position (Projected Coordinates) (X) 710042.75 (Y) 323687.41 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140905\2014SEP05_0026.sds • Ping Number: 252215 • Range to Target: 18.57 US Feet • Line Name: 2014SEP05_0026	Target Height >= 0.3 US Feet Target Length: 11.4 US Feet Target Width: 2.0 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-B.** A linear object and/or bottom scour (11' long) and a small square feature and/or scour (3' x 2') are lying flat on the bottom surface. (NFI).

S-B3



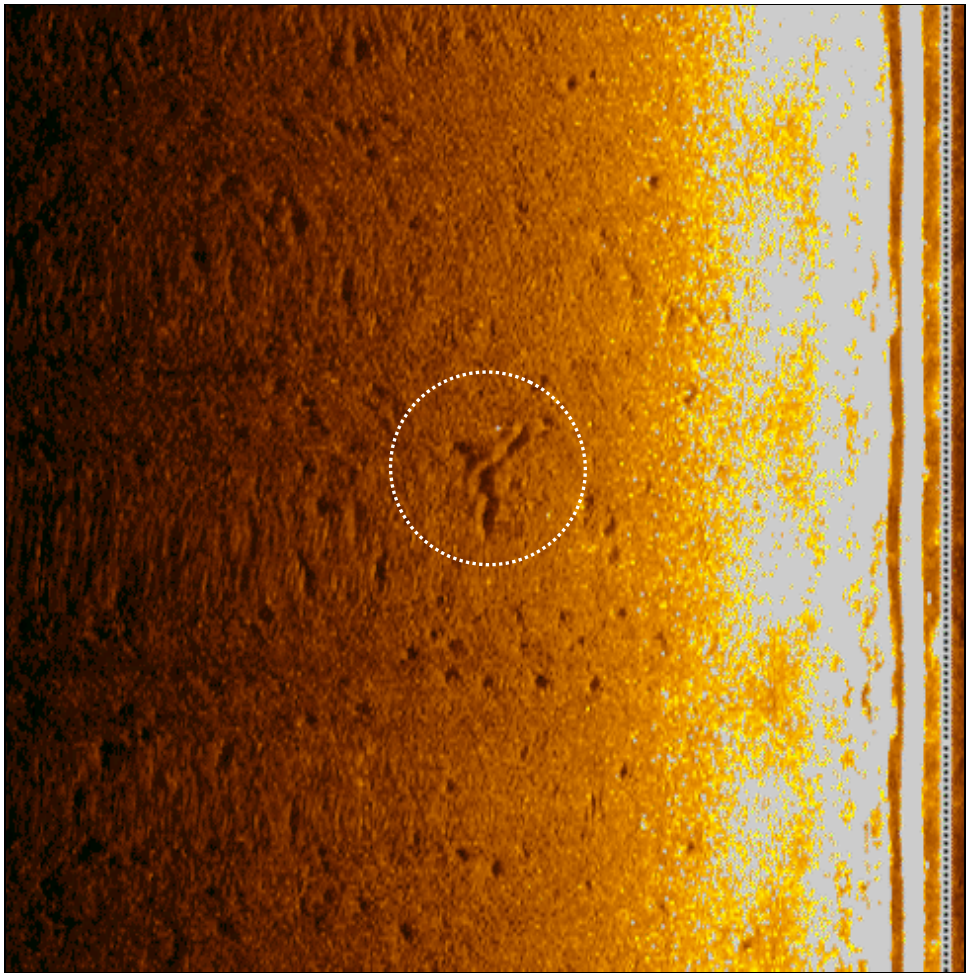
Contact Info: S-B3	Comments
• Sonar Time at Target: 09/05/2014 15:17:24 • Click Position (Lat/Lon Coordinates) 38° 52.98156' N 075° 13.63632' W (WGS84) • Click Position (Projected Coordinates) (X) 710082.38 (Y) 321642.41 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140905\2014SEP05_0028.sds • Ping Number: 261841 • Range to Target: 14.57 US Feet • Line Name: 2014SEP05_0028	Target Height >= 1.3 US Feet Target Length: 3.0 US Feet Target Width:2.4 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-B.** Three small square objects, largest one is 3'x2' Suspect crab traps or rocks. (NFI).

S-B4



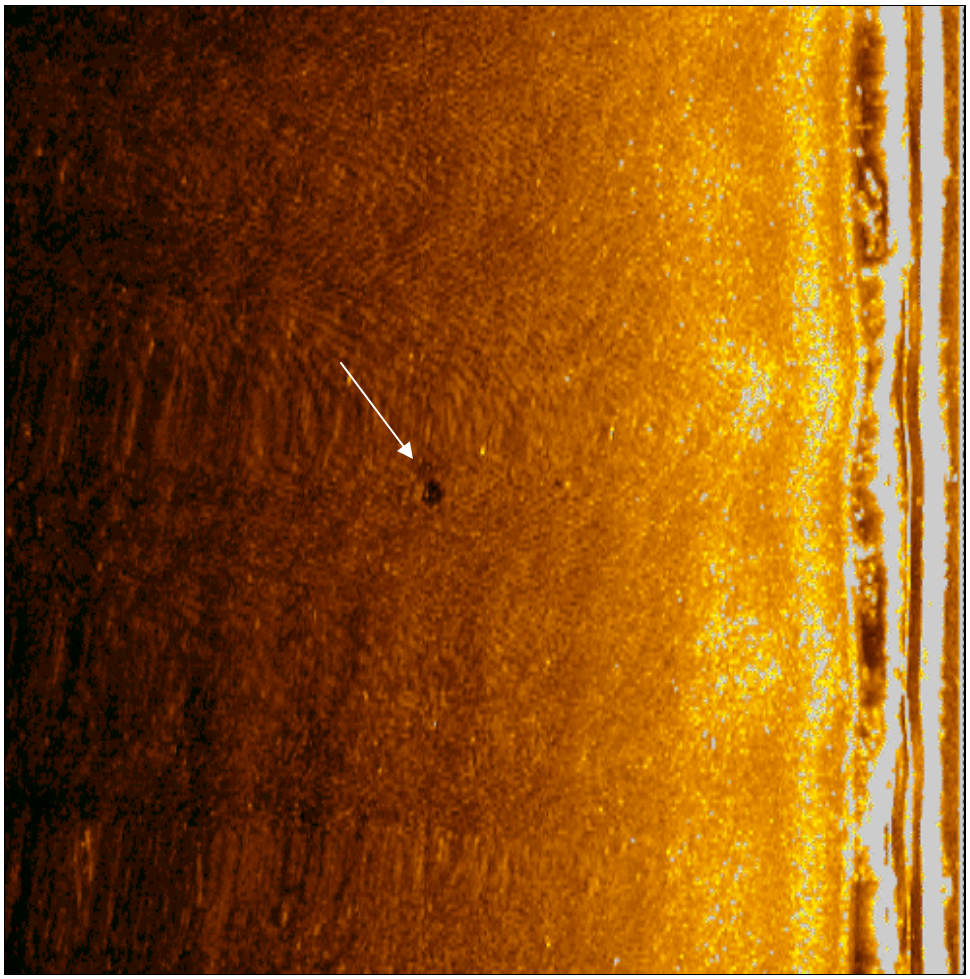
Contact Info: S-B4	Comments
• Sonar Time at Target: 09/05/2014 15:27:14 • Click Position (Lat/Lon Coordinates) 38° 52.13378' N 075° 13.64273' W (WGS84) • Click Position (Projected Coordinates) (X) 710063.38 (Y) 316495.41 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140905\2014SEP05_0028.sds • Ping Number: 272633 • Range to Target: 11.79 US Feet • Line Name: 2014SEP05_0028	Target Height >= 1.3 US Feet Target Length: 2.4 US Feet Target Width: 2.7 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-B.** Small square object that is isolated on an otherwise featureless bottom. (NFI).

S-B5



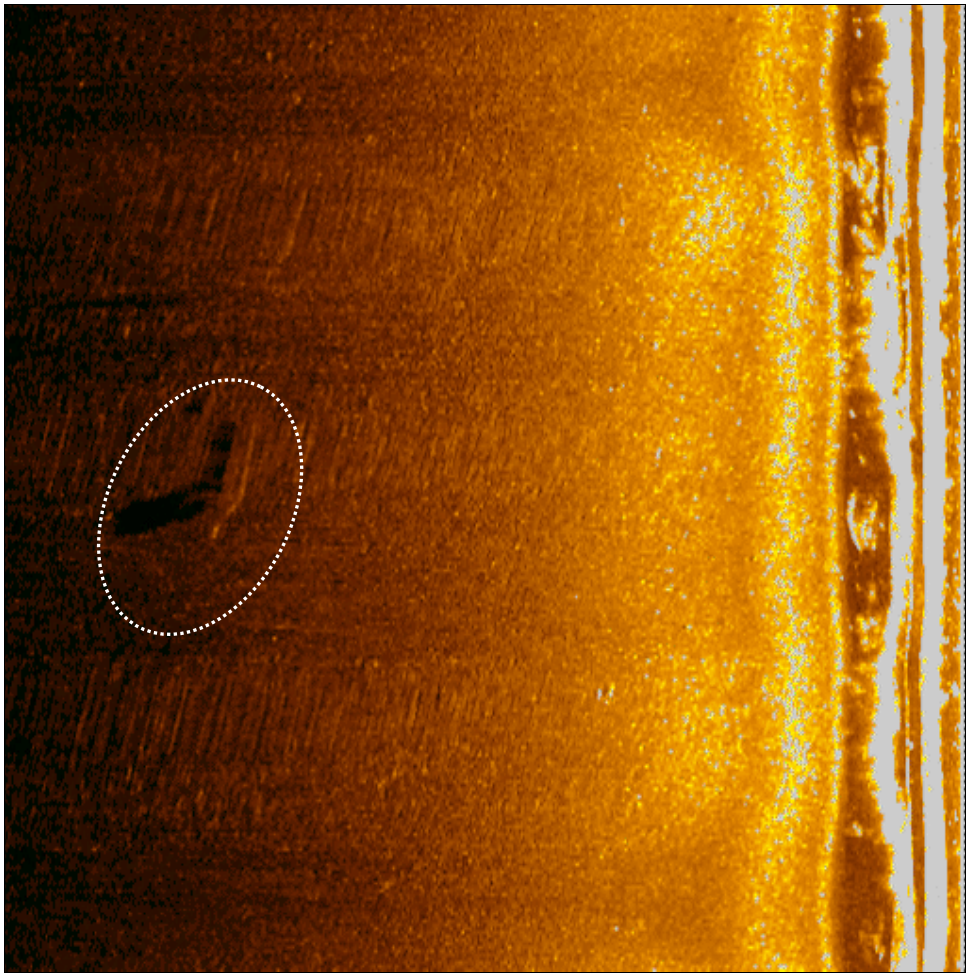
Contact Info: S-B5	Comments
• Sonar Time at Target: 09/06/2014 11:59:42 • Click Position (Lat/Lon Coordinates) 38° 52.71812' N 075° 13.82720' W (WGS84) • Click Position (Projected Coordinates) (X) 709180.75 (Y) 320041.84 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140906\2014SEP06_0004.sds • Ping Number: 32734 • Range to Target: 17.57 US Feet • Line Name: 2014SEP06_0004	Target Height >= 0.2 US Feet Target Length: 13.1 US Feet Target Width: 1.6 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-B.** A 13' long linear feature (and/or scour) is laying partially buried in the bottom. (NFI).

S-C1



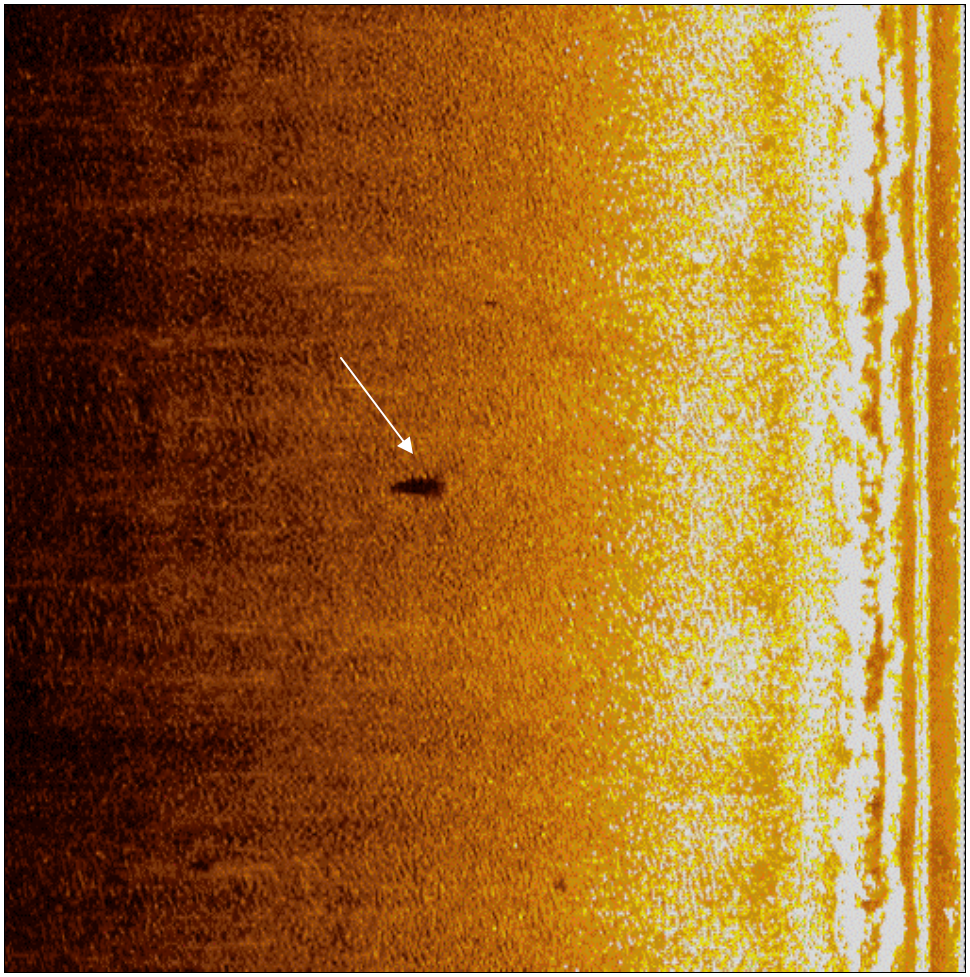
Contact Info: S-C1	Comments
• Sonar Time at Target: 09/10/2014 16:03:10 • Click Position (Lat/Lon Coordinates) 38° 50.94474' N 075° 10.79818' W (WGS84) • Click Position (Projected Coordinates) (X) 723580.00 (Y) 309309.66 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140910\2014SEP10_0020.sds\ • Ping Number: 143510 • Line Name: 2014SEP10_0020	Target Height >= 0.8US Feet Target Length1.4 US Feet Target Width:1.7 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-C**. Small square object - isolated on flat river bottom. Suspect crab trap. (NFI).

S-C2



Contact Info: S-C2	Comments
• Sonar Time at Target: 09/10/2014 17:04:40 • Click Position (Lat/Lon Coordinates) 38° 50.73783' N 075° 11.02981' W (WGS84) • Click Position (Projected Coordinates) (X) 722484.38 (Y) 308051.34 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140910\2014SEP10_0028.sds • Ping Number: 205995 • Range to Target: 56.79 US Feet • Line Name: 2014SEP10_0028	Target Height >= 1.1 US Feet Target Length16.4 US Feet Target Width:1.2 US Feet Mag Anomaly: no **Description**: Located in Area **PHB-C**. A 16' long linear feature that has a bend in it. (NFI).

S-C3



Contact Info: S-C3	Comments
• Sonar Time at Target: 09/10/2014 17:51:15 • Click Position (Lat/Lon Coordinates) 38° 51.04660' N 075° 10.50064' W (WGS84) • Click Position (Projected Coordinates) (X) 724990.19 (Y) 309931.63 • Map Proj: DE83F • Acoustic Source File: F:\Sonar Data\Primehook 14\20140910\2014SEP10_0034.sds • Ping Number: 252728 • Range to Target: 19.72 US Feet • Line Name: 2014SEP10_0034	Target Height : 1.6 US Feet Target Length : 3.2 US Feet Target Width: 2.9 US Feet Mag Anomaly: no Description: Located in Area **PHB-C**. Small, square object isolated on a flat bottom. Suggestive of crab trap. (NFI).

7.0 CONCLUSIONS AND RECOMMENDATIONS

Background research confirms historic maritime activity near the mouth of Delaware Bay as early as the first quarter of the 17th century. Swedish and Dutch settlers were the first Europeans to colonize the region and were the first to extensively use Delaware Bay to connect their settlements with the rest of the world. Since the 17th century, Delaware Bay and its tributaries have provided a transportation artery that fostered the subsequent economic and social development of the entire region. Vessels using Delaware Bay were involved with coastal trading networks linking the Delaware River ports and New York with other ports from Maine to Texas. Additionally, maritime traffic through the Bay extended to ports in the Caribbean, Europe, and Central and South America.

As a result of these historic activities in lower Delaware Bay, submerged cultural resources that are associated with every phase of the region's historical development have been deposited in Delaware Bay. Historic research documented over 300 shipwreck losses and accidents in along the Delaware Atlantic Coast and at the mouth of Delaware Bay since the 17th century. The identification of underwater resources relating to this historic maritime activity is critically relevant to the goals developed in Delaware's published statewide historic preservation planning documents.

In an effort to identify potentially significant historic and/or prehistoric submerged cultural resources that may be impacted by proposed dredging activities in the three borrow areas, comprehensive remote sensing surveys were completed. Magnetic and acoustic seismic data were collected to identify and assess remote sensing targets that may have an association with submerged cultural resources. However, the comprehensive remote sensing survey resulted in the identification of no remote sensing targets considered to be associated with shipwreck sites. Additionally, remote sensing records did not reveal the presence of any potential inundated prehistoric archaeological sites within the three borrow areas.

No additional underwater archaeological work is recommended within the three Delaware Bay borrow areas, PHB-A, PHB-B, and PHB-C, Sussex County, Delaware.

Remote sensing survey results completely fulfilled the project research design and no problems were encountered with the fieldwork methodology. This project is also consistent with the stated goals and priorities of the Delaware Plan.

Note: All underwater survey field notes, magnetometer and sonar records, are stored at the offices of Dolan Research, 30 Paper Mill Road, Newtown Square, Pennsylvania, 19073.

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FIGURES

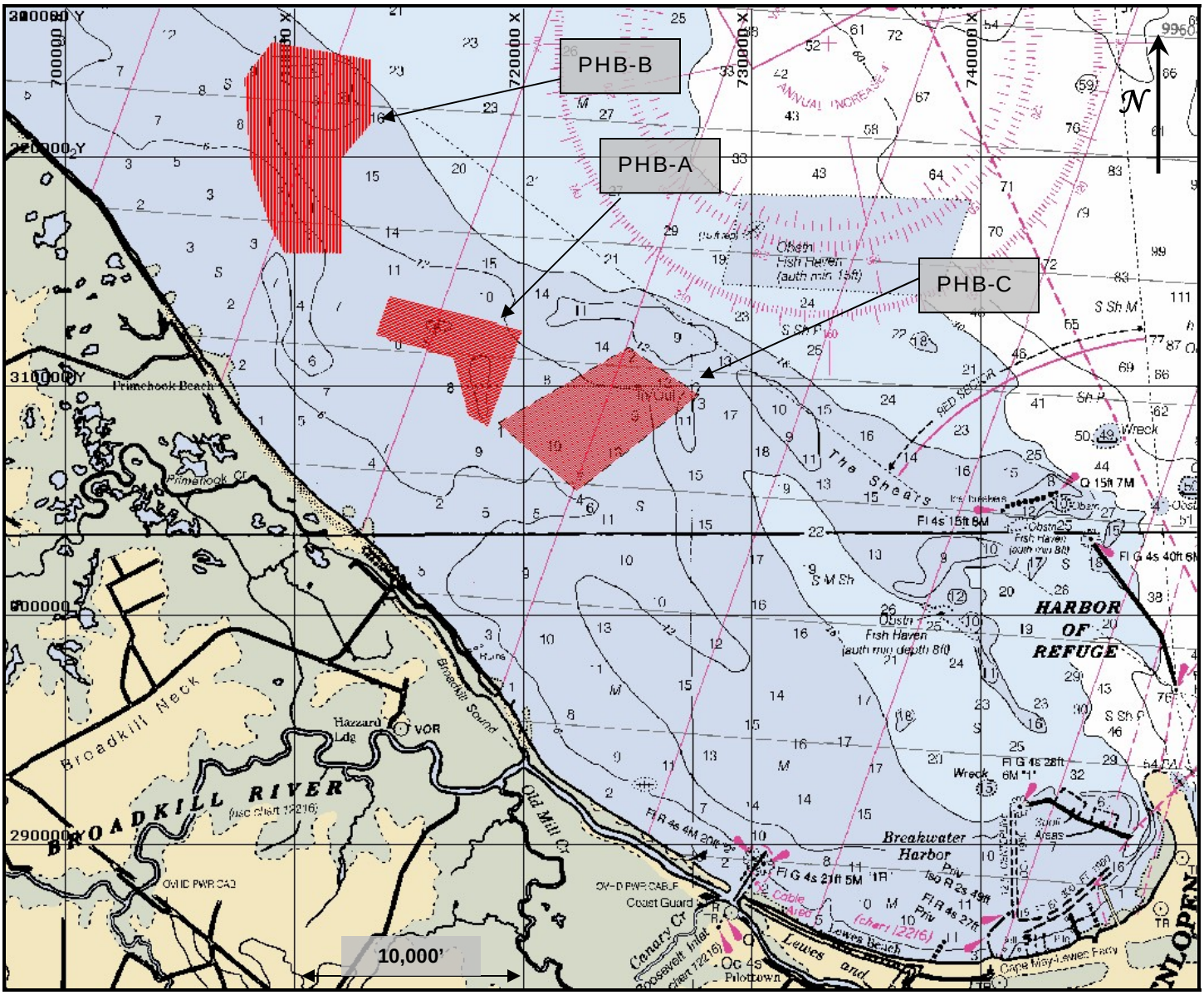


Figure 1. Project Location Map – Borrow Areas PHB-A, PHB-B, and PHB-C

Notes: 1) Background Map is NOAA Chart #12304
2) Background Grid = Delaware State Plane System, NAD83

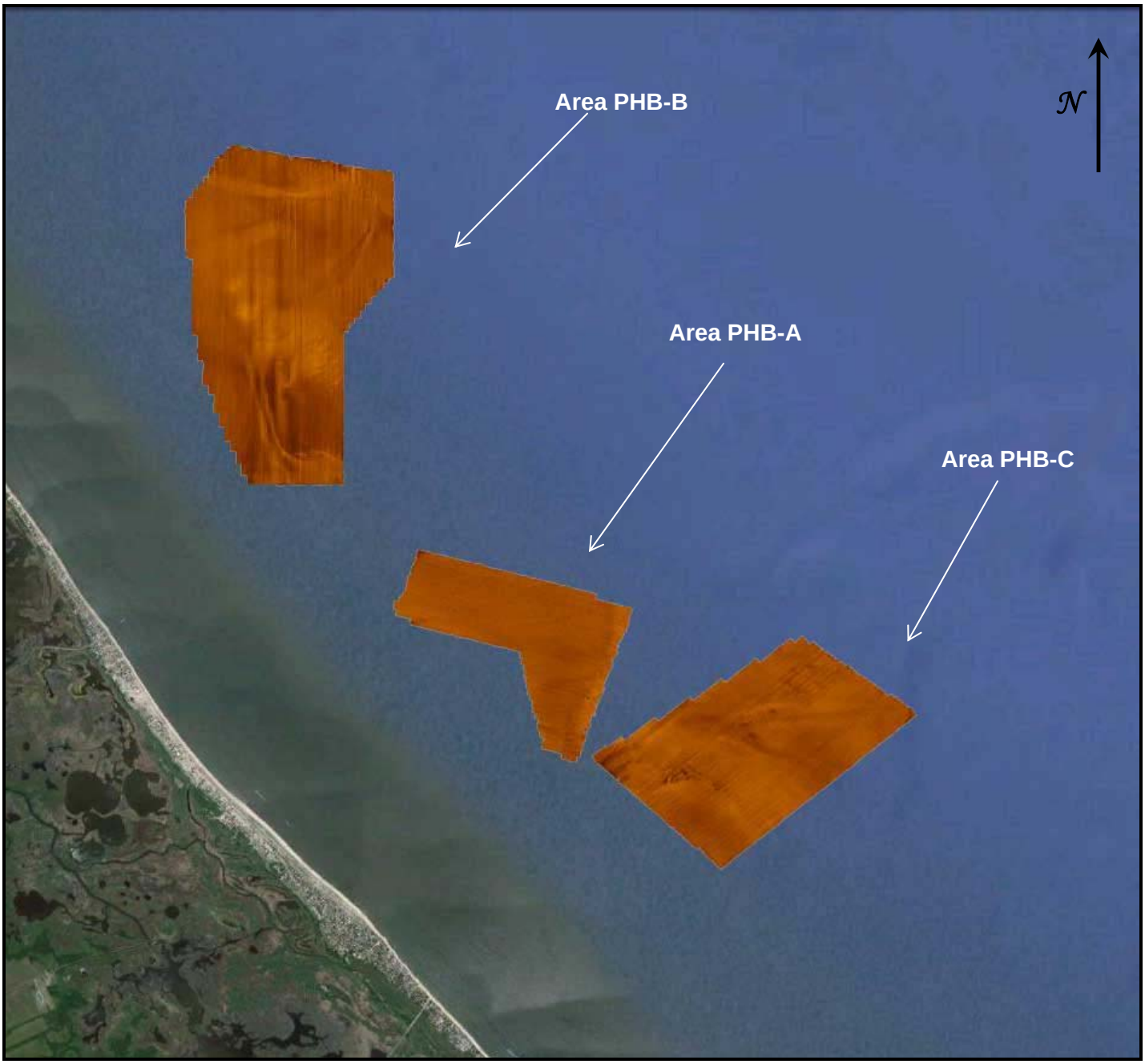


Figure 2. Sonar Mosaics of All Three Borrow Areas

Note: Sonar Data collected with a dual 600/1200 kHz sensor, using a range of 120' per channel

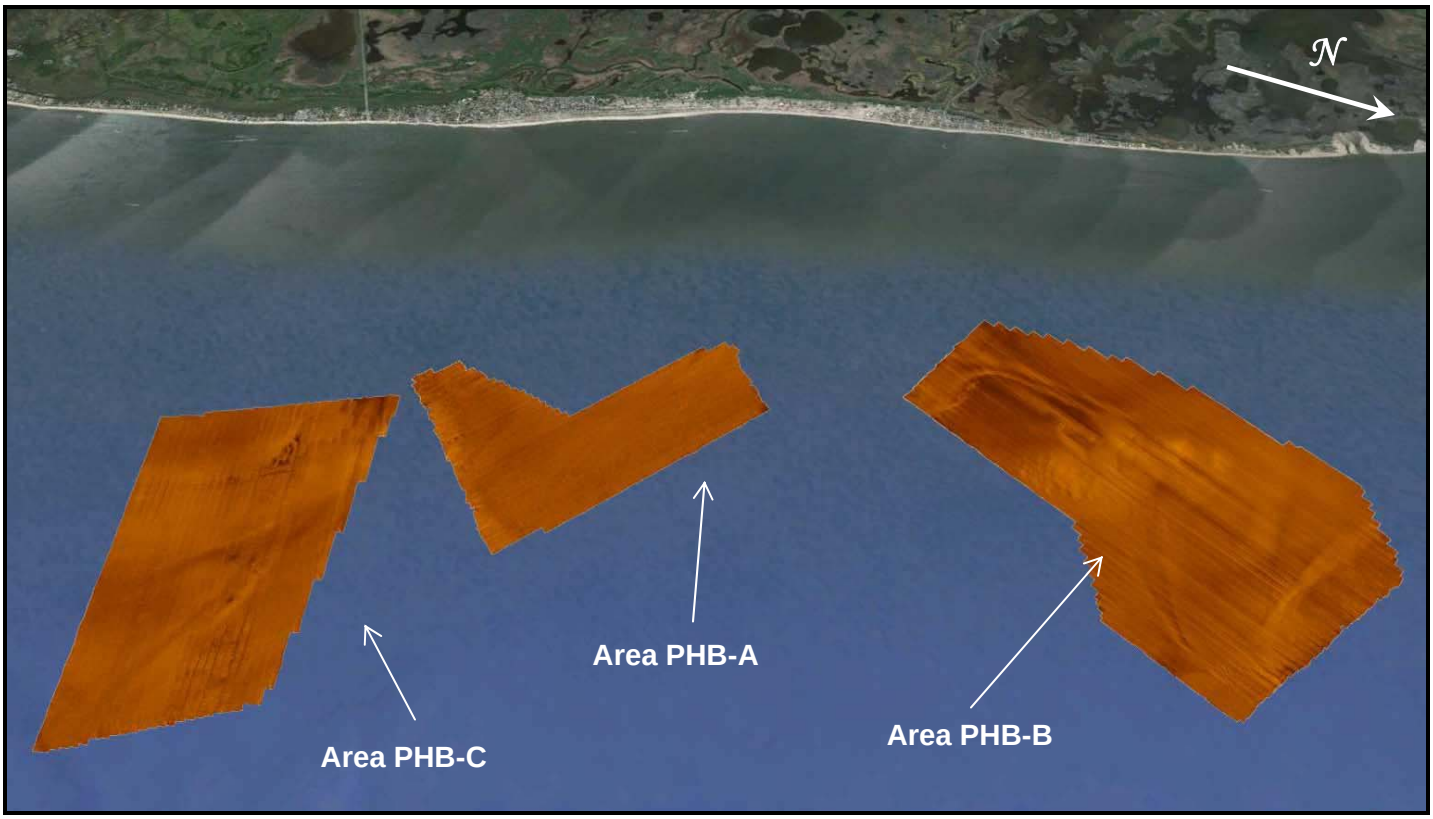


Figure 3. Sonar Mosaics of All Three Borrow Areas, View Looking Onshore - West

Note: Sonar Data collected with a dual 600/1200 kHz sensor, using a range of 120' per channel

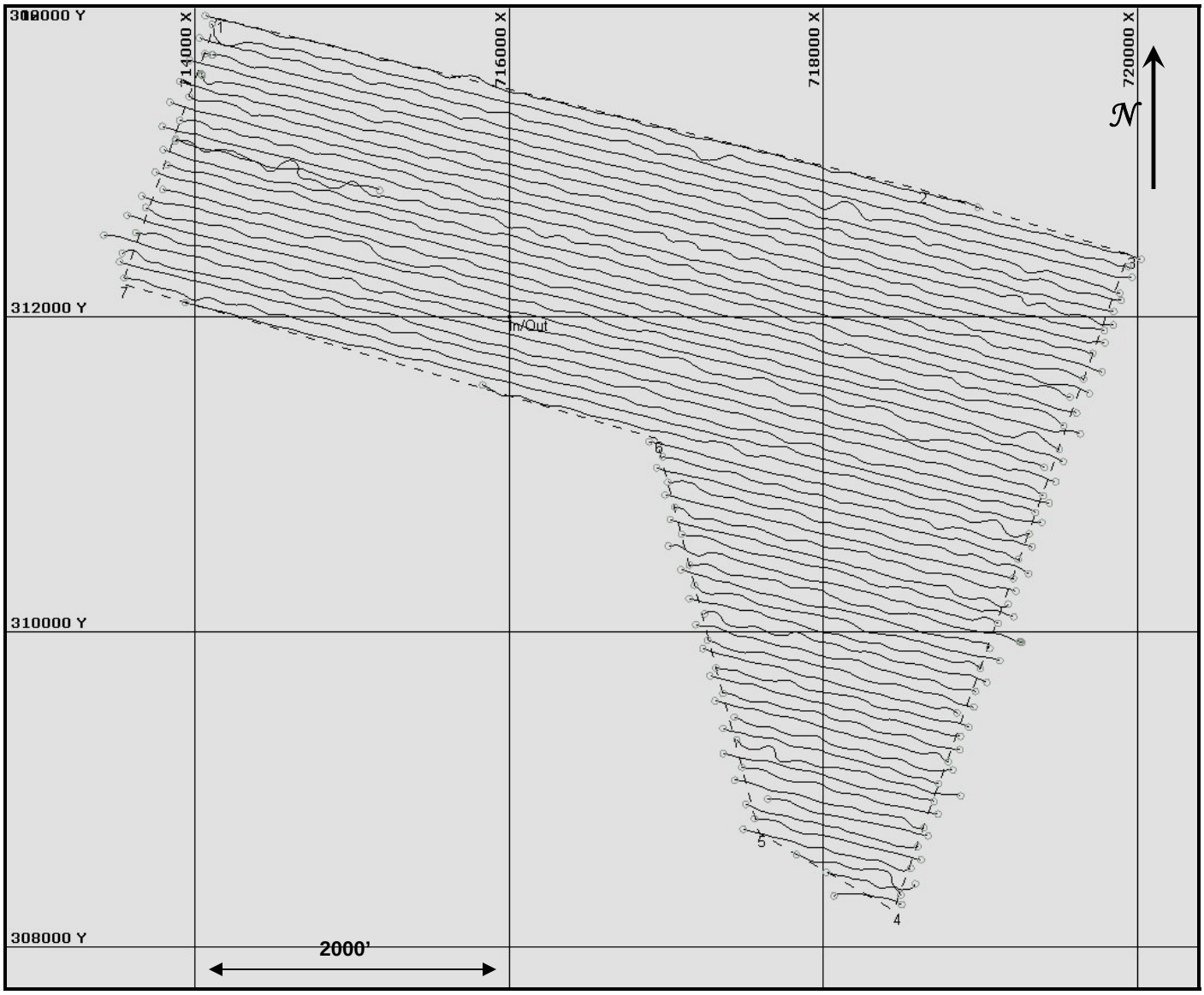


Figure 4. Survey Track Plots – Area PHB-A

Notes:
1) Lane spacing was 75 feet
2) Background grid = Delaware State Plane System, NAD83

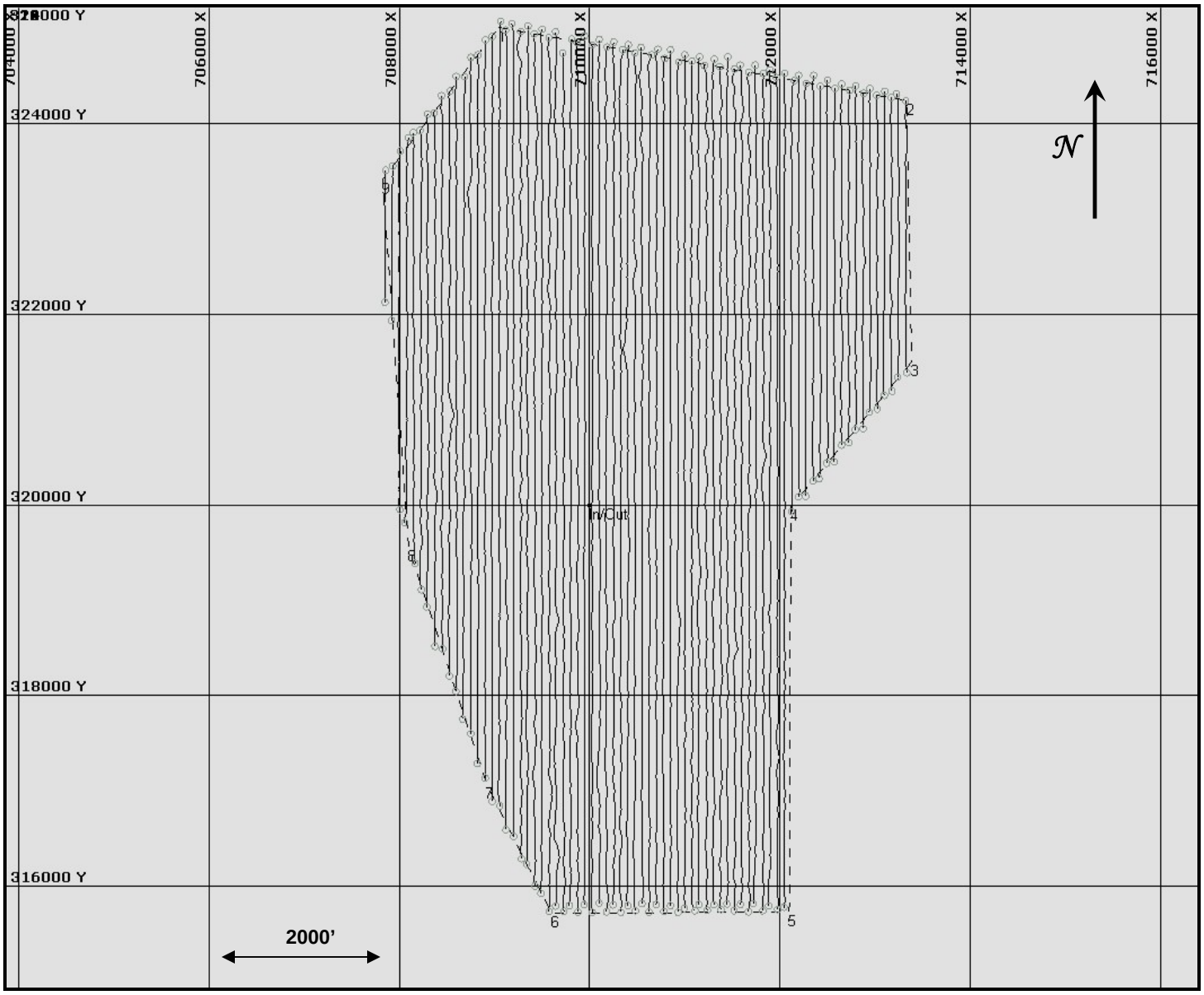


Figure 5. Survey Track Plots – Area PHB-B

Notes:
1) Lane spacing was 75 feet
2) Background grid = Delaware State Plane System, NAD83

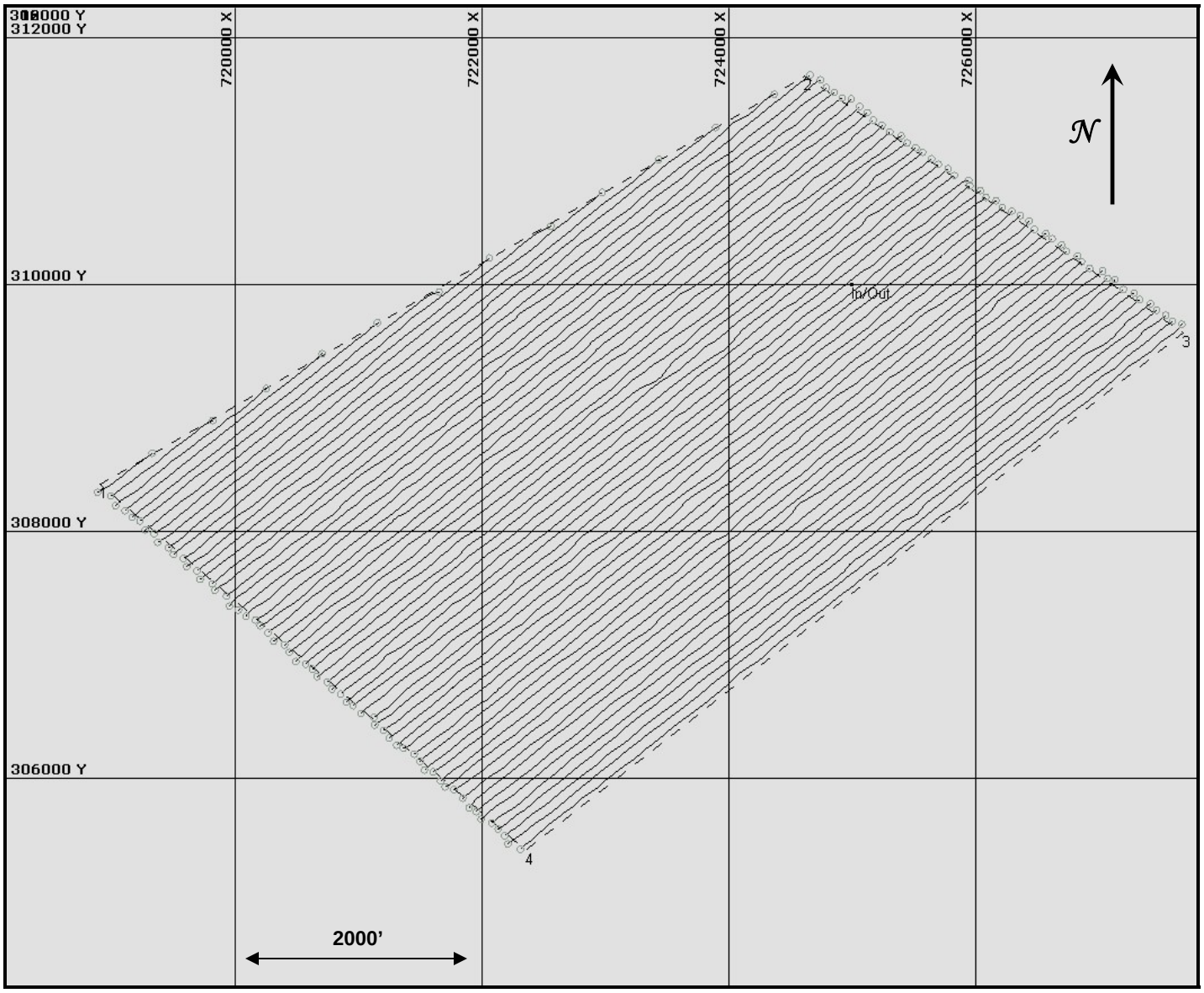


Figure 6. Survey Track Plots – Area PHB-C

Notes:
1) Lane spacing was 75 feet
2) Background grid = Delaware State Plane System, NAD83

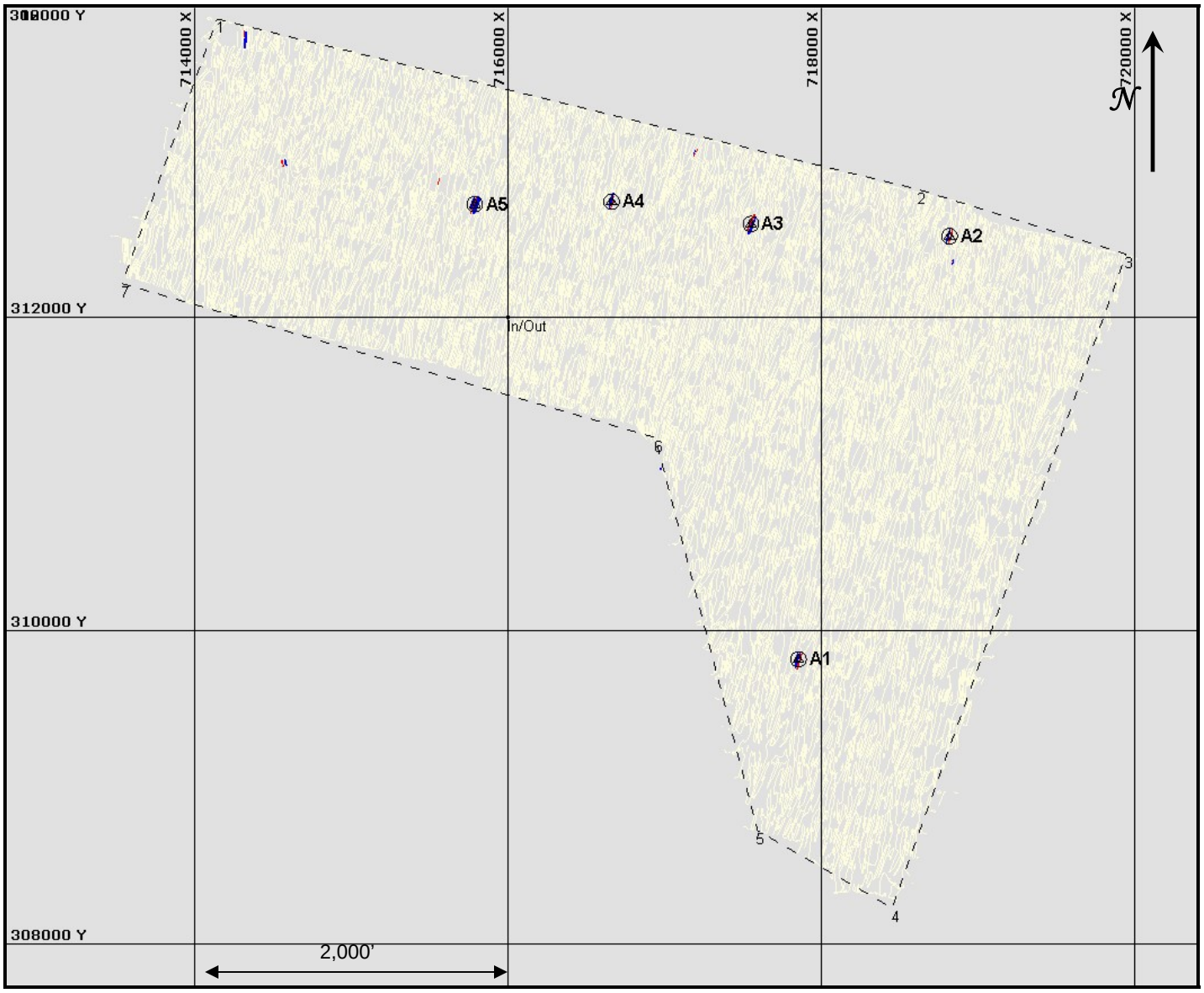


Figure 7. Area PHB-A - Magnetic Contour Map at Five Gamma Intervals

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Five magnetic anomalies were identified – listed in Table 1.
4) Background grid = Delaware State Plane System, NAD83

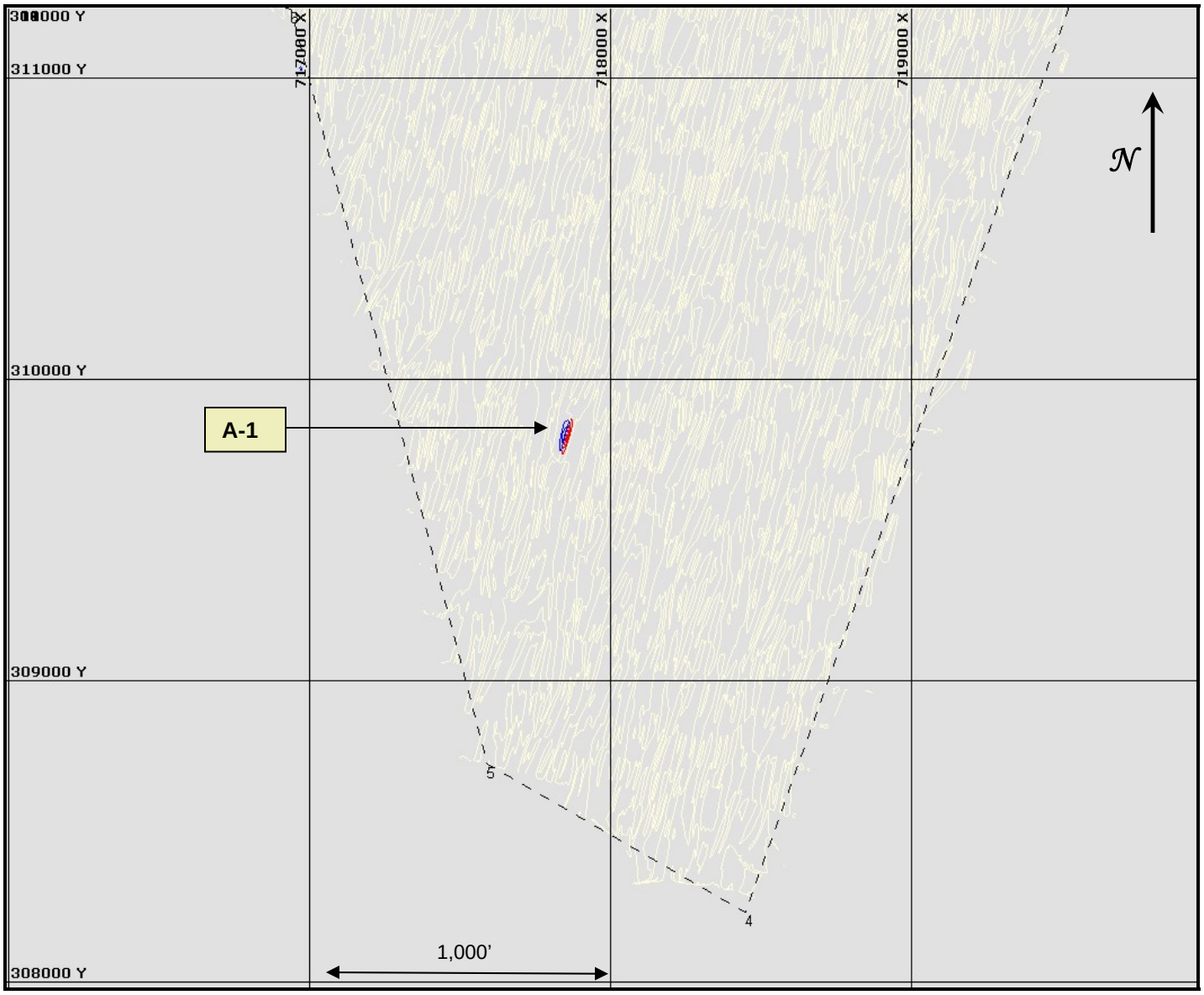


Figure 8. Detail of Magnetic Contour Map for South End of PHB-A

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Target A1 was identified as an isolated single source anomaly
4) Background grid = Delaware State Plane System, NAD83

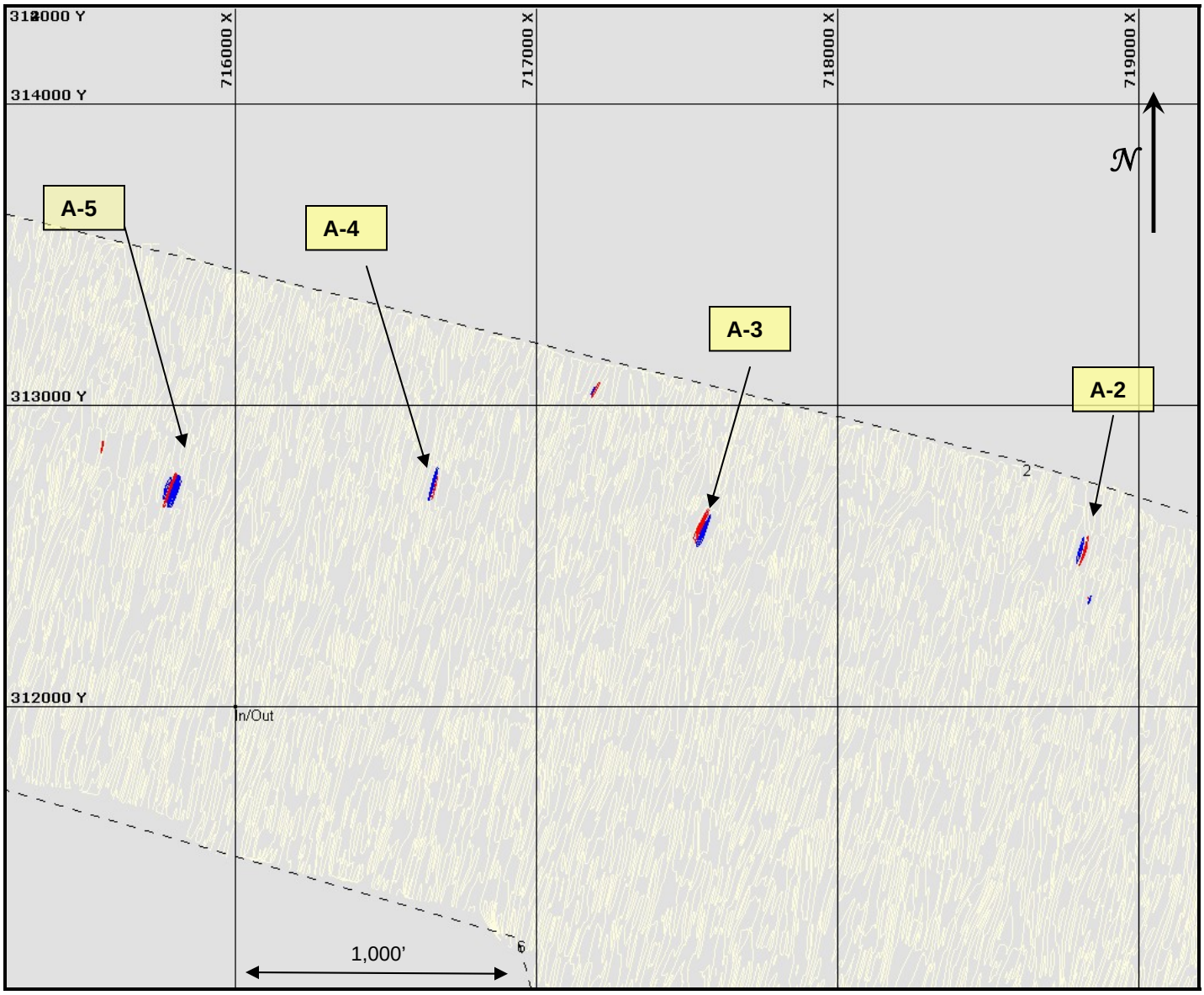


Figure 9. Detail of Magnetic Contour Map for North End of PHB-A

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Targets A2 - A5 were identified as isolated single source anomalies
4) Background grid = Delaware State Plane System, NAD83

Figure 10. Sonar Mosaic of Area PHB-A

Notes:
1) Sonar Data collected with a dual 600/1200 kHz sensor, using a range of 120' per channel
2) One typical sonar feature was identified in PHB-A. Sonar features are listed in Table 2.

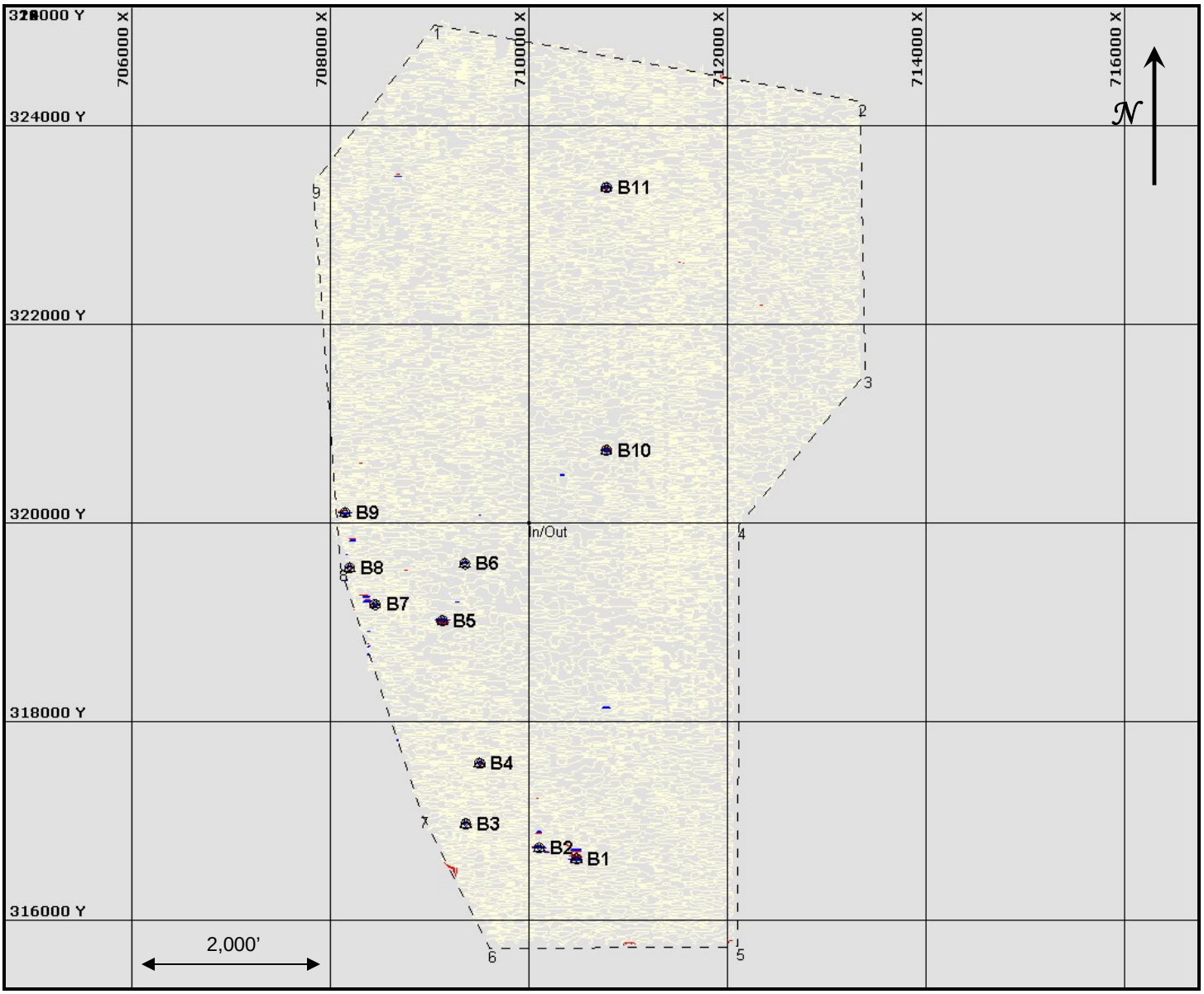


Figure 11. Area PHB-B - Magnetic Contour Map at Five Gamma Intervals

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Eleven magnetic anomalies were identified – listed in Table 1.
4) Background grid = Delaware State Plane System, NAD83

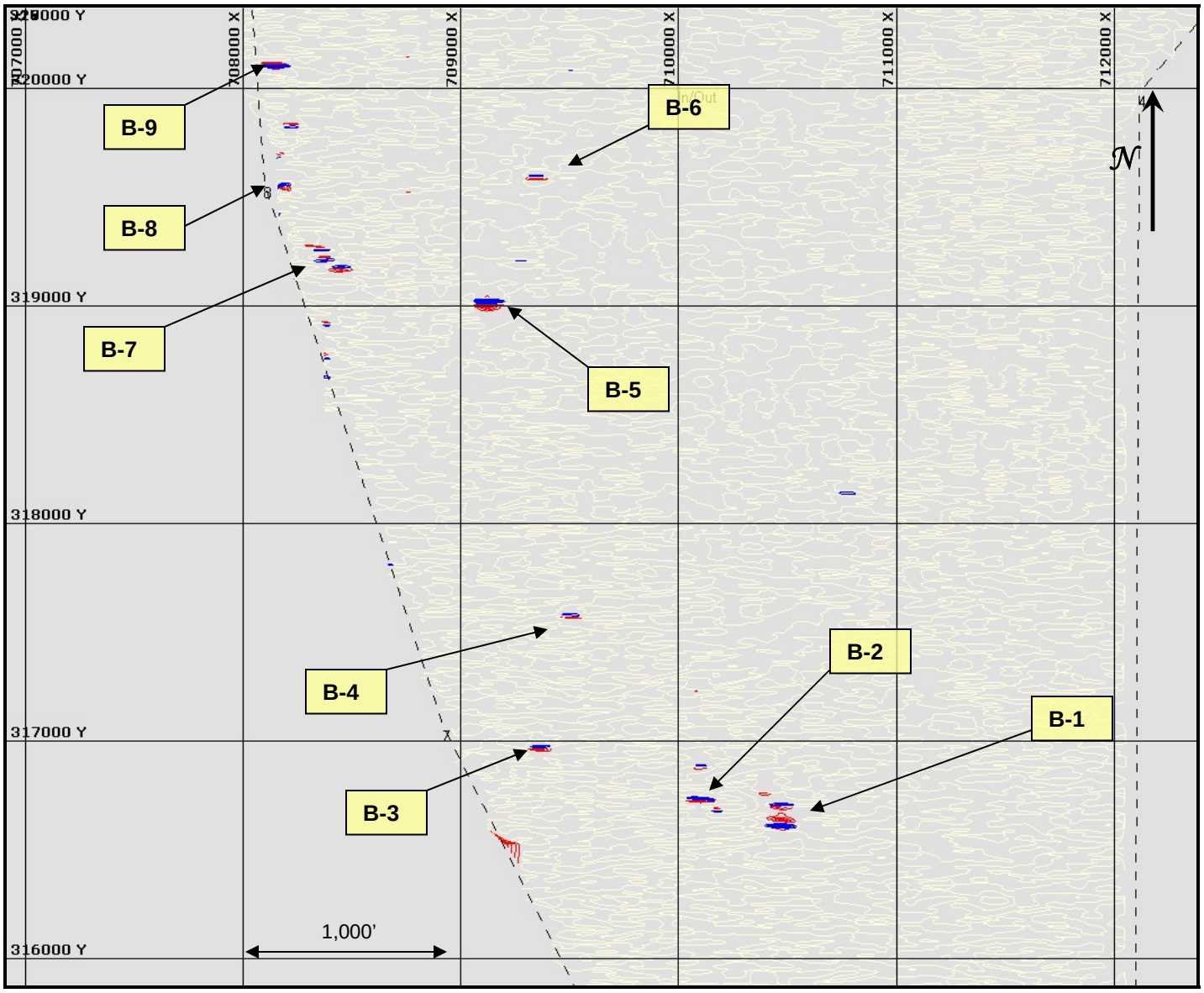


Figure 12. Detail of Magnetic Contour Map for Southern/Central Portion of PHB-B

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Targets B2 - B6 and B8 & B9 were identified as single-source anomalies. Targets B1 & B7 had a noisy, linear signature; considered suggestive of wire rope
4) Background grid = Delaware State Plane System, NAD83.

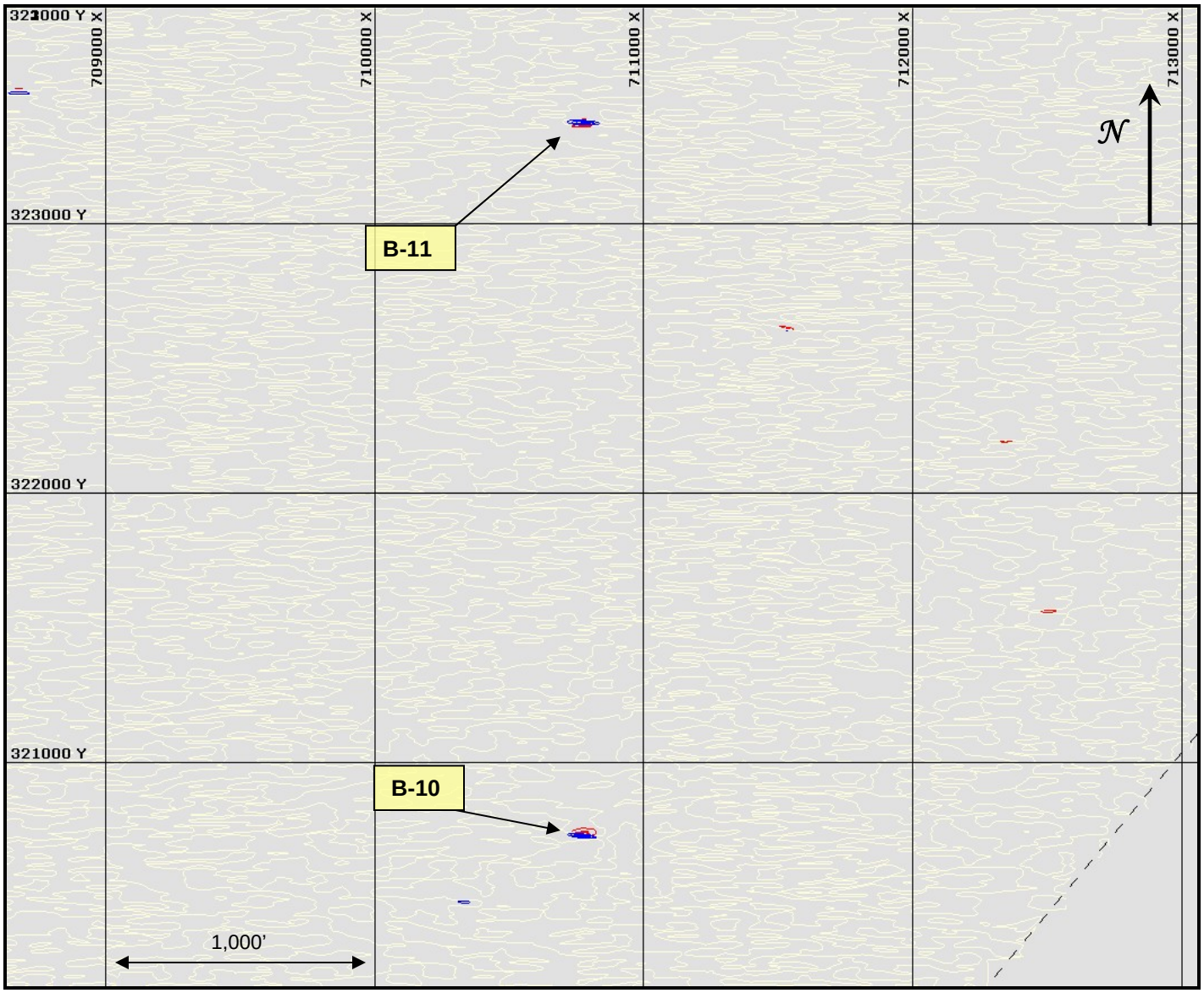


Figure 13. Detail of Magnetic Contour Map for Northern Portion of PHB-B

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Targets B10 & B11 were identified as single-source anomalies.
4) Background grid = Delaware State Plane System, NAD83.

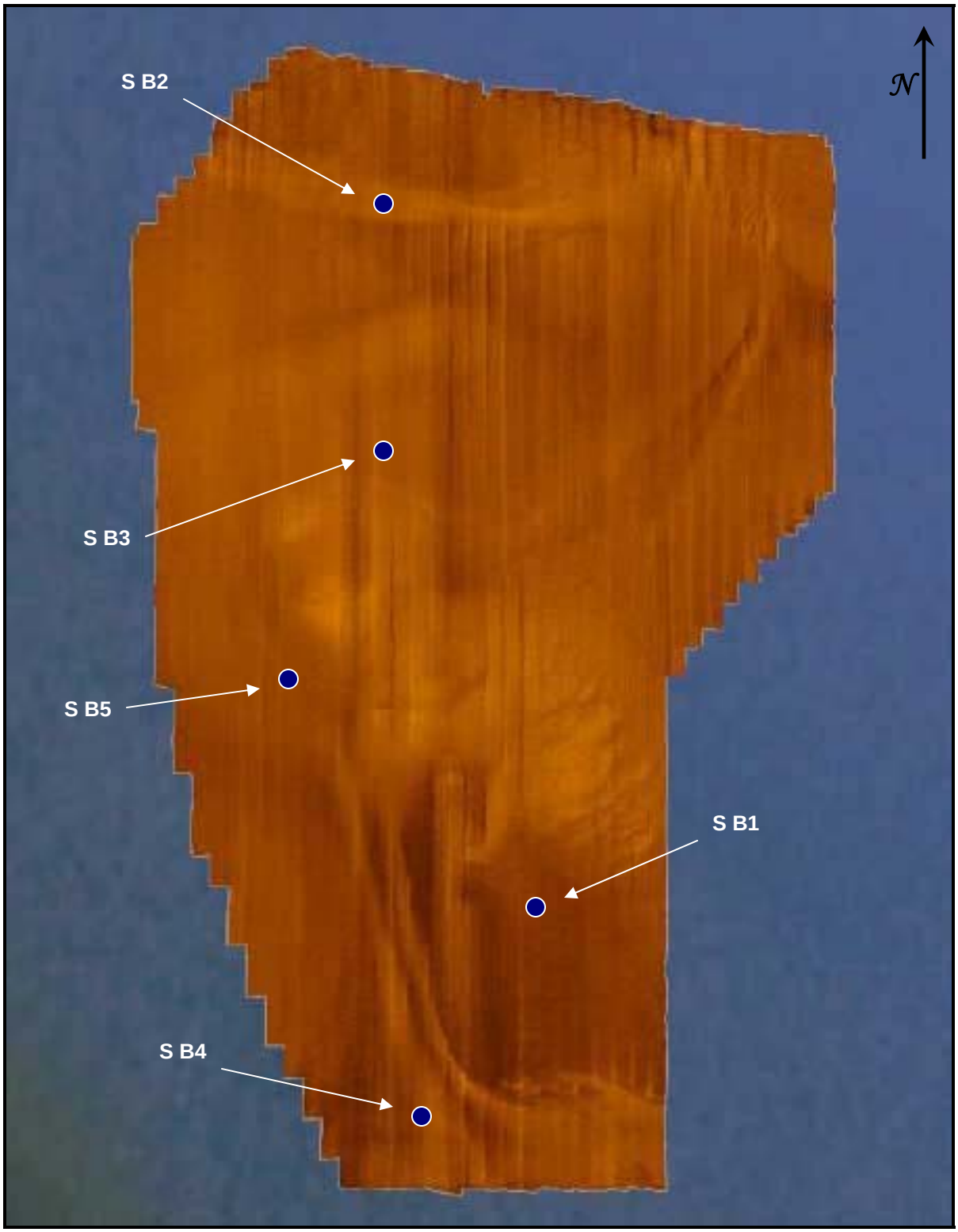


Figure 14. Sonar Mosaic of Area PHB-B

Notes:
1) Sonar Data collected with a dual 600/1200 kHz sensor, using a range of 120' per channel
2) Five typical sonar features were identified in PHB-B. Sonar features are listed in Table 2.

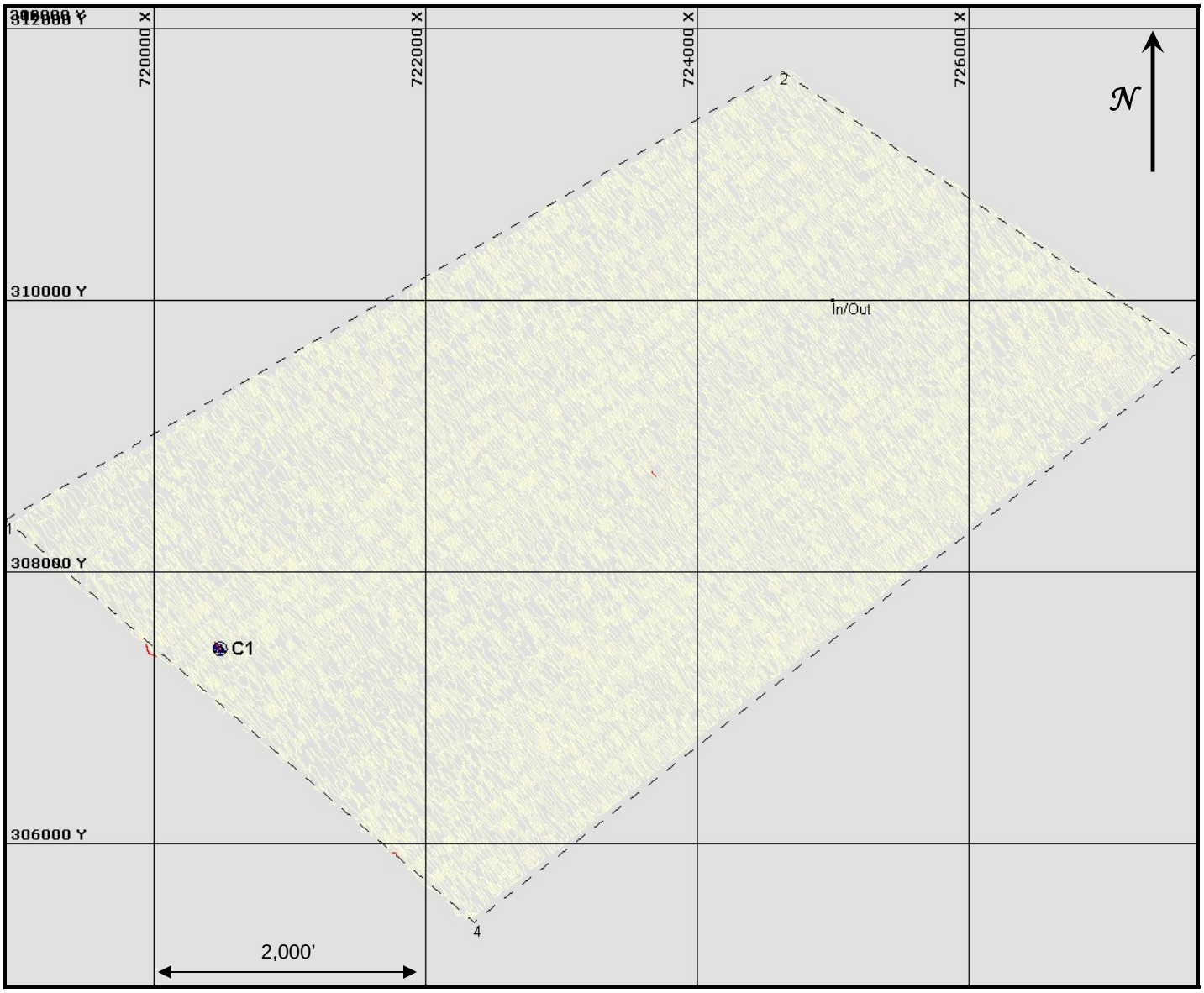


Figure 15. Area PHB-C - Magnetic Contour Map at Five Gamma Intervals

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) One magnetic anomaly was identified – listed in Table 1.
5) Background grid = Delaware State Plane System, NAD83

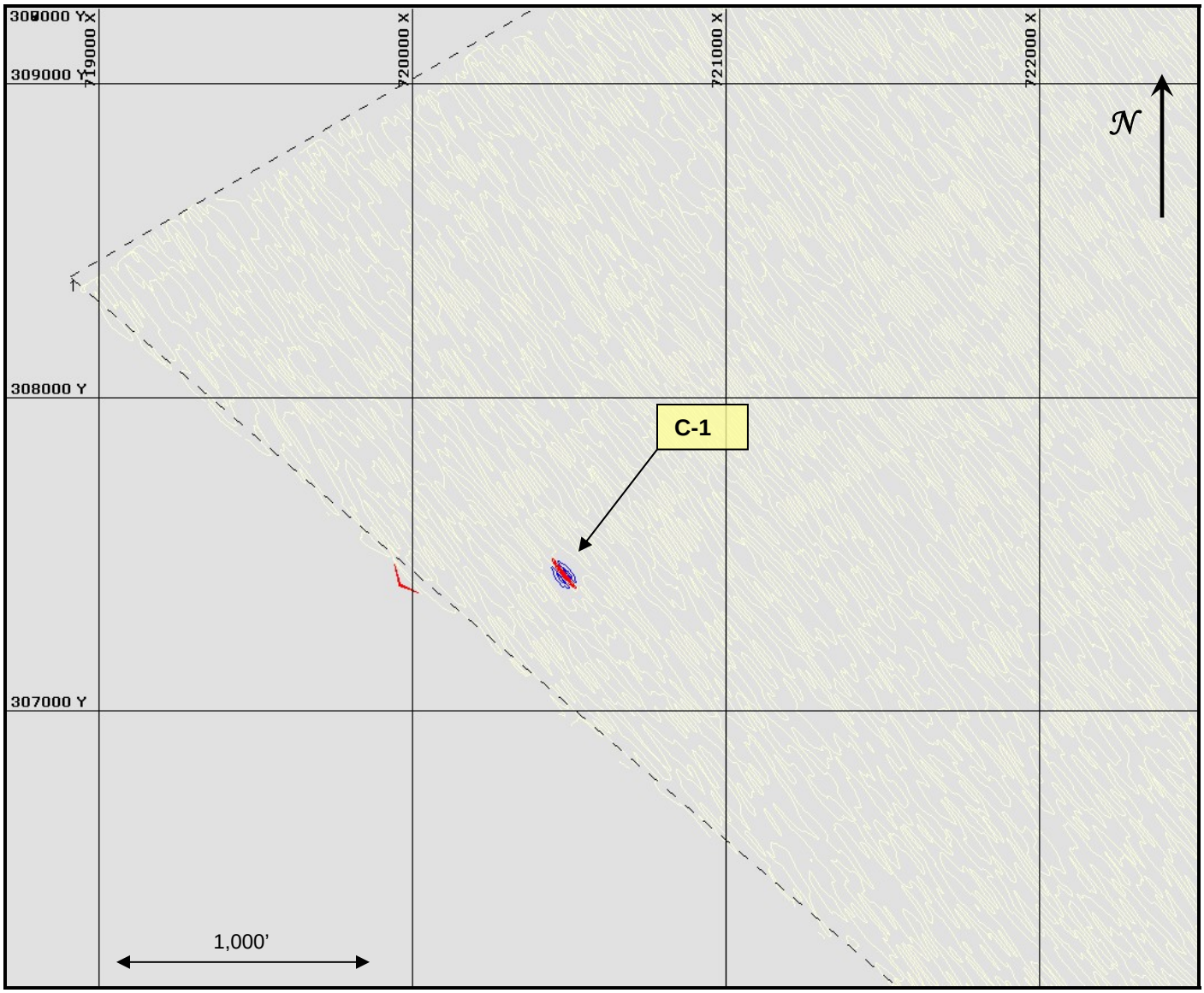


Figure 16. Detail of Magnetic Contour Map for Southwestern Portion of PHB-C

Notes:
1) Contour Interval is 5 gammas
2) Magnetic data are reduced to pole: all positive readings are depicted as red and negative readings as blue; tan lines are zero readings (≤5 gammas)
3) Target C1 was identified as a single-source anomaly.
4) Background grid = Delaware State Plane System, NAD83.

