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VINEYARD WIND

Draft
Construction and Operations Plan

Volume III
Appendices

Vineyard Wind Project

October 22, 2018

Submitted by
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Submitted to
Bureau of Ocean Energy Management
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Sterling, Virginia 20166

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October 22, 2018

Appendix III-A

Hydrodynamic and Sediment Dispersion Modeling Study

Hydrodynamic and Sediment Dispersion Modeling Study for the Vineyard Wind Project

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Executive Summary

Project Overview

Vineyard Wind, LLC ("Vineyard Wind") is proposing an ~800 megawatt ("MW") wind energy project within BOEM Lease Area OCS-A 0501, consisting of offshore wind turbine generators ("WTGs") each placed on a foundation support structure, electrical service platforms ("ESPs"), an Onshore Substation, offshore and onshore cabling, and onshore Operations & Maintenance Facilities (these facilities will hereafter be referred to as the "Project"). A sediment dispersion modeling study of sediment disturbing construction activities (namely offshore cable installation and pre cable installation spot dredging of sand waves) that will be part of the Project was performed in support of the Project's Construction and Operations Plan ("COP").

Briefly described, the Project will install WTGs in the Wind Development Area ("WDA") within the northern half of BOEM Lease Area OCS-A 0501, located approximately 23 kilometers ("km") south of Martha's Vineyard, Massachusetts. The Project will include inter-array cables to connect the WTGs to the ESPs, inter-link cables to connect the ESPs to each other, and offshore export cables (located within an offshore Export Cable Corridor, "OECC") to connect the ESPs to a Landfall Site. Up to two cables may be installed within the OECC which would be each installed in separate trenches.

The Project will rely on a variety of cable installation methods that may vary along the route depending on subsurface conditions which are described in detail within the COP. The COP has been developed utilizing a Project Envelope concept to define and bracket the potential Project characteristics for purposes of environmental review and permitting while maintaining a reasonable degree of flexibility with respect to selection of key Project components, including the specific export cable routes. In keeping with the Project Envelope concept, this study has been designed to simulate the physical impacts of installation of a representative inter-array cable and variants of the OECC. The physical impacts quantified are those relating to excess (i.e., above ambient) total suspended sediment ("TSS") concentrations and eventual seabed deposition resulting from sediments that get resuspended in the water column during installation (i.e., burial) of the cables and during pre-cable installation spot sand wave dredging. The WDA does not have sand waves; however, all OECC variants intersect regions of sand waves.

The Project is considering two distinct approaches to remove the upper portions of the sand waves above the stable seabed where necessary along the OECC. The first technique is a trailing suction hopper dredge ("TSHD"). The second approach involves jetting (also known as mass flow excavation), which uses a pressurized stream of water to push sand to the side. The dredging could be accomplished entirely by the TSHD on its own (the "TSHD Pre Dredge" option) or the dredging could be accomplished by a combination of jetting and TSHD, where jetting would be used in smaller sand waves and the TSHD would be used to remove the larger sand waves (this is referred to as "Limited TSHD Pre Dredge + Jetting"). Once any needed sand wave removal occurs, burial of the cable will occur.

- For the "TSHD Pre Dredge" approach, cable installation is a separate activity that occurs after dredging is complete (this is referred to simply as "Cable Installation"). Therefore, the model first simulates the TSHD dredging, then separately simulates the cable installation. This combined approach of TSHD dredging followed by cable installation is referred to as "TSHD Pre Dredge + Cable Installation]".
- For the "Limited TSHD Pre Dredge Approach + Jetting" approach, the jetting activity both removes the tops of sand waves and buries the cable. (Such jetting occurs only for very limited portions of the cable corridor.) Therefore, the model accounts for cable installation both through jetting (in smaller sand wave segments only) and through one of the other potential cable burial methods (such as a jet plow) that may be used in areas without sand waves requiring removal; this approach is referred to as "Cable Installation aided by Jetting." Accordingly, the model first simulates the limited TSHD dredging, then separately simulates the cable installation (which consists of jetting in limited segments for sand wave clearance and cable burial plus jet plow or one of the other cable installation techniques listed in the project's Construction and Operations Plan [COP] for the remainder of the route). This combined approach of limited TSHD dredging (in larger sand waves) followed by cable installation via either jetting (in smaller sand waves) or one of the other potential cable burial methods (such as a jet plow) is referred to as "Limited TSHD Pre Dredge + Cable Installation aided by Jetting."

Description of Model

RPS applied customized hydrodynamic, and sediment transport and dispersion models to assess potential impacts from sediment resuspension during Project construction. As part of this assessment, RPS gathered and analyzed environmental data, developed a hydrodynamic model grid and application using RPS's HYDROMAP model, verified the hydrodynamic model performance, developed the appropriate sediment source loads to reflect planned activities, set up and ran sediment transport and dispersion model applications of the various Project components using RPS's SSFATE model, and post processed modeling results to provide (1) maps of maximum excess (above ambient) TSS concentrations, (2) maps of final seabed deposition, (3) tabular summaries of total area over specific concentration thresholds for various durations, and (4) area summaries of deposition over specific thickness thresholds. Thresholds used to display results were chosen based on a combination of timeframes of biological significance and values that would help demonstrate the transient nature of the physical impacts.

The HYDROMAP hydrodynamic model domain extended from approximately Provincetown (northeast extent) at the northern tip of Cape Cod to Sandy Hook, New Jersey ("NJ") (southwest extent) south of New York City including Nantucket Sound, Martha's Vineyard Sound, Buzzards Bay, Narragansett Bay, Block Island Sound, Rhode Island Sound and Long Island Sound. The domain is significantly larger than the Project Area, however the extent was chosen to best locate and define open boundary conditions. The model was forced with tidal harmonics and wind so it was able to reproduce patterns of tides and currents at multiple locations within the domain. The currents are predominately tidal and predominantly semi-diurnal, meaning the speeds ramp up and down in a cyclical manner and reverse in direction approximately twice daily. After the model application was verified, a second model run was completed for a period exhibiting winds close to the average winds in the region for a March timeframe. This second model application was used as the hydrodynamic forcing in the sediment transport and dispersion modeling.

The hydrodynamic model was shown to recreate the spatial and temporal patterns and trends of the observed tides and currents as verified by comparison at discrete sites with in-situ data. The model did overpredict the vertical shear and surface currents during periods of high wind; however, the bottom current during those periods was well represented. As the sediment disturbing work (i.e., the cable installation) will occur at the seafloor, it was determined that the hydrodynamic model was appropriate for assessing Project impacts. In general, the currents are variable throughout the Project: currents are relatively weak within the WDA but increase sharply through the potential OECC within Muskeget Channel. Within Vineyard Sound, the currents are moderate as they decrease towards the coast.

Sediment transport modeling and analysis was performed to simulate the pre-cable installation sand wave dredging and installation (i.e., burial) of multiple offshore cable systems. A representative inter-array cable within the WDA was modeled as were all variants of the OECC. All simulations utilized the scenario hydrodynamic modeling output from HYDROMAP, and a concentration grid of 50 meter ("m") resolution in the horizontal dimensions and 0.5 m resolution in the vertical dimension. The model timestep and output writing interval was 5 minutes for the cable installation scenarios and 2 minutes for the pre cable installation dredging. The sediment source load for each simulation was developed based on sediment and installation characteristics. The simulations were run in SSFATE and post processed to determine the spatial and temporal characteristics of excess (i.e., above ambient) TSS concentrations and the spatial patterns of deposition at multiple thickness thresholds.

Inter-array Cable Installation

For the representative inter-array cable, a single inter-array route was simulated which was selected as the longest individual route within a representative configuration. The route was simulated for typical and maximum impact installation parameters.

- Typical installation reflected a 1 m wide by 2 m deep trench, a production rate (i.e., installation rate) of 200 m/hour ("hr") and a sediment mobilization fraction of 0.25 (25% of total trench volume).
- Maximum impact installation reflected a 1 m wide by 3 m deep trench, a production rate of 300 m/hr and a sediment mobilization fraction of 0.35 (35% of total trench volume).

It is anticipated that the typical parameters would be utilized for approximately 90% of the cable installation and that the maximum impact parameters would only be utilized for 10% of the cable installation. The vertical initialization of resuspended sediments was based on the possible methods and limited to the bottom 3 m of the water column with 85% of the sediment introduced to the bottom 1 m of the water column. In order to be conservative, the entire route was assumed to have the sediment characteristics associated with the sample with the greatest relative fraction of fine material, which was ~23% for the 2 m deep trench and ~29% for the 3 m deep trench. The sediment characterization was developed based on depth weighted averages of sediment grain sizes.

The simulation of the typical installation of the inter-array cable predicted the 10 mg/L plume to oscillate about the route centerline due to the tidal currents and extend up to 3.1 km from the centerline. High concentrations were limited to a smaller extent from the centerline, with the 50 mg/L plume extending up to 160 m from the centerline. The associated deposition showed thickness of 1.0 millimeters ("mm") or greater mainly centered around the centerline (within ~ 100 m) and maximum deposition thickness was less than 5 mm.

The simulation of the maximum impact installation of the inter-array cable showed a noticeably larger footprint, with the 10 mg/L , 50 mg/L and 100 mg/L contours extending up to ~7.5 km, ~2.0 km and ~860 m from the centerline, respectively. The deposition of 1.0 mm or greater was limited to ~140 m from the route centerline and the deposition thickness was less than 5 mm. These increases are as expected due to the increased total mass and mass flux associated with the maximum impact parameters. Both simulations showed the maximum concentrations were located near the bottom of the water column, which is expected based on the initialization of sediments due to the bottom activity.

Offshore Export Cable Installation

The Project includes one predominate OECC which has two variants through Muskeget Channel (West Muskeget [WM] and East Muskeget [EM]) and two options for landfall (Covell's Beach and New Hampshire Avenue); these combine for four variants of the OECC.

1. OECC through west Muskeget to Covell's Beach
2. OECC through west Muskeget to New Hampshire Avenue
3. OECC through east Muskeget to Covell's Beach
4. OECC through east Muskeget to New Hampshire Avenue

For the two approaches a total of eight simulations were run, the pre cable installation dredging and the cable installation for each of the four route variants. An additional simulation was run with maximum impact burial parameters for one of the route variants. As with the inter-array cable installation described above, it is anticipated that the typical parameters would be utilized for approximately 90% of the offshore export cable installation and that the maximum impact parameters would only be utilized for 10% of the offshore export cable installation.

The sediment characteristics for the OECC segments were based on the characterizations from sediment sample analysis along the segment, and were therefore spatially varied along each segment and between each segment. In general, the total set of sediment grain size distribution analysis showed that the samples were predominately coarse sand with some exceptions.

For each simulation, maps of time integrated maximum excess TSS concentration and seabed deposition were generated. Model results (the area over specific thresholds for specific durations and deposition) were also tabulated.

The results from one OECC route variant (East Muskeget to NH Avenue) were presented in greater detail to provide more insight as to the impacts. Due to the similarity between the routes and the impacts, this route serves as a proxy for the results of any of the OECC variants. The cable installation without jetting or aided by jetting are negligibly different; however, the dredging impact footprint associated with the Limited TSHD Pre Dredge + Jetting approach is smaller than that of the TSHD Pre Dredge approach due to the reduced required volume of dredging.

A summary of different results metrics is provided in ES Table 1. This table presents the modeling results for both TSHD (either as part of the "TSHD Pre Dredge + Cable Installation" approach or as part of the "Limited TSHD Pre Dredge + Cable Installation aided by Jetting" approach) and for cable installation. ES Table 1 lists the maximum excursion of the 10 mg/L excess concentration, the maximum extent of the 1 mm thickness deposition, the maximum extent of the 20 mm thickness deposition and the area over 10 mg/L for durations of 1 hour ("hr"), 2 hr, 3 hr, 4 hr, and 6 hrs.

Simulations of pre-cable installation dredging using a TSHD along the OECC show that plumes originating from the source are intermittent along the route, due to the intermittent need for dredging. The plume of excess TSS at 10 mg/L and 750 mg/L extends up to 16 km and 5 km from the route centerline for 2-3 hours, respectively, though may be less extensive at varying locations along the route. Relatively high concentrations (>1000 mg/L) are predicted at distances up to 5 km from the route centerline in response to the relatively high loading of dumping and swift transport of the dumped sediments, but this high concentration only persists for <2 hours. In general, the excess concentrations over 10 mg/L from dredging can extend several km from the route centerline and may be present throughout the entire water column but are temporary and typically dissipate within about 6 hours. The deposition greater than 1.0 mm associated with the TSHD drag arm is mainly constrained to within 80 m from the route centerline, whereas the deposition greater than 1.0 mm associated with overflow and disposal extends to greater distances from the source (disposal locations ~ 250 m east of the route centerline), mainly within 1 km though such deposition can extend up to 2.3 km in isolated patches when subject to swift currents through Muskeget Channel. Deposition greater than 20 mm resulted only from the dumping activities. Since the dumping takes place away from the route centerline the majority of the 20 mm thickness was located in isolated patches offset from the route centerline. Very small patches of areas greater than 20 mm were noted up to ~0.9 km from the dumping location, however such occurrences were not typical; typically the 20 mm deposition was within 0.35 km from the source.

The simulations of the cable installation showed that both the footprint of the 10 mg/L excess concentration plume and the footprint of deposition over 1.0 mm stayed close to the route centerline. The maximum excursion of the 10 mg/L excess plume extended up to ~2 km, though typically less than 200 m from the route centerline. The excess concentrations stemming from cable installation, both with and without jetting for sand wave clearance, remain relatively close to the route centerline, are constrained to the bottom of the water column, and are also short-lived (typically dissipating within 4-6 hours). Deposition greater than 1.0 mm was limited to within 100 m from the route centerline, though was mainly within 80 m.

A simulation of one variant of the OECC was also run using maximum impact parameters for cable installation. This simulation showed relatively similar results as compared to the simulation with typical cable installation parameters; however, the maximum impact simulation had more areas of higher concentration directly along the route and a slightly larger excursion of the 10 mg/L plume. The deposition patterns of the maximum impact cable installation simulation were similar to the typical cable installation parameters, with deposition greater than 1.0 mm limited to within 140 m from the route centerline though typically within 100 m.

ES Table 1 Summary of results metrics for each route simulated. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	**Comp.**	**Route**	**Activity**	**Typ or Max**	**Maximum Extent of the 10 mg/L contour[1] (km)**	**Maximum Extent of Deposition > 1 mm[1] (km)**	**Maximum Extent of Deposition > 20 mm[2] (km)**	**Area (square kilometers ["km2"] over 10 mg/L for various duration (hrs)**				
								1	**2**	**3**	**4**	**6**
1	WDA	Inter-Array	Cable Installation	Typ	3.1	0.10	N/A	9.73	4.67	1.3	0.27	
2	WDA	Inter-Array	Cable Installation	Max	7.5	0.14	N/A	36.4	21.4	12.1	6.88	1.33
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ	20	0.95	0.70	2.36	0.168			
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ	8.5	2.30	0.90	5.27	0.877	0.105		
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ	20	0.95	0.70	2.26	0.178			
6	OECC	EM – Covell's	Limited TSHD Pre Dredge	Typ	8.5	2.30	0.90	5.27	0.877	0.105		
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ	0.67	0.10	N/A	13.7	1.51	0.178		
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ	2	0.10	N/A	14.8	1.14	0.098		
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ	0.62	0.10	N/A	12.3	1.06	0.153		
10	OECC	EM – Covell's	Cable Installation aided by Jetting	Typ	2.1	0.10	N/A	13.3	0.722	0.07	0.005	
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	15.75	1.3	0.85	19.7	5.94	1.69	0.453	
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	16	2.3	0.35	19.7	7.12	3.87	1.9	0.058
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ	15.75	1.3	0.85	17.4	3.85	0.833	0.085	
14	OECC	EM – Covell's	TSHD Pre Dredge	Typ	16	2.3	0.35	17.2	5.7	2.78	1.18	
15	OECC	WM - NH Ave	Cable Installation	Typ	1.02	0.10	N/A	13.5	1.45	0.181	0.015	
16	OECC	EM - NH Ave	Cable Installation	Typ	2	0.10	N/A	14.7	1.09	0.075		
17	OECC	WM - Covell's	Cable Installation	Typ	0.86	0.10	N/A	12.1	1.06	0.15	0.015	
18	OECC	EM – Covell's	Cable Installation	Typ	1.85	0.10	N/A	13.3	0.714	0.058		
19	OECC	EM - NH Ave	Cable Installation	Max	2.8	0.10	N/A	9.94	0.654	0.14	0.008	

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[1] Distances were measured from the nearest source, either the route centerline or dumping site. The dumping sites were approximately 250 m east of the centerline. Therefore the distances listed when measured from the disposal site are either +/- 250 m from the route centerline.

[2] The 20 mm deposition was exclusively associated with the dumping.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Project Background

This report documents the sediment dispersion modeling study of sediment disturbing construction activities that will be part of the proposed Vineyard Wind's offshore wind project (the Project).

Briefly described, the Project will install WTGs in the Wind Development Area ("WDA") within the northern half of BOEM Lease Area OCS-A 0501, located approximately 23 kilometers ("km") south of Martha's Vineyard, Massachusetts. The Project will include inter-array cables to connect the wind turbine generators ("WTGs") to the electric service platforms ("ESPs"), inter-link cables to connect the ESPs to each other, and offshore export cables (located within an offshore Export Cable Corridor, "OECC") to connect the ESPs to a Landfall Site. Up to two offshore export cables may be installed within a given corridor, each in separate trenches.

The Project will rely on a variety of cable installation methods that may vary along the route depending on subsurface conditions which are described in detail within the COP. The COP has been developed utilizing a Project Envelope concept to define and bracket the potential Project characteristics for purposes of environmental review and permitting while maintaining a reasonable degree of flexibility with respect to selection of key Project components, including the specific export cable routes. In keeping with the Project Envelope concept, this study has been designed to simulate the physical impacts of installation of a representative inter-array cable and variants of the OECC as well as the impacts associated with dredging sand waves along the OECC which will be necessary in varying degrees prior to cable installation.

1.2 Objectives, Tasks and Study Output

In keeping with the Project Envelope, this study has been designed to simulate the physical impacts associated with installation of a representative inter-array cable and variants of the OECC as well as the impacts associated with dredging sand waves along the OECC. The physical impacts quantified are those relating to excess (i.e., above ambient) total suspended sediment ("TSS") concentrations and eventual seabed deposition resulting from sediments that get resuspended in the water column during installation (i.e., burial) of the cables or during dredging operations. For each OECC variant, the activities associated with a single cable were simulated, though up to two cables may be installed; the single cable simulation is representative of the impacts that would be associated with each additional potential cable. An illustration of the location of key Project components is presented in Figure 1.

RPS applied customized hydrodynamic, and sediment transport and dispersion models to assess potential impacts from sediment resuspension during Project. Specifically, the analysis includes two interconnected modeling tasks:

1. The development of a three-dimensional hydrodynamic model application of a domain encompassing Project activities using the HYDROMAP modeling system.
2. Simulations of the suspended sediment fate and transport (including evaluation of seabed deposition and suspended sediment plumes) using the SSFATE modeling system to simulate Project activities. Velocity fields developed using the HYDROMAP model are used as the primary forcing for SSFATE.