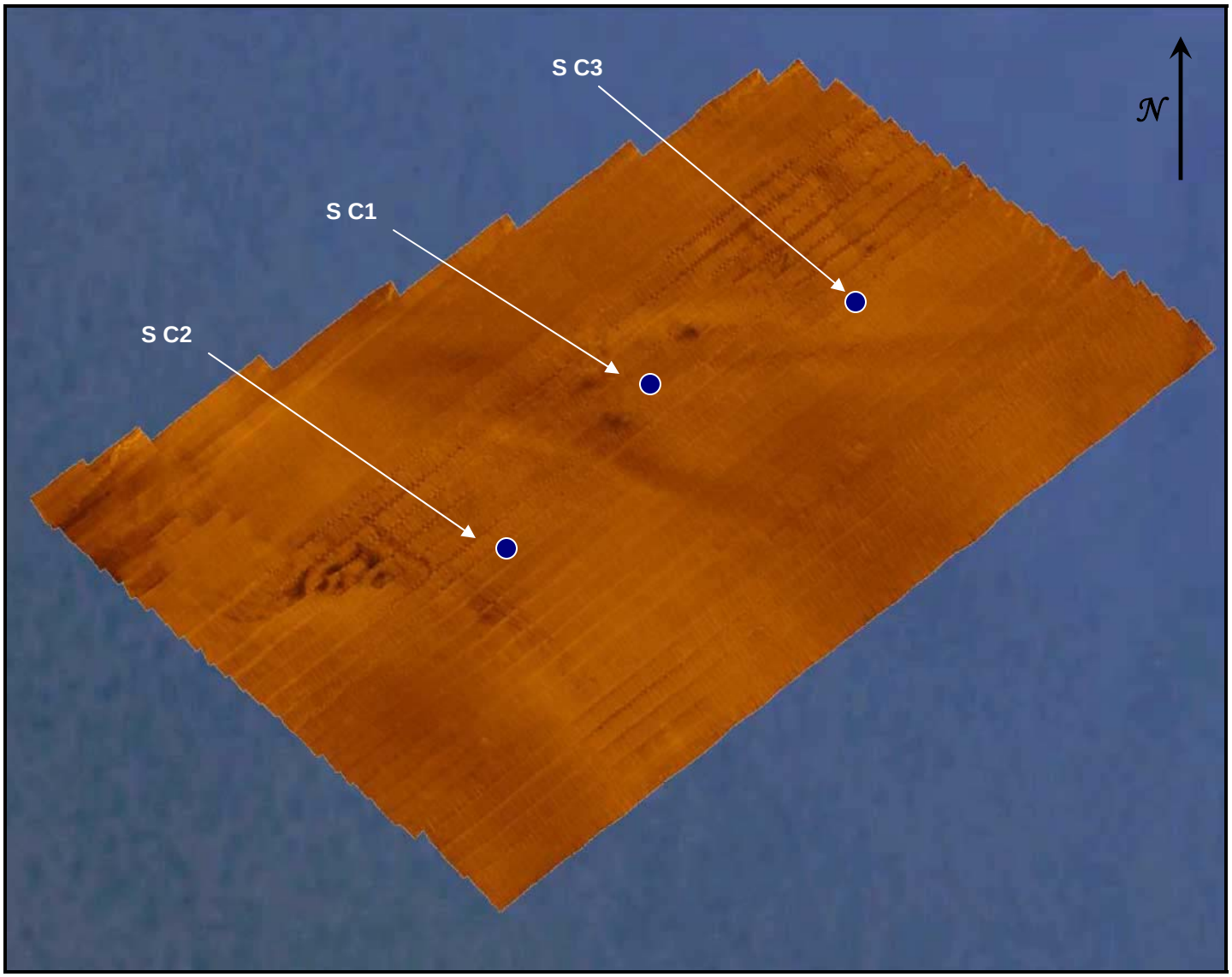


Figure 17. Sonar Mosaic of Area PHB-C

Notes:
1) Sonar Data collected with a dual 600/1200 kHz sensor, using a range of 120' per channel
2) Three typical sonar features were identified in PHB-C. Sonar features are listed in Table 2.

APPENDIX I:

DELAWARE BAY SHIPWRECK LIST

A list of shipwrecks and marine accidents near the mouth of Delaware Bay and along the Delaware Atlantic Coast has been compiled from numerous primary and secondary sources. Wrecks listed as "Delaware Bay" are included for this report, since many vessels in peril were heading for the refuge of the bay when tragedy struck and many perished before reaching the bay. Among the sources used during the compilation of this list include: Maritime Records: Record of Wrecks 1874 - 1937 (Pennsylvania Historical Society); Encyclopedia of American Shipwrecks (Berman, 1972); Shipwrecks off the New Jersey Coast (Krotee and Krotee, 1965); "A Preliminary Survey to Analyze The Potential Presence of Submerged Cultural Resources In the Delaware and Susquehanna Rivers" (Cox 1984); Shipwrecks in the Americas (Marx, 1971); Shipwrecks of Delaware and Maryland (Gentile 1990); Shipwrecks of New Jersey, South (Gentile 2002); Automated Wreck and Obstruction Information System - AWOIS, (National Oceanographic and Atmospheric Administration); Merchant Vessels of the United States, Wreck List; The Monthly Nautical Magazine and Quarterly Review; The Steamship Inspection Service, Wreck File, 1852-1937, National Archives; U.S. Coast Guard, Records of Life Saving Service, National Archives; Wreck Chart of the North American Coast of America, General Records of the Hydrographic Office, National Archives; Hazard Annuals of Pennsylvania 1609 - 1682 (Hazard, 1850); "Underwater Cultural Resources Background Study and Field Survey of the Delaware Inner Continental Shelf," (Koski-Karell, 1984), and Maritime Theme in Delaware with the Sub-Theme Shipwrecks, Coastal Zone (Koski-Karell 1995).

Many of the wrecks, particularly the more modern accidents that occurred in or near the shipping channel, were subsequently salvaged or removed because they were threats to safe navigation.

Name	Year Lost	Comments
Mercury	1641	English merchantman, Captain Hogg, sailing from Philadelphia to London, lost near the Delaware River.
Unidentified sloop	1747	Sloop was lost a few leagues south of the Delaware Capes in September.
Pusey	1757	Captain Good, arriving from Jamaica wrecked on Reedy Island in the Delaware River.
Cornelia	1757	Captain Smith, sailing from Philadelphia to Gibraltar, sank between Capes Henlopen and May.
Vaughan	1763	English merchantman, under Captain Foster, sailing from Bristol to Philadelphia, wrecked in Delaware Bay.
Pitt Packet	1763	English merchantman, under Captain Montgomery sailing from Belfast to Philadelphia with a large number of passengers, foundered in Delaware Bay with a total loss of life.

Kildare	1768	Captain Nicholson, sailing from Barbados to Philadelphia, lost at the mouth of Delaware River.
Commerce	1771	English merchantman, under Captain Addis, sailing from England to New York, wrecked at Cape Henlopen.
Severn	1774	English merchantman, under Captain Hathorn sailing from Bristol to Philadelphia, wrecked in Delaware Bay, but all of her crew was saved.
Endeavor	1775	English merchantman, under Captain Caldwell, sailing from Philadelphia to Londonderry, caught fire and sank off Reedy Island in the Delaware River but most of her cargo was saved.
9 unidentified ships	1783	Wrecked at Cape Henlopen during a severe gale in the fall.
Faithful Steward	1785	Scottish immigrant ship, under Captain M'Causland, sailing from Londonderry to Philadelphia sank near Cape Henlopen, over 200 persons perished.
Santa Rosalea	1788	Spanish merchantman, under Captain Pardenus sailing from Baltimore to Havana wrecked near Cape Henlopen.
Pomona	1789	English ship, under Captain Hopkins arriving from Quebec, sank in Delaware Bay in October.
John	1790	English merchantman, under Captain Staples, arriving from England, wrecked on December 5, in Delaware Bay.
Industry	1793	American merchantman, under Captain Carson, sailing from France to Philadelphia sank in Delaware Bay, near Cape May.
San Joseph	1794	Spanish merchantman, sailing from Philadelphia to Cuba, was lost in Delaware Bay when ice crushed her hull.
Peggy	1794	American merchantman, sailing from Philadelphia for Savannah, was lost in Delaware Bay.

Lively	1795	Sailing from Amsterdam to New York, under Captain Lawrence, ship sank near Lewes.
Henry & Charles	1796	American merchantman, sailing from Hamburg to Philadelphia wrecked near Cape Henlopen.
Favorite	1796	American merchantman, sailing from Cadiz to Philadelphia sank in Delaware Bay.
Minerva	1796	American merchantman, sailing from Lisbon to Philadelphia wrecked near the mouth of Delaware River.
DeBraak	1798	A British Sloop of War that capsized approximately one mile off Cape Henlopen.
New Jersey	1799	American merchantman, under Captain Clay sailing from Puerto Rico to Philadelphia, wrecked on the west side of the Delaware Bay.
Susannah	1800	Merchantman, sailing from Hamburg to Philadelphia under Captain Medlin wrecked in Delaware Bay.
Adriana	1801	American merchantman, sailing from Philadelphia to Dublin sank in Delaware Bay due to heavy ice.
Constellation	1801	American merchantman sailing for New York sank in Delaware Bay.
China	1805	Merchantman, under Captain M'Pherson sailing from Batavia for Philadelphia sank in Delaware Bay.
Fanny	1805	Merchantman, under Captain Wing, sailing from France for Philadelphia sank in Delaware Bay.
Betsey	1807	Schooner drove ashore at Reedy Island.
Ann Jane	1807	Brig bound for Bordeaux drove ashore during a gale and bilged inside Cape May.
Nanina	1807	Brig bound for Teneriffe drove ashore during the same gale and bilged inside of Cape May.
South Carolina	1807	Ship-rigged sailing vessel arriving from Canton drove ashore during the same gale and bilged inside of Cape May.

Friendship	1807	Schooner from St.Thomas driven ashore near Lewistown (Lewes).
Nancy	1808	Brig from Havana was driven ashore on the oyster beds in Delaware Bay in January.
Greyhound	1809	Sloop from Baltimore was driven ashore and lost on Cape May in December.
Camillus	1809	Brig from New Orleans was driven ashore and heavily damaged by ice near Reedy Island in February.
Clementina	1810	Schooner bound for Laguira was cut by ice and sank in the bay in February.
Guatamzon	1810	Ship-rigged sailing vessel bound for New York from Canton drove ashore under Cape May and bilged in February.
Growler	1810	Brig, inbound from Havana was driven upon "the Brandywine" and lost in December.
Three Brothers	1812	Brig inbound from St. Thomas was driven ashore and lost under Cape Henlopen in January.
Juliet	1812	Schooner inbound from Havana was driven ashore near the point of Cape Henlopen in January.
Unidentified prize vessel	1812	Schooner, prize vessel, was driven ashore near Lewistown (Lewes) in January and all were lost.
Perseverance	1812	Schooner, inbound from Havana was driven ashore on Lewistown (Lewes) beach in January.
Unidentified vessel	1812	Spanish schooner, was driven ashore on Lewistown (Lewes) beach in January and all were lost.
General Apodaca	1813	Spanish brig was driven ashore at Cape Henlopen in January and her cargo was lost.
Helen	1817	Schooner was driven by ice from her anchors onshore at Lewistown (Lewes) in March and was totally lost.
Concord	1817	Schooner, en route from Ocracoke to New York was blown ashore and cast away on Cape May; cargo and vessel were lost.

Tryphenia	1818	Sloop, traveling from New York to Norfolk, put in to Delaware Bay and was cast away on Cape May in February. Four people were lost while the captain and one man drifted onshore on the quarterdeck.
Ann Marie	1818	Schooner, bound for Darien drove ashore on Cape Henlopen and bilged in February.
Orleans	1821	Ship-rigged sailing vessel from New Orleans, was sunk by ice in the bay in February.
Unidentified sloop	1821	Sloop, under the direct of Master Winslow, drove on her anchors and was lost near Lewistown (Lewes).
Seaman	1822	Sloop, from New York, was driven on the Overfalls; afterwards in a heavy storm was totally lost in May.
Nancy	1824	Schooner, en route from Martinique to Plymouth, while in search of shelter driven ashore near Cape May and bilged in February.
Adeline	1824	American merchantman, under Captain Israel, sailing from North Carolina to Philadelphia wrecked in December at Cape Henlopen.
Spartan	1825	Sloop, from Savannah, was driven ashore in a gale above Lewistown (Lewes) and was probably totally lost in April.
31 vessels	1825	A June gale caused considerable damage throughout the bay. Numerous vessels including the sloops Kitty Ann, George Ogden, and Friendship, and 13 other vessels were driven ashore near Cape May. An additional 8 other sloops were driven ashore under Cape Henlopen. Seven vessels were driven ashore between Cohanzy and Back creeks.
Uno	1825	Vessel, from New York, was not heard from after June gale and supposed lost with all hands within Delaware Bay.
Emeline	1825	Vessel was lost within the bay during June gale.

Edward Thompson	1825	Pilot-boat and a smack were driven on Cape May from Cape Henlopen and both were lost during the June gale.
Three Friends	1825	Sloop was driven ashore near Cape May during June gales and sank.
Mountaineer	1850	Steamer foundered at Cape Henlopen.
Osceola	1855	Brig went ashore near Fenwick Island on January 5.
Wasp	1855	Schooner ran ashore near Indian River in January.
Autumn	1855	Schooner stranded on Indian River Bar on February 21.
James C. Dobbin	1856	Schooner went ashore near Indian River Inlet on January 9.
E.J. Dupont	1856	Steamer stranded near Indian River and was listed as a total loss on June 14.
John Currier	1856	Ship went ashore on Fenwick Island in August.
Sylvina	1856	Brig was lost near Fenwick Island.
John McMakin	1860	Steamer foundered at Lewes.
Unidentified Schooner	1860	Schooner wrecked in a storm below Indian River Inlet on February 3.
Ellen Holgate	1875	Wood-hull Schooner foundered at lower end of Reedy Island, Delaware Bay.
Cienfuegos	1875	Wood-hull, bark-rigged sailing vessel sank 3 miles south, southwest of Cape Henlopen.
Rillie S. Derby	1876	Wood-hull schooner was lost at Delaware Breakwater.
Scud	1876	Bark-rigged sailing vessel foundered at Fenwick Light
Babel H. Irons	1877	Wood-hull schooner carrying coal and iron foundered during a sudden cyclone near Delaware Breakwater.
Vashti Sharp	1877	Wood-hull schooner, stranded at Fenwick Island Shoals, Delaware Bay.

Trade Wind	1877	Wood-hull schooner, stranded three quarters of a mile opposite Lewes.
Jesse Wilson	1877	Two-masted wood-hull schooner sailing from Philadelphia to Boston carrying coal foundered inside the breakwater near Lewes.
J.B. Austin	1877	Wood-hull, two-masted schooner foundered north of breakwater during severe October gale.
Mary E. Smith	1877	Wood-hull schooner foundered at anchor near the Delaware Breakwater during October gale.
Bessie Morris	1877	Three-masted wood-hull schooner foundered at anchors near the Delaware Breakwater during a severe October gale.
M.A. McGahan	1877	Wood-hull schooner carrying coal foundered inside the Delaware Breakwater.
R.K. Vaughn	1878	Schooner foundered 3 miles south of Fenwick Island Light.
E. Sinnickson	1879	Schooner foundered at Delaware Breakwater.
Champion	1879	Steamer collided with bark Lady Octavia off of Cape Henlopen and sank on November 7.
Wanderer	1880	Steamer en route from New York to Apalachicola, Florida, was lost due to ice at the Delaware breakwater on December 26.
Argonauta	1881	Tow boat founded at Reedy Island
Archer & Reeves	1881	Schooner foundered at Delaware Breakwater.
Sewell	1881	Schooner, carrying brick and lime was lost on the south side of Indian River on July 23.
Josephine	1882	Schooner foundered at Delaware Breakwater.
Minnie Hunter	1883	Wood-hull bark-rigged sailing vessel foundered at Cape Henlopen.
John Taylor	1884	Steamer wrecked on Cape May. Her boiler and machinery were saved.
Hattie Page	1884	Schooner foundered at Delaware Breakwater.

Walter S. Massey	1885	Wood-hull barkentine-rigged sailing vessel foundered at Cape Henlopen.
Adolphus	1886	Schooner en route from Antwerp to Philadelphia foundered on the breakwater, she went ashore and went to pieces.
Brinkburn	1886	Iron-hull brig-rigged steamer stranded on Fenwick Island Shoals, Delaware Bay, after mistaking lights and the absence of the bell buoy named on charts.
William Snow	1886	Vessel stranded at Fenwick Island Shoals.
William G. Bolton	1886	Steam tug sank in 20 feet of water near Fourteen Foot Bank due to heavy ice on January 10.
Aldora	1887	Bark-rigged sailing vessel foundered at Lewes.
Baylies Wood	1887	Schooner foundered at Cape Henlopen.
Uranus	1887	Steamer was lost off Rehoboth on May 10.
Mascotte	1888	Bark was lost at Rehoboth on February 12.
Allie H. Belden	1888	Schooner foundered in Delaware Bay during storm on March 12.
C. B. Hazeltine	1888	Schooner foundered in Delaware Bay during storm on March 12.
Tamesi	1888	Wrecking steamer was pounded by gale winds against the breakwater and sank on March 12.
George W. Simpson	1888	Tug was driven from pier at breakwater by gale on March 12; anchored off Stonepile and sank in 7 fathoms of water.
Emma	1888	Schooner was lost at Rehoboth on November 26.
Ella	1888	Schooner was lost at Rehoboth on November 27.
Elizabeth de Hart	1888	Schooner foundered at Cape Henlopen.
Flora A. Newcomb	1888	Schooner foundered off Lewes.
George H. Bent	1888	Schooner foundered at Delaware Breakwater.
Geo. W. Anderson	1888	Schooner foundered off Lewes.

Jan Melchers	1888	Bark-rigged sailing vessel foundered on Fenwick Island Shoal.
Hannah	1888	Bark-rigged sailing vessel foundered at Lewes.
Lewis Clark	1888	Steamer foundered at Cape Henlopen.
Moro Castle	1888	Bark-rigged sailing vessel foundered at breakwater in November.
Paul & Thompson	1888	Schooner foundered at Lewes.
William C. Bartlett	1888	Schooner foundered at Cape Henlopen.
Addie B. Bacon	1889	Schooner foundered at Delaware Breakwater on September 10.
Sarah C. Park	1889	Schooner foundered two miles north of Rehoboth Beach Life Saving Station on September 10.
Alena Covert	1889	Schooner foundered at Delaware Breakwater during storm on September 11.
Kate E. Morse	1889	Schooner foundered in Delaware Bay during storm on September 11.
Mima A. Reed	1889	Schooner foundered at Breakwater during storm on September 11.
Patriot	1889	Bark-rigged sailing vessel foundered at breakwater on September 11.
S. A. Randolph	1889	Schooner foundered at breakwater during storm on September 11.
Brooklyn	1889	Steamer foundered off Fenwick Island in approximately 150’ of water.
Sunrise	1889	Ship-rigged sailing vessel foundered at breakwater on April 6.
Independence	1889	Sloop-rigged sailing vessel foundered at Cape Henlopen.
Major Wm. H. Tantam	1889	Schooner foundered at Delaware Breakwater.
Walter F. Parker	1889	Schooner foundered off 14 Foot Shoal, Delaware Bay, after a collision with another vessel .

Chas. P. Stickney	1889	Schooner foundered at Delaware Breakwater.
Thos. Keillor	1889	Bark-rigged sailing vessel foundered at breakwater.
Sallie C. Morton	1889	Vessel foundered on a shoal near the Cape May channel.
Cleopathra	1889	Steamer foundered off Delaware Capes after collided with the Side-wheeler Crystal Wave on October 29.
Crystal Wave	1889	Sank near the Five Fanthom Bank Lightship after colliding with the steamer Cleopathra.
Manhattan	1889	Steamer, 1,525 tons, sank in 90' of water after colliding with schooner Agnes Manning off Fenwick Island.
Cricket	1890	Barge foundered at Five Fathom Bank.
Nellie C. Raine	1890	Schooner foundered in Delaware Bay on March 15.
Oceanus	1890	Schooner foundered off Delaware Capes.
Dan	1890	Schooner, was lost one mile south of Indian River Inlet Life Saving Station on December 25.
Alsenborn	1891	Steamer foundered in Delaware Bay on January 11.
William B. Orr	1891	Schooner foundered in Delaware Bay on April 28.
George Henry	1891	Schooner foundered in Delaware Bay on June 18.
Red Wing	1891	Schooner involved with fishing stranded and went to pieces 3.5 miles south of the Indian River Inlet Life Saving Station on October 22.
Minnie & Gussie	1891	Schooner foundered near Cape Henlopen.
Syringa	1891	Bark-rigged sailing vessel foundered in Delaware Bay.
Sara B. Reynolds	1893	Steam tug struck jetties off Reedy Island during a snowstorm and sank in Delaware River on January 17.

Equator	1893	Wooden-hull barge carrying railroad ties foundered off Fenwick Island on March 23.
W.T. Sherman	1893	Sloop carrying fish scraps from Chincoteague to Philadelphia stranded four miles north of Fenwick Island Life Saving Station on September 15.
John A. Griffin	1894	Schooner foundered at Ice Breaker, Lewes.
Odorilla	1894	Wooden-hull brig carrying phosphate rock stranded four miles north of Fenwick Island Life Saving Station on December 16.
Scow No. 7	1898	Scow was lost 1.5 miles north of Fenwick Island Life Saving Station on May 8.
J.W. Somers	1899	Schooner stranded on beach 200 yards south of Indian River Inlet Life Saving Station.
A.A. Shaw	1900	Schooner sank at mouth of Delaware Bay after colliding with steamer Hamilton on October 7.
Sutton	1900	Freighter, 2,526 tons, stranded on Fenwick Island Shoals January 21. She was never salvaged.
Lida Fowler	1901	Schooner foundered at 14 Foot Shoal, Delaware Bay.
Annie T. Bailey	1902	Schooner foundered at Cape Henlopen.
Edna Earl	1902	Schooner collided with steamer Ramsdale, in vicinity of Reedy Point, Delaware River on March 29.
Anna Murray	1902	Schooner stranded 2.5 miles south of Indian River Inlet Life Saving Saving Station on February 17.
Addie	1902	Schooner foundered one and one-quarter miles south, one-half mile east of Indian River Inlet Life Saving Station on November 7.
Carrigan	1903	Vessel foundered at Cape Henlopen.
William H. Davidson	1903	Schooner carrying lumber foundered 2.5 miles south of Indian River Inlet Life Saving Station on March 26.

Spartan	1903	Tug with two barges in tow bound from Salem, Massachusetts foundered in hurricane off Brown Shoal, Delaware Bay, on September 16.
Gilberton	1903	Schooner barge in tow of Spartan foundered off Brown Shoal on September 16.
Kalmia	1903	Schooner barge in tow of Spartan foundered off Brown Shoal on September 16.
Saginaw	1903	Liner, 1,835 tons, foundered after colliding with steamer Hamilton south of the Fenwick Island lightship.
E. C. Allen	1904	Schooner foundered at the old breakwater, Lewes.
Stetson and Ellison	1906	Schooner foundered in Delaware Bay.
Car float	1906	Towing steamer Defiance was towing two car floats when one sank about two miles below Brown Shoal Buoy on January 26.
Ira D. Sturgis	1906	Schooner stranded near Indian River on February 15.
Norumbega	1906	Schooner collided with schooner Edith L. Allen near Fenwick Island on April 23.
John J. Ward	1907	Schooner stranded at Lewes.
Van Brunt	1907	Schooner, 1,191 gross tons collided with schooner Crosby near Delaware Breakwater on April 24. Schooner was towed and beached on mud flats inside Delaware Breakwater.
Frederica	1908	Schooner foundered in Delaware Bay.
White Band	1908	Barge, loaded with coal, being towed by towing steamer M.E. Scully parted from steamer and was rediscovered with hull awash one-half mile northwest of Overfalls Shoals spar buoy at the mouth of Delaware Bay on January 24.
Marie F. Cummins	1908	Wooden-hull schooner stranded 12 miles below Delaware Breakwater on November 14.
John Proctor	1909	Schooner stranded at Cape Henlopen.

USS Nina	1910	Steam tug, built for the Navy in 1865, sank during a storm on February 6 in 80' of water off the coast of Delaware.
Sunbury	1910	Schooner barge foundered near the Fenwick Island Light on August 17, 1910.
Leiv Eriksen	1910	Schooner collided with steamship Chesapeake near Fenwick Island Light on September 1.
O.D. Witherell	1911	Schooner stranded near the Fenwick Island Light on April 1911.
Estelle	1912	Barge, in tow of steamer Winfield S. Cahill collided with British steamer Antaeus while abreast of New Castle Flats and sank on May 8.
T. Morris Perot	1913	Schooner collided with steamer Shawmut 23 miles north, northeast of Winterquarter light vessel. Schooner was towed toward Delaware Breakwater but sank one-half mile east of Fenwick Island buoy on September 28.
City of Georgetown	1913	Schooner collided with screw steamer Prinz Oskar at Delaware Capes.
Dunlo	1914	Schooner foundered at Harbor of Refuge, Delaware.
Elizabeth Palmer	1915	Five-masted schooner sank after colliding with the steamer Washingtonian near the mouth of Delaware Bay on January 26.
Washingtonian	1915	Steamer, 6,650 tons, sank in 90' of water after colliding with schooner Elizabeth Palmer off the Delaware Coast.
Ella A. Call	1917	Schooner foundered off Reedy Island.
Western Belle	1917	Schooner barge foundered near Fenwick Island on September 23.
New Orleans	1917	A coastal passenger-freighter steamer , 1,564 tons, foundered somewhere off the Maryland-Delaware Coast after heading north out of Chesapeake Bay.
Poseidon	1918	Steel-hulled freighter collided with the steamer Somerset about 5 miles northeast of the Five Fathom Bank lightship and sank in 90' of water.

Merrimac	1918	Schooner barge stranded at Rehoboth on April 10.
Cherokee	1918	Steam tug (formerly the Edgar F. Luckenbach) foundered in 90' of water off the coast of Delaware on July 26.
Scully	1919	Schooner foundered at Delaware Breakwater.
Marie C. Beazley	1920	Schooner burned near Fenwick Island Light on February 8.
Maurice	1920	Tug, 38 gross tons, while towing an oil barge developed a sudden list and sank in the Delaware River while on New Castle Range, near red buoy No. 8, on December 2.
George May	1921	Barge foundered in Delaware Bay.
Wade Hampton	1923	Screw steamer foundered in Delaware Bay.
Corrotoman	1924	Barge foundered at Brown's Shoal, Delaware Bay.
Lenape	1925	Screw steamer burned at Delaware Breakwater.
Thomaston	1925	Barge being towed with three other barges by the towing steamer Tamaqua collided with the British steamer London Exchange in mid-channel of the Delaware River below Reedy Island and sank in three minutes on April 25.
Solvang	1926	Freighter sank near the Delaware Breakwater after colliding with the tanker Vacuum.
Tigress	1928	Wood-hull, auxiliary yawl stranded behind the breakwater at Lewes during a hurricane and went up on to the beach and broke up.
Lottie	1928	Barge foundered at Lewes.
Emily A. Foote	1930	Oil screw ship foundered at Delaware Breakwater.
S.G. Wilder	1933	Wooden barge sank in 80' of water north of the Winter Quarter Lightship. Also lost were fellow barges Whitehaven and Brunswick.
Octoraro	1935	Barge, 807 gross tons, sank in Delaware Bay three-quarters of a mile southwest of Brown Shoal Gas Buoy on January 25.

Long Island	1936	Screw fishing steamer, 390 gross tons, foundered inside Overfall, Delaware Bay during a hurricane on September 18.
F. H. Beckwith	1937	Steamship sank after a collision and now rests in 40 feet of water, approximately three miles south of Cape May.
Talbot	1938	Barge burned at Delaware Breakwater.
Effie M. Lewis	1941	Oil screw ship foundered in Delaware Bay.
Harry K. Fooks	1941	Fishing schooner out of Lewes sank 1,000 yards from Hens and Chicken Whistling Buoy after a collision with steamship E.J. Codd.
William L. Hooper	1942	Barge foundered at Lewes.
Indian Arrow	1942	Vessel was torpedoed and sunk near mouth of Delaware Bay while in route from Texas to New York. Resting in 40 feet of water.
Hvoslef	1942	Norwegian vessel was torpedoed and sun south of Cape Henlopen on March 10.
Gypsum Prince	1942	Steam freighter sank after a collision with the tanker Voco on May 2, near the end of the Delaware Breakwater. Sank in 60 feet of water and was cleared to a 50 foot depth by demolition.
John R. Williams	1942	Tugboat sank after striking a German mine south of Cape Henlopen on June 24.
Jacob Jones	1942	U.S. Navy Destroyer sunk in 120' of water of the Delaware Coast after being torpedoed by German U-578.
Moonstone	1943	U.S. Navy Patrol Craft (ex- Lone Star), sank in 130' of water after colliding with USS Greer.
Thomas Tracy	1944	Freighter foundered in 25' of water near mouth of Delaware Bay; September 14; approximately ¼ mile off Rehoboth Beach.
Hannah A. Lennen	1944	Screw steamer collided with tanker at entrance to Delaware Bay.
B. F. Macomber	1944	Single screw, 257 ton fishing trawler sank following a collision with steamer Henry C.

		Brown near the Delaware Breakwater and lies in 69 feet of water.
Reliance	1944	Racing sloop, which won the America's Cup four times foundered and sank near the shore at Fenwick Island on August 17.
Joyce I	1945	Oil screw vessel burned near Fenwick Island on August 22.
Joseph E. Hooper	1945	Schooner barge foundered 1.5 miles south by east of Fenwick Island on November 15.
Martha	1946	Gas screw vessel stranded at Indian River Inlet.
Southern Sword	1946	Steel barge foundered in 70' of water off Indian River Inlet on March 18.
Gordon C. Cooke	1947	Steel barge foundered off the coast of Delaware between Fenwick Island and Winterquarter Shoal on April 12.
Lu Lu	1947	Gas screw vessel foundered at the rock jetty of the Indian River Inlet on October 12.
A.C. Dodge	1952	Motor barge foundered 1200 yards from Reedy Island, near Port Penn after collision with oil tanker Michael.
Phoenix	1953	Screw steamer collided with Pan-Massachusetts, exploded and sank on the east side of channel, north of Reedy Island on June 6.
Cape May	1962	A pilot boat that was lost just off Cape Henlopen.
Miss Nottingham	1962	Gas screw vessel was destroyed by storm at Rehoboth Beach on March 7.
Flo-Mel	1964	Gas screw yacht burned at Rehoboth on June 7.
Thomas E.	1967	Gas screw vessel burned at Indian River Inlet on January 16.
Resolute	1968	Oil screw wooden-hull vessel foundered off Bethany Beach on May 27.
Emma	1977	Gas screw fishing boat foundered at Indian River Inlet.

King Cobra	1979	92-year old tug disappeared in a storm after rounding Cape May in Delaware Bay. In 1981, divers found the wreck in 42' of water 5 miles south of Cape May.

APPENDIX II:

QUALIFICATIONS OF THE PRINCIPAL INVESTIGATOR

J. Lee Cox, Jr., owner of Dolan Research, Inc. served as the Principal Investigator. He directed the underwater archaeological investigation. Mr. Cox received a MA from East Carolina University in Maritime Research/Underwater Archaeology and a BA from Duke University in Archaeology. He meets or exceeds the standards for a principal investigator in archaeology as set forth in the Secretary of the Interior's Professional Qualifications Standards (36 CRF Part 61). He has been involved with over 150 different underwater archaeological projects over the last 32 years in 22 different states, Bermuda, Puerto Rico, Trinidad and Tobago, and Canada. He has authored over 100 reports and published seven articles and one book in conjunction with professional experience. He is a member of the Register of Professional Archaeologists (RPA).

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419
http://primehook.fws.gov

October 21, 2014

Ms. Gwen Davis
Deputy State Historic Preservation Officer
89 Kings Highway
Dover, DE 19901

Dear Ms. Davis,

Prime Hook National Wildlife Refuge (Service or refuge) is seeking concurrence with the State of Delaware Historical and Cultural Affairs for any potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended.

The Service is proposing to restore the damage incurred by Super Storm Sandy to Prime Hook National Wildlife Refuge located in Sussex County, Delaware which entails the discharge of approximately 1 million cubic yards of clean native fill along the Delaware Bay beach to re-establish a foreshore, dune, and back-barrier marsh platform within Unit II of the refuge.

The clean fill material originates from Delaware Bay shoal areas offshore from the project area. This area is currently being surveyed both culturally and biologically and these results will be available within a Supplementary Environmental Impact Statement that is currently being prepared by the U.S. Army Corps of Engineers.

We are proposing to discharge the fill material utilizing a cutter-suction dredge along an approximately 4,000 linear foot stretch on the east side of Unit II. The Service plans to conduct these activities in late fall of 2015 or 2016 once time-of-year restrictions have been lifted.

The proposed project does not require any excavation for the foreshore, dune, back-barrier marsh portion of the project, but the excavation of a series of sinuous tidal channels within Units II & III to convey the necessary hydrology to sustain a brackish marsh will be necessary.

The subject area was archaeologically surveyed in August 2013 by the State of Delaware Historical and Cultural Affairs (ER 2013.08.07.02) when a smaller wetland restoration was proposed (see attachment).

Service staff met with the Joint Permitting Process representatives in Dover, Delaware on May 02, 2014 to brief the regulatory agencies on the purpose and need for the project.

If you need any additional information or have questions please contact me at the number above.

Sincerely,

Arthur J. Coppola
Refuge Manager

Attachment

State of Delaware
Historical and Cultural Affairs

21 The Green
Dover, DE 19901-3611

Phone: (302) 736.7400 Fax: (302) 739.5660

August 30, 2013 ER 2013.08.07.02

Arthur J. Coppola
Refuge Manger
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Project Proposed Wetland Restoration
Prime Hook National Wildlife Refuge, Sussex County, Delaware.

Dear Mr. Coppola,

The above referenced project was reviewed for potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended. The undertaking will occur in wet areas with low archaeological probability. In addition there are no recorded historic properties in the area to be impacted. The upland staging areas appear to have been disturbed, and would be very unlikely to contain intact archaeological resources. It is the conclusion of the reviewer that no archaeological survey should be required. Also, given the limited nature of construction associated with this project, no architectural historic properties can be affected by this project.

If you have any questions, please contact me at craig.lukezic@state.de.us.

Sincerely,

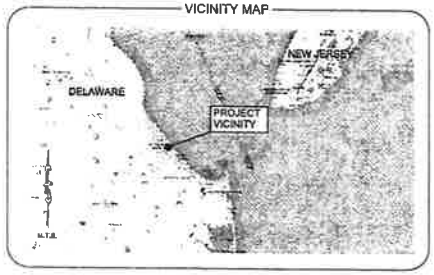
Craig Lukezic
Archaeologist, Division of Historical and Cultural Affairs

Cc Gwen Davis, Deputy State Historic Preservation Officer

PRIME HOOK RESTORATION PROJECT

PERMIT DRAWINGS
MILTON, DELAWARE

VICINITY MAP



PROJECT LOCATION

THE PROJECT AREA IS LOCATED IN MILTON DELAWARE ALONG THE WESTERN SHORE OF DELAWARE BAY.

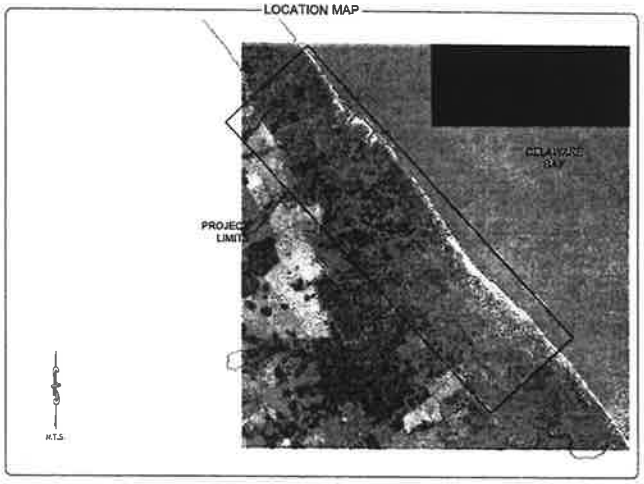
INDEX OF DRAWINGS

SHEET TITLE	SHEET NUMBERS
COVER	C-000
PLAN VIEW - VICINITY MAP	C-001
PLAN SHEET LAYOUT	C-002
PLAN VIEW - BACK BAY MARSH PLATFORM AND TIDAL CREEKS	C-300 TO C-309
TYPICAL CROSS SECTIONS - BACK BAY MARSH PLATFORM AND TIDAL CREEKS	C-500
MARSH CHANNEL PROJECT CROSS SECTIONS	C-600 TO C-603

Know what's **below.**
Call before you dig.

ATTENTION IS DIRECTED TO THE FACT THAT THESE PLANS MAY HAVE BEEN REDUCED IN SIZE BY REPRODUCTION.

LOCATION MAP



CLIENT

U.S. FISH & WILDLIFE SERVICE
PRIME HOOK NATIONAL WILDLIFE REFUGE
11978 TURKLE POND ROAD
MILTON, DELAWARE 19968
TEL. (302) 684-8419

THE Louis Berger Group, INC.

ENGINEER OF RECORD

LOUIS BERGER - JEFFREY R. TABAR, P.E.
412 MOUNT KEMBLE AVE.
MORRISTOWN, NEW JERSEY 07960
TEL. (856) 418-1243

AUGUST 2014

GENERAL NOTES

1. THE PURPOSE OF THIS PROJECT IS TO RESTORE THE PRIMEHOOK BEACHES AND WETLAND AREAS AS A RESULT OF HURRICANE SANDY. ALL QUANTITIES ARE APPROXIMATE AND THE CONTRACTOR IS RESPONSIBLE FOR VERIFYING ESTIMATED QUANTITIES.
2. BEACH NOURISHMENT AND WETLAND RESTORATION ACTIVITY WILL BE CONDUCTED IN DESIGNATED AREAS ONLY AND IN ACCORDANCE WITH THE PLANS AND SPECIFICATIONS.
3. CONTRACTOR SHALL MAINTAIN TURBIDITY CONTROL MEASURES THROUGHOUT THE PROJECT.
4. TOPOGRAPHIC AND BATHYMETRIC DATA HAVE BEEN PROVIDED BY XXXXX DATED XXXXX. SURVEY INFORMATION DEPICTED WITHIN THIS PLAN SET REPRESENT THE EXISTING CONDITIONS AT THE TIME OF THE SURVEY WITH A VERTICAL ACCURACY OF +/- 0.3'.
5. GRID COORDINATES ARE IN FEET, AND ARE REFERENCED TO THE DELAWARE STATE PLANE COORDINATE SYSTEM, EAST ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
6. ELEVATIONS SHOWN WITHIN THIS PLAN SET ARE IN FEET, AND ARE REFERENCED TO NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).
7. MEAN HIGH WATER (MHW) IS EQUAL TO XXXXX' (NAVD 88).
8. AERIAL PHOTOGRAPHS WERE PROVIDED BY XXXXX (DATED XXXXX).

NOTICE

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PREPARED BY

ATKINS

PROJECT NUMBER: 100039575

TREADWAY TOWERS
SUITE 316
9 EAST LOOCKERMAN STREET
DOVER, DELAWARE 19901
(800) 477-7275

DATE:

ENGINEER OF RECORD: JEFFREY R. TABAR
DELAWARE P.E. #18229

NOT VALID FOR CONSTRUCTION UNLESS SIGNED IN THIS BLOCK

USFWS

PRIME HOOK RESTORATION PROJECT

PLAN VIEW - Y TY MAP

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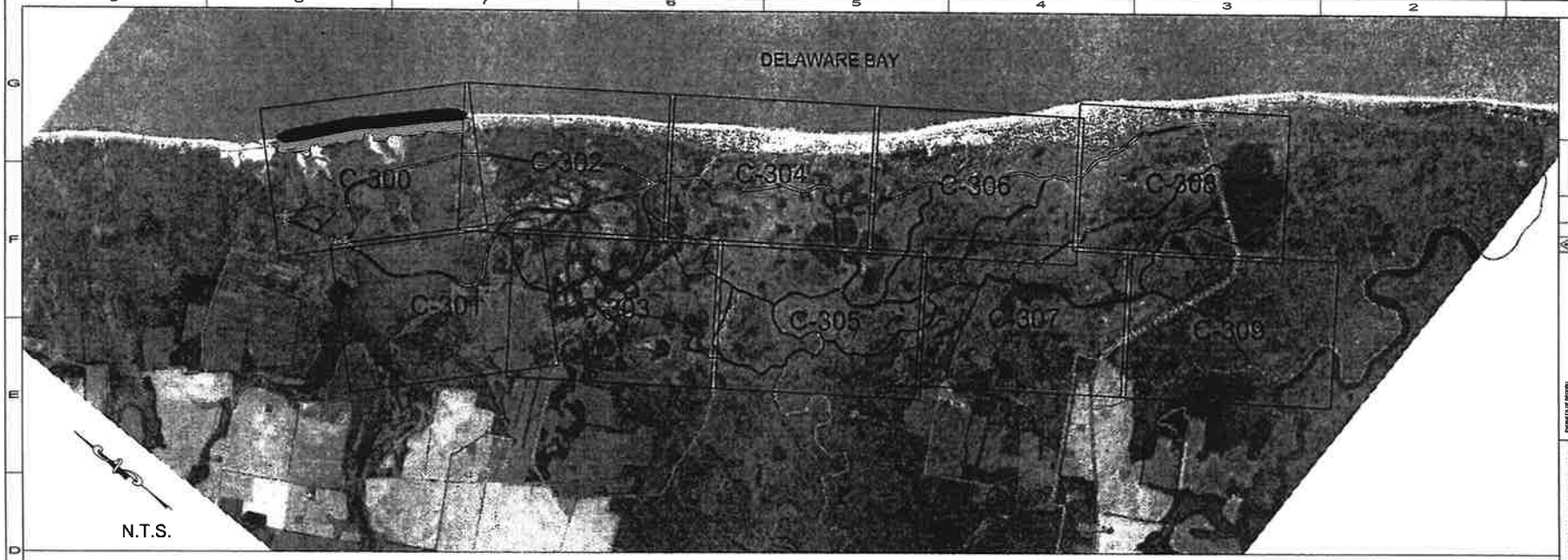
JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-001

CONCEPTUAL DRAWINGS



PLAN SHEET LAYOUT

U.S. FISH & WILDLIFE SERVICE

	DATE	DESCRIPTION
1		
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5		
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7		
8		

ORIGINAL SHEET SIZE

DATE:

DATUM OF RECORD:
EPSG:2140 - NAD83 / UTM zone 18N

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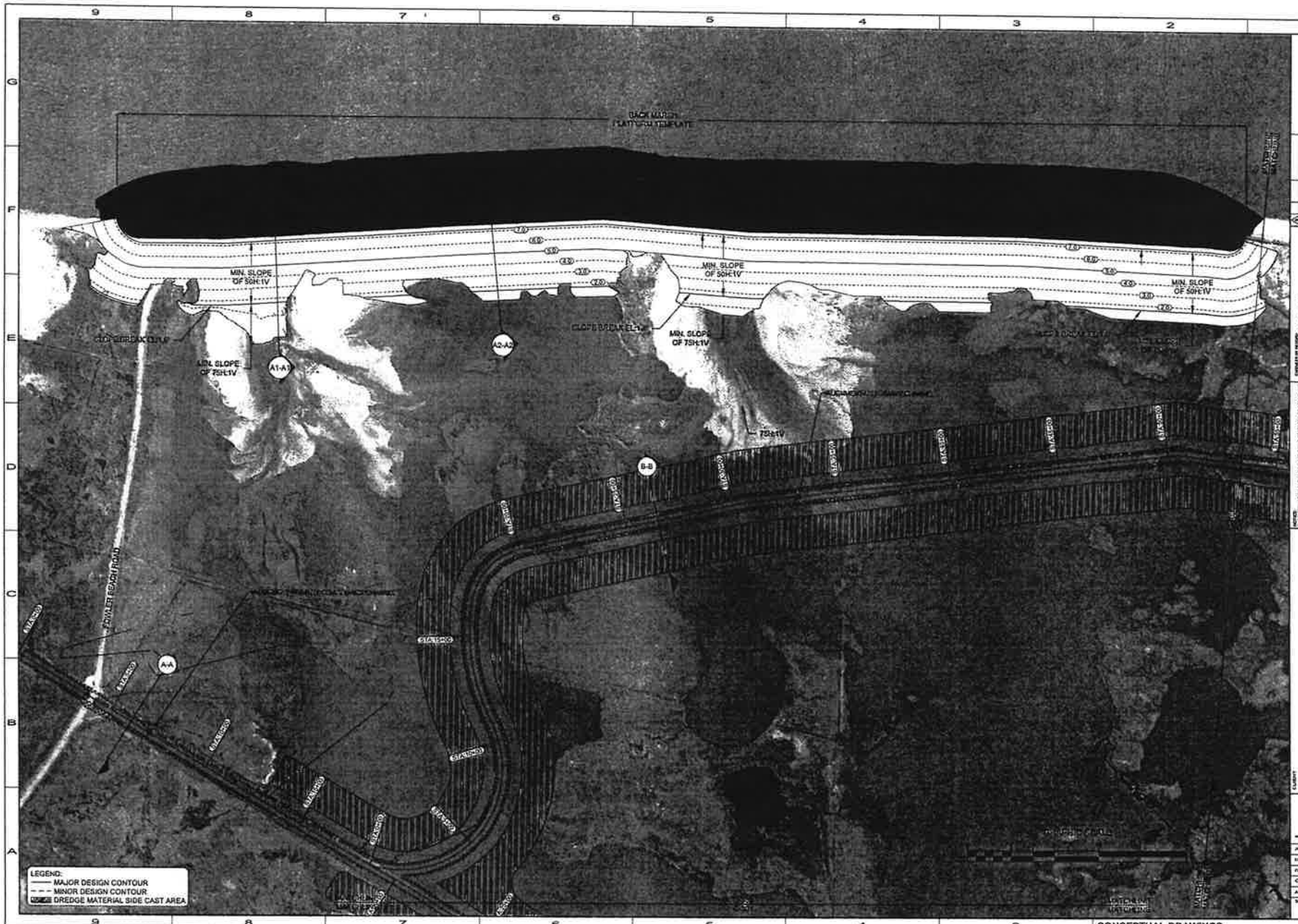

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ORIGINAL DRAWING DATE:

CONCEPTUAL DRAWINGS

DATE

NOTES:

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - BA[illegible]Y MARSH PLATFORM AND [illegible] CREEKS

ATKINS

JOB NO.	100031176
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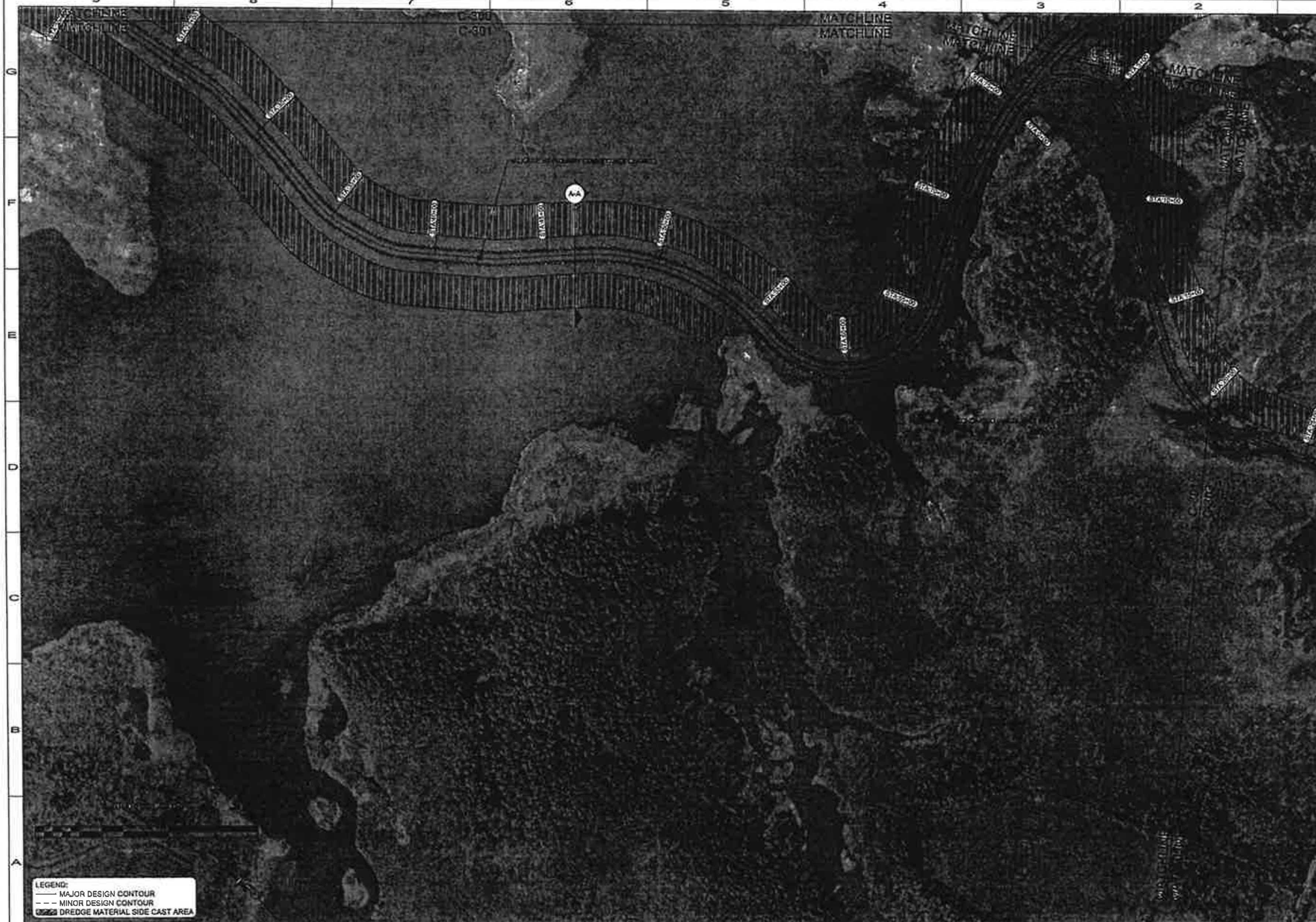
APPROVED:	J.R.T.
SHEET NO.	C-300



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PRIME HOOK RESTORATION PROJECT

TITLE
PLAN VIEW 'K BAY MARSH PLATFORM IDAL CREEKS

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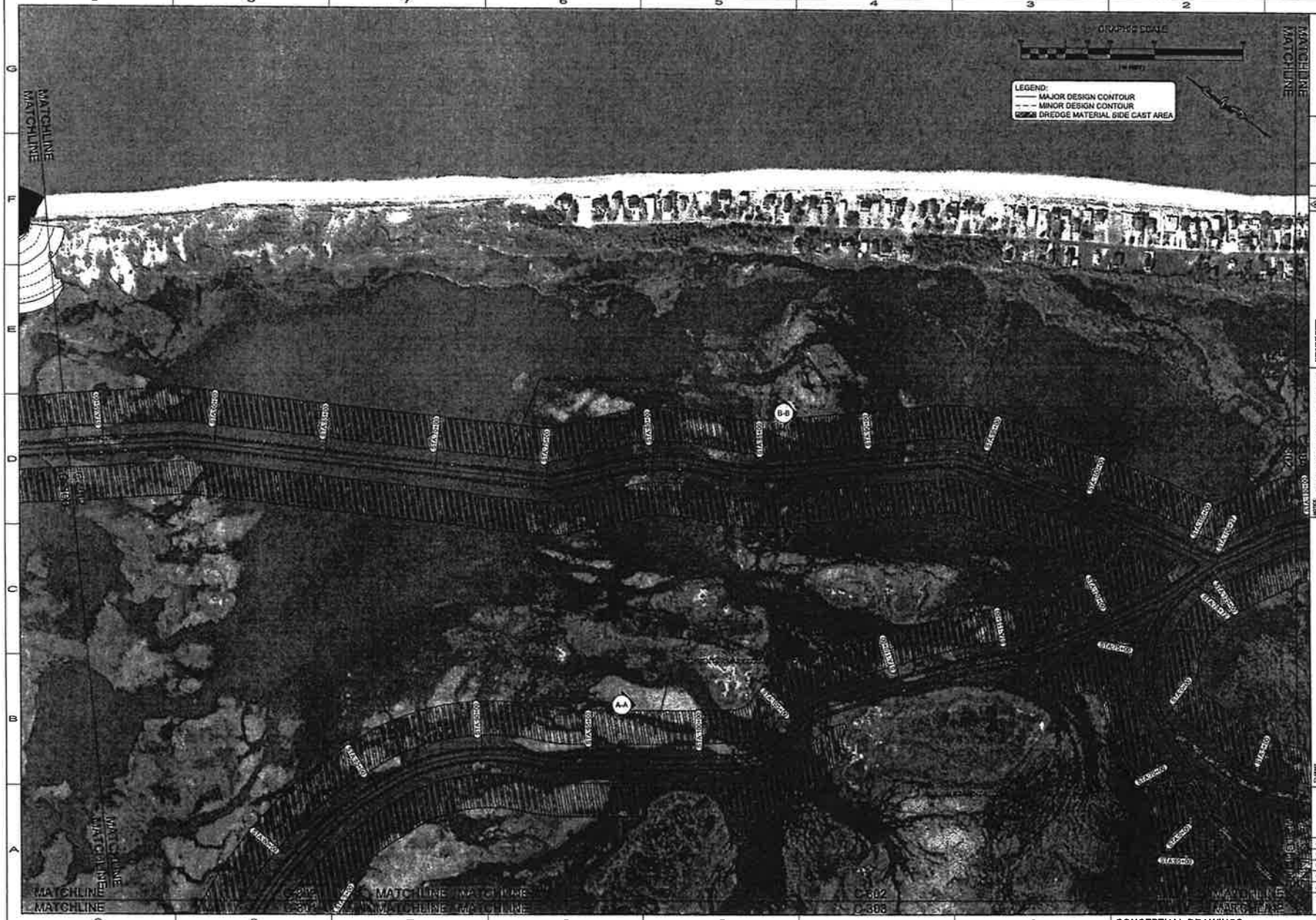

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7	DATE	DESCRIPTION

ORIGINAL SHEET SIZE: 22" x 34"

USFWS

PRIME HOOK RESTORATION PROJECT

PLAN VIEW - BAY MARSH PLATFORM AND CREEKS

ATKINS

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APPROVED:	J.R.T.
SHEET NO.	C-302

CONCEPTUAL DRAWINGS

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PLAN VIEW - K BAY MARSH PLATFORM DAL CREEKS

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JOB NO.:	100031176
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SHEET NO.:	C-303

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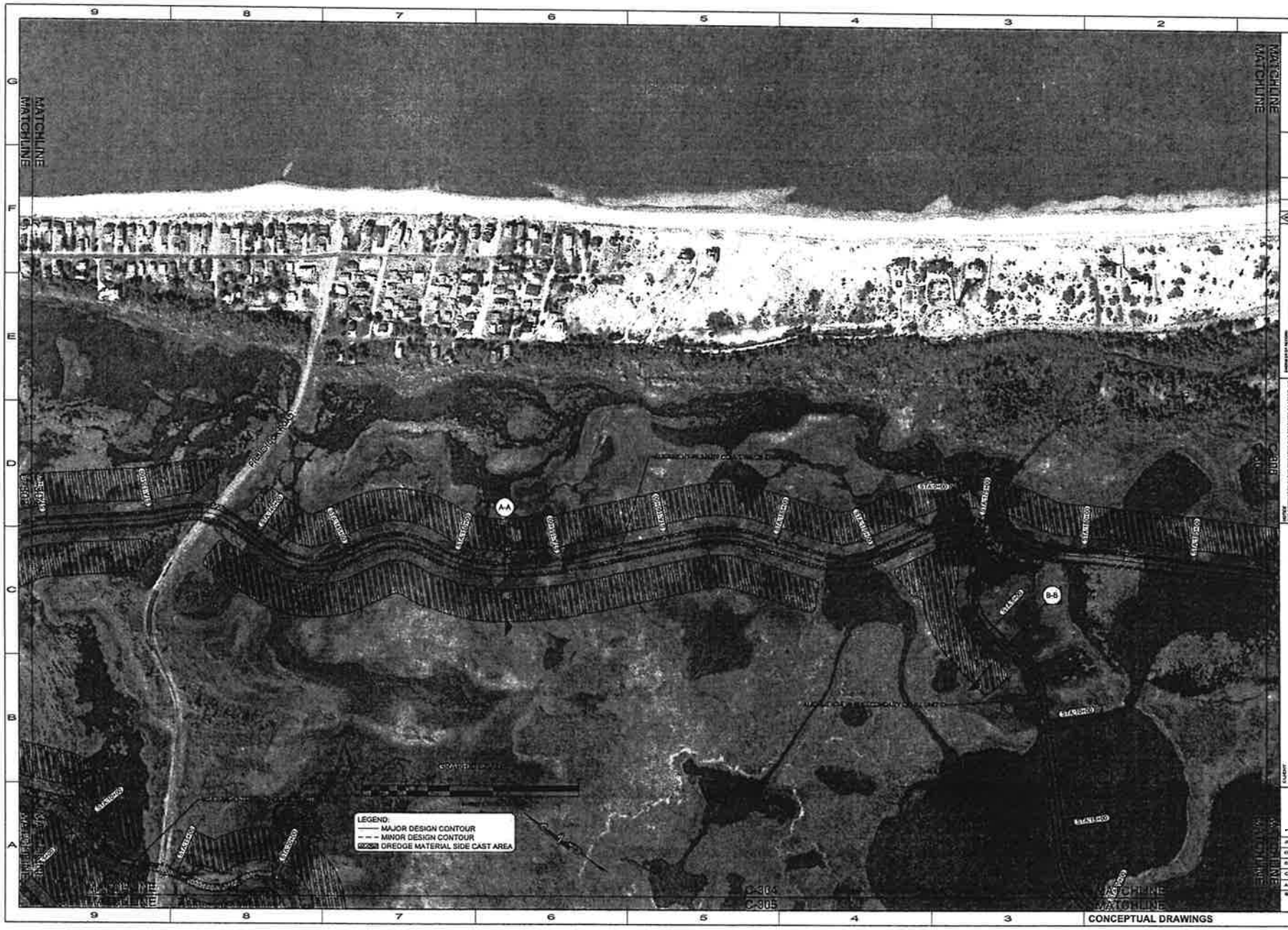

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	DATE	DESCRIPTION

USFWS

PRIME HOOK RESTORATION PROJECT

PLAN VIEW - BAC[illegible]AY MARSH PLATFORM AND [illegible] CREEKS

ATKINS

JOB NO.:	100031176
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DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-304

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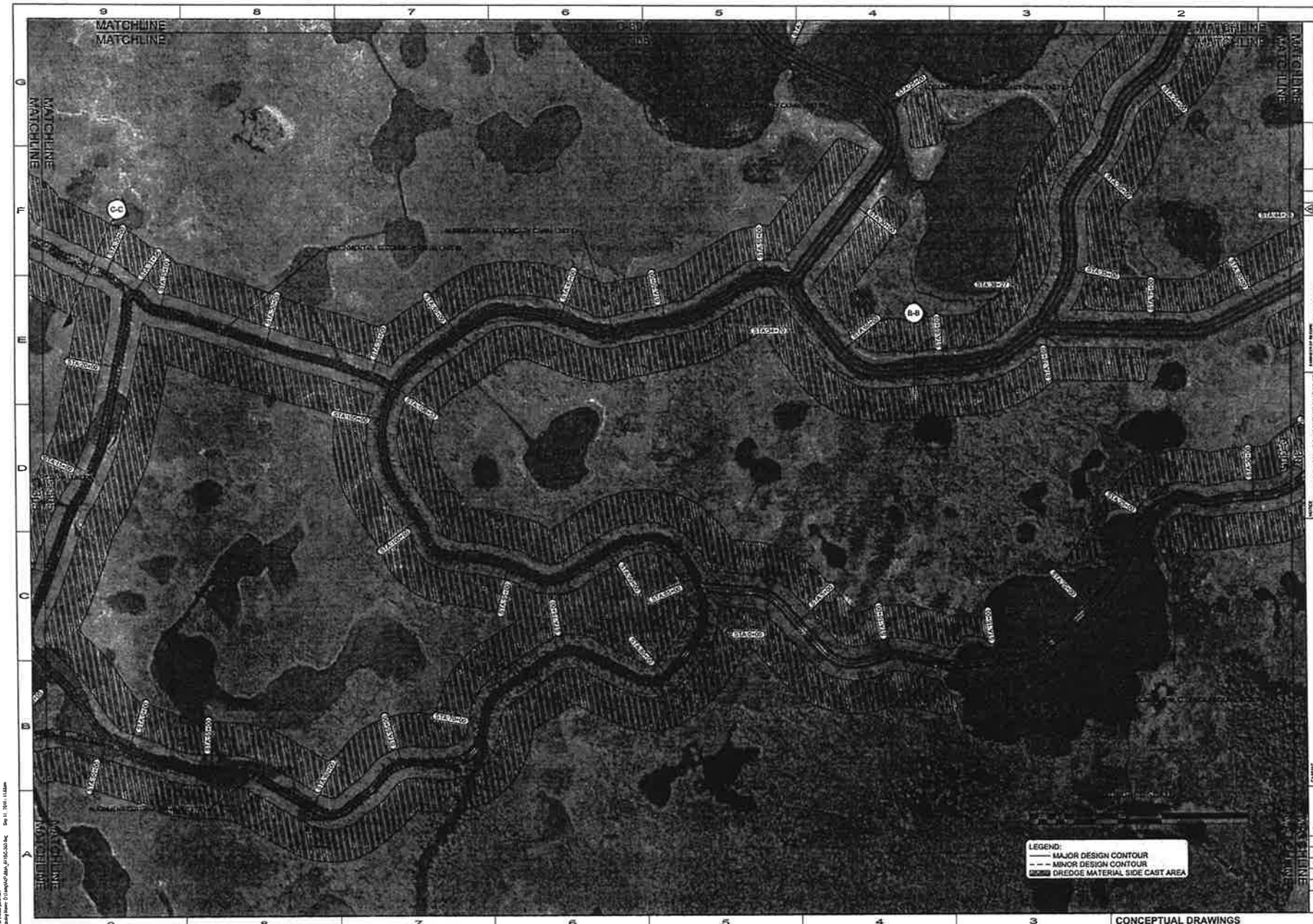

CONCEPTUAL DRAWINGS

U.S. FISH & WILDLIFE SERVICE

REV	DATE	DESCRIPTION

ATKINS

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW 'K BAY MARSH PLATFORM JDAL CREEKS

JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.:	C-305

GRAPHIC SCALE
LEGEND:
MAJOR DESIGN CONTOUR
MINOR DESIGN CONTOUR
DREDGE MATERIAL SIDE CAST AREA
MATCHLINE
C-305
C-306
C-308
A-A
B-B
U.S. FISH & WILDLIFE SERVICE
USFWS
PRIME HOOK RESTORATION PROJECT
PLAN VIEW - BAY MARSH PLATFORM AND CREEKS
ATKINS
JOB NO.: 100031176
DRAWN: J.L.P.
DESIGN: J.R.T.
CHECKED: W.J.D.
APPROVED: J.R.T.
SHEET NO.: C-306
CONCEPTUAL DRAWINGS

CONCEPTUAL DRAWINGS

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REV	DATE	DESCRIPTION

ORIGINAL REVISED DATE

NOTES

CLIENT: USFWS

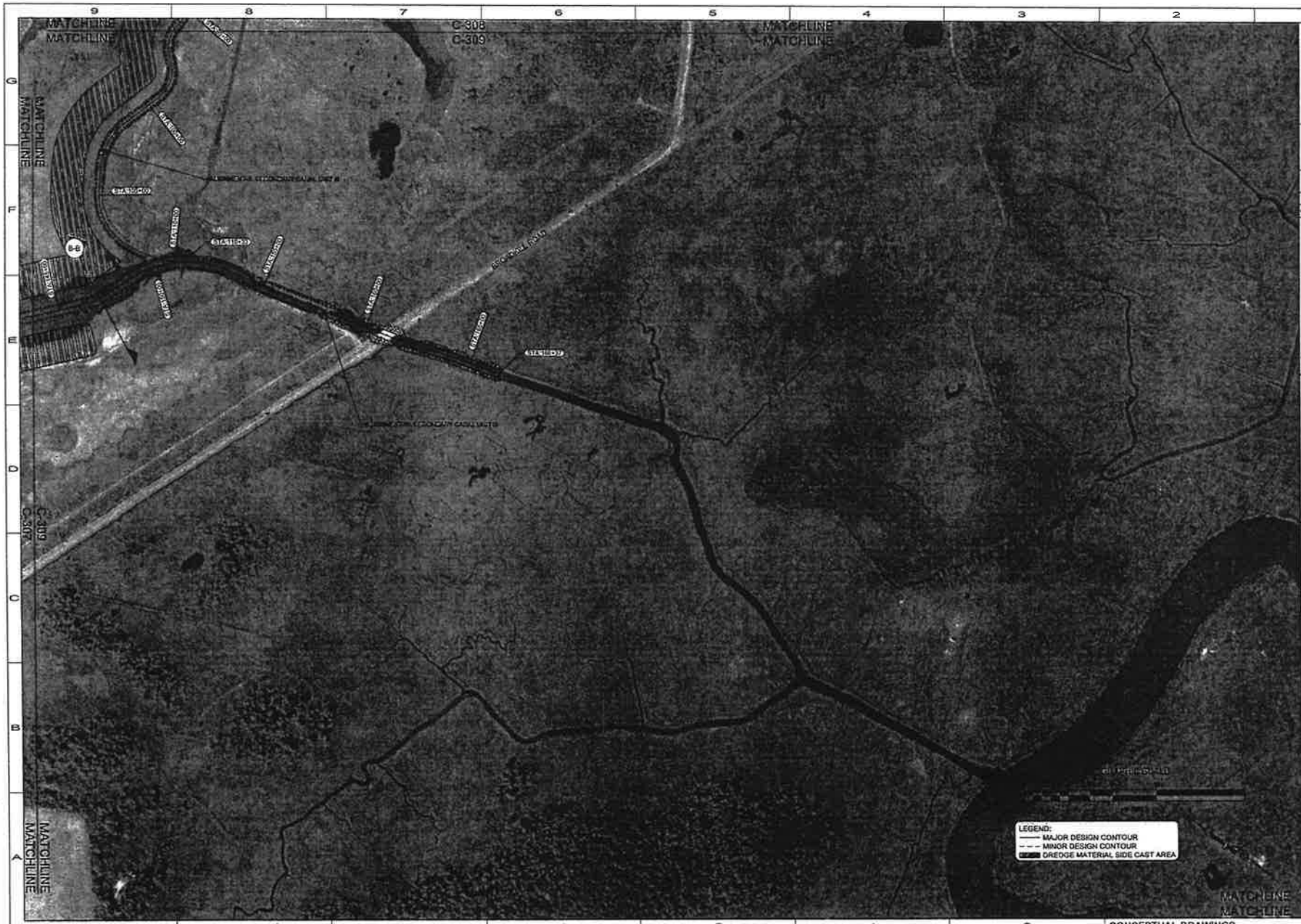
PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - K BAY MARSH PLATFORM DAL CREEKS

ATKINS

JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.:	C-307

GRAPHIC SCALE
LEGEND:
MAJOR DESIGN CONTOUR
MINOR DESIGN CONTOUR
DREDGE MATERIAL SIDE CAST AREA
MATCHLINE
C-308
C-307
C-309
A-A
B-B
U.S. FISH & WILDLIFE SERVICE
USFWS
PRIME HOOK RESTORATION PROJECT
PLAN VIEW - BAY MARSH PLATFORM AND CREEKS
ATKINS
JOB NO.: 100031176
DRAWN: J.L.P.
DESIGN: J.R.T.
CHECKED: W.J.D.
APPROVED: J.R.T.
SHEET NO.: C-308
CONCEPTUAL DRAWINGS



U.S. FISH & WILDLIFE SERVICE

REV	DATE	DESCRIPTION
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ORIGINAL SHEET DATE

DATE

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CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

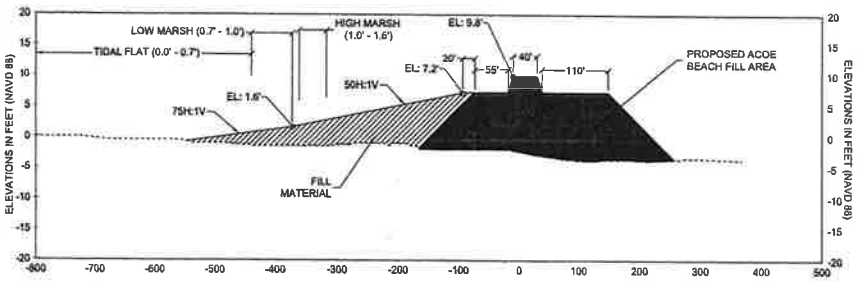
TITLE: PLAN VIEW - K BAY MARSH PLATFORM /DAL CREEKS

ATKINS

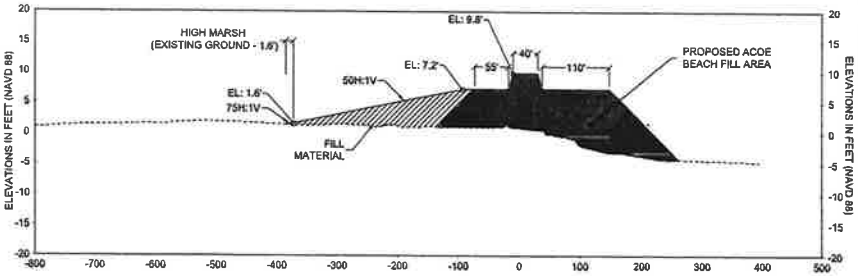
JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-309

CONCEPTUAL DRAWINGS

BACK BAY MARSH PLATFORM TYPICAL DETAILS

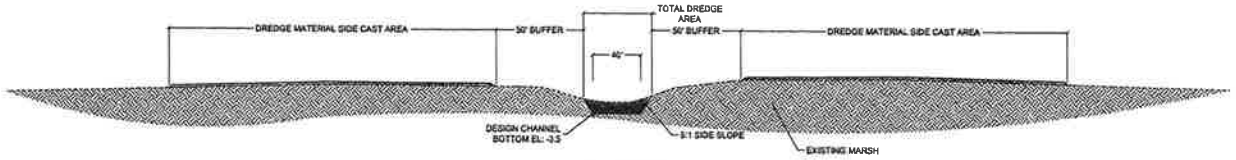


A1-A1: TYPICAL BACK MARSH PLATFORM THROUGH DEEPENED BREACH

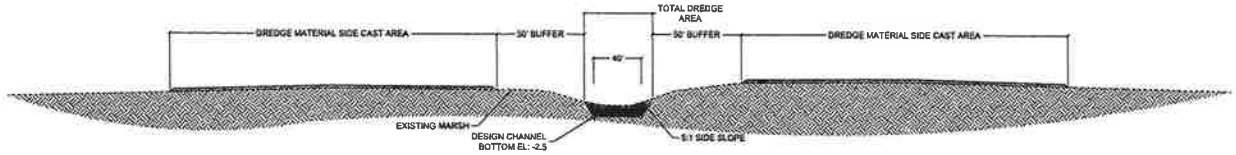


A2-A2: BACK MARSH PLATFORM THROUGH SHALLOW BREACK

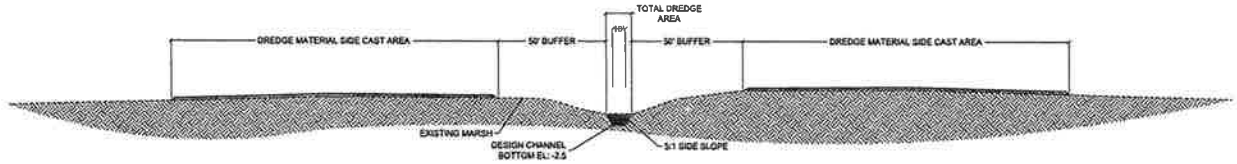
MARSH TIDAL CREEK TYPICAL DETAILS



A-A: PRIMARY CONVEYANCE CHANNEL TYPICAL DETAIL



B-B: SECONDARY CONVEYANCE CHANNEL TYPICAL DETAIL



C-C: TERTIARY CONVEYANCE CHANNEL TYPICAL DETAIL

U.S. FISH & WILDLIFE SERVICE

A			
A			
A			
A			
A			
A			
A			
A			
		DATE	DESCRIPTION

ORIGINAL ISSUED DATE:

CONVERTED TO ASCERD: ARTWORK & MAP CLEARANCE Ed. 1.0820

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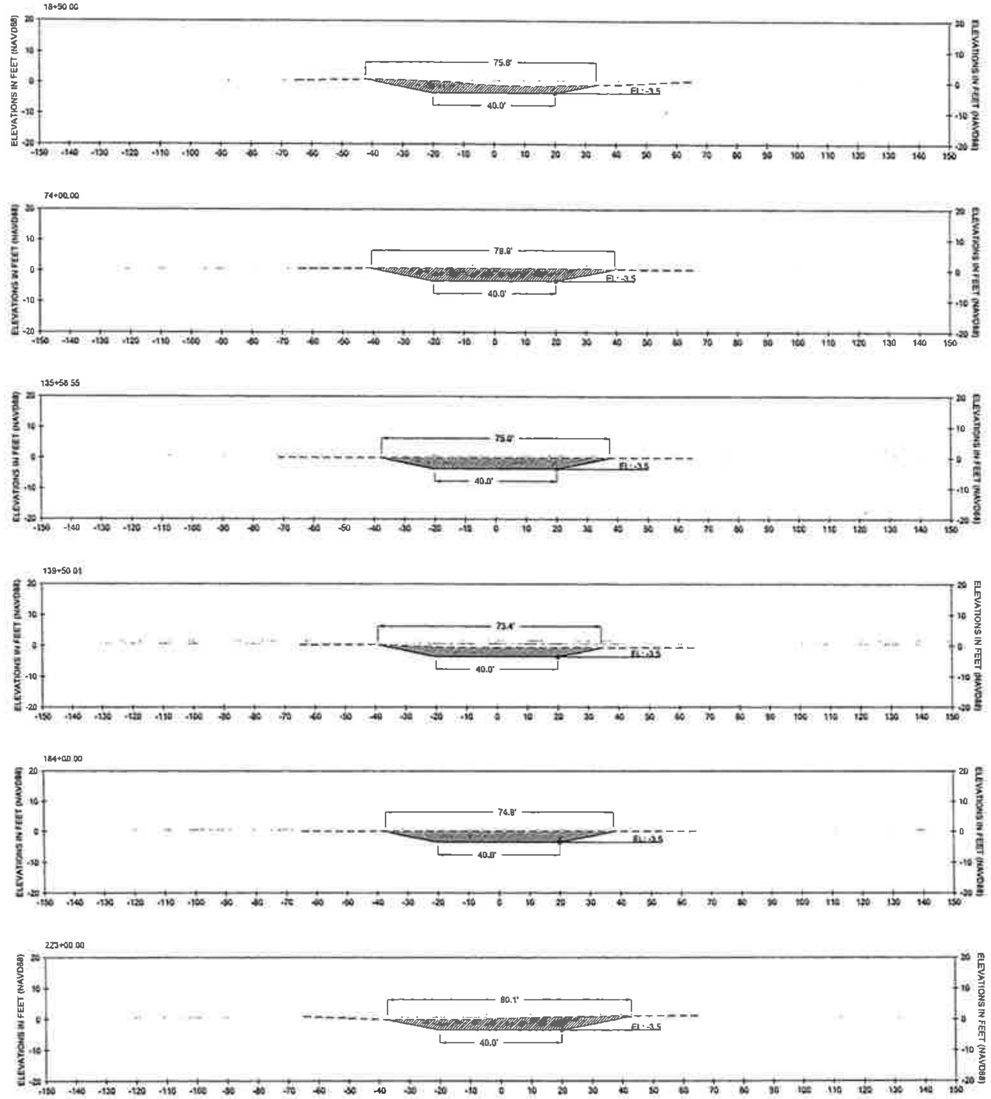
CLIENT	USFWS
PROJECT	PRIME HOOK RESTORATION PROJECT
TITLE	TYPICAL CROSS SECTIONS - BACK BAY MARSH PLATFORM TIDAL CREEKS

ATKINS

JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-500

CONCEPTUAL DRAWINGS

MAIN CONVEYANCE CHANNEL



LEGEND:
- - - EXISTING GROUND
—— DESIGN CHANNEL
-·-·- ESTIMATED HIGH WATER ELEVATION (1.6' NAVD88)
-··- ESTIMATED LOW WATER ELEVATION (0.8' NAVD88)
MATERIAL TO BE DREDGED

SCALE:
HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 20'

U.S. FISH & WILDLIFE SERVICE

CLIENT: USFWS

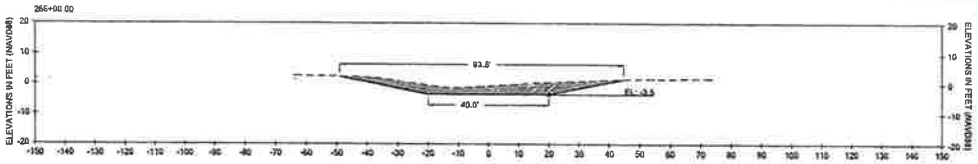
PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: MARSH CHANN[illegible] PROJECT CROSS SE[illegible]IS

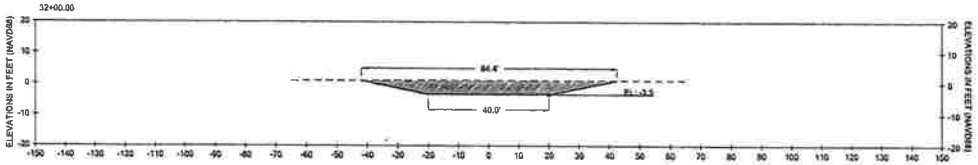
ATKINS

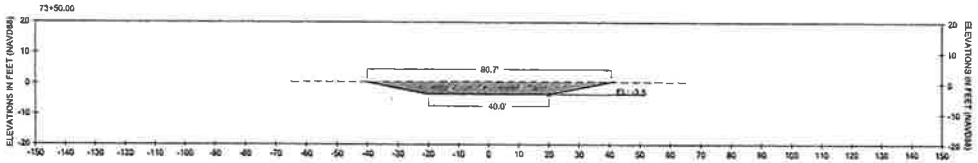
JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.:	C-600

CONCEPTUAL DRAWINGS



NE MAIN CONVEYANCE CHANNEL





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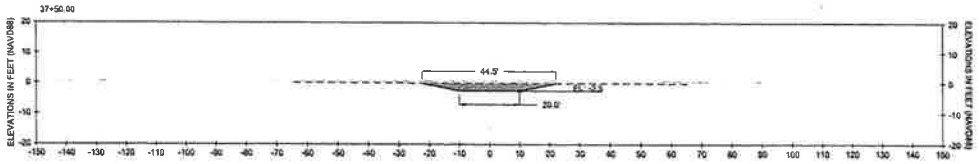
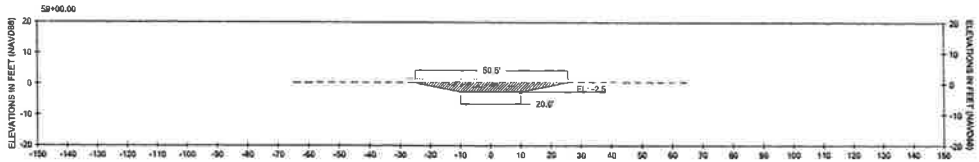
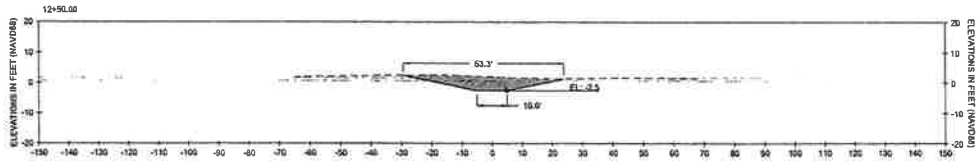




TERTIARY CANAL WEST I



LEGEND:
- - - EXISTING GROUND
—— DESIGN CHANNEL
—·— ESTIMATED HIGH WATER ELEVATION (1.5' NAVD88)
—·— ESTIMATED LOW WATER ELEVATION (0.8' NAVD88)
▨ MATERIAL TO BE DREDGED

SCALE:
HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 20'

REV	DATE	DESCRIPTION

ORIGINAL ISSUED DATE:

CONCEPTUAL DRAWINGS

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

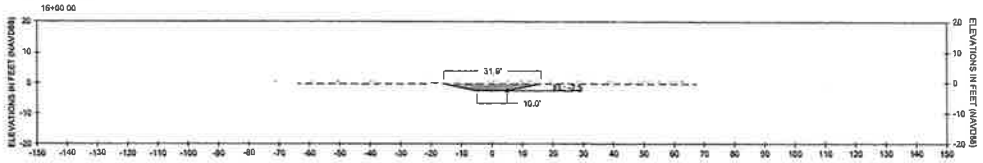
TITLE: MARSH CHANNEL CROSS SECTIONS

ATKINS

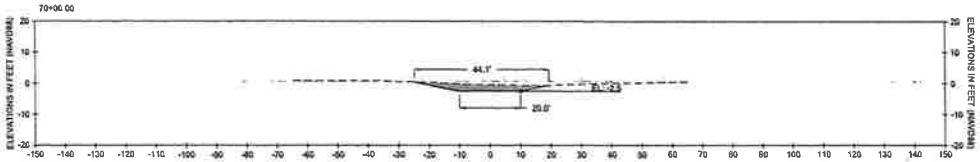
JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.:	C-601

TERTIARY CANAL WEST II

16+00.00

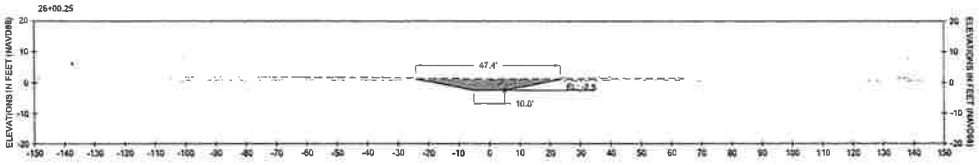


70+00.00



TERTIARY CANAL CENTRAL II

26+00.25



TERTIARY CANAL CENTRAL III

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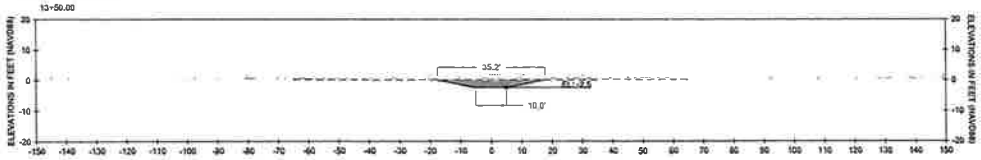
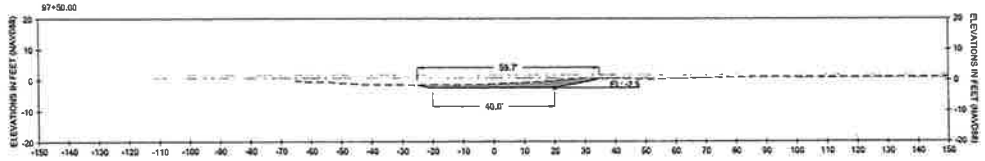
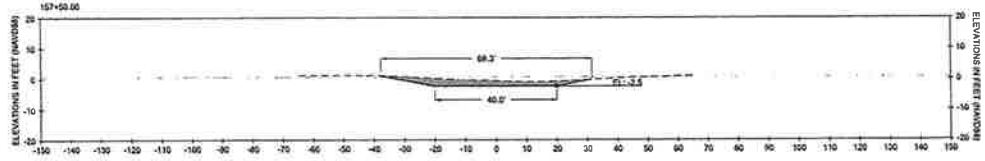


W. SECONDARY CANAL UNIT III

97+50.00



157+50.00



LEGEND:
- EXISTING GROUND
- DESIGN CHANNEL
- ESTIMATED HIGH WATER ELEVATION (1.8' NAVD88)
- ESTIMATED LOW WATER ELEVATION (0.8' NAVD88)
- MATERIAL TO BE DREDGED

SCALE:
HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 20'

CONCEPTUAL DRAWINGS

U.S. FISH & WILDLIFE SERVICE

NO.	DATE	DESCRIPTION

ORIGINAL REVISED DATE:

DIRECTOR OF RECORD
JEFFREY K. OAKER TELEPHONE FAX: 1-0000

DATE:

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

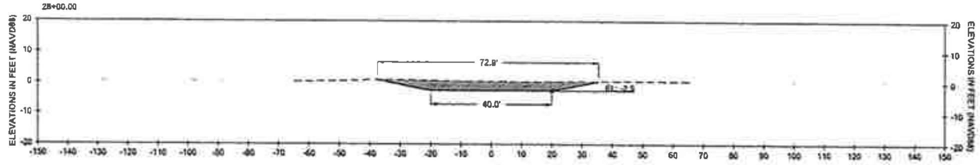
TITLE: MARSH CHANNEL PROJECT CROSS SECTIONS

ATKINS

JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-602

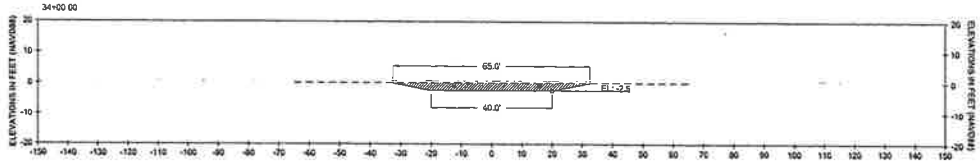
EW. N. SECONDARY CANAL UNIT III

28+00.00



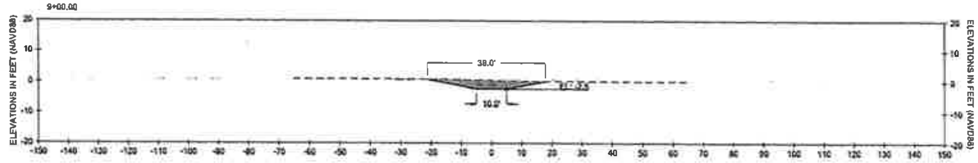
EW. S. SECONDARY CANAL UNIT III

34+00.00



SC TERTIARY UNIT III

9+00.00



LEGEND:
- EXISTING GROUND
- DESIGN CHANNEL
- ESTIMATED HIGH WATER ELEVATION (1.6' NAVD88)
- ESTIMATED LOW WATER ELEVATION (0.6' NAVD88)
- MATERIAL TO BE DREDGED

SCALE:
HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 20'

CONCEPTUAL DRAWINGS

U.S. FISH & WILDLIFE SERVICE

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: MARSH CHANNEL [...]JECT CROSS SECT[...]

ATKINS

JOB NO.:	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-603

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419

November 12, 2014

Ms. Gwen Davis
Deputy State Historic Preservation Officer
89 Kings Highway
Dover, De 19901

Dear Ms. Davis,

Prime Hook National Wildlife Refuge (Service or Refuge) is seeking concurrence with the State of Delaware Historic and Cultural Affairs for any potential effects on Historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended.

As enclosed in previously submitted concurrence submissions (July 31,2013 and October 21, 2014; copy of letters enclosed), the Service is proposing to restore the damage incurred by Super Storm Sandy to Prime Hook National Wildlife Refuge located in Sussex County, Delaware through: the placement of approximately 1.1 million yards of clean native fill along a 6,400 foot section of beach on the Delaware Bay (to re-establish or restoration of a foreshore, dune, and back-barrier marsh platform, within Unit II of the Refuge); the excavation of 30 miles of channels within the tidal wetlands of Unit II and III (to aid in restoring a natural hydrology to the entire Refuge); the removal of approximately 1800 linear feet of Fowler's Beach Road (to assist in the establishment of natural hydrology between Units I and II); and the removal of a section of Prime Hook Beach Road to enable the installation of a 60 foot wide bridge (to develop a greater hydrologic connectivity between Unit II and III).

The clean fill material, for the beach restoration, will originate from borrow site B, a shoal area offshore from the project area, which was surveyed for both cultural and biological resources. This borrow site was selected, as no cultural resources were identified and it contained the lowest benthic species diversity. The detailed assessment of the cultural and biological resources will be available within the Supplementary Environmental Impact Statement (SEIS).

As previously discussed, in the October 21, 2014 concurrence letter, no excavation of the foreshore, dune, back-barrier marsh portion will be necessary for the beach replenishment aspect

of the project, but the excavation of the interior tidal channels within Units II and III will necessitate the use of several shallow draft cutter-suction dredges to excavate the tidal channels and side cast the material on adjacent open water and tidal marsh area. These channels are necessary to restore natural hydrology to sustain the development of saltmarsh in Unit II and brackish marsh within Unit III. No adjacent upland areas will be impacted during this portion of the project, by either: excavation, sediment deposition, or vegetation removal.

To further assist in development of a natural hydrology to the Refuge, the removal of approximately 1800 linear feet of a degraded section of Fowler's Beach Road will be conducted as part of the proposed project. The road fill shall be removed to elevation of 1.4 feet (NAVD 88), just above the elevation of native sediments. The removed road footprint will then be encouraged to naturally vegetate with tidal marsh florae. A section of Prime Hook Beach Road will be also removed to enable the connection of a major tidal channel, between Units II and III, to flow without restriction. A 60 foot wide bridge will be installed over the channel, by the Department of Transportation, to allow for the continued use of the road by the residence of the Town of Prime Hook Beach.

The proposed projects require the use of three staging areas (Northern, Central, and Southern Construction Staging Areas; maps attached), within the Refuge boundary, to store equipment, vehicles, and stockpile supplies. The activities within the identified staging areas will result in no land disturbances (particularly below the level of the plow plane, the A horizon, in the Northern and Central Staging Areas) or clearing of existing vegetation. The contractors utilizing these staging areas will also be required to attain compliance with all Sediment and Stormwater regulations, to assure that adjacent land and waterways will not be negatively impacted by any and all activities occurring within the staging areas.

Upon the completion of the previously discussed proposed restoration projects, the metal and wood component of the water control structures (WCS) will be removed to further expedite a lowering of the water levels within Units II and III. The concrete structures will remain undisturbed.

It is our determination that no cultural resources of significance will be adversely impacted by any of the proposed activities, throughout the Refuge.

The beach and barrier area was previously archaeologically surveyed in August 2013 by the State of Delaware Historical and Cultural Affairs (ER 2013.08.07.02; see attachments). Service staff met with the Joint Permitting Process (JPP) representatives in Dover, Delaware on May 02, 2014 to brief the regulatory agencies on the purpose and need for the project. A regulatory agency update meeting is scheduled for November 20, 2014 to inform all State of Delaware regulators on the advancements of the proposed project, subsequent to the last JPP meeting. It is expected that the Supplemental Environmental Impact Statement (SEIS) for the entire scope of the Prime Hook National Wildlife Refuge restoration is expected to be forth coming in December 2014.

List of Attachments

- July 31, 2013 Letter of Concurrence to the State of Delaware Historical and Cultural Affairs
- October 21, 2014 Letter of Concurrence to the State of Delaware Historical and Cultural Affairs
- Map of Prime Hook National Wildlife Refuge Concurrence Project Locations
- Map of Fowler's Beach Road removal project location
- Topographic map of Fowler's Beach Road removal project location
- Soil map of the Fowler's Beach Road removal project location
- October 20, 2014 Delaware Department of Transportation letter of approval for proposed vacation/abandonment of a portion of Fowler's Beach Road
- Map of Prime Hook Road removal project location
- Topographic map of Prime Hook Road removal project location
- Soil map of the Prime Hook Road removal project location
- Map of Northern Construction Staging location
- Topographic map of Northern Construction Staging location
- Soil map of the Northern Construction Staging location
- Map of Central Construction Staging location
- Topographic map of Central Construction Staging location
- Soil map of the Central Construction Staging location
- Map of Southern Construction Staging location
- Topographic map of Southern Construction Staging location
- Soil map of the Southern Construction Staging location

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419

July 31, 2013

Ms. Gwen Davis
State Historic Preservation Officer
89 Kings Highway
Dover, DE 19901

Dear Ms. Davis,

Prime Hook National Wildlife Refuge (Service or refuge) is seeking concurrence with the National Oceanic and Atmospheric Administration's Office of Habitat Conservation.

The Service proposes to discharge approximately 50,000 cubic yards of clean fill at two isolated sites to re-establish a living shoreline in Unit II on the refuge. Since our intention is to restore Unit II to its historic salt marsh state, this smaller wetland restoration will service as a pilot project to give us an understanding as to how the unit will react to the incorporation of sediment.

The clean fill material that will be discharged into Unit II originates from excess sand/silt (90% sand/10% silt) material owned by the Delaware Department of Transportation (DelDOT). Unit II north of Prime Hook Beach Road was, since 1982, a fresh water impoundment but is in transition back to a salt water marsh. We are proposing to discharge clean fill material using bulldozers and/or trackhoes with mats along approximately 4,000 linear foot stretch on the east side of Unit II and approximately 1,500 linear feet on the west side of Unit II. The Service plans to conduct these activities in late fall of 2013 once time-of-year restrictions have been lifted. The clean fill material to be discharged will be at approximately 20:1 slope and the proposed project is on refuge lands and therefore landowner permission is not necessary.

Service staff met with the Joint Permitting Process representatives in Dover, Delaware on May 16, 2013 to brief the regulatory agencies on the purpose and need for the project.

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419
http://primehook.fws.gov

October 21, 2014

Ms. Gwen Davis
Deputy State Historic Preservation Officer
89 Kings Highway
Dover, DE 19901

Dear Ms. Davis,

Prime Hook National Wildlife Refuge (Service or refuge) is seeking concurrence with the State of Delaware Historical and Cultural Affairs for any potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended.

The Service is proposing to restore the damage incurred by Super Storm Sandy to Prime Hook National Wildlife Refuge located in Sussex County, Delaware which entails the discharge of approximately 1 million cubic yards of clean native fill along the Delaware Bay beach to re-establish a foreshore, dune, and back-barrier marsh platform within Unit II of the refuge.

The clean fill material originates from Delaware Bay shoal areas offshore from the project area. This area is currently being surveyed both culturally and biologically and these results will be available within a Supplementary Environmental Impact Statement that is currently being prepared by the U.S. Army Corps of Engineers.

We are proposing to discharge the fill material utilizing a cutter-suction dredge along an approximately 4,000 linear foot stretch on the east side of Unit II. The Service plans to conduct these activities in late fall of 2015 or 2016 once time-of-year restrictions have been lifted.

The proposed project does not require any excavation for the foreshore, dune, back-barrier marsh portion of the project, but the excavation of a series of sinuous tidal channels within Units II & III to convey the necessary hydrology to sustain a brackish marsh will be necessary.

The subject area was archaeologically surveyed in August 2013 by the State of Delaware Historical and Cultural Affairs (ER 2013.08.07.02) when a smaller wetland restoration was proposed (see attachment).

Service staff met with the Joint Permitting Process representatives in Dover, Delaware on May 02, 2014 to brief the regulatory agencies on the purpose and need for the project.

If you need any additional information or have questions please contact me at the number above.

Sincerely,

Arthur J. Coppola
Refuge Manager

Attachment

State of Delaware
Historical and Cultural Affairs

21 The Green
Dover, DE 19901-3611

Phone: (302) 736.7400 Fax: (302) 739.5660

August 30, 2013 ER 2013.08.07.02

Arthur J. Coppola
Refuge Manger
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Project Proposed Wetland Restoration
Prime Hook National Wildlife Refuge, Sussex County, Delaware.

Dear Mr. Coppola,

The above referenced project was reviewed for potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended. The undertaking will occur in wet areas with low archaeological probability. In addition there are no recorded historic properties in the area to be impacted. The upland staging areas appear to have been disturbed, and would be very unlikely to contain intact archaeological resources. It is the conclusion of the reviewer that no archaeological survey should be required. Also, given the limited nature of construction associated with this project, no architectural historic properties can be affected by this project.

If you have any questions, please contact me at craig.lukezic@state.de.us.

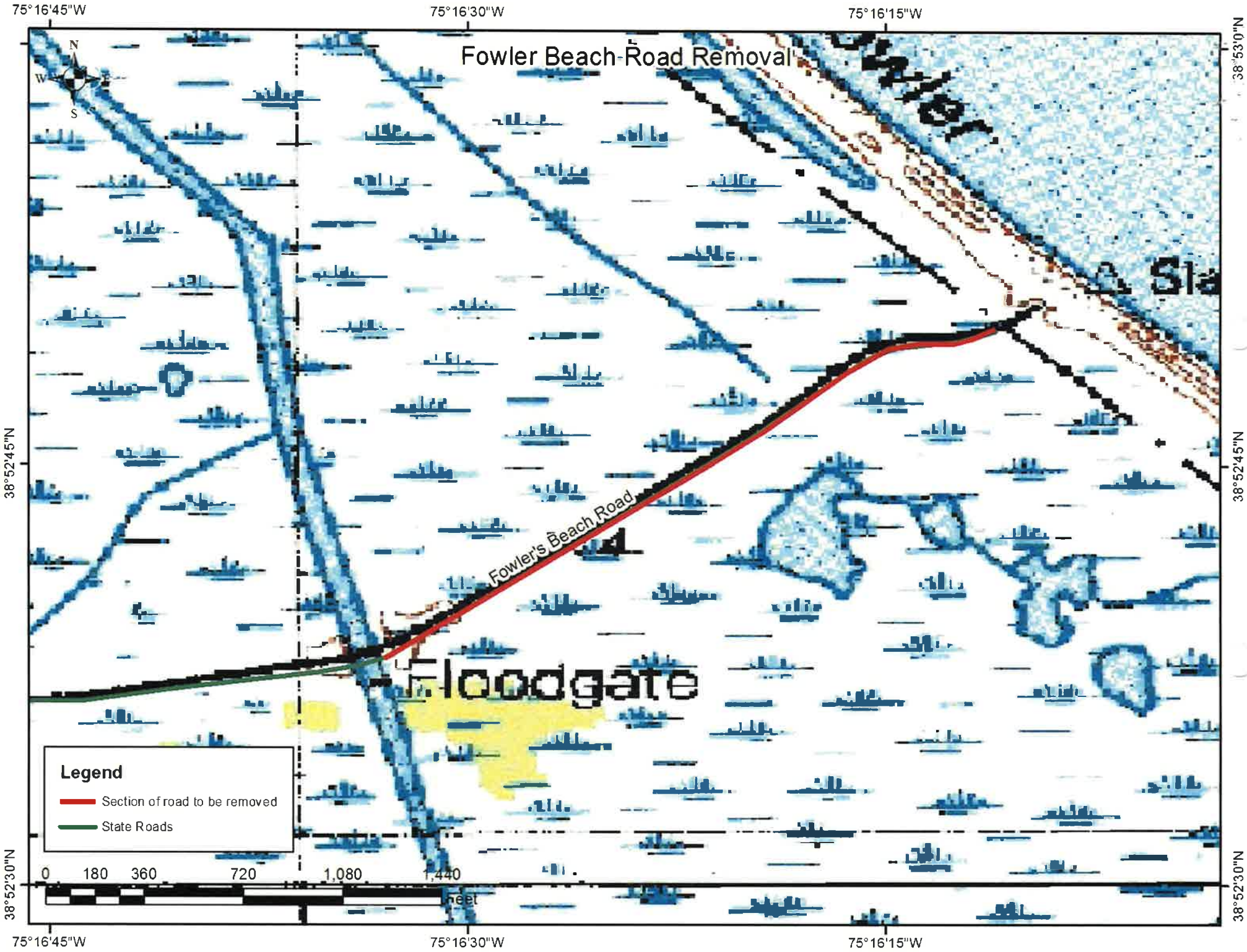
Sincerely,

Craig Lukezic
Archaeologist, Division of Historical and Cultural Affairs

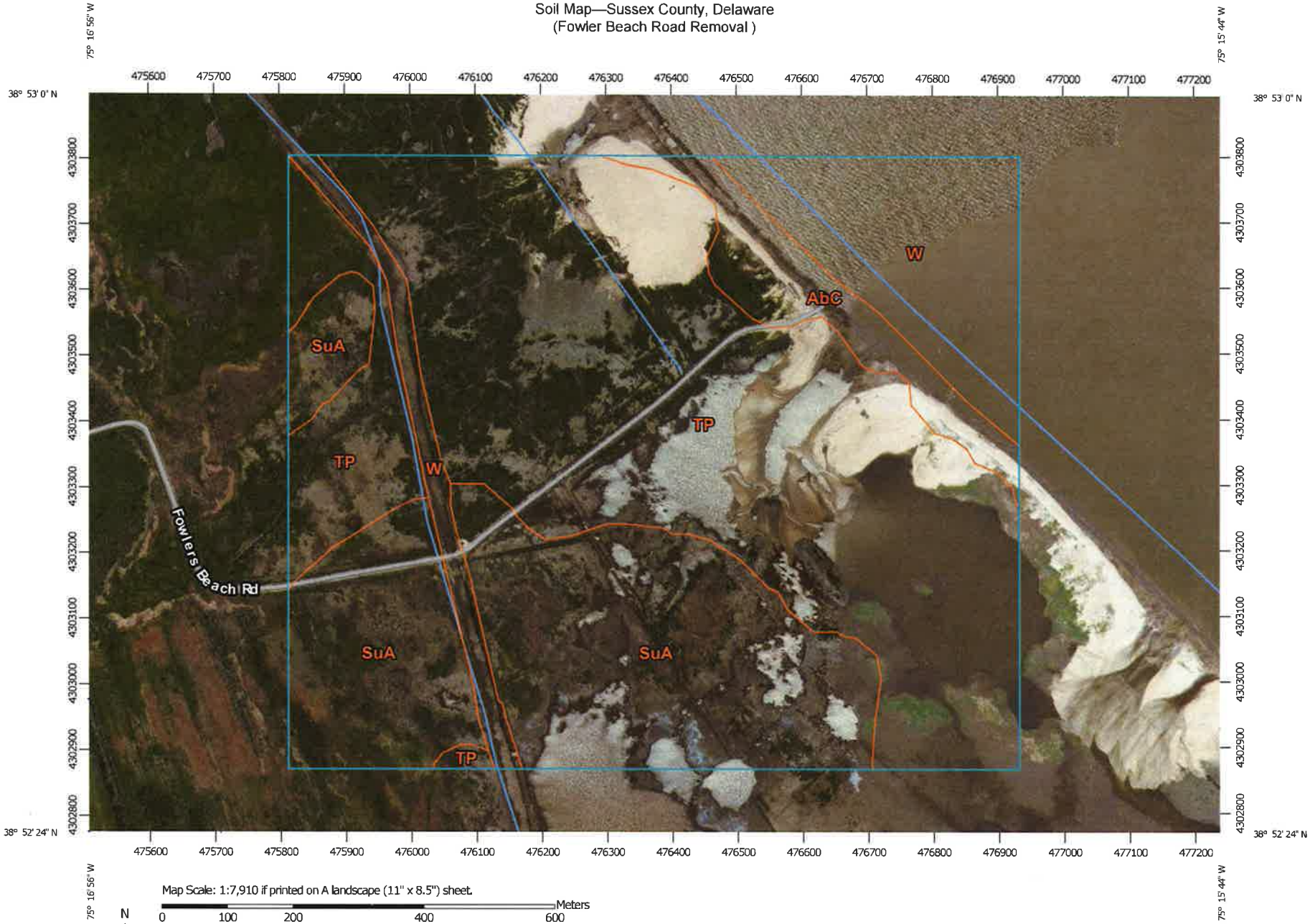
Cc Gwen Davis, Deputy State Historic Preservation Officer

Prime Hook National Wildlife Refuge
Concurrence Project Locations
N
W
E
S
75°16'40"W
75°14'30"W
38°52'50"N
38°50'40"N
38°48'30"N
Unit 1
Unit 2
Unit 3
Unit 4
Fowler's Beach Road
Beach, Dune, and Back-barrier Restoration Area
Northern Construction Staging Area
Cedd's Road
Central Construction Staging Area
Prime Hook Beach Road
Little Neck Road
Southern Construction Staging Area
Coastal Highway
Broadkill Road
Legend
Construction Staging Areas
Section of road to be removed
Prime Hook Units
State Roads
Beach and Dune Restoration Area
Extent
Back-Barrier Platform Restoration Area
Extent
0 0.375 0.75 1.5 2.25 3
Miles

Fowler Beach Road Removal
Fowler's Beach Road
Legend
Section of road to be removed
State Roads
0 180 360 720 1,080 1,440
Feet
75°16'40"W
75°16'30"W
75°16'20"W
75°16'10"W
38°52'50"N
38°52'40"N
38°52'30"N


Fowler Beach Road Removal
75°16'45"W
75°16'30"W
75°16'15"W
38°53'0"N
38°52'45"N
38°52'30"N
N
S
W
E
Fowler's Beach Road
Floodgate
Legend
Section of road to be removed
State Roads
0 180 360 720 1,080 1,440
feet

Soil Map—Sussex County, Delaware
(Fowler Beach Road Removal)



Map Scale: 1:7,910 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 100 200 400 600

Feet: 0 350 700 1400 2100

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Sussex County, Delaware
Survey Area Data: Version 13, Sep 25, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 17, 2010—Jul 4, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Sussex County, Delaware (DE005)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AbC	Acquango-Beaches complex, 0 to 10 percent slopes	13.7	5.3%
SuA	Sunken mucky silt loam, 0 to 2 percent slopes, occasionally flooded, tidal	76.7	29.6%
TP	Transquaking and Mispillion soils, very frequently flooded, tidal	134.9	52.0%
W	Water	34.0	13.1%
Totals for Area of Interest		**259.4**	**100.0%**

STATE OF DELAWARE
DEPARTMENT OF TRANSPORTATION
800 BAY ROAD
P.O. BOX 778
DOVER, DELAWARE 19903

SHAILEN P. BHATT
SECRETARY

October 20, 2014

U.S. Fish and Wildlife Services
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, Delaware 19968
Attn.: Arthur J. Coppola, Refuge Manager

Re: Road Vacation Program … Sussex County
Portion of Fowlers Beach Road (County Road 199)

Dear Mr. Coppola:

Please be advised the Department of Transportation has approved the proposed vacation/abandonment of a portion of Fowlers Beach Road (County Road 199). Secretary Shailen P. Bhatt signed the Resolution Order dated October 13, 2014, for the roadway's official vacation.

After expiration of the legally required appeal time of 30 days, if no appeal to the order is filed with Superior Court, the Department will record the Resolution in the Sussex County Recorder of Deeds office.

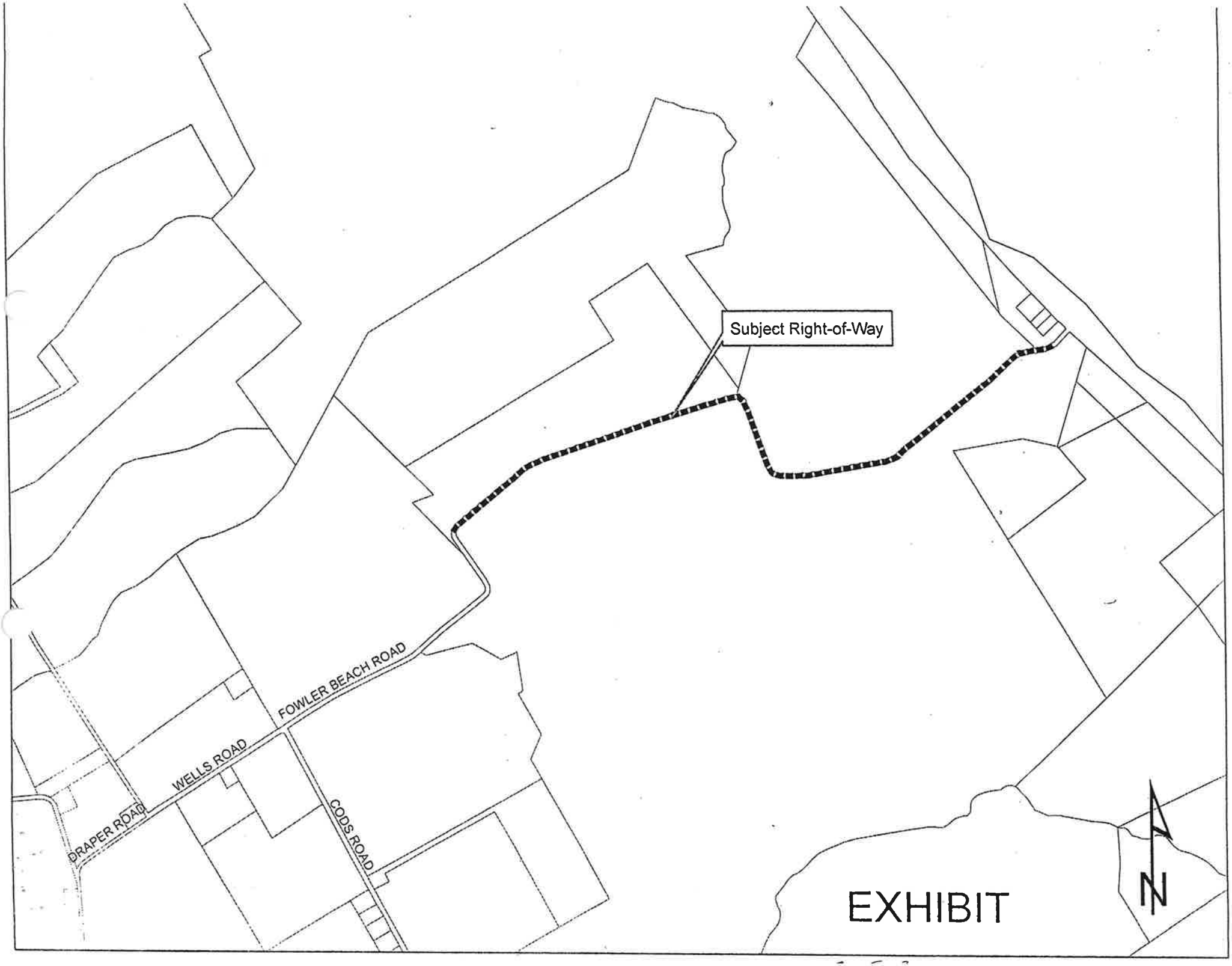
Upon the filing of the Resolution in the County public records, the roadway shall cease to exist as a public road and the persons entitled to enclose it may proceed to use and occupy the vacated roadway.

If you have any question, please do not hesitate to contact me at 302-760-2242.

Very truly yours,

Ida J. Parrett, SR/WA
Right of Way Agent III

TEAM DelDOT
Transparent Efficient Accountable Measured

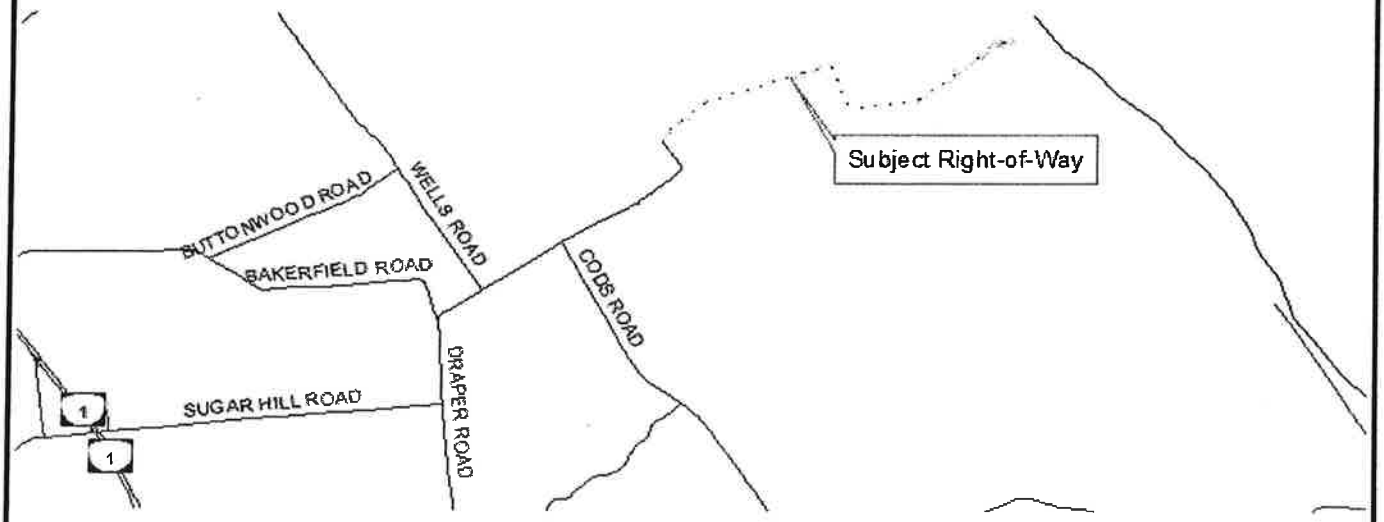

Subject Right-of-Way
FOWLER BEACH ROAD
WELLS ROAD
DRAPER ROAD
CODS ROAD
EXHIBIT
N

Delaware Department of Transportation

Shailen P. Bhatt
Secretary

PUBLIC HEARING

For The Abandonment & Vacation of a portion of
Fowlers Beach Road/Sussex County Road 199
Sussex County, Delaware



Wednesday, September 10, 2014
1:00 a.m.
DelDOT South District Administration Building

WHEREAS, The Delaware Department of Transportation, (DelDOT) has custody and control of Fowlers Beach Road/Sussex County Road 199; and

WHEREAS, The Department of Transportation due to public safety concerns, is considering the vacation and abandonment a portion of Fowlers Beach Road/Sussex County Road 199 within the boundaries of the Prime Hook National Wildlife Refuge, measuring approximately 1.5 linear miles +/-, which has ceased to be of necessity to the highway system. *** Should the right-of-way be vacated, the Refuge plans to maintain a public access to the waterfront for wildlife viewing, photography, fishing, etc. in addition to preserving public safety.

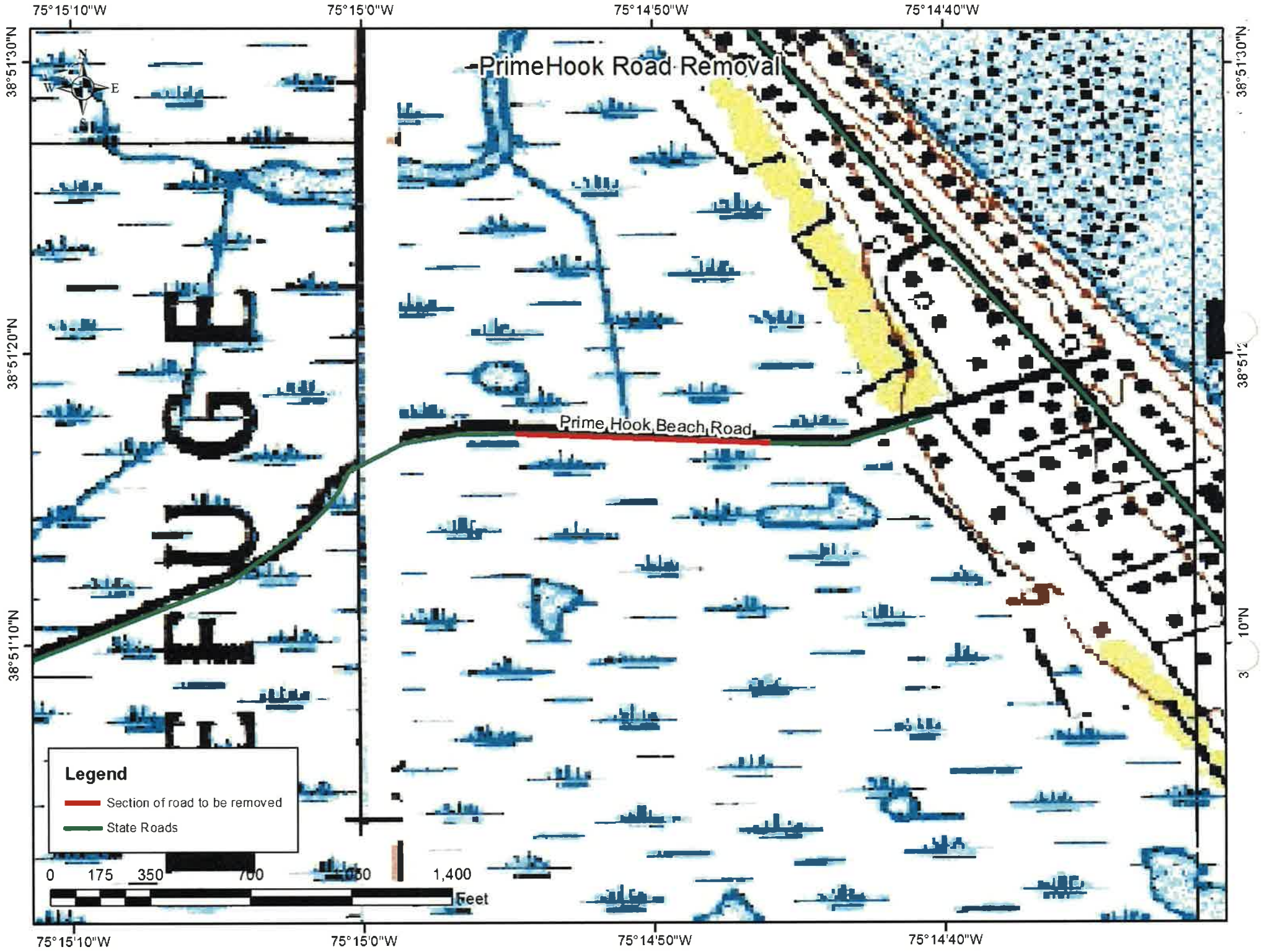
WHEREAS, Title 17, Section 1311 of the Delaware Code grants DelDOT the authority to vacate and abandon public roads or parts thereof, ceasing to be of necessity to the general highway system.

NOW, THEREFORE, BE IT RESOLVED by DelDOT that a **Public Hearing** shall be held with regard to the proposed vacation and abandonment of a portion Fowlers Beach Road/Sussex County Road 199. The hearing will be held at the **DelDOT South District Administration Building (conference room), 23697 DuPont Boulevard** (located at the intersection of County Road No. 431 & U.S. Route 113), **Georgetown, DE,** on **Wednesday, September 10, 2014** at **10:00 am.** Public comments concerning this matter will be received at this time.

DEPARTMENT OF TRANSPORTATION
Shailen P. Bhatt, Secretary
Robert B. McCleary, P.E. Chief Engineer and Director of DOTS

PUBLIC NOTICE

PrimeHook Road Removal
Prime Hook Beach Road
Legend
Section of road to be removed
State Roads
0 175 350 700 1,050 1,400
Feet
75°15'10"W
75°15'0"W
75°14'50"W
75°14'40"W
38°51'30"N
38°51'20"N
38°51'10"N


PrimeHook Road Removal
Prime Hook Beach Road
75°15'10"W
75°15'0"W
75°14'50"W
75°14'40"W
38°51'30"N
38°51'20"N
38°51'10"N
N
E
W
Legend
Section of road to be removed
State Roads
0
175
350
700
1,400
Feet

Soil Map—Sussex County, Delaware
(Prime Hook Road Removal)

Map Scale: 1:4,910 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 200 400 800 1200

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

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Survey Area Data: Version 13, Sep 25, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

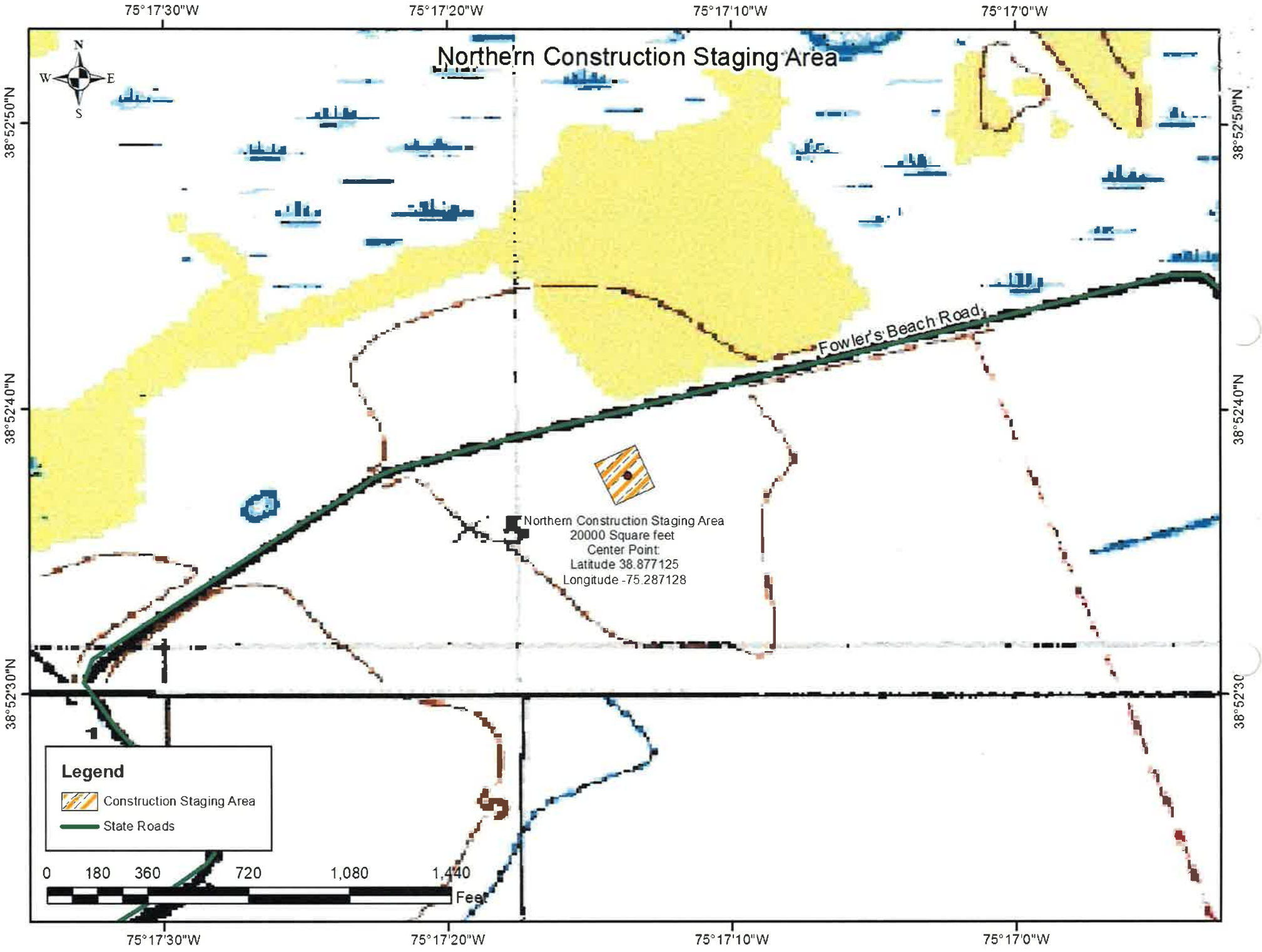
Date(s) aerial images were photographed: Jun 17, 2010—Jul 4, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Sussex County, Delaware (DE005)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AbC	Acquango-Beaches complex, 0 to 10 percent slopes	12.8	11.7%
Br	Broadkill mucky peat, very frequently flooded, tidal	7.3	6.7%
TP	Transquaking and Mispillion soils, very frequently flooded, tidal	88.5	81.5%
W	Water	0.1	0.1%
Totals for Area of Interest		**108.7**	**100.0%**

Northern Construction Staging Area
75°17'30"W
75°17'20"W
75°17'10"W
75°17'0"W
38°52'50"N
38°52'40"N
38°52'30"N
N
S
E
W
Fowler's Beach Road
Northern Construction Staging Area
20000 Square feet
Center Point:
Latitude 38.877125
Longitude -75.287128
Legend
Construction Staging Area
State Roads
0
180
360
720
1,080
1,440
Feet


Northern Construction Staging Area
75°17'30"W
75°17'20"W
75°17'10"W
75°17'0"W
38°52'50"N
38°52'40"N
38°52'30"N
N
S
E
W
Fowler's Beach Road
Northern Construction Staging Area
20000 Square feet
Center Point:
Latitude 38.877125
Longitude -75.287128
Legend
Construction Staging Area
State Roads
0
180
360
720
1,080
1,440
Feet

Soil Map—Sussex County, Delaware
(Northern Construction Staging Area)

Map Scale: 1:8,350 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 100 200 400 600

Feet: 0 400 800 1600 2400

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

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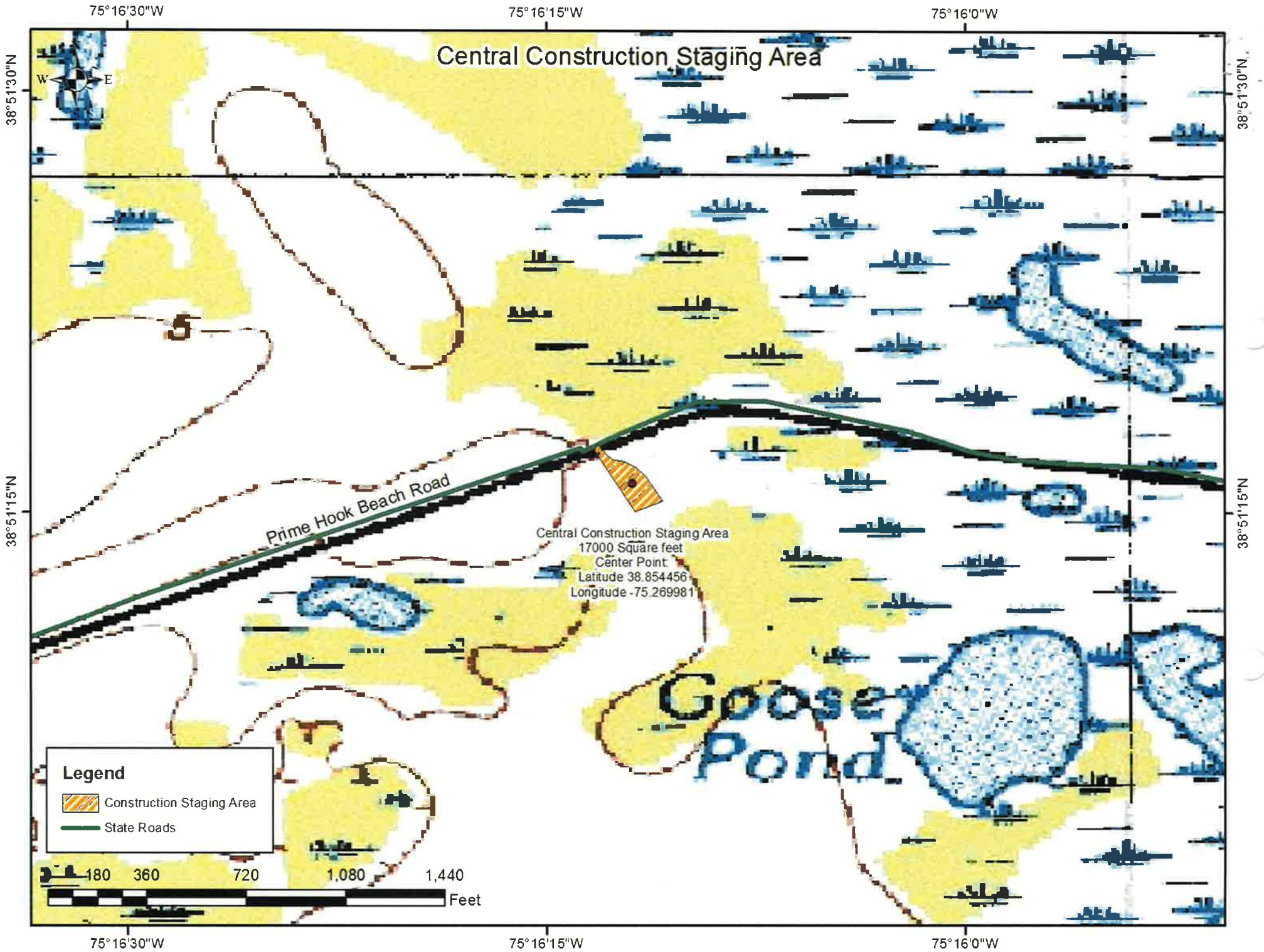
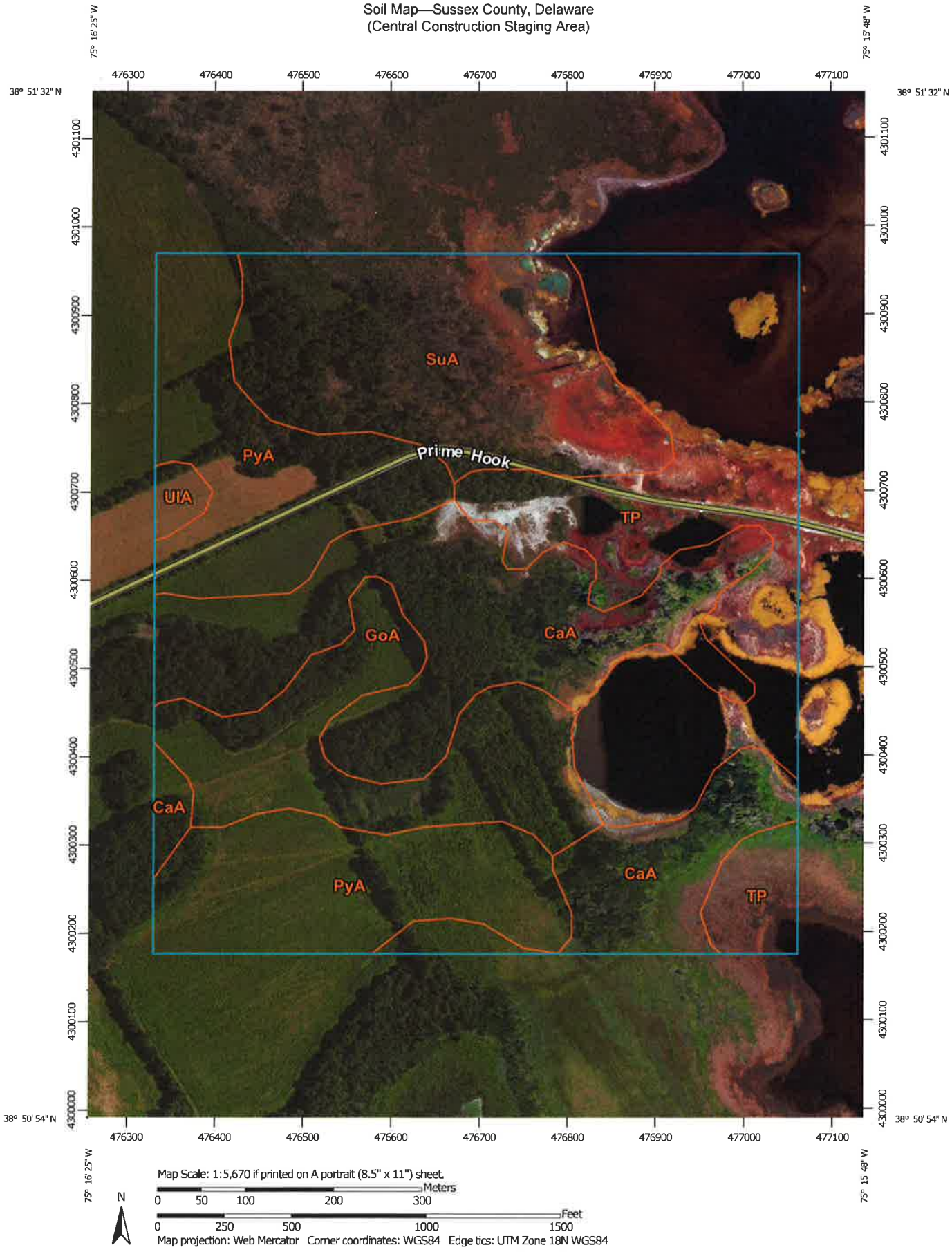
Map Unit Legend

Sussex County, Delaware (DE005)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
CaA	Carmichael loam, 0 to 2 percent slopes	4.5	1.3%
FgA	Fallsington loam, 0 to 2 percent slopes	1.5	0.4%
HnA	Hammonton sandy loam, 0 to 2 percent slopes	20.9	5.9%
HvA	Hurlock sandy loam, 0 to 2 percent slopes	12.8	3.6%
IeA	Ingleside loamy sand, 0 to 2 percent slopes	10.9	3.1%
MdA	Marshyhope sandy loam, 0 to 2 percent slopes	18.8	5.3%
MmA	Mullica mucky sandy loam, 0 to 2 percent slopes	5.1	1.4%
PyA	Pineyneck loam, 0 to 2 percent slopes	35.8	10.1%
SuA	Sunken mucky silt loam, 0 to 2 percent slopes, occasionally flooded, tidal	76.1	21.5%
TP	Transquaking and Mispillion soils, very frequently flooded, tidal	20.8	5.9%
UlA	Unicorn loam, 0 to 2 percent slopes	146.3	41.4%
Totals for Area of Interest		**353.6**	**100.0%**

Central Construction Staging Area
75°16'30"W
75°16'20"W
75°16'10"W
75°16'0"W
38°51'30"N
38°51'20"N
38°51'10"N
N
S
E
W
Prime Hook Beach Road
Central Construction Staging Area
17000 Square feet
Center Point:
Latitude 38.854456
Longitude -75.269981
Legend
Construction Staging Area
State Roads
0 180 360 720 1,080 1,440
Feet


Central Construction Staging Area
75°16'30"W
75°16'15"W
75°16'0"W
38°51'30"N
38°51'15"N
W
E
Prime Hook Beach Road
Central Construction Staging Area
17000 Square feet
Center Point:
Latitude 38.854456
Longitude -75.269981
Goose Pond
Legend
Construction Staging Area
State Roads
180
360
720
1,080
1,440
Feet

Soil Map—Sussex County, Delaware
(Central Construction Staging Area)



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

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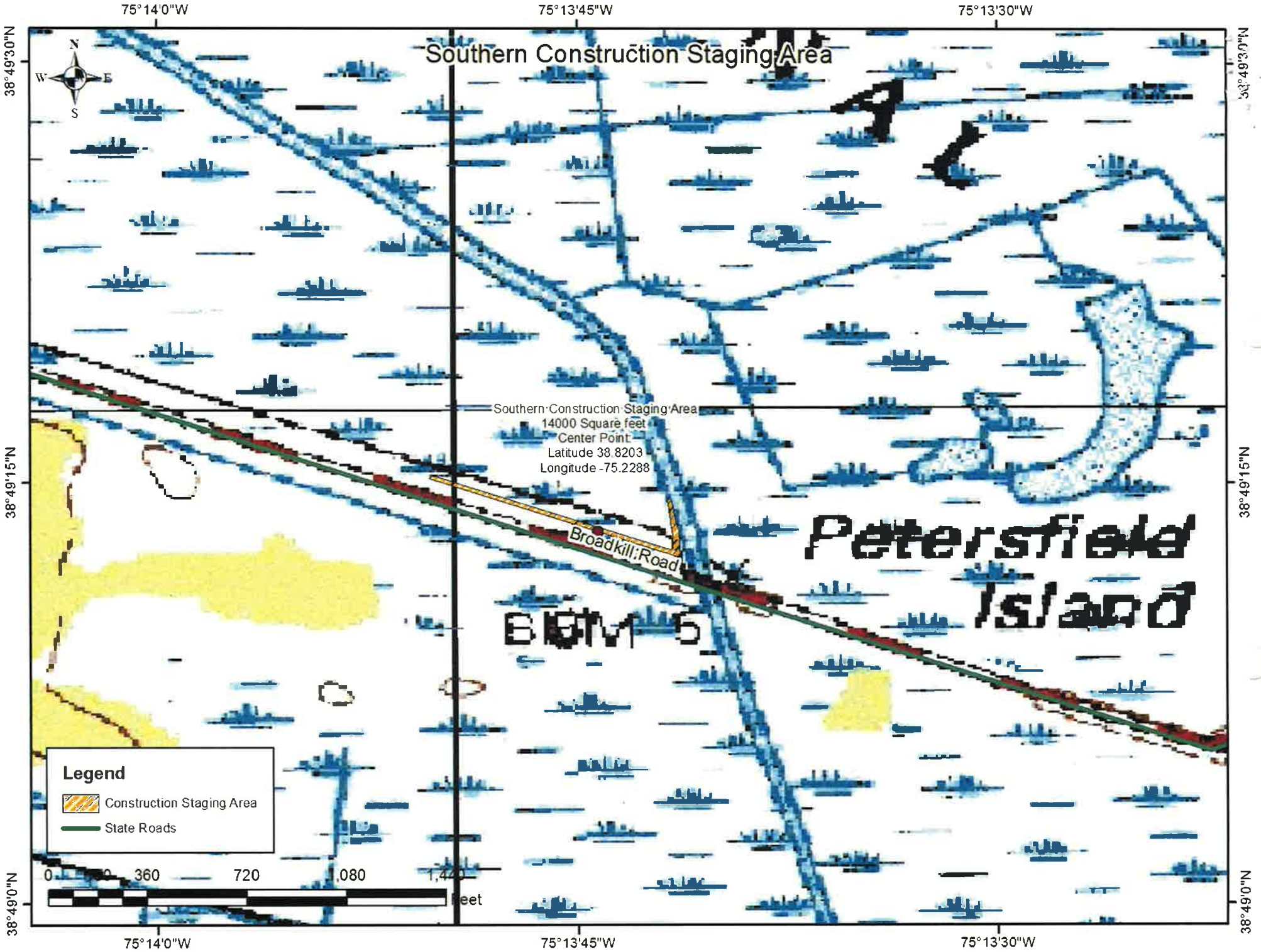
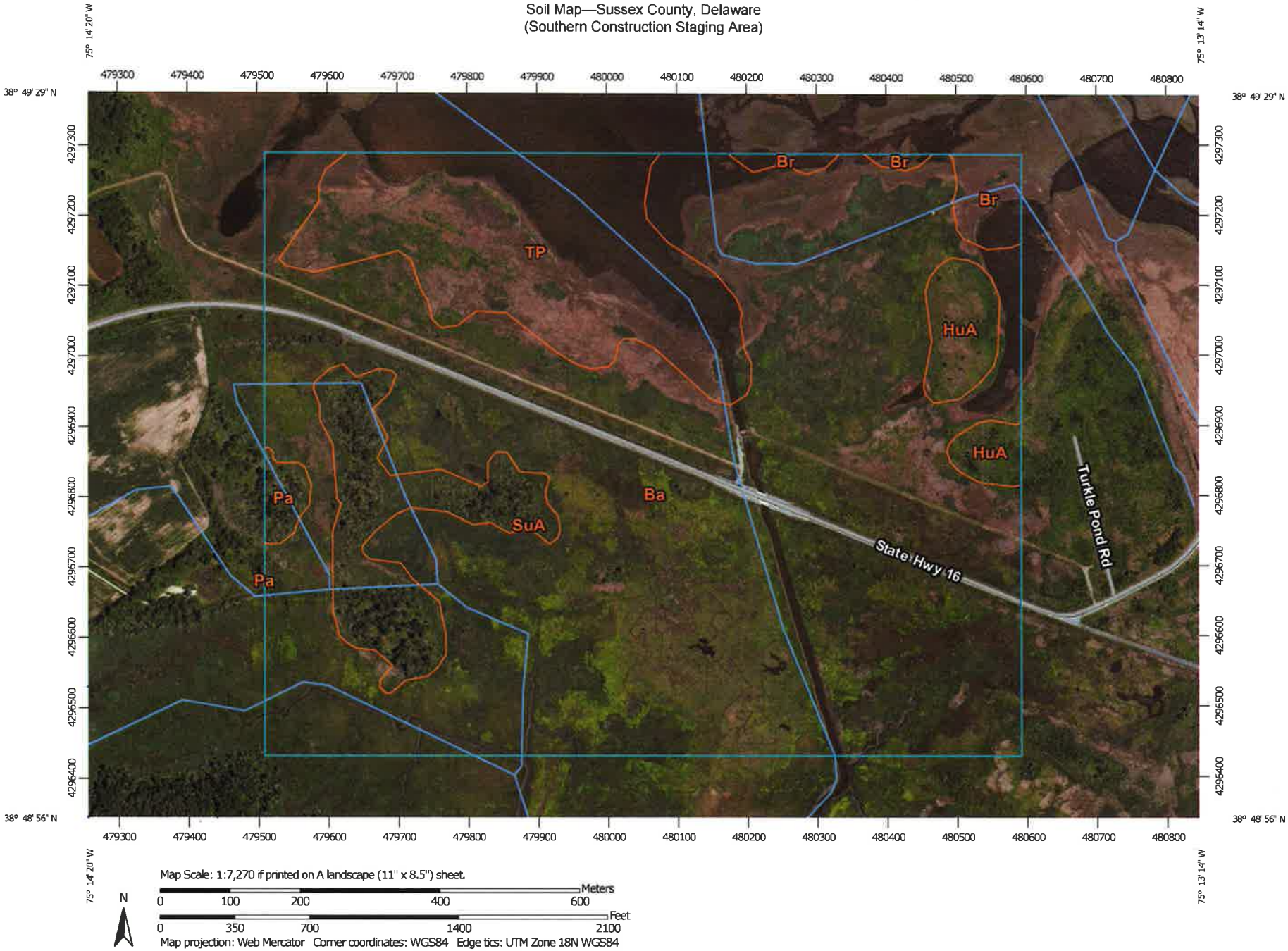
Map Unit Legend

Sussex County, Delaware (DE005)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
CaA	Carmichael loam, 0 to 2 percent slopes	35.4	24.6%
GoA	Glassboro sandy loam, 0 to 2 percent slopes	16.5	11.5%
PyA	Pineyneck loam, 0 to 2 percent slopes	31.2	21.7%
SuA	Sunken mucky silt loam, 0 to 2 percent slopes, occasionally flooded, tidal	23.9	16.6%
TP	Transquaking and Mispillion soils, very frequently flooded, tidal	35.8	24.9%
UlA	Unicorn loam, 0 to 2 percent slopes	1.0	0.7%
Totals for Area of Interest		**143.9**	**100.0%**

Southern Construction Staging Area
N
W
E
S
75°14'0"W
75°13'50"W
75°13'40"W
75°13'30"W
38°49'20"N
38°49'10"N
38°49'0"N
Southern Construction Staging Area
14000 Square feet
Center Point:
Latitude 38.877125
Longitude -75.287128
Broadkill Road
Legend
Construction Staging Area
State Roads
0 180 360 720 1,080 1,440
Feet


Southern Construction Staging Area
75°14'0"W
75°13'45"W
75°13'30"W
38°49'30"N
38°49'15"N
38°49'0"N
N
S
E
W
Southern Construction Staging Area
14000 Square feet
Center Point:
Latitude 38.8203
Longitude -75.2288
Broadkill Road
Petersfield
Island
Legend
Construction Staging Area
State Roads
0
360
720
1,080
1,440
Feet

Soil Map—Sussex County, Delaware
(Southern Construction Staging Area)



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

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Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Sussex County, Delaware
Survey Area Data: Version 13, Sep 25, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 17, 2010—Jul 4, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Sussex County, Delaware (DE005)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ba	Broadkill-Appoquinimink complex, very frequently flooded, tidal	170.8	74.1%
Br	Broadkill mucky peat, very frequently flooded, tidal	4.1	1.8%
HuA	Hurlock loamy sand, 0 to 2 percent slopes	6.4	2.8%
Pa	Pawcatuck mucky peat, very frequently flooded, tidal	1.6	0.7%
SuA	Sunken mucky silt loam, 0 to 2 percent slopes, occasionally flooded, tidal	14.4	6.3%
TP	Transquaking and Mispillion soils, very frequently flooded, tidal	33.1	14.3%
Totals for Area of Interest		**230.4**	**100.0%**

Delaware Tribe Historic Preservation Representatives
Department of Anthropology
Gladfelter Hall
Temple University
1115 W. Polett Walk
Philadelphia, PA 19122
temple@delawaretribe.org

November 24, 2014

United States Department of the Interior
Fish and Wildlife Service
Attn: Arthur J. Coppola
Refuge Manager
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Re: Wetland Restoration Project at the Prime Hook National Wildlife Refuge in Milton

Dear Arthur J. Coppola,

Thank you for informing the Delaware Tribe regarding the above referenced project. The Delaware Tribe is committed to protecting historic sites important to our tribal heritage, culture and religion.

We are interested in learning more about the marine archaeological study conducted as part of the above project and look forward receiving the results of the study. We would also like to continue as a consulting party on this project. We appreciate your cooperation and look forward to working together on our shared interests in preserving Delaware cultural heritage.

If you have any questions, feel free to contact this office by phone at (609) 220-1047 or by e-mail at temple@delawaretribe.org.

Sincerely,

Blair Fink

Blair Fink
Delaware Tribe Historic Preservation Representatives
Department of Anthropology
Gladfelter Hall
Temple University
1115 W. Polett Walk
Philadelphia, PA 19122

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419

September 30, 2014

Delaware Nation of Oklahoma
P.O. Box 825
Andarko, OK 73005

Dear President Alligood:

The U.S. Fish & Wildlife Service (Service) invites the Delaware Nation of Oklahoma to be a consulting party under Section 106 of the National Historic Preservation Act for the proposed Wetland Restoration project at the Prime Hook National Wildlife Refuge in Milton, Delaware. The undertaking is funded by the Disaster Relief Appropriations Act of 2013, Public Law 113-12. The Service is the lead agency for the undertaking, which will be located on Refuge property.

The proposed undertaking will entail the restoration of the forebeach, associated dune and back barrier marsh that was destroyed by a series of winter storms over the past 8 years. Superstorm Sandy alone destroyed over 1800 linear feet of barrier beach and dune which resulted in the loss of 2000 acres of marsh. The Service proposed to repair the breached barrier beach and back barrier marsh by placing approximately 800,000 to 1.15 million cubic yards of sand that will be excavated approximately 1.5 miles off-shore in the Delaware Bay. We are currently in the process of conducting a marine archaeological study in this proposed borrow area to ensure no culturally or biologically significant resources will be negatively impacted. We have already been in consultation with the State of Delaware Office of Historic Preservation regarding the interior marsh restoration. I have attached the letter from them affirming no significant impacts will occur in the marsh interior that is on the refuge. The State SHPO will also be reviewing the offshore information.

The clean fill material that will be discharged into Unit II originates from the aforementioned offshore borrow area and will be displaced onto the foreshore, dune-line and back barrier marsh using a cutter suction dredge along approximately 3,000 linear foot stretch on the east side of Unit II. The Service also plans to cut meandering channels with Units II & III for the purpose of distributing the diurnal tide cycles to allow for the necessary hydrology to support a *Spartina alterniflora* dominated salt marsh.

The final design for the project is still being developed and the Service plans to conduct these activities in late fall of 2015 once time-of-year restrictions have been lifted.

If the Delaware Nation of Oklahoma wishes to be a consulting party for this project, the Service respectfully requests a response within 30 days of receipt of this letter. The State Historic Preservation Officer for the State of Delaware has previously concurred that a similar proposed project would have no effect on historic properties (please refer to Enclosure). If you have any questions or need further information, please contact me at (302) 684-8419.

Sincerely,

Arthur J. Coppola
Refuge Manager
Prime Hook National Wildlife Refuge

Cc: D.J. Monette, NWRS
Timothy Binzen, NWRS

Enclosure

State of Delaware
Historical and Cultural Affairs

21 The Green
Dover, DE 19901-3611

Phone: (302) 736.7400 Fax: (302) 739.5660

August 30, 2013 ER 2013.08.07.02

Arthur J. Coppola
Refuge Manger
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Project : Proposed Wetland Restoration
Prime Hook National Wildlife Refuge, Sussex County, Delaware.

Dear Mr. Coppola,

The above referenced project was reviewed for potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended. The undertaking will occur in wet areas with low archaeological probability. In addition there are no recorded historic properties in the area to be impacted. The upland staging areas appear to have been disturbed, and would be very unlikely to contain intact archaeological resources. It is the conclusion of the reviewer that no archaeological survey should be required. Also, given the limited nature of construction associated with this project, no architectural historic properties can be affected by this project.

If you have any questions, please contact me at craig.lukezic@state.de.us.

Sincerely,

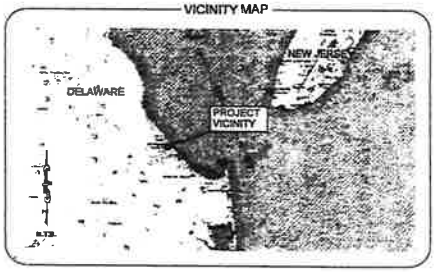
Craig Lukezic
Archaeologist, Division of Historical and Cultural Affairs

Cc Gwen Davis, Deputy State Historic Preservation Officer

PRIME HOOK RESTORATION PROJECT

PERMIT DRAWINGS
MILTON, DELAWARE

VICINITY MAP



PROJECT LOCATION

THE PROJECT AREA IS LOCATED IN MILTON DELAWARE ALONG THE WESTERN SHORE OF DELAWARE BAY.