This report describes the models, modeling approach, model inputs and outputs used to evaluate the Project activities. A description of environmental data sources used is provided in Section 2. The HYDROMAP hydrodynamic model and its application to the Project Area are presented in Section 3. Section 4 provides an overview of the SSFATE sediment dispersion model and results from the application of SSFATE for a range of base case construction scenarios. References are provided in Section 5.

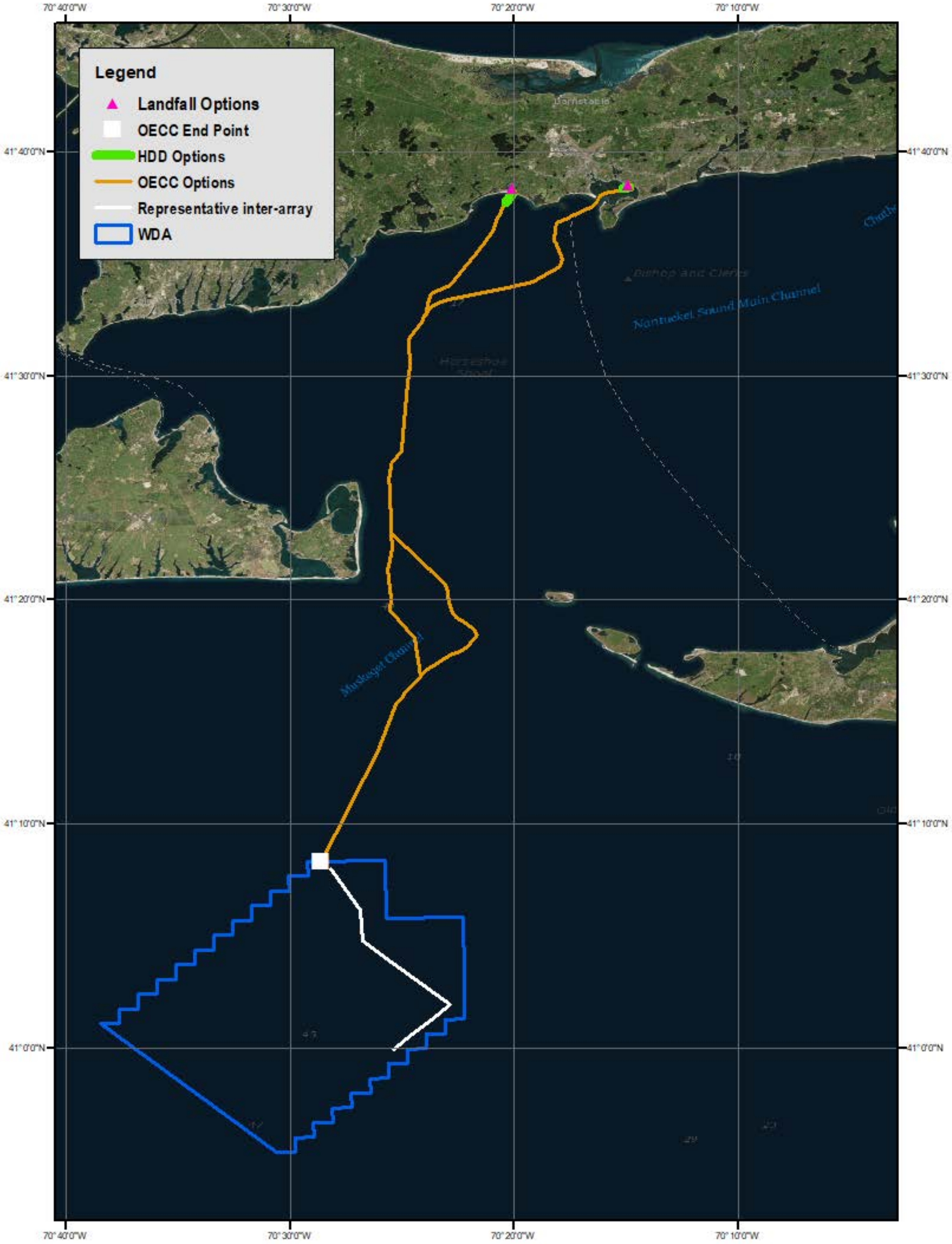

Figure 1. Map of Project components.

2 Environmental Data

This study used environmental data gathered from public or client-provided sources. The environmental data gathered were used to either develop modeling inputs or for hydrodynamic model validation. An overview of the data types and sources is provided below, however the details of the data are presented in the hydrodynamic modeling and sediment transport modeling sections. A map illustrating the location of the discrete data sources is presented in Figure 3.

2.1 Shoreline Data

The shoreline for the domain was developed based on merging shoreline data from each of the relevant states- Massachusetts ("MA"), Rhode Island ("RI"), Connecticut ("CT") and New York ("NY")- from their respective GIS clearinghouses per the links below. Each shoreline was projected from its native state plane coordinate system to the geographic coordinate system GCS_WGS_1984, which is the coordinate system used in the hydrodynamic and sediment transport modeling systems.

- MA - https://www.mass.gov/get-massgis-data (OUTLINE25K_POLY.shp)
- RI - http://www.rigis.org/ (towns.shp)
- CT - http://www.ct.gov/deep/gisdata/ (CT_TOWN.shp)
- NY - http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=927 (Counties_Shoreline.shp)

The shoreline data were used as a guide for development of the hydrodynamic model grid and to develop the land water boundaries in the concentration and deposition grid used in the sediment transport modeling.

2.2 Bathymetry Data

Bathymetry data was gathered from publicly available data provided by the National Oceanic and Atmospheric Administration ("NOAA") for coastal and offshore waters of MA, CT, RI and NY as well as high resolution data provided by the client for swaths within the WDA.

The NOAA soundings were downloaded from the NOAA ENC Direct to GIS portal (https://encdirect.noaa.gov/), where ENC refers to Electronic Navigational Chart. Data were obtained for the harbor, coastal and approach ENC band levels. Sounding are available from their native positioning, which is irregular in spacing.

Vineyard Wind provided high resolution bathymetry data for swaths within the WDA from field work completed for this project (Section 2 of COP Volume II). This data set was provided on a 0.5 m resolution. This high resolution was interpolated to create a grid at a 50 m resolution from which the grid centroids were then merged with the NOAA data for a complete data set of the study area waters.

The combined bathymetry data set was used to develop the depths from the hydrodynamic model grid as well as the depth grid used in the sediment transport modeling.

2.3 Meteorological Observations

Meteorological (wind) data to be used as input to the hydrodynamic model was obtained from the National Data Buoy Center (“NDBC”) BUZ3M Buzzards Bay station located as shown in Figure 3. Wind speed and direction at this location is obtained from an anemometer located approximately 24.8 m above mean sea level. Measurements are recorded on an hourly time step. The data was reviewed to determine the average wind speeds and identify an average March time period since March is the potential construction time period.

The monthly average wind speed for the period of 2006-2016 is presented in Table 1 along with annual averages and a wind rose of the period is provided in Figure 2. The monthly average wind speed ranges from 3.83 m/second (“s”) to 10.29 m/s though is mainly between 5.78 m/s (5th percentile) and 9.38 m/s (95th percentile). The average annual speed at this location is 7.6 m/s and the average March monthly wind speed is 8.10 m/s. Reviewing the monthly averages throughout the record March 2016 was identified having a monthly average (8.14 m/s) close to the record March average monthly windspeed.

Table 1. Summary monthly average wind speeds for 2006 -2016

Timeframe	**Monthly Average Wind Speed (m/s)**											**Average**
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Jan	9.13	7.19	8.86	8.68	8.63	7.84	9.15	8.61	9.40	10.05	9.59	8.83
Feb	9.84	7.30	8.50	8.87	8.80	8.93	7.88	9.11	8.30	9.33	9.37	8.75
Mar	7.94	7.25	8.67	7.68	8.72	8.32	7.77	8.54	8.23	7.87	8.14	8.10
Apr	7.62	8.02	6.78	8.19	6.56	8.02	7.29	7.59	7.63	7.64	7.89	7.57
May	7.75	6.83	7.83	6.87	6.89	6.84	5.99	6.81	7.03	6.73	7.01	6.96
Jun	7.35	7.29	5.92	5.95	6.27	5.84	6.79	7.24	5.96	6.66	6.20	6.50
Jul	6.94	5.90	5.79	6.22	5.65	5.97	3.83	6.50	6.78	5.78	6.15	5.96
Aug	5.80	5.78	5.04	5.72	6.54	6.24	5.27	5.84	5.40	5.82	6.14	5.78
Sep	6.81	6.63	6.53	6.79	7.65	6.54	6.58	6.55	6.34	6.34	7.13	6.72
Oct	9.36	7.62	8.14	8.64	9.59	8.16	7.82	6.99	8.66	9.09	8.00	8.37
Nov	7.46	9.09	8.24	8.67	9.04	8.45	8.79	9.21	9.30	8.10	8.43	8.62
Dec	8.78	8.90	10.07	10.29	10.17	7.96	8.65	8.35	8.63	8.12	9.13	9.00
Annual	7.90	7.32	7.53	7.71	7.88	7.43	7.15	7.61	7.64	7.63	7.76	**7.60**

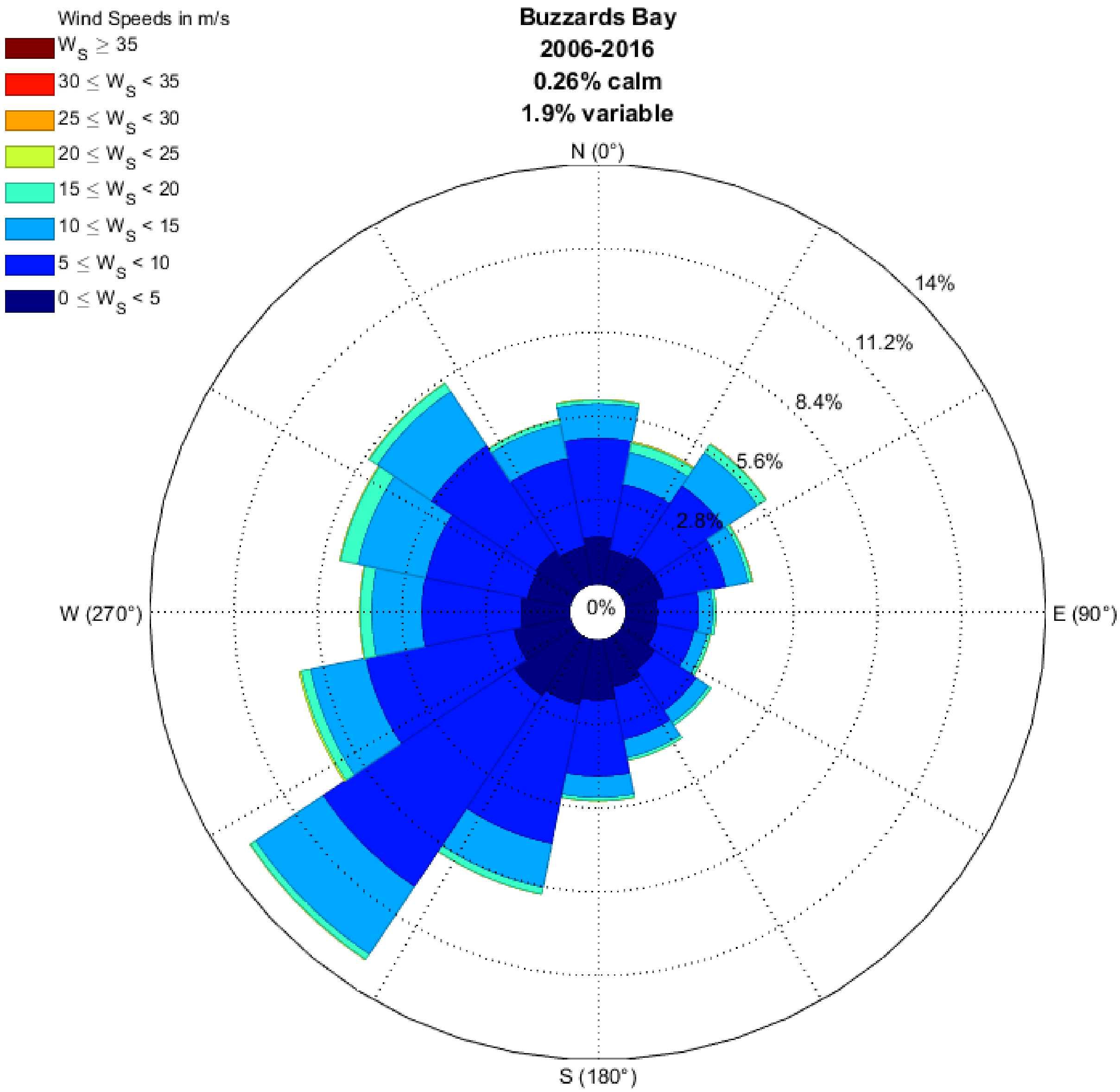

Figure 2. Wind rose for the period of 2006-2016 at NDBC BUZ3M Buzzards Bay station.

2.4 Sea Surface Height (Tides) Data

Sea surface height ("SSH") characteristics were used for both developing model forcing and for verification of the hydrodynamic model predictions. Four different sources of data were used for this study. The data were available either as time histories of observations of water surface elevation or in the form of harmonic constituents. Harmonic constituents are the amplitude and phase of known periodic constituents of the tidal signal and the tidal signal is the sum of all constituents signal added together by superposition. The amplitude describes the difference between a mean sea level datum and the peak water level for a constituent and the phase describes the timing of the signal relative to a time datum. The constituent period determines the time for one full oscillation of the signal. Tidal harmonic constituents names indicate the approximate period (e.g., M2 is ~twice daily and O1 is ~once daily).

The publicly available output from the TPXO7 global tidal model developed by Oregon State University ("OSU") was used as a source of characterizing the tides for use in hydrodynamic model boundary forcing. This model output contains tidal harmonic constituent data on a ¼ degree resolution across the globe. The model was based on data from the TOPEX/Poseidon and Jason satellites and the model methodology is documented in Egbert et al. (1994) and Ebgert and Erofeeva (2002). A summary of the constituents obtained and their period is provided in Table 2. Details on the spatially varying amplitude and phase are provided in Section 3.

Table 2. Tidal constituents used as boundary forcing

Name	Constituent	Speed (degrees/hour)	Period (hours)
M2	Principal lunar semidiurnal constituent	28.98	12.42
S2	Principal solar semidiurnal constituent	30.00	12.00
N2	Larger lunar elliptic semidiurnal constituent	28.44	12.66
K1	Lunar diurnal constituent	15.04	23.93
O1	Lunar diurnal constituent	13.94	25.82

Observational based tidal harmonic data was obtained from NOAA Tides and Currents for stations within the study area (see Figure 3). The harmonic constituents provided by NOAA are based on a harmonic analysis of observed water levels at observations stations. These constituents were used to develop the time histories of sea surface height at each location for different periods of time using the publicly available T_Tide Matlab Toolbox with methodologies of the toolbox described in Pawlowicsz et al. (2002). The time histories were used to validate model predictions. The NOAA published amplitude and phase for M2, N2, S2, K1, and O1 constituents are in Table 3 and Table 4 respectively.

Both time histories of observational data and published harmonic constituents from Grilli et al. (2010) characterizing the tides at two of the Rhode Island Ocean Special Area Management Plan (“OSAMP”) offshore buoys (“POF” and “POS”) were used in this study. The location of the buoys is as shown in Figure 3; note that the OSAMP had a total of four buoys but only two collected pressure which was converted to water depth to capture the tides. The data was available from October 2009 through June 2010 at a two hour time step. The amplitude and phase for the M2, N2, S2, K1, and O1 for the OSAMP stations are in Table 3 and Table 4, respectively.

Table 3. Summary of amplitudes of harmonic constituents in the vicinity of the study domain

Summary of Harmonic Constituent Amplitude (m)						
Location	**Source**	**M2**	**S2**	**N2**	**K1**	**O1**
Sandy Point	NOAA	0.688	0.134	0.158	0.103	0.054
Montauk	NOAA	0.302	0.065	0.079	0.074	0.054
Newport	NOAA	0.505	0.108	0.124	0.062	0.047
Nantucket	NOAA	0.439	0.047	0.113	0.092	0.084
Chatham	NOAA	0.713	0.089	0.139	0.103	0.088
POS	Grilli et al.	0.443	0.095	0.104	0.073	0.022
POF	Grilli et al.	0.452	0.098	0.111	0.068	0.034

Table 4. Summary of phases of harmonic constituents in the vicinity of the study domain

Summary of Harmonic Constituent Phase (degrees)						
Location	**Source**	**M2**	**S2**	**N2**	**K1**	**O1**
Sandy Point	NOAA	6.0	32.6	348.6	175.7	172.5
Montauk	NOAA	46.8	56.6	22.2	178.7	209.8
Newport	NOAA	2.3	25.0	345.8	166.1	202.0
Nantucket	NOAA	134.7	166.7	102.5	221.6	215.9
Chatham	NOAA	140.0	182.1	108.5	237.6	223.4
POS	Grilli et al.	3.9	18.7	350.5	166.8	16.3
POF	Grilli et al.	0.9	18.2	344.7	167.2	7.4

2.5 Current Observations

Observations of currents were obtained from four OSAMP stations (MDF, MDS, POF, POS). The location of these buoys is shown in Figure 3. At each station currents were obtained at multiple depths through the water column through a number of different vertical bins. A summary of metrics for each station is provided in Table 5. The current observations were used for verification of model predictions.

Table 5. Summary of stations with current observations

Source	Station Name	Time Step (hr)	Start Day Obtained	End Day Obtained	Bin Resolution (m)
OSAMP	POS	2	9/15/2009	1/15/2010	0.75
OSAMP	POF	2	9/15/2009	1/15/2010	0.75
OSAMP	MDF	1	10/9/2009	6/10/2010	1
OSAMP	MDS	1	10/9/2009	5/21/2010	1

2.6 Sediment Grain Size Distribution Data

This study utilized sediment data from two separate field campaigns, one focused on the WDA and the other focused on the OECC. The sample sites and details on the grain size are documented in Section 2 of COP Volume II and the reader is referred there for details. The samples in the WDA were vibracore samples which included multiple analyses of the boring data at various depths. The samples obtained along the OECC were a combination of surface grab samples, which are applicable to the upper half meter of the seabed, and vibracores which had grain size analyses reported at multiple depths. The details on the samples that were used to develop inputs to the sediment transport modeling are provided in Section 4 of this report.

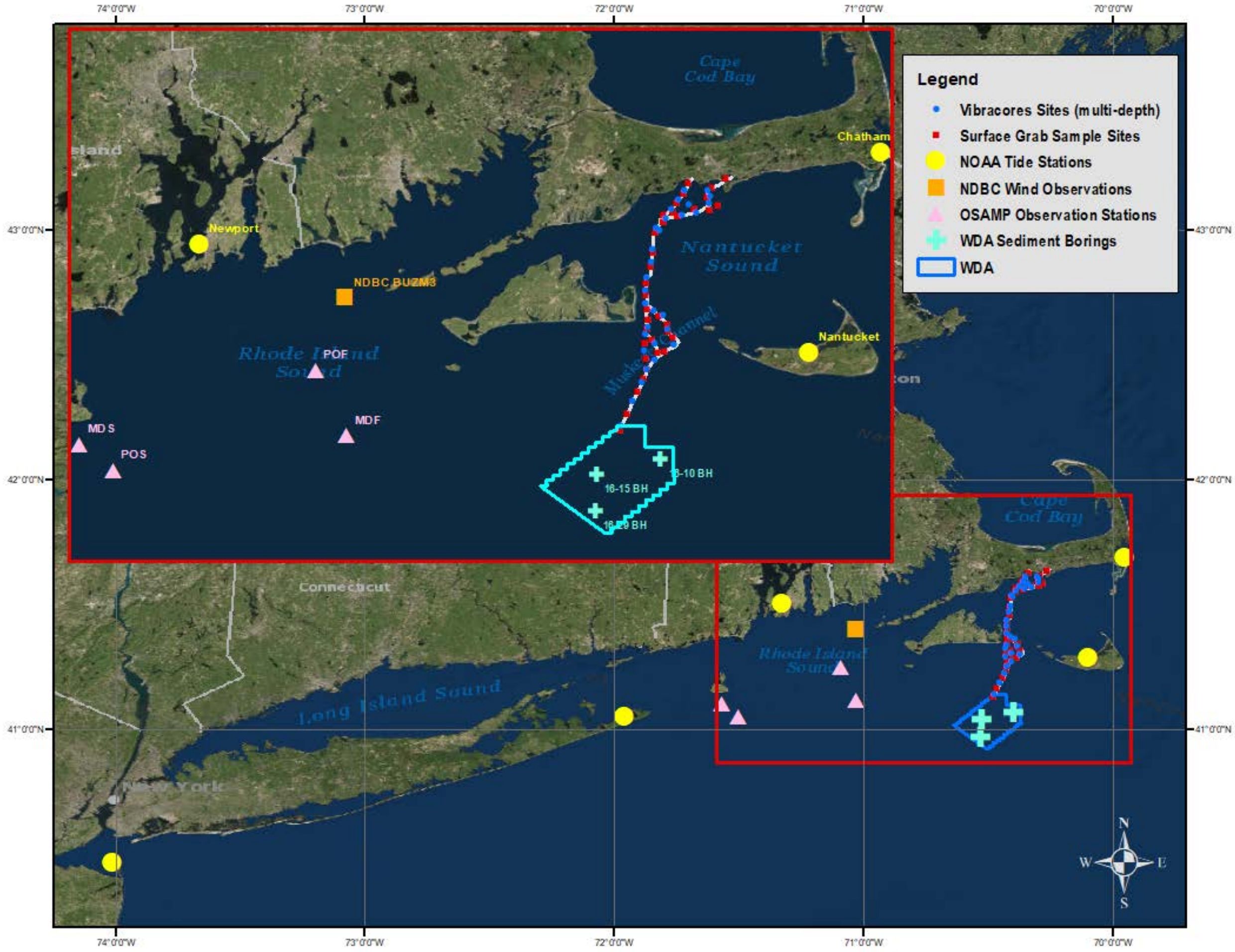

Figure 3. Map showing locations of environmental data sources.

3 Hydrodynamic Modeling

The first modeling task was the development, validation, and application of a three-dimensional hydrodynamic model application of a domain that includes all Project activities. RPS' HYDROMAP hydrodynamic model (Isaji et al., 2001) was used to model the circulation pattern and water volume flux through the study area and to provide hydrodynamic conditions (spatially and temporally varying currents) for input to the sediment dispersion model. The hydrodynamic modeling task included gathering and analyzing environmental data, development of a hydrodynamic model grid and boundary conditions, validation of model performance for a period with observations, and development of currents for a timeframe characterized by typical wind conditions to be used in sediment transport simulations.

The circulation (currents) in the Project Area are tidally dominated (Spaulding & Gordon, 1982) with wind and density variations playing a smaller role. The tidal currents in the Project Area are a combination of rectilinear reversing currents and rotary currents (Haight, F.J., 1936) and are predominately semi-diurnal and diurnal. Notably strong tidal (peaks greater than 1.5 m/s) currents exist in the area surrounding the Muskeget channel located between Nantucket Sound and the waters of the Atlantic Ocean (NOAA, 2017).

Tidal currents are present throughout the water column and their predominance is clear when evaluating observed current data, particularly near the bottom where resuspended sediment will be introduced to the water column from the cable installations. Wind can influence surface through bottom currents at times, depending on the wind speed and water depth, and therefore plays a minor role in the transport of sediments in the majority of the Project Area. Therefore, since the tidal currents exhibit cyclical, repeating patterns and are not characterized by season, wind was chosen as the metric for identifying an environmental timeframe for use in sediment transport and dispersion modeling.

3.1 HYDROMAP Description

HYDROMAP, developed by RPS (formerly ASA), is a globally re-locatable hydrodynamic model capable of simulating complex circulation patterns due to tidal forcing ,wind stress and fresh water flows quickly and efficiently anywhere on the globe. HYDROMAP employs a novel step-wise-continuous-variable rectangular ("SCVR") gridding strategy with up to six levels of resolution. The term "step-wise-continuous" implies that the boundaries between successively smaller and larger grids are managed in a consistent integer step. The advantage of this approach is that large areas of widely differing spatial scales can be addressed within one consistent model application. Grids constructed by the SCVR are still "structured," so that arbitrary locations can be easily located to corresponding computational cells. This mapping facility is particularly advantageous when outputs of the hydrodynamics model are used in subsequent application programs (e.g., Lagrangian particle transport model) that use another grid or grid structure.

The hydrodynamic model solves the three-dimensional conservation equations in spherical coordinates for water mass, density, and momentum with the Boussinesq and hydrostatic assumptions applied. These equations are solved subject to the following boundary conditions:

1) At land boundaries the normal component of velocity is set to zero;
2) At the open boundaries the sea surface elevation is specified by the dominant tidal constituents, each with its own amplitude and phase from a reference time zone, or as a time series of total surface elevation defined relative to the local surface elevation;
3) At the sea surface the applied stress due to the wind is matched to the local stress in the water column and the kinematic boundary condition is satisfied; and
4) At the sea floor a quadratic stress law, based on the local bottom velocity, is used to represent frictional dissipation and a friction coefficient parameterizes the loss rate.

The numerical solution methodology follows that of Davies (1977) and Owen (1980). The vertical variations in horizontal velocity are described by an expansion of Legendre polynomials. The resulting equations are then solved by a Galerkin-weighted residual method in the vertical and by an explicit finite difference algorithm in the horizontal. A space staggered grid scheme in the horizontal plane is used to define the study area. Sea surface elevation and vertical velocity are specified in the center of each cell while the horizontal velocities are given on the cell face. To increase computational efficiency, a "split-mode" or "two mode" formulation is used (Owen, 1980; Gordon, 1982). In the split-mode, the free-surface elevation is treated separately from the internal, three-dimensional flow variables. The free-surface elevation and vertically integrated equations of motion (external mode), for which the Courant-Friedrichs-Lewis ("CFL") limit must be met, is solved first. The vertical structure of the horizontal components of the current then may be calculated such that the effects of surface gravity waves are separated from the three-dimensional equations of motion (internal mode). Therefore, surface gravity waves no longer limit the internal mode calculations and much longer time steps are possible. The interested reader is directed to Isaji et al. (2001), and Isaji and Spaulding (1984) for a detailed description of the model physics and numerical implementation.

3.2 HYDROMAP Model Application

The model application was developed for simulations in the three-dimensional mode. First an application was developed for a period with available in-situ current observations to verify model performance. Subsequent to model verification an additional scenario application was developed for a period that reflected typical wind conditions. The scenario application output was used in the sediment dispersion modeling. The main model application features are the model grid and bathymetry and the boundary forcing. These features are described in more detail below.

3.2.1 Model Grid

The model domain extended from approximately Provincetown (northeast extent) at the northern tip of Cape Cod to Sandy Hook, NJ (southwest extent) south of New York City including Nantucket Sound, Martha's Vineyard Sound, Buzzards Bay, Narragansett Bay, Block Island Sound, Rhode Island Sound and Long Island Sound. The domain is significantly larger than the Project Area, however the extent was chosen to best locate and define open boundary conditions.

The shoreline for the domain was developed based on merging shoreline data from each of the relevant states (MA, RI, CT and NY). The grid is mapped to the shoreline, with a coarse resolution at distances farther away from the immediate Project Area and fine resolution in the areas closest to Project activities or where necessary to capture the physical characteristics of the study area.

Figure 4 shows the computational model grid cells for the entire domain, consisting of 24,313 active water cells. At the open eastern and southern boundaries and in the outer regions away from the WDA, a maximum cell size of ~1.0 km was assigned. Cell resolution was increased as needed to capture finer features and to adequately resolve coastal features within the Project Area. The finest resolution of ~125 m was applied closer to shore to capture shoreline and bathymetry changes. The model set up allows for three dimensional model simulations, which was utilized for this study. The vertical grid is represented by Legendre polynomials, in this instance six polynomials were used to represent the vertical variability in the currents from tidal and wind forcing.

The model grid bathymetry was assigned by interpolating from a set of individual data points (developed as described in Section 2.2) onto the model grid. For grid cells with multiple soundings within it, the values are averaged and for grid cells without soundings the value is interpolated based on the closest soundings. The final gridded bathymetry zoomed in to the Project Area in shown in Figure 5.

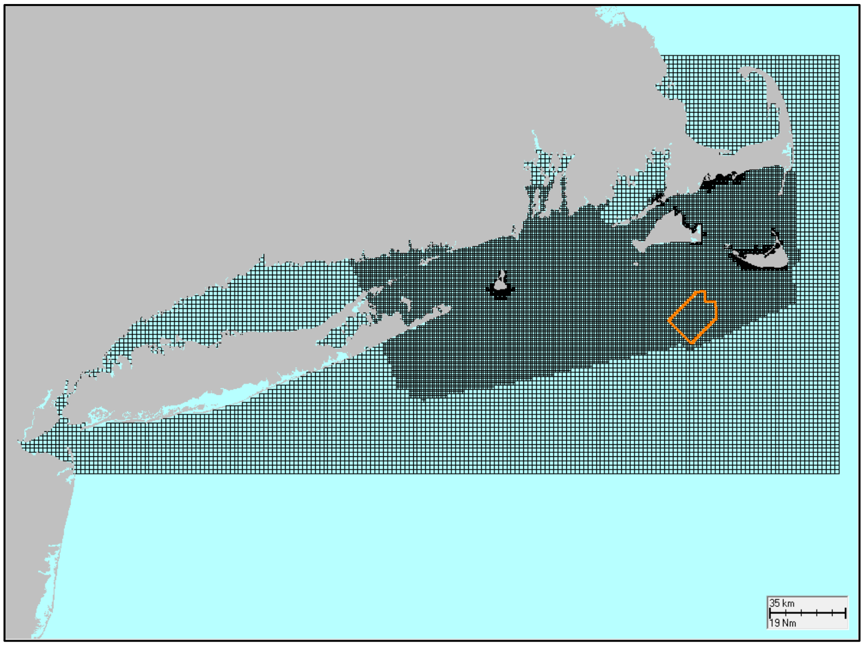

Figure 4. Hydrodynamic model grid.

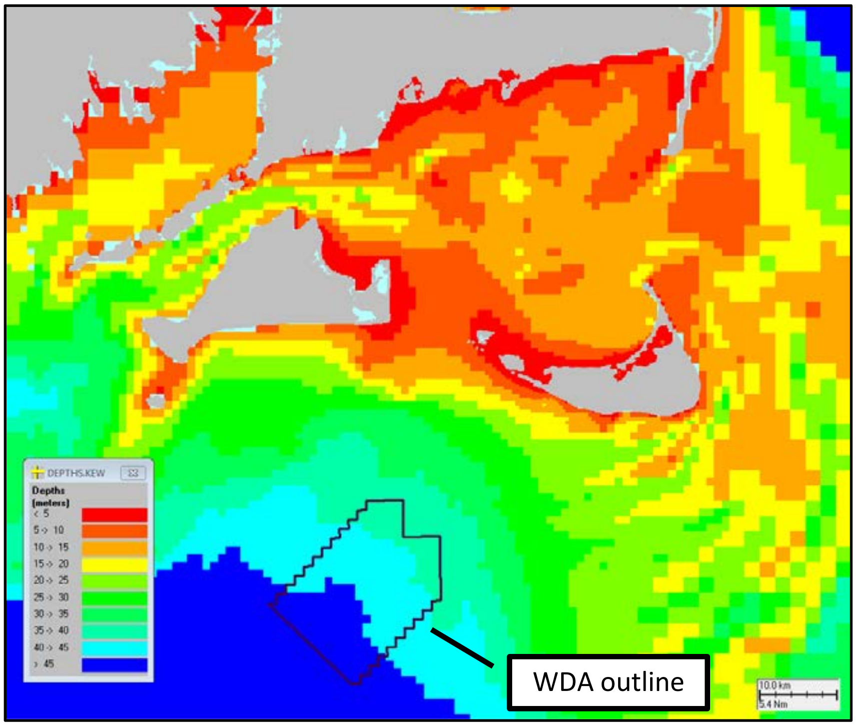

Figure 5. Model grid bathymetry focused on Project Area. Outline of WDA is shown in black.

3.2.2 Model Boundary Conditions

Model boundary conditions for this application included specification of tidal harmonic characteristics at open boundary water cells at the edge of the domain and surface winds applied to all cell surfaces.

Tidal Boundary Conditions

The water circulation in the study area is tidally dominated (Spaulding & Gordon, 1982) and is the key boundary forcing. Harmonic constituent data extracted from the TPXO global tidal model was used at the model open boundaries. Each boundary cell was assigned a unique set of the harmonic constituent amplitudes and phases. In total, the open boundary was specified for the predominant five tidal constituents in the area: three semi-diurnals (M2, N2, and S2) and two diurnals (K1 and O1). HYDROMAP (Isaji et al., 2001), employs a strategy that uses the harmonic construction of astronomic tidal currents where each harmonic (constituent) is simulated individually and then the real time tide is assembled using the harmonic summation of these simulated constituents. The dominant tidal constituent in this region is the M2-principal lunar semi-diurnal (twice daily) constituent. The M2 causes the sea level to rise and fall approximately twice daily which creates currents that peak and change direction approximately twice daily in the areas of reversing currents and rotary currents complete their rotation approximately twice daily. Illustrations of amplitude and phase along the model grid open boundaries are shown in Figure 6. This figure illustrates that the M2 amplitude is greater than 0.4 m in most places with the exception of the southeast region of the domain. The figure also illustrates how the M2 phase is generally similar parallel to Long Island and Narragansett Bay however a sharp change in phase is present southeast of Nantucket; north of this transition the phase is again relatively similar. These notable features create the predominately semidiurnal surface elevation and current patterns; and the sharp phase change southeast of Nantucket contributes to relatively fast moving rotary currents within this domain.

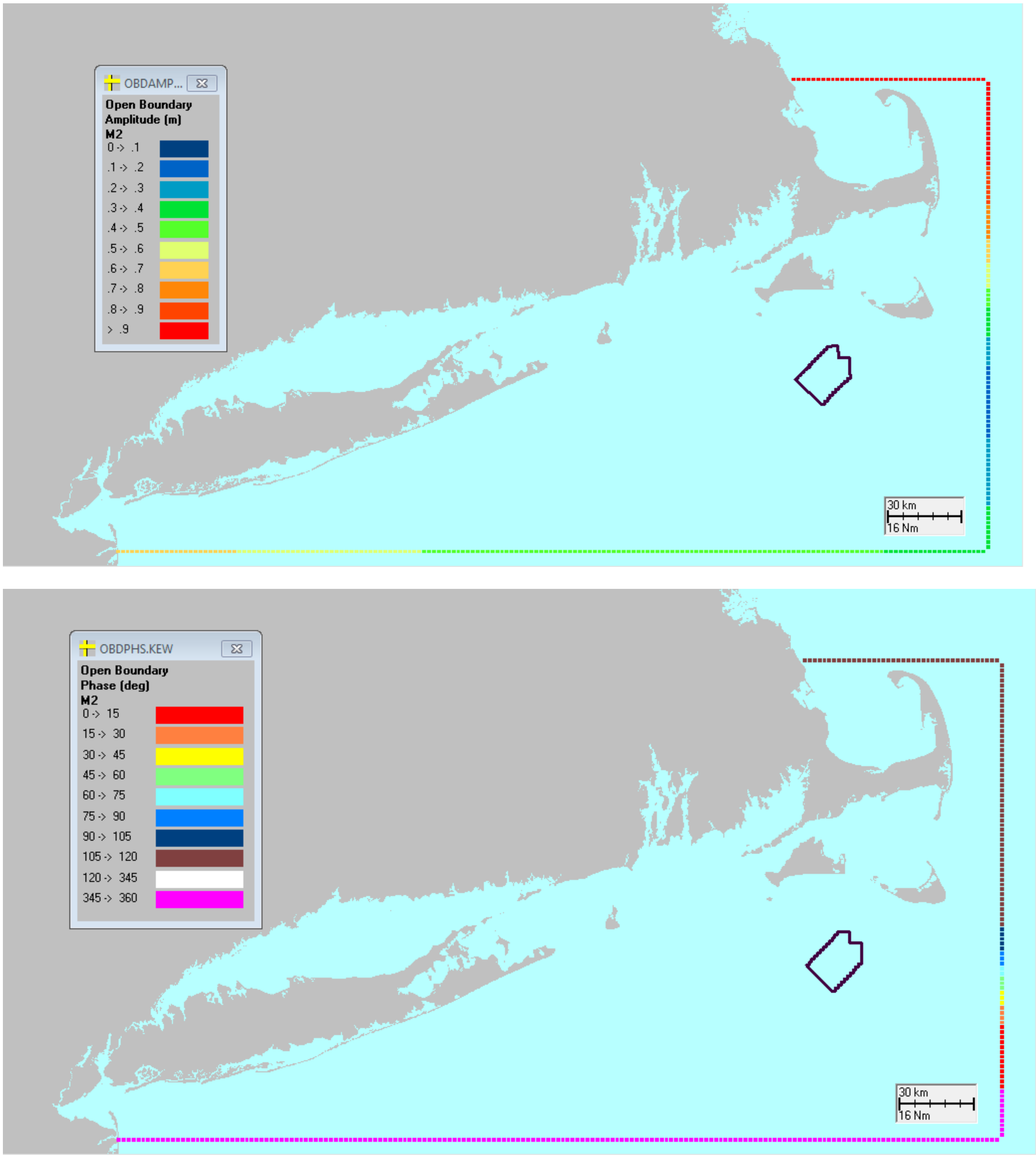

Figure 6. Tidal boundary forcing M2 amplitude (top) and phase (bottom). Note that phase is defined between 0-360 degrees (and 360 degrees also equals 0 degrees) and there are no phases between 120-345 degrees which is why there are no white cells per the legend above.