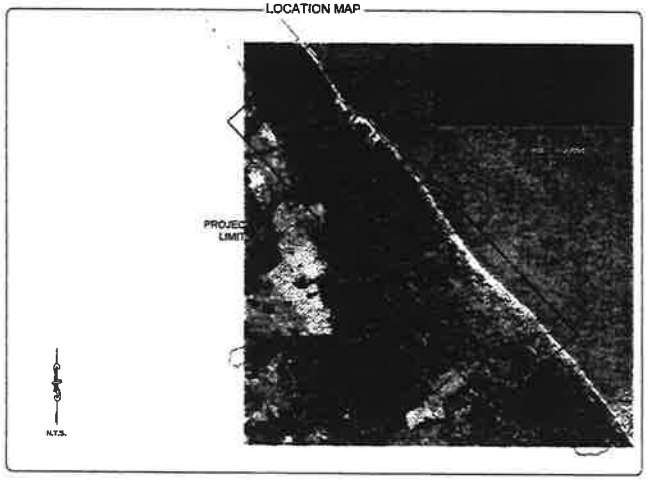
INDEX OF DRAWINGS

SHEET TITLE	SHEET NUMBERS
COVER	C-000
PLAN VIEW - VICINITY MAP	C-001
PLAN SHEET LAYOUT	C-002
PLAN VIEW - BACK BAY MARSH PLATFORM AND TIDAL CREEKS	C-300 TO C-309
TYPICAL CROSS SECTIONS - BACK BAY MARSH PLATFORM AND TIDAL CREEKS	C-500
MARSH CHANNEL PROJECT CROSS SECTIONS	C-600 TO C-603

Know what's below. Call before you dig.

ATTENTION IS DIRECTED TO THE FACT THAT THESE PLANS MAY HAVE BEEN REDUCED IN SIZE BY REPRODUCTION.

LOCATION MAP



CLIENT

U.S. FISH & WILDLIFE SERVICE
PRIME HOOK NATIONAL WILDLIFE REFUGE
11978 TURKLE POND ROAD
MILTON, DELAWARE 19968
TEL. (302) 684-8419

THE Louis Berger Group, INC.

ENGINEER OF RECORD

LOUIS BERGER - JEFFREY R. TABAR, P.E.
412 MOUNT KEMBLE AVE.
MORRISTOWN, NEW JERSEY 07960
TEL. (856) 418-1243

AUGUST 2014

GENERAL NOTES

1. THE PURPOSE OF THIS PROJECT IS TO RESTORE THE PRIMEHOOK BEACHES AND WETLAND AREAS AS A RESULT OF HURRICANE SANDY. ALL QUANTITIES ARE APPROXIMATE AND THE CONTRACTOR IS RESPONSIBLE FOR VERIFYING ESTIMATED QUANTITIES.
2. BEACH NOURISHMENT AND WETLAND RESTORATION ACTIVITY WILL BE CONDUCTED IN DESIGNATED AREAS ONLY AND IN ACCORDANCE WITH THE PLANS AND SPECIFICATIONS.
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8. AERIAL PHOTOGRAPHS WERE PROVIDED BY XXXXX (DATED XXXXX).

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PREPARED BY

ATKINS

PROJECT NUMBER: 100039575

TREADWAY TOWERS
SUITE 316
9 EAST LOOCKERMAN STREET
DOVER, DELAWARE 19901
(800) 477-7275

DATE:

ENGINEER OF RECORD: JEFFREY R. TABAR
DELAWARE P.E. #18229

NOT VALID FOR CONSTRUCTION UNLESS SIGNED IN THIS BLOCK

CONCEPTUAL DRAWINGS

ATKINS

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - VICINITY MAP

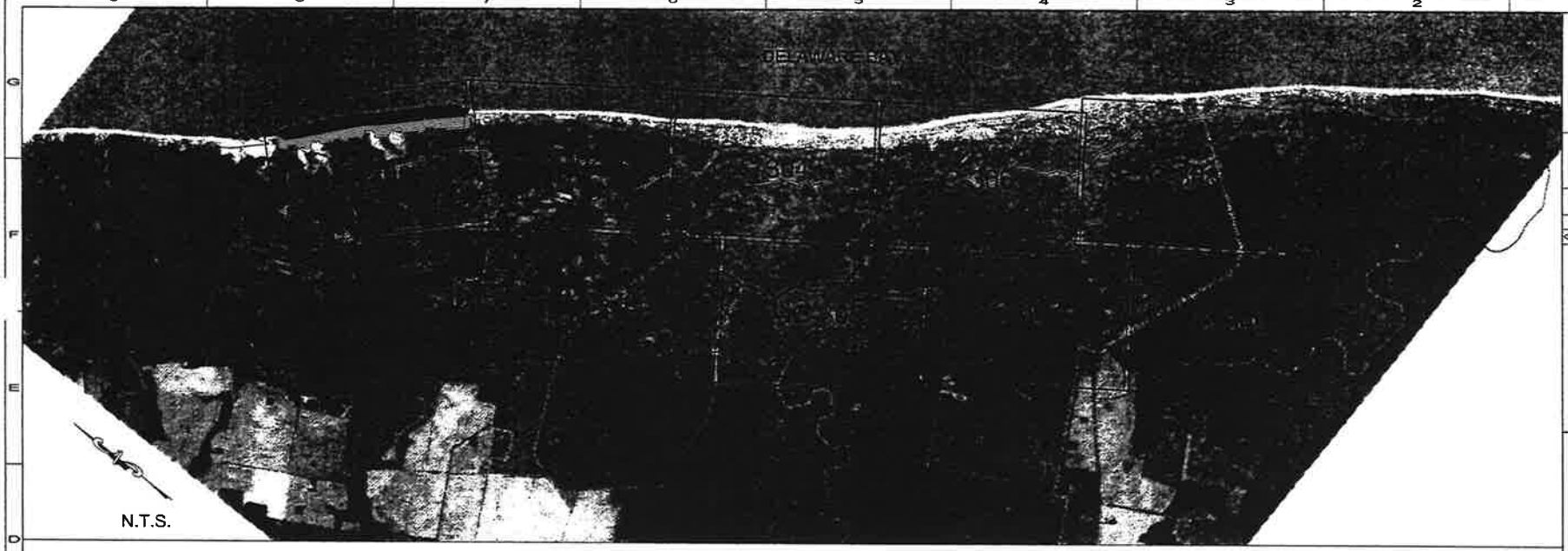
NOTICE

ENGINEER OF RECORD:

REV	DATE	DESCRIPTION

ORIGINAL ISSUED DATE:

JOB NO.	100031176
DRAWN	J.L.P.
TRACED	J.R.T.
CHECKED	W.J.D.
APPROVED	J.R.T.
SHEET NO.	C-001



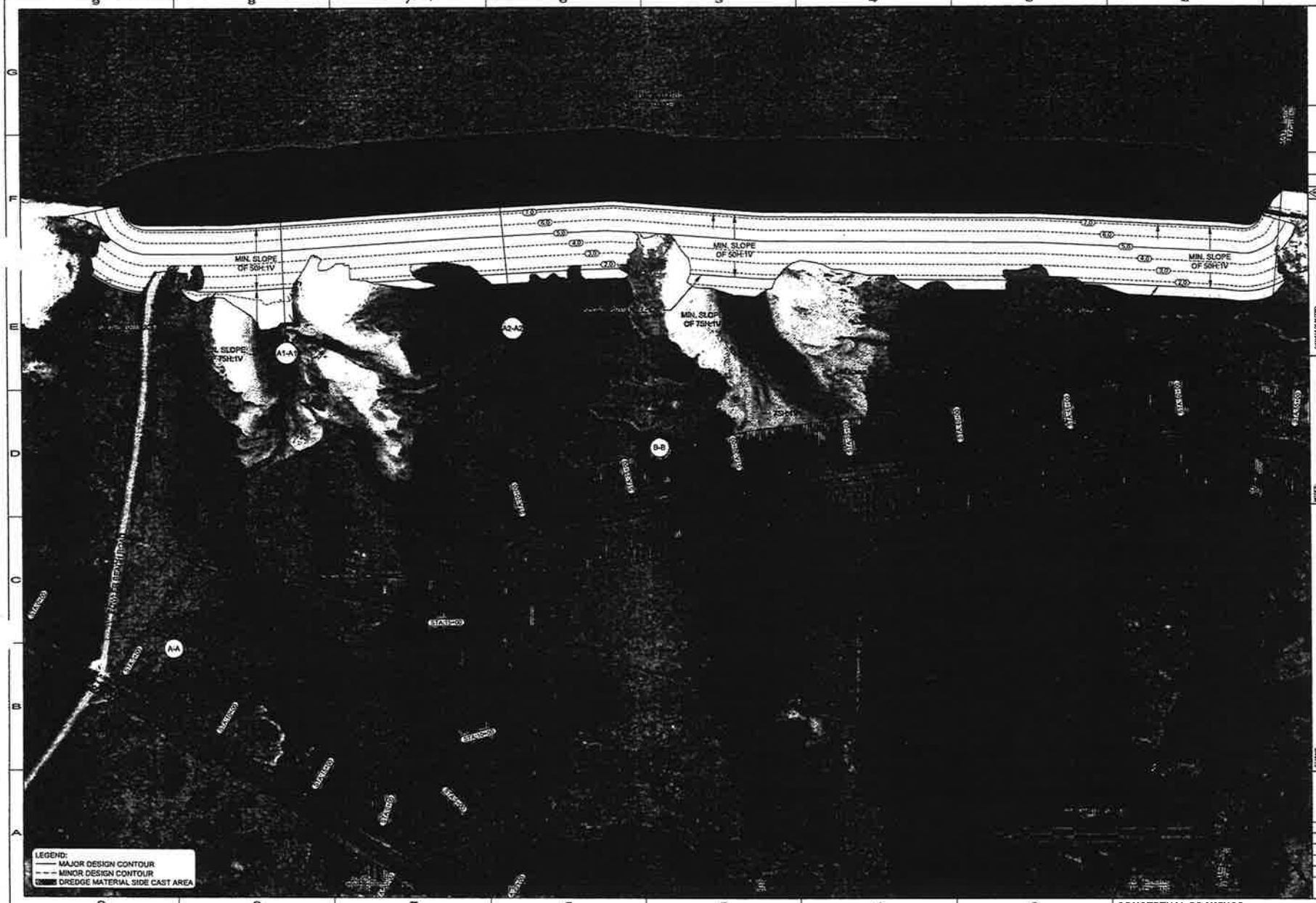
PLAN SHEET LAYOUT

CLIENT	USFWS	
PROJECT	PRIME HOOK RESTORATION PROJECT	
TITLE	PLAN SHEET LAYOUT	

ATKINS

JOB NO.	100031176
DRAWN	J.L.P.
DESIGN	J.R.T.
CHECKED	W.J.D.
APPROVED	J.R.T.
SHEET NO.	C-002

CONCEPTUAL DRAWINGS



CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - BACK BAY MARSH PLATFORM AND TIDAL CREEKS

ATKINS

JOB NO.: 100031176
DRAWN: J.L.P.
DESIGN: J.R.T.
CHECKED: W.J.D.
APPROVED: J.R.T.
SHEET NO.: C-300

CONCEPTUAL DRAWINGS

COPY

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968
(302) 684-8419

September 30, 2014

Delaware Tribe of Indians
170 NE Barbara
Bartlesville, OK 74006

Dear President Obermeyer:

The U.S. Fish & Wildlife Service (Service) invites the Delaware Tribe of Indians to be a consulting party under Section 106 of the National Historic Preservation Act for the proposed Wetland Restoration project at the Prime Hook National Wildlife Refuge in Milton, Delaware. The undertaking is funded by the Disaster Relief Appropriations Act of 2013, Public Law 113-12. The Service is the lead agency for the undertaking, which will be located on Refuge property.

The proposed undertaking will entail the restoration of the forebeach, associated dune and back barrier marsh that was destroyed by a series of winter storms over the past 8 years. Superstorm Sandy alone destroyed over 1800 linear feet of barrier beach and dune which resulted in the loss of 2000 acres of marsh. The Service proposed to repair the breached barrier beach and back barrier marsh by placing 800,000 to 1.15 million cubic yards of sand that will be excavated approximately 1.5 miles off-shore in the Delaware Bay. We are currently in the process of conducting a marine archaeological study in this proposed borrow area to ensure no culturally or biologically significant resources will be negatively impacted. We have already been in consultation with the State of Delaware Office of Historic Preservation regarding the interior marsh restoration. I have attached the letter from them affirming no significant impacts will occur in the marsh interior that is on the refuge. The State SHPO will also be reviewing the offshore information.

The clean fill material that will be discharged into Unit II originates from the aforementioned offshore borrow area and will be displaced onto the foreshore, dune-line and back barrier marsh using a cutter suction dredge along approximately 3,000 linear foot stretch on the east side of Unit II. The Service also plans to cut meandering channels with Units II & III for the purpose of distributing the diurnal tide cycles to allow for the necessary hydrology to support a *Spartina alterniflora* dominated salt marsh.

The final design for the project is still being developed and the Service plans to conduct these activities in late fall of 2015 once time-of-year restrictions have been lifted.

If the Delaware Tribe of Indians wishes to be a consulting party for this project, the Service respectfully requests a response within 30 days of receipt of this letter. The State Historic Preservation Officer for the State of Delaware has previously concurred that a similar proposed project would have no effect on historic properties (please refer to Enclosure). If you have any questions or need further information, please contact me at (302) 684-8419.

Sincerely,

Arthur J. Coppola
Refuge Manager
Prime Hook National Wildlife Refuge

Cc: D.J. Monette, NWRS
Timothy Binzen, NWRS

Enclosure

State of Delaware
Historical and Cultural Affairs

21 The Green
Dover, DE 19901-3611

Phone: (302) 736.7400 Fax: (302) 739.5660

August 30, 2013 ER 2013.08.07.02

Arthur J. Coppola
Refuge Manger
Coastal Delaware NWR Complex
Prime Hook National Wildlife Refuge
11978 Turkle Pond Road
Milton, DE 19968

Project: Proposed Wetland Restoration
Prime Hook National Wildlife Refuge, Sussex County, Delaware.

Dear Mr. Coppola,

The above referenced project was reviewed for potential effects on historic properties as required under Section 106 of the National Historic Preservation Act of 1966, as amended. The undertaking will occur in wet areas with low archaeological probability. In addition there are no recorded historic properties in the area to be impacted. The upland staging areas appear to have been disturbed, and would be very unlikely to contain intact archaeological resources. It is the conclusion of the reviewer that no archaeological survey should be required. Also, given the limited nature of construction associated with this project, no architectural historic properties can be affected by this project.

If you have any questions, please contact me at craig.lukezic@state.de.us.

Sincerely,

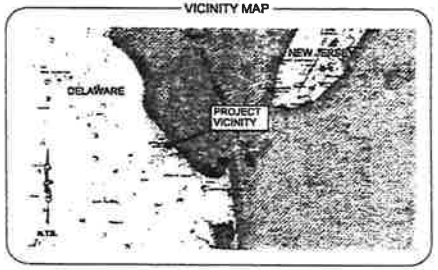
Craig Lukezic
Archaeologist, Division of Historical and Cultural Affairs

Cc Gwen Davis, Deputy State Historic Preservation Officer

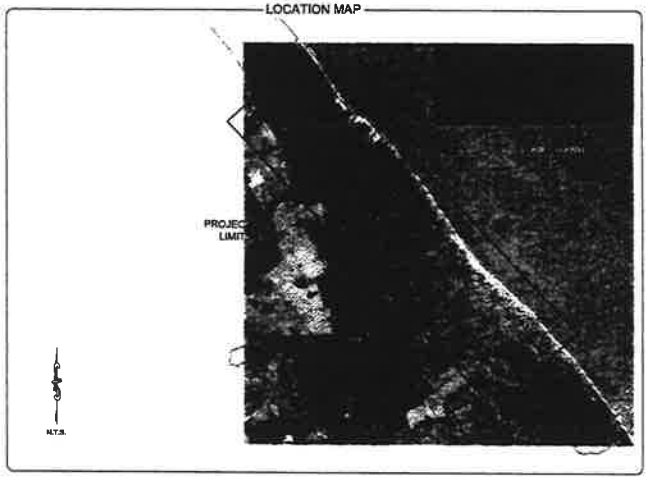
PRIME HOOK RESTORATION PROJECT

PERMIT DRAWINGS
MILTON, DELAWARE

VICINITY MAP



LOCATION MAP



PROJECT LOCATION

THE PROJECT AREA IS LOCATED IN MILTON DELAWARE ALONG THE WESTERN SHORE OF DELAWARE BAY.

INDEX OF DRAWINGS

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TYPICAL CROSS SECTIONS - BACK BAY MARSH PLATFORM AND TIDAL CREEKS	C-500
MARSH CHANNEL PROJECT CROSS SECTIONS	C-600 TO C-603

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Know what's below.
Call before you dig.

ATTENTION IS DIRECTED TO THE FACT THAT THESE PLANS MAY HAVE BEEN REDUCED IN SIZE BY REPRODUCTION.

CLIENT

U.S. FISH & WILDLIFE SERVICE
PRIME HOOK NATIONAL WILDLIFE REFUGE
11978 TURKLE POND ROAD
MILTON, DELAWARE 19968
TEL. (302) 684-8419

THE Louis Berger Group, INC.

ENGINEER OF RECORD

LOUIS BERGER - JEFFREY R. TABAR, P.E.
412 MOUNT KEMBLE AVE.
MORRISTOWN, NEW JERSEY 07960
TEL. (856) 418-1243

AUGUST 2014

PREPARED BY

ATKINS
PROJECT NUMBER: 100039575

TREADWAY TOWERS
SUITE 316
9 EAST LOOCKERMAN STREET
DOVER, DELAWARE 19901
(800) 477-7275

DATE:

ENGINEER OF RECORD: JEFFREY R. TABAR
DELAWARE P.E. #18229

NOT VALID FOR CONSTRUCTION UNLESS SIGNED IN THIS BLOCK

CONCEPTUAL DRAWINGS

ATKINS

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - VICINITY MAP

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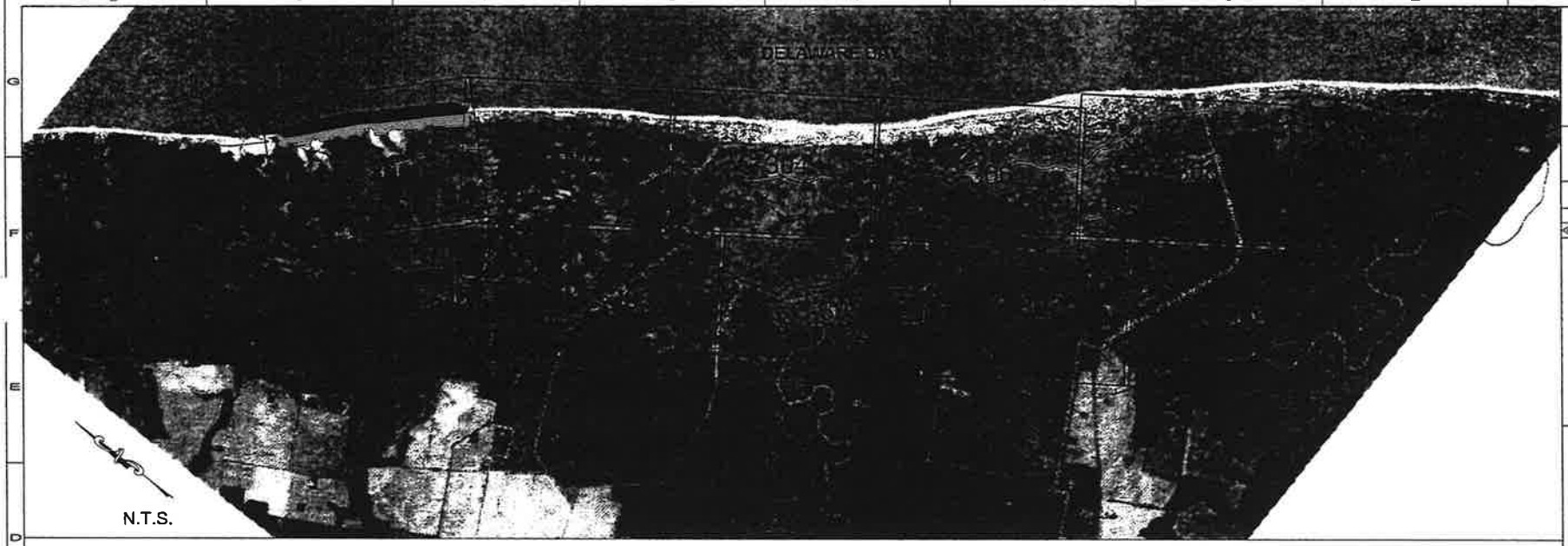
LICENSED OR RECORD
JEFFREY R. TAYLOR (DELAWARE P.E. # 11677)

DATE:

REV	DATE	DESCRIPTION
A		
A		
A		
A		
A		
A		
A		
A		

ORIGINAL ISSUED DATE:

JOB NO.	100031176
DRAWN:	J.L.P.
REVIEW:	J.R.T.
DESIGNED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-D01



PLAN SHEET LAYOUT

USFWS

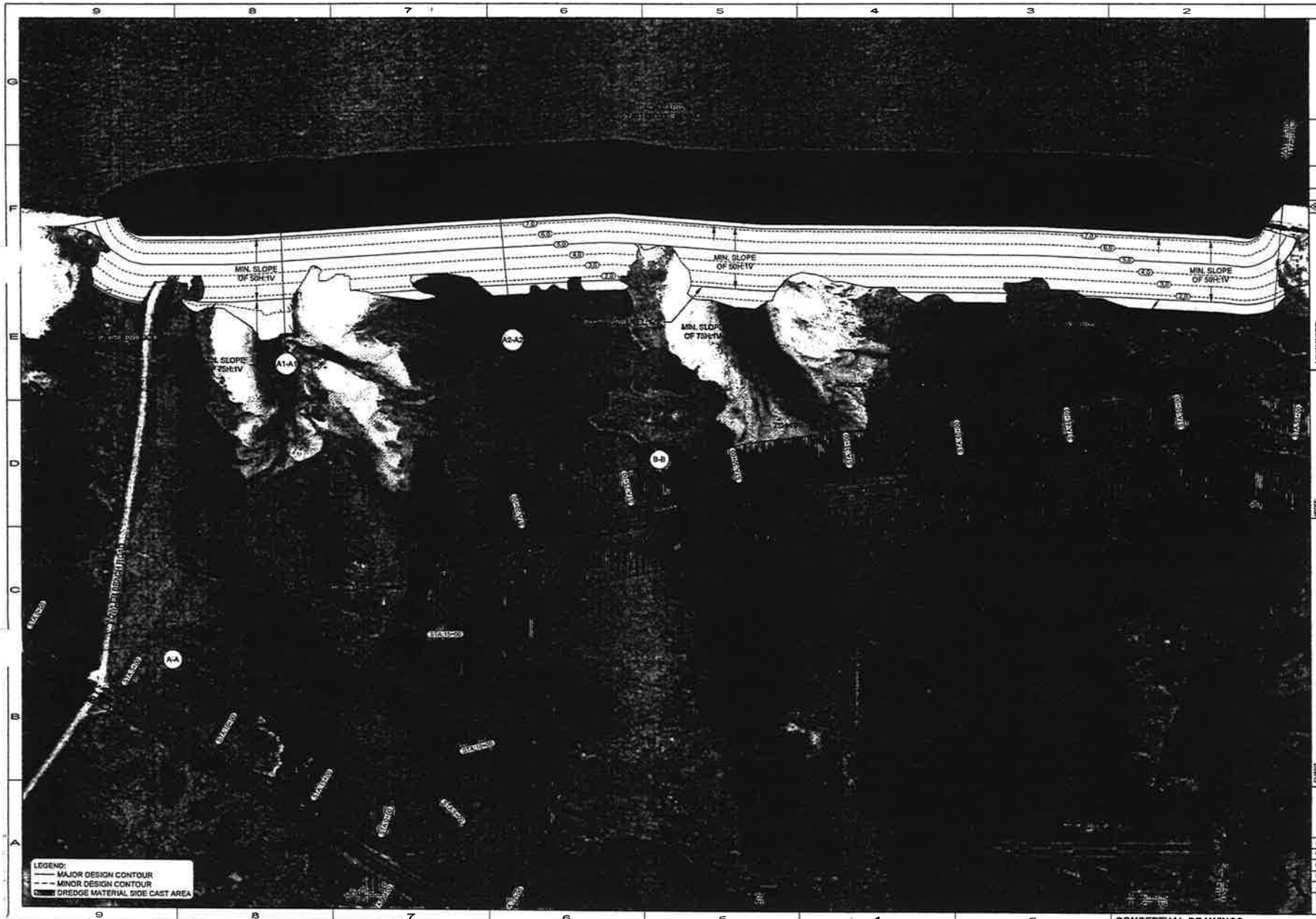
PRIME HOOK RESTORATION PROJECT

PLAN SHEET LAYOUT

ATKINS

JOB NO.	100031176
DRAWN:	J.L.P.
DESIGN:	J.R.T.
CHECKED:	W.J.D.
APPROVED:	J.R.T.
SHEET NO.	C-002

CONCEPTUAL DRAWINGS



NO.	DATE	DESCRIPTION

DRAWING REVISIONS

DATE

NOTES:

CLIENT: USFWS

PROJECT: PRIME HOOK RESTORATION PROJECT

TITLE: PLAN VIEW - BACK BAY MARSH PLATFORM AND TIDAL CREEKS

ATKINS

JOB NO.	100031176
DRAWN	J.L.P.
REVIEW	J.R.T.
CHECKED	W.J.D.
APPROVED	J.R.T.
SHEET NO.	C-300

CONCEPTUAL DRAWINGS

APPENDIX E

Benthic Organism Assessment

BENTHIC COMMUNITY RESOURCE MONITORING AND ASSESSMENT FOR THE LOWER DELAWARE BAY PRIME HOOK NATIONAL WILDLIFE REFUGE DUNE BREACH REPAIR PROJECT, DE

Prepared for

Coastal Delaware National Wildlife Refuge Complex
U.S. Fish and Wildlife Service
11978 Turkle Pond Rd
Milton, DE 19968

Prepared by

Lisa C. Scott

Versar, Inc.
9200 Rumsey Road
Columbia, MD 21045

Prepared Under the Supervision of

William H. Burton
Principal Investigator

December 2014

FOREWORD

This report entitled "Benthic community resource monitoring and assessment for the Lower Delaware Bay Prime Hook National Wildlife Refuge Dune Breach Repair Project, DE." was prepared by Versar, Inc., for Al Rizzo, Project Leader, Coastal Delaware National Wildlife Refuge Complex, U.S Fish and Wildlife Service.

EXECUTIVE SUMMARY

Coastal shorelines in and around the Prime Hook National Wildlife Refuge in the lower Delaware Bay has incurred severe erosion due to storms, tidal flooding and other natural processes. To help stem this erosion and restore the shoreline, the U.S. Fish and Wildlife Service and Army Corps of Engineers, Philadelphia District (USACE) is conducting a dune breach repair project. As part of this project, sediment from offshore borrow areas is dredged and used as beachfill material to restore and enhance the shoreline. Three nearby offshore source borrow areas (Areas A, B and C) have been targeted for use as a potential sediment source for this restoration project. Part of the evaluation process for the targeting of suitable borrow areas is the documentation of the biological resources within each targeted area.

Between the months of August and September, 2014 a benthic community study and epi-benthic survey was conducted within the three potential borrow areas in order to characterize the current living resources in each area and evaluate their suitability as a sediment source for shoreline restoration. Additionally, data collected for this study was assessed and evaluated in terms of limiting potential long-term impacts that may occur from dredging operations. Methods used to collect and process the biological samples followed those conducted for previous USACE studies conducted in the lower Delaware Bay. In this way, living resource information collected from previous and future studies in and around the region can be used to evaluate impacts that may occur due to dredging operations.

The benthic community resources inhabiting the borrow areas near Prime Hook consisted of a mix of species typical to estuarine and marine salinity regimes. The community, overall, was not unique to the lower Delaware Bay area when compared to previous studies conducted in the Lower Delaware Bay Region. The most abundant species collected for this study were collected in high numbers at some sampling stations but because they and most of the other species collected from the borrow areas were small in size, the overall biomass in the three borrow areas was low. Commercially important species such as the surf clam (*Spisula solidissima*) and the hard clam (*Mercenaria mercenaria*) were only present in a third of the total benthic sampling stations and in very small numbers. None of these commercially important species were collected during the epi-benthic tows nor was there evidence of colonies of the ecologically important sand reef building worm *Sabellaria vulgaris*.

All of the stations sampled in Areas A and C and 6 stations in Area B had predominantly clean sand (i.e., very little silt/clay), while 9 stations in Area B had predominantly silty/sand or mud sediments (i.e., > 10% silt/clay). Bray-Curtis similarity values displayed on a Multi-Dimensional Scaling (MDS) graph differentiated the benthic assemblages by these two sediment types. Examination of the individual species inhabiting each station indicated that species such as haustorid amphipods and the small tanaid crustacean *Tanaissus psammophilus* had an affinity for the clean sand areas. Species such as the polychaete worm *Mediomastus ambiseta*, the gastropod *Acteocina canaliculata*, and the small clam, *Nucula proxima* were more prominent at the sites with higher amounts of silty-sized sediment particles.

The communities in the three borrow areas near Prime Hook, on whole, consisted of species with opportunistic life-history characteristics that include short-lived, high fecundity and high productivity that result in high abundance and low biomass. This type of community has a great ability to rapidly recover from disturbances whether natural or anthropogenic. The commonality and ubiquity of the dominant species in the three areas will allow for an abundant supply of nearby organisms capable of rapid recovery after a dredging disturbance. Additionally, dredging operations should have little to no impact on commercially important species populations since so few juveniles were documented from the three areas and no adults were present.

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1.0 INTRODUCTION

The lower Delaware Bay coastline has incurred severe erosion caused by storms, tidal flooding, and natural processes. To protect and restore shoreline habitats along the lower Delaware Bay coastline near the Prime Hook National Wildlife Refuge Area, the U.S. Fish and Wildlife Service and Army Corps of Engineers, Philadelphia District is conducting a dune breach repair project. As part of the project's evaluation process, three nearby offshore source borrow areas were targeted for use as a potential shoreline restoration sediment source. The location of these borrow areas are provided in Figure 1-1.

A critical component for evaluating the suitability of an area as a sand source for coastline restoration projects is documenting the current living resources in the potential borrow area and determining any potential long-term impacts sediment dredging may have on these living resources. Environmental concerns with sediment dredging include the removal of existing communities and food resources and the potential disruption of commercial and recreational fisheries. Other possible effects of dredging include borrow area habitat modification, disruption of natural recruitment patterns of macroinvertebrate fauna, and changing the community mix from an older, established community with large, deep dwelling organisms to one with high abundances of small, surface dwelling, opportunist taxa.

The purpose of this report was to provide an evaluation of the macrobenthic living resources within each of the three potential borrow areas. The living resource data collected for this study was used to describe the current, existing benthic community within each borrow area, evaluate the suitability for use as a borrow area sediment source and assess any potential long-term impacts that may occur from dredging operations. The presence of commercially important species was also documented and evaluated in terms of recovery potential from dredging operations. Based on this study's results, alterations in dredging methods could be implemented to minimize dredging impacts on the current benthic community inhabiting each borrow area. Additionally, since this study provides a benthic community inventory of current biological data, the data provides a baseline to determine any immediate or long-term impacts of dredging on the benthic biota and its habitat. After dredging operations cease, this pre-dredge data can be statistically compared to post-dredge data to access 1) any changes in the sediment habitat; 2) any changes to the macrobenthic community; and 3) the speed of recovery within the benthic community.

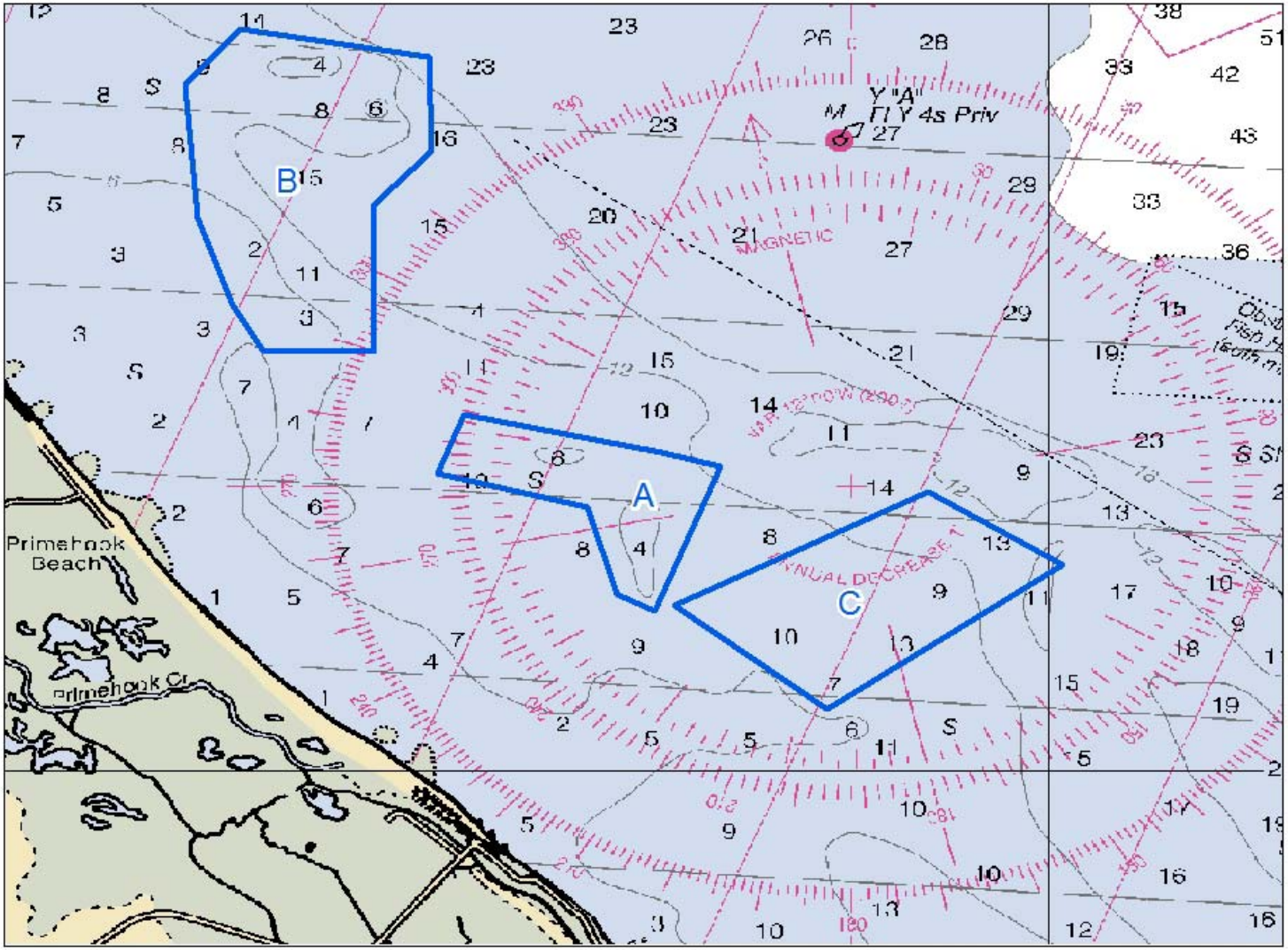

Figure 1-1. Location of the three proposed sediment borrow area near the Prime Hook National Wildlife Refuge

2.0 METHODS

2.1 MACROBENTHIC SAMPLE DESIGN

As specified in the Scope of Work (Appendix A), seventeen sampling stations were sampled within each of the three potential borrow areas near the Prime Hook National Wildlife Refuge. Sampling locations were randomly selected using a computer software program before the field collection and latitude and longitudes for these stations were provided to the field crew. Sampling stations were located in the field by GPS using these provided coordinates. After positioning the vessel on station, the exact position coordinates were obtained from the GPS and recorded on the field data sheets (Appendix B). Benthic sampling in Area B was conducted on August 26, Area C on August 27 and Area A on September 18, 2014. GIS produced maps indicating each sampling location within the three borrow areas are depicted in Figures 2-1 to 2-3.

2.2 MACROBENTHIC SAMPLE COLLECTION METHODS

Benthic and sediment samples were collected with a 0.044-m^2 stainless steel, Young grab sampler. Samples collected for benthic macroinvertebrates were sieved through a 0.5-mm screen and preserved in a 10% solution of buffered formaldehyde stained with rose bengal. Sediment samples for analysis of grain-size and total organic content (TOC) were collected from a second grab and frozen until laboratory processing. Water quality measurements were taken near the sediment bottom at each sampling station to document current water conditions the day of sampling. Measurements included dissolved oxygen concentration (DO), salinity, conductivity, temperature, and pH.

A trawl survey of epi-benthic species was conducted at 5 randomly selected stations of the 17 benthic sampling stations in each borrow area. In Area A, stations A-01, 06 09, 12, and 16; in Area B, stations B-03, 04, 07, 10 and 17; in Area C; stations C-02, 03, 04, 15, and 17 were sampled for epi-benthic species (Figures 2-1 to 2-3). At each station, a 2-foot oyster dredge was towed between 2-5 minutes and all collected organisms were identified and counted.

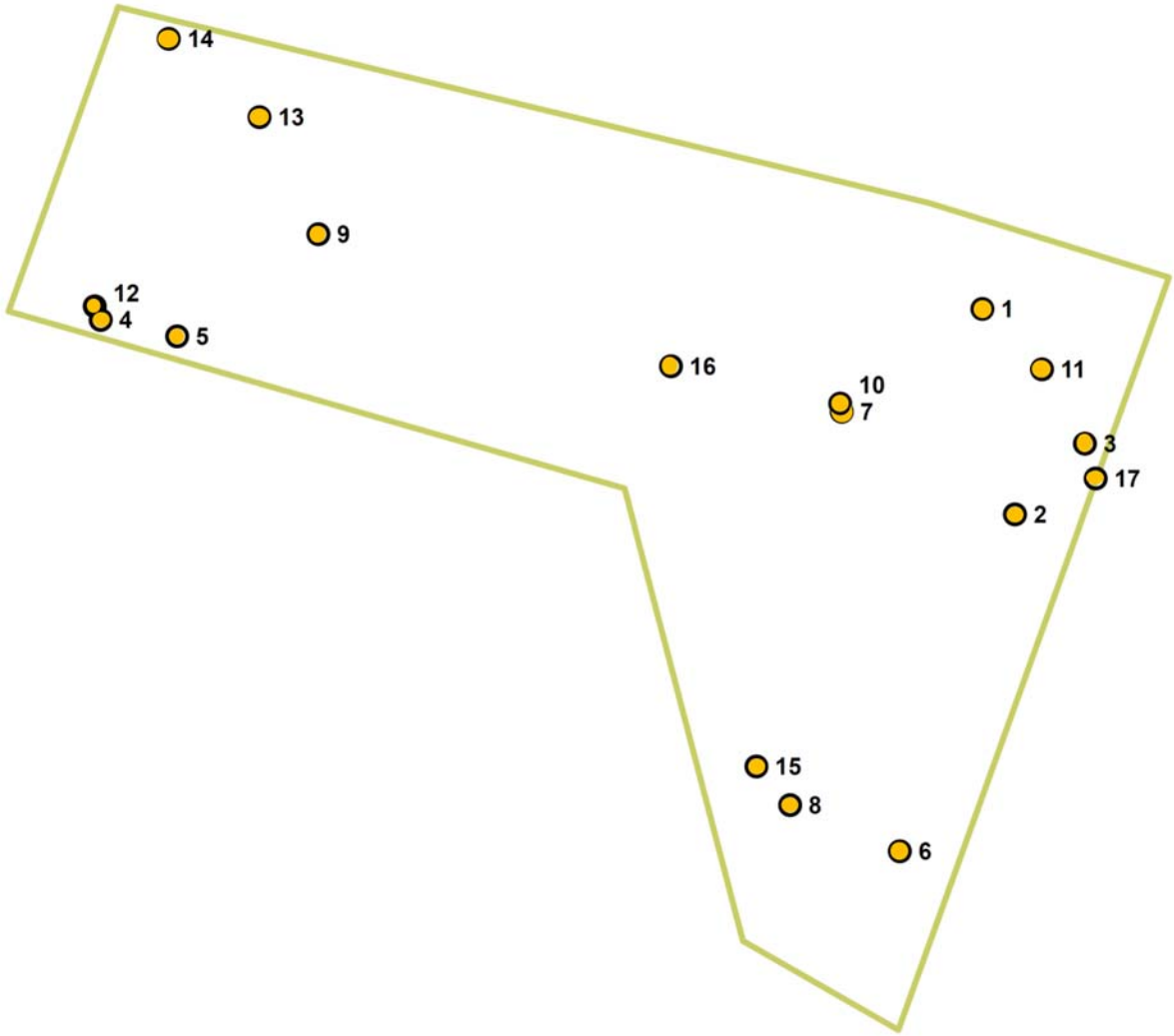

Figure 2-1. Location of the 17 benthic stations sampled within borrow Area A near the Prime Hook National Wildlife Refuge, 2014

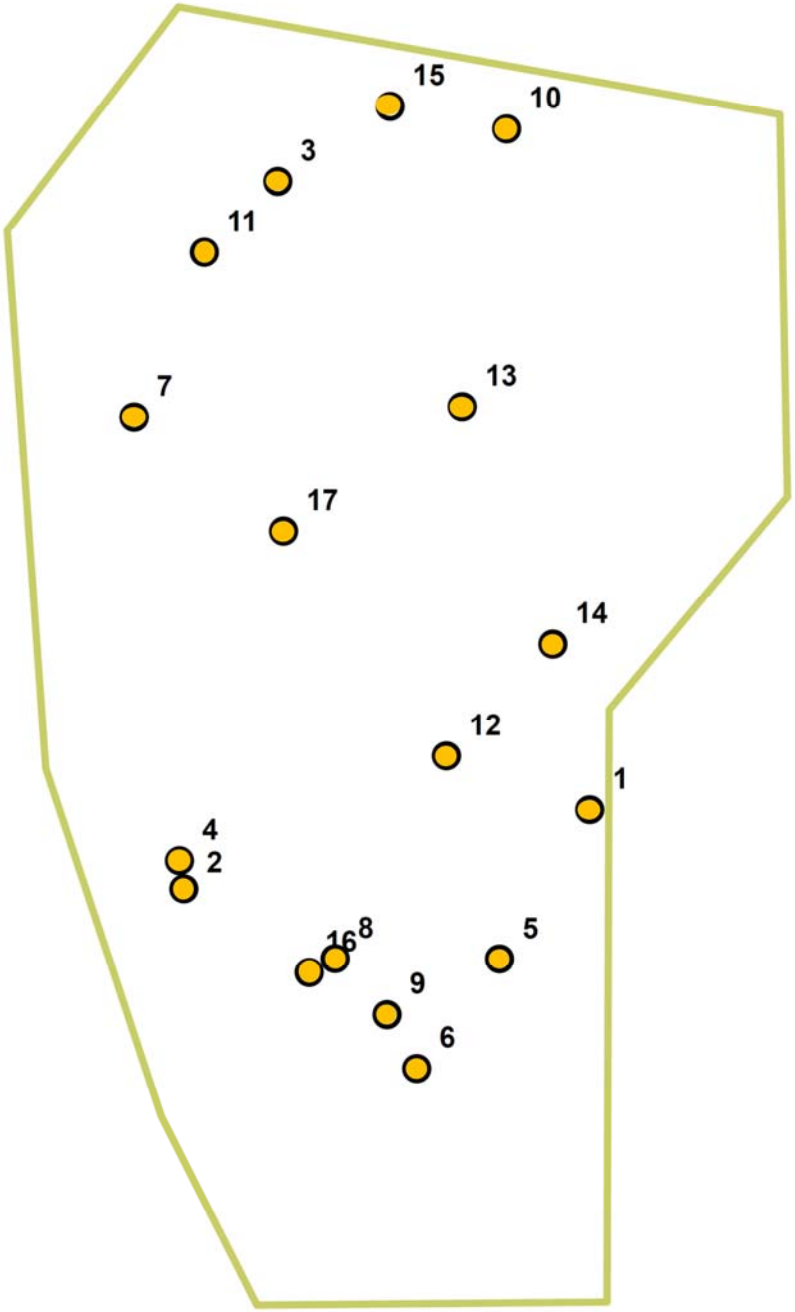

Figure 2-2. Location of the 17 benthic stations sampled within borrow Area B near the Prime Hook National Wildlife Refuge, 2014

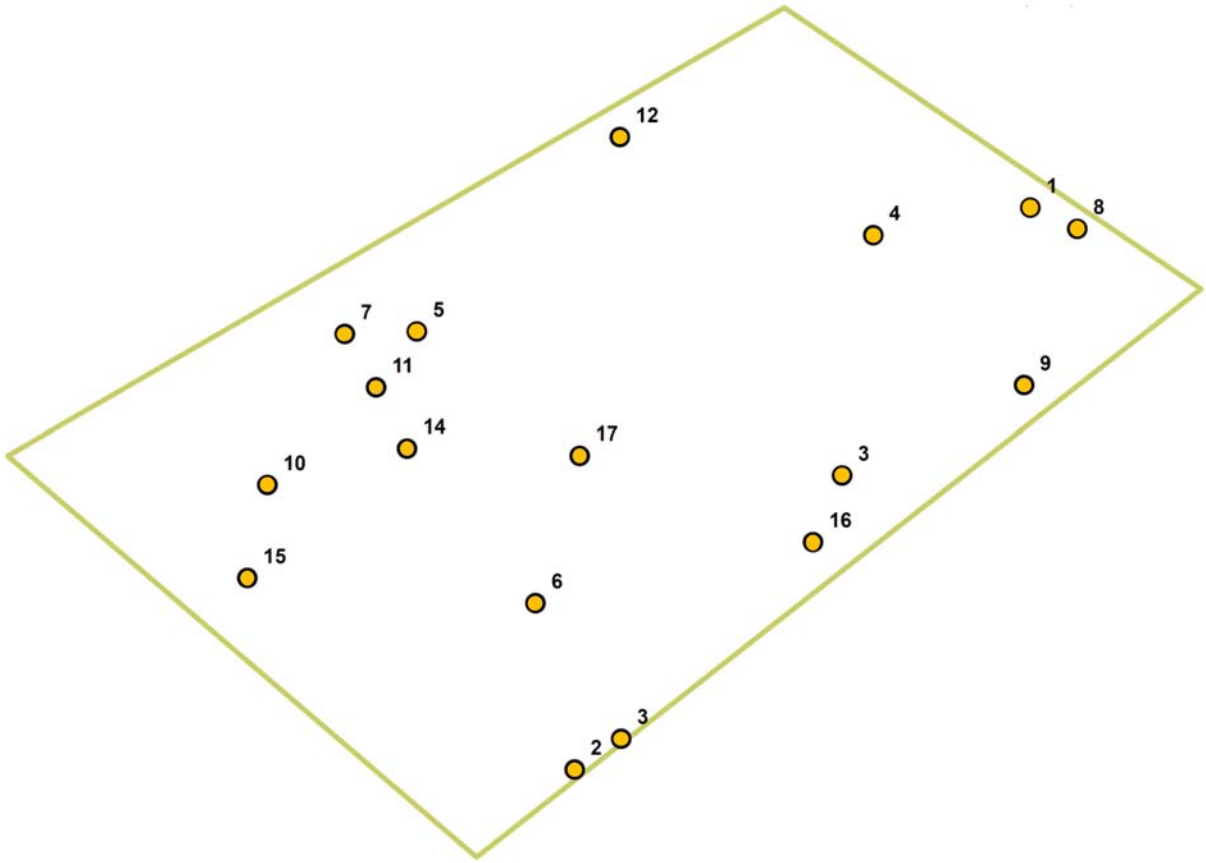

Figure 2-3. Location of the 17 benthic stations sampled within borrow Area C near the Prime Hook National Wildlife Refuge, 2014

2.3 LABORATORY SAMPLE PROCESSING

2.3.1 Benthic Macroinvertebrates

Samples were re-sieved in the laboratory using a 0.5-mm standard laboratory sieve to wash off the preservative. Benthic organisms in each sample were removed from the remaining debris using a dissecting microscope. All organisms present in the sample were identified to the lowest practical taxonomic category and counted. The number of organisms longer than 2 cm for each taxon was also recorded. Organisms were grouped according to the lowest taxonomic level to determine taxa specific ash-free dry weight (AFDW) biomass. AFDW biomass was determined by drying each taxon to a constant weight at 60 °C, ashing in a muffle furnace at 500 °C for 4 hours, and weighing the remains.

2.3.2 Grain-size and Total Organic Carbon

Grain-size analysis was performed according to ASTM Method D422-63. Sieve sizes ranged from 4.75 mm (U.S. Standard Sieve No. 4) to 63 µm (U.S. Standard Sieve No. 230). Sediments were categorized by Wentworth's classifications (Table 2-2). Total organic content (TOC) was measured by weight loss upon ignition at 500 °C for 4 hours after obtaining a dry weight by drying the sample to a constant weight for 24 hours at 60 °C.

Table 2-1. Sieve sizes used for sediment particle distribution and the Wentworth sediment size categories (Buchanan 1984)

Sieve Number	Sieve Size	Wentworth Size Category
4	4.75-mm	Pebble
10	2.00-mm	Granule
20	850-µm	Very Coarse Sand
40	425-µm	Coarse Sand
60	250-µm	Medium Sand
140	106-µm	Fine Sand
200	75-µm	Undefined
230	63-µm	Very Fine Sand
	< 63-µm	Silt-Clay

2.4 DATA REPORTING

The Primer-E Ltd. statistical package was used to perform a cluster analysis (Clark and Warwick, 2001) on the benthic data from all three borrow areas. The aim of the analysis was to differentiate between groupings of stations based on the benthic community data collected at each station as a means of determining stations with similar benthic communities. The cluster analysis used for this study started with the calculation of a similarity matrix using the Bray-Curtis coefficient. The abundance data were log 10-transformed for the analysis. The hierarchical clustering method using the similarity matrix creates a dendrogram of station groupings based on the coefficient. The resulting dendrogram attempts to group samples into "natural groupings" of similar samples and the Bray-Curtis similarity value is a measure of the similarity between these station "groupings." The method used for displaying the station similarity results was a Multi-Dimensional Scaling (MDS) program that displays station similarities in a 2-dimensional figure (Clark and Warwick, 2001). This figure displays a more informative viewing of station groupings based on the Bray-Curtis results. Once the MDS plot is developed, factors such as sediment habitat type can be used as a means to evaluate causes for station groupings.

Several measures of macroinvertebrate community composition including diversity, abundance, and biomass were documented and examined at each sampling station. The formula for the calculation of the Shannon-Wiener Index is:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where

H = index of species diversity
S = number of species
p_i = proportion of total sample belonging to ith species

The formula for the calculation of the Simpson's Dominance Index is:

$$D = 1 - \sum_{i-1}^{2} (p_i)^2$$

An analysis of variance (ANOVA) was conducted on total abundance, total number of taxa, and total biomass to evaluate differences in these parameters between the three borrow areas. Duncan's Multiple Range Test was preformed to determine if statistical differences (p level of 0.5) on log transformed data (to meet requirements for normality) from these three areas was evident.

3.0 RESULTS

3.1 HABITAT CHARACTERISTICS

3.1.1 Water Quality

Water quality measurements taken at the 3 borrow areas did not indicate any dissolved oxygen (DO) problems (Table 3-1). Bottom DO ranged between 6.50 to 7.37 mg/L at the 51 benthic sampling stations while bottom depths ranged between 2.3 and 5.7 meters. Area A was on average (2.9 m) shallower than both Area B (4.3 m) and Area C (4.9 m). Bottom temperatures were warmer by about 2 °C at both Areas B and C than Area A which was sampled about 3 weeks later in September. Bottom salinity and pH were within expected ranges at all three borrow areas (Table 3-1).

Table 3-1. Water quality measurements at the three borrow areas near the Prime Hook National Wildlife Refuge

Station	Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (ppt)	pH	Dissolved Oxygen (mg/l)
Area A						
A-01	3.07	21.94	45.24	29.32	7.97	6.83
A-02	2.94	22.05	45.33	29.38	7.98	6.57
A-03	3.45	22.03	45.30	29.36	7.97	6.67
A-04	3.07	21.66	45.25	29.34	7.96	7.06
A-05	3.22	21.77	45.27	29.35	7.96	7.13
A-06	3.33	21.74	45.33	29.39	7.98	6.56
A-07	2.55	21.91	45.23	29.32	7.97	6.90
A-08	2.61	21.76	45.29	29.36	7.99	7.10
A-09	2.62	21.70	45.12	29.24	7.99	7.31
A-10	2.50	21.90	45.24	29.32	7.97	6.85
A-11	3.00	21.99	45.27	29.34	7.97	6.67
A-12	3.19	21.62	45.23	29.32	7.96	7.04
A-13	2.67	21.66	45.09	29.22	7.99	7.23
A-14	2.90	21.64	45.10	29.23	7.98	7.25
A-15	2.27	21.77	45.32	29.38	7.98	7.20
A-16	2.66	21.82	45.18	29.28	7.98	7.12
A-17	3.70	22.05	45.32	29.38	7.97	6.77

Table 3-1. (Continued)

Station	Depth (m)	Temperature (°C)	Conductivity (mS/cm)	Salinity (ppt)	pH	Dissolved Oxygen (mg/l)
Area B						
B-01	5.45	23.90	44.09	28.46	8.02	6.84
B-02	2.99	23.99	44.23	28.57	8.00	6.72
B-03	3.67	24.24	44.18	28.52	8.03	6.97
B-04	2.97	24.03	44.24	28.57	8.01	6.66
B-05	4.91	24.26	44.29	28.6	8.06	7.26
B-06	3.49	24.51	44.30	28.6	8.07	7.18
B-07	3.95	24.55	44.35	28.64	8.08	7.33
B-08	3.67	24.57	44.34	28.63	8.05	7.21
B-09	3.23	24.58	44.33	28.63	8.07	7.35
B-10	5.50	24.20	44.00	28.39	8.05	6.98
B-11	4.13	24.18	44.20	28.54	8.04	6.99
B-12	5.66	24.25	44.27	28.59	8.07	7.37
B-13	3.44	24.36	44.12	28.48	8.09	7.50
B-14	5.47	24.17	44.15	28.5	8.07	7.24
B-15	5.35	24.22	44.06	28.44	8.06	7.08
B-16	4.30	24.57	44.41	28.68	8.07	7.23
B-17	4.91	24.61	44.33	28.62	8.09	7.41
Area C						
C-01	5.14	23.76	44.81	28.98	8.06	6.74
C-02	4.32	23.91	44.22	28.56	8.14	7.09
C-03	4.26	23.83	44.64	28.86	8.08	6.85
C-04	5.34	23.77	44.73	28.92	8.07	6.79
C-05	4.50	23.78	44.65	28.87	8.07	6.74
C-06	5.38	23.80	44.48	28.74	8.09	6.62
C-07	4.39	23.77	44.60	28.83	8.07	6.76
C-08	5.07	23.75	44.82	28.99	8.07	6.72
C-09	5.15	23.76	44.75	28.95	8.07	6.73
C-10	4.96	23.92	44.24	28.57	8.12	6.98
C-11	4.67	23.76	44.60	28.83	8.08	6.71
C-12	5.69	23.80	44.70	28.90	8.07	6.74
C-13	5.09	23.84	44.42	28.70	8.10	6.74
C-14	5.30	23.72	44.58	28.82	8.11	6.50
C-15	4.15	24.10	44.22	28.55	8.12	6.97
C-16	4.49	23.84	44.61	28.84	8.09	6.82
C-17	4.95	23.84	44.61	28.84	8.09	6.80

3.1.2 Sediment Characteristics

Sediments taken from sampling stations in both borrow Areas A and C were mostly clean sand (< 10% silt/clay percentage) with particle distributions in the fine to coarse sand category (Appendix C, Table 3-2). Sediments collected from borrow Area B were less uniform. Three general categories of sediment types were detected in Area B. Stations 02, 03, 04, 07, 11, and 13 had clean sandy sediments similar to those identified in Areas A and C (Table 3-2). Stations 01, 12, 14, and 17 had a muddy sand mix with silt/clay percentages between 11 and 27%. Predominantly muddy stations, with silt/clay percentages between 59 and 92 were collected from stations 05, 06, 08, 09, and 16 (Table 3-2).

When the location of the three sediment types were mapped on the station map for Area B, a sediment distribution pattern was detected. Stations exhibiting muddy sediments where located in the southern section of the borrow (Figure 3-1). Stations that were predominantly sandy were located to the east of the borrow area, closer to the shore-line. Stations exhibiting a muddy sand mix were located in the more northern region and central region of the borrow area (Figure 3-1).

Table 3-2. Sediment characteristics for each station sampled within the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

Station	Percent Silt/Clay	Percent Sands	TOC (%)
Area A			
A-01	2.60	97.40	0.43
A-02	1.59	98.41	0.45
A-03	2.39	97.61	0.47
A-04	8.98	91.02	0.68
A-05	9.70	90.30	0.76
A-06	3.41	96.59	0.62
A-07	1.63	98.37	0.43
A-08	1.79	98.21	0.47
A-09	3.15	96.85	0.43
A-10	1.37	98.63	0.39
A-11	2.39	97.61	0.61
A-12	7.23	92.77	0.52
A-13	2.65	97.35	0.39
A-14	7.28	92.72	0.55
A-15	1.72	98.28	0.46
A-16	1.57	98.43	0.40
A-17	2.48	97.52	0.47

Table 3-2. (Continued)

Station	Percent Silt/Clay	Percent Sands	TOC (%)
Area B			
B-01	18.60	81.40	1.74
B-02	1.66	98.34	0.74
B-03	5.71	94.29	0.54
B-04	1.49	98.51	0.40
B-05	87.53	12.47	4.00
B-06	78.69	21.31	4.88
B-07	1.80	98.20	0.33
B-08	85.28	14.72	5.17
B-09	92.41	7.59	7.34
B-10	25.51	74.49	1.06
B-11	1.63	98.37	0.30
B-12	11.50	88.50	1.32
B-13	1.69	98.31	0.33
B-14	27.10	72.90	1.73
B-15	24.04	75.96	1.24
B-16	58.61	41.39	2.61
B-17	17.14	82.86	1.39
Area C			
C-01	2.02	97.98	0.35
C-02	3.60	96.40	0.51
C-03	1.52	98.48	0.40
C-04	2.83	97.17	0.48
C-05	1.54	98.46	0.39
C-06	2.63	97.37	0.50
C-07	2.79	97.21	0.61
C-08	1.91	98.09	0.42
C-09	1.64	98.36	0.31
C-10	6.46	93.54	0.63
C-11	1.79	98.21	0.44
C-12	3.00	97.00	0.51
C-13	3.27	96.73	0.53
C-14	5.76	94.24	0.70
C-15	2.42	97.58	0.39
C-16	1.55	98.45	0.39
C-17	1.80	98.20	0.40

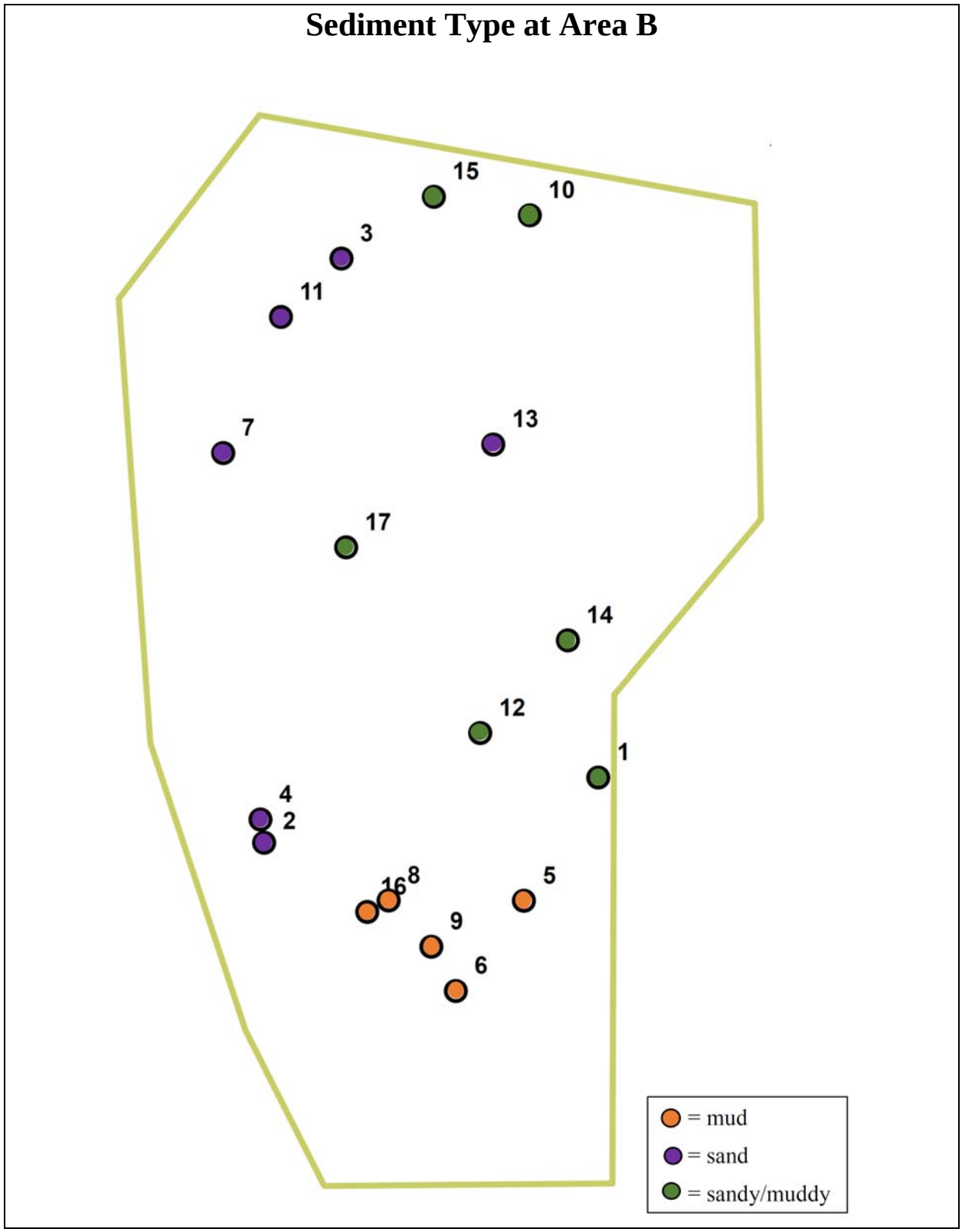

Figure 3-1. Sediment habitats based on surface grain-size analysis at each sampling station within Area B

3.2 BENTHIC COMMUNITY CHARACTERISTICS

3.2.1 Community Composition

A total of 130 distinct taxa were collected from the 3 potential borrow areas near the Prime Hook National Wildlife Refuge (Table 3-3). Twenty-eight of the taxa collected are classified as epifaunal species meaning that they live either on the surface of the sediments, attached to a surface structure (i.e., rocks or shells) or in the near-by water column as opposed to infaunal species which live within the sediments (Table 3-3). Sixty-four of the taxa identified from the 3 borrow areas were present in at least 10% of the samples while 66 were present in less than 10% of the sampling stations. Of those 66, 20 taxa were only collected at one of the 51 total sampling stations (Table 3-3). Of the 130 taxa, 54 were polychaete worm taxa, 39 were arthropod crustacean taxa, and 22 were molluscs (clams or snails, Table 3-3). Individual taxa abundance and biomass collected from each station is presented in Appendix D.

Overall community composition based on abundances of major taxonomic groups was similar between Areas A and B (Figure 3-2). Both of these areas were dominated by amphipod crustaceans followed by polychaete worms. Area C, however, had a greater percentage of polychaete worms followed by similar percentages of oligochaete worms, other crustaceans, and amphipod crustaceans (Figure 3-2).

Community composition at individual stations within a borrow area displayed differing patterns. In Area A, although amphipod crustaceans dominated the community composition overall, some stations (i.e., 04, 05, 12, and 14) had greater percentages of polychaetes (Figure 3-3). At Area B, amphipods dominated the community composition over all stations (Figure 3-2) but they were only dominant at 5 of the 17 individual stations (01, 12, 14, 15, and 17, Figure 3-3). Because they were present in such high numbers at these five stations, they contributed the most to the overall community composition of the borrow area (Appendix E). Individual stations at Area C displayed various differences in terms of community composition which in turn led to the more evenly distributed pattern displayed over the area as a whole (Figure 3-2). For example, Station C-01 had more molluscs, Station C-05 had more amphipods, Station C-10 had more polychaetes, Station C-15 had more oligochaetes, and Station C-16 had more crustaceans (Figure 3-3).

3.2.2 Benthic Community Parameters

Number of taxa collected from all 51 stations ranged from a low of 9 at B-09 to a high of 45 at C-10 (Appendix D). Overall, Area B had the highest mean number of taxa (Figure 3-4) but the variability between stations was also highest in Area B (Figure 3-5). No significant difference between the 3 borrow areas in terms of number of taxa was detected.

Total abundance was also, on average, greater at Area B compared to the other 2 areas (Figure 3-4). Since the variability between the stations at Area B was large and no significant difference in mean abundance was detected between the three borrow areas (Figure 3-5). At

Table 3-3. List of all species collected from the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

Taxonomic Group	Taxonomic Family	Taxon	Total Collected (#/m2)	Number of Stations Found
Cnidaria : Anthozoa	Cerianthidae	*Ceriantheopsis americanus*	45	2
	Edwardsiidae	*Edwardsia elegans*	705	14
Nemertina	Amphiporidae	*Amphiporus bioculatus*	1,114	22
	Carinomidae	*Carinoma* spp.	2,273	30
	Cerebratulidae	*Cerebratulus lacteus*	91	4
	Lineidae	*Micrura* spp.	182	8
	Tubulanidae	*Carinomella lactea*	2,568	14
		Nemertina	2,477	25
Platyhelminthes : Turbellaria	Stylochidae	*Stylochus ellipticus* *	136	5
Annelida : Oligochaeta		Oligochaeta	10,977	28
Annelida : Polychaeta	Ampharetidae	*Asabellides oculata*	955	10
	Arabellidae	*Dipolydora socialis*	68	2
		Drilonereis longa	23	1
	Capitellidae	*Amastigos caperatus*	341	9
		Heteromastus filiformis	523	12
		Mediomastus ambiseta	44,818	27
	Chaetopteridae	*Spiochaetopterus costarum*	1,591	14
	Cirratulidae	*Caulleriella venefica*	2,341	29
		Tharyx sp. A	4,500	23
	Dorvilleidae	*Parougia caeca*	136	4
	Glyceridae	*Glycera dibranchiata*	1,114	26
	Goniadidae	*Glycinde solitaria*	3,932	16
	Lumbrineridae	*Scoletoma tenuis*	23	1
	Magelonidae	*Magelona* spp.	68	3
	Maldanidae	*Clymenella torquata*	68	2
		Euclymene zonalis	182	5
		Maldanidae	432	13
		Sabaco elongatus	68	2
	Nephtyidae	Nephtyidae	182	7
		Nephtys bucera	591	12
		Nephtys picta	68	3
	Nereididae	*Neanthes arenaceodentata*	1,727	19
		Neanthes succinea	795	12
	Onuphidae	*Diopatra cuprea*	614	12
	Opheliidae	Opheliidae	159	5
		Travisia sp. A	523	11
	Orbiniidae	*Leitoscoloplos robustus*	4,159	38
		Scoloplos rubra	1,886	20
	Paraonidae	*Aricidea catherinae*	614	10
		Paradoneis sp. B	114	3
		Paraonis fulgens	159	2
		Paraonis pygoenigmatica	136	5
	Pectinariidae	*Pectinaria gouldii*	318	5

Table 3-3. (Continued)

Taxonomic Group	Taxonomic Family	Taxon	Total Collected (#/m2)	Number of Stations Found
Annelida : Polychaeta Cont'd	Phyllodocidae	*Eteone heteropoda*	23	1
		Eumida sanguinea	227	4
		Paranaitis speciosa	23	1
		Phyllodoce arenae	318	8
	Polygordiidae	*Polygordius jouinae*	318	10
	Polynoidae	*Lepidonotus sublevis* *	45	2
	Sabellariidae	*Sabellaria vulgaris* *	45	1
	Serpulidae	*Hydroides dianthus* *	23	1
	Sigalionidae	*Sigalion arenicola*	23	1
	Spionidae	*Dispio uncinata*	250	8
		Paraprionospio pinnata	568	8
		Polydora cornuta	23	1
		Scolelepis texana	3,750	29
		Spiophanes bombyx	1,318	24
		Streblospio benedicti	250	3
		Erinaceusyllis erinaceus	1,045	11
		Exogone dispar	182	4
		Parapionosyllis longicirrata	3,818	23
		Proceraea cornuta *	23	1
		Streptosyllis pettiboneae	636	8
	Terebellidae	*Polycirrus eximius*	227	2
Arthropoda : Amphipoda	Ampeliscidae	*Ampelisca abdita*	23,750	15
		Ampelisca vadorum	159	3
		Ampelisca verrilli	1,841	8
	Bateidae	*Batea catharinensis* *	2,341	12
	Corophiidae	*Monocorophium tuberculatum* *	5,227	16
	Haustoriidae	*Acanthohaustorius millsi*	9,477	27
		Bathyporeia quoddyensis	2,023	15
		Protohaustorius cf. *deichmannae*	7,068	23
	Isaeidae	*Microprotopus raneyi* *	3,409	14
	Ischyroceridae	*Cerapus tubularis* *	235,317	28
		Ericthonius brasiliensis *	318	4
	Liljeborgiidae	*Listriella barnardi*	568	15
	Oedicerotidae	*Americhelidium americanum*	114	4
	Phoxocephalidae	*Rhepoxynius hudsoni*	9,614	30
	Stenothoidae	*Paracaprella tenuis* *	45	1
		Parametopella cypris *	91	3
		Stenothoe minuta *	932	1
	Unciolidae	*Unciola irrorata*	182	1
		Unciola serrata	114	2
		Unciola spp.	45	2
Arthropoda : Cumacea	Bodotriidae	*Mancocuma stellifera*	205	5
		Pseudoleptocuma minor	68	1
	Diastylidae	*Oxyurostylis smithi*	795	19
	Leuconidae	*Leucon americanus*	2,932	10

Table 3-3. (Continued)

Taxonomic Group	Taxonomic Family	Taxon	Total Collected (#/m2)	Number of Stations Found
Arthropoda : Decapoda	Paguridae	*Pagurus longicarpus* *	841	20
	Pinnotheridae	*Pinnixa chaetopterana*	1,500	29
		Pinnixa retinens	23	1
	Porcellanidae	*Euceramus praelongus*	91	3
	Xanthidae	*Dyspanopeus sayi* *	250	6
		Rhithropanopeus harrisii *	23	1
Arthropoda : Isopoda	Anthuridae	*Cyathura burbancki*	409	6
		Ptilanthura tenuis	114	4
	Idoteidae	*Chiridotea caeca*	23	1
		Chiridotea tuftsi	23	1
		Edotea triloba *	1,341	13
		Synidotea laticauda *	91	4
	Sphaeromatidae	*Ancinus depressus*	68	2
Arthropoda : Mysidacea	Mysidae	*Americamysis bigelowi* *	45	2
Arthropoda : Tanaidacea	Nototanaididae	*Tanaissus psammophilus*	20,159	27
Mollusca : Bivalvia	Carditidae	*Cyclocardia borealis*	1,432	3
	Lyonsiidae	*Lyonsia hyalina*	91	3
	Mactridae	*Mulinia lateralis*	386	8
		Spisula solidissima	318	12
	Nuculanidae	*Yoldia limatula*	23	1
	Nuculidae	*Nucula proxima*	4,841	18
	Pandoridae	*Pandora gouldiana*	91	4
	Solenidae	*Ensis directus*	636	25
	Tellinidae	*Tellina agilis*	5,909	38
		Tellina tenella	68	3
	Veneridae	*Gemma gemma*	2,318	20
		Mercenaria mercenaria	182	5
Mollusca : Gastropoda	Calyptraeidae	*Crepidula fornicata**	318	10
		Crepidula plana *	91	3
	Columbellidae	*Astyris lunata* *	295	5
	Epitoniidae	*Epitonium rupicola* *	182	2
	Nassariidae	*Nassarius trivittatus*	227	8
	Pyramidellidae	*Odostomia engonia* *	23	1
		Turbonilla interrupta *	114	2
	Scaphandridae	*Acteocina canaliculata*	8,477	16
	Turridae	*Kurtziella atrostyla* *	68	3
		Nudibranchia *	114	2
Echinodermata : Holothuroidea	Phyllophoridae	*Pentamera pulcherrima*	91	4
Echinodermata : Echinoidea		Echinoidea	23	1
Hemichordata	Harrimaniidae	*Saccoglossus kowalevskii*	5,341	34
Chordata : Ascidiacea		Ascidiacea *	250	5
Chordata : Cephalochordata	Branchiostomidae	*Branchiostoma caribaeum*	136	4

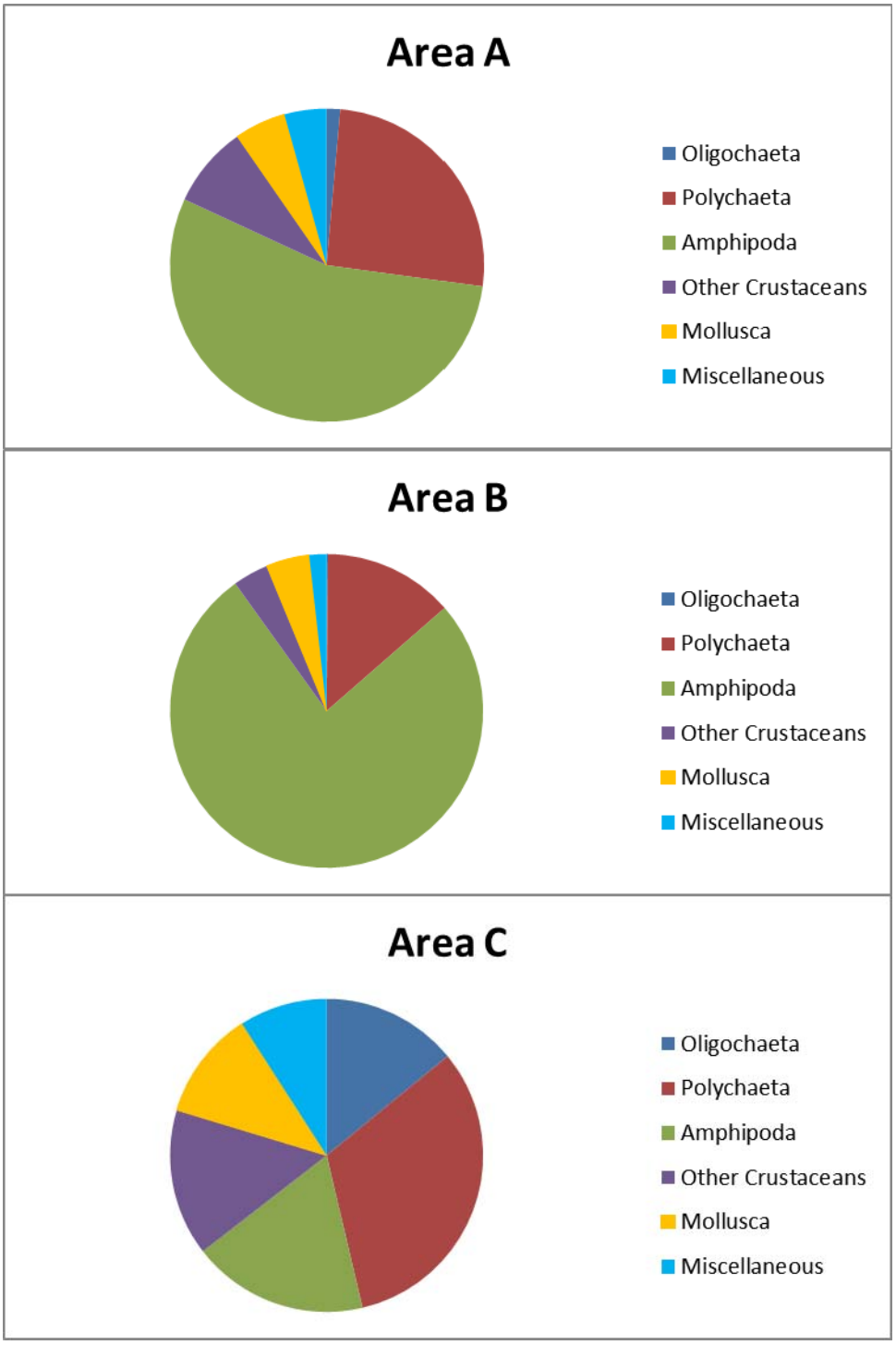

Figure 3-2. Overall percent contribution of major taxonomic groups to the benthic community composition at each of the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

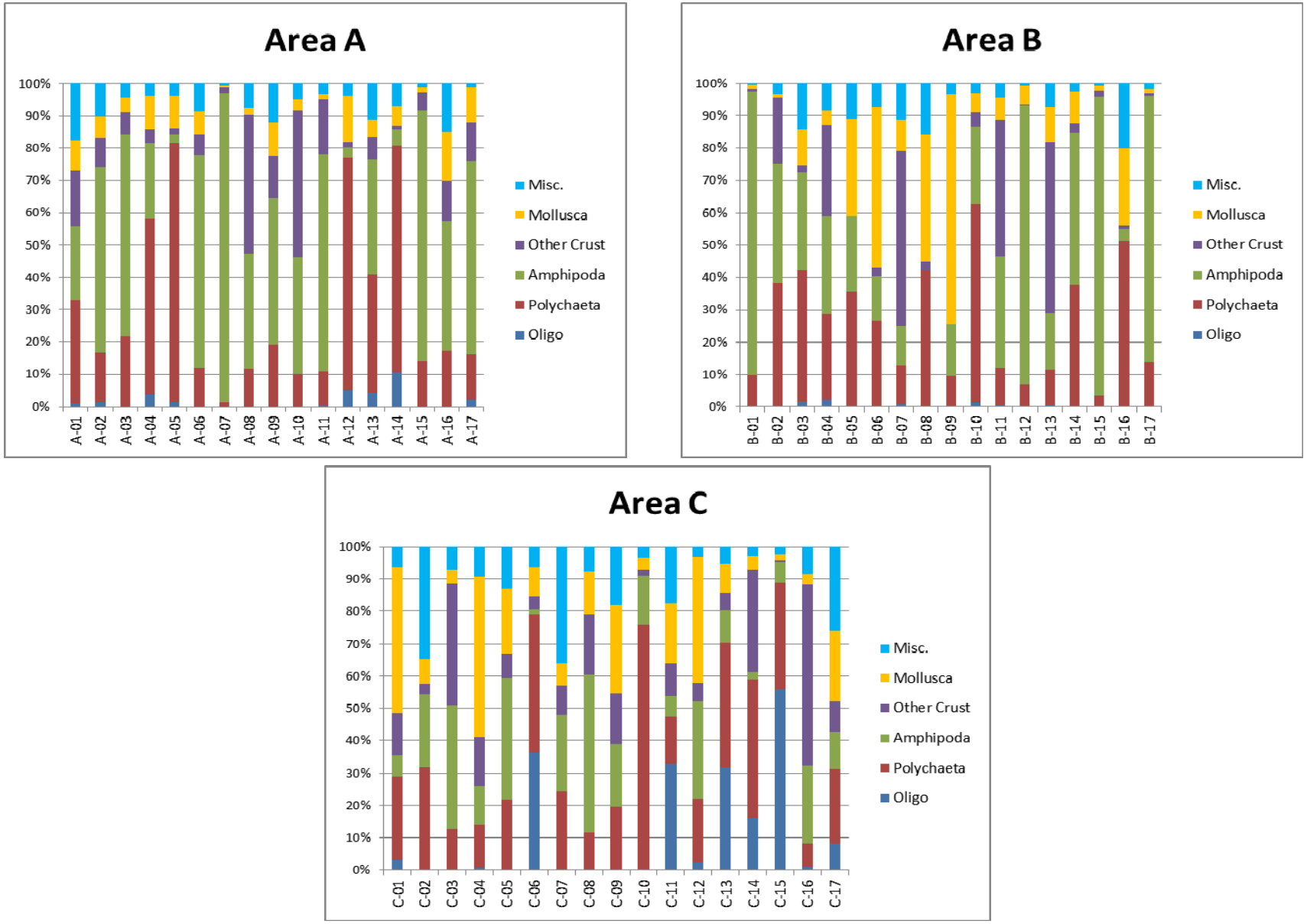

Figure 3-3. Percent contribution of major taxonomic groups at each station sampled within the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

Area A total abundance ranged between 1,977 to 27,386 (inds/m^2), however the bulk of the stations (12) had less than 4,000 (inds/m^2, Appendix D). Total abundance at Area B ranged from a low of 864 at Station B-08 to a high of 83,318 (inds/m^2) at Station B-15 (Appendix D). Six stations in Area B had abundances greater than 10,000 (inds/m^2, Figure 3-5). Area C had total abundances ranging from 1,409 to 11,114 (inds/m2) but 13 stations had abundances less than 4,000 (inds/m^2, Appendix D, Figure 3-5). No significant difference in mean total abundance was detected between the three borrow areas.