Meteorological (Water Surface) Boundary Condition

The water surface boundary covers the entire gridded area, and is influenced by the wind speed and direction. Meteorological data was obtained from the NDBC Buzzards Bay Station as described in Section 2 and was applied to the entire grid surface.

3.2.3 Model Results

The hydrodynamic model was set up and run for two different time periods, a model verification period that was used to verify model performance and a scenario period which was used to simulate a time period of potential construction (March) with typical wind conditions to be used in the sediment transport modeling.

3.2.1 Model Application for Verification Period

Model-predicted surface elevations, and current speeds at multiple water depths (top – mid – bottom), were compared to available observations to ensure the modeling was adequately reproducing tidal amplitude, current velocity, and vertical structure of the water column. The period used for model verification was from October 15, 2009 – November 14, 2009, this period was chosen because it had oceanographic (current) observations from the OSAMP available. The comparison of model predictions (pink) to either the observed signal or that reconstructed based on harmonics from predictions (blue) of water surface elevations at the stations with tide data is presented in Figure 7 (note the figure is shown for a shorter period to facilitate viewing). This figure shows that the model was able to recreate the amplitude and phase well throughout the domain.

The comparison of speeds (top, middle, bottom) between model (pink) and observations (blue) are shown in Figure 8. For clarity all levels (top, middle, bottom) were shown in the same color. The trend of magnitude from top to bottom is high to low. This figure shows that the model is able to recreate the trends well; however, it does overestimate the vertical shear and surface currents during periods of relatively strong winds where the currents deviate from cyclical. When the currents are more predominately tidal, however, the model does well to recreate the observed trend and there is minimal vertical shear at these locations. Note that the bottom currents are predicted well at all times and the bottom speeds are of the most relevance to this application, indicating that the model is acceptable for assessing Project impacts. The current speeds are relatively weak at these sites, peaking less than 0.5 m/s on most days.

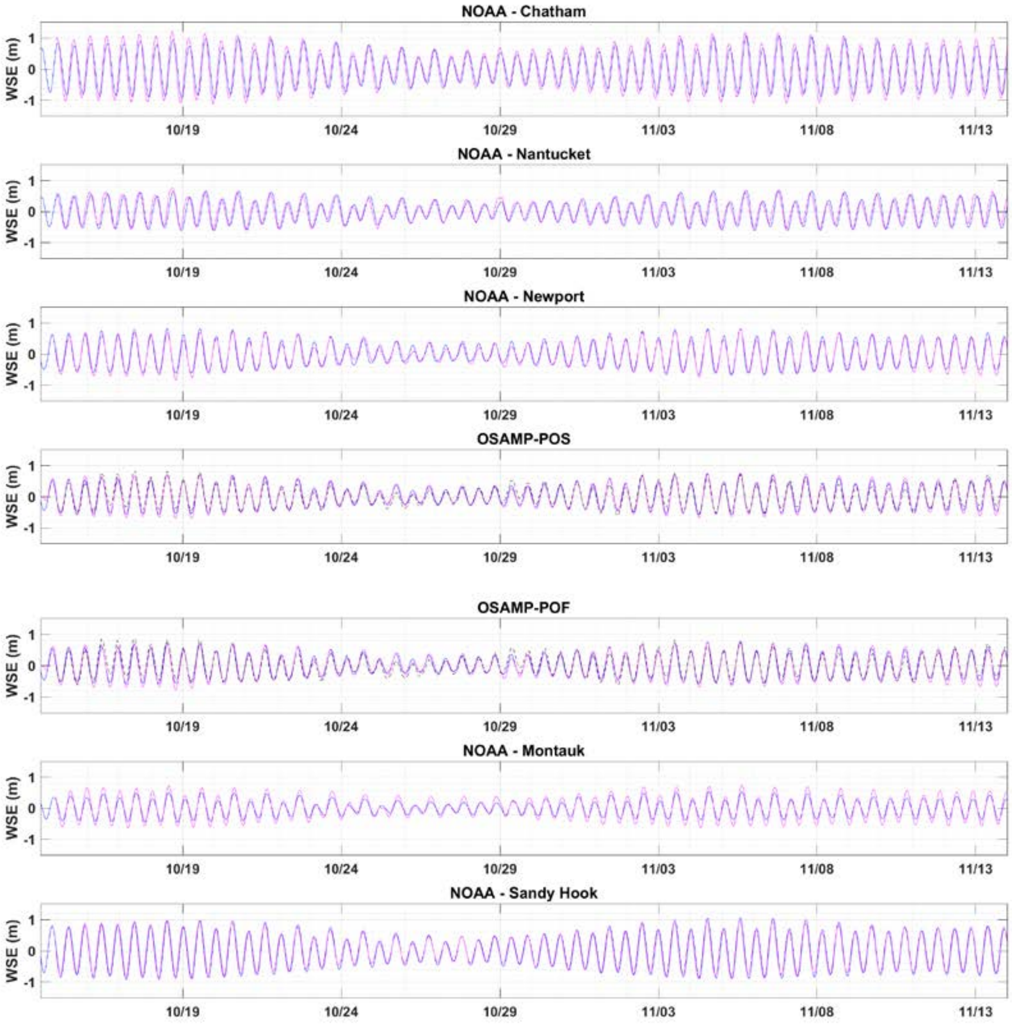

Figure 7. Comparison of model predicted to constructed tidal elevations from station harmonics at stations within the model domain. Modeled data is shown in pink and reconstructed data in blue. Y-axis for each sub plot ranges from -1.5 m to 1.5 m.

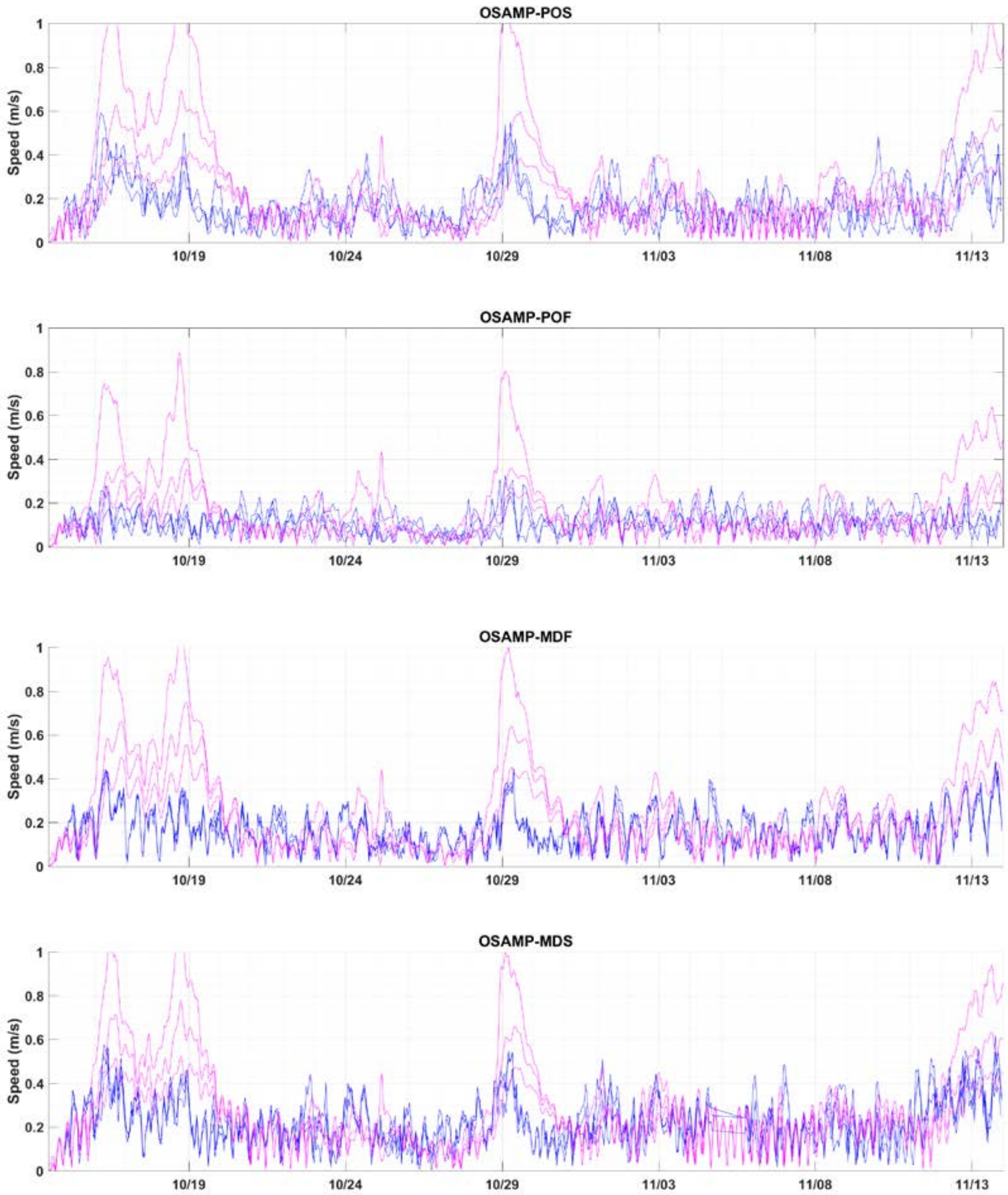

Figure 8. Comparison of model predicted to observed currents at stations within the model domain. Modeled data is shown in pink and observed data in blue. A representative top, middle and bottom proxy is plotted.

3.2.1 Model Application for Scenario Period

Once the model performance was verified a second application for a period with typical winds for a possible construction time period (March) was modeled. The period modeled was from March 1, 2016 – April 3, 2016. Snapshots of typical flood and ebb bottom current speeds and patterns are shown in Figure

9 and Figure 10, respectively; surface speeds are of a similar pattern, however, a slightly stronger magnitude. The currents are variable throughout the Project and are relatively weak within the WDA, though they increase sharply through Muskeget Channel. Within Vineyard Sound the currents are moderate, as they decrease towards the coast.

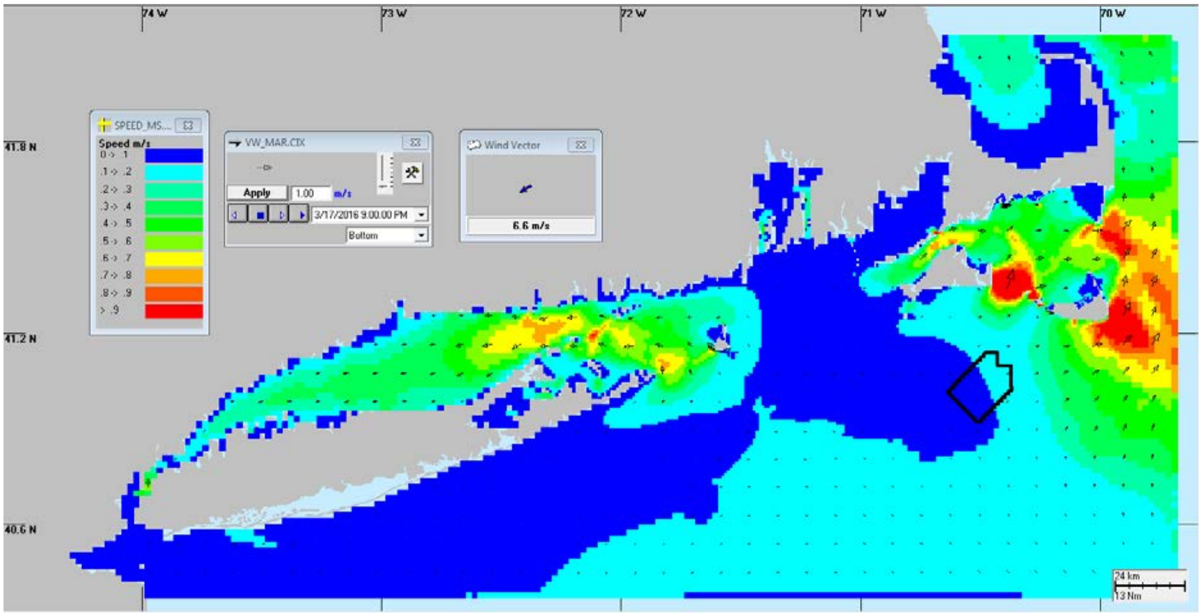

Figure 9. Snapshot showing peak flood current. Cells are contoured by speed magnitude and vectors (sub-sampled for every 4th cell for clarity) show direction.

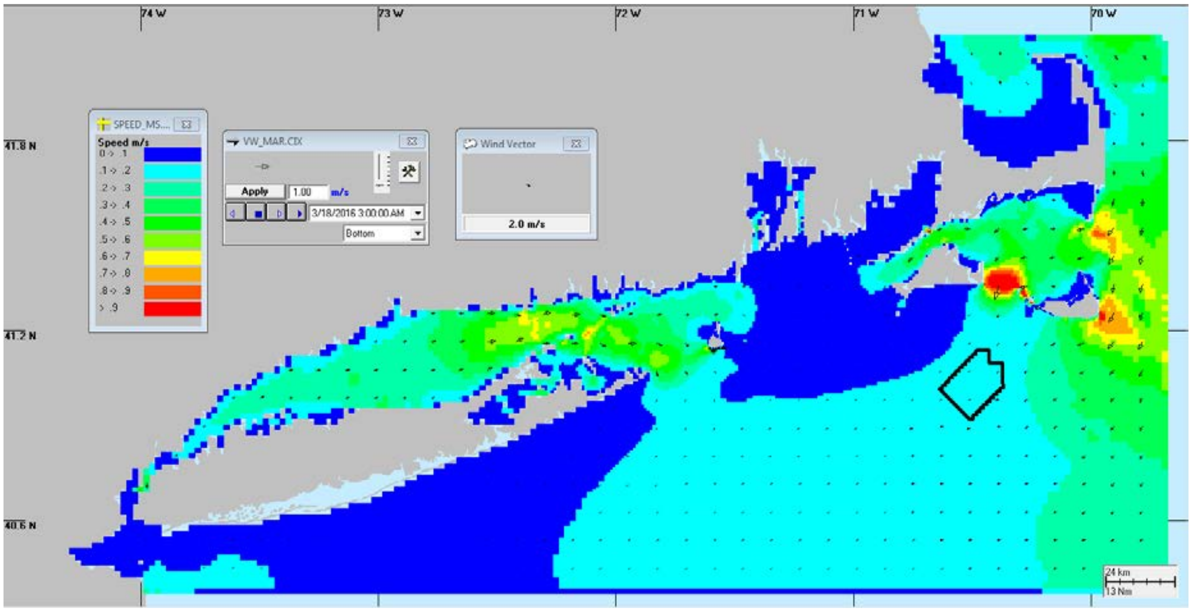

Figure 10. Snapshot showing peak ebb current. Cells are contoured by speed magnitude and vectors (sub-sampled for every 4th cell for clarity) show direction.

4 Suspended Sediment Modeling

4.1 SSFATE Description

SSFATE (Suspended Sediment FATE) is a three-dimensional Lagrangian (particle) model developed jointly by the US. Army Corps of Engineers ("USACE") Environmental Research and Development Center ("ERDC") and Applied Science Associates (now part of RPS) to simulate sediment resuspension and deposition originally from marine dredging operations. Model development was documented in a series of USACE Dredging Operations and Environmental Research ("DOER") Program technical notes (Johnson et al., 2000; Swanson et al., 2000); at previous World Dredging Conferences (Anderson et al., 2001) and a series of Western Dredging Association Conferences (Swanson et al., 2006; Swanson and Isaji, 2004). Following dozens of technical studies which demonstrated successful application to dredging, SSFATE was further developed to include the simulation of cable and pipeline burial operations using water jet trenchers (Swanson et al., 2006) and mechanical ploughs, as well as sediment dumping and dewatering operations. The current modeling system includes a GIS-based interface for visualization and analysis of model output.

SSFATE computes TSS concentrations in the water column and sedimentation patterns on the seabed resulting from sediment disturbing activities. The model requires a spatial and time varying circulation field (typically from hydrodynamic model output), definition of the water body bathymetry, and parameterization of the sediment disturbance (source), which includes sediment grain size description and sediment flux description. The model predicts the transport, dispersion and settling of suspended sediment released to the water column. The focus of the model is on the far-field (i.e., beyond the initial disturbance) processes affecting the dispersion of suspended sediment. The model uses specifications for the suspended sediment source strengths (i.e., mass flux), vertical distributions of sediments and sediment grain-size distributions to represent loads to the water column from different types of mechanical or hydraulic dredges, sediment dumping practices or other sediment disturbing activities such as jetting or ploughing for cable or pipeline burial. Multiple sediment types or fractions can be simulated simultaneously as can discharges from moving sources.

SSFATE has been successfully applied to a number of recent modeling studies with these studies receiving acceptance from federal and state regulatory agencies.

4.1.1 Model Theory

SSFATE addresses the short-term movement of sediments that are disturbed during mechanical ploughing, hydraulic jetting, dredging, and other processes where sediment is resuspended into the water column. The model predicts the three-dimensional path and fate of the sediment particles based on sediment properties, sediment loading characteristics, and environmental conditions (bathymetry and currents). The computational model utilizes a Lagrangian or particle-based scheme to represent the total mass of sediments suspended over time. The particle-based approach provides a method to track suspended sediment without any loss of mass as compared to Eulerian (continuous) models due to the nature of the numerical approximation used for the conservation equations. Thus, the method is not subject to artificial diffusion near sharp concentration gradients and can easily simulate all types of sediment sources.

Sediment particles in SSFATE are divided into five size classes (see Table 6.), each having unique behaviors for transport, dispersion, and settling. For any given location (segment of the route), the sediment characterization is defined by this set of five classes with each class representing a portion of the distribution and all five classes sum up to 100%. The model determines the number of particles to be used per time step depending on the model time step and the overall duration, in this way ensuring equal number of particles used to define the source throughout the simulation. A minimum of one particle per sediment size class per time step is enforced however typically multiples are used. The mass per particle varies depending on the total number of particles released, the grain size distribution and the mass flux per time step.

Table 6. Sediment size classes used in SSFATE

Description	Class	Type	Size Range (microns)
Fine	1	Clay	0-7
	2	Fine silt	8-35
↓	3	Coarse silt	36-74
	4	Fine sand	75-130
Coarse	5	Coarse sand	>130

Horizontal transport, settling, and turbulence-induced suspension of each particle are computed independently by the model for each time step. Particle advection is based on the relationship that a particle moves linearly, in three-dimensions, with a local velocity obtained from the hydrodynamic field, for a specified model time step. Diffusion is assumed to follow a simple random walk process. The diffusion distance is defined as the square root of the product of an input diffusion coefficient and at each time step is decomposed into X and Y displacements via a random direction function. The vertical Z diffusion distance is scaled by a random positive or negative direction.