Mean total biomass was highest in Area B and lowest in Area C but no significant difference between the borrow areas was detected (Figure 3-4). Individual station patterns in total biomass did not follow the same patterns as total abundance. For example, Station B-15 had by far the greatest abundance but Station B-11 had the greatest biomass of all stations (Figure 3-5). Other stations with high total abundances did not have equally high total biomass, indicating that individuals collected from these high abundance areas were generally small in size.

3.2.3 Individual Borrow Comparisons

Examination of individual station locations and their benthic communities can reveal patterns in benthic abundance and number of taxa distributions within a borrow area as well as habitat differences related to sediment type.

Area A

As previously noted, all of the stations sampled within Area A were clean sand habitats (< 10% silt/clay, Table 3-2). Except for the region around Station A-07, all regions within Area A had similar abundance patterns (Figure 3-6). Station A-13, located in the north-west corner of the borrow area, and A-11, located in the north-east section of the borrow area had the highest number of taxa (Figure 3-6). The two most abundant taxa collected from the 17 stations in Area A were the small, tube-building epifaunal amphipod crustacean, *Cerapus tubularis* and the small opportunistic polychaete worm, *Mediomastus ambiseta* (Appendix Table D-1). A total of 27,613 individual *C. tubularis* (per m^2) were collected from the 17 stations, however, 23,523 of these individuals were collected from one station (A-07). Of the total 13,023 (per m^2) *M. ambiseta* individuals collected within Area A, 12,295 were collected from three stations (04, 05, 12), all located in the south-west corner of the borrow area (Figure 3-6).

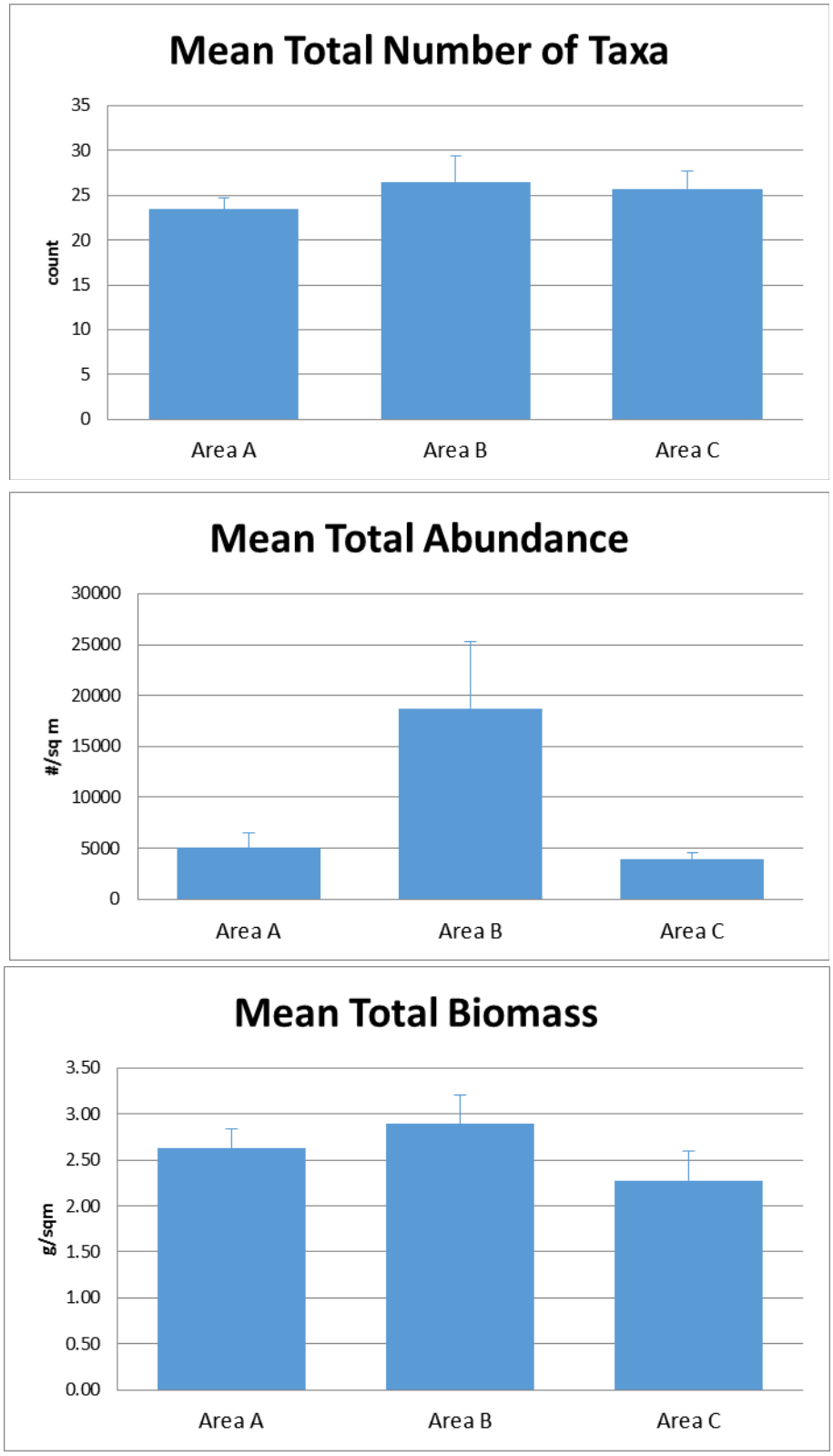

Figure 3-4. Mean number of taxa, total abundance, and total biomass from each of the three borrow areas sampled near the Prime Hook National Wildlife Refuge, 2014

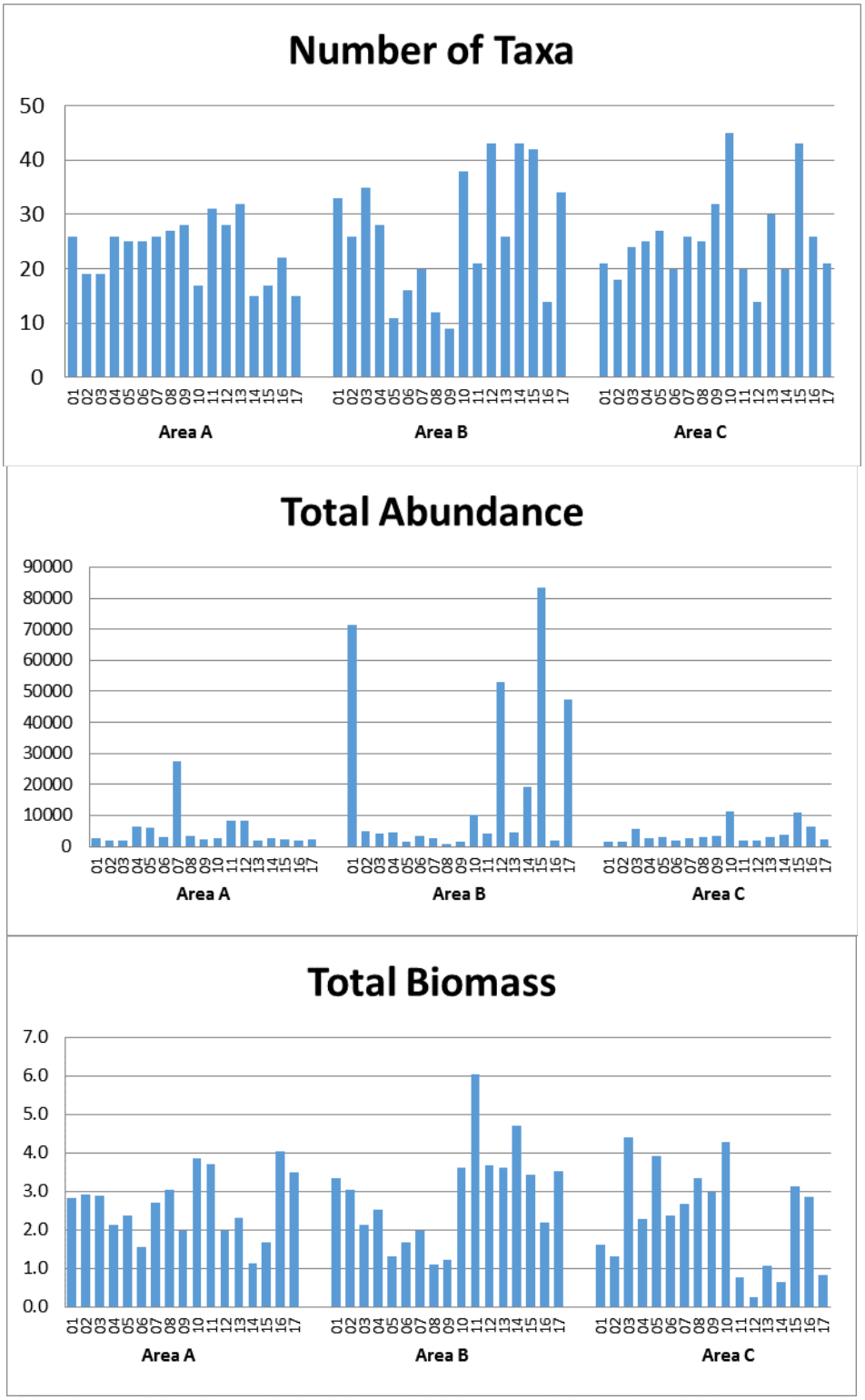

Figure 3-5. Number of taxa, total abundance, and total biomass at each of the 51 stations sampled in the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

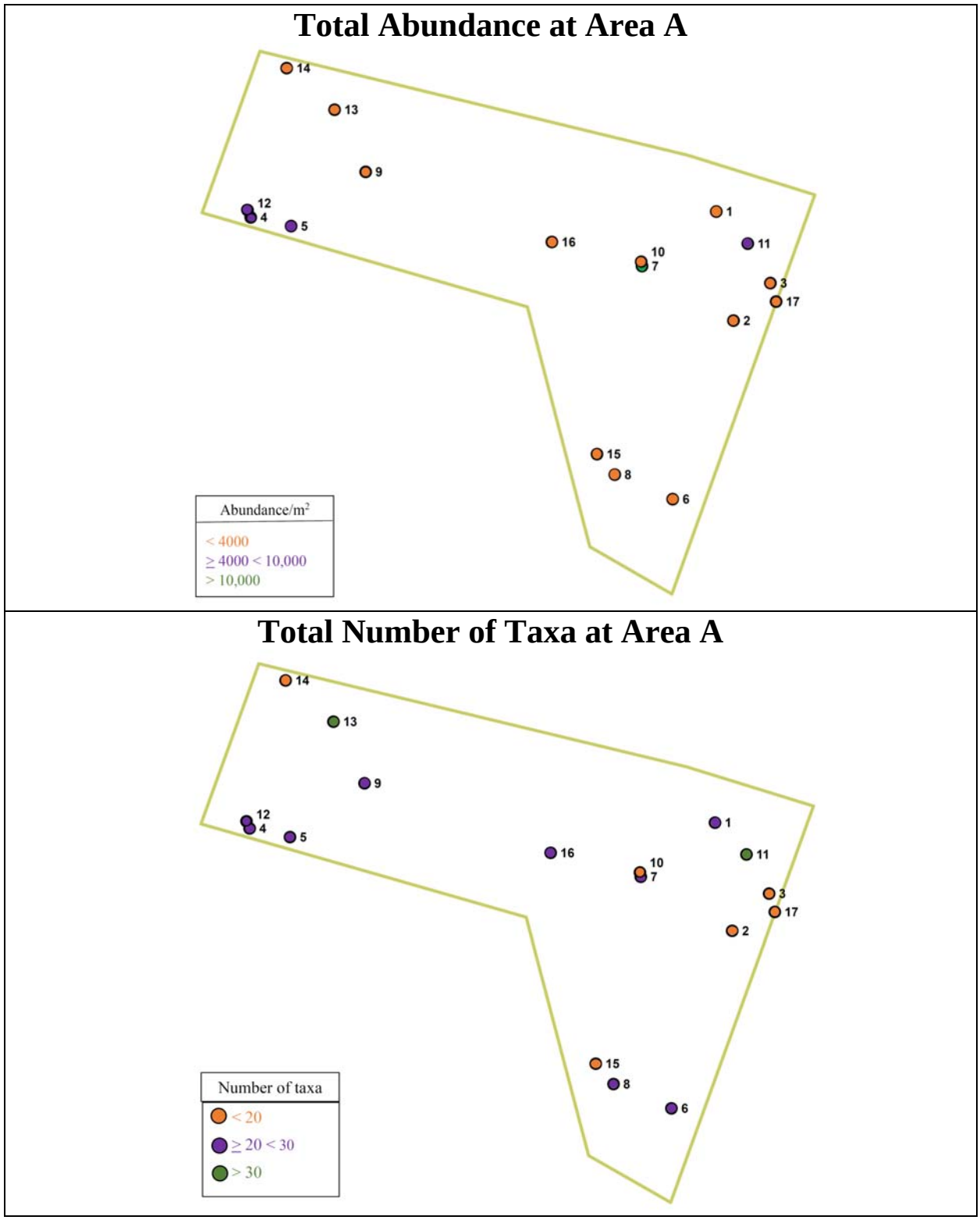

Figure 3-6. Total abundance (top) and number of taxa (bottom) measured at each sampling station within Area A near the Prime Hook National Wildlife Refuge, 2014

Area B

Area B station differences in terms of number of taxa and number of benthic specimens were closely associated with the sediment habitat at each station. The muddy sites located in the southern region of the borrow (Figure 3-1) had the least number of taxa collected and the least number of organisms in terms of abundance (Figure 3-7). The stations with the most benthic taxa and abundance were the muddy sand stations. These stations had, on average, double the amount of specimens collected than the other two sediment types (Figure 3-7).

The six muddy sand stations (B-01, 10, 12, 14, 15, and 17) also had similarities in terms of individual species abundances. For example, all of these stations had high numbers of the polychaete *Mediomastus ambiseta*, and most of them had high numbers of the amphipod, *Ampelisca abdita, Cerapus tubularis* or both (Appendix Table D-2). Sandy stations (B-02, 03, 04, 07, 11, and 13) had higher numbers of the small crustacean *Tanaissus psammophilus* and haustorid amphipods (Appendix Table D-2). This is not unusual as these species have an affinity for living in sandy habitats along the mid-Atlantic coast. Although Station B-7 had lower abundances than the other sandy stations, the species composition of this station was similar to the other sandy stations. The muddy stations, on whole, had lower abundances and number of taxa than the stations with more sand content. The most abundant taxon associated from these stations was the small gastropod snail *Acteocina canaliculata* (Appendix Table D-2).

Area C

In Area C, only 2 stations (C-10 and C-15) had abundances over 10,000 (inds/m2) and both of these stations were located in the western portion of the borrow area (Figure 3-8). These same two stations, along with C-09 and C-13 had the most taxa as well (Figure 3-8). All of the stations within Area C had sandy sediments with very little silt/clay particles (Table 3-2) so no patterns in sediment/benthic community was detected. The top 2 most abundant taxa, the small opportunistic Oligochaeta worms (9,318 inds/m2) and small polychaete worm, Mediomastus ambiseta (7,636 inds/m2) were collected in the greatest numbers at the two stations with the highest abundance (Appendix Table D-3). The third most abundant species, the small crustacean, Tanaissus psammophilus was collected in the greatest numbers at the two stations with overall abundances greater than 4,000 (inds/m2, Stations C-03 and C-16, Figure 3-8).

3.2.4 Bray-Curtis Similarity Results

The Multi-Dimensional Scaling (MDS) program run on all 51 stations within the three borrow areas resulted in the differentiation of two relatively distinct station groups (Figure 3-8). The stations in Area B that had more than 10% silt/clay sediment particles in the sediment composition had benthic communities more similar to each other than the stations in all three areas with a clean sand habitat (< 10% silt/clay, Figure 3-9).

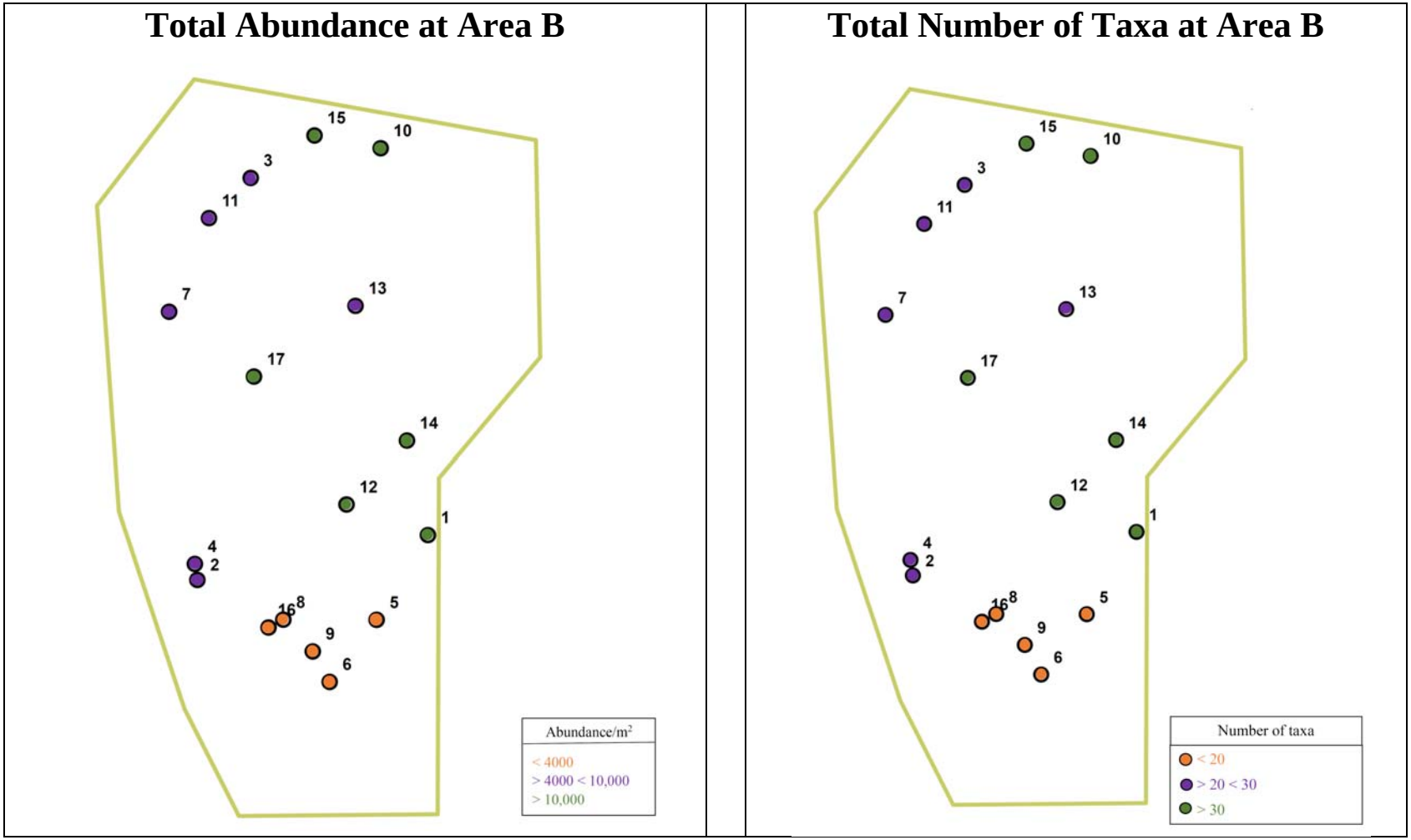

Figure 3-7. Total abundance (left) and number of taxa (right) measured at each sampling station within Area B near the Prime Hook National Wildlife Refuge, 2014

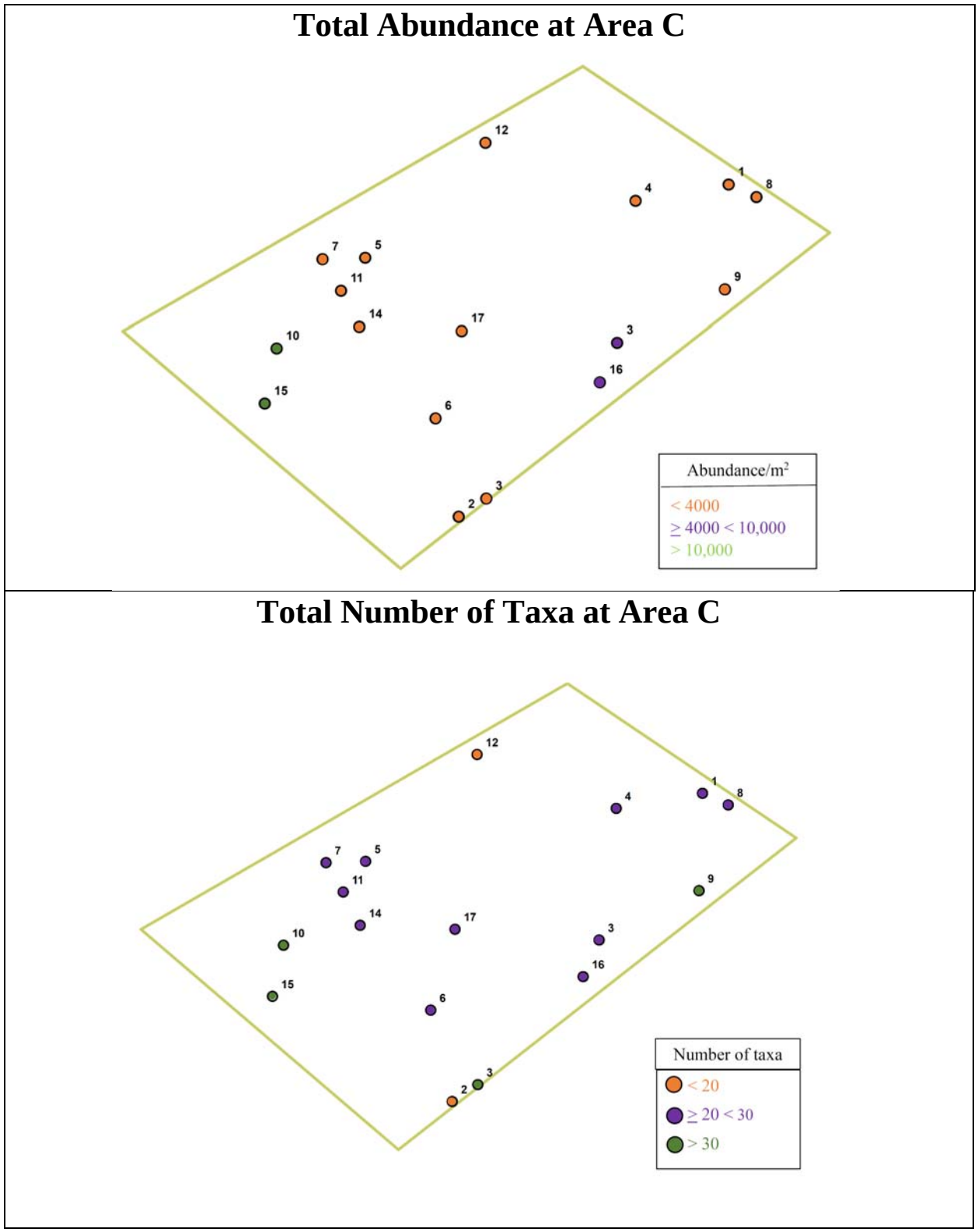

Figure 3-8. Total abundance (top) and number of taxa (bottom) measured at each sampling station within Area C near the Prime Hook National Wildlife Refuge, 2014

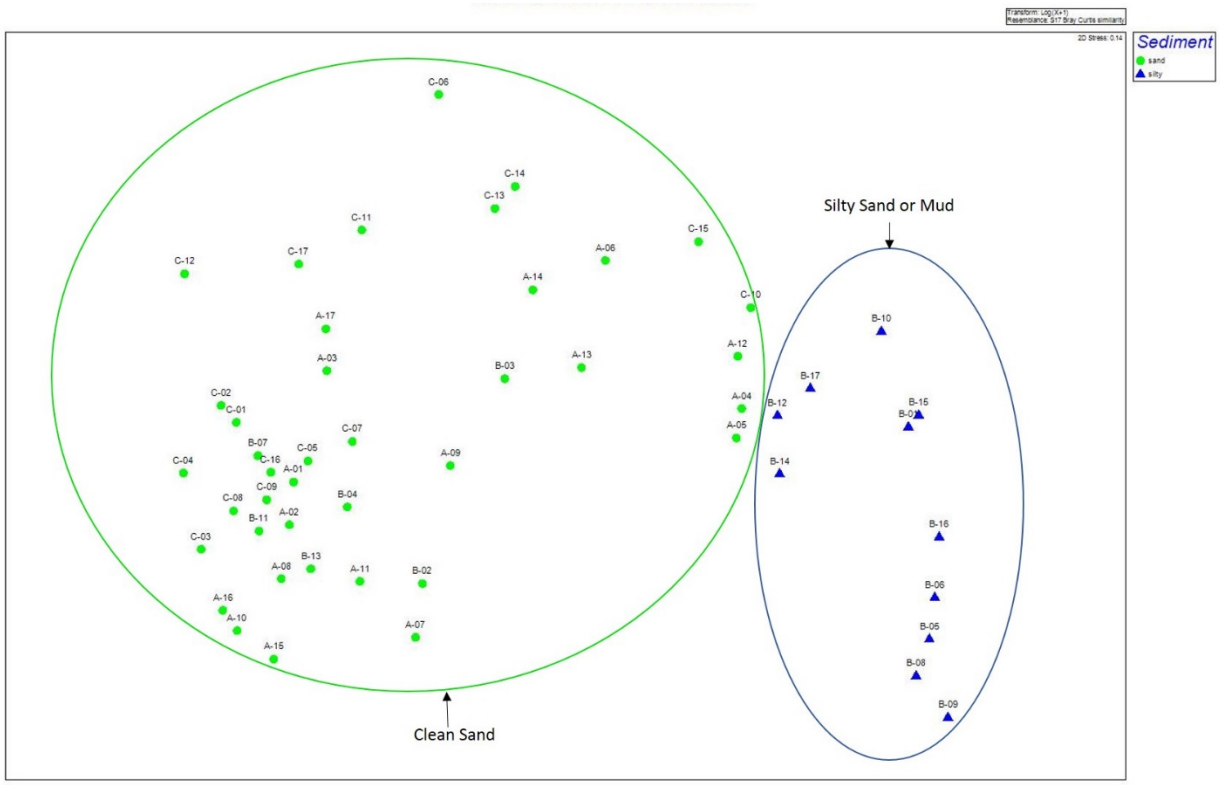

Figure 3-9. Multiple Dimensional Scaling (MDS) results depicting the similarities in macrobenthic community abundances as determined by Bray-Curtis Analysis for the 51 stations sampled at the three potential borrow areas near Prime Hook National Wildlife Refuge, 2014

3.2.5 Commercially Important Species

Overall, only two commercially important species, the surf clam (*Spisula solidissima*) and the hard clam (*Mercenaria mercenaria*) were collected from the three borrow areas near Prime Hook. These species were collected in very small numbers (< 46/m^2) from the stations where present and *Mercenaria* were only collected from Area B (Appendix D). The location of the stations with either *Spisula*, *Mercenaria*, or both are provided in (Figures 3-10 to 3-12).

3.3 EPI-BENTHIC SURVEY

Nine taxa were collected during the tows but no large commercially important clams or oysters were collected from any of the tows (Table 3-4). The knobbed whelk was the most abundant species collected and was found at 11 of the 15 sampling stations. There was no evidence of large colonies of the sand reef building worm *Sabellaria vulgaris* in any of the borrow areas.

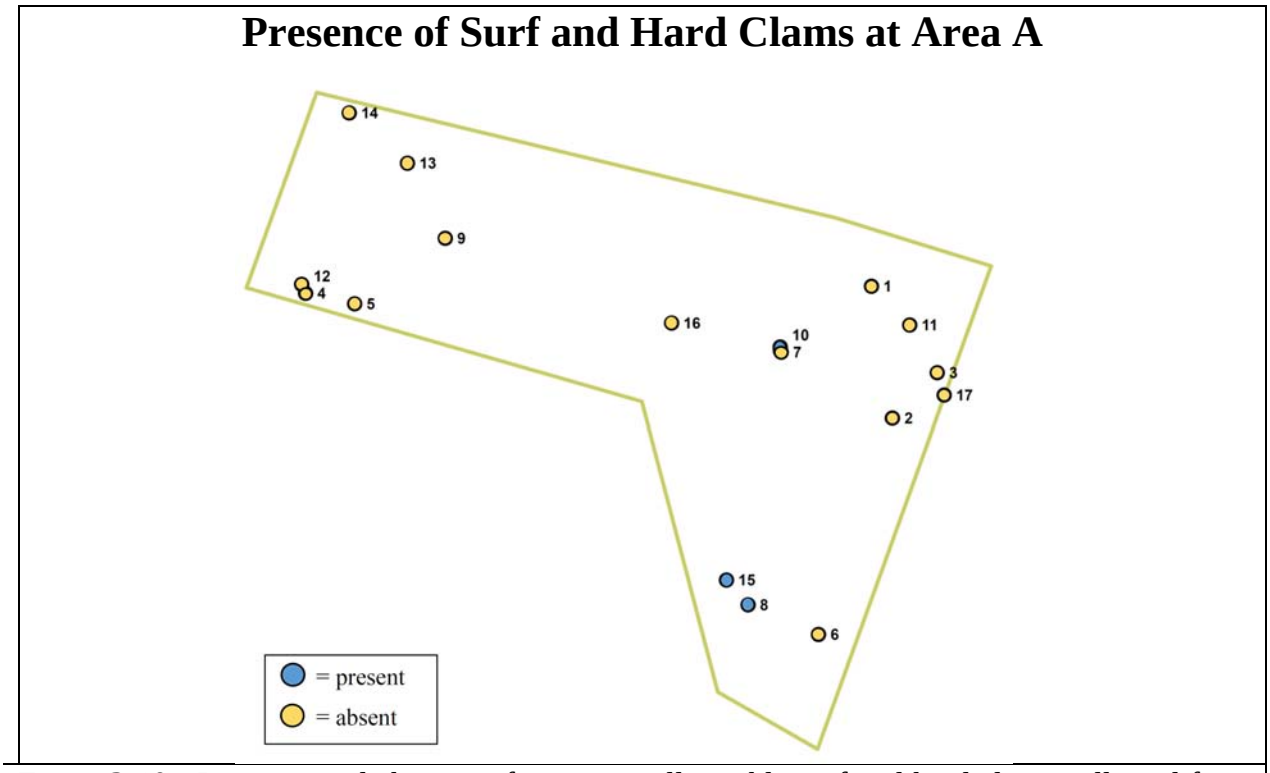

Figure 3-10. Presence and absence of commercially viable surf and hard clams collected from grab samples collected at each sampling station within Area A

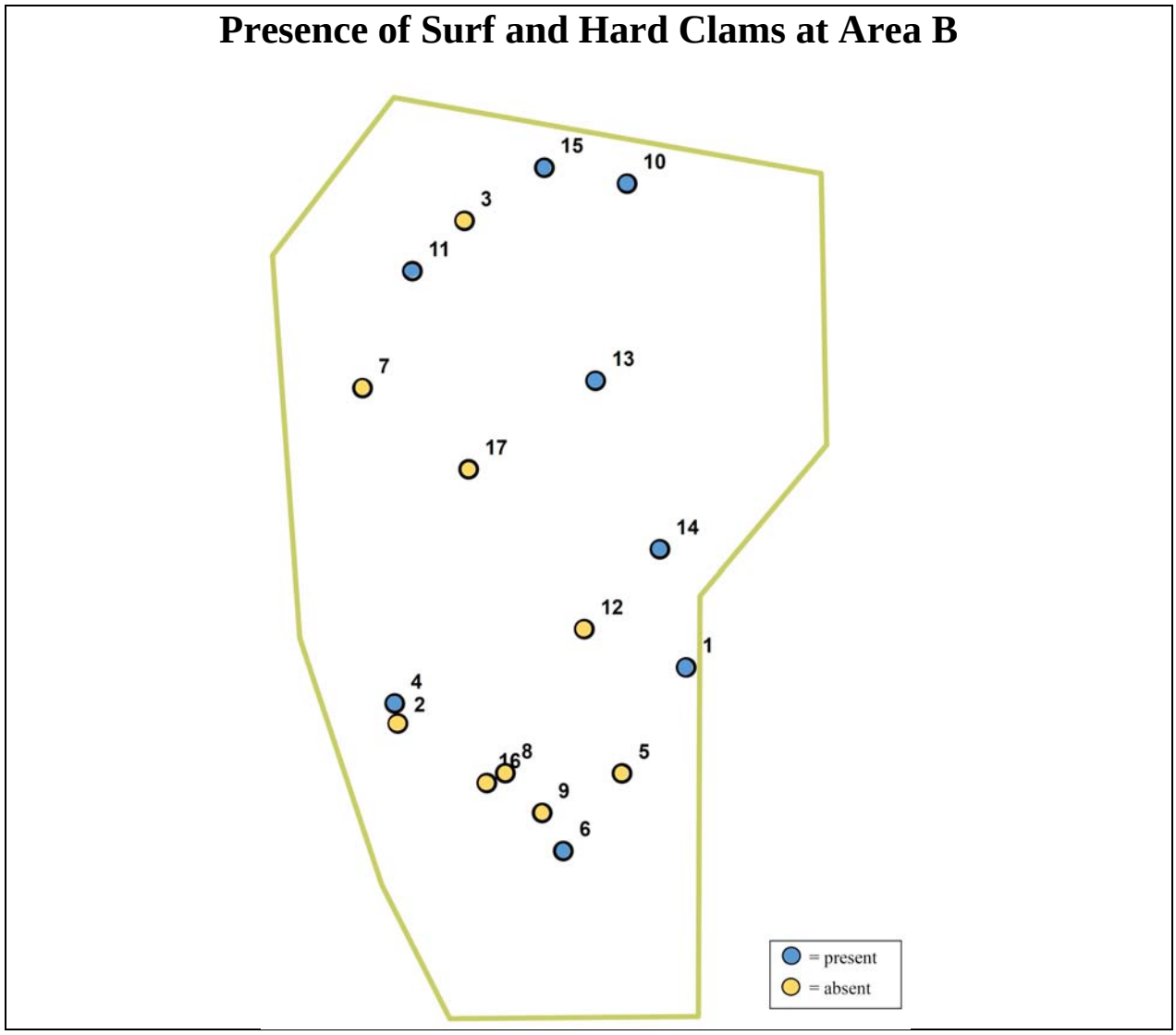

Figure 3-11. Presence and absence of commercially viable surf and hard clams collected from grab samples collected at each sampling station within Area B

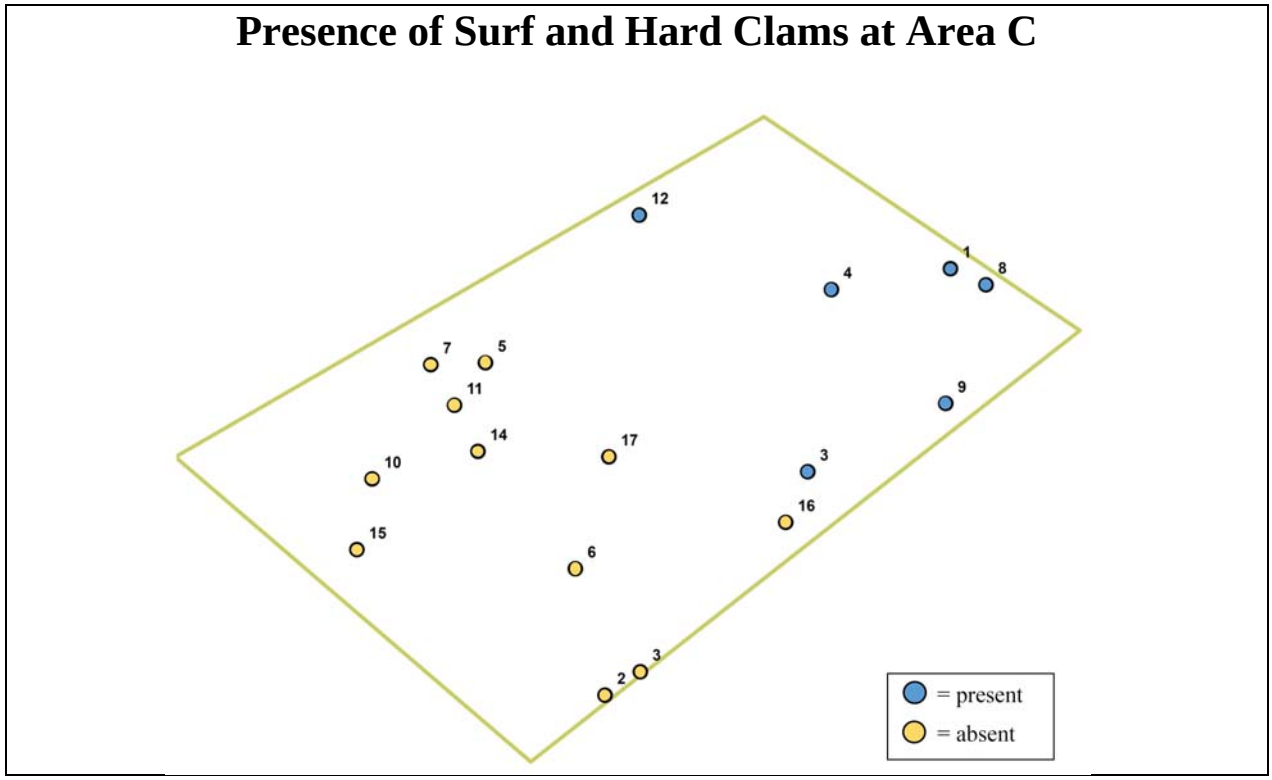

Figure 3-12. Presence and absence of commercially viable surf and hard clams collected from grab samples collected at each sampling station within Area C

Table 3-4. Results of epi-benthic tows at 5 stations sampled in Areas A, B, and C near the Prime Hook National Wildlife Refuge

Station	Tow time (minutes)	Knobbed Whelk	Horse-shoe Crab	Blue Crab	Lady Crab	Hermit Crab	Sponge	Sand Dollar	Spider Crab	Mud Crab
Area A										
A-01	4	1		1		1	1			2
A-06	4	4			1					
A-09	4				1	1				
A-12	4	5			1					
A-16	4							1		
Area B										
B-03	2	5	1							
B-04	5				1					
B-07	2		1				1			
B-10	2	17					1			2
B-17	3	2								
Area C										
C-02	4	2			3	1	1			
C-03	4	2								
C-04	4	6	1				1			3
C-15	4	14	1			1			12	
C-17	4	2		1	1		1			2

4.0 DISCUSSION

Dredging of sediments from a borrow area can have immediate localized effects on the benthic macroinvertebrate community and clam populations. The most direct affect is the removal of the existing natural, established communities. Survival of organisms during dredging and recolonization after the disturbance can vary widely. The benthic community can be initially decimated but resettling and recolonization can be rapid, typically taking from three months to a few years for complete recovery (Saloman et al. 1982, Van Dolah et al. 1984, and Hirsch et al. 1978). Longer-term impacts to the existing benthic community can occur if the habitat conditions within the area are changed during dredging operations.

One way of evaluating the possible impacts of dredging on the benthic communities within a potential borrow area is to examine the existing conditions prior to dredging in terms of the community's ability to recover from a disturbance. The benthic community existing in all three borrow areas examined near Prime Hook consisted of a mix of species typical to estuarine and marine salinity regimes. The community, overall, was not unique to the lower Delaware Bay area and was similar to other communities studied in this region (Kelley and Scott 1996, Scott 2003 and 2008). The commonality and ubiquity of the dominant species in the three areas near Prime Hook will allow for an abundant supply of nearby organisms capable of rapid recovery after a dredging disturbance.

Additionally, the communities, on whole, consisted of species with opportunistic life-history characteristics that include short-lived, high fecundity and high productivity that result in high abundance and low biomass. This type of community has a great ability to rapidly recover from disturbances whether natural or anthropogenic. The most abundant species collected for this study, including the tube-building amphipod *Cerapus tubularis*, the polychaete worm *Mediomastus ambiseta*, another tube-building amphipod *Ampelisca abdita*, the small tanaid crustacean *Tanaissus psammophilus*, and small worm Oligochaeta were collected in high numbers but because they and most of the other species collected from the borrow areas were small in size, the overall biomass in the three borrow areas was low.

Comparisons of benthic community characteristics found in previous studies can provide insight into the recovery potential of the borrow areas examined near Prime Hook after a dredging disturbance. Previous studies conducted in the lower Delaware Bay near the Cape May area documented similar benthic community patterns and species to the ones collected for this current study. Pre- and post-dredge studies conducted in these areas showed that the communities had recovered within a few years after dredging cessation and that differences detected were due to sediment habitat differences (Scott 2005, 2007, and 2012).

Benthic community characteristics documented at each station within the three Prime Hook borrow areas were associated with the sediment type at the station. All of the stations sampled in Areas A and C and 6 stations in Area B had predominantly clean sand (i.e., very little silt/clay) and at these sites, benthic species with an affinity for sand, such as haustorid amphipods and the small tanaid crustacean *Tanaissus psammophilus*, were prevalent. Sampling sites in Area B that had predominantly either silty/sand or mud sediments (i.e., > 10% silt/clay)

had higher numbers of species such as the polychaete *Mediomastus ambiseta*, the gastropod *Acteocina canaliculata*, and the small clam, *Nucula proxima.* Samples differentiated by sediments had similar benthic assemblages as grouped by the Bray-Curtis coefficient.

Overall, commercially important species such as the surf clam (*Spisula solidissima*) and the hard clam (*Mercenaria mercenaria*) were only present in very small numbers in the grab samples collected from the borrow (< 46/m^2). Additionally, they were only collected in a third (17) of the total 51 stations examined in the three borrow areas. During the epi-benthic dredge survey, no large commercially important clams or oysters were collected from any of the tows and there was no evidence of large colonies of the sand reef building worm *Sabellaria vulgaris* in the borrow areas.

In conclusion, the benthic communities inhabiting the three borrow areas near the Prime Hook National Wildlife Refuge as documented in this pre-dredge survey are common along the lower Delaware Bay coastline. These communities typically consist of species capable of quickly recovering from either natural or anthropogenic disturbances such as dredging. The majority of the taxa collected have life history attributes that would allow them to quickly recover from dredging operations either by recruitment of new juveniles or by mobile adults from nearby undisturbed areas. Benthic assemblage differences detected due to sediment habitat differences will not preclude an area from consideration for dredging since these habitat differences are common to lower estuaries as is the communities inhabiting them. Dredging operations in any of the three borrow areas should have little to no impact on commercially important species populations since so few juveniles were documented from the areas and no adults were present.

5.0 REFERENCES

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APPENDIX A

SCOPE OF WORK

SCOPE OF WORK

LOWER DELAWARE BAY
PRIME HOOK NATIONAL WILDLIFE REFUGE
DUNE BREACH REPAIR PROJECT

PRE-DREDGE BENTHIC AND CULTURAL RESOURCES MONITORING

Project Name: An Evaluation of the Benthic Community And Cultural Resources Within Potential Sand Sources for The Prime Hook National Wildlife Refuge

U.S. Fish and Wildlife Service Contact: Prime Hook National Wildlife Refuge, 11978 Turkle Pond Road, Milton, DE 19968. Project Biologist: Art Coppola, by telephone: (302) 684-8419; by email: arthur_coppola@fws.gov.

Corps District and Contact: Philadelphia District Corps of Engineers, Wanamaker Building, and 100 Penn Square East, Philadelphia, PA 19107-3390. **Project Biologist:** Barbara Conlin, Environmental Resources Branch, by telephone at (215) 656-6557 or by e-mail at Barbara.E.Conlin@usace.army.mil, and **Cultural Resource Specialist:** Nikki Minnichbach, Environmental Resources Branch by phone (215) 656-6556 or by e-mail at Nicole.C.Minnichbach@usace.army.mil.

INTRODUCTION

This scope of work is for the purpose of providing baseline data on benthic resources and an evaluation of the potential impacts to benthic resources from dredging within potential sand source area offshore of the lower Delaware Bay, Delaware coastline. The sand source areas could potentially provide sand necessary to replenish the lower Delaware Bay coastline that has incurred severe erosion due to storms and tidal flooding. The work to be performed will involve benthic grab sampling, epibenthic dredge sampling, water and sediment quality measurements, and cultural resources investigations.

Seventeen benthic grab samples will be collected from within each of 3 separate potential nearshore borrow areas as shown in Figure 1. The sample locations shall be positioned in a stratified random manner to give adequate representation throughout the borrow areas. The specific requirements for the benthic grab samples are detailed in Task 1. The corner point geographic coordinates for the benthic resources investigation are provided in Table 1 and displayed in Figure 1. The contractor shall obtain all appropriate collection permits from the State of Delaware to complete the field sampling tasks outlined in this scope of work.

A biological dredge will be utilized to assess the presence/absence of epibenthic organisms. This survey will be conducted by towing an biological dredge for 5 randomly selected locations within each of the three borrow areas. Lastly, cultural resources Phase

1a and Phase 1b surveys will also be performed for the three proposed borrow areas. The specific requirements for the cultural resources investigation requirements are detailed in Task 2.

Table 1. Geographic Coordinates of Area PHB-B (880 acres)

AREA CORNER POINTS	Easting (NAD83)	Northing (NAD 83)
#1	709044.307537	325010.995458
#2	713332.619391	324243.842427
#3	713386.321426	321501.099625
#4	712115.488093	319979.224625
#5	712099.863093	315734.953791
#6	709604.02976	315713.165597
#7	708921.738093	317064.728097
#8	708098.126982	319558.449162
#9	707825.019594	323414.473007

Geographic Coordinates of Area PHB-A (351 acres)

AREA CORNER POINT	Easting (NAD83)	Northing (NAD 83)
#1	714141.647169	313901.39451
#2	718619.077724	312813.720899
#3	719942.862446	312401.39451
#4	718449.603202	308230.5975
#5	717591.269869	308723.653056
#6	716938.284481	311230.294404
#7	713537.480502	312213.89451

Geographic Coordinates of Area PHB-C (599 acres)

AREA CORNER POINT	Easting (NAD83)	Northing (NAD 83)
#1	718909.615919	308384.467427
#2	724620.320795	311691.927434
#3	727684.615919	309613.634094
#4	722357.532585	305420.92576

Task 1: Benthic Infauna Grab Sampling and Water Quality Monitoring

1.1 Benthic Infaunal Sampling: at each benthic sampling station one sample shall be collected using a 0.04 m^2, stainless steel, Young Grab Sampler. Each "grab" will be at least 75% full and show no evidence of surface washout. A total of 17 sample stations shall be located within each of the three proposed borrow areas. The samples shall be distributed as stratified random.

Benthic macroinvertebrates will be sieved in the field using 500 um mesh and preserved (isopropyl, ethanol or 5% buffered formalin) for laboratory processing. No samples will be composited; all will be handled individually.

1.2 Grain Size Analysis: a sediment grab sample for substrate particle size and organic content analysis will be collected at each sample station using the same equipment. This sample will be subsampled, frozen, and then transported to the laboratory for analysis. In the laboratory, sediment samples will be analyzed for grain size using ASTM D2487. Classification will be taken down to the U.S. standard sieve No. 200; the hydrometer portion of the ASTM test will not be run. A grain size curve will be generated for each sample tested. Samples will be measured for total organic carbon (TOC) as measured by loss on ignition.

1.3 Laboratory Analysis: macroinvertebrates will be sorted from sample residue, identified, enumerated, and weighed. All taxa as measured by numerical count and/or biomass shall be identified to species or lowest possible taxonomic group. Length of all specimens relative to 2 cm (i.e., < or > 2 cm) will be recorded. All surfclams (*Spisula solidissima*) shall be measured to the nearest millimeter and weighed separately from other mollusks.

Noting that benthic macroinvertebrate community composition is strongly correlated with the nature of substrate conditions, the substrate particle size and organic content, these data will be examined for each sampling station. If, in the opinion of the contractor, these data are similar for all measurements made at all borrow area sample stations, then the biological data will be grouped for the purpose of data analysis. If two or more distinctive groups of substrate condition data are recognized, the biological data will be grouped similarly. In effect, this is data stratification on the basis of substrate

conditions.

Each of the top ten species (as measured by numerical count and/or biomass) shall be counted and dry-weighed separately. Each group shall be weighed to within 0.001 grams. Biomass determination shall be completed on each sample within the same day to avoid sample degradation.

1.4 Epibenthic dredge tows along the bottom for 100 feet in 5 randomly selected locations within each of the three borrow areas. The length of tow will be measured by deploying an anchored tag line at the start of each tow. Start position of the tow will be recorded using the sampling vessels GPS. *Sabelleria* colonies and other benthic organisms collected by the dredge will be quantified on board. Results of the epibenthic dredge tows will be quantified and include a table summary of species. The contractor shall be aware of the potential presence of crab/conch pots or other obstructions within the area to be investigated, which may potentially snag on the dredge.

1.5 Physical Data Collection: the following information shall be recorded for each station: date, time of day, depth (meters), weather conditions (height of sea, overcast/sunny), and latitude and longitude coordinates (differential global positioning system). The time of high and low tide for that geographic location shall be recorded.

1.6 Water Quality: water quality and physical measurements shall be obtained from within 2 feet from the bottom. The parameters shall be recorded for depth, temperature, conductivity, salinity, dissolved oxygen, pH and turbidity.

1.7 Health and Safety Plan/UXO Technician: the contractor shall develop a health and safety plan to address the potential for encountering unexploded ordnance (UXO), and to insure that workers are adequately protected from potential hazards from encountering UXO's. The Contractor is required to obtain the services of a qualified Unexploded Ordnance (UXO) Health and Safety Technician to be responsible for conducting adequate health and safety practices related to the potential for encountering unexploded ordnance during sampling. This technician would be responsible for developing and/or reviewing safety practices outlined in the health and safety plan.

1.8 Benthic Invertebrate Data Analysis: A publishable report shall be prepared presenting the data, analysis, and discussions of the infaunal benthic sampling and epibenthic dredge samples. The report will describe, in detail, all methods that were used and the data obtained. Maps will be included to show the project area and sample locations. Data will be compiled and stored. Separate files will be maintained for benthic invertebrate abundance, benthic invertebrate biomass, and sediment grain size. The horizontal grid will be based on a standard latitude and longitude coordinate system or North American Datum (NAD83), Delaware State Plane System. Data will be delivered on a CD or DVD.

For benthic macroinvertebrate data, the identity and number of individuals for the species will be reported in terms of mean numbers per square meter of benthos. The

identity and numbers of all individuals with length > 2 cm will be reported by species. Biomass data will be reported by taxon as mean value per square meter of benthos. The number of surfclams (*Spisula solidissima*), if any, will be reported in terms of mean numbers per square meter of benthos. Data collected from this study will be compared to data that has been collected in other similar studies in the area.

Biological data will be discussed in terms of species composition and population density that may be adversely impacted by turbidity or excavation by dredging. The report should also include a discussion of re-colonization potential. Taxonomic groups will be described in terms of their accessibility and desirability as a food source for water and shorebirds, fish, blue crabs, horseshoe crabs, clams and other commercial, recreational, or ecological important species, as well as whether the benthic communities found indicate a healthy or stressed environment. This information shall be presented in a typewritten scientific report, including sections describing the objective, methods, results, discussion, and conclusions. The results and analyses shall include but not be limited to graphical, tabular, and chart presentations of the data and findings. The conclusions section shall evaluate the potential for recovery of the benthic community based on the species found, as well as comparison of the results of this study with other similar benthic studies done in the area. Original data sheets shall be provided in the appendices of the report.

The following information shall be presented in the report:

-Maps showing locations of sample stations.
-Coordinates of sample stations.
-All stations shall have recorded depth measurements.
-Dry weight biomass of major taxonomic groups per sample (as summed from individual taxa measured).
-Taxonomic distribution per sample.
-Abundance and sizes of important commercial and recreational species per sample.
-Abundance of opportunistic species per sample.
-Physical/chemical parameters at each station.
-Sediment grain sizes of each station.

1.9 Data and Statistical Analysis: The data and statistical analysis shall compare the benthic community, defined by species abundance, biomass, and diversity at a minimum, with respect to the water depth, habitat type and grain size distribution at that station to that of other stations. Data and statistical analysis shall include, but not be limited to abundance and/or densities (*i.e.*, biomass/unit area, numbers of organisms/unit area, *etc.*), benthic community structure and diversity (*i.e.*, Shannon-Weiner Index, Simpson's Dominance, species richness, evenness, and station similarity/dissimilarity). Data analysis shall be presented in graphical or tabular form to provide easy comparisons between stations.

Sand builder worms *Sabellaria vulgaris*, often referred to as "coral", are of particular note in this assessment, although they are not reef-forming corals. *Sabellaria* are likely to occur in the project vicinity. *Sabellaria* are common in many areas of the east coast of the United States and produce large numbers of planktonic larvae that will soon recolonize any affected areas with suitable habitat when larvae are in the plankton. They are gregarious settlers and can be found on a wide variety of substrata, including clamshells, horseshoe crabs carapaces, other worm tubes, pilings and debris.

Deliverables for PMH- Area A

- Benthic Field Sampling is to be completed by 29 August 2014
- Draft Report is to be provided (2 paper copies; 2 digital copies) to the U.S. Fish and Wildlife Service, Prime Hook Wildlife Refuge office within 35 days of completion of sample collection.
- The Service will have 14 calendar days to review the draft report and submit request for changes to the contractor.
- The contractor will have an additional 14 days to make required changes to the report, if needed, and submit a Final Report (3 paper copies and 3 digital copies.

Deliverables for PMH- Area B & C

- Benthic Field Sampling is to be completed by 29 September 2014
- Draft Report is to be provided (2 paper copies; 2 digital copies) to the U.S. Fish and Wildlife Service, Prime Hook Wildlife Refuge office within 35 days of completion of sample collection.
- The Service will have 14 calendar days to review the draft report and submit request for changes to the contractor.
- The contractor will have an additional 14 days to make required changes to the report, if needed, and submit a Final Report (3 paper copies and 3 digital copies.

Task 2: Phase 1 Cultural Resource Investigation. The contractor will conduct an intensive remote-sensing survey of the study area location as depicted in Figure 1.

A. Archival Research. The Contractor shall identify known resources and potential property types within the study area, and will also identify high, medium, low and no culturally-sensitive areas, in addition to characterizing the existing land conditions, cultural landscape features, and disturbed areas.

B. Marine Remote Sensing Investigation. In accordance with requirements established by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEM) and additional procedures from the US Army Corps of Engineers, Philadelphia District (USACE) and the Delaware State Historic Preservation Office (SHPO), this scope of work document describes the survey area, equipment and methods to be used for conducting the surveys.

A comprehensive magnetic (magnetometer) and acoustic (side-scan sonar) remote sensing survey will be conducted across the expansion of the borrow area. At the discretion of the principal investigator, a sub-bottom profiler may also be used as an aid to identify questionable targets. Transect spacing across the survey areas will be established at no more than 75-foot (23 meter) offsets. At all magnetic or sonar target locations, a grid of survey lanes (perpendicular transects) will be run at 25-foot offsets to help delineate the boundaries of cultural material at each target site. Additional perpendicular transects (tie-in-lanes) will be run at 150-foot intervals across both of the entire survey area.

A marine archaeologist meeting the Secretary of the Interior's Standards for Professional Qualifications as stated in Code of Federal Regulations, 36 CFR Part 61 and with demonstrated experience conducting and interpreting marine electronic remote-sensing survey in the project region will either conduct the survey, or be present on board during all survey operations.

Side-Scan Survey

A dual frequency (900-1200 kHz) side scan sonar will be used to provide a minimum of 100% coverage of the sea floor. The acquisition strategy should facilitate reliable detection of targets measuring 0.5 m or smaller. When appropriate, additional side scan sonar passes should be made to perform detailed inspection of anomalous seafloor features and unidentified targets. The sonar system will be integrated with a cable counter and the navigation system so that data positioning annotations are corrected accordingly.

Magnetometer

A proton precession or cesium total field magnetometer will be used to detect ferrous objects along all survey transects. Instrument sensitivity will be one (1) gamma or one (1) nanoTesla or less, the sampling interval will not exceed 1 second.

The magnetometer will be towed as near as possible to the seafloor. A depth sensor will be used with the magnetometer to allow continuous monitoring and recording of towfish of

altitude. A cable counter will be used and integrated with the survey navigation system for correction of towfish location to earth coordinates.

Sub-Bottom Profiler

A sub-bottom profiler operating in the 1.5 – 4.5 kHz range will be used to collect very high resolution of near surface geological features to a depth of 12 m below the seabed. The system shall achieve a resolution of vertical bed separation of at least one foot in the upper 15 m below the seabed.

Sub-bottom data will be recorded digitally to allow signal processing to improve data quality further and to allow export to a workstation for integrated interpretation and mapping of the data.

Survey positioning data will be provided by differentially corrected GPS (DGPS) and will provide a precision of (+ or -) one meter. An inertial measurement and compensation system will be used to correct data for vessel motion. The navigation system will be calibrated daily. Offsets between navigation antennae(s), the vessel center of motion and relevant sensor equipment will be measured, diagrammed and programmed into the data acquisition system so that corrections are applied to data in real time. A navigation and data-logging computer shall be used for maintaining course on tracklines and recording all pertinent navigational, positioning, and motion data.

Data Analysis

An evaluation and synthesis of data gathered during this underwater investigation shall be included in a report prepared and signed by the project archaeologist. Professional personnel in this field should have credentials and experience sufficient to ensure that they are able to adequately perform the necessary work. As needed, specialists in other fields may participate in data analysis and report preparation.

1. The contractor shall undertake an analysis of all evidence uncovered during the documentary research review, underwater investigation, and National Register evaluation.

2. Final interpretation of the data and the report of the findings of the surveys must be prepared by a qualified marine archaeologist.

3. The contractor shall provide the Corps with the required number of copies, as specified below, of a draft report and final report of this investigation. The report shall provide a written narrative of the results of the background research and underwater investigation and be of sufficient scope and detail to address the potential eligibility of each target for listing in the National Register of Historic Places.

4. Draft and final copies of the report of cultural resource investigations shall reflect and report the analysis outlined in required investigations. They shall be prepared with reference to and consistence with the guidelines for archaeological resource field surveys prepared by BOEM

contained in
http://www.gomr.boemre.gov/homepg/regulate/regs/ntls/2005%20NTLs/NTL2005-G07.pdf . Strict adherence to the format requirements of the BOEM guidelines is a prerequisite for approval of the draft and final report.

Report Preparation

The contractor shall prepare two separate formal reports for the benthic investigation and the cultural resources investigation. These reports shall be publishable and present the data, analysis, and discussions of these studies. These reports shall summarize that data in graphical or tabular form to provide easy comparisons between sampling sites and previous data (where applicable). In addition, a table and map identifying sampling locations, geographic coordinates (obtained from differential global positioning system (DGPS)), and corresponding data collection results will be included. Draft and final reports must be polished products, clean-typed, complete with all figures, tables, and appendices and reflect and report the analyses outlined in this scope of work. The recommended content and format should follow quality assurance and quality control guidelines and shall be structured as follows:

For the Cultural Resources Investigation Report:

(1) TITLE PAGE - bearing the appropriate title, date, author, and contract number.
(2) EXECUTIVE SUMMARY - a brief description of the study's purpose, findings, and conclusions.
(3) TABLE OF CONTENTS - including a list of all figures and tables presented in the report.
(4) INTRODUCTION – includes a description of the area surveyed, why it was surveyed and an evaluation and synthesis of the data collected.
(5) PROJECT DESCRIPTION – include a description of the project, agencies involved and the area surveyed including lease/tract/block number (if any).
(6) BACKGROUND – include a brief prehistoric and historic background relevant to the region and project area.
(7) METHODOLOGY - describe the sampling and analysis equipment and methodologies used which will include/ but not be limited to, a discussion of the field survey instrumentation, scale, sensitivity settings, sampling rates, tow heights, survey vessel size, sensor configuration, instrument setback, vessel speed/course changes, sea and weather conditions, survey procedures, comparison of survey line crossings and discussion of any problems encountered.
(8) MAPPING/FIGURES/MOSAICS – include maps of the survey area showing actual survey track lines, project area, etc. at a reasonable scale (basemap). Include a photo mosaic of the project area with high-resolution images of all side-scan targets. Contour ll magnetometer data and provide analysis of all targets in excess of 10 gamma variation, duration of target, and its signature (monopole, dipole, complex, multi-component). Include maps of known shipwreck/obstructions/relict geomorphic features having potential for prehistoric sites (such as tidal estuaries, embayments, beach ridge sequences, fluvial systems).
(9) DATA INTERPRETATION – describe the technique used to analyze the data whether through length/duration/amplitude or comparative dipole analysis.
(10) CONCLUSIONS – summary of conclusions and recommendations supported by survey data and archaeological/geomorphological analyses.
(11) A LIST OF REFERENCES - includes literature cited and agencies or individuals consulted.

The bibliography must be in a format used by professional scientific journals.
(12) APPENDICES - for personnel qualifications, a copy of this scope of work, raw data sheets, record logs, and other pertinent information.