Particle settling rates are calculated using Stokes equations and based on the size and density of each particle class. Settling of mixtures of particles is a complex process due to interaction of the different size classes, some of which tend to be cohesive and thus clump together to form larger particles that have different settling rates than would be expected from their individual sizes. Enhanced settlement rates due to flocculation and scavenging are particularly important for clay and fine-silt sized particles (Teeter 1998; Swanson 2004) and these processes have been implemented in SSFATE. These processes are bound by upper and lower concentrations limits, defined through empirical studies, which contribute to flocculation for each size class of particles. Above and below these limits, particle collisions are either too infrequent to promote aggregation or so numerous that the interactions hinder settling.

Deposition is calculated as a probability function of the prevailing bottom stress and local sediment concentration and size class. The bottom shear stress is based on the combined velocity due to waves (if used) and currents using the parametric approximation by Soulsby (1998). Sediment particles that are deposited may be subsequently resuspended into the lower water column if critical levels of bottom stress are exceeded, and the model employs two different resuspension algorithms. The first applies to material deposited in the last tidal cycle (Lin et al., 2003). This accounts for the fact that newly deposited material will not have had time to consolidate and will be resuspended with less effort (lower shear force) than consolidated bottom material. The second algorithm is the established Van Rijn method (Van Rijn, 1989) and applies to all other material that has been deposited prior to the start of the last tidal cycle. Swanson et al. (2007) summarize the justifications and tests for each of these resuspension schemes. Particles initially released by operations are continuously tracked for the length of the simulation, whether in suspension or deposited.

For each model time step, the suspended concentration of each sediment class as well as the total concentration is computed on a concentration grid. The concentration grid is a uniform rectangular grid in the horizontal dimension with user-specified cell size and a uniform thickness in the vertical dimension (z-grid). The concentration grid is independent of the resolution of the hydrodynamic data used to calculate transport, thus supporting finer spatial differentiation of plume concentrations and avoiding underestimation of concentrations caused by spatial averaging over larger volumes/areas. Model outputs include water-column concentrations in both horizontal and vertical dimensions, time-series plots of suspended sediment concentrations at points of interest, and thickness contours of sediment deposited on the sea floor. Deposition is calculated as the mass of sediment particles that accumulate over a unit area and is calculated on the same grid as concentration. Because the amount of water in the sediment deposited is not known, SSFATE by default converts deposition mass to thickness by assuming no water content.

For detailed description of the SSFATE model equations governing sediment transport, settling, deposition, and resuspension, the reader is directed to Swanson et al. (2007).

4.2 Description of SSFATE Model Set-up

Setup of a SSFATE model scenario consists of defining how each sediment disturbance activity will be parameterized and establishing the sediment source terms as well as defining environmental and numerical calculation parameters. For each scenario the source definition includes defining:

- The geographic extent of the activity (point release vs. line source)
- The grain size distribution along the route
- The timing and duration of the activity
- The volumes, cross-sectional areas and depths of the trench or excavation pit
- The production (advance) rate for each sediment disturbance method
- Loss (mobilization) rates for each sediment disturbance method
- The vertical distribution of sediments as they are initially released to the water column

The sediment source for cable installation simulations is defined through a load source file. The load source files provide definition of the location of the sources, the mass flux of sediment disturbed through operations, the loss rate of the disturbed flux that is resuspended in to the water column, the vertical position of the mass introduced to the water column, and the grain size distribution of the mass introduced to the water column along the route of installation. A component of the sediment grain size distribution is a definition of the percent solids which is used in the mass flux calculation. Bed sediments contain some water within interstitial pore spaces and therefore the trench volume consists of both sediment and interstitial water. Therefore, the percent solid of the sediment sample as based on laboratory measure of moisture content is used in the calculation of total mass flux. The sediment source can vary spatially. Therefore, the line source file is discretized to multiple entries, each representing a segment of the route with uniform characteristics and is broken in to small segments as needed to capture curved route geometry. The segments are defined in order to provide a continuous definition of the route aligned with the installation plan.

A model scenario also requires characterization of the environment including a definition of the spatially and time varying currents in the study area (HYDROMAP output) and the water body bathymetry in the study area. Model setup also requires specification of the concentration and deposition grid which is the grid at which concentration and deposition calculations are made. The concentration and deposition grid in SSFATE is independent of the resolution of the hydrodynamic or bathymetric data used as inputs; this allows finer resolution which better captures water column concentrations without being biased by numerical diffusion. The concentration and deposition gridding is based on a prescribed square gird resolution in the horizontal plan view and a constant thickness in the vertical. The extent of the concentration is determined dynamically, fit to the extent the sediments travel.

4.3 Study Scenario Definition

A number of SSFATE model scenarios were run to encompass the potential cable routes and construction approaches included in the Project Envelope. The following sections describe the routes and the associated sediment generating activities along the route as they pertain to defining modeling inputs.

4.3.1 Project Components: Routes

The model scenarios have been separated into two components: (1) the inter-array cables located within the WDA and (2) the offshore export cables located within the OECC. The two primary OECC routes include one which runs through west Muskeget (WM) and the other which runs through east Muskeget (EM), both with two possible associated landfall sites: Covell's Beach and New Hampshire Avenue. A summary of the cable routes is presented in Table 7.

Table 7. Offshore cables modeled and assessed in this study

Project Functional Component	Total Route Length (km)
WDA Representative inter-array	19.1
OECC: WM to Covell's Beach	58.3
OECC: WM to New Hampshire Ave	66.1
OECC: EM to Covell's Beach	61.2
OECC: EM to New Hampshire Ave	69.0

Inter-array Cable

The representative inter-array route modeled was selected from a representative layout of the set of inter-array cables that was provided by Vineyard Wind. The individual component with the longest length was chosen to be modeled. Both the potential layout and the individual component modeled are shown in Figure 11. The WDA does not have any sand waves on the seabed and therefore there is no pre cable installation spot dredging required for this component.

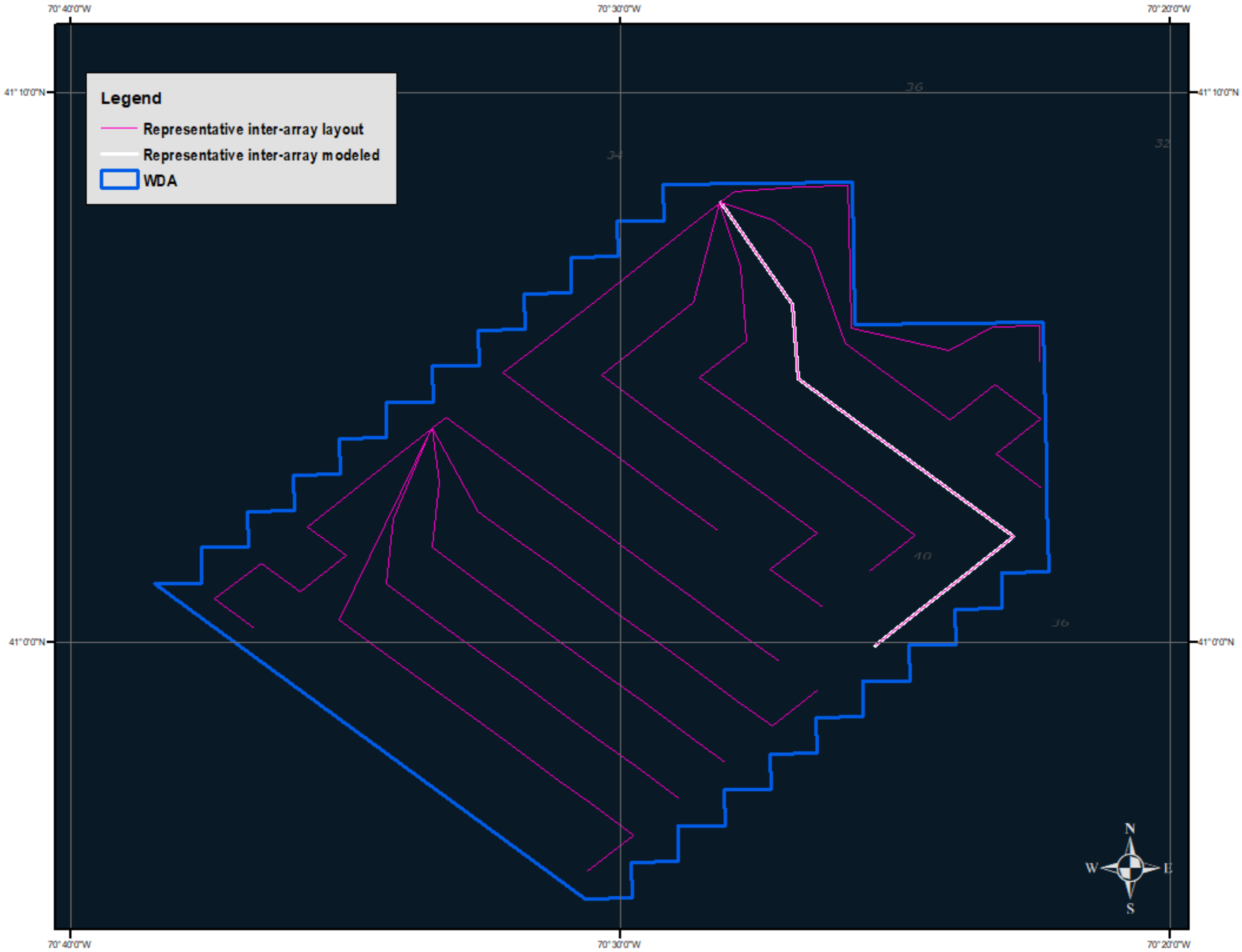

Figure 11. Representative inter-array cable layout and modeled component.

Offshore Export Cable Corridor

As stated above there is one predominate OECC which has two variants through Muskeget Channel (WM and EM) and two options for landfall (Covell's Beach and New Hampshire Avenue); the variants and constants of the OECC are presented in Figure 12. The four unique OECC that these variants form are listed below and shown in Figure 13 and Figure 14 for the WM and EM variants respectively.

1. OECC through west Muskeget (WM) to Covell's Beach
2. OECC through west Muskeget (WM) to New Hampshire Avenue
3. OECC through east Muskeget (EM) to Covell's Beach
4. OECC through east Muskeget (EM) to New Hampshire Avenue

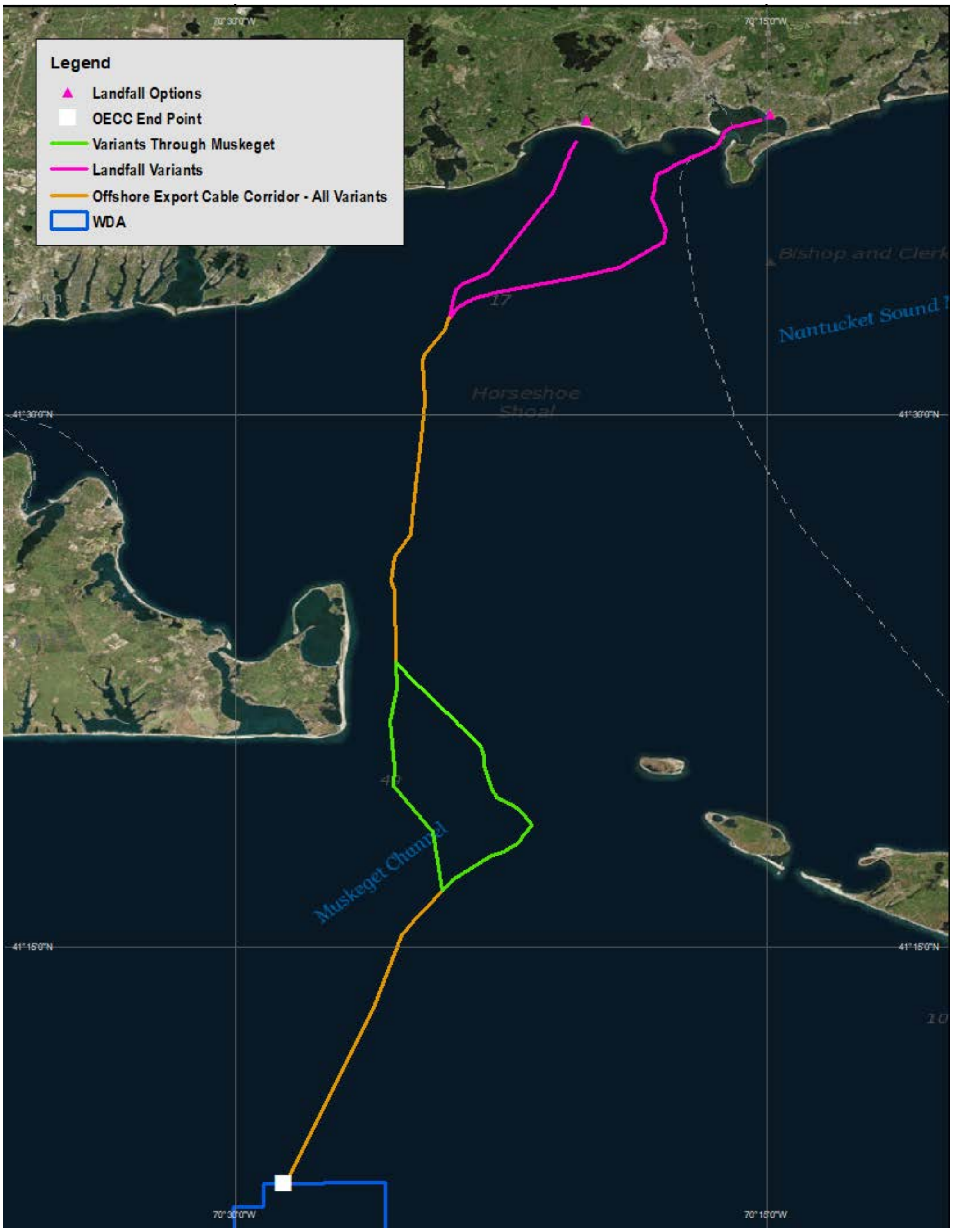

Figure 12. OECC variants and constants. Orange lines represent constants (sections that are present in all routes). Green lines represents the two variants of route through Muskeget Channel. Pink lines represent the two variants for routes to landfall options.

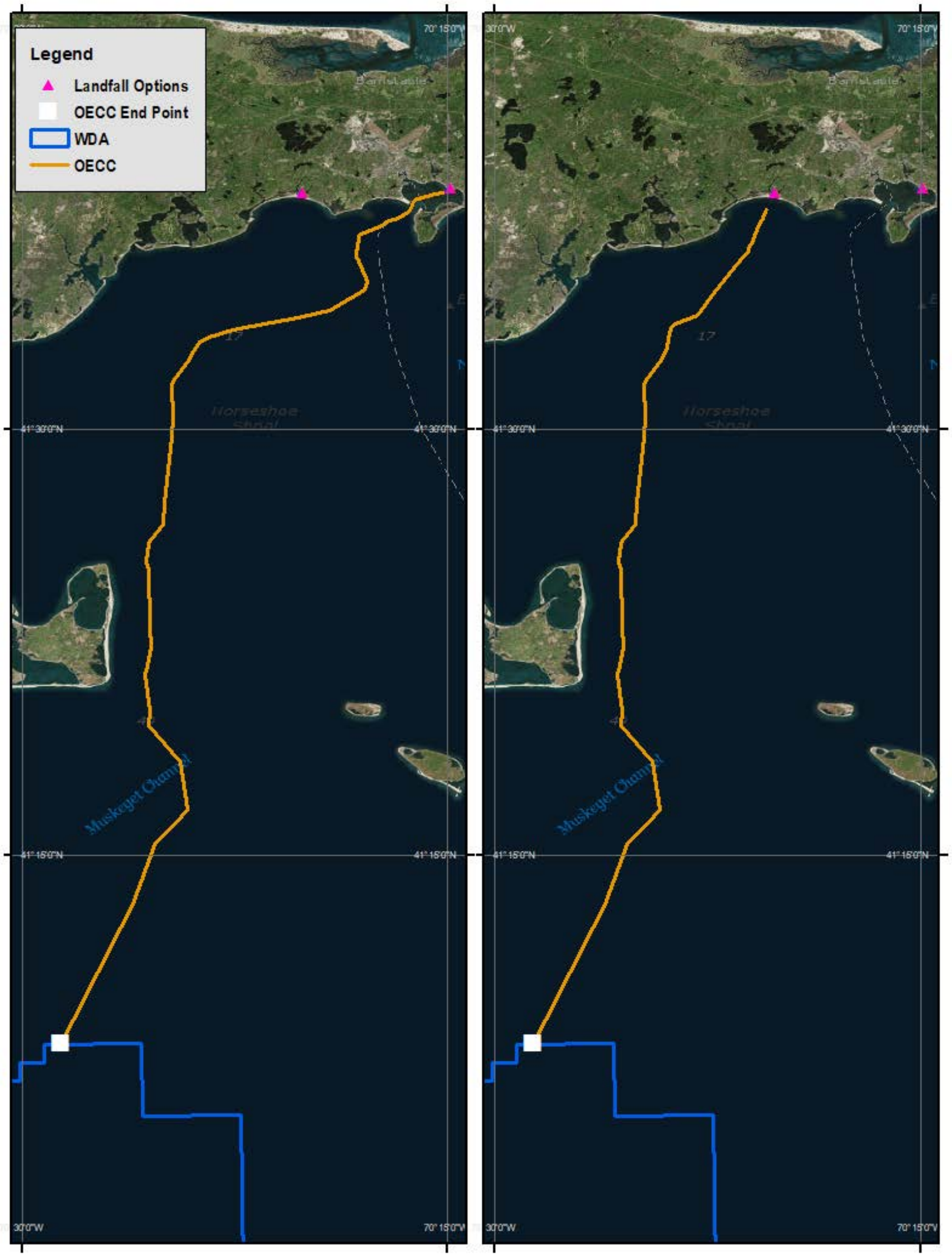

Figure 13. OECC through west Muskeget. Landfall at New Hampshire Ave (left) and Covell's Beach (right).

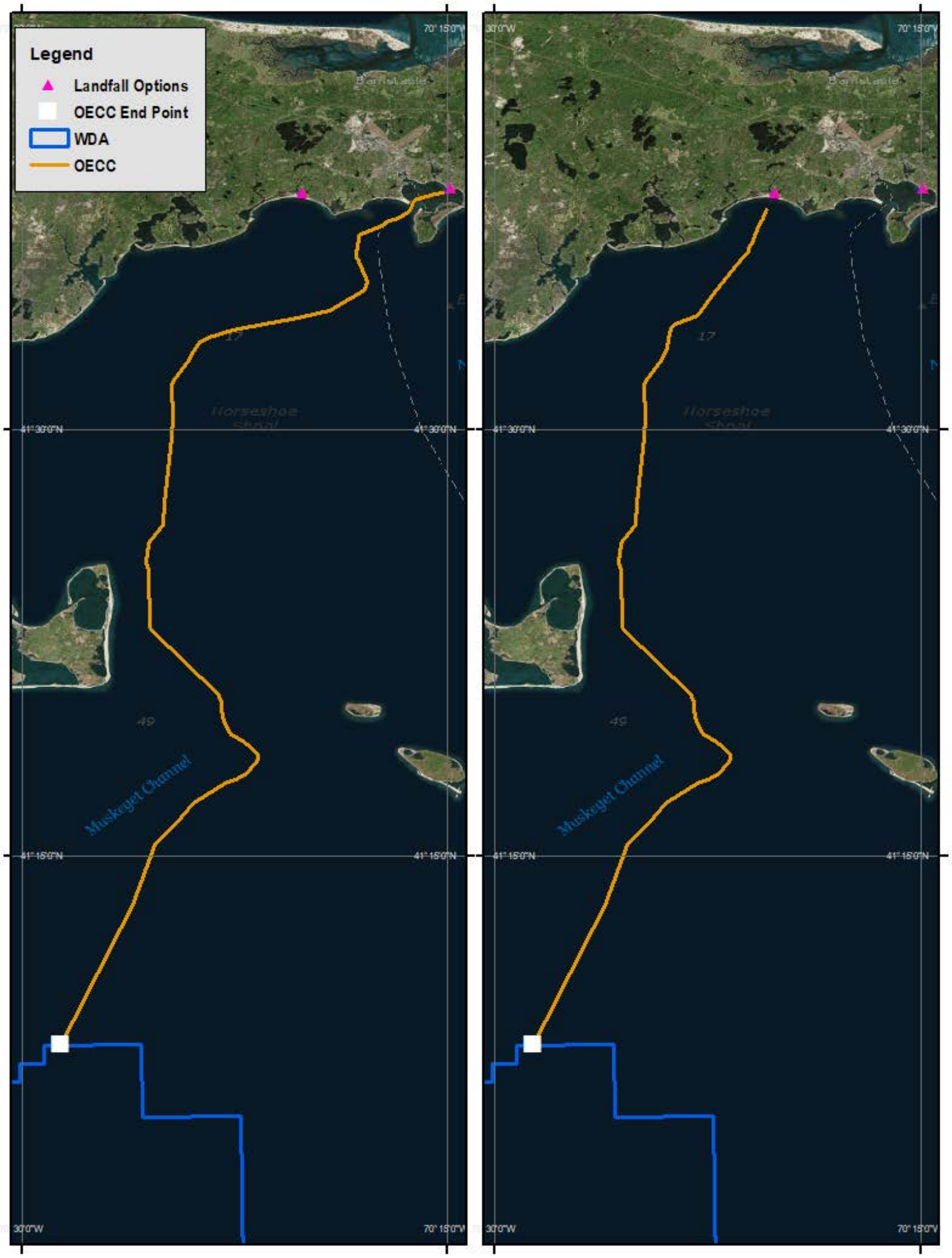

Figure 14. OECC through east Muskeget. Landfall at New Hampshire Ave (left) and Covell's Beach (right).

4.3.1 Project Components: Construction Activities

The construction activities that will resuspend sediments in the water column include cable burial within the WDA (inter-array cables) and along the OECCs (offshore export cables) and pre-cable installation spot dredging along some locations of the OECC variants only.

The WDA does not have sand waves that require removal prior to installation of the inter-array cables; however, all OECC variants intersect regions of sand waves. Portions of the sand waves may be mobile over time; therefore, the upper portions of the sand waves may need to be removed via dredging so that the cable laying equipment can achieve the proper burial depth below the sand waves and into the stable sea bottom. The amount of sand wave dredging required varies depending on the cable installation methods employed.

The Project is considering two distinct approaches to remove the upper portions of the sand waves above the stable seabed where necessary along the OECC. The first technique is a trailing suction hopper dredge (“TSHD”). Dredges of this type are typically used for European offshore wind projects and are also commonly used in the US for channel maintenance, beach nourishment projects, and other uses. For this Project, a TSHD would be used to remove a 20 m (65.6 ft) wide section of a sand wave (for each of the up to two cables) that is deep enough to allow subsequent installation of the cable within the stable seabed (this is referred to as “TSHD Pre Dredge”). After the dredging was complete, cable installation would occur using one of the methods (such as a jet plow) described in Section 4.2.3.3.2 of Volume I of the COP. The second approach involves jetting (also known as mass flow excavation), which uses a pressurized stream of water to push sand to the side. Jetting is a post-lay burial technique that removes the tops of sand waves while burying a section of cable that has previously been placed on the sand waves. Accordingly, jetting both removes the tops of sand waves where required and buries the cable. Jetting is a viable technique where excavation less than approximately 2 m through sand waves and into the stable seabed is required. If excavation greater than approximately 2 m is required, additional dredging by the TSHD would be required. Accordingly, the dredging could be accomplished entirely by the TSHD on its own (the “TSHD Pre Dredge” described above) or the dredging could be accomplished by a combination of jetting and TSHD, where jetting would be used in smaller sand waves and the TSHD would be used to remove the larger sand waves (this is referred to as “Limited TSHD Pre Dredge + Jetting”). Once any needed sand wave removal occurs, burial of the cable will occur.

- For the “TSHD Pre Dredge” approach, cable installation is a separate activity that occurs after dredging is complete (this is referred to simply as “Cable Installation ”). Therefore, the model first simulates the TSHD dredging, then separately simulates the cable installation. This combined approach of TSHD dredging followed by cable installation is referred to as “TSHD Pre Dredge + Cable Installation]”.

- For the “Limited TSHD Pre Dredge Approach + Jetting” approach, the jetting activity both removes the tops of sand waves where required and buries the cable (such jetting occurs only for very limited portions of the cable corridor). Therefore, the model accounts for cable installation both through jetting (in smaller sand waves) and through one of the other potential cable burial methods listed in the COP (such as a jet plow) in areas without sand waves requiring removal; this approach is referred to as “Cable Installation aided by Jetting”. Accordingly, the model first simulates the limited TSHD dredging, then separately simulates the cable installation (which consists of jetting in limited segments for sand wave clearance and cable burial, plus jet plow or one of the other cable installation techniques listed in the COP for the remainder of the route). This combined approach of limited TSHD dredging (in larger sand waves) followed by cable installation via either jetting (in smaller sand waves) or one of the other potential cable burial methods (such as a jet plow) is referred to as “Limited TSHD Pre Dredge + Cable Installation aided by Jetting.”

These two modeled approaches - TSHD Pre Dredge + Cable Installation and Limited TSHD Pre Dredge + Cable Installation aided by Jetting - are part of the Project Envelope. Actual installation parameters could be one of these approaches on its own or some combination of these approaches.

All components that are considered part of the Project Envelope were modeled as based on established “typical” installation parameters which are described in more detail below. In addition to “typical”, a “maximum impact” scenario using more conservative assumptions for the representative inter-array scenario and one OECC cable installation was modeled to address potential variation in model input assumptions and project details. A summary of the individual SSFATE modeling scenarios is presented in Table 8.

Table 8. Individual SSFATE model scenarios

#	Component	Route	Installation Scenario	Scenario Category	Scenario
1	WDA	Inter-Array	Cable Installation	Typical	WDA-IA1-TYP
2	WDA	Inter-Array	Cable Installation	Maximum Impact	WDA-IA1-MAX
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typical	OECC-1A-1-TYP
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typical	OECC-2A-1-TYP
5	OECC	WM - Covell's Beach	Limited TSHD Pre Dredge	Typical	OECC-3A-1-TYP
6	OECC	EM - Covell’s Beach	Limited TSHD Pre Dredge	Typical	OECC-4A-1-TYP
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typical	OECC-1A-2-TYP
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typical	OECC-2A-2-TYP
9	OECC	WM - Covell's Beach	Cable Installation aided by Jetting	Typical	OECC-3A-2-TYP
10	OECC	EM – Covell’s Beach	Cable Installation aided by Jetting	Typical	OECC-4A-2-TYP
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typical	OECC-1B-1-TYP
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typical	OECC-2B-1-TYP
13	OECC	WM - Covell's Beach	TSHD Pre Dredge	Typical	OECC-3B-1-TYP
14	OECC	EM – Covell’s Beach	TSHD Pre Dredge	Typical	OECC-4B-1-TYP
15	OECC	WM - NH Ave	Cable Installation	Typical	OECC-1B-2-TYP
16	OECC	EM - NH Ave	Cable Installation	Typical	OECC-2B-2-TYP
17	OECC	WM - Covell's Beach	Cable Installation	Typical	OECC-3B-2-TYP
18	OECC	EM – Covell’s Beach	Cable Installation	Typical	OECC-4B-2-TYP
19	OECC	EM - NH Ave	Cable Installation	Maximum Impact	OECC-2B-2-MAX

4.3.1.1 Construction Activities: Dredging

As noted above, OECC installation will likely require spot dredging to ensure that the subsequent cable burial activities will be able to install the cable to the appropriate target depth below the stable seabed. The sand waves are not uniform in presence or size (volume) and therefore the required dredging varies depending on the specific route and techniques used.

As noted above, the TSHD may be used along the entire OECC where required (the “TSHD Pre Dredge” approach) or in combination with jetting where TSHD would only be used in the larger sand waves (the “Limited TSHD Pre Dredge + Jetting”) approach. In both options where the TSHD is used, a 20 m wide swath is required to be dredged for each cable (up to 3 cables within the corridor is possible). The TSHD method includes a vessel with a drag arm that extends below the vessel to the seabed. The drag arm has an opening through which vessel-housed pumps suction the sediments (and water) from the seabed to the vessel hopper. The drag arm will induce some suspended sediments in the water column. It is assumed that it will resuspend 1% of the target sediments; this loss rate was based on a study (Anchor

QEA 2003) which established the average loss rate to be 0.77%, therefore the 1% is slightly conservative rounded up to the nearest integer. The suction process typically results in acquisition of 80% water and 20% sediment and therefore the vessel allows for overflow. The overflow will occur at the water surface and the overflow waters will contain some of the dredge sediments, preferentially the fine material. It is assumed that the overflow waters will contain 5% of the coarse material (fine sand and coarse sand as defined by the modeled binning of sediments) and 30% of the fine material (clay, fine silt and coarse silt as defined by the model binning of sediments); these values are based on a review of quantification of dredge related resuspension source terms. Given that the hopper will contain 99% of the target volume (since 1% is lost near the drag arm) this means that the overflow of coarse and fine sediments is equivalent to 4.95% and 29.7 % of the target volumes, respectively. Further it is assumed that the hopper will retain some of the water and the hopper will have a ratio of 20% water to 80% sediments on average.

Based on the parameters of this project it is anticipated that a 2,294 m^3 (3000 cy) hopper will be employed and that the total (sediment plus water with a higher water content in the drag arm than in the hopper) production rate is 9,175 m^3/hr (12,000 cy/hr). Using the assumptions presented above, after 1 hour the hopper will contain approximately 1,835 m^3 (2,400 cy) of sediment and therefore the sediment production rate is 1,835 m^3/hour. This is approximate since, for the ease of discussion, it neglects the losses at the seabed or from overflow. Note that while ~ 30% of fines will overflow, fine material typically represents less than 5% of the sediment grain size distribution. Once the hopper is filled, the drag arm will stop suctioning and the vessel will sail offsite (but within the 810 m wide Offshore Export Cable Corridor) to dump the hopper contents (sediments and water). The hopper was assumed to open 6.09 m (20 ft) below the water surface. For the purposes of defining modeling inputs it was assumed that the suction dredging would occur for approximately an hour, then the TSHD would sail to a location approximately 250 m east of the route and dump the hopper load and then sail back to the position along the route. The entire cycle of stopping the dredge, sailing to dump and sailing back is estimated to take approximately a half hour. Further, since the sand waves and associated dredging are intermittent, there are intermittent stoppages along the route and an average sail speed of 5.6 km/hr (3 knots) is assumed.

The actual volume of dredging is dependent on the cable installation method and achievable burial depth. The dredge volumes listed in Table 9 were prepared using a conservative estimate of the volume of dredging required. Table 9 presents the dredge volumes associated with the TSHD Pre Dredge approach, where all sand waves >0 m in height are removed by the TSHD. Table 9 also presents dredge volumes for the Limited TSHD Pre Dredge + Jetting approach, where jetting is used in areas with sand waves less than 2 m in height and the TSHD is only used in areas with sand waves greater than 2 m in height. This is a conservative estimate of the amount of jetting, since jetting may be limited to even smaller sand waves than 2 m to ensure appropriate cable burial. In this case, less jetting will occur and more sand wave removal will occur by TSHD. As noted above, the Project Envelope includes both the "TSHD Pre Dredge

+ Cable Install ” and the “Limited TSHD Pre Dredge + Cable Installation aided by Jetting” approaches or various combinations of the jetting and TSHD amounts listed in these approaches.

Table 9. Summary of approximate length and volumes of the required dredging for the TSHD Pre Dredge and the Limited TSHD Pre Dredge + Jetting options.

OECC Route	**TSHD Pre Dredge Option**		**Limited TSHD Pre Dredge + Jetting Option**		
	~ Length with Sand Waves > 0m where TSHD may Occur	**Per Cable Volume of Sand Waves > 0m where TSHD may Occur[3]**	**~ Length with Sand Waves > 2m where Limited TSHD may Occur[3]**	**Per Cable Volume of Sand Waves > 2m where Limited TSHD may Occur**	**Average Percent Solid**
	km	**m^3**	**km**	**m^3**	**%**
WM - NH Ave	8.22	64,310	0.66	20,404	72.34
EM - NH Ave	7.21	48,799	0.37	11,365	72.75
WM - Covell's Beach	7.65	60,080	0.63	19,634	72.85
EM - Covell’s Beach	6.64	44,569	0.34	10,595	73.27

A summary of the TSHD dredge, overflow, and disposal operational assumptions are provided Table 10 and a summary of the vertical initialization of sediment mass associated with each of these activities is presented in Table 11. The model allows for spreading the resuspended sediments across five bins that can be defined as either discrete distances above the bottom (used for dredging) or below the surface (used for overflow and disposal). The distribution of mass as defined by percentages in Table 11 is relative to the mass of that specific activity.

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[3] These volumes are a conservative estimate based on the assumption that cable installation equipment would only be able to bury the cable up to 1.5 m below the seabed and thus require a greater volume of sediment above the stable seabed to be removed. The cable installation equipment may be able to reach a greater burial depth of 2.5 m which would mean less of the sediment above the stable seabed would have to be removed

Table 10. Summary of typical and maximum cable installation impact parameters.

Grain Size Distribution		Depth weighted to 2 m*
Total Production	**m^3/hr**	9175
Sediment Production	**m^3/hr**	1835
Hopper Volume	**m^3**	2294
Target Resuspended at Drag Head (Both Fines and Coarse)	**%**	1
Target Fines in Overflow	**%**	29.7
Target Coarse in Overflow	**%**	4.95
Target Fines Dumped	**%**	70.3
Target Coarse Dumped	**%**	94.05
Operations	**hrs/day**	24
Time to Fill Hopper	**hrs**	1
Time to Sail - Dump - Sail Back	**hrs**	0.5

**Details of the procedure to develop depth weighted grain size distributions are provided in Section 4.4.*

Table 11. Summary of vertical initial distribution of mass associated with dredging, overflow and dumping.

Dredging			**Overflow**			**Dumping**		
Individual Bin Percent	**Cumulative Percent**	**Meters Above bottom**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Below Surface**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Below Surface**
5	100	3	100	100	0	100	100	6.1
10	95	2						
28	85	1						
28	57	0.66						
29	29	0.33						

4.3.1.2 Construction Activities: Cable Installation

The typical and maximum impact cable installation parameters were developed based on typical modeling assumptions and discussions with the Project team and are as summarized in Table 12. The typical installation will have a one meter wide trench that is two meters deep and the installation will advance at a rate of 200 m/hr. The maximum impact installation was assumed to have a one meter wide and three meters deep trench (more volume/mass of sediment) and was assumed to advance at a rate of 300 m/hr (increased mass flux). For cable installation aided by jetting, sections requiring jetting will have a trench that is two meters wide and two meters deep and the excavation along these portions will advance at a rate of 100 m/hr. Mobilization fraction or percentage (often referred to as the loss rate or resuspension rate) during installation for the envelope of installation methods typically range from 10-35% (Foreman, 2002). The typical sediment mobilization fraction for cable burial including sections where jetting was used was assumed to be 25% and maximum impact simulations assumed the upper limit of 35%. For both typical and maximum impact simulations, the mass is assumed to be initialized in the bottom three meters (or less when depths are shallower than three meters) of the water column per Table 13. Additionally for both typical and maximum impact simulations, operations were assumed to be continuous (24 hrs/ day).

Table 12. Summary of typical and maximum cable installation impact parameters

Scenario Description	**Grain Size Distribution**	**Trench Width (m)**	**Trench Depth (m)**	**Trench Volume per meter (m^3)**	**Advance Rate (m/hr)**	**Percent Mobilized (%)**
Typical – cable burial	Depth weighted to 2m*	1	2	2	200	25
Typical – jetting	Depth weighted to 2m*	2	2	4	100	25
Maximum impact- cable burial	Depth weighted to 3m*	1	3	3	300	35

**Details of the procedure to develop depth weighted grain size distributions are provided in Section 4.4.*

Table 13. Summary of vertical initial distribution of mass associated with cable installation and jetting.

Cumulative Percent Mass (%)	**Individual Percent Mass (%)**	**Height Above Bottom (m)**
29	29	0.33
57	28	0.66
85	28	1
95	10	2
100	5	3

4.4 Sediment Grain Size Distribution

The sediment grain size distribution is a key factor of the sediment load characterization used as input to the SSFATE model. The text below describes the development of sediment characterization.

4.4.1 Sediment Grain Size Distribution for Inter-array Cable Burial Simulations

Sediment boring samples from three different locations in the WDA were available for analysis. Each sediment boring sample had laboratory measurements of the sediment grain size and water content at various depths. The distributions were discretized to determine the fraction in each of the five bin classes used in SSFATE (see Table 6). For the purposes of modeling the installation activities, only the sediments at depths consistent with the depths of disturbance are relevant to characterizing the sediment loading. Figure 15 illustrates the distributions at each of the three locations at depths within close proximity to the target burial depth. For each location the depth weighted composite distribution within the upper 2 m was calculated; these composited distributions are shown in Figure 16. Since the samples were sparse and only a representative inter-array cable was modeled, it was decided to use the most conservative representation of the sediment characterization from the three available for the characterization along the entire inter-array cable route. The designation of the most conservative sediment characterization was made based on the sample with the largest percentage of fine sediments (clay, fine silt, and coarse silt); the composite sample BH-10 had the highest fraction of fine sediments and this characterization was used in the modeling of the inter-array cable.

In addition to sediment grain size measurements, the laboratory analysis included a measure of water content at multiple depths for each boring. The depths of measurements were not perfectly aligned with the depths of grain size analysis, however.