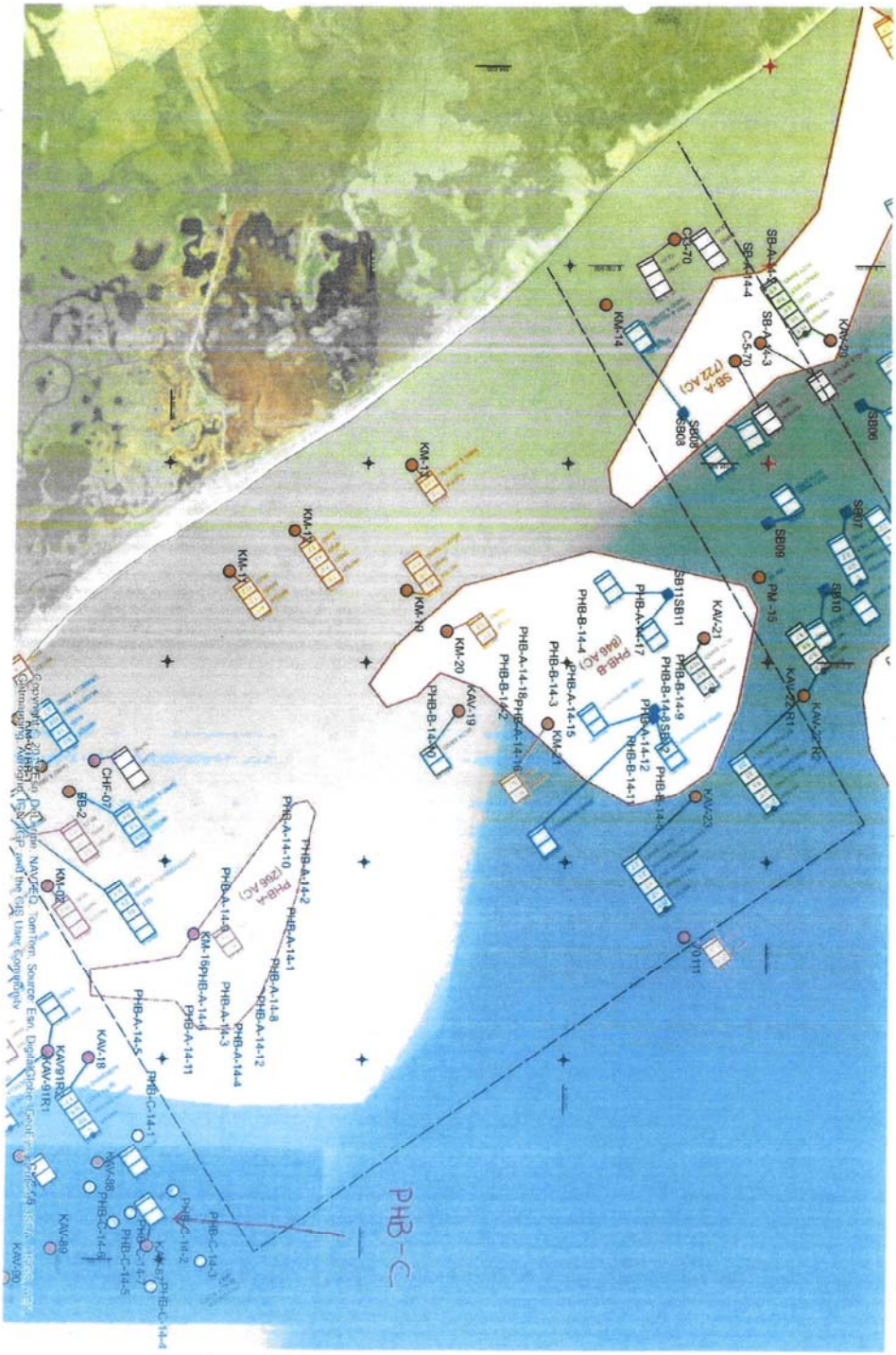


FIGURE 1
SB-A (722 AC)
PHB-B (846 AC)
PHB-A (266 AC)
PHB-C

APPENDIX B

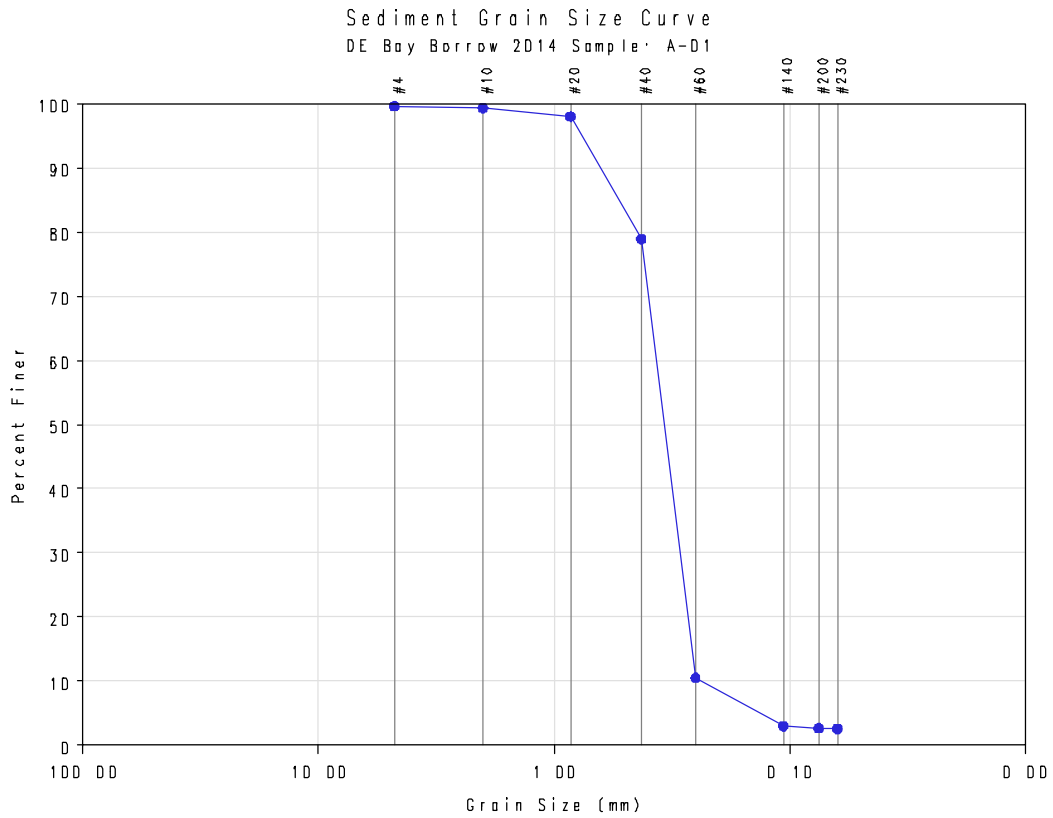
LATITUDE/LONGITUDE COORDINATES FOR INDIVIDUAL STATIONS SAMPLED IN 2014

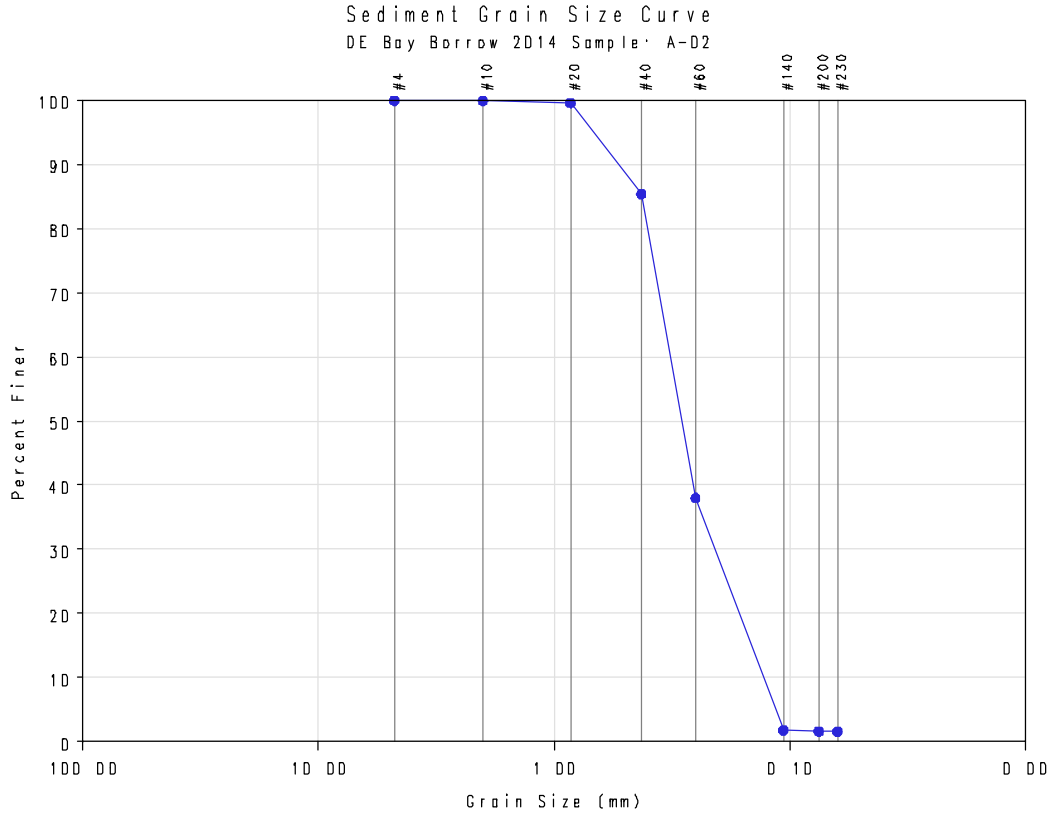
Table B-1. Individual latitude and longitude for stations sampled in the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

Area A					
Station	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
A01	38.85712	75.19633	A10	38.85568	75.19909
A02	38.85399	75.19571	A11	38.85620	75.19518
A03	38.85506	75.19435	A12	38.85719	75.21354
A04	38.85698	75.21342	A13	38.86007	75.21033
A05	38.85673	75.21194	A14	38.86126	75.21209
A06	38.84887	75.19796	A15	38.85017	75.20073
A07	38.85556	75.19906	A16	38.85626	75.20237
A08	38.84958	75.20008	A17	38.85453	75.19414
A09	38.85828	75.20920			
Area B					
Station	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
B01	38.87648	75.22063	B10	38.88988	75.22268
B02	38.87494	75.23080	B11	38.88746	75.23025
B03	38.88886	75.22841	B12	38.87754	75.22422
B04	38.87549	75.23091	B13	38.88441	75.22380
B05	38.87354	75.22290	B14	38.87974	75.22155
B06	38.87139	75.22498	B15	38.89032	75.22559
B07	38.88422	75.23202	B16	38.87328	75.22767
B08	38.87356	75.22702	B17	38.88197	75.22828
B09	38.87245	75.22572			
Area C					
Station	**Latitude**	**Longitude**	**Station**	**Latitude**	**Longitude**
C01	38.85154	75.16996	C10	38.84597	75.18967
C02	38.84018	75.18176	C11	38.84793	75.18686
C03	38.84613	75.17483	C12	38.85300	75.18055
C04	38.85099	75.17401	C13	38.84081	75.18056
C05	38.84906	75.18580	C14	38.84670	75.18606
C06	38.84356	75.18276	C15	38.84409	75.19020
C07	38.84902	75.18766	C16	38.84478	75.17559
C08	38.85111	75.16875	C17	38.84655	75.18161
C09	38.84795	75.17013			

APPENDIX C

SURFACE SEDIMENT CURVES


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-01
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)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DE Bay Borrow 2014 Sample: A-02
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#20
#40
#60
#140
#200
#230
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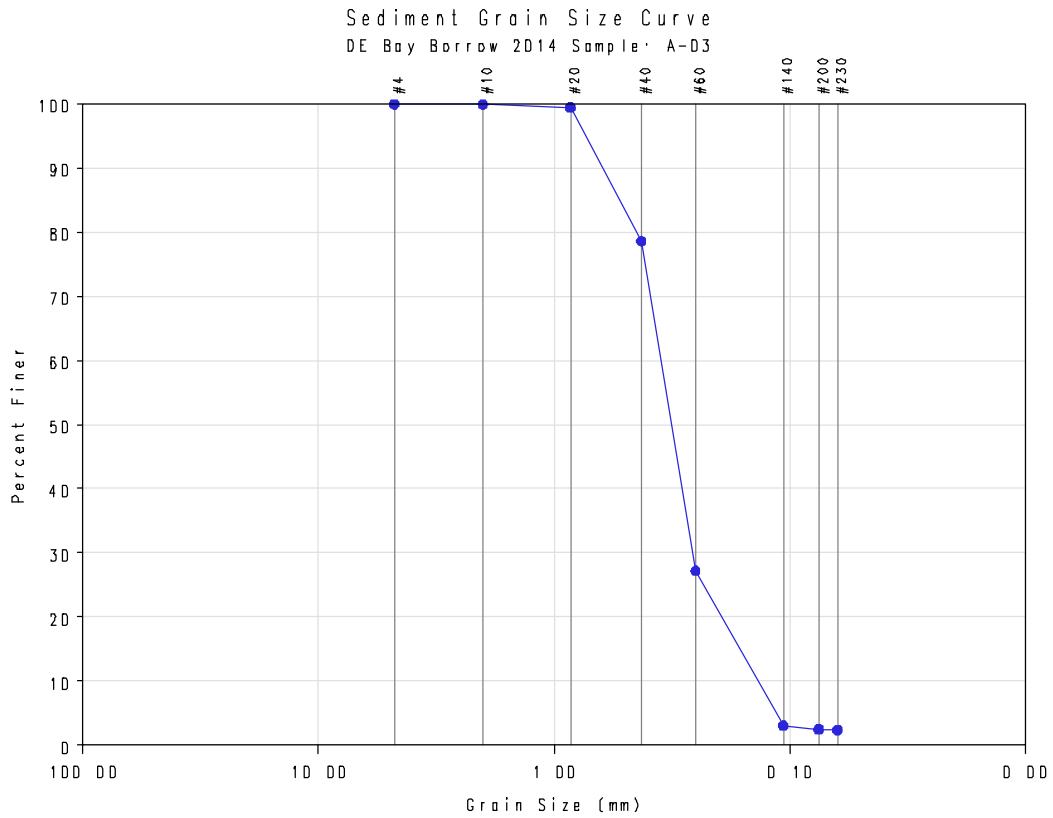
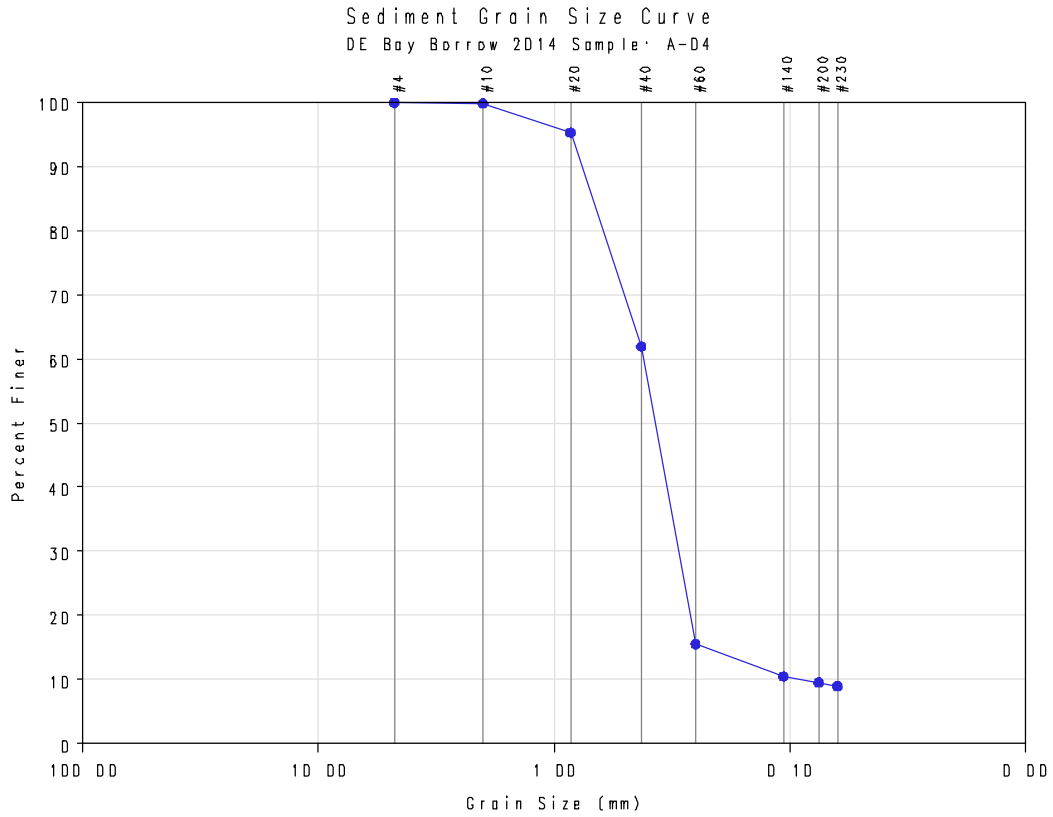
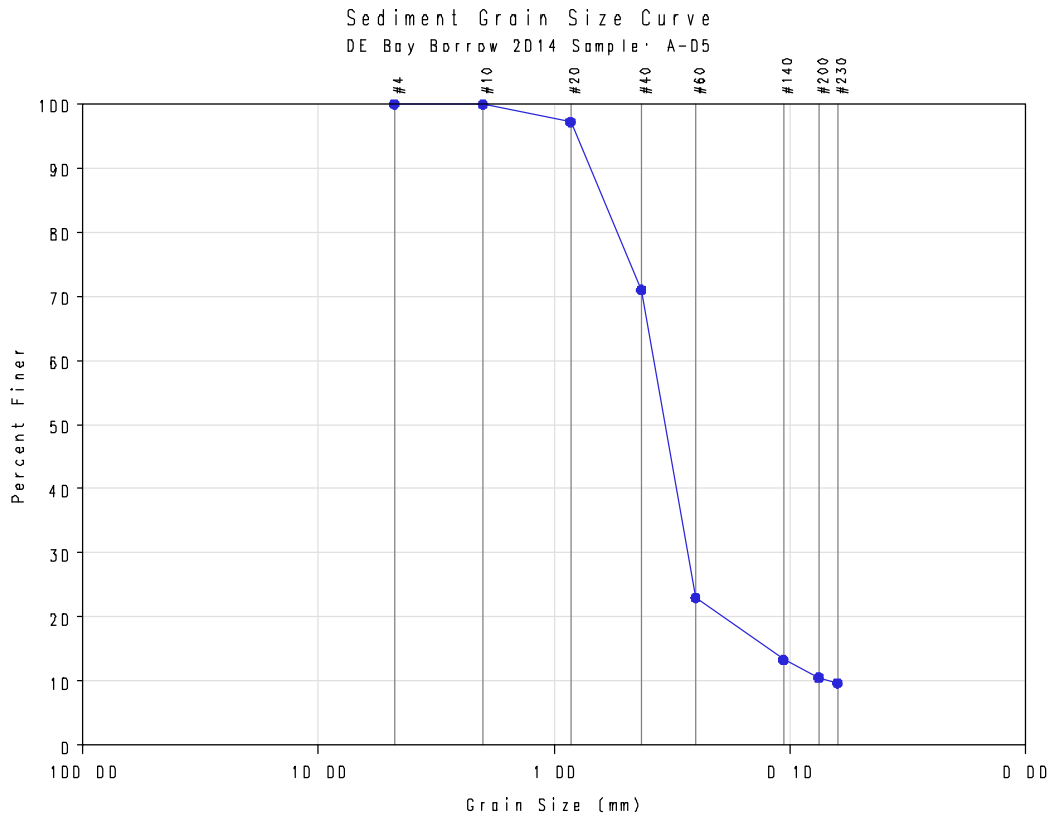
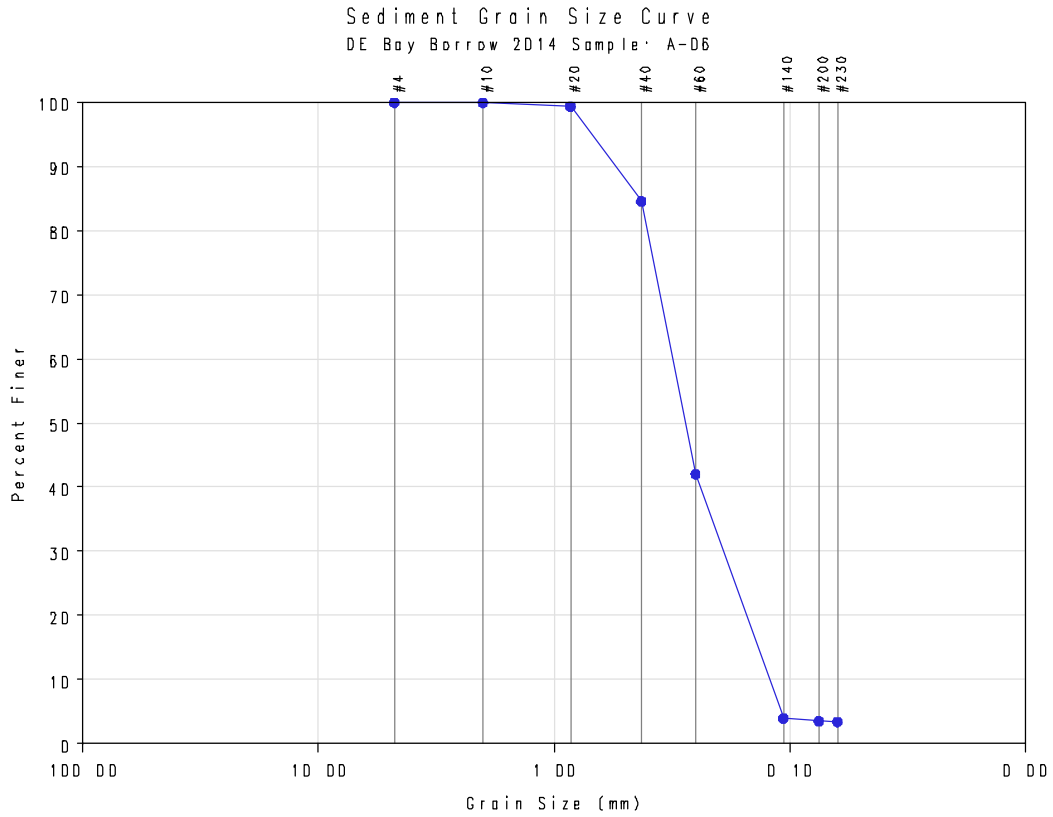
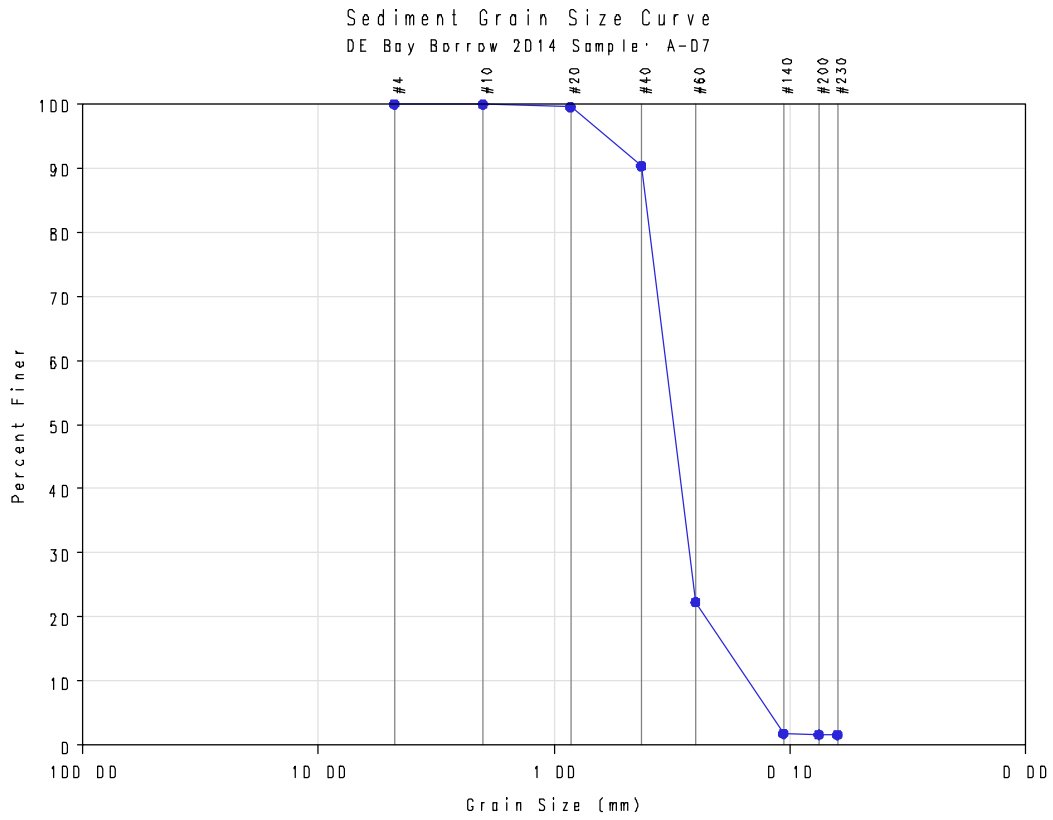
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

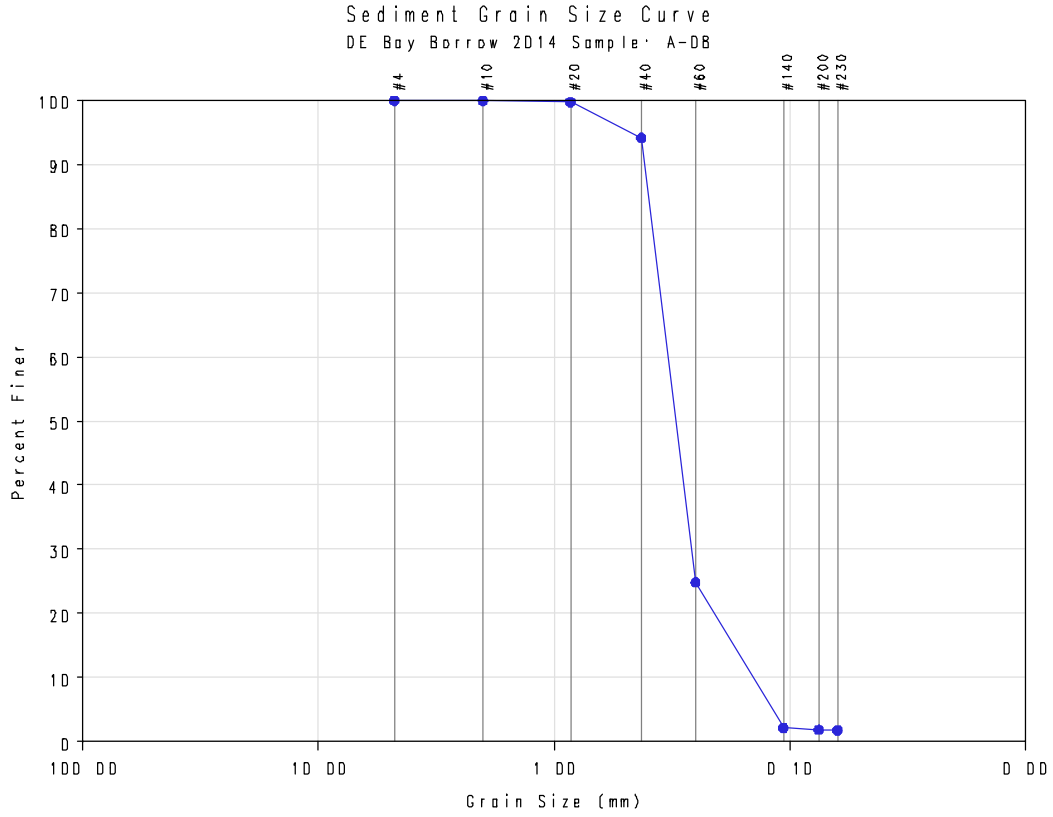

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-03
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

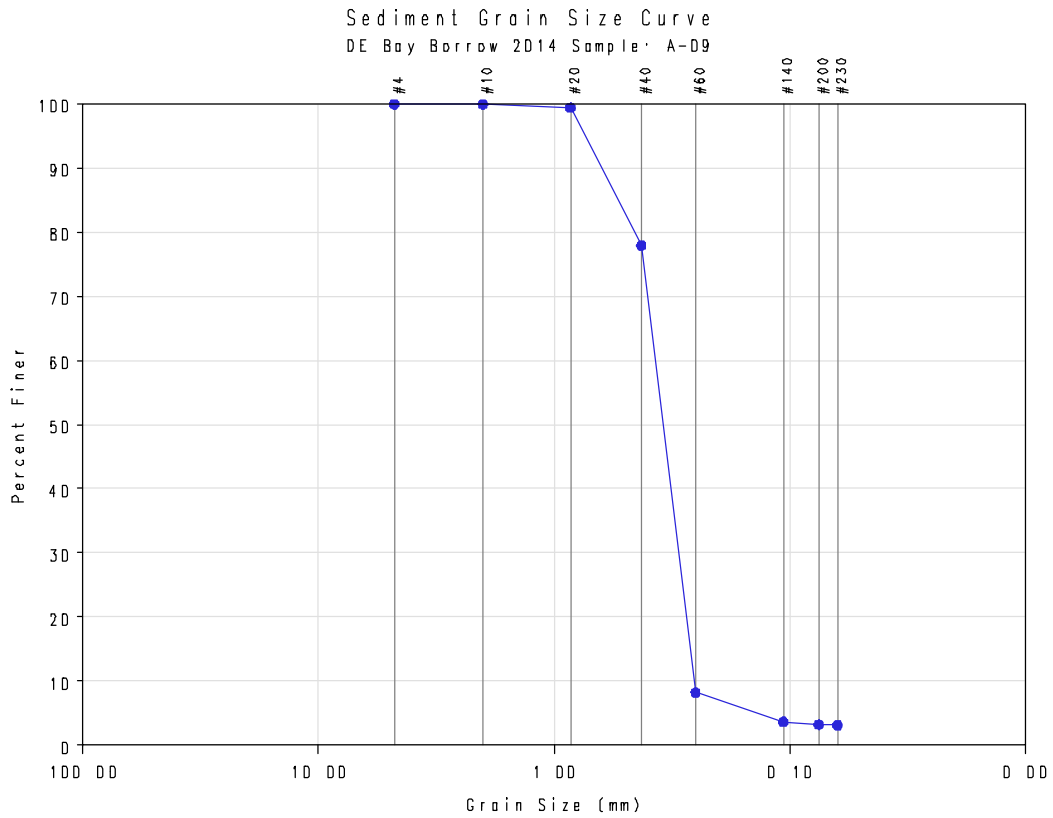

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-04
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

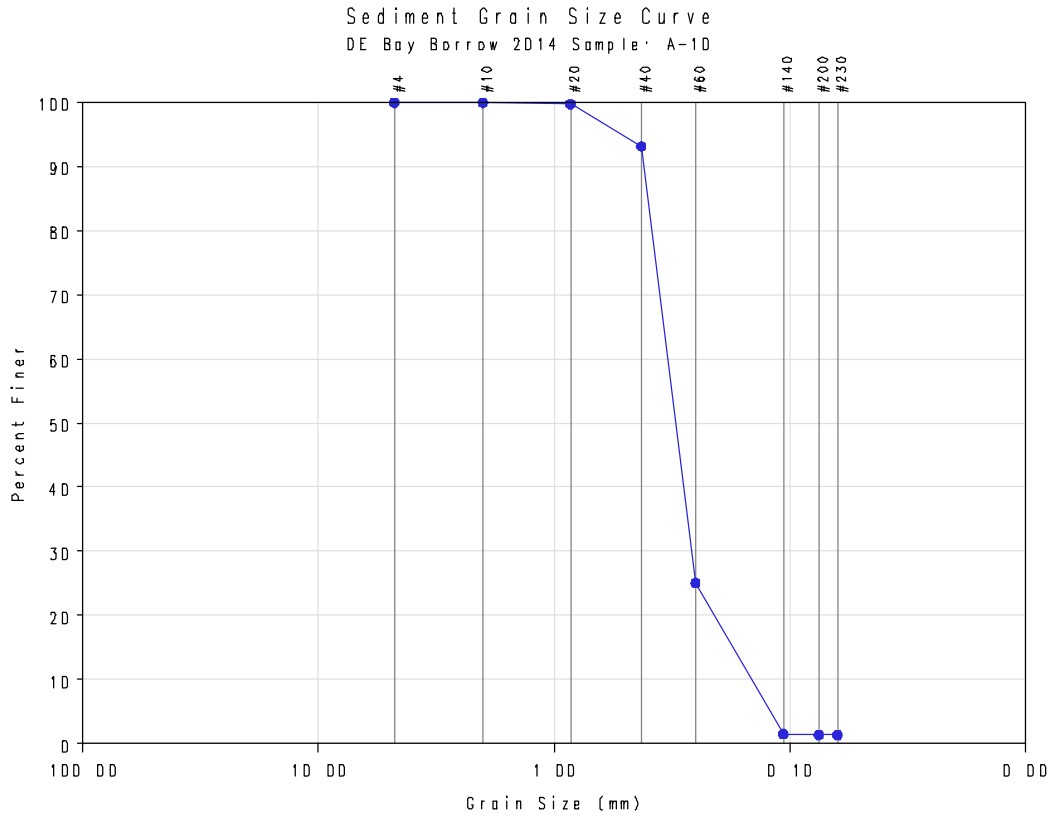

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-05
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

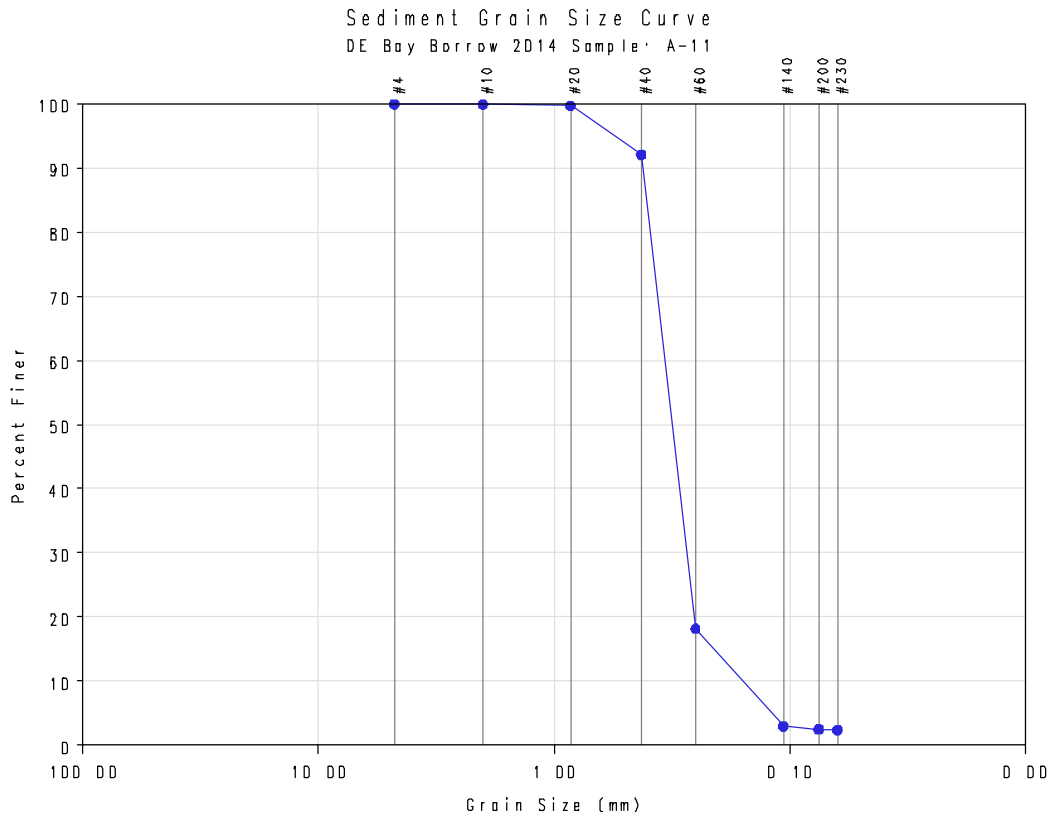

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-06
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

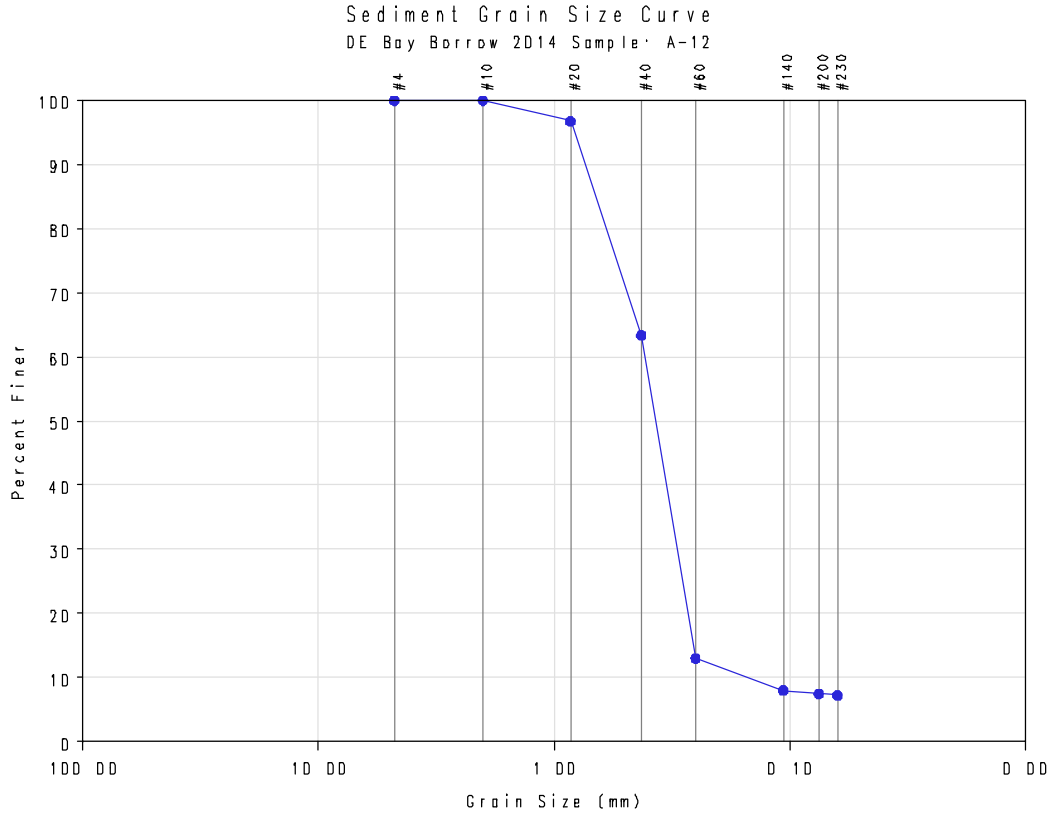

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-07
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

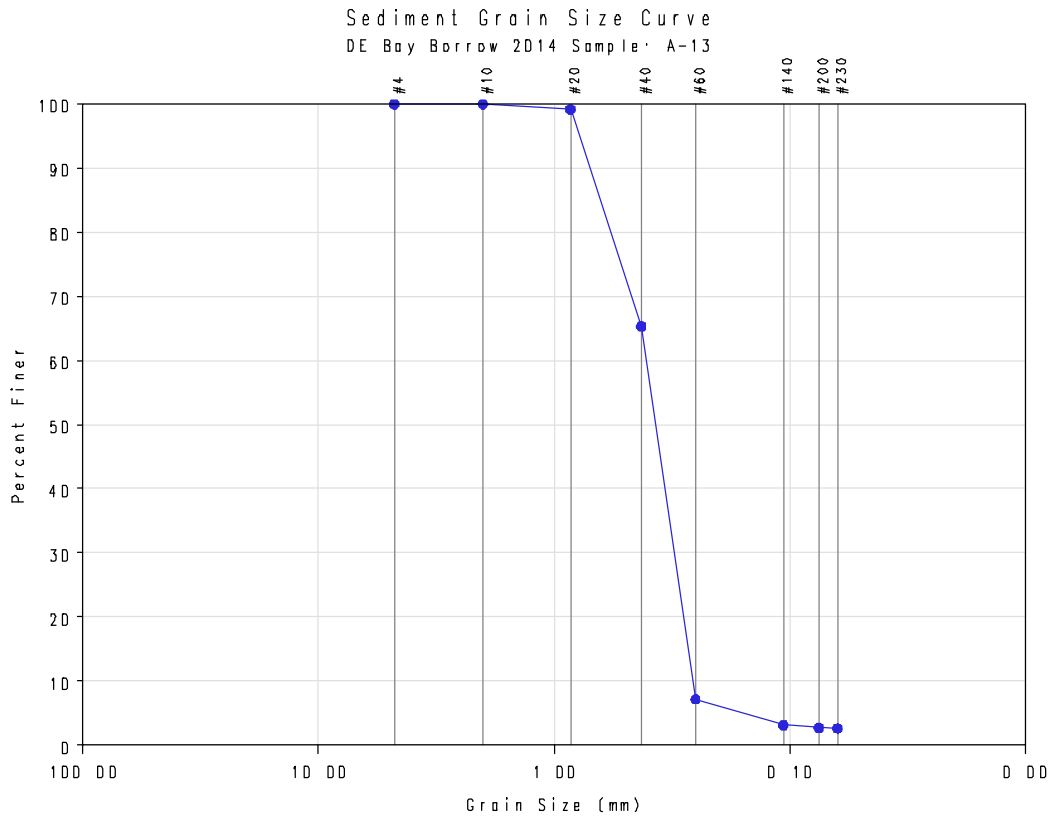

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-08
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

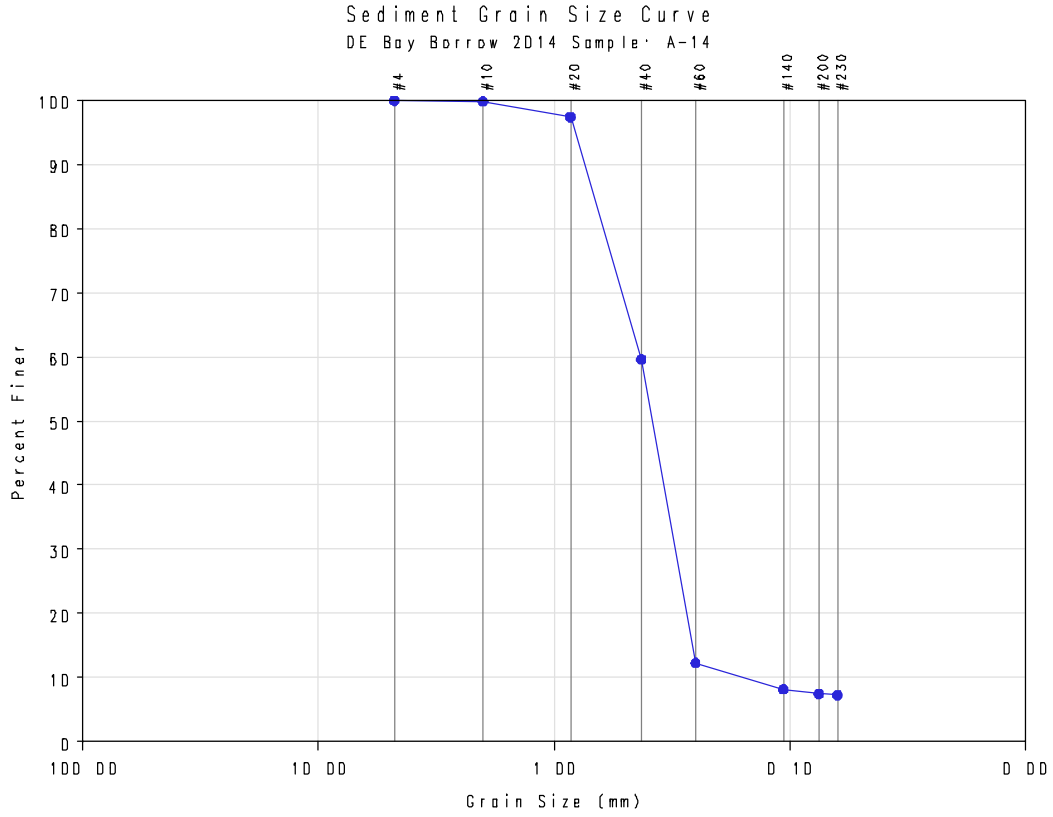

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-09
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

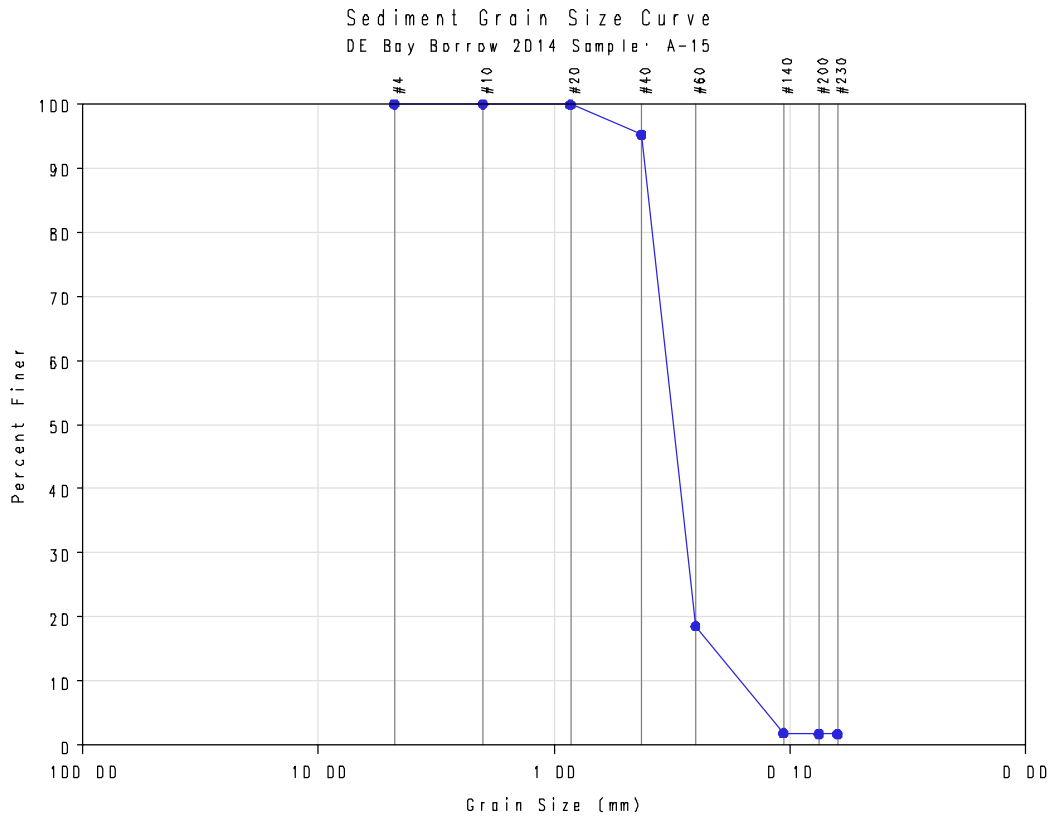

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-10
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

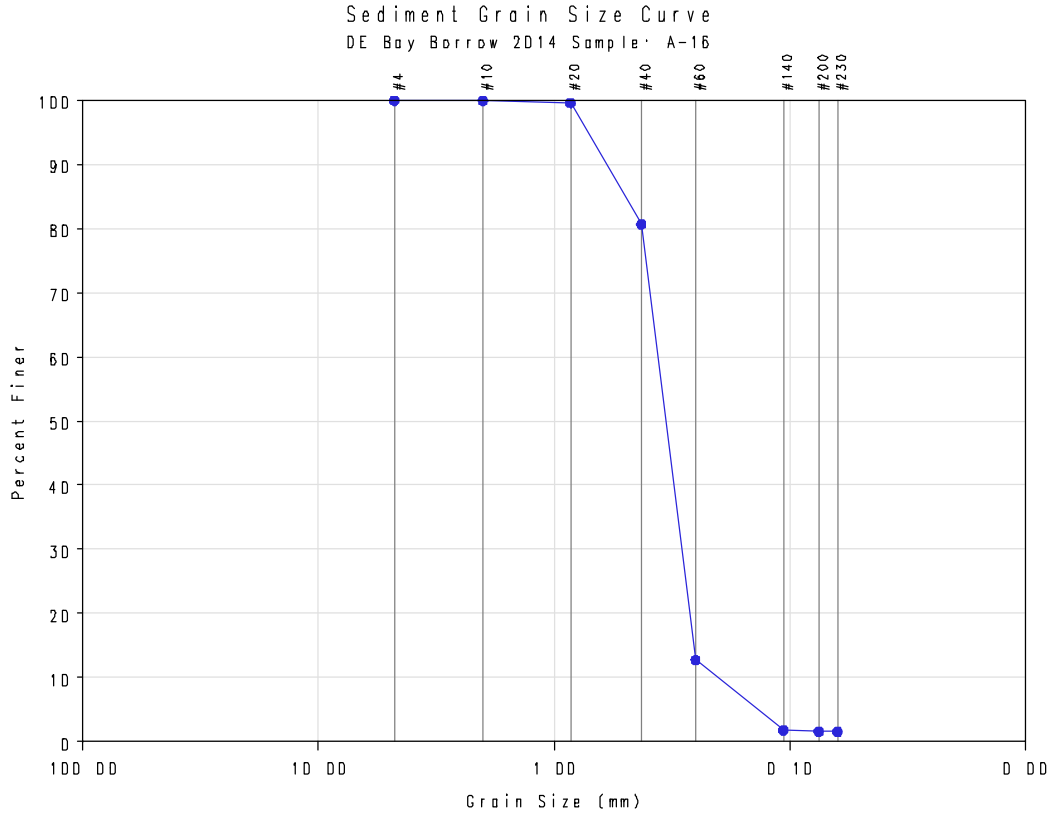

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-11
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

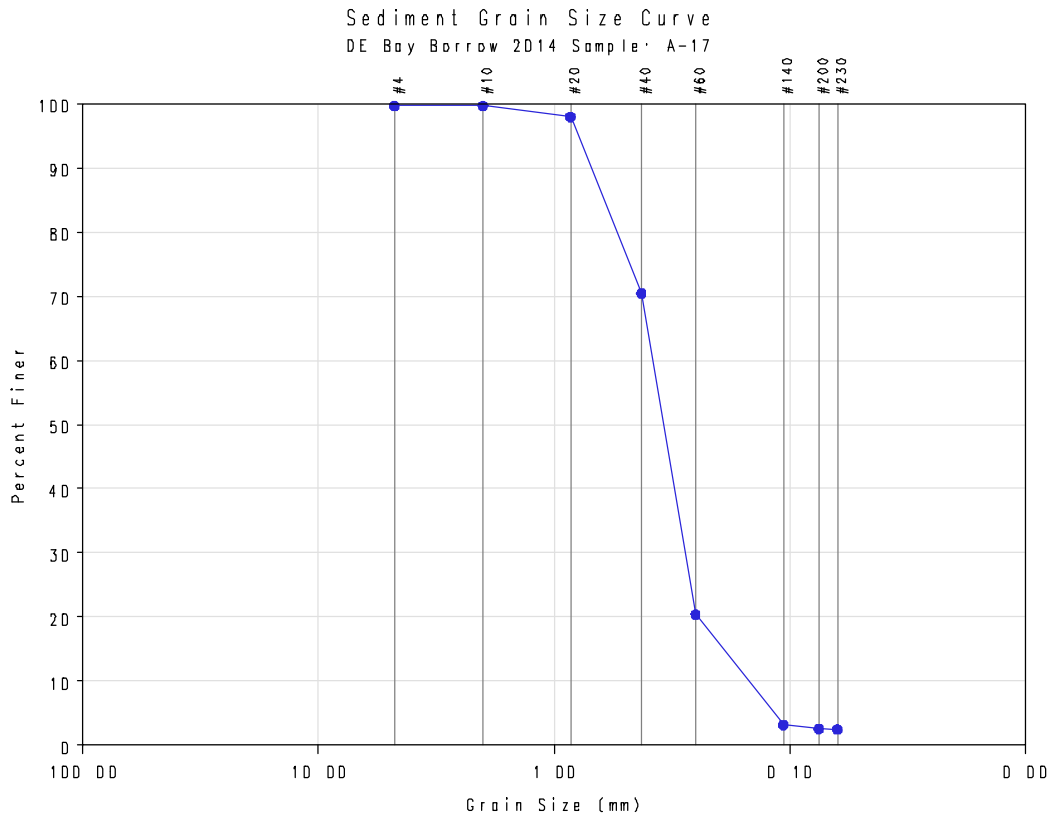

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-12
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

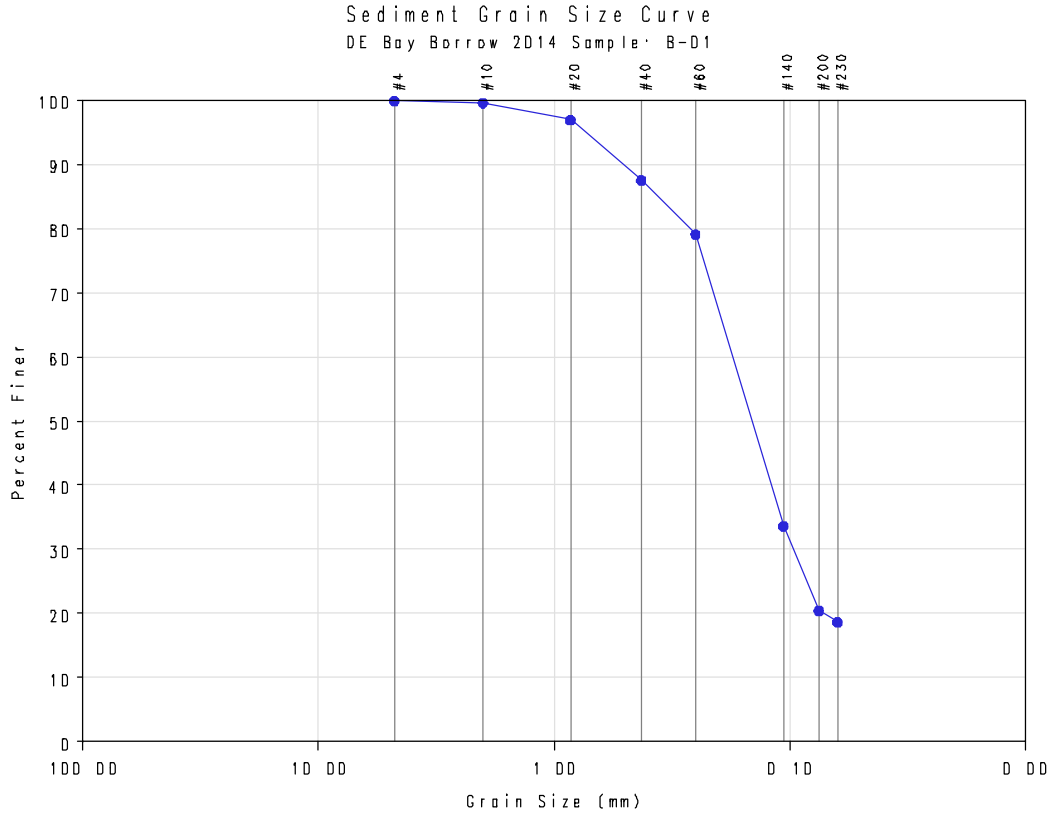

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-13
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

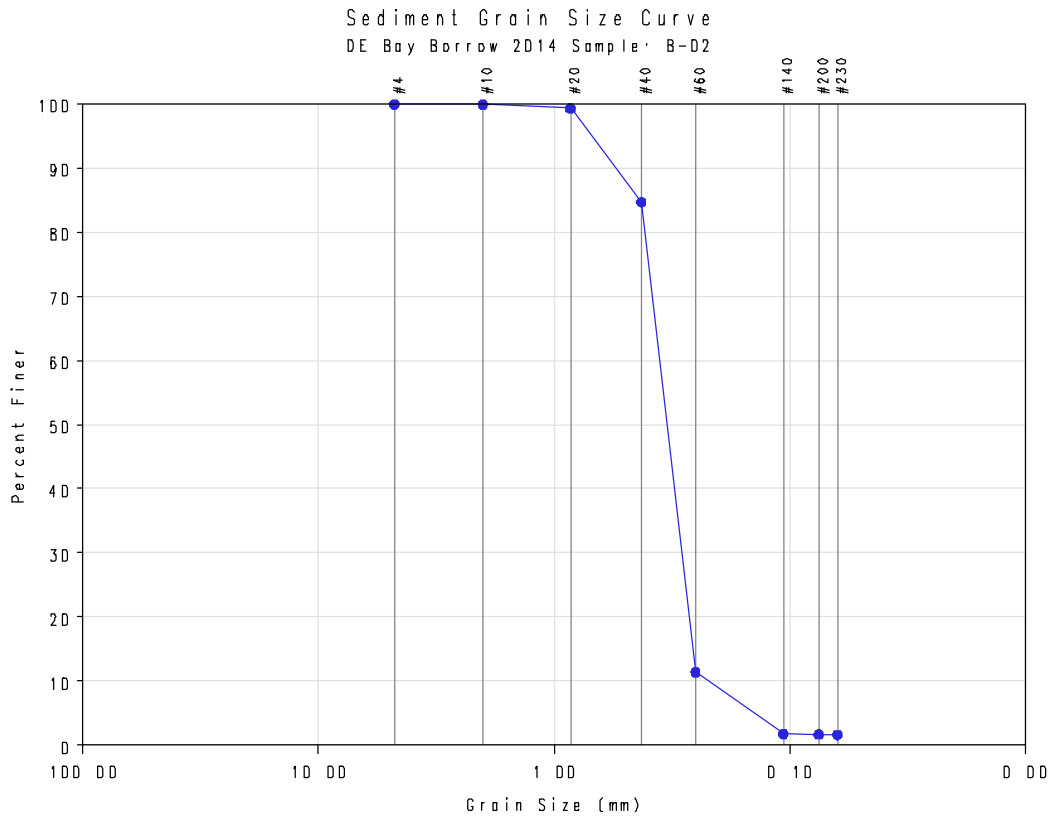

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-14
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

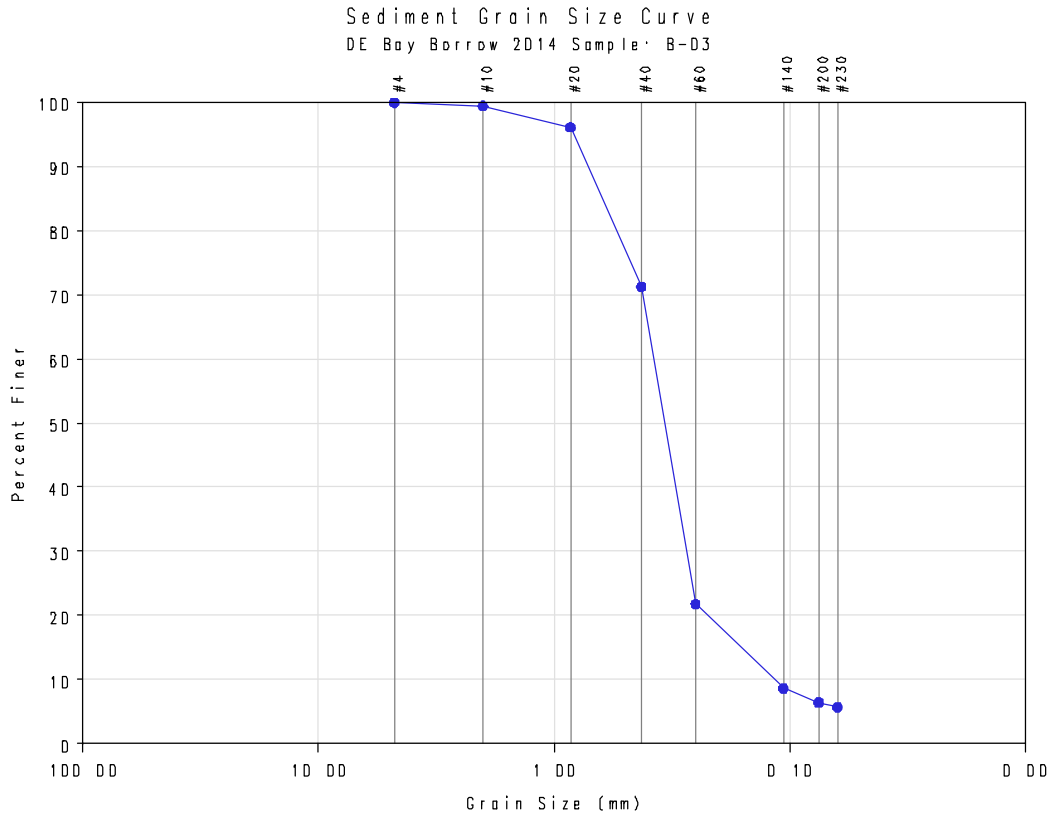

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-15
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

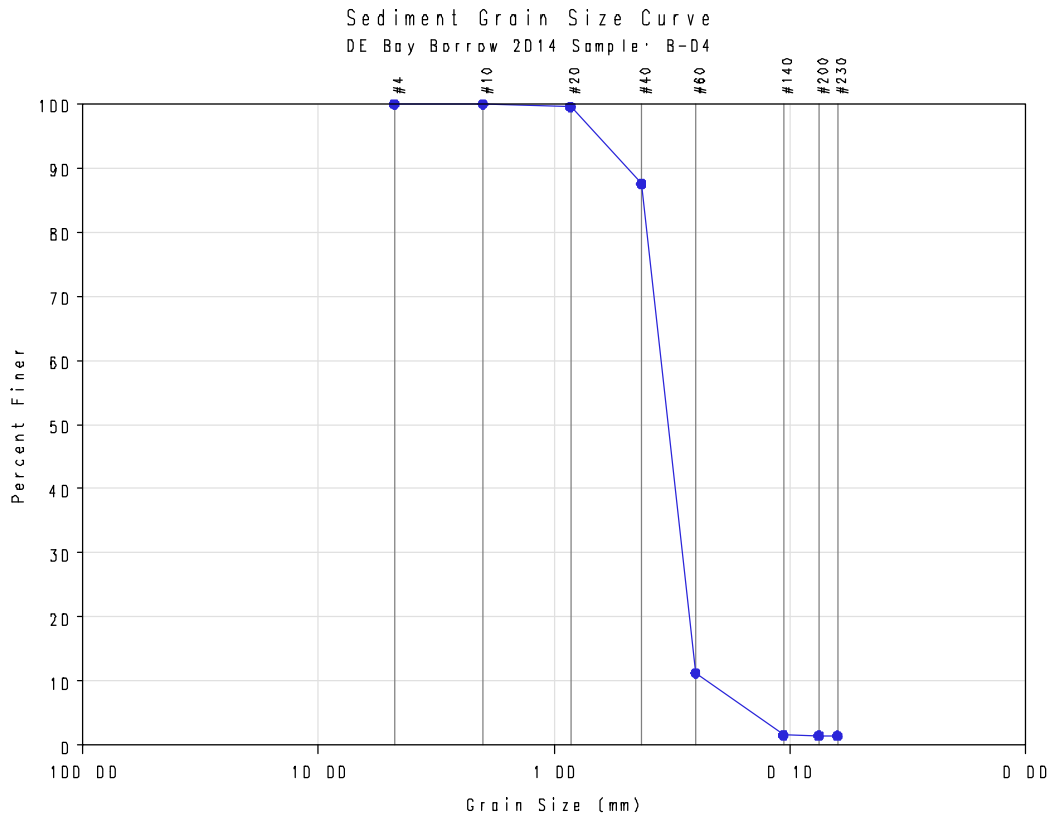

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-16
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

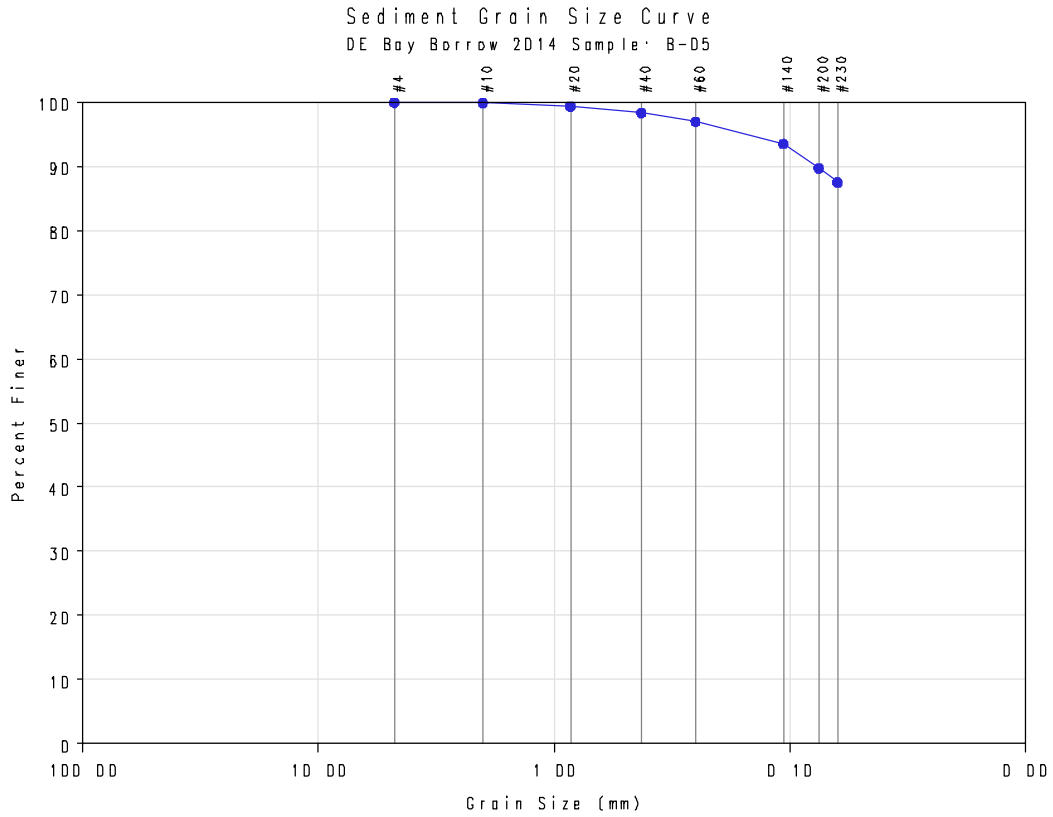

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: A-17
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

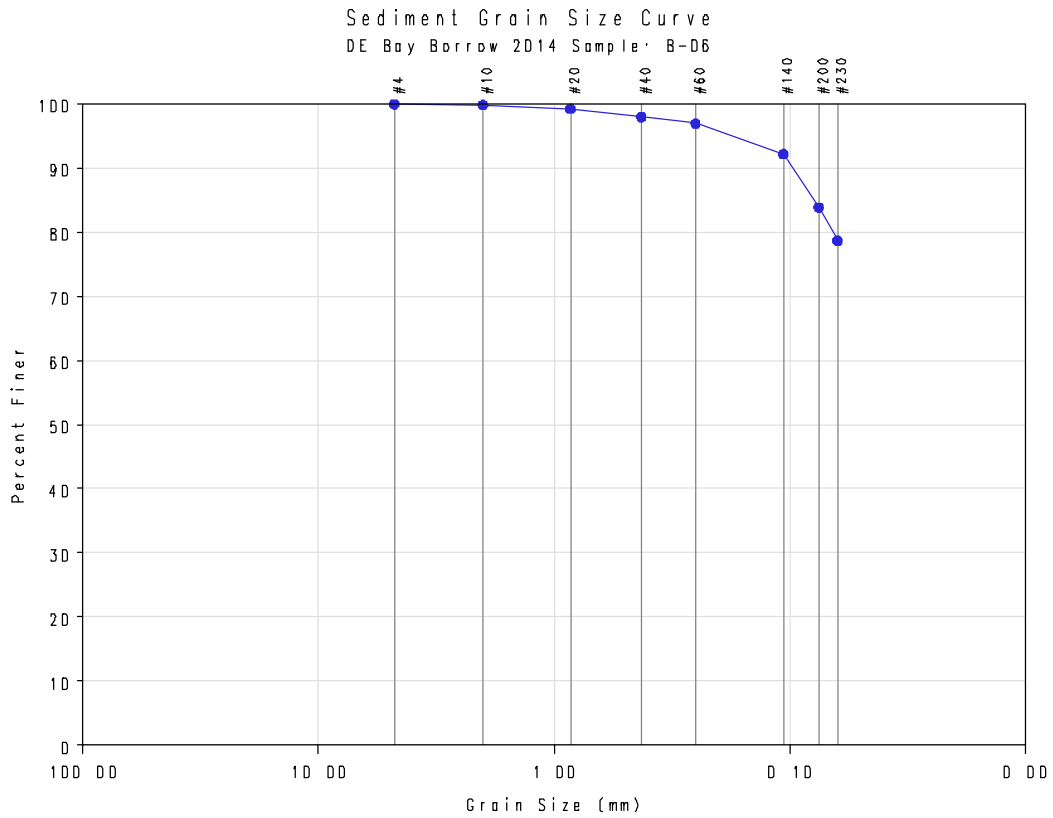

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-01
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

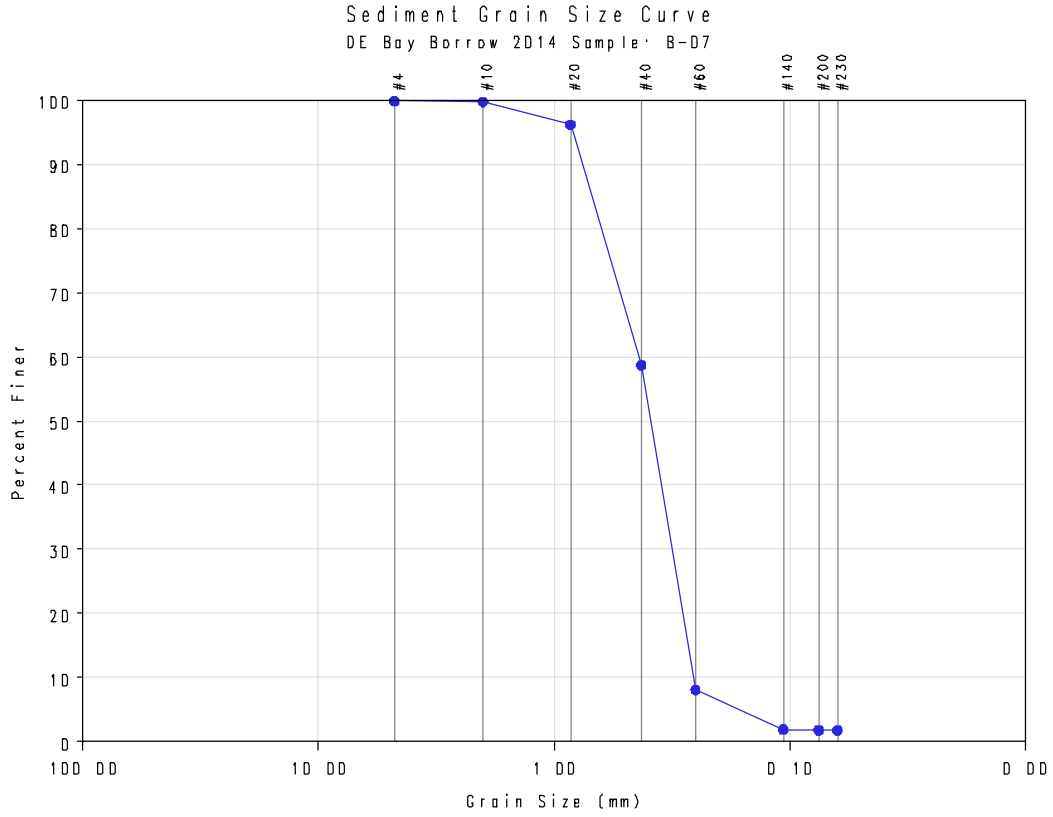

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-02
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

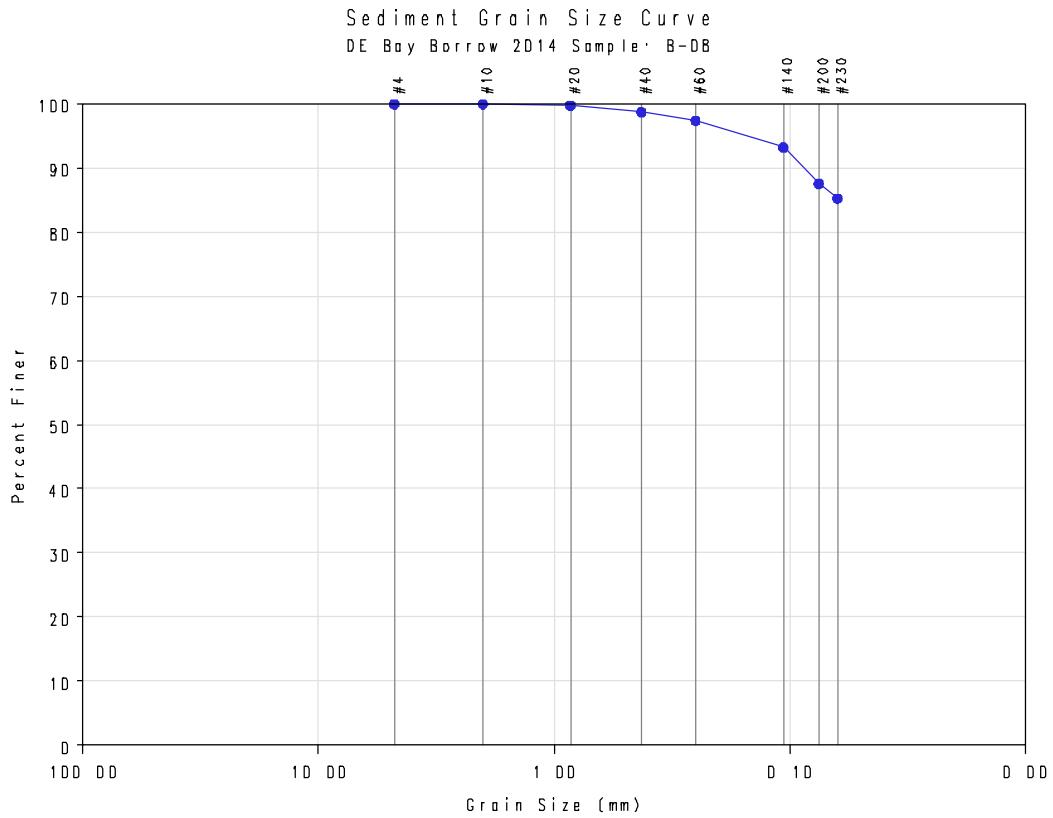

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-03
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

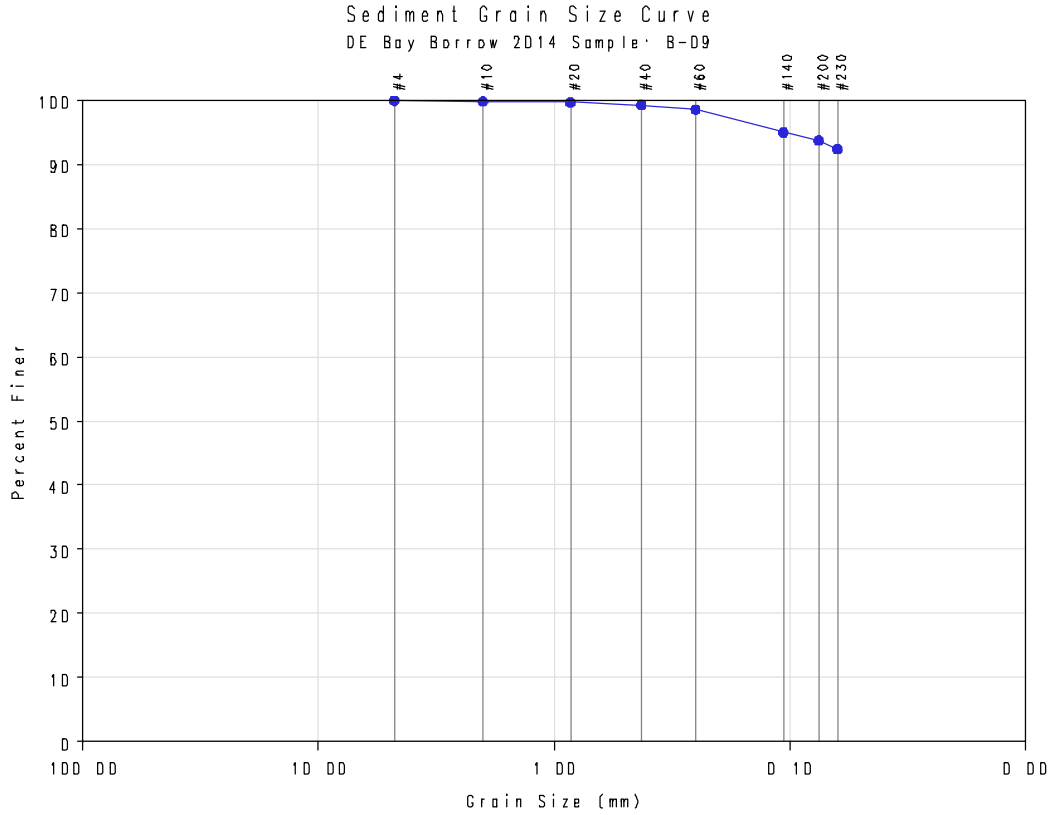

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-04
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

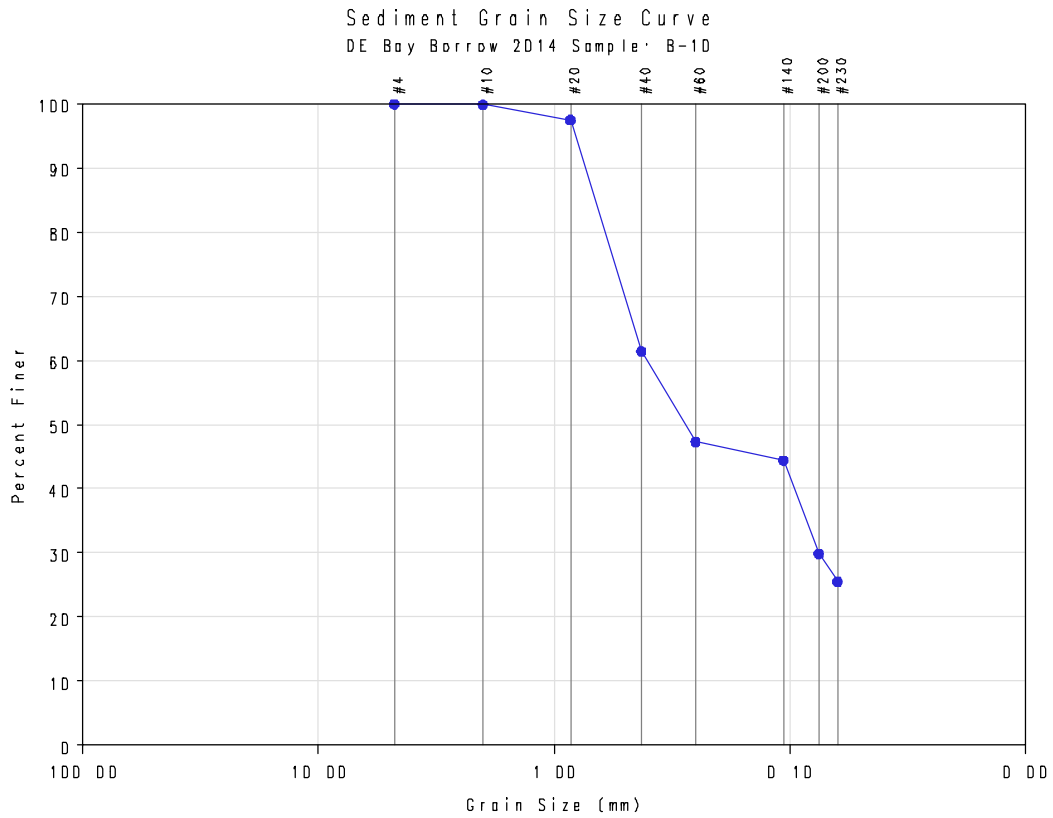

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-05
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

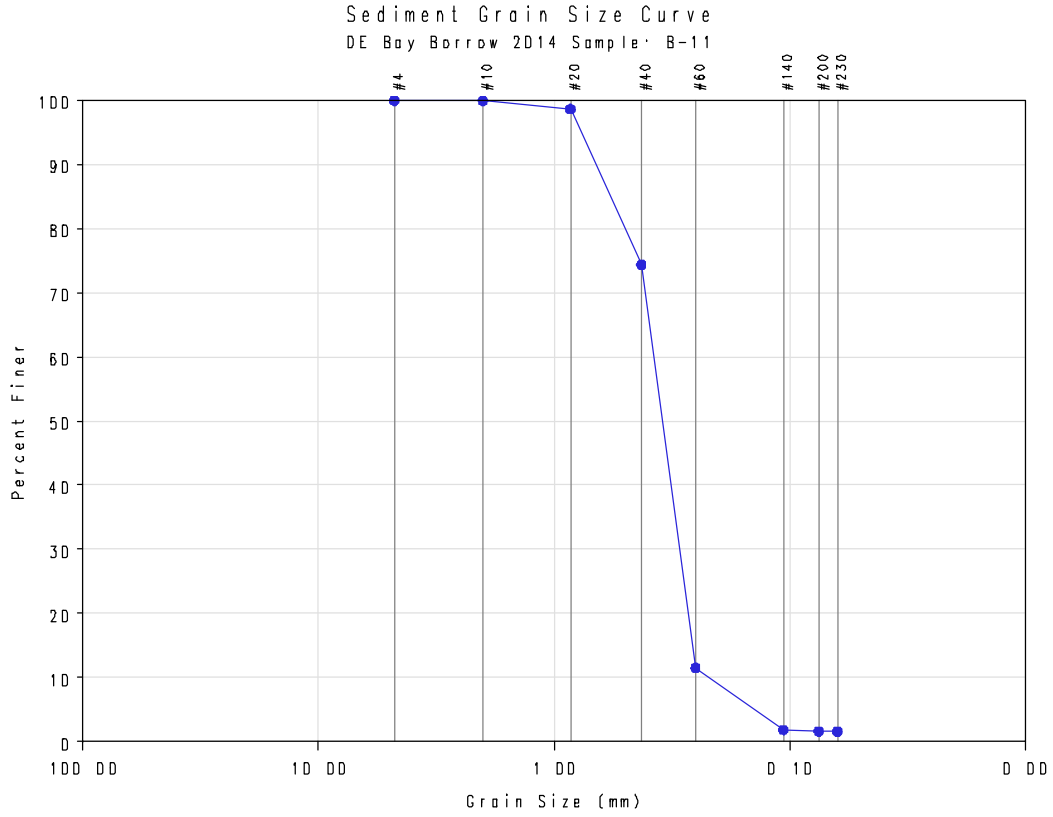

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-06
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