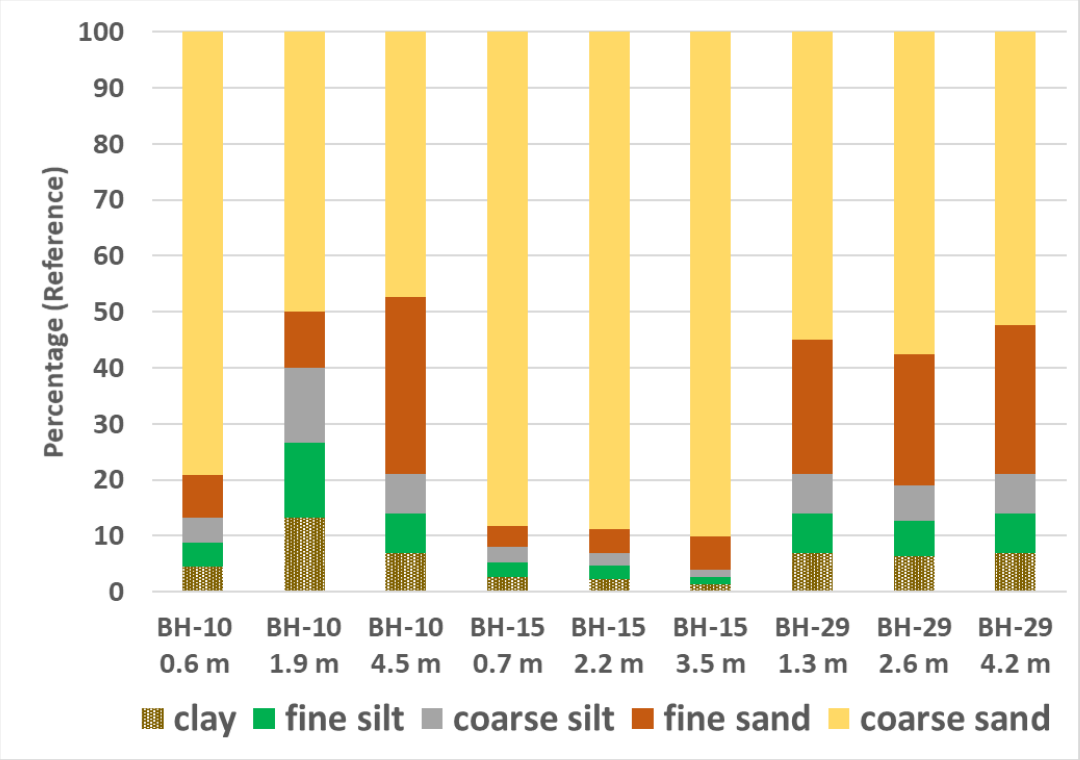


Figure 15. Sediment grain size distributions within the upper seabed at the three sample locations within the WDA. Distributions are delineated by the bins used in SSFATE.

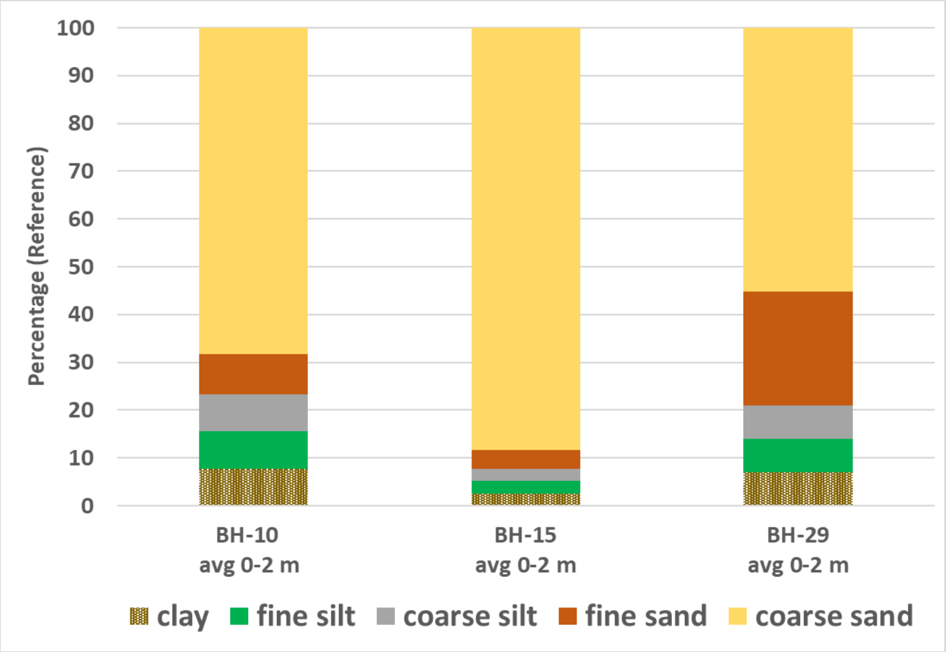


Figure 16. Depth weighted composite sediment grain size distributions for the upper 2 m of the seabed at the three sample locations within the WDA. Distributions are delineated by the bins used in SSFATE.

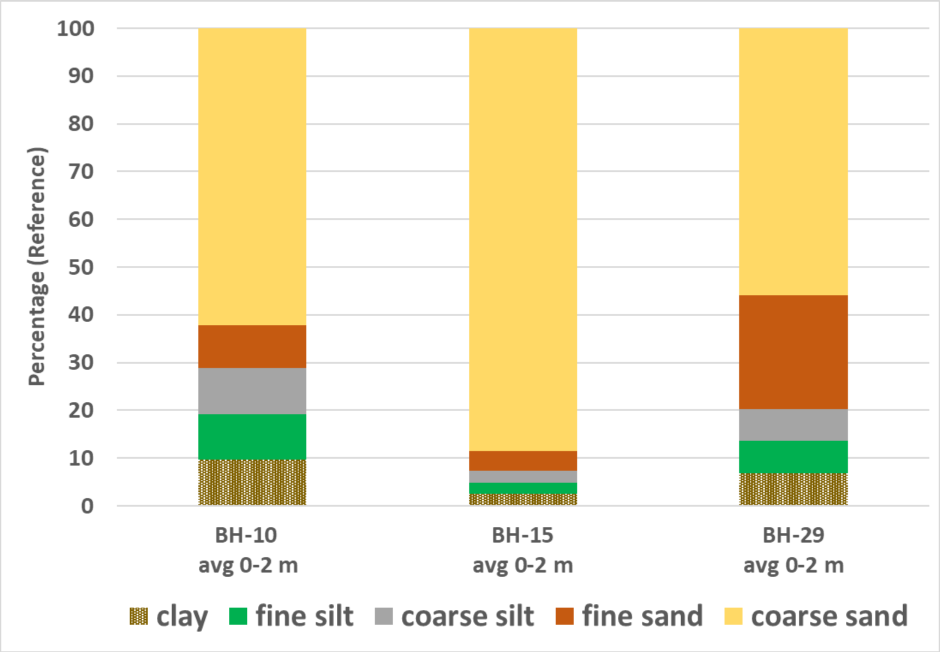


Figure 17. Depth weighted composite sediment grain size distributions for the upper 3 m of the seabed at the three sample locations within the WDA. Distributions are delineated by the bins used in SSFATE.

Table 14. Sediment grain size distributions used in SSFATE for the typical (2 m deep) and maximum impact (3 m deep) trench

SSFATE Sediment Class	Name in Figure 18 and Figure 19	WDA - Composite 2 m Trench	WDA - Composite 3 m Trench
clay	**clay**	7.77	9.63
fine silt	**fst**	7.77	9.63
coarse silt	**cst**	7.77	9.63
fine sand	**fsd**	8.47	8.98
coarse sand	**csd**	68.21	62.14
% solid		100	100

4.4.2 Sediment Grain Size Distribution for Offshore Export Cable Corridor Dredging and Cable Burial Simulations

A combination of surface grab samples and sediment cores were available at locations along the OECC. The grab samples contained both sieve and hydrometer analysis as well as moisture content, and were taken within the upper half meter of the seabed. The vibracore stations all yielded sieve data and a few stations also contained hydrometer analysis. Sediment analysis at multiple depths (typically two) within the upper three meters of the seabed were available at most vibracore stations, however they did not include analysis of the surface sediments; therefore, this information was obtained from the grab samples as described below. All vibracore stations analysis included a measure of moisture content. The distributions at each location at each depth were discretized to determine the fraction in each of the five bin categories used in SSFATE. For all stations without hydrometer data, the remaining fraction (percent finer than fine sand) was split evenly in the three bins of clay, fine silt, and coarse silt. A depth weighted average sample at each of the vibracore station locations was developed by assuming the nearest grab sample characterization represented the upper half meter and then combining this number with all remaining samples to determine the depth weighted characterization for the target depth. The resulting sediment characterizations for the typical (two meter target depth) and maximum impact (three meter target depth) are illustrated in Figure 18 and Figure 19, respectively.

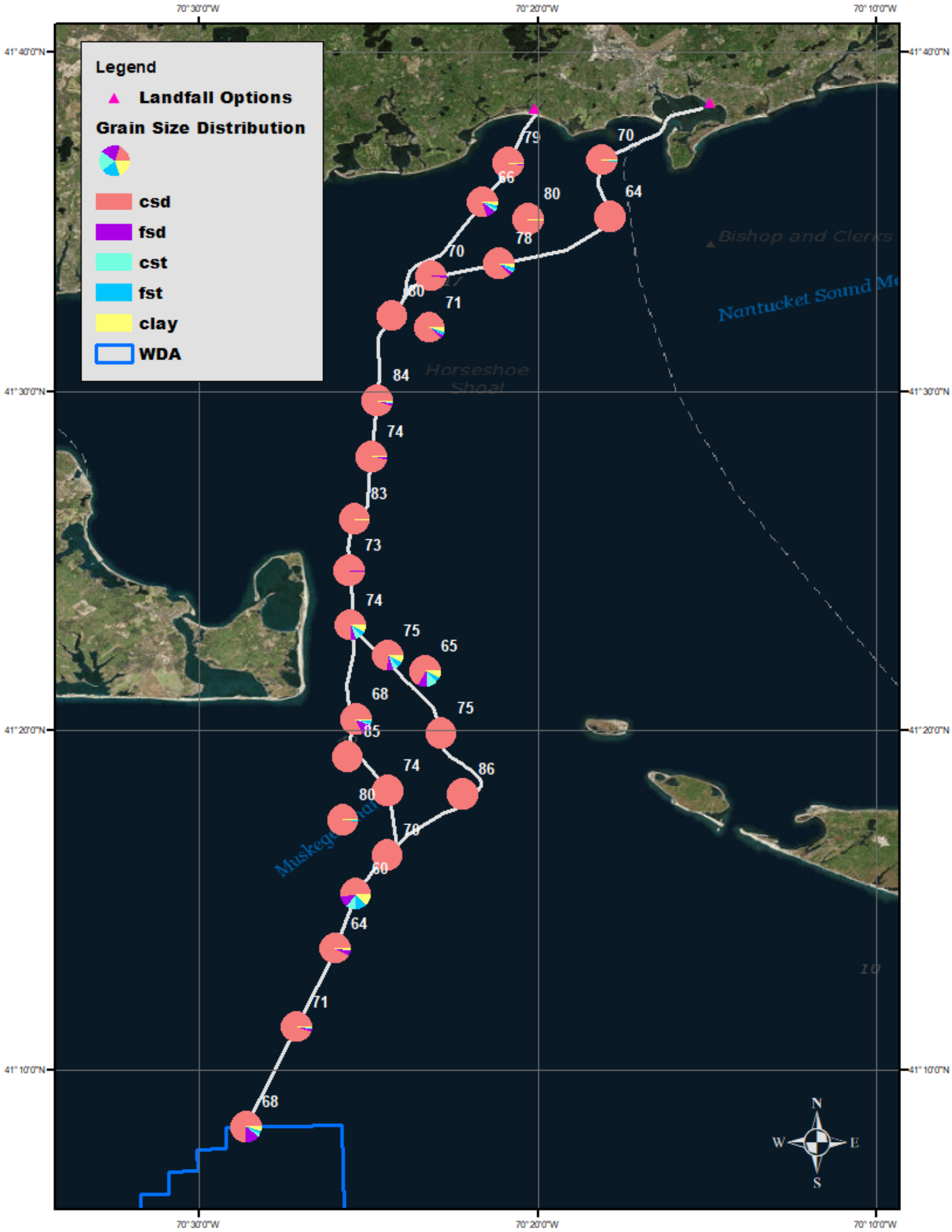


Figure 18. Sediment grain size distribution for target depth of two meters. Adjacent number represents the percent solid of the sample. Legend labels are described in Table 14.

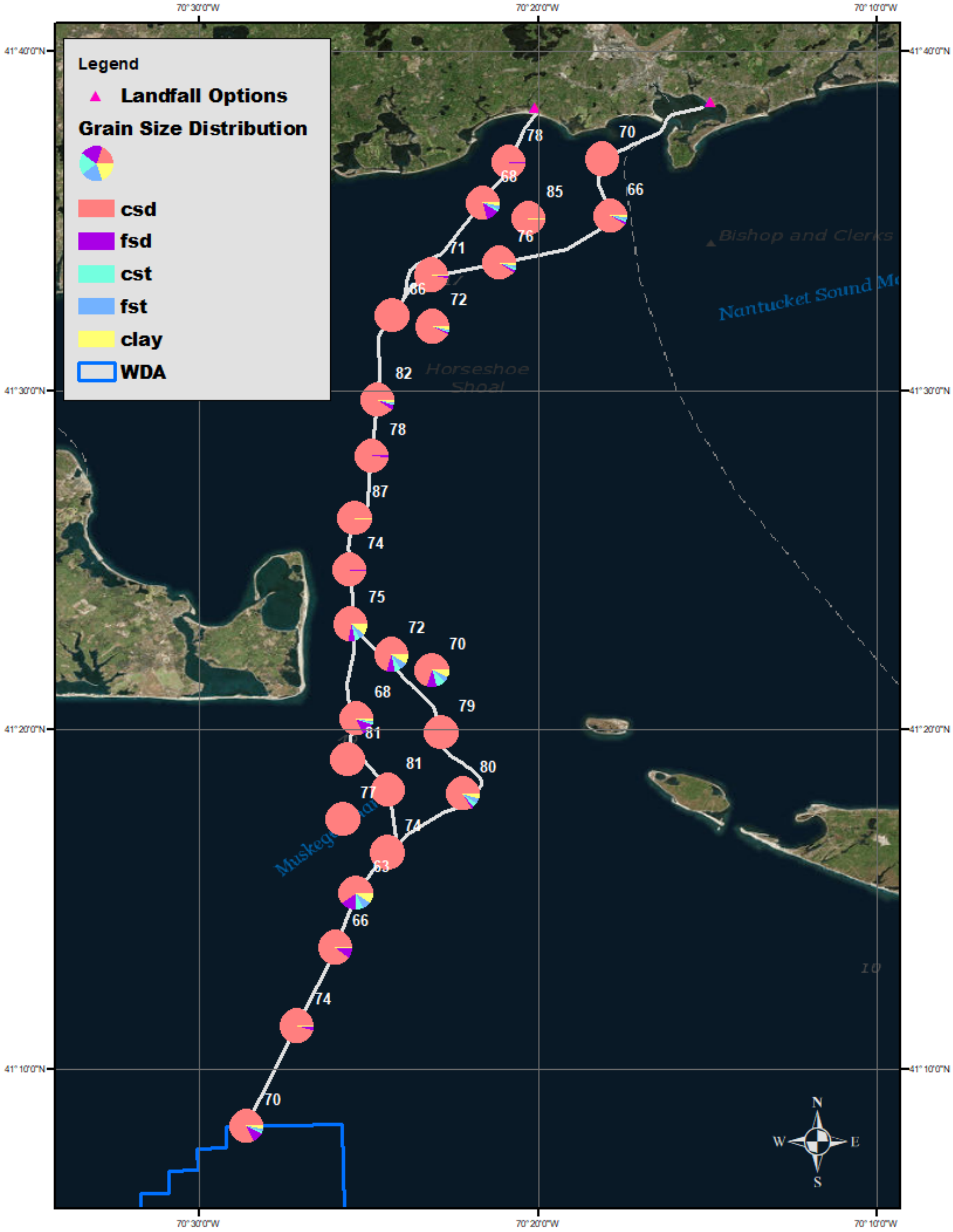


Figure 19. Sediment grain size distributions for target depth of three meters. Adjacent number represents the percent solid of the sample. Legend labels are described in Table 14.

4.5 SSFATE Results

SSFATE simulations were performed for each sediment disturbance activity. Sediment concentrations were computed on a grid with resolution of 50 m x 50 m in the horizontal dimension and 0.5 m in the vertical dimension. The model time step and output results saving interval was 5 minutes for the cable installation scenarios and 2 minutes for the dredging/overflow/disposal simulations; a smaller timestep was necessary for the dredging due to the faster production rate of the dredging operations. Model predicted concentrations are "excess" concentrations above the background concentration (i.e., a concentration of 0 mg/L is assumed for the ambient concentration in the Project Area).

The results from the model runs are presented through a set of figures and tables. Maps of maximum excess TSS concentration and seabed deposition are provided for each modeled scenario and tables of areas over specific excess TSS concentration thresholds for specific durations as well as areas of seabed deposition over specific thickness thresholds are presented for the representative inter-array cable and the each of the total OECC routes. Further, for the first set of results for the inter-array cable and one OECC, examples of instantaneous concentration snapshot are presented to provide further details.

Further details on the standard graphical outputs that are provided for each scenario are provided below.