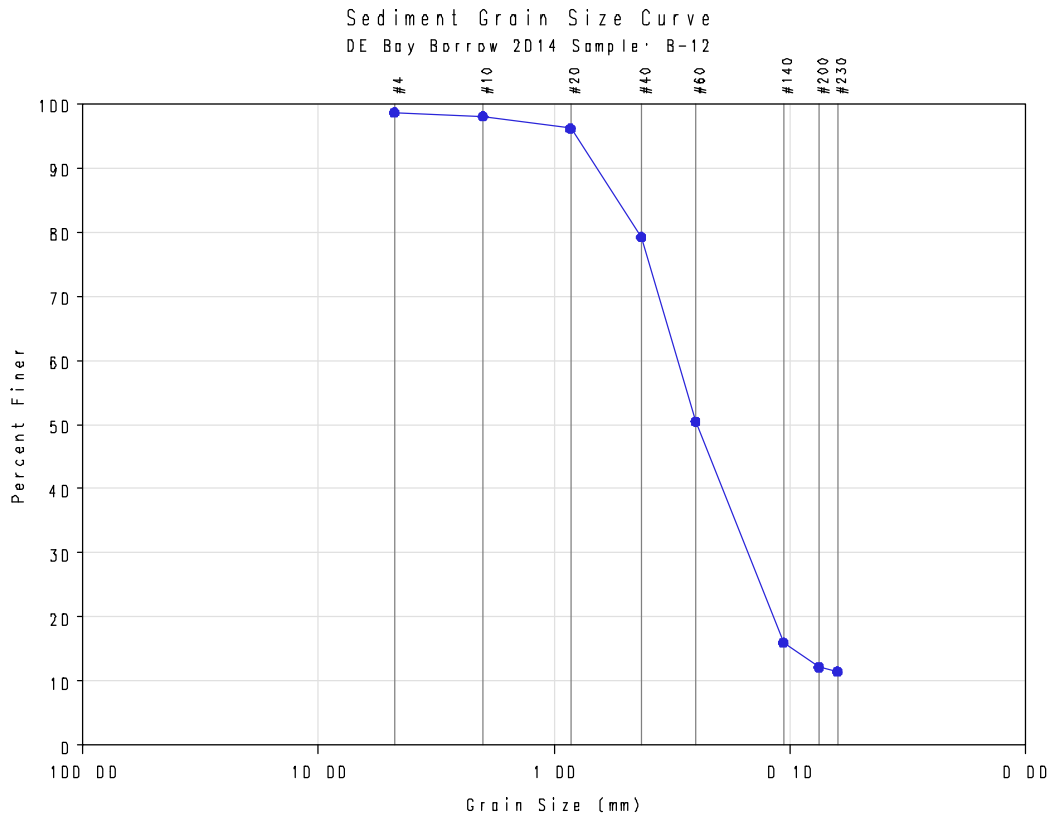

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-07
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

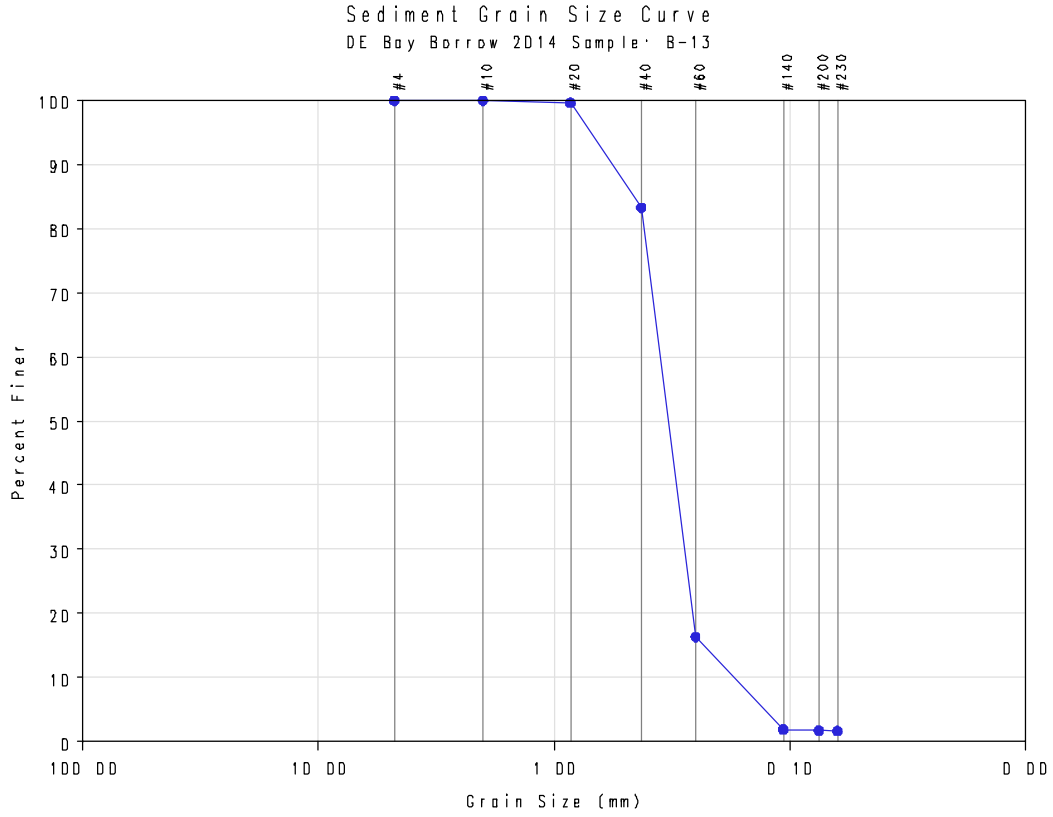

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-08
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

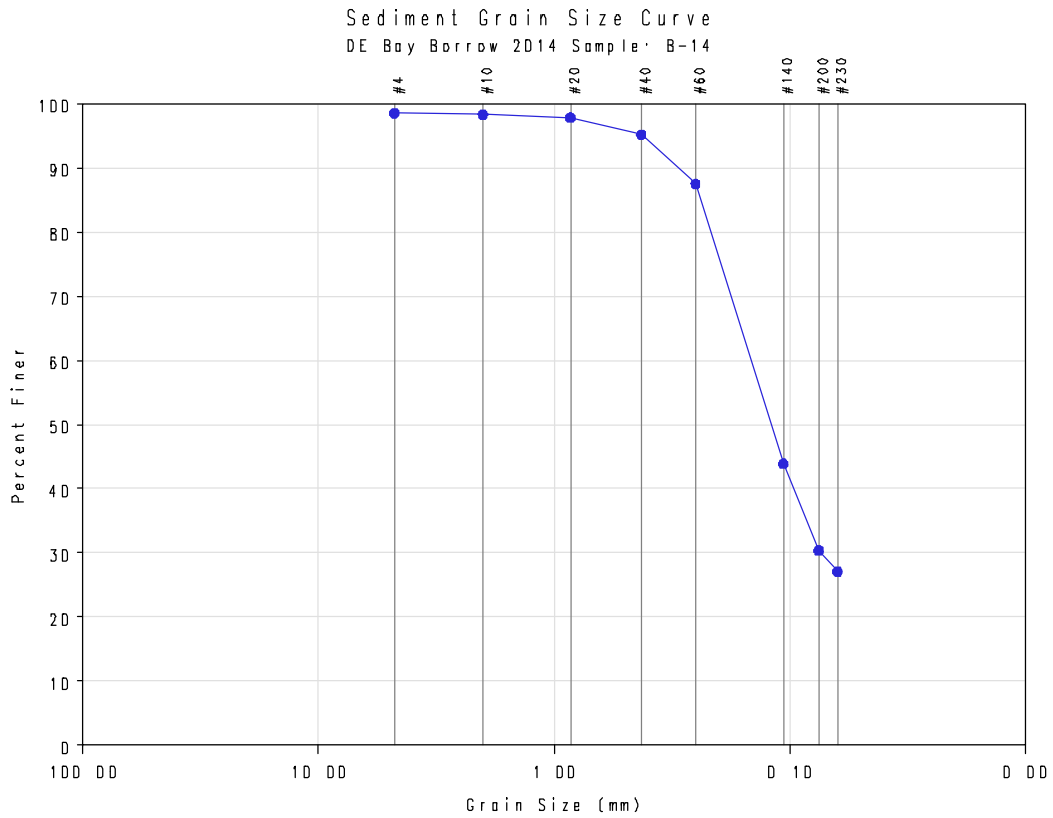

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-09
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

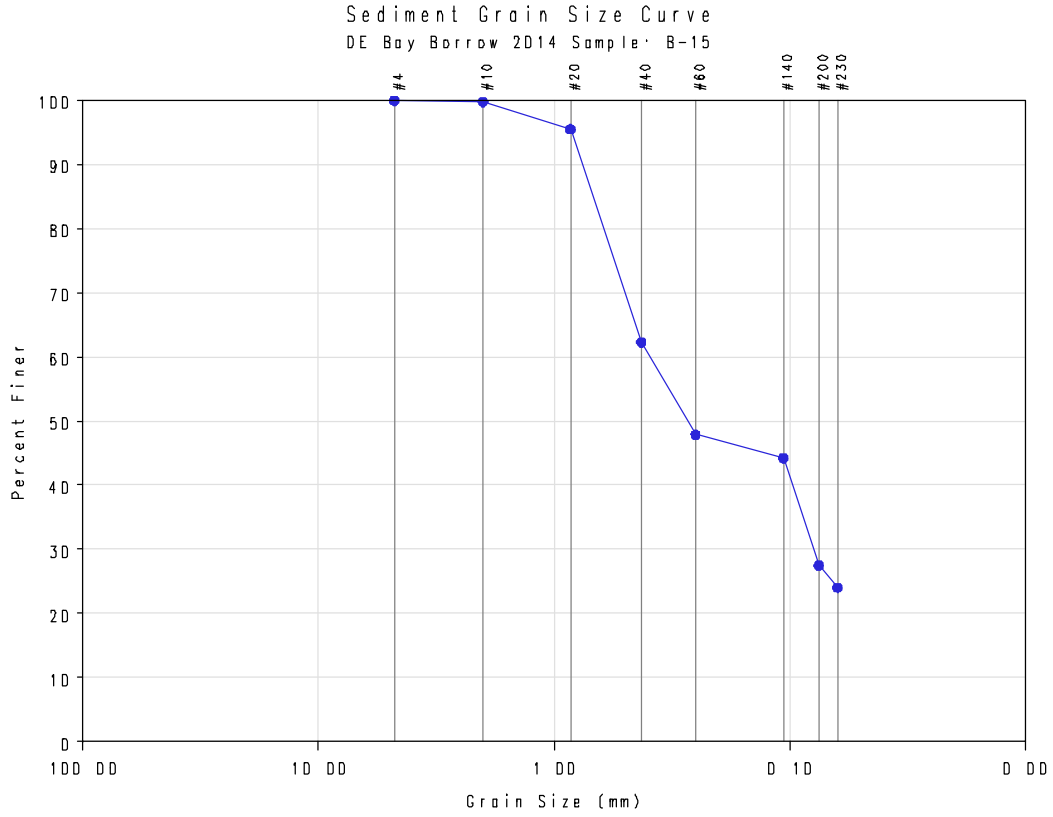

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-10
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

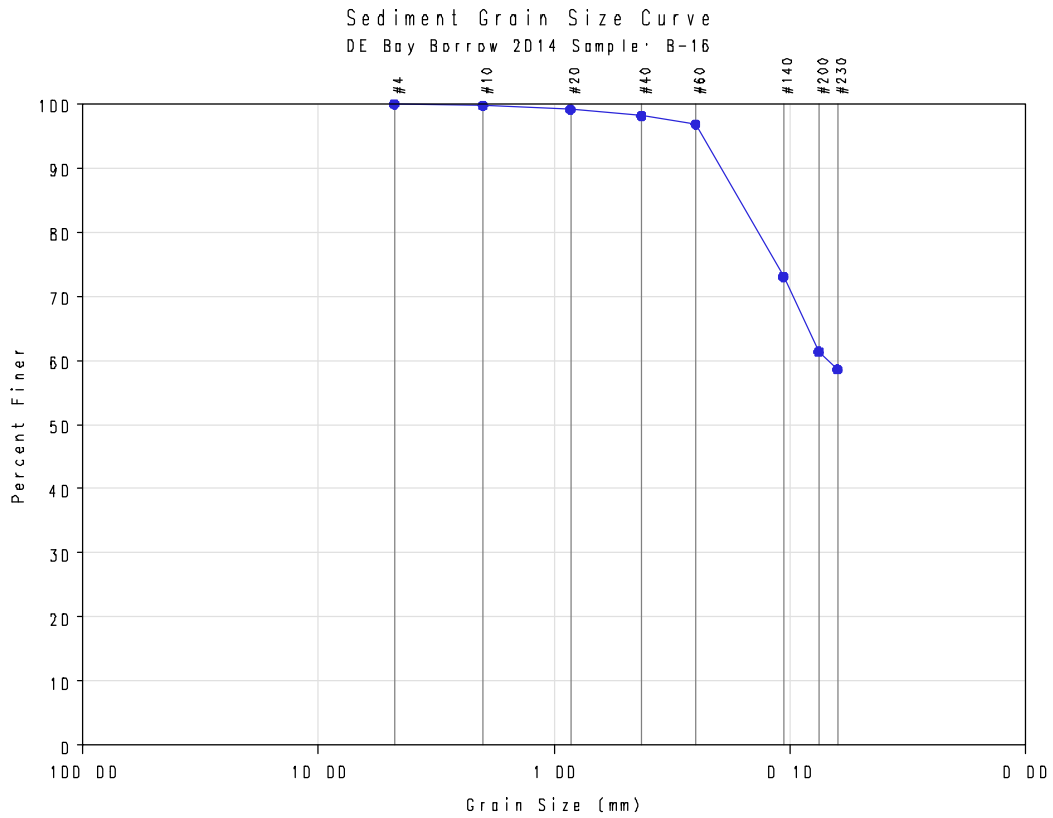

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-11
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

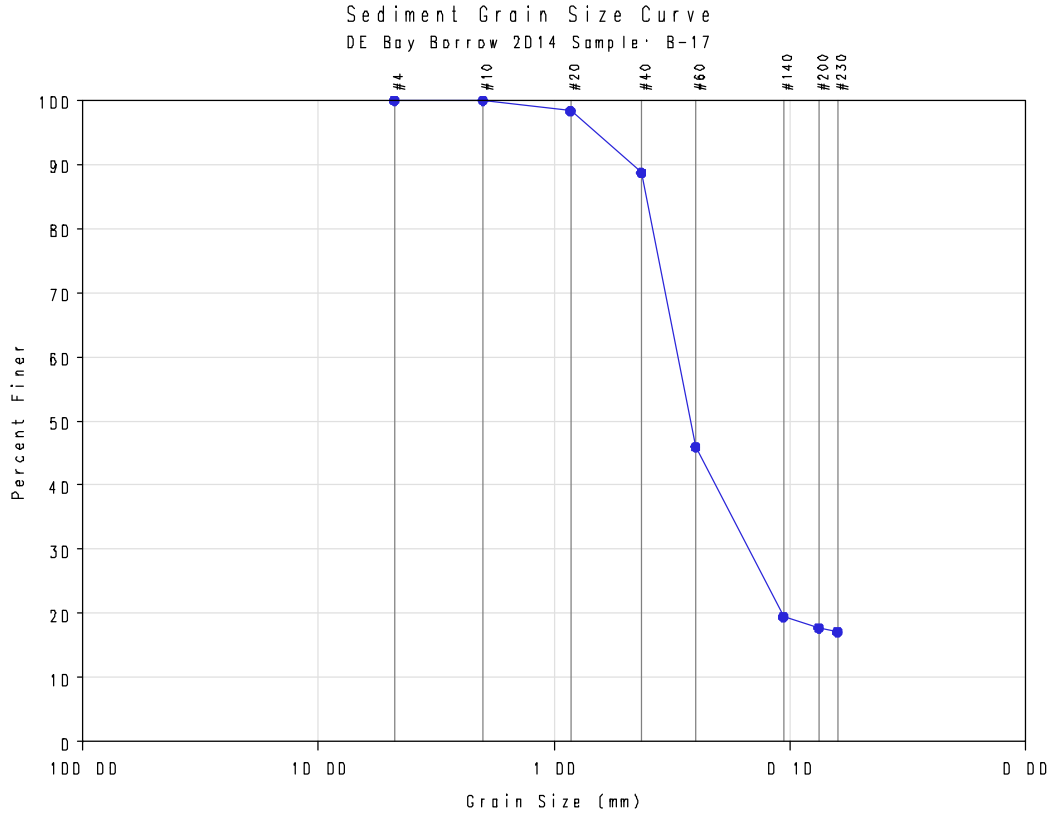

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-12
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

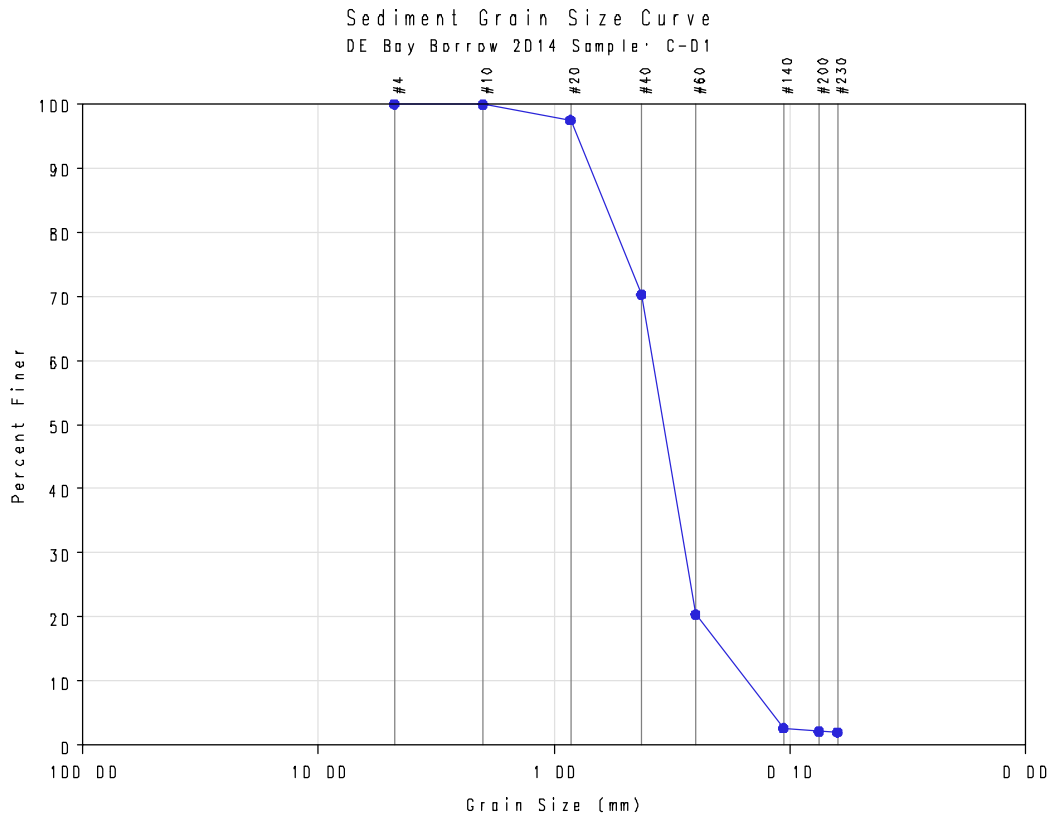

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-13
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

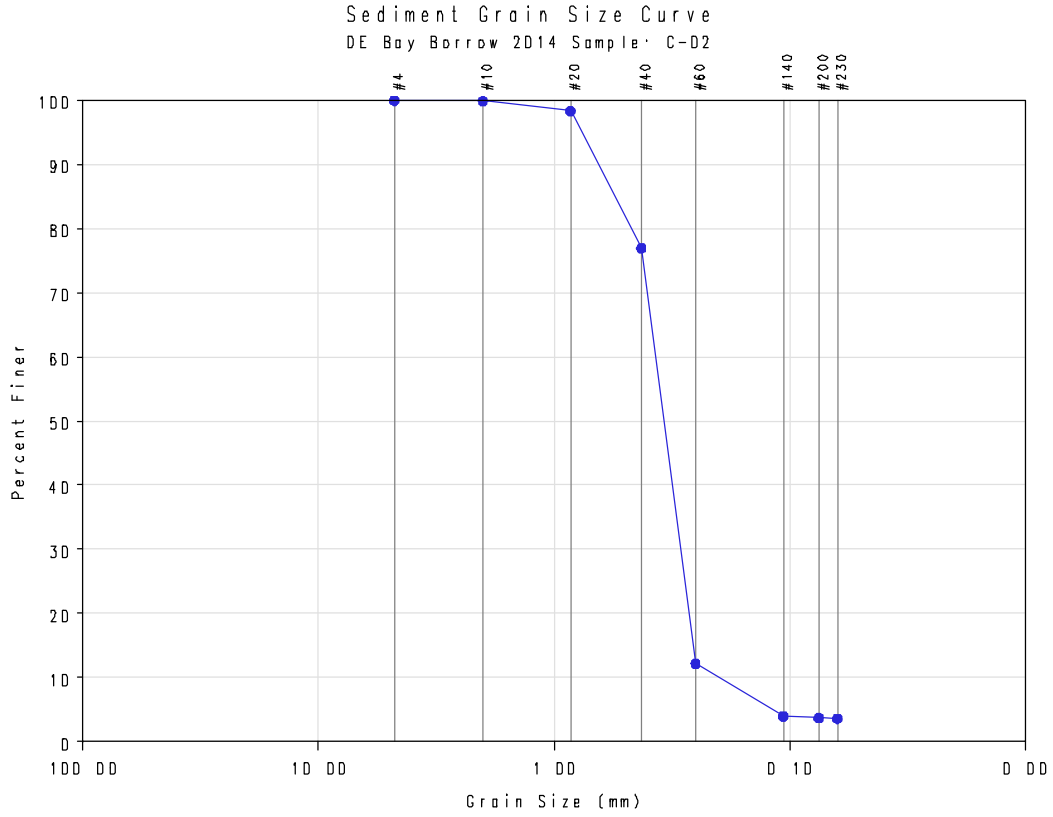

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-14
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

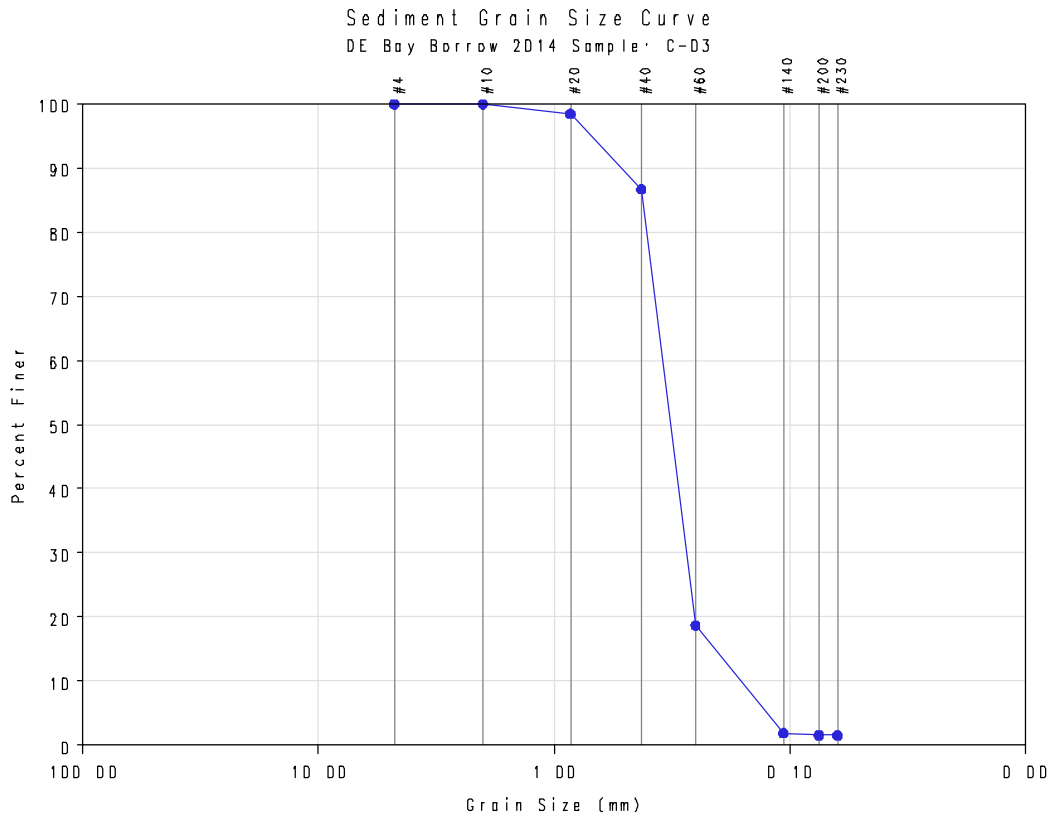

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-15
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

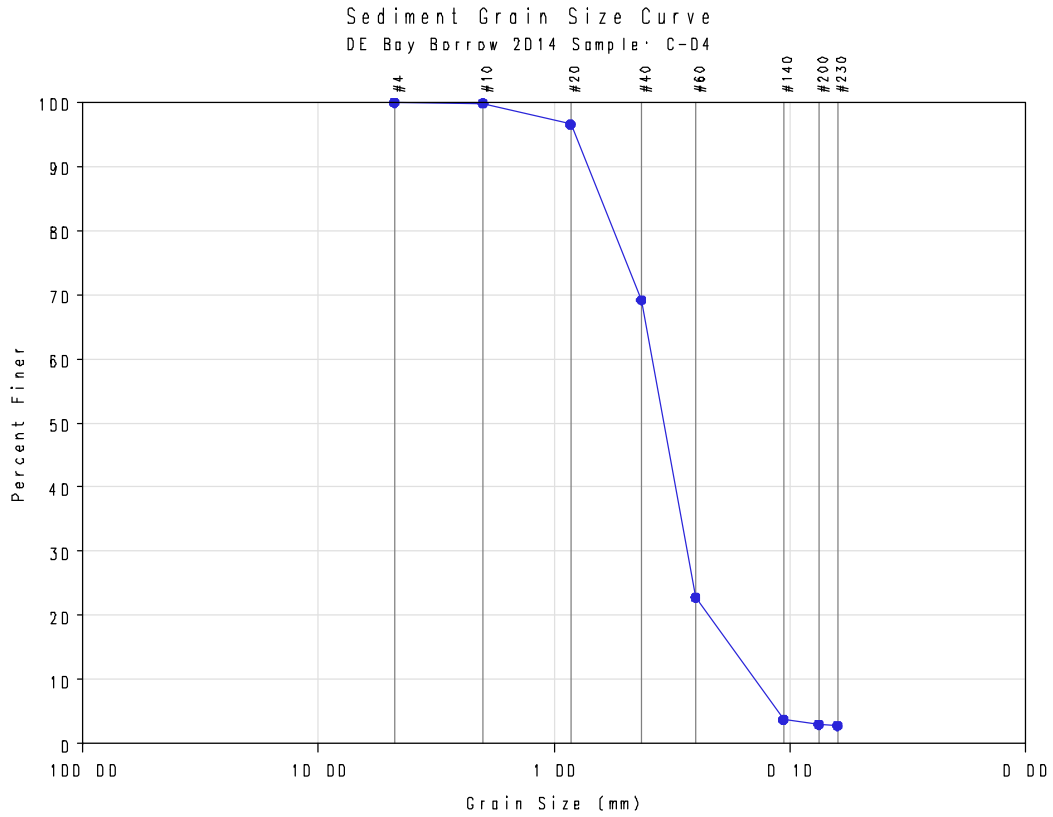

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-16
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.01
Grain Size (mm)

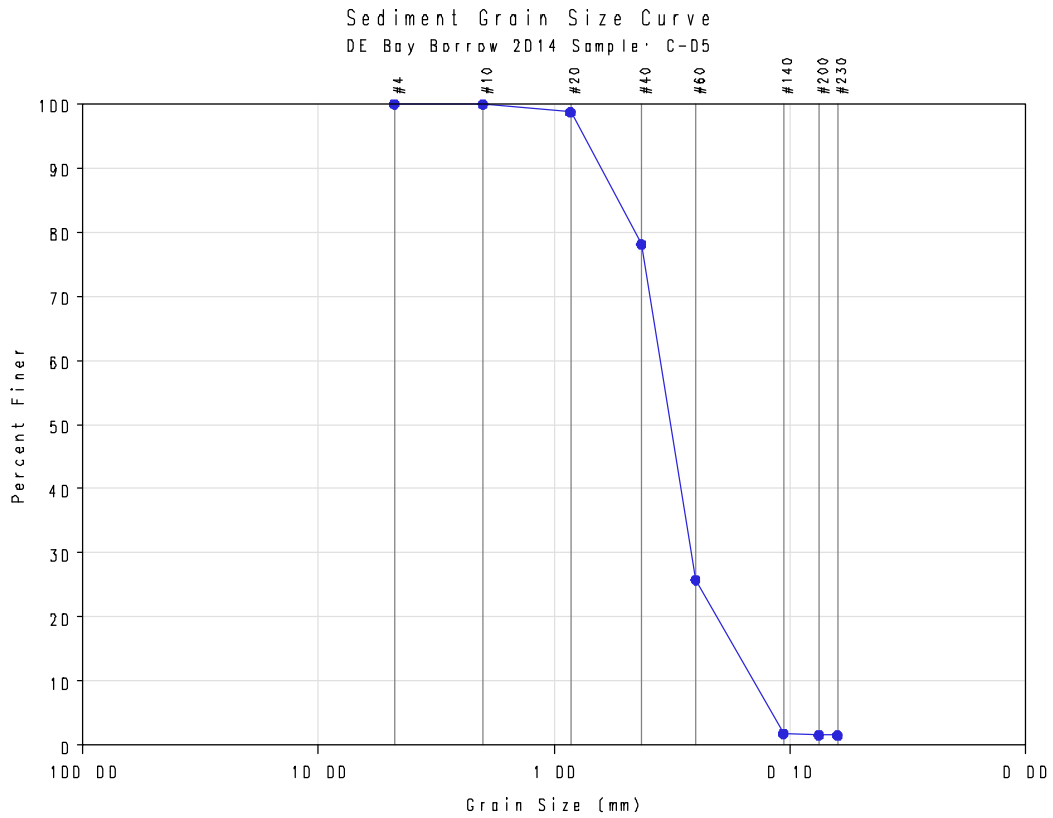

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: B-17
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.01
Grain Size (mm)

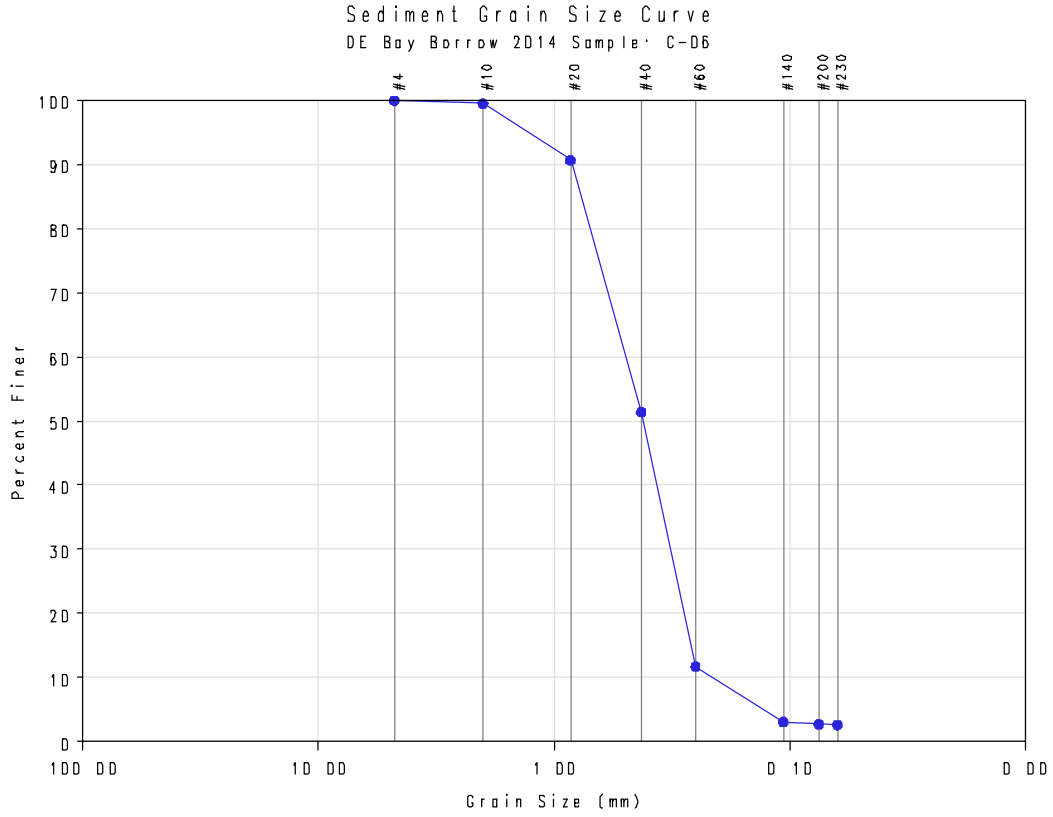

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-D1
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-D2
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-03
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-04
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-05
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-06
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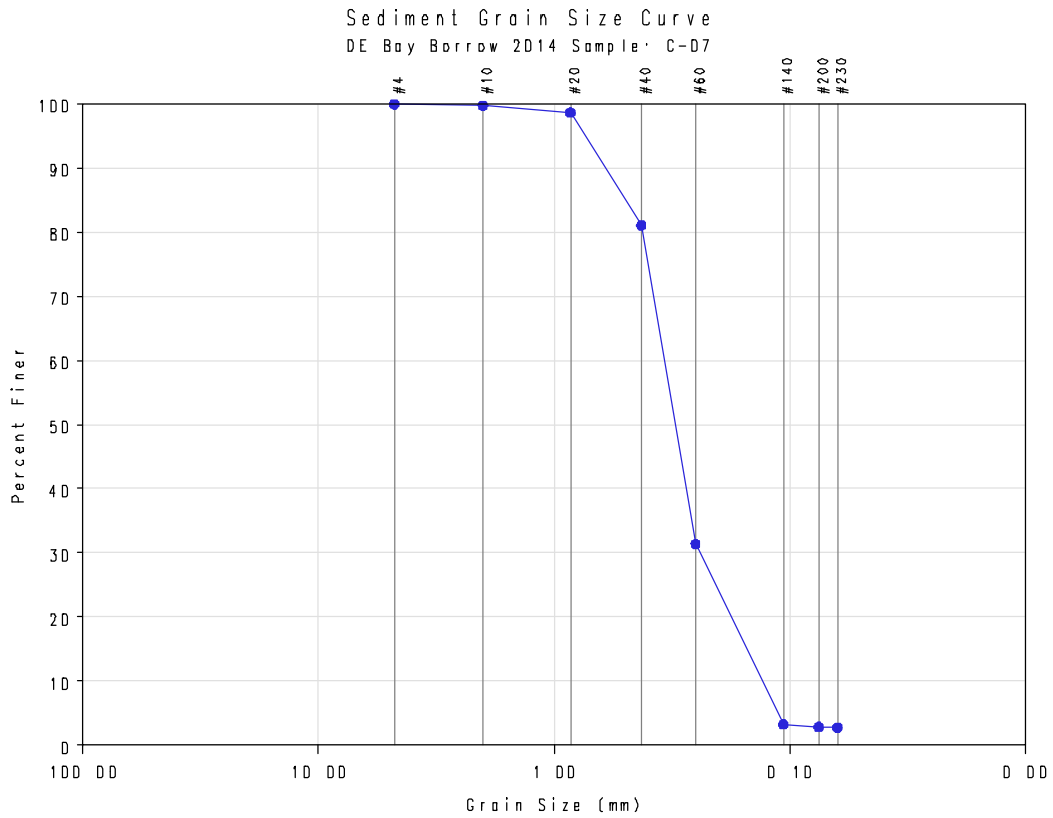
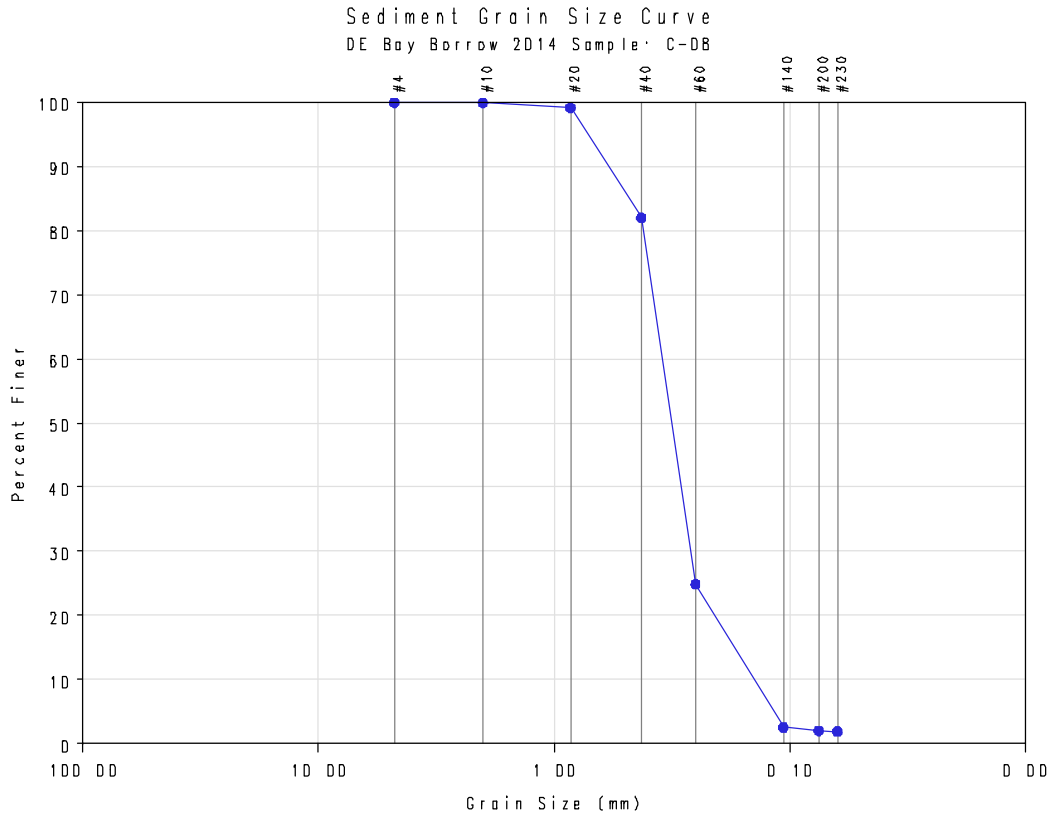
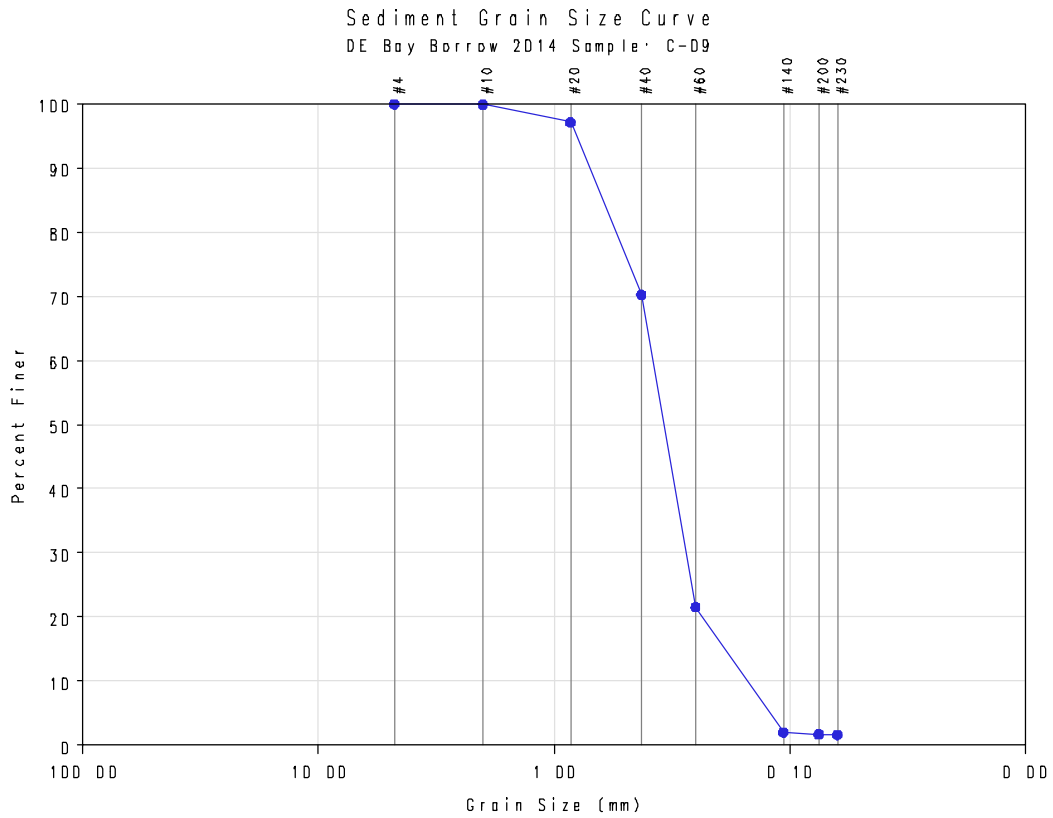
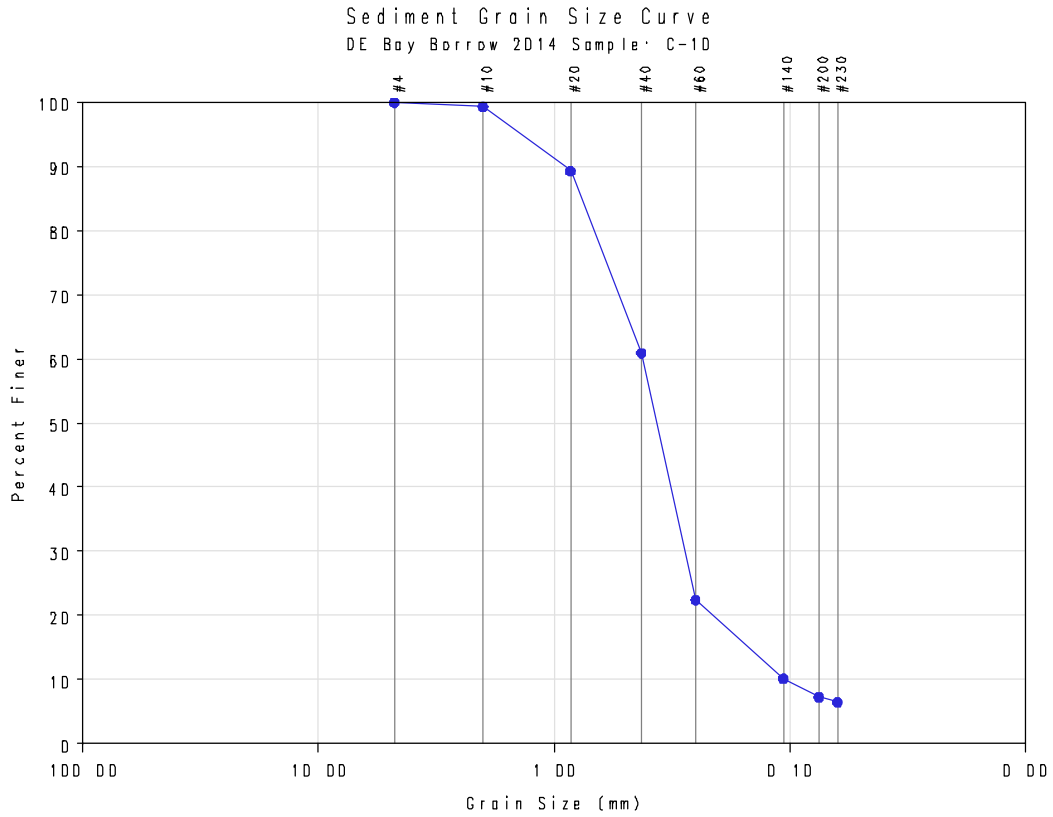
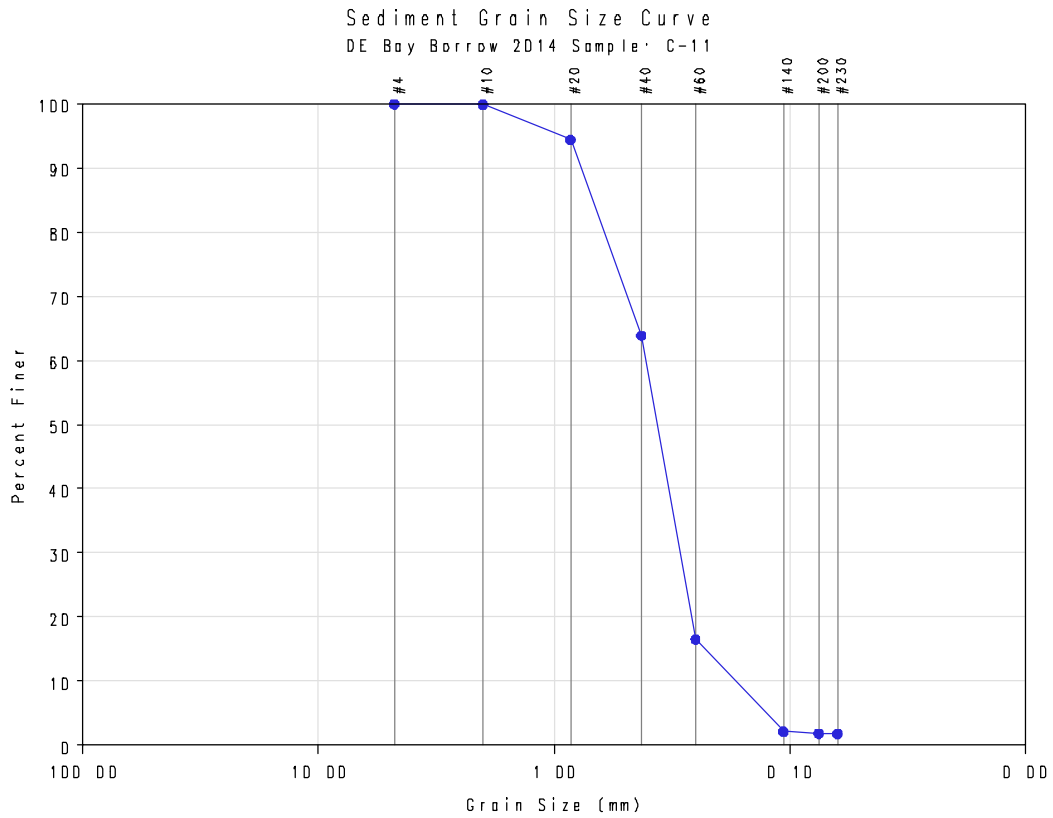
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

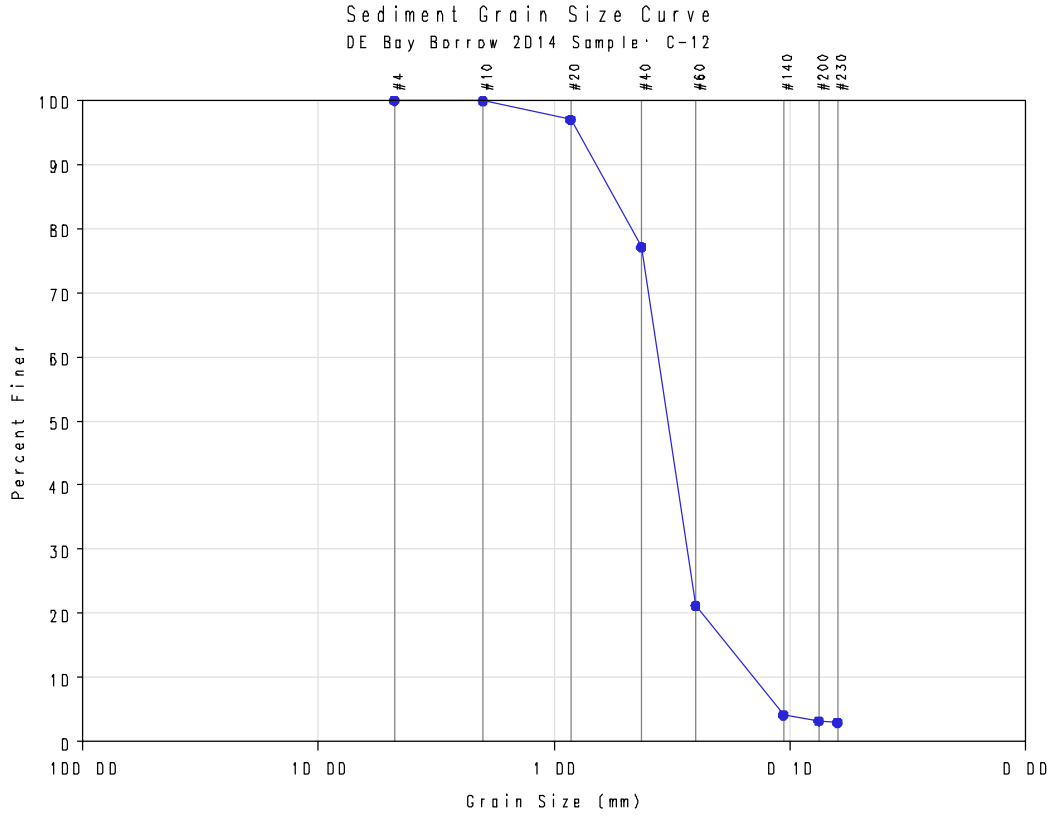

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-07
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

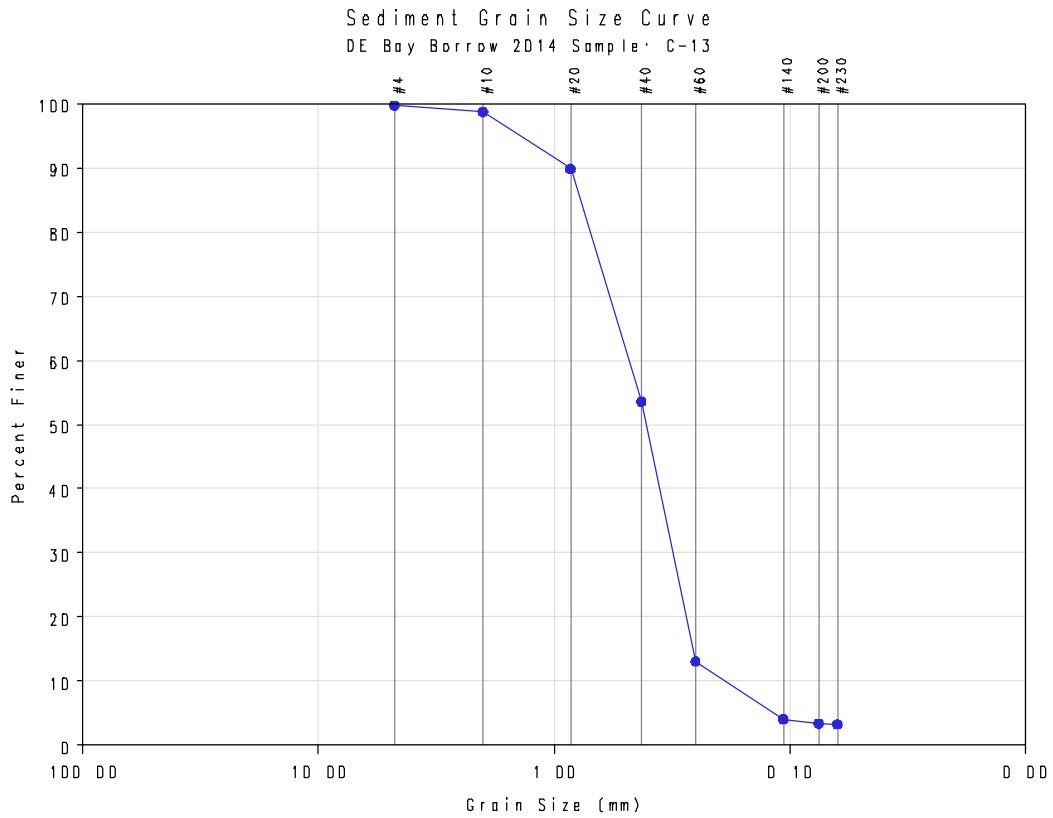

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-08
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

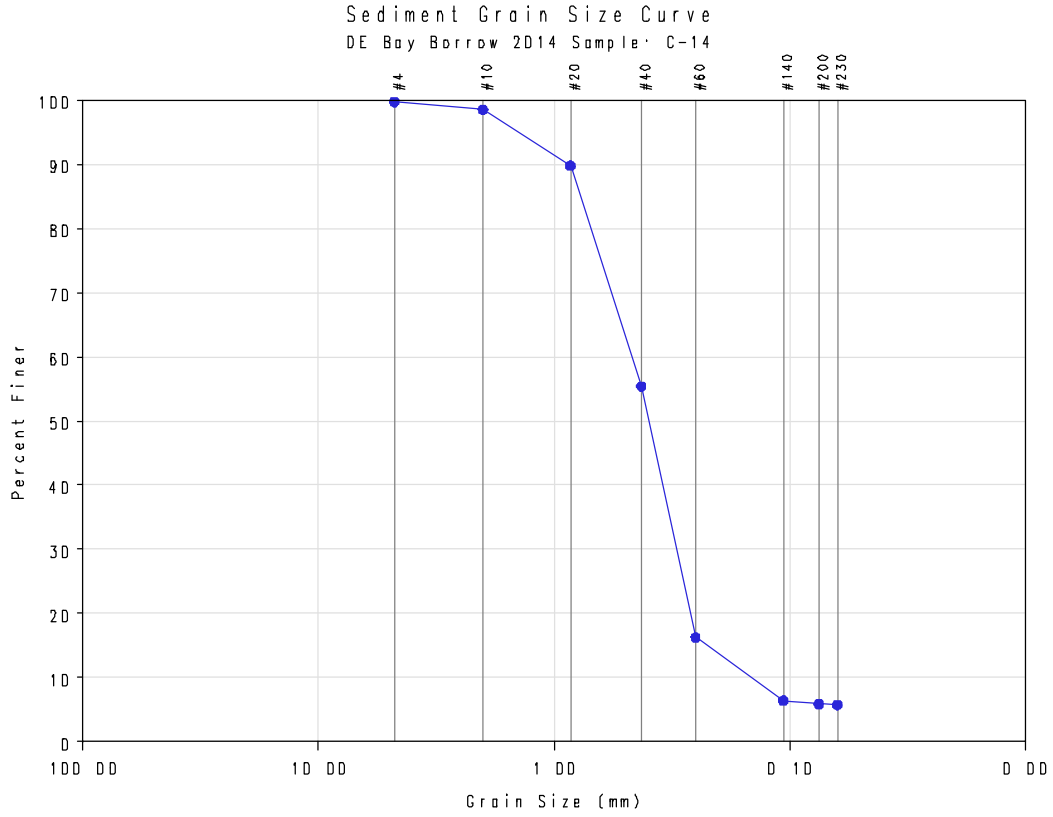

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-09
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

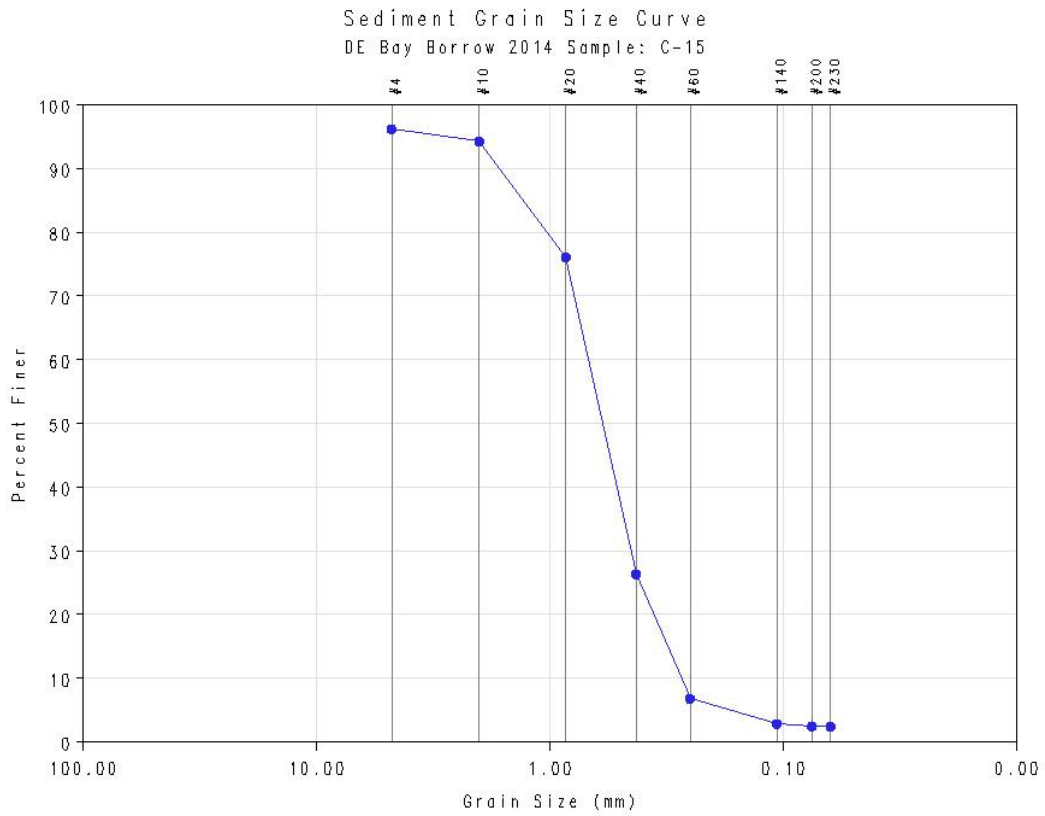

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-10
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

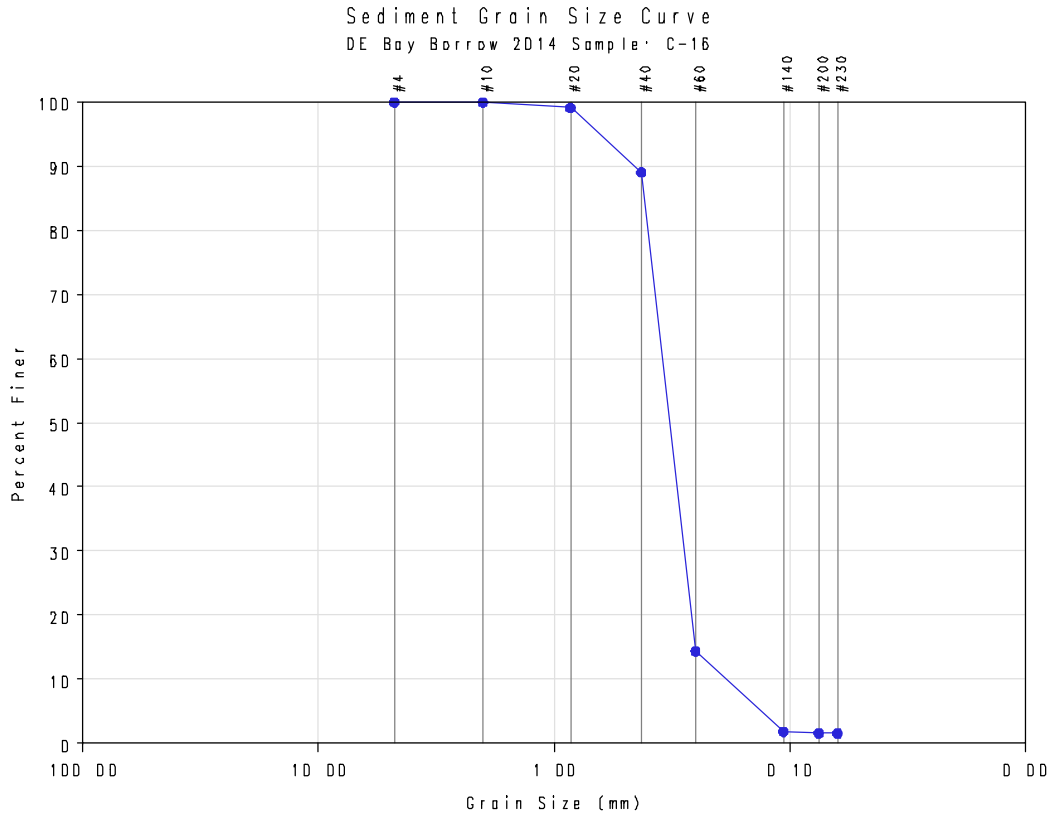

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-11
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

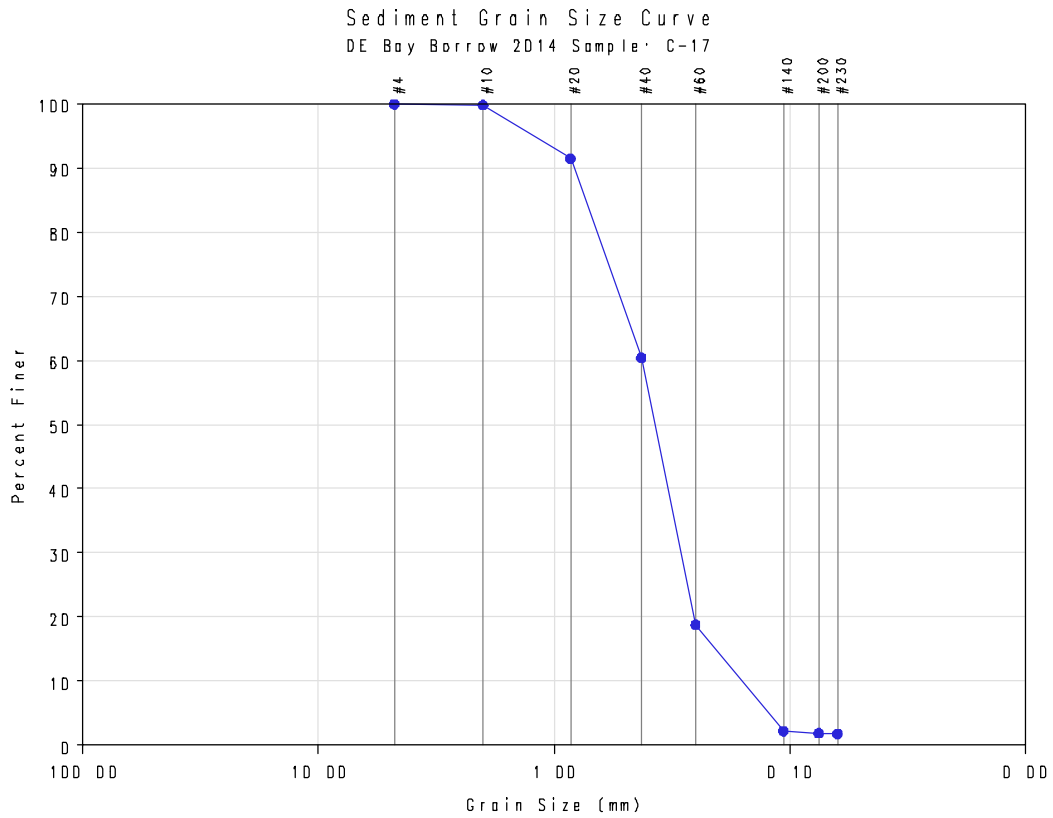

Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-12
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-13
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-14
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-15
#4
#10
#20
#40
#60
#140
#200
#230
Percent Finer
100
90
80
70
60
50
40
30
20
10
0
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-16
#4
#10
#20
#40
#60
#140
#200
#230
Percent Finer
100
90
80
70
60
50
40
30
20
10
0
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)


Sediment Grain Size Curve
DE Bay Borrow 2014 Sample: C-17
#4
#10
#20
#40
#60
#140
#200
#230
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100.00
10.00
1.00
0.10
0.00
Grain Size (mm)

APPENDIX D

STATION-SPECIFIC MEASUREMENTS FOR VARIOUS BENTHIC COMMUNITY PARAMETERS

Table D-1. Station specific macrobenthic abundance and biomass measurements for the 17 stations sampled at the Area A near Prime Hook National Wildlife Refuge, 2014

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-01	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Amastigos caperatus*	68.2		0.6500
		Mediomastus ambiseta	22.7		0.0182
		Caulleriella venefica	272.7		0.1091
		Glycera dibranchiata	45.5	22.7	0.0364
		Euclymene zonalis	45.5		0.0409
		Nephtys bucera	68.2	45.5	0.0091
		Neanthes arenaceodentata	45.5		0.0136
		Scolelepis texana	159.1		0.0023
		Spiophanes bombyx	45.5	22.7	0.0011
		Parapionosyllis longicirrata	22.7		0.0045
		Streptosyllis pettiboneae	45.5		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	250.0		1.4909
		Bathyporeia quoddyensis	68.2		0.1591
		Protohaustorius cf. deichmannae	181.8		0.0023
		Rhepoxynius hudsoni	90.9		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Arthropoda : Isopoda	*Cyathura burbancki*	22.7		0.0682
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	363.6		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	181.8		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	22.7		0.0011
		Gemma gemma	227.3		0.0364
	Nemertina	*Carinoma spp.*	113.6		0.1250
		Micrura spp.	22.7		0.0182
		Nemertina	136.4		0.0114
	Total		2613.6	90.9	2.8227
	Total Number of Taxa		26	3	
A-02	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Amastigos caperatus*	22.7		0.6114
		Caulleriella venefica	22.7		0.1000
		Glycera dibranchiata	22.7	22.7	0.0364
		Maldanidae	22.7		0.0205
		Travisia sp. A	22.7		0.0011
		Leitoscoloplos robustus	68.2		0.0250
		Paraonis fulgens	45.5		0.0068
		Scolelepis texana	90.9		0.0023
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	272.7		1.7909
		Bathyporeia quoddyensis	136.4		0.1568
		Protohaustorius cf. deichmannae	295.5		0.0023
		Rhepoxynius hudsoni	454.5		0.0023
	Arthropoda : Cumacea	*Mancocuma stellifera*	22.7		0.0205
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	159.1		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	136.4		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	136.4		0.0011
	Nemertina	*Carinoma* spp.	45.5		0.1205
		Micrura spp.	22.7		0.0159
	Total		2022.7	22.7	2.9239
	Total Number of Taxa		19	1	
A-03	Annelida : Polychaeta	*Amastigos caperatus*	22.7		0.6068
		Mediomastus ambiseta	22.7		0.0182
		Glycera dibranchiata	22.7		0.0341
		Maldanidae	22.7		0.0205
		Nephtys bucera	45.5	45.5	0.0091
		Neanthes arenaceodentata	22.7		0.0136

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-03 Cont'd	Annelida : Polychaeta Cont'd	*Leitoscoloplos robustus*	45.5		0.0250
		Paraonis pygoenigmatica	22.7		0.0045
		Polygordius jouinae	45.5		0.0045
		Scolelepis texana	136.4		0.0023
		Spiophanes bombyx	22.7		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	431.8		2.0000
		Rhepoxynius hudsoni	818.2		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	90.9		0.0045
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	90.9		0.0011
	Nemertina	*Carinoma* spp.	68.2		0.1250
	Total		2000.0	45.5	2.8886
	Total Number of Taxa		19	1	
A-04	Annelida : Oligochaeta	Oligochaeta	250.0		0.0091
	Annelida : Polychaeta	*Mediomastus ambiseta*	2931.8		0.0205
		Spiochaetopterus costarum	113.6	68.2	0.0011
		Glycera dibranchiata	68.2		0.0364
		Glycinde solitaria	22.7		0.0318
		Nephtys bucera	45.5	22.7	0.0091
		Neanthes succinea	45.5		0.0136
		Scoloplos rubra	159.1		0.0023
		Parapionosyllis longicirrata	90.9		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	45.5		0.3795
		Batea catharinensis	22.7		0.1773
		Monocorophium tuberculatum	22.7		0.0159
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	1386.4		0.0909
		Rhepoxynius hudsoni	22.7		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
		Leucon americanus	181.8		0.0250
	Arthropoda : Isopoda	*Ptilanthura tenuis*	45.5		0.0023
		Edotea triloba	22.7		0.0545
	Echinodermata : Holothuroidea	*Pentamera pulcherrima*	22.7		0.0045
	Hemichordata	*Saccoglossus kowalevskii*	113.6		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	159.1		0.0091
		Ensis directus	22.7		0.0432
	Mollusca : Gastropoda	*Acteocina canaliculata*	477.3		0.7909
	Nemertina	*Amphiporus bioculatus*	45.5		0.2614
		Carinoma spp.	68.2	22.7	0.1295
	Total		6431.8	113.6	2.1420
	Total Number of Taxa		26	3	
A-05	Annelida : Oligochaeta	Oligochaeta	68.2		0.0068
		Heteromastus filiformis	45.5	22.7	0.0295
		Mediomastus ambiseta	4068.2		0.0205
		Spiochaetopterus costarum	22.7	22.7	0.0011
		Tharyx sp. A	45.5		0.0011
		Glycera dibranchiata	45.5	22.7	0.0364
		Glycinde solitaria	227.3		0.0318
		Leitoscoloplos robustus	45.5		0.0250
		Scoloplos rubra	227.3		0.0023
		Aricidea catherinae	22.7		0.2273
	Arthropoda : Amphipoda	*Cerapus tubularis*	45.5		0.0818
		Listriella barnardi	45.5		0.0227
		Americhelidium americanum	45.5		0.5273
		Rhepoxynius hudsoni	22.7		0.0023

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-05 Cont'd	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
		Leucon americanus	22.7		0.0250
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	45.5		0.0045
		Dyspanopeus sayi	22.7		0.0568
	Cnidaria : Anthozoa	*Edwardsia elegans*	45.5	22.7	0.0523
	Hemichordata	*Saccoglossus kowalevskii*	90.9		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	136.4		0.0091
		Pandora gouldiana	22.7		0.0068
	Mollusca : Gastropoda	*Acteocina canaliculata*	431.8		0.8227
	Nemertina	*Amphiporus bioculatus*	45.5		0.2545
		Carinoma spp.	45.5		0.1250
	Total		5909.1	90.9	2.3818
	Total Number of Taxa		25	4	
A-06	Annelida : Polychaeta	*Caulleriella venefica*	22.7		0.1000
		Tharyx sp. A	22.7		0.0011
		Glycera dibranchiata	90.9	68.2	0.0364
		Neanthes arenaceodentata	45.5		0.0136
		Diopatra cuprea	68.2	68.2	0.0659
		Leitoscoloplos robustus	68.2		0.0273
		Aricidea catherinae	45.5		0.2205
		Lepidonotus sublevis	22.7		0.0250
	Arthropoda : Amphipoda	*Batea catharinensis*	136.4		0.1795
		Monocorophium tuberculatum	90.9		0.0159
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	250.0		0.0909
		Listriella barnardi	22.7		0.0227
		Rhepoxynius hudsoni	1568.2		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus*	90.9		0.0068
		Pinnixa chaetopterana	68.2		0.0045
	Arthropoda : Isopoda	*Synidotea laticauda*	22.7		0.0011
	Echinodermata : Holothuroidea	*Pentamera pulcherrima*	22.7		0.0045
	Mollusca : Bivalvia	*Tellina agilis*	159.1		0.0011
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0727
		Astyris lunata	22.7		0.1864
		Kurtziella atrostyla	22.7		0.0295
	Nemertina	*Amphiporus bioculatus*	45.5		0.2773
		Carinoma spp.	204.5	22.7	0.1364
	Total		3181.8	159.1	1.5466
	Total Number of Taxa		25	3	
A-07	Annelida : Polychaeta	*Amastigos caperatus*	22.7		0.5591
		Caulleriella venefica	113.6		0.1068
		Magelona spp.	22.7	22.7	0.0227
		Neanthes succinea	22.7		0.0136
		Scolelepis texana	45.5		0.0023
		Spiophanes bombyx	90.9	45.5	0.0011
	Arthropoda : Amphipoda	*Batea catharinensis*	181.8		0.1795
		Monocorophium tuberculatum	68.2		0.0159
		Acanthohaustorius millsi	181.8		1.2409
		Bathyporeia quoddyensis	250.0		0.1659
		Protohaustorius cf. deichmannae	500.0		0.0045
		Microprotopus raneyi	181.8		0.0182
		Cerapus tubularis	23522.7		0.0932
		Listriella barnardi	22.7		0.0227
		Rhepoxynius hudsoni	409.1		0.0023
		Stenothoe minuta	931.8		0.0011
	Arthropoda : Cumacea	*Oxyurostylis smithi*	90.9		0.0068

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-07 Cont'd	Arthropoda : Decapoda	*Pagurus longicarpus spp.*	22.7		0.0068
		Pinnixa chaetopterana	68.2		0.0045
	Arthropoda : Isopoda	*Edotea triloba*	68.2		0.0568
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	318.2		0.0011
	Cnidaria : Anthozoa	*Edwardsia elegans*	68.2		0.0500
	Hemichordata	*Saccoglossus kowalevskii*	90.9		0.0023
	Mollusca : Gastropoda	*Nassarius trivittatus*	22.7		0.0136
	Nemertina	*Carinoma* spp.	22.7		0.1136
		Nemertina	45.5		0.0114
	Total		27386.3	68.2	2.7170
	Total Number of Taxa		26	2	
A-08	Annelida : Polychaeta	*Caulleriella venefica*	45.5		0.1045
		Parougia caeca	22.7		0.0045
		Euclymene zonalis	22.7	22.7	0.0409
		Travisia sp. A	22.7		0.0011
		Leitoscoloplos robustus	45.5		0.0250
		Phyllodoce arenae	22.7		0.0045
		Dispio uncinata	22.7	22.7	0.0614
		Scolelepis texana	45.5		0.0023
		Spiophanes bombyx	45.5		0.0011
		Parapionosyllis longicirrata	45.5		0.0045
		Streptosyllis pettiboneae	45.5		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	568.2		2.2250
		Bathyporeia quoddyensis	90.9		0.1545
		Protohaustorius cf. deichmannae	454.5		0.0045
		Cerapus tubularis	45.5		0.0864
		Rhepoxynius hudsoni	22.7		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus spp.*	22.7		0.0068
		Pinnixa chaetopterana	22.7		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1363.6		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	159.1		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Ensis directus	22.7	22.7	0.0500
		Gemma gemma	22.7		0.0364
	Nemertina	*Carinoma* spp.	45.5		0.1205
		Cerebratulus lacteus	22.7	22.7	0.0818
		Micrura spp.	22.7		0.0159
	Total		3318.2	90.9	3.0511
	Total Number of Taxa		27	4	
A-09	Annelida : Polychaeta	*Heteromastus filiformis*	90.9		0.0295
		Spiochaetopterus costarum	45.5	22.7	0.0011
		Glycera dibranchiata	22.7	22.7	0.0364
		Maldanidae	22.7		0.0205
		Nephtyidae	22.7		0.0114
		Neanthes arenaceodentata	22.7		0.0136
		Diopatra cuprea	22.7	22.7	0.0659
		Leitoscoloplos robustus	68.2		0.0273
		Scoloplos rubra	22.7		0.0023
		Aricidea catherinae	22.7		0.2205
		Polygordius jouinae	45.5		0.0045
		Spiophanes bombyx	22.7		0.0011
	Arthropoda : Amphipoda	*Monocorophium tuberculatum*	68.2		0.0159
		Acanthohaustorius millsi	136.4		1.1659
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	45.5		0.0864
		Rhepoxynius hudsoni	750.0		0.0023

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-09 Cont'd	Arthropoda : Cumacea	*Mancocuma stellifera*	22.7		0.0205
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	45.5		0.0045
	Arthropoda : Isopoda	*Ptilanthura tenuis*	22.7		0.0023
		Edotea triloba	22.7		0.0545
		Synidotea laticauda	22.7		0.0011
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	159.1		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	159.1		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	159.1		0.0011
		Gemma gemma	68.2		0.0386
	Nemertina	*Carinoma* spp.	90.9		0.1295
		Nemertina	22.7		0.0114
	Total		2250.0	68.2	1.9898
	Total Number of Taxa		28	3	
A-10	Annelida : Polychaeta	*Heteromastus filiformis*	22.7		0.0295
		Caulleriella venefica	22.7		0.1000
		Nephtys bucera	22.7		0.0091
		Scolelepis texana	136.4		0.0023
		Spiophanes bombyx	68.2	45.5	0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	431.8		3.3818
		Bathyporeia quoddyensis	181.8		0.1636
		Protohaustorius cf. deichmannae	250.0		0.0023
		Listriella barnardi	22.7		0.0227
		Rhepoxynius hudsoni	90.9		0.0023
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1227.3		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	68.2		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Tellina agilis	45.5		0.0011
	Mollusca : Gastropoda	*Nassarius trivittatus*	22.7		0.0136
	Nemertina	*Carinoma* spp.	45.5		0.1227
		Micrura spp.	22.7		0.0159
	Total		2704.5	45.5	3.8727
	Total Number of Taxa		17	1	
A-11	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Amastigos caperatus*	45.5		0.5568
		Caulleriella venefica	45.5		0.1023
		Parougia caeca	45.5		0.0045
		Nephtys bucera	45.5	45.5	0.0091
		Neanthes arenaceodentata	545.5		0.0136
		Travisia sp. A	22.7		0.0011
		Paraonis pygoenigmatica	45.5		0.0045
		Polygordius jouinae	22.7		0.0045
		Scolelepis texana	22.7		0.0023
		Spiophanes bombyx	22.7		0.0011
		Streptosyllis pettiboneae	22.7		0.0011
	Arthropoda : Amphipoda	*Ampelisca abdita*	22.7		0.3864
		Unciola serrata	22.7		0.0011
		Batea catharinensis	340.9		0.1818
		Monocorophium tuberculatum	68.2		0.0159
		Acanthohaustorius millsi	454.5		1.8523
		Bathyporeia quoddyensis	45.5		0.1477
		Protohaustorius cf. deichmannae	113.6		0.0023
		Microprotopus raneyi	2250.0		0.0182
		Cerapus tubularis	2000.0		0.0932
		Rhepoxynius hudsoni	340.9		0.0023
	Arthropoda : Cumacea	*Mancocuma stellifera*	45.5		0.0205
	Arthropoda : Isopoda	*Edotea triloba*	22.7		0.0545
		Synidotea laticauda	22.7		0.0011
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1340.9		0.0011

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-11 Cont'd	Hemichordata	*Saccoglossus kowalevskii*	181.8		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	113.6		0.0011
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0727
	Nemertina	*Carinoma* spp.	45.5		0.1205
		Nemertina	45.5		0.0114
	Total		8409.1	45.5	3.6943
	Total Number of Taxa		31	1	
A-12	Annelida : Oligochaeta	Oligochaeta	409.1		0.0091
	Annelida : Polychaeta	*Asabellides oculata*	45.5		0.2136
		Mediomastus ambiseta	5295.4		0.0205
		Tharyx sp. A	22.7		0.0011
		Glycera dibranchiata	22.7		0.0341
		Glycinde solitaria	250.0		0.0318
		Diopatra cuprea	22.7	22.7	0.0636
		Leitoscoloplos robustus	136.4	45.5	0.0273
		Scoloplos rubra	113.6		0.0023
		Pectinaria gouldii	22.7		0.0045
A-12 Cont'd	Annelida : Polychaeta (Cont'd)	*Eumida sanguinea*	22.7		0.0386
		Parapionosyllis longicirrata	90.9		0.0045
	Arthropoda : Amphipoda	*Microprotopus raneyi*	22.7		0.0182
		Cerapus tubularis	136.4		0.0818
		Listriella barnardi	45.5		0.0227
		Rhepoxynius hudsoni	45.5		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
		Leucon americanus	90.9		0.0227
	Arthropoda : Isopoda	*Synidotea laticauda*	22.7		0.0011
	Echinodermata : Holothuroidea	*Pentamera pulcherrima*	22.7		0.0045
	Hemichordata	*Saccoglossus kowalevskii*	68.2		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	272.7		0.0091
		Ensis directus	22.7		0.0455
	Mollusca : Gastropoda	*Acteocina canaliculata*	886.4		0.8682
		Kurtziella atrostyla	22.7		0.0295
	Nemertina	*Amphiporus bioculatus*	68.2		0.2909
		Carinoma spp.	136.4		0.1318
	Platyhelminthes : Turbellaria	*Stylochus ellipticus*	22.7		0.0011
	Total		8363.6	68.2	1.9898
	Total Number of Taxa		28	2	
A-13	Annelida : Oligochaeta	Oligochaeta	90.9		0.0091
	Annelida : Polychaeta	*Asabellides oculata*	22.7		0.2136
		Amastigos caperatus	22.7		0.5864
		Mediomastus ambiseta	136.4		0.0182
		Spiochaetopterus costarum	22.7		0.0011
		Glycera dibranchiata	45.5	22.7	0.0364
		Neanthes arenaceodentata	204.5		0.0136
		Diopatra cuprea	22.7		0.0636
		Leitoscoloplos robustus	22.7		0.0273
		Scoloplos rubra	68.2		0.0023
		Paradoneis sp. B	68.2		0.0068
		Pectinaria gouldii	22.7		0.0045
		Dipolydora socialis	22.7		0.0614
		Scolelepis texana	22.7		0.0023
		Erinaceusyllis erinaceus	22.7		0.0011
		Parapionosyllis longicirrata	22.7		0.0045
	Arthropoda : Amphipoda	*Batea catharinensis*	22.7		0.1705
		Monocorophium tuberculatum	340.9		0.0159
		Bathyporeia quoddyensis	22.7		0.1432
		Cerapus tubularis	113.6		0.0818
		Rhepoxynius hudsoni	227.3		0.0023

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-13 Cont'd	Arthropoda : Cumacea	*Mancocuma stellifera*	22.7		0.0205
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	68.2		0.0045
		Dyspanopeus sayi	22.7		0.0591
	Arthropoda : Isopoda	*Ptilanthura tenuis*	22.7		0.0023
	Hemichordata	*Saccoglossus kowalevskii*	136.4		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	68.2		0.0011
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0727
		Astyris lunata	22.7		0.1886
	Nemertina	*Amphiporus bioculatus*	45.5		0.2773
		Carinoma spp.	22.7		0.1227
		Carinomella lactea	22.7		0.1091
	Total		2045.4	22.7	2.3261
	Total Number of Taxa		32	1	
A-14	Annelida : Oligochaeta	Oligochaeta	272.7		0.0091
	Annelida : Polychaeta	*Mediomastus ambiseta*	545.5		0.0205
		Caulleriella venefica	45.5		0.0977
		Glycera dibranchiata	90.9	68.2	0.0364
		Leitoscoloplos robustus	22.7		0.0250
		Scoloplos rubra	590.9		0.0023
		Parapionosyllis longicirrata	522.7		0.0045
	Arthropoda : Amphipoda	*Rhepoxynius hudsoni*	136.4		0.0023
A-14 Cont'd	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	22.7		0.0091
		Ensis directus	22.7		0.0455
		Tellina agilis	22.7		0.0011
	Mollusca : Gastropoda	*Acteocina canaliculata*	90.9		0.7386
	Nemertina	*Carinoma* spp.	159.1		0.1182
	Total		2590.9	68.2	1.1170
	Total Number of Taxa		15	1	
A-15	Annelida : Polychaeta	*Caulleriella venefica*	45.5		0.1023
		Maldanidae	22.7		0.0205
		Nephtys bucera	22.7	22.7	0.0091
		Leitoscoloplos robustus	45.5		0.0273
		Paradoneis sp. B	22.7		0.0068
		Scolelepis texana	90.9		0.0023
		Spiophanes bombyx	90.9	22.7	0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	204.5		1.2205
		Bathyporeia quoddyensis	272.7		0.1659
		Protohaustorius cf. deichmannae	409.1		0.0045
		Cerapus tubularis	45.5		0.0818
		Rhepoxynius hudsoni	954.5		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	90.9		0.0011
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
	Mollusca : Gastropoda	*Nassarius trivittatus*	22.7	22.7	0.0159
	Nemertina	Nemertina	22.7		0.0114
	Total		2431.8	68.2	1.6807
	Total Number of Taxa		17	3	
A-16	Annelida : Polychaeta	*Caulleriella venefica*	90.9		0.1023
		Nephtys picta	22.7		0.0091
		Travisia sp. A	68.2		0.0011
		Paraonis pygoenigmatica	22.7		0.0045
		Dispio uncinata	45.5		0.0614
		Scolelepis texana	22.7		0.0023
		Spiophanes bombyx	22.7		0.0011
		Parapionosyllis longicirrata	45.5		0.0045

Table D-1. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
A-16 Cont'd	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	477.3		3.0727
		Protohaustorius cf. deichmannae	272.7		0.0023
		Cerapus tubularis	22.7		0.0818
		Listriella barnardi	22.7		0.0227
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Arthropoda : Isopoda	*Ptilanthura tenuis*	22.7		0.0023
		Ancinus depressus	22.7		0.2477
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	181.8		0.0011
	Chordata : Ascidiacea	Ascidiacea	22.7		0.1932
	Hemichordata	*Saccoglossus kowalevskii*	159.1		0.0023
	Mollusca : Bivalvia	*Ensis directus*	22.7		0.0455
		Gemma gemma	272.7		0.0386
	Nemertina	*Carinoma* spp.	22.7		0.1205
		Nemertina	90.9		0.0114
	Total		1977.3	0	4.0329
	Total Number of Taxa		22	0	
A-17	Annelida : Oligochaeta	Oligochaeta	45.5		0.0068
	Annelida : Polychaeta	*Amastigos caperatus*	22.7		0.5795
		Glycera dibranchiata	22.7		0.0364
		Polygordius jouinae	22.7		0.0045
		Scolelepis texana	159.1		0.0023
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	454.5		2.4954
		Rhepoxynius hudsoni	795.5		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus* spp.	45.5		0.0068
		Pinnixa chaetopterana	68.2		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	90.9		0.0011
	Mollusca : Bivalvia	*Ensis directus*	22.7		0.0455
		Tellina agilis	204.5		0.0011
	Nemertina	*Amphiporus bioculatus*	22.7		0.2886
	Total		2090.9	0	3.5091
	Total Number of Taxa		15	0	

Table D-2. Station specific macrobenthic abundance and biomass measurements for the 17 stations sampled at the Area B near Prime Hook National Wildlife Refuge, 2014

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-01	Annelida : Polychaeta	*Asabellides oculata*	22.7		0.2023
		Drilonereis longa	22.7	22.7	0.0614
		Mediomastus ambiseta	4363.6		0.0205
		Spiochaetopterus costarum	681.8	363.6	0.0011
		Tharyx sp. A	22.7		0.0011
		Glycera dibranchiata	68.2	68.2	0.0364
		Glycinde solitaria	727.3		0.0341
		Neanthes succinea	227.3		0.0136
		Leitoscoloplos robustus	454.5	227.3	0.0273
		Aricidea catherinae	136.4	45.5	0.2341
		Pectinaria gouldii	204.5	113.6	0.0045
		Phyllodoce arenae	45.5	22.7	0.0045
		Paraprionospio pinnata	22.7	22.7	0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	6590.9		0.4909
		Ampelisca verrilli	113.6		0.3500
		Monocorophium tuberculatum	681.8		0.0159
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	54954.4		0.0955
		Ericthonius brasiliensis	204.5		0.0432
		Parametopella cypris	22.7		0.0068
	Arthropoda : Cumacea	*Leucon americanus*	22.7		0.0250
	Arthropoda : Decapoda	*Pagurus longicarpus* spp.	22.7		0.0068
	Arthropoda : Isopoda	*Edotea triloba*	250.0		0.0568
	Cnidaria : Anthozoa	*Edwardsia elegans*	90.9		0.0523
	Mollusca : Bivalvia	*Mulinia lateralis*	90.9		0.0159
		Nucula proxima	318.2		0.0091
		Tellina agilis	90.9		0.0011
		Mercenaria mercenaria	45.5		0.0182
	Mollusca : Gastropoda	*Astyris lunata*	22.7		0.1864
		Nassarius trivittatus	22.7		0.0136
		Acteocina canaliculata	500.0		0.8545
	Nemertina	*Amphiporus bioculatus*	22.7		0.3159
		Carinomella lactea	136.4		0.1114
	Total		71227.0	886.4	3.3329
	Total Number of Taxa		33	8	
B-02	Annelida : Polychaeta	*Heteromastus filiformis*	90.9		0.0295
		Mediomastus ambiseta	159.1		0.0182
		Spiochaetopterus costarum	22.7		0.0011
		Caulleriella venefica	159.1		0.1068
		Glycera dibranchiata	22.7	22.7	0.0364
		Maldanidae	45.5		0.0205
		Neanthes arenaceodentata	45.5		0.0136
		Opheliidae	22.7		0.0068
		Travisia sp. A	22.7		0.0011
		Leitoscoloplos robustus	136.4		0.0273
		Eteone heteropoda	22.7		0.0409
		Scolelepis texana	1045.5		0.0023
		Streblospio benedicti	22.7		0.0011
	Arthropoda : Amphipoda	*Ampelisca abdita*	136.4		0.4795
		Acanthohaustorius millsi	318.2		1.8977
		Bathyporeia quoddyensis	477.3		0.1705
		Protohaustorius cf. deichmannae	90.9		0.0023
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	522.7		0.0932
		Listriella barnardi	68.2		0.0227
		Rhepoxynius hudsoni	113.6		0.0023
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	977.3		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	90.9		0.0023

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-02 Cont'd	Mollusca : Bivalvia	*Tellina agilis*	22.7		0.0011
		Gemma gemma	22.7		0.0364
	Nemertina	Nemertina	68.2		0.0114
	Total		4750.0	22.7	3.0443
	Total Number of Taxa		26	1	
B-03	Annelida : Oligochaeta	Oligochaeta	68.2		0.0068
	Annelida : Polychaeta	*Heteromastus filiformis*	45.5	22.7	0.0295
		Mediomastus ambiseta	1022.7		0.0205
		Parougia caeca	45.5		0.0045
		Glycera dibranchiata	22.7	22.7	0.0341
		Glycinde solitaria	22.7		0.0318
		Magelona spp.	22.7		0.0227
		Euclymene zonalis	22.7		0.0409
		Nephtys picta	22.7		0.0091
		Neanthes arenaceodentata	136.4		0.0136
		Neanthes succinea	68.2	22.7	0.0136
		Diopatra cuprea	68.2		0.0636
		Leitoscoloplos robustus	22.7		0.0250
		Scoloplos rubra	45.5		0.0023
		Phyllodoce arenae	68.2	45.5	0.0045
		Polygordius jouinae	22.7		0.0045
		Scolelepis texana	45.5		0.0023
		Erinaceusyllis erinaceus	22.7		0.0409
		Parapionosyllis longicirrata	22.7		0.0045
	Arthropoda : Amphipoda	*Batea catharinensis*	477.3		0.1864
		Monocorophium tuberculatum	568.2		0.0159
		Acanthohaustorius millsi	22.7		1.0182
		Cerapus tubularis	22.7		0.0864
		Listriella barnardi	22.7		0.0227
		Rhepoxynius hudsoni	181.8		0.0023
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	68.2		0.0045
	Chordata : Cephalochordata	*Branchiostoma caribaeum*	45.5		0.1409
	Hemichordata	*Saccoglossus kowalevskii*	340.9		0.0023
	Mollusca : Bivalvia	*Lyonsia hyalina*	22.7		0.0227
		Tellina agilis	204.5		0.0011
		Gemma gemma	204.5		0.0386
	Mollusca : Gastropoda	*Crepidula fornicata*	45.5		0.0727
	Nemertina	*Carinoma* spp.	159.1		0.1318
	Nemertina	Nemertina	68.2		0.0114
	Total		4295.4	113.6	2.1398
	Total Number of Taxa		35	4	
B-04	Annelida : Oligochaeta	Oligochaeta	90.9		0.0091
	Annelida : Polychaeta	*Mediomastus ambiseta*	45.5		0.0205
		Caulleriella venefica	295.5		0.1091
		Tharyx sp. A	45.5		0.0011
		Maldanidae	22.7		0.0205
		Opheliidae	22.7		0.0068
		Travisia sp. A	45.5		0.0011
		Leitoscoloplos robustus	22.7		0.0273
		Phyllodoce arenae	22.7	22.7	0.0045
		Scolelepis texana	568.2		0.0023
		Spiophanes bombyx	22.7		0.0011
		Parapionosyllis longicirrata	45.5		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	22.7		0.4705
		Acanthohaustorius millsi	250.0		1.1727
		Bathyporeia quoddyensis	250.0		0.1614
		Protohaustorius cf. deichmannae	318.2		0.0045
		Cerapus tubularis	113.6		0.0932
		Rhepoxynius hudsoni	363.6		0.0023

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-04 Cont'd	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1204.5		0.0011
	Chordata : Ascidiacea	Ascidiacea	45.5		0.2000
	Hemichordata	*Saccoglossus kowalevskii*	204.5		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Tellina agilis	159.1		0.0011
		Gemma gemma	22.7		0.0386
	Nemertina	*Carinoma* spp.	22.7	22.7	0.1318
		Micrura spp.	22.7	22.7	0.0182
		Nemertina	68.2		0.0114
	Total		4363.6	68.2	2.5227
	Total Number of Taxa		28	3	
B-05	Annelida : Polychaeta	*Mediomastus ambiseta*	90.9		0.0205
		Spiochaetopterus costarum	22.7		0.0011
		Caulleriella venefica	45.5		0.1068
		Glycinde solitaria	90.9		0.0318
		Leitoscoloplos robustus	136.4	22.7	0.0273
		Paraprionospio pinnata	204.5	204.5	0.0045
	Arthropoda : Amphipoda	*Cerapus tubularis*	386.4		0.0932
	Mollusca : Bivalvia	*Mulinia lateralis*	45.5		0.0159
		Nucula proxima	90.9		0.0091
	Mollusca : Gastropoda	*Acteocina canaliculata*	363.6		0.9023
	Nemertina	*Carinomella lactea*	181.8		0.1136
	Total		1659.1	227.3	1.3261
	Total Number of Taxa		11	2	
B-06	Annelida : Polychaeta	*Heteromastus filiformis*	22.7		0.0295
		Spiochaetopterus costarum	22.7		0.0011
		Glycinde solitaria	136.4		0.0318
		Leitoscoloplos robustus	727.3	272.7	0.0295
	Arthropoda : Amphipoda	*Ampelisca abdita*	22.7		0.3818
		Cerapus tubularis	431.8		0.0909
		Listriella barnardi	22.7		0.0227
	Arthropoda : Cumacea	*Leucon americanus*	68.2		0.0250
	Arthropoda : Isopoda	*Edotea triloba*	22.7		0.0568
	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7		0.0523
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Mulinia lateralis*	22.7		0.0159
		Nucula proxima	1045.5		0.0091
		Mercenaria mercenaria	22.7		0.0182
	Mollusca : Gastropoda	*Acteocina canaliculata*	613.6		0.8023
	Nemertina	*Carinomella lactea*	204.5		0.1136
	Total		3431.8	272.7	1.6829
	Total Number of Taxa		16	1	
B-07	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Caulleriella venefica*	68.2		0.1068
		Glycera dibranchiata	22.7	22.7	0.0364
		Maldanidae	22.7		0.0205
		Nephtys picta	22.7	22.7	0.0091
		Neanthes arenaceodentata	22.7		0.0136
		Scolelepis texana	68.2		0.0023
		Spiophanes bombyx	45.5		0.0011
		Streblospio benedicti	22.7		0.0011
		Erinaceusyllis erinaceus	45.5		0.0409
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	250.0		1.4954
		Protohaustorius cf. deichmannae	90.9		0.0023
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	45.5		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1500.0		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	136.4		0.0023

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-07 Cont'd	Mollusca : Bivalvia	*Ensis directus*	22.7	22.7	0.0477
		Tellina agilis	136.4		0.0011
		Gemma gemma	113.6		0.0386
	Nemertina	*Carinoma* spp.	68.2		0.1295
		Nemertina	113.6		0.0114
	Total		2840.9	68.2	1.9727
	Total Number of Taxa		20	3	
B-08	Annelida : Polychaeta	*Heteromastus filiformis*	22.7		0.0295
		Mediomastus ambiseta	68.2		0.0182
		Spiochaetopterus costarum	45.5		0.0011
		Neanthes succinea	22.7		0.0136
		Leitoscoloplos robustus	181.8	90.9	0.0273
		Paraprionospio pinnata	22.7	22.7	0.0045
	Arthropoda : Isopoda	*Edotea triloba*	22.7		0.0545
	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7		0.0523
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	68.2		0.0091
	Mollusca : Gastropoda	*Acteocina canaliculata*	272.7		0.7886
	Nemertina	*Carinomella lactea*	90.9		0.1114
	Total		863.6	113.6	1.1125
	Total Number of Taxa		12	2	
B-09	Annelida : Polychaeta	*Mediomastus ambiseta*	90.9		0.0182
		Glycinde solitaria	22.7		0.0318
		Leitoscoloplos robustus	22.7		0.0273
	Arthropoda : Amphipoda	*Cerapus tubularis*	227.3		0.0909
	Mollusca : Bivalvia	*Nucula proxima*	454.5		0.0091
	Mollusca : Gastropoda	*Nassarius trivittatus*	22.7		0.0136
		Odostomia engonia	22.7		0.0091
		Acteocina canaliculata	522.7		0.9114
	Nemertina	*Carinomella lactea*	45.5		0.1091
	Total		1431.8	0.0	1.2205
	Total Number of Taxa		9	0	
B-10	Annelida : Oligochaeta	Oligochaeta	136.4		0.0068
	Annelida : Polychaeta	*Asabellides oculata*	45.5		0.2045
		Mediomastus ambiseta	3159.1		0.0205
		Tharyx sp. A	2250.0		0.0011
		Glycera dibranchiata	45.5	22.7	0.0364
		Glycinde solitaria	431.8		0.0341
		Neanthes succinea	90.9		0.0136
		Diopatra cuprea	45.5	22.7	0.0636
		Scoloplos rubra	22.7		0.0023
		Phyllodoce arenae	45.5		0.0045
		Paraprionospio pinnata	22.7		0.0045
		Polydora cornuta	22.7		0.0045
		Parapionosyllis longicirrata	68.2		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	1227.3		0.4818
		Ampelisca vadorum	90.9		0.3773
		Ampelisca verrilli	45.5		0.3273
		Batea catharinensis	90.9		0.1750
		Monocorophium tuberculatum	863.6		0.0159
		Cerapus tubularis	68.2		0.0841
		Ericthonius brasiliensis	45.5		0.0432
		Listriella barnardi	22.7		0.0227
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
		Leucon americanus	272.7		0.0250
	Arthropoda : Decapoda	*Dyspanopeus sayi*	90.9	22.7	0.0614
	Arthropoda : Isopoda	*Edotea triloba*	45.5		0.0545
	Cnidaria : Anthozoa	*Edwardsia elegans*	45.5	22.7	0.0500

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-10 Cont'd	Mollusca : Bivalvia	*Lyonsia hyalina*	22.7		0.0227
		Mulinia lateralis	22.7		0.0159
		Nucula proxima	272.7		0.0091
		Tellina agilis	68.2		0.0011
		Mercenaria mercenaria	45.5		0.0182
	Mollusca : Gastropoda	*Crepidula plana*	22.7		0.0705
		Astyris lunata	68.2		0.1909
		Nassarius trivittatus	45.5	45.5	0.0159
		Acteocina canaliculata	45.5		0.7273
	Nemertina	*Amphiporus bioculatus*	22.7		0.3045
		Carinomella lactea	204.5		0.1114
	Platyhelminthes : Turbellaria	*Stylochus ellipticus*	22.7		0.0011
	Total		10204.5	136.4	3.6148
	Total Number of Taxa		38	5	
B-11	Annelida : Oligochaeta	Oligochaeta	22.7		0.0091
	Annelida : Polychaeta	*Caulleriella venefica*	22.7		0.0977
		Euclymene zonalis	68.2		0.0409
		Neanthes arenaceodentata	68.2		0.0136
		Opheliidae	22.7		0.0068
		Travisia sp. A	136.4		0.0011
		Scolelepis texana	68.2		0.0023
		Spiophanes bombyx	45.5		0.0011
		Parapionosyllis longicirrata	22.7		0.0045
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	954.5		5.3841
		Protohaustorius cf. deichmannae	340.9		0.0045
		Cerapus tubularis	90.9		0.0886
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	68.2		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	1613.6		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	45.5		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Ensis directus	45.5		0.0432
		Tellina agilis	159.1		0.0011
		Gemma gemma	45.5		0.0386
	Nemertina	*Amphiporus bioculatus*	22.7		0.2841
		Nemertina	113.6		0.0114
	Total		4000.0	0.0	6.0420
	Total Number of Taxa		21	0	
B-12	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Heteromastus filiformis*	45.5		0.0295
		Mediomastus ambiseta	2386.4		0.0205
		Spiochaetopterus costarum	113.6	22.7	0.0011
		Tharyx sp. A	159.1		0.0011
		Glycera dibranchiata	68.2	22.7	0.0364
		Glycinde solitaria	431.8		0.0318
		Neanthes succinea	90.9		0.0136
		Diopatra cuprea	90.9	68.2	0.0636
		Leitoscoloplos robustus	136.4	22.7	0.0273
		Scoloplos rubra	45.5		0.0023
		Aricidea catherinae	45.5		0.2205
		Eumida sanguinea	68.2		0.0409
		Phyllodoce arenae	45.5		0.0045
		Scolelepis texana	45.5		0.0023
	Arthropoda : Amphipoda	*Ampelisca abdita*	68.2		0.4159
		Ampelisca vadorum	45.5		0.3773
		Ampelisca verrilli	204.5		0.3409
		Monocorophium tuberculatum	522.7		0.0159
		Microprotopus raneyi	636.4		0.0182
		Cerapus tubularis	44136.2		0.0955
		Listriella barnardi	22.7		0.0227

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-12 Cont'd	Arthropoda : Cumacea	*Oxyurostylis smithi*	113.6		0.0068
		Leucon americanus	22.7		0.0250
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
		Euceramus praelongus	22.7		0.0409
	Arthropoda : Isopoda	*Edotea triloba*	22.7		0.0568
	Cnidaria : Anthozoa	*Edwardsia elegans*	45.5		0.0523
	Echinodermata : Holothuroidea	*Pentamera pulcherrima*	22.7		0.0045
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Lyonsia hyalina*	45.5		0.0227
		Mulinia lateralis	45.5		0.0159
		Nucula proxima	727.3		0.0091
		Ensis directus	22.7	22.7	0.0500
		Tellina agilis	45.5		0.0011
	Mollusca : Gastropoda	*Turbonilla interrupta*	45.5		0.0011
		Acteocina canaliculata	2045.4		0.9886
		Kurtziella atrostyla	22.7		0.0295
		Nudibranchia	22.7		0.0091
	Nemertina	*Amphiporus bioculatus*	136.4		0.3136
		Carinoma spp.	45.5		0.1273
		Carinomella lactea	68.2		0.1136
	Platyhelminthes : Turbellaria	*Stylochus ellipticus*	22.7		0.0011
	Total		53022.6	159.1	3.6648
	Total Number of Taxa		43	5	
B-13	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Mediomastus ambiseta*	45.5		0.0182
		Caulleriella venefica	90.9		0.1068
		Neanthes arenaceodentata	45.5		0.0136
		Opheliidae	68.2		0.0068
		Travisia sp. A	45.5		0.0011
		Paraonis fulgens	113.6		0.0068
		Scolelepis texana	68.2		0.0023
		Spiophanes bombyx	22.7		0.0011
		Parapionosyllis longicirrata	22.7		0.0045
	Arthropoda : Amphipoda	*Batea catharinensis*	68.2		0.1795
		Monocorophium tuberculatum	45.5		0.0159
		Acanthohaustorius millsi	431.8		2.9091
		Protohaustorius cf. deichmannae	250.0		0.0023
		Cerapus tubularis	22.7		0.0841
	Arthropoda : Decapoda	*Pagurus longicarpus*	227.3		0.0068
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	2250.0		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	136.4		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	45.5		0.0011
		Ensis directus	22.7		0.0432
		Tellina agilis	136.4		0.0011
		Gemma gemma	136.4		0.0386
	Mollusca : Gastropoda	*Crepidula fornicata*	45.5		0.0750
		Crepidula plana	45.5		0.0705
		Nudibranchia	90.9		0.0091
	Nemertina	Nemertina	204.5		0.0114
	Total		4704.5	0.0	3.6193
	Total Number of Taxa		26	0	
B-14	Annelida : Polychaeta	*Asabellides oculata*	90.9		0.3182
		Heteromastus filiformis	45.5		0.0318
		Mediomastus ambiseta	5681.8		0.0205
		Spiochaetopterus costarum	318.2	227.3	0.0011
		Tharyx sp. A	204.5		0.0011
		Glycera dibranchiata	45.5		0.0364
		Glycinde solitaria	409.1		0.0341
		Neanthes succinea	45.5		0.0136
		Diopatra cuprea	90.9	90.9	0.0659
		Leitoscoloplos robustus	113.6	22.7	0.0273

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-14 Cont'd	Annelida : Polychaeta Cont'd	*Scoloplos rubra*	22.7		0.0023
		Aricidea catherinae	68.2		0.2295
		Pectinaria gouldii	45.5		0.0045
		Paraprionospio pinnata	113.6	113.6	0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	7000.0		0.4886
		Ampelisca verrilli	863.6		0.3614
		Unciola spp.	22.7		0.0011
		Monocorophium tuberculatum	590.9		0.0159
		Acanthohaustorius millsi	22.7		1.0886
	Arthropoda : Amphipoda	*Protohaustorius cf. deichmannae*	90.9		0.0023
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	386.4		0.0886
		Ericthonius brasiliensis	22.7		0.0432
		Listriella barnardi	68.2		0.0227
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
		Leucon americanus	68.2		0.0250
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	68.2		0.0045
		Dyspanopeus sayi	22.7		0.0591
		Rhithropanopeus harrisii	22.7		0.0023
	Arthropoda : Isopoda	*Edotea triloba*	295.5		0.0545
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	45.5		0.0011
	Cnidaria : Anthozoa	*Edwardsia elegans*	90.9	22.7	0.0523
	Mollusca : Bivalvia	*Mulinia lateralis*	22.7		0.0159
		Nucula proxima	409.1		0.0091
		Ensis directus	45.5	45.5	0.0500
		Tellina agilis	136.4		0.0011
		Mercenaria mercenaria	22.7		0.0182
	Mollusca : Gastropoda	*Crepidula fornicata*	45.5		0.0727
		Nassarius trivittatus	45.5		0.0136
		Acteocina canaliculata	1181.8		0.9614
	Nemertina	*Amphiporus bioculatus*	45.5		0.3136
		Carinomella lactea	318.2	318.2	0.1136
	Total		19318.1	840.9	4.7034
	Total Number of Taxa		43	7	
B-15	Annelida : Polychaeta	*Asabellides oculata*	181.8		0.2114
		Heteromastus filiformis	22.7		0.0318
		Mediomastus ambiseta	1795.4		0.0205
		Spiochaetopterus costarum	90.9		0.0011
		Tharyx sp. A	272.7		0.0011
		Glycera dibranchiata	45.5		0.0341
		Glycinde solitaria	204.5		0.0341
		Clymenella torquata	22.7		0.0750
		Sabaco elongatus	22.7	22.7	0.0023
		Neanthes succinea	90.9		0.0136
		Diopatra cuprea	22.7	22.7	0.0636
		Leitoscoloplos robustus	181.8	90.9	0.0273
		Aricidea catherinae	159.1		0.2341
		Paraprionospio pinnata	22.7		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	7863.6		0.5023
		Ampelisca verrilli	318.2		0.3545
		Unciola spp.	22.7		0.0011
		Paracaprella tenuis	45.5		0.0068
		Monocorophium tuberculatum	22.7		0.0159
		Cerapus tubularis	68477.1		0.0955
		Ericthonius brasiliensis	45.5		0.0432
		Parametopella cypris	45.5		0.0068
	Arthropoda : Cumacea	*Leucon americanus*	1113.6		0.0250
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	45.5		0.0045
		Pinnixa retinens	22.7		0.0045

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-15 Cont'd	Arthropoda : Isopoda	*Edotea triloba*	386.4		0.0568
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	22.7		0.0011
	Cnidaria : Anthozoa	*Edwardsia elegans*	68.2	22.7	0.0523
	Mollusca : Bivalvia	*Mulinia lateralis*	90.9		0.0159
		Yoldia limatula	22.7		0.0011
		Nucula proxima	386.4		0.0091
		Ensis directus	22.7	22.7	0.0477
		Mercenaria mercenaria	45.5		0.0182
	Mollusca : Gastropoda	*Crepidula plana*	22.7		0.0705
		Epitonium rupicola	90.9		0.0432
		Turbonilla interrupta	68.2		0.0011
		Acteocina canaliculata	431.8		0.8023
	Nemertina	*Amphiporus bioculatus*	22.7		0.3023
		Cerebratulus lacteus	22.7	22.7	0.0795
		Carinomella lactea	386.4		0.1136
	Platyhelminthes : Turbellaria	*Stylochus ellipticus*	45.5		0.0011
	Total		83317.9	204.5	3.4375
	Total Number of Taxa		42	6	
B-16	Annelida : Polychaeta	*Mediomastus ambiseta*	363.6		0.0182
		Tharyx sp. A	45.5		0.0011
		Glycinde solitaria	136.4		0.0318
		Sabaco elongatus	45.5	45.5	0.0023
		Leitoscoloplos robustus	181.8	113.6	0.0295
		Aricidea catherinae	22.7	22.7	0.2341
		Paraprionospio pinnata	136.4	136.4	0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	45.5		0.4250
		Cerapus tubularis	22.7		0.0841
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Mollusca : Bivalvia	*Mulinia lateralis*	45.5		0.0159
	Mollusca : Gastropoda	*Acteocina canaliculata*	386.4		0.9227
	Nemertina	*Amphiporus bioculatus*	22.7		0.3045
		Carinomella lactea	340.9		0.1136
	Total		1818.2	318.2	2.1920
	Total Number of Taxa		14	4	
B-17	Annelida : Oligochaeta	Oligochaeta	68.2		0.0068
	Annelida : Polychaeta	*Asabellides oculata*	68.2		0.2091
		Mediomastus ambiseta	4886.3		0.0205
		Spiochaetopterus costarum	45.5		0.0011
		Tharyx sp. A	772.7		0.0011
		Glycera dibranchiata	22.7		0.0341
		Glycinde solitaria	500.0		0.0318
		Neanthes succinea	45.5	22.7	0.0136
		Diopatra cuprea	68.2	45.5	0.0636
		Phyllodoce arenae	22.7		0.0045
		Paraprionospio pinnata	22.7		0.0045
		Scolelepis texana	22.7		0.0023
	Arthropoda : Amphipoda	*Ampelisca abdita*	409.1		0.4795
		Ampelisca verrilli	159.1		0.3523
		Monocorophium tuberculatum	454.5		0.0159
		Microprotopus raneyi	113.6		0.0182
		Cerapus tubularis	37772.6		0.0932
		Listriella barnardi	90.9		0.0227
	Arthropoda : Cumacea	*Pseudoleptocuma minor*	68.2		0.0023
		Oxyurostylis smithi	90.9		0.0068
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	113.6		0.0045
		Euceramus praelongus	22.7		0.0409
	Arthropoda : Isopoda	*Edotea triloba*	113.6		0.0545
	Arthropoda : Mysidacea	*Americamysis bigelowi*	22.7		0.5568
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	22.7		0.0011
	Cnidaria : Anthozoa	*Edwardsia elegans*	113.6		0.0523

Table D-2. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
B-17 Cont'd	Mollusca : Bivalvia	*Nucula proxima*	204.5		0.0091
		Tellina agilis	68.2		0.0011
	Mollusca : Gastropoda	*Crepidula fornicata*	45.5		0.0727
		Epitonium rupicola	90.9		0.0432
		Acteocina canaliculata	204.5		0.7568
	Nemertina	*Amphiporus bioculatus*	181.8		0.3182
		Carinoma spp.	159.1		0.1295
		Carinomella lactea	363.6		0.1136
	Total		47431.7	68.2	3.5386
	Total Number of Taxa		34	2	

Table D-3. Station specific macrobenthic abundance and biomass measurements for the 17 stations sampled at the Area C near Prime Hook National Wildlife Refuge, 2014

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-01	Annelida : Oligochaeta	Oligochaeta	45.5		0.0068
	Annelida : Polychaeta	*Caulleriella venefica*	136.4		0.1068
		Tharyx sp. A	45.5		0.0011
		Leitoscoloplos robustus	45.5		0.0250
		Scoloplos rubra	22.7		0.0023
		Dispio uncinata	45.5	45.5	0.0614
		Spiophanes bombyx	68.2	22.7	0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	68.2		1.1364
		Protohaustorius cf. deichmannae	22.7		0.0023
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	45.5		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	113.6		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	68.2		0.0023
	Mollusca : Bivalvia	*Cyclocardia borealis*	250.0		0.0659
		Spisula solidissima	22.7		0.0011
		Pandora gouldiana	22.7		0.0068
		Ensis directus	22.7		0.0477
		Tellina agilis	68.2		0.0011
		Gemma gemma	227.3		0.0386
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0750
	Nemertina	Nemertina	22.7		0.0114
	Total		1409.1	68.2	1.6057
	Total Number of Taxa		21	2	
C-02	Annelida : Polychaeta	*Tharyx* sp. A	22.7		0.0011
		Nephtys bucera	22.7		0.0091
		Leitoscoloplos robustus	22.7		0.0250
		Polygordius jouinae	22.7		0.0045
		Scolelepis texana	204.5		0.0023
		Spiophanes bombyx	45.5	22.7	0.0011
		Parapionosyllis longicirrata	90.9		0.0045
		Streptosyllis pettiboneae	45.5		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	90.9		1.0455
		Protohaustorius cf. deichmannae	22.7		0.0023
		Rhepoxynius hudsoni	227.3		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	22.7		0.0045
	Chordata : Cephalochordata	*Branchiostoma caribaeum*	22.7		0.1409
	Hemichordata	*Saccoglossus kowalevskii*	454.5		0.0023
	Mollusca : Bivalvia	*Tellina agilis*	90.9		0.0011
		Gemma gemma	22.7		0.0386
	Nemertina	Nemertina	45.5		0.0114
	Total		1500.0	22.7	1.3045
	Total Number of Taxa		18	1	
C-03	Annelida : Polychaeta	*Parougia caeca*	22.7		0.0045
		Maldanidae	68.2		0.0205
		Nephtys bucera	45.5	22.7	0.0091
		Neanthes arenaceodentata	22.7		0.0136
		Leitoscoloplos robustus	159.1	22.7	0.0273
		Dispio uncinata	45.5		0.0614
		Scolelepis texana	45.5		0.0023
		Spiophanes bombyx	22.7		0.0011
		Streptosyllis pettiboneae	272.7		0.0011
	Arthropoda : Amphipoda	*Ampelisca vadorum*	22.7		0.3659
		Acanthohaustorius millsi	750.0		3.4886
		Bathyporeia quoddyensis	68.2		0.1545
		Protohaustorius cf. deichmannae	1272.7		0.0045
		Rhepoxynius hudsoni	22.7		0.0023

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-03 Cont'd	Arthropoda : Decapoda	*Pagurus longicarpus*	45.5		0.0068
		Pinnixa chaetopterana	22.7		0.0045
	Arthropoda : Isopoda	*Chiridotea tuftsi*	22.7		0.0773
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	2000.0		0.0011
	Cnidaria : Anthozoa	*Ceriantheopsis americanus*	22.7		0.0773
	Hemichordata	*Saccoglossus kowalevskii*	386.4		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Ensis directus	22.7		0.0455
		Tellina agilis	113.6		0.0011
		Gemma gemma	68.2		0.0386
	Total		5568.2	45.5	4.4125
	Total Number of Taxa		24	2	
C-04	Annelida : Oligochaeta	Oligochaeta	22.7		0.0068
	Annelida : Polychaeta	*Caulleriella venefica*	45.5		0.1045
		Tharyx sp. A	22.7		0.0011
		Maldanidae	22.7		0.0205
		Nephtyidae	22.7		0.0091
		Paraonis pygoenigmatica	22.7		0.0045
		Dispio uncinata	22.7		0.0614
		Spiophanes bombyx	68.2		0.0011
		Parapionosyllis longicirrata	45.5		0.0045
		Streptosyllis pettiboneae	90.9		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	181.8		1.5364
		Protohaustorius cf. deichmannae	113.6		0.0023
		Rhepoxynius hudsoni	22.7		0.0023
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
	Arthropoda : Isopoda	*Cyathura burbancki*	22.7		0.0682
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	363.6		0.0011
	Hemichordata	*Saccoglossus kowalevskii*	159.1		0.0023
	Mollusca : Bivalvia	*Cyclocardia borealis*	795.5		0.0682
		Spisula solidissima	22.7		0.0011
		Ensis directus	22.7		0.0455
		Tellina agilis	90.9		0.0011
		Tellina tenella	22.7		0.0011
		Gemma gemma	386.4		0.0386
	Nemertina	*Amphiporus bioculatus*	22.7		0.2841
		Nemertina	68.2		0.0114
	Total		2704.5	0.0	2.2852
	Total Number of Taxa		25	0	
C-05	Annelida : Polychaeta	*Amastigos caperatus*	22.7		0.6341
		Caulleriella venefica	113.6		0.1068
		Tharyx sp. A	22.7		0.0011
		Glycera dibranchiata	22.7		0.0341
		Maldanidae	22.7		0.0205
		Nephtyidae	22.7	22.7	0.0114
		Neanthes arenaceodentata	45.5		0.0136
		Travisia sp. A	90.9		0.0011
		Leitoscoloplos robustus	45.5		0.0250
		Scolelepis texana	113.6		0.0023
		Spiophanes bombyx	136.4		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	477.3		2.3000
		Protohaustorius cf. deichmannae	181.8		0.0023
		Rhepoxynius hudsoni	477.3		0.0023
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	22.7		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	181.8		0.0011
	Chordata : Ascidiacea	Ascidiacea	22.7		0.1977
	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7		0.0500
	Hemichordata	*Saccoglossus kowalevskii*	204.5		0.0023

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-05 Cont'd	Mollusca : Bivalvia	*Ensis directus*	22.7		0.0477
		Tellina agilis	500.0		0.0011
		Gemma gemma	68.2		0.0386
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0727
	Nemertina	*Amphiporus bioculatus*	68.2		0.3068
		Micrura spp.	22.7		0.0159
		Nemertina	45.5		0.0114
	Total		3022.7	22.7	3.9125
	Total Number of Taxa		27	1	
C-06	*Annelida : Oligochaeta*	*Oligochaeta*	636.4		0.0091
	Annelida : Polychaeta	*Amastigos caperatus*	90.9		0.5705
		Caulleriella venefica	22.7		0.0977
		Neanthes arenaceodentata	45.5		0.0136
		Leitoscoloplos robustus	68.2		0.0250
		Scoloplos rubra	22.7		0.0011
		Polygordius jouinae	22.7		0.0045
		Erinaceusyllis erinaceus	204.5		0.0011
		Exogone dispar	22.7		0.0386
		Parapionosyllis longicirrata	250.0		0.0045
	Arthropoda : Amphipoda	*Americhelidium americanum*	22.7		0.5045
	Arthropoda : Decapoda	*Pagurus longicarpus*	45.5		0.0068
	Arthropoda : Mysidacea	*Americamysis bigelowi*	22.7		0.5295
	Chordata : Cephalochordata	*Branchiostoma caribaeum*	22.7	22.7	0.1409
	Mollusca : Bivalvia	*Nucula proxima*	45.5		0.0091
		Ensis directus	22.7	22.7	0.0500
		Tellina agilis	90.9		0.0011
	Nemertina	*Amphiporus bioculatus*	22.7		0.2682
		Cerebratulus lacteus	22.7	22.7	0.0795
		Nemertina	45.5		0.0114
	Total		1750.0	68.2	2.3670
	Total Number of Taxa		20	3	
C-07	Annelida : Polychaeta	*Mediomastus ambiseta*	22.7		0.0182
		Caulleriella venefica	90.9		0.1068
		Tharyx sp. A	22.7		0.0011
		Glycera dibranchiata	22.7	22.7	0.0364
		Euclymene zonalis	22.7		0.0409
		Neanthes arenaceodentata	22.7		0.0136
		Scoloplos rubra	22.7		0.0023
		Phyllodoce arenae	45.5	45.5	0.0045
		Scolelepis texana	250.0		0.0023
		Spiophanes bombyx	68.2		0.0011
		Parapionosyllis longicirrata	68.2		0.0045
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	272.7		1.7750
		Bathyporeia quoddyensis	22.7		0.1523
		Protohaustorius cf. deichmannae	90.9		0.0023
		Rhepoxynius hudsoni	250.0		0.0023
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	45.5		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	181.8		0.0011
	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7		0.0500
	Hemichordata	*Saccoglossus kowalevskii*	636.4		0.0023
	Mollusca : Bivalvia	*Pandora gouldiana*	22.7		0.0068
		Ensis directus	22.7		0.0477
		Tellina agilis	136.4		0.0011
	Nemertina	*Amphiporus bioculatus*	22.7		0.2545
		Carinoma spp.	68.2		0.1273
		Nemertina	227.3		0.0114
	Total		2704.5	68.2	2.6773
	Total Number of Taxa		26	2	

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-08	Annelida : Polychaeta	*Caulleriella venefica*	45.5		0.1000
		Tharyx sp. A	45.5		0.0011
		Magelona spp.	22.7		0.0227
		Nephtys bucera	68.2	45.5	0.0091
		Leitoscoloplos robustus	22.7		0.0250
		Scoloplos rubra	22.7		0.0011
		Dispio uncinata	22.7		0.0614
		Scolelepis texana	68.2		0.0023
		Spiophanes bombyx	22.7	22.7	0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	863.6		2.5204
		Bathyporeia quoddyensis	45.5		0.1477
		Protohaustorius cf. deichmannae	386.4		0.0023
		Rhepoxynius hudsoni	136.4		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
	Arthropoda : Isopoda	*Chiridotea caeca*	22.7		0.0773
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	477.3		0.0011
	Cnidaria : Anthozoa	*Ceriantheopsis americanus*	22.7		0.0795
	Hemichordata	*Saccoglossus kowalevskii*	159.1		0.0023
	Mollusca : Bivalvia	*Spisula solidissima*	22.7		0.0011
		Pandora gouldiana	22.7		0.0068
		Ensis directus	22.7	22.7	0.0477
		Tellina agilis	250.0		0.0011
		Gemma gemma	68.2		0.0386
	Nemertina	*Carinoma spp.*	22.7		0.1159
		Cerebratulus lacteus	22.7	22.7	0.0795
	Total		2931.8	113.6	3.3545
	Total Number of Taxa		25	4	
C-09	Annelida : Polychaeta	*Caulleriella venefica*	295.5		0.1068
		Tharyx sp. A	22.7		0.0011
		Maldanidae	22.7		0.0205
		Nephtyidae	45.5		0.0114
		Travisia sp. A	22.7		0.0011
		Leitoscoloplos robustus	22.7		0.0250
		Scoloplos rubra	68.2		0.0023
		Scolelepis texana	45.5		0.0023
		Spiophanes bombyx	22.7		0.0011
		Erinaceusyllis erinaceus	22.7		0.0409
		Parapionosyllis longicirrata	22.7		0.0045
		Streptosyllis pettiboneae	22.7		0.0011
	Arthropoda : Amphipoda	*Ampelisca abdita*	22.7		0.4273
		Acanthohaustorius millsi	272.7		1.1864
		Bathyporeia quoddyensis	22.7		0.1500
		Protohaustorius cf. deichmannae	295.5		0.0023
		Rhepoxynius hudsoni	22.7		0.0023
	Arthropoda : Isopoda	*Ancinus depressus*	45.5		0.2432
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	477.3		0.0011
	Chordata : Ascidiacea	Ascidiacea	22.7		0.1932
	Hemichordata	*Saccoglossus kowalevskii*	340.9		0.0023
	Mollusca : Bivalvia	*Cyclocardia borealis*	386.4		0.0659
		Spisula solidissima	45.5		0.0011
		Ensis directus	22.7		0.0455
		Tellina agilis	159.1		0.0011
		Tellina tenella	22.7		0.0011
		Gemma gemma	250.0		0.0386
	Nemertina	*Amphiporus bioculatus*	22.7		0.2500
		Carinoma spp.	68.2		0.1273
		Micrura spp.	22.7		0.0159
		Nemertina	90.9		0.0114
	Platyhelminthes : Turbellaria	*Stylochus ellipticus*	22.7		0.0011
	Total		3272.7	0.0	2.9852
	Total Number of Taxa		32	0	

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-10	Annelida : Oligochaeta	Oligochaeta	45.5		0.0068
	Annelida : Polychaeta	*Asabellides oculata*	386.4		0.2159
		Heteromastus filiformis	45.5		0.0295
		Mediomastus ambiseta	6477.3		0.0205
		Tharyx sp. A	272.7		0.0011
		Glycera dibranchiata	136.4	45.5	0.0364
		Glycinde solitaria	250.0		0.0341
		Maldanidae	22.7		0.0205
		Neanthes arenaceodentata	159.1		0.0136
		Diopatra cuprea	68.2	22.7	0.0659
		Leitoscoloplos robustus	204.5		0.0250
		Scoloplos rubra	22.7		0.0023
		Aricidea catherinae	45.5		0.2227
		Pectinaria gouldii	22.7		0.0045
		Eumida sanguinea	22.7		0.0386
		Sigalion arenicola	22.7		0.0011
		Dipolydora socialis	45.5		0.0636
		Erinaceusyllis erinaceus	22.7		0.0409
		Exogone dispar	22.7		0.0386
		Parapionosyllis longicirrata	136.4		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	204.5		0.4523
		Ampelisca verrilli	113.6		0.3364
		Unciola irrorata	181.8		0.0011
		Batea catharinensis	318.2		0.1864
		Monocorophium tuberculatum	750.0		0.0159
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	45.5		0.0841
		Listriella barnardi	22.7		0.0227
		Americhelidium americanum	22.7		0.5045
	Arthropoda : Cumacea	*Oxyurostylis smithi*	45.5		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	22.7		0.0045
		Euceramus praelongus	45.5		0.0409
		Dyspanopeus sayi	22.7		0.0568
	Arthropoda : Isopoda	*Edotea triloba*	45.5		0.0545
	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7		0.0523
	Mollusca : Bivalvia	*Nucula proxima*	90.9		0.0091
		Tellina agilis	90.9		0.0011
	Mollusca : Gastropoda	*Crepidula fornicata*	22.7		0.0727
		Astyris lunata	159.1		0.1909
		Acteocina canaliculata	22.7		0.7068
	Nemertina	*Amphiporus bioculatus*	90.9		0.3045
		Carinoma spp.	90.9		0.1318
		Micrura spp.	22.7		0.0159
		Carinomella lactea	181.8		0.1114
	Total		11113.6	68.2	4.2750
	Total Number of Taxa		45	2	
C-11	Annelida : Oligochaeta	Oligochaeta	681.8		0.0091
	Annelida : Polychaeta	*Caulleriella venefica*	22.7		0.1000
		Glycera dibranchiata	22.7		0.0341
		Scoletoma tenuis	22.7		0.0023
		Nephtyidae	22.7		0.0114
		Travisia sp. A	22.7		0.0011
		Leitoscoloplos robustus	45.5		0.0250
		Scoloplos rubra	22.7		0.0023
		Aricidea catherinae	45.5		0.2273
		Polygordius jouinae	45.5		0.0045
		Scolelepis texana	22.7		0.0023
		Erinaceusyllis erinaceus	22.7		0.0409
	Arthropoda : Amphipoda	*Rhepoxynius hudsoni*	136.4		0.0023
	Arthropoda : Isopoda	*Cyathura burbancki*	181.8		0.0705

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-11 Cont'd	Cnidaria : Anthozoa	*Edwardsia elegans*	22.7	22.7	0.0523
	Hemichordata	*Saccoglossus kowalevskii*	22.7		0.0023
	Mollusca : Bivalvia	*Ensis directus*	22.7	22.7	0.0500
		Tellina agilis	363.6		0.0011
	Nemertina	*Carinoma* spp.	45.5		0.1182
		Nemertina	272.7		0.0114
	Total		2068.2	45.5	0.7682
	Total Number of Taxa		20	2	
C-12	Annelida : Oligochaeta	Oligochaeta	45.5		0.0068
	Annelida : Polychaeta	*Tharyx* sp. A	22.7		0.0011
		Nephtys bucera	113.6	45.5	0.0091
		Neanthes arenaceodentata	22.7		0.0136
		Leitoscoloplos robustus	159.1		0.0250
		Scolelepis texana	68.2		0.0023
		Spiophanes bombyx	22.7		0.0011
	Arthropoda : Amphipoda	*Rhepoxynius hudsoni*	613.6		0.0023
	Arthropoda : Isopoda	*Cyathura burbancki*	113.6		0.0705
	Echinodermata : Echinoidea	Echinoidea	22.7		0.0568
	Mollusca : Biv+C1154alvia	*Spisula solidissima*	22.7		0.0011
	Mollusca : Bivalvia	*Tellina agilis*	750.0		0.0011
		Gemma gemma	22.7		0.0386
	Nemertina	Nemertina	45.5		0.0114
	Total		2045.4	45.5	0.2409
	Total Number of Taxa		14	1	
C-13	Annelida : Oligochaeta	Oligochaeta	954.5		0.0091
	Annelida : Polychaeta	*Asabellides oculata*	22.7		0.2023
		Heteromastus filiformis	22.7		0.0295
		Mediomastus ambiseta	22.7		0.0182
		Caulleriella venefica	45.5		0.1000
		Maldanidae	90.9		0.0227
		Neanthes arenaceodentata	90.9		0.0136
		Neanthes succinea	22.7		0.0136
		Leitoscoloplos robustus	159.1		0.0250
		Scoloplos rubra	45.5		0.0023
		Paranaitis speciosa	22.7		0.0068
		Polygordius jouinae	22.7		0.0045
		Erinaceusyllis erinaceus	45.5		0.0409
		Exogone dispar	113.6		0.0386
		Parapionosyllis longicirrata	227.3		0.0045
		Proceraea cornuta	22.7		0.0045
		Polycirrus eximius	181.8		0.0045
	Arthropoda : Amphipoda	*Batea catharinensis*	272.7		0.1818
		Parametopella cypris	22.7		0.0068
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus*	45.5		0.0068
		Pinnixa chaetopterana	22.7		0.0045
		Dyspanopeus sayi	45.5	22.7	0.0591
	Arthropoda : Isopoda	*Cyathura burbancki*	22.7		0.0682
	Hemichordata	*Saccoglossus kowalevskii*	45.5		0.0023
	Mollusca : Bivalvia	*Nucula proxima*	68.2		0.0091
		Ensis directus	45.5	45.5	0.0500
		Tellina agilis	159.1		0.0011
	Nemertina	*Carinoma* spp.	90.9		0.1318
		Nemertina	22.7		0.0114
	Total		3000.0	68.2	1.0807
	Total Number of Taxa		30	2	
C-14	Annelida : Oligochaeta	Oligochaeta	613.6		0.0091
	Annelida : Polychaeta	*Mediomastus ambiseta*	22.7		0.0182
		Caulleriella venefica	45.5		0.1000
		Tharyx sp. A	68.2		0.0011
		Glycera dibranchiata	22.7		0.0341

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
C-14 Cont'd	Annelida : Polychaeta Cont'd	Nephtyidae	22.7		0.0114
		Opheliidae	22.7		0.0068
		Leitoscoloplos robustus	90.9		0.0250
		Scoloplos rubra	159.1		0.0023
		Erinaceusyllis erinaceus	363.6		0.0011
		Parapionosyllis longicirrata	818.2		0.0045
	Arthropoda : Amphipoda	*Batea catharinensis*	22.7		0.1705
		Microprotopus raneyi	22.7		0.0182
		Listriella barnardi	45.5		0.0227
	Arthropoda : Cumacea	*Leucon americanus*	1068.2		0.0250
	Arthropoda : Decapoda	*Pinnixa chaetopterana*	136.4		0.0045
	Mollusca : Bivalvia	*Ensis directus*	22.7		0.0477
		Tellina agilis	136.4		0.0011
	Nemertina	*Carinoma* spp.	90.9		0.1250
		Nemertina	22.7		0.0114
	Total		3818.2	0.0	0.6398
	Total Number of Taxa		20	0	
C-15	Annelida : Oligochaeta	Oligochaeta	6022.7		0.0091
	Annelida : Polychaeta	*Asabellides oculata*	68.2		0.2159
		Mediomastus ambiseta	1022.7		0.0205
		Spiochaetopterus costarum	22.7		0.0011
		Caulleriella venefica	22.7		0.0977
		Tharyx sp. A	45.5		0.0011
		Glycera dibranchiata	22.7	22.7	0.0364
		Glycinde solitaria	68.2		0.0318
		Clymenella torquata	45.5	22.7	0.0750
		Nephtyidae	22.7		0.0091
		Neanthes arenaceodentata	113.6		0.0136
		Neanthes succinea	22.7		0.0136
		Diopatra cuprea	22.7		0.0636
		Leitoscoloplos robustus	68.2	22.7	0.0273
		Scoloplos rubra	159.1		0.0023
		Eumida sanguinea	113.6		0.0409
		Lepidonotus sublevis	22.7		0.0250
		Sabellaria vulgaris	45.5		0.0023
		Hydroides dianthus	22.7		0.0295
		Scolelepis texana	22.7		0.0023
		Streblospio benedicti	204.5		0.0011
		Erinaceusyllis erinaceus	227.3		0.0409
		Exogone dispar	22.7		0.0386
		Parapionosyllis longicirrata	1090.9		0.0045
		Polycirrus eximius	45.5		0.0045
	Arthropoda : Amphipoda	*Ampelisca abdita*	68.2		0.3977
		Ampelisca verrilli	22.7		0.3318
		Unciola serrata	90.9		0.0011
		Batea catharinensis	386.4		0.1818
		Monocorophium tuberculatum	68.2		0.0159
		Microprotopus raneyi	22.7		0.0182
		Cerapus tubularis	22.7		0.0864
		Americhelidium americanum	22.7		0.5045
	Arthropoda : Decapoda	*Pagurus longicarpus*	45.5		0.0068
		Dyspanopeus sayi	22.7		0.0568
	Chordata : Cephalochordata	*Branchiostoma caribaeum*	45.5	22.7	0.1386
	Mollusca : Bivalvia	*Nucula proxima*	68.2		0.0091
		Ensis directus	22.7	22.7	0.0500
		Tellina agilis	68.2		0.0011
	Mollusca : Gastropoda	*Nassarius trivittatus*	22.7		0.0159
	Nemertina	*Amphiporus bioculatus*	68.2		0.2773
		Carinoma spp.	113.6	45.5	0.1364
		Carinomella lactea	22.7		0.1091

Table D-3. (Continued)

Station	Taxonomic Category	Taxon	Total Abund (#/m^2)	Abund of Total > 2 cm (#/m^2)	Total Biomass (g/m^2)
	Total		10772.7	159.1	3.1466
	Total Number of Taxa		43	6	
C-16	Annelida : Oligochaeta	Oligochaeta	68.2		0.0068
	Annelida : Polychaeta	*Caulleriella venefica*	22.7		0.1068
		Nephtys bucera	22.7	22.7	0.0091
		Leitoscoloplos robustus	68.2		0.0273
		Paradoneis sp. B	22.7		0.0068
		Paraonis pygoenigmatica	22.7		0.0045
		Dispio uncinata	22.7		0.0614
		Scolelepis texana	45.5		0.0023
		Spiophanes bombyx	113.6	22.7	0.0011
		Parapionosyllis longicirrata	22.7		0.0045
		Streptosyllis pettiboneae	90.9		0.0011
	Arthropoda : Amphipoda	*Acanthohaustorius millsi*	386.4		2.0454
		Bathyporeia quoddyensis	68.2		0.1545
		Protohaustorius cf. deichmannae	1022.7		0.0045
		Rhepoxynius hudsoni	45.5		0.0023
	Arthropoda : Cumacea	*Oxyurostylis smithi*	22.7		0.0068
	Arthropoda : Decapoda	*Pagurus longicarpus*	22.7		0.0068
		Pinnixa chaetopterana	136.4		0.0045
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	3363.6		0.0011
	Chordata : Ascidiacea	Ascidiacea	136.4		0.1932
	Hemichordata	*Saccoglossus kowalevskii*	250.0		0.0023
	Mollusca : Bivalvia	*Ensis directus*	22.7		0.0455
		Tellina agilis	159.1		0.0011
		Gemma gemma	45.5		0.0364
	Nemertina	*Carinoma* spp.	22.7		0.1182
		Nemertina	113.6		0.0114
	Total		6340.9	45.5	2.8659
	Total Number of Taxa		26	2	
C-17	Annelida : Oligochaeta	Oligochaeta	181.8		0.0068
	Annelida : Polychaeta	*Mediomastus ambiseta*	68.2		0.0182
		Caulleriella venefica	22.7		0.1000
		Tharyx sp. A	22.7		0.0011
		Nephtys bucera	68.2	22.7	0.0091
		Leitoscoloplos robustus	22.7		0.0273
		Polygordius jouinae	45.5		0.0045
		Dispio uncinata	22.7		0.0614
		Spiophanes bombyx	159.1	90.9	0.0011
		Erinaceusyllis erinaceus	45.5		0.0409
		Parapionosyllis longicirrata	22.7		0.0045
	Arthropoda : Amphipoda	*Rhepoxynius hudsoni*	250.0		0.0023
	Arthropoda : Cumacea	*Mancocuma stellifera*	90.9		0.0205
	Arthropoda : Isopoda	*Cyathura burbancki*	45.5		0.0682
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	68.2		0.0011
	Mollusca : Bivalvia	*Tellina agilis*	431.8		0.0011
		Tellina tenella	22.7		0.0011
		Gemma gemma	22.7		0.0386
	Nemertina	*Amphiporus bioculatus*	45.5		0.2750
		Carinoma spp.	68.2	22.7	0.1364
		Nemertina	454.5		0.0114
	Total		2181.8	136.4	0.8307
	Total Number of Taxa		21	3	

APPENDIX E

STATION-SPECIFIC ABUNDANCE AND BIOMASS

Table E-1. Measurements of various benthic community parameters at the three borrow areas near the Prime Hook National Wildlife Refuge, 2014

Station	Shannon Wiener Index	Simpson Index	Amphipod Abundance (#/m^2)	Bivalve Abundance (#/m^2)	Polychaete Abundance (#/m^2)	Amphipod Biomass (g/m^2)	Bivalve Biomass (g/m^2)	Polychaeta Biomass (g/m^2)
Area A								
A-01	4.17	0.93	590.91	250.00	840.91	0.16	0.01	1.50
A-02	3.55	0.88	1159.09	136.36	318.18	0.29	0.15	0.18
A-03	2.95	0.77	1250.00	90.91	431.82	0.36	0.04	0.26
A-04	2.81	0.74	1522.72	181.82	3477.26	0.03	0.15	0.71
A-05	2.11	0.52	159.09	159.09	4749.98	0.01	0.20	0.47
A-06	3.08	0.74	2090.90	159.09	386.36	0.29	0.06	2.97
A-07	1.12	0.26	26249.92	0.00	318.18	0.76	0.00	0.22
A-08	3.08	0.78	1181.81	68.18	386.36	0.27	1.49	0.30
A-09	3.81	0.86	1022.72	227.27	431.82	0.23	0.15	1.54
A-10	2.77	0.75	977.27	68.18	272.73	0.28	0.03	0.17
A-11	3.25	0.83	5659.07	113.64	886.36	0.31	0.02	0.41
A-12	2.32	0.58	250.00	295.45	6045.44	0.02	0.30	0.68
A-13	4.34	0.93	727.27	68.18	750.00	0.08	0.12	0.47
A-14	3.04	0.84	136.36	68.18	1818.18	0.05	0.12	0.55
A-15	2.96	0.79	1886.36	22.73	340.91	0.45	0.00	0.20
A-16	3.61	0.88	795.45	295.45	340.91	0.23	0.11	0.51
A-17	2.85	0.79	1250.00	227.27	295.45	0.32	0.37	0.09
Area B								
B-01	1.43	0.39	62590.71	545.45	6999.98	2.00	2.08	2.31
B-02	3.61	0.88	1749.99	45.45	1818.18	0.21	0.05	0.38
B-03	4.01	0.90	1295.45	431.82	1749.99	0.12	0.19	0.85
B-04	3.71	0.88	1318.18	204.54	1159.09	0.35	0.27	0.56
B-05	3.05	0.85	386.36	136.36	590.91	0.02	0.28	0.81
B-06	2.79	0.81	477.27	1090.91	909.09	0.08	0.45	2.08
B-07	2.81	0.70	340.91	272.73	340.91	0.11	1.05	0.79
B-08	2.97	0.83	0.00	68.18	363.64	0.00	0.01	0.69
B-09	2.27	0.73	227.27	454.54	136.36	0.01	0.07	0.03
B-10	3.37	0.83	2454.54	431.82	6249.98	0.15	0.44	1.43
B-11	2.89	0.77	1386.36	272.73	454.54	0.40	0.15	0.41
B-12	1.27	0.30	45636.22	886.36	3772.72	1.29	3.29	1.01
B-13	3.16	0.75	818.18	340.91	522.73	0.23	0.16	0.16
B-14	3.07	0.77	9090.88	636.36	7295.43	1.09	2.97	1.76
B-15	1.19	0.31	76840.66	568.18	3136.35	2.77	2.17	0.96
B-16	3.13	0.86	68.18	45.45	931.82	0.00	0.11	1.36
B-17	1.37	0.35	38999.88	272.73	6477.25	1.16	0.24	0.84
Area C								
C-01	3.90	0.91	90.91	613.63	363.64	0.03	1.36	0.42
C-02	3.34	0.85	340.91	113.64	477.27	0.03	0.12	0.10
C-03	2.93	0.79	2136.36	227.27	704.54	0.53	0.08	0.97
C-04	3.55	0.86	318.18	1340.90	363.64	0.12	1.14	0.12
C-05	3.89	0.90	1136.36	590.91	659.09	0.24	0.35	0.87
C-06	3.28	0.82	22.73	159.09	750.00	0.00	2.32	0.02
C-07	3.86	0.90	636.36	181.82	659.09	0.13	1.23	0.24
C-08	3.47	0.85	1431.81	386.36	340.91	0.26	0.84	0.13
C-09	4.10	0.92	636.36	886.36	636.36	0.15	1.42	0.11
C-10	2.93	0.65	1681.81	181.82	8386.34	0.17	0.40	2.37

Table E-1. (Continued)

Station	Shannon Wiener Index	Simpson Index	Amphipod Abundance (#/m^2)	Bivalve Abundance (#/m^2)	Polychaete Abundance (#/m^2)	Amphipod Biomass (g/m^2)	Bivalve Biomass (g/m^2)	Polychaeta Biomass (g/m^2)
C-11	3.19	0.83	136.36	386.36	318.18	0.03	1.70	0.15
C-12	2.64	0.76	613.63	795.45	409.09	0.14	1.01	0.35
C-13	3.86	0.87	295.45	272.73	1159.09	0.02	3.94	0.26
C-14	3.14	0.83	90.91	159.09	1636.36	0.01	0.29	0.13
C-15	2.79	0.66	704.54	159.09	3545.44	0.04	3.37	0.79
C-16	2.66	0.68	1522.72	227.27	454.54	0.48	0.25	0.67
C-17	3.63	0.88	250.00	477.27	500.00	0.07	0.22	0.20

APPENDIX F

Draft SEIS Comments and Responses

APPENDIX G

FINDING OF NO NEW SIGNIFICANT IMPACTS

Finding of No New Significant Impact (FONNSI)

In December 2012, the U.S. Fish and Wildlife Service (Service) considered and evaluated three alternatives in the Prime Hook National Wildlife Refuge (Refuge) Comprehensive Conservation Plan (CCP) and Environmental Impact Statement (EIS) for the future management of the refuge (*http://www.fws.gov/refuge/Prime_Hook/what_we_do/finalccpeis.html*). Subsequently, in May 2013, the Service published the final CCP and Record of Decision (ROD), which is hereby incorporated by reference (*http://www.fws.gov/refuge/Prime_Hook/what_we_do/finalccp.html*). The Prime Hook National Wildlife Refuge CCP provides management guidance for conservation of refuge resources and public use activities during the next 15 years, incorporating a combination of passive and active management approaches to foster or achieve more ecologically sustainable habitats than occur on the refuge at present. The CCP detailed that the Refuge would implement management actions that mimic natural processes to enhance habitat restoration where deemed most appropriate. At the same time, the Refuge would strategically reduce management actions that detract from the resiliency and sustainability of a healthy system, such as artificial maintenance of extensive freshwater wetlands that are vulnerable to sea level rise. The Refuge would also pursue careful sediment placement or marsh restoration to return previously managed wetlands to a natural salt marsh, which will be more sustainable in light of sea level rise. The Service's selected alternative was determined to be the most effective alternative at addressing the key issues and concerns identified during the planning process and would best achieve the purpose and need for developing the CCP, the purposes and goals of the Refuge, as well as the mission and goals of the National Wildlife Refuge System. The EIS analyzed the environmental effects of the proposed action and two other alternatives on the biological, physical, socioeconomic, and cultural resources within the project area.

The Service has researched and identified new information that has become available since publication of the EIS in 2012 that pertains to the proposed project and to some of the resources that were analyzed in the EIS. A hydrodynamic numerical model was developed for the Service by Atkins Global to analyze restoration alternatives with respect to water levels, salinity patterns and circulation trends within the refuge. The modeling report (*https://app.box.com/s/frclxl03g8a07diuxaq2*) is summarized and further used in the environmental assessment (EA) to determine whether the Service needs to supplement its existing analysis under the National Environmental Policy Act (NEPA). This EA, in accordance with Council on Environmental Quality (CEQ) regulations, examines whether the new information indicates that there are "substantial changes in the proposed action that are relevant to environmental concerns" or "significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts" that either were not fully discussed or did not exist at the time the EIS was prepared (40 CFR 1502.9).

Federal agencies are encouraged to tier their NEPA analysis to avoid repetition of issues and to focus on the issues for decision at each level of review. Tiering is appropriate when the sequence of statements or analyses is from a plan EIS to a site-specific analysis. The EA tiers to the 2012 EIS (and 2013 ROD) in accordance with 40 CFR 1508.28, and finds that the conditions and environmental effects described in the earlier NEPA documents are still valid or address any exceptions. "An environmental assessment may be prepared, and a finding of no significant impact reached, for a proposed action with significant effects, whether direct, indirect, or cumulative, if the environmental assessment is tiered to a broader environmental impact statement which fully analyzed those significant effects. Tiering to the programmatic or broader-scope environmental impact statement would allow the preparation of an environmental assessment and a finding of no significant impact for the individual proposed action, so long as any previously unanalyzed effects are not significant. A finding of no significant impact other than those already disclosed and analyzed in the environmental impact statement to which the

environmental assessment is tiered may also be called a 'finding of no new significant impact.'" (43 CFR 46.140).

The proposed action discussed in the EA, and the alternatives, including the no action alternative, addressed in the 2012 EIS, have been analyzed to determine the potential environmental effects on the biological, physical, socioeconomic, and cultural resources within the project area. The selected plan of a beach breach repair, back barrier marsh platform design, and creation of a tidal channel network in the marsh interior, is supported by the modeling. A *Spartina*-dominated marsh community appears to be capable of being sustained by the salt water delivered through Slaughter Canal (north) and Broadkill River (south) of the project area. The plan includes removal of the water control structure and partial removal of Fowler Beach Road (approximately 1,800 feet at the easternmost end). Tidal influx will provide both a mechanism for sediment transport and should enhance the rate of marsh development. The selected plan involves the placement of beachfill sand obtained from a nearshore borrow area via hydraulic pipeline dredging on approximately 6,375 linear feet of shoreline within the Refuge's Management Unit II.

The proposed construction would result in removal of the benthic community from some of the borrow and channel areas, and burial of the existing beach, nearshore, and adjacent intertidal communities. The dredging methodology in the borrow area is designed to minimize impacts to the borrow area's benthic community recolonization potential by limiting the maximum dredge cut to – 5 feet. The cutterhead typically cuts a path approximately 5 feet wide by 150-200 feet long, thereby creating ridges to mimic natural bottom habitat from currents, and allow for more rapid recolonization of benthic organisms from neighboring untouched bottom substrate.

The proposal for restoration involves minor, localized and unavoidable adverse effects as described in the EA. Some habitat types, such as the former freshwater impoundments in Units II and III, have been impacted as a result of saltwater inundation. The proposed project will result in less acreage of freshwater habitat in the easternmost portions of the refuge; however, in areas where conversion from freshwater to salt marsh has already occurred due to flooding, these areas had been originally historic tidal salt marsh habitat. The project is designed to retain freshwater fed habitat within the interior of Unit III. Potential adverse effects generally are minor or short-term, and more than offset by the long-term gains in habitat quality, fish and wildlife productivity, plant productivity, increased recreational opportunities and higher coastal storm resiliency. Unavoidable impacts that result from actual construction can be mitigated by the use of practices and precautions that safeguard water quality, such as siltation curtains, and avoid sensitive or rare habitats or time of year restrictions. No long-term adverse impacts are anticipated to result from implementation of the proposed plan. Furthermore, as the refuge land is managed by full-time staff, any unforeseeable impacts would be mitigated with best management practices.

In addition, a comprehensive monitoring program has been developed to track the response of vegetation communities, fish, and wildlife, as well as to monitor changes in physical parameters such as water level, salinity, water quality, sediment concentrations, and marsh elevation. The monitoring program will provide data-evaluating success and for applying adaptive management during the restoration project and beyond. Based on the information presented in this EA, and on evaluation and consideration of comments received on the 2012 EIS and an earlier Environmental Assessment for dune work in 2010, it is concluded that any changes to the project or changes to the physical conditions where the project will be constructed would have no significant adverse effects on the human environment, over and above the potential environmental effects already addressed in the earlier NEPA documents. No new significant adverse environmental effects are expected to occur as a result of the issues addressed in this EA.

The Service is committed to working closely with Federal and State resource agencies, prior to and during project construction to continue monitoring and collection of additional environmental data, provide

relevant supplemental information as needed, and to apply adaptive management and best management practices as appropriate. The U.S. Army Corps of Engineers (Corps) and the National Marine Fisheries Service are serving as cooperating agencies in the preparation of the NEPA documentation for this project.

The EA also concludes that the project can be conducted in a manner, which should not violate Delaware's Wetland and Subaqueous Lands Regulations and Surface Water Quality Standards. Pursuant to Section 401 of the Clean Water Act, a 401 Water Quality Certificate (WQC) is being requested from the DNREC. Based on the information developed during preparation of the Environmental Assessment, and the application of appropriate measures to minimize project impacts, it was determined in accordance with Section 307(c) of the Coastal Zone Management Act of 1972 that the plan complies with and can be conducted in a manner that is consistent with the approved Coastal Zone Management Programs of Delaware. Federal consistency determinations and Wetland and Subaqueous Land permits for this project will be provided by DE DNREC in 2015.

The Service is applying for a Department of the Army permit from the Corps concurrent with the review of the EA. For a given project, the Corps issues one permit, citing both of their statutory permitting authorities: Section 10 of the Rivers and Harbor Act of 1899 and Section 404 of the Clean Water Act, as amended in 1977. In addition to the permitting authorities, the Corps will assure that its permit decisions are compliant with the provisions of the Endangered Species Act, Section 106 of the National Historic Preservation Act, and the Magnuson Stevens Act, as well as NEPA.

The analyses, potential impacts, and conclusions detailed in the EIS remain applicable and valid. Therefore, the Service has determined that a supplemental EIS is not required, and is issuing this FONNSI. Furthermore, we find that implementing the proposed action, as described in the EA, will not have a significant impact on the quality of the human environment, in accordance with Section 102(2)(c) of NEPA, and this FONNSI is appropriate and warranted.

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Scott B. Kahan
Regional Chief
National Wildlife Refuge System
U.S. Fish and Wildlife Service

Date