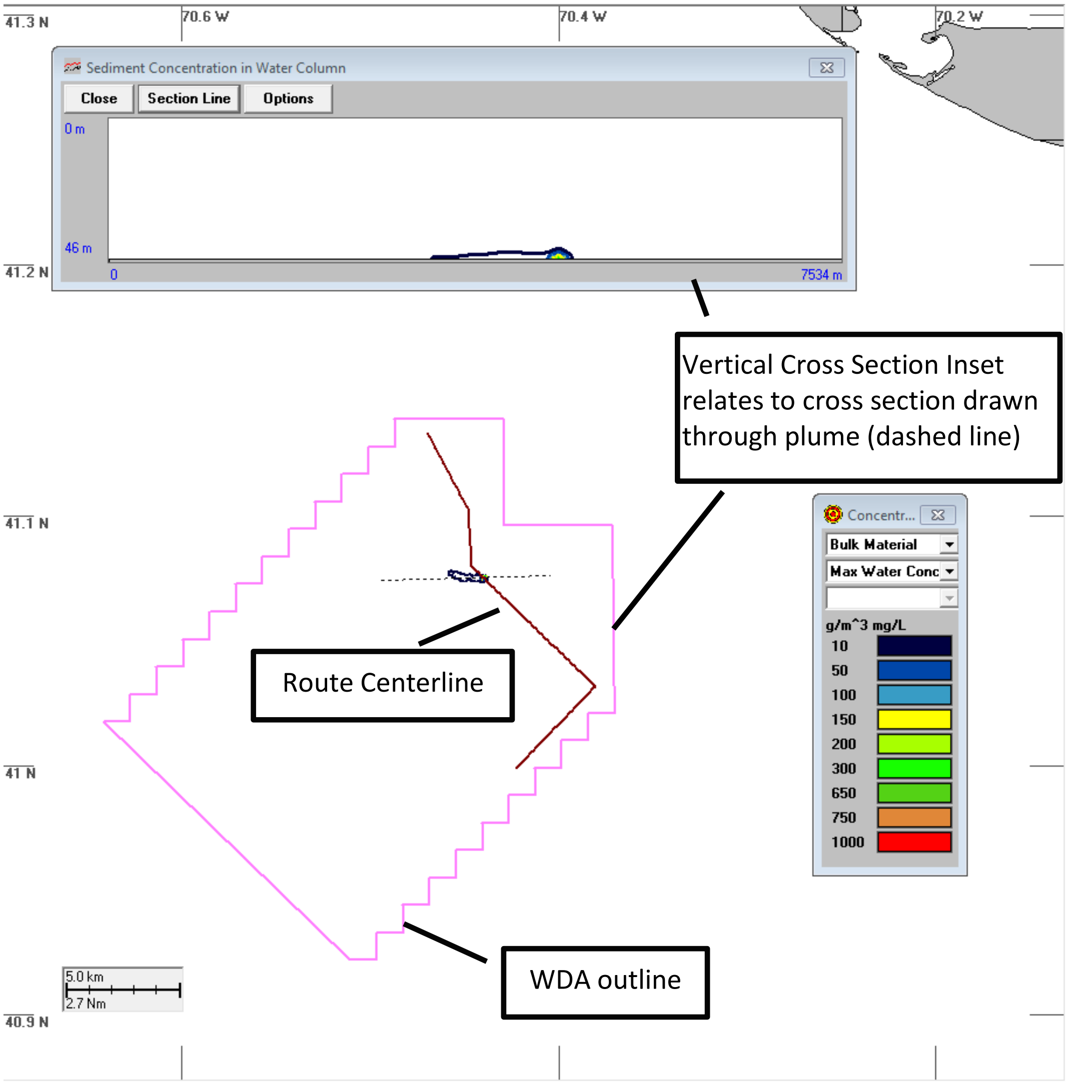
(i) Map of time-integrated maximum TSS concentrations. These figures show the maximum time-integrated water column concentration from the entire water column in a plan view map based view. Most figures include an upper inset shows the cross sectional view of concentrations from which it can be seen where in the water column the maximum occurred, this cross section is not to scale while the plan based map view is to scale. The concentrations are shown as contours, delineated at levels in units of mg/L of interest or tied to biological significance. The entire area within the contour is at or above the contour level. Most importantly it should be noted that this map shows the maximum that occurred throughout the entire simulation and that (1) these concentrations do not persist throughout the entire simulation and may be just one time step (30 minutes); and (2) these concentrations do not occur synoptically but are the time-integrated spatial view of maximum concentrations that the model predicted.

(ii) Map of seabed deposition. These figures show the deposition on the seabed that would occur once the activity has been completed. The thickness levels are shown as contours and the entire area within the contour is at or above the contour level. The contours are in units of mm and have been delineated at levels either tied to biological significance (1 mm and 20 mm) or to facilitate viewing the results. Previous versions of the report used different contour levels, and levels less than the minimum threshold of biological significance have been removed to facilitate a better view of the biologically significant impacts.

4.6 SSFATE Application to the Inter-array cables in the WDA

A snapshot of instantaneous excess TSS concentration associated with the installation of the inter-array cable using typical installation parameters is presented in Figure 20. In this figure, the cross sectional view runs across the centerline. This figure illustrates that the higher concentrations are centered around the centerline with lower concentrations biased towards the west – which is due to the bottom currents moving towards the west at the time of the snapshot. The vertical cross section shows that all concentrations are constrained to the bottom of the water column with the higher concentrations closest to the bottom and lower concentrations at increasing distance above the bottom, further it illustrates that the higher concentrations are localized to the source.

The map of time-integrated maximum concentrations for the typical inter-array cable is presented in Figure 21. The overall footprint shows how the plume oscillates with the tides, which is reflective in the oscillations of the 10 mg/L (dark blue) contour back and forth around the route centerline; though the oscillations during the simulation time period are biased predominately to the west of the route centerline. The higher concentrations, above 10 mg/L, generally remain centered on the route centerline. The contiguous 10 mg/L contour has a maximum excursion of ~3.1 km from the centerline and the 50 mg/L contour has a maximum excursion of ~160 m from the centerline. In this figure the cross sectional view (top inset) runs across the centerline and shows that the plume is contained within the bottom of the water column. A second figure showing the map of time-integrated maximum concentrations is presented in Figure 22, this figure includes an inset that illustrates the time history of concentrations (x-axis in days) at a designated point during the simulation. This figure shows that concentrations above 10 mg/L at the location identified persist for less than 0.1 days (2.4 hours). The map of deposition thickness for this scenario is presented in Figure 23. This figure shows that deposition is mainly centered on the route centerline with deposition of 1.0 mm or greater limited to within ~ 100 m from the centerline and deposition does not reach 5 mm. Both Figure 21 and Figure 23 indicate that most of the mass settles out quickly and is not transported for long by the currents.



Vertical Cross Section Inset relates to cross section drawn through plume (dashed line)

Route Centerline

WDA outline

Figure 20 Snapshot of instantaneous concentrations associated with a representative inter-array cable installation simulation using maximum impact cable burial parameters. The upper panel shows the vertical cross section of a line that runs through the plume (the line is 7,534 m long and 46 m deep in this instance). The pink outline depicts the outline of the WDA and the brown line depicts the centerline of the inter-array cable trench (note: trench thickness not to scale).

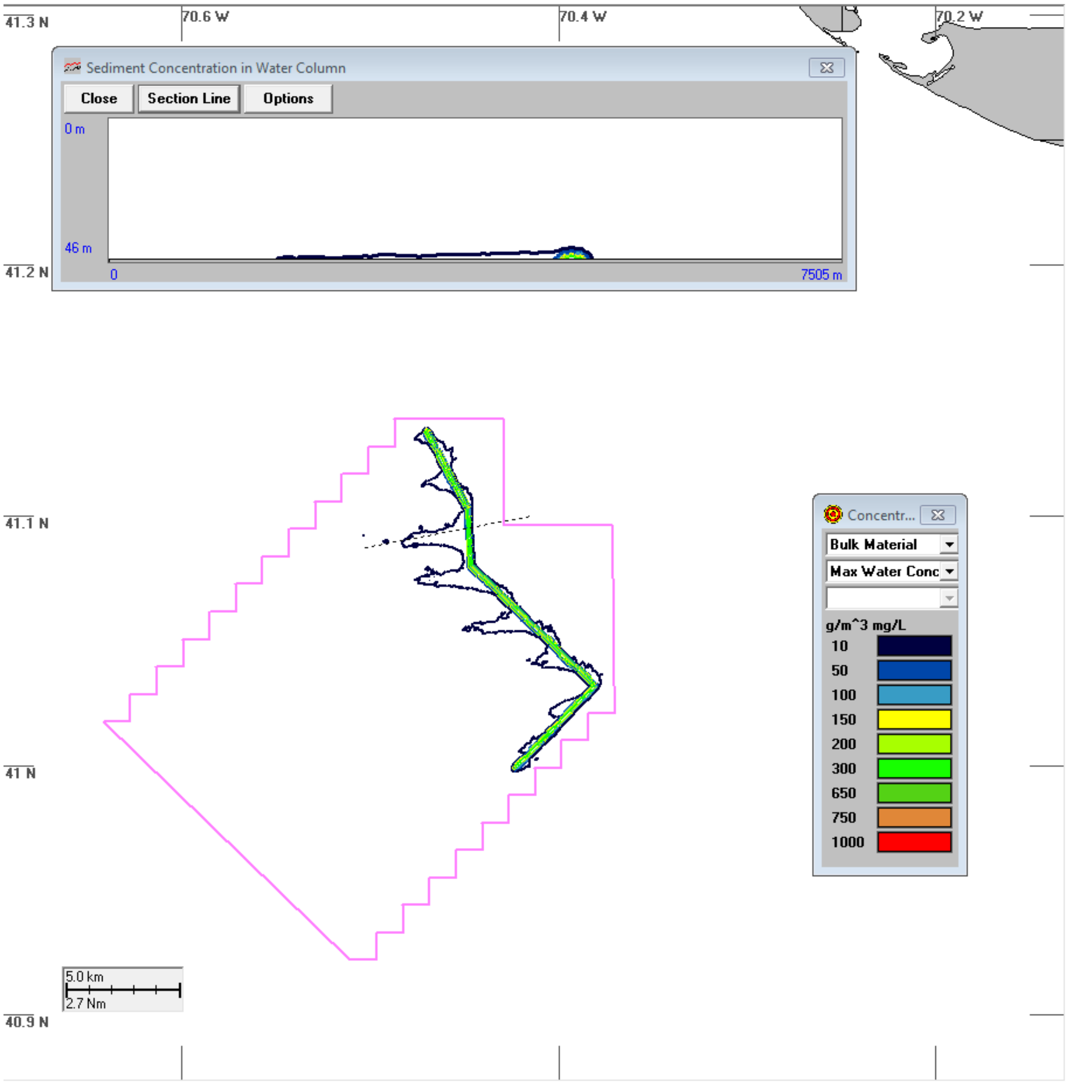


Figure 21. Map of time-integrated maximum concentrations associated with a representative inter-array cable installation simulation using typical cable burial parameters. The upper panel shows the vertical cross section of a line that runs through the plume (the line is 7,505 m long and 46 m deep in this instance). The pink outline depicts the outline of the WDA).

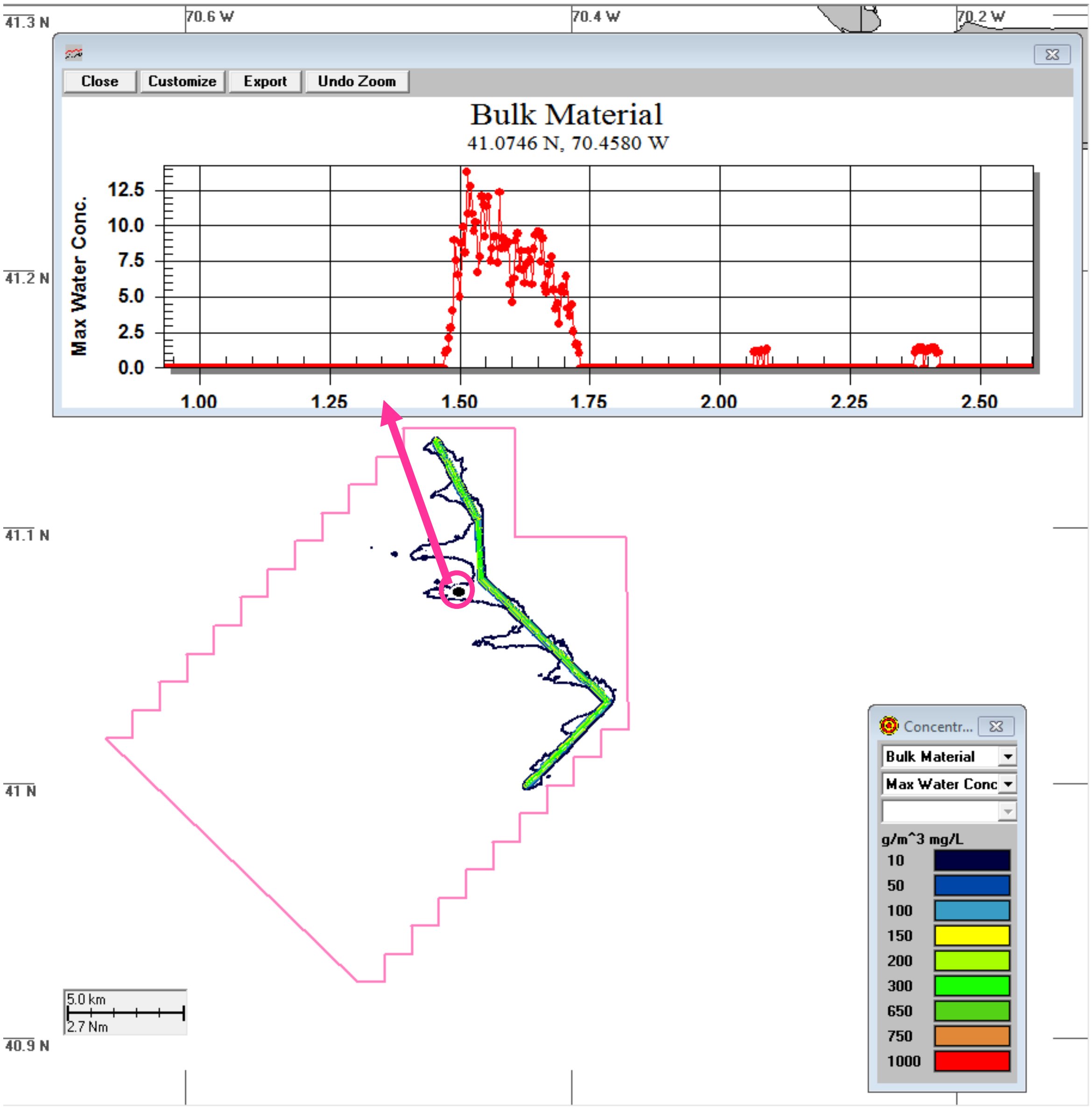


Figure 22. Map of time-integrated maximum concentrations associated with a representative inter-array cable installation simulation using typical cable burial parameters. The pink outline depicts the outline of the WDA. The inset shows the time history of concentrations at the point indicated in the figure (circled in pink); y-axis is concentration in mg/L and x-axis is time in days. The blue outline at the bottom of the figure depicts the outline of the WDA.

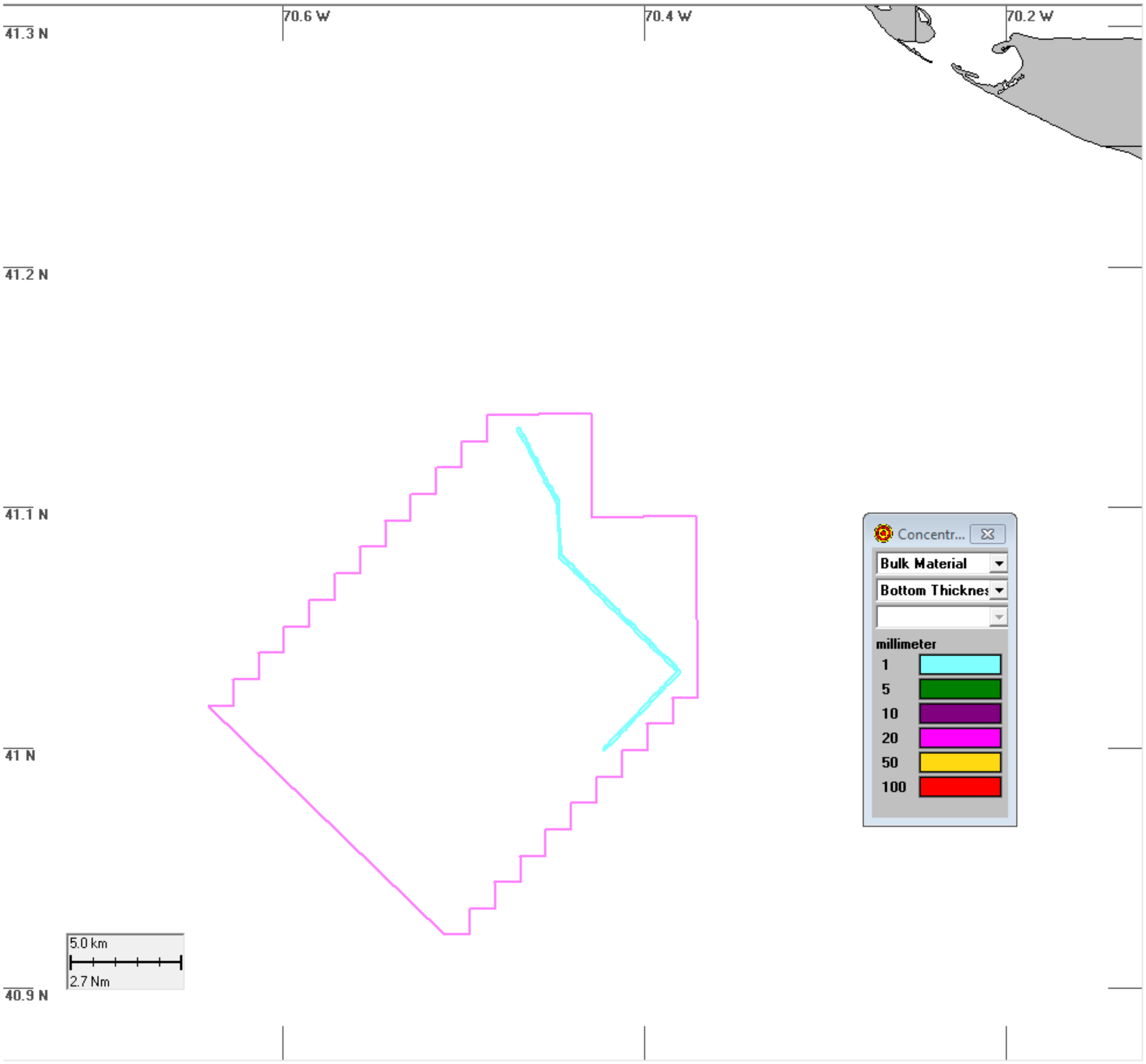


Figure 23 Map of deposition thickness associated with a representative inter-array cable installation simulation using typical cable burial parameters. The pink outline depicts the outline of the WDA and the brown line depicts the centerline of the inter-array cable trench (note: trench thickness not to scale).

The map of time-integrated maximum concentrations for the maximum impact inter-array cable is presented in Figure 24. The overall footprint shows how the plume oscillates with the tides, which is reflected in the oscillations of the lower level contours back and forth around the route centerline; though again illustrates a bias to the west. The higher concentrations, above 100 mg/L, generally remain centered on the route centerline. The 10 mg/L contours has a maximum excursion of 7.5 km from the centerline and the 50 mg/L and 100 mg/L contours have a maximum excursion of ~2.0 km and 860 m, respectively. These contours are also often close (within ~200 m) to the plume centerline with episodic larger excursion due to the peaking currents. Further, the 150 mg/L contour is nearly always within ~200 m from the centerline. In this figure (Figure 24), the cross sectional view (top inset) runs across the centerline and shows that the plume is contained within the bottom of the water column. The map of deposition thickness for this scenario is presented in Figure 25. This figure shows that deposition is mainly centered around the route centerline with deposition of 1.0 mm or greater limited to within ~140 m from the centerline and deposition does not reach 5 mm. Both Figure 24 and Figure 25 indicate that most of the mass settles out quickly and is not transported for long by the currents. Relative to the simulation with typical installation parameters the overall plume footprint is noticeably larger and the deposition footprint is slightly larger.

In summary, the model results indicate most of the mass settles out quickly and is not transported for long by the currents. The plume is confined to the bottom 3 m of the water column, which is only a fraction of the water column in the WDA. Deposition greater than 1.0 mm is confined within 100 m to 150 m of the trench centerline for the typical and maximum impact simulations, respectively, and maximum deposition in both simulations is less than 5 mm. Water quality impacts from inter-array cable installation are therefore short-term and localized.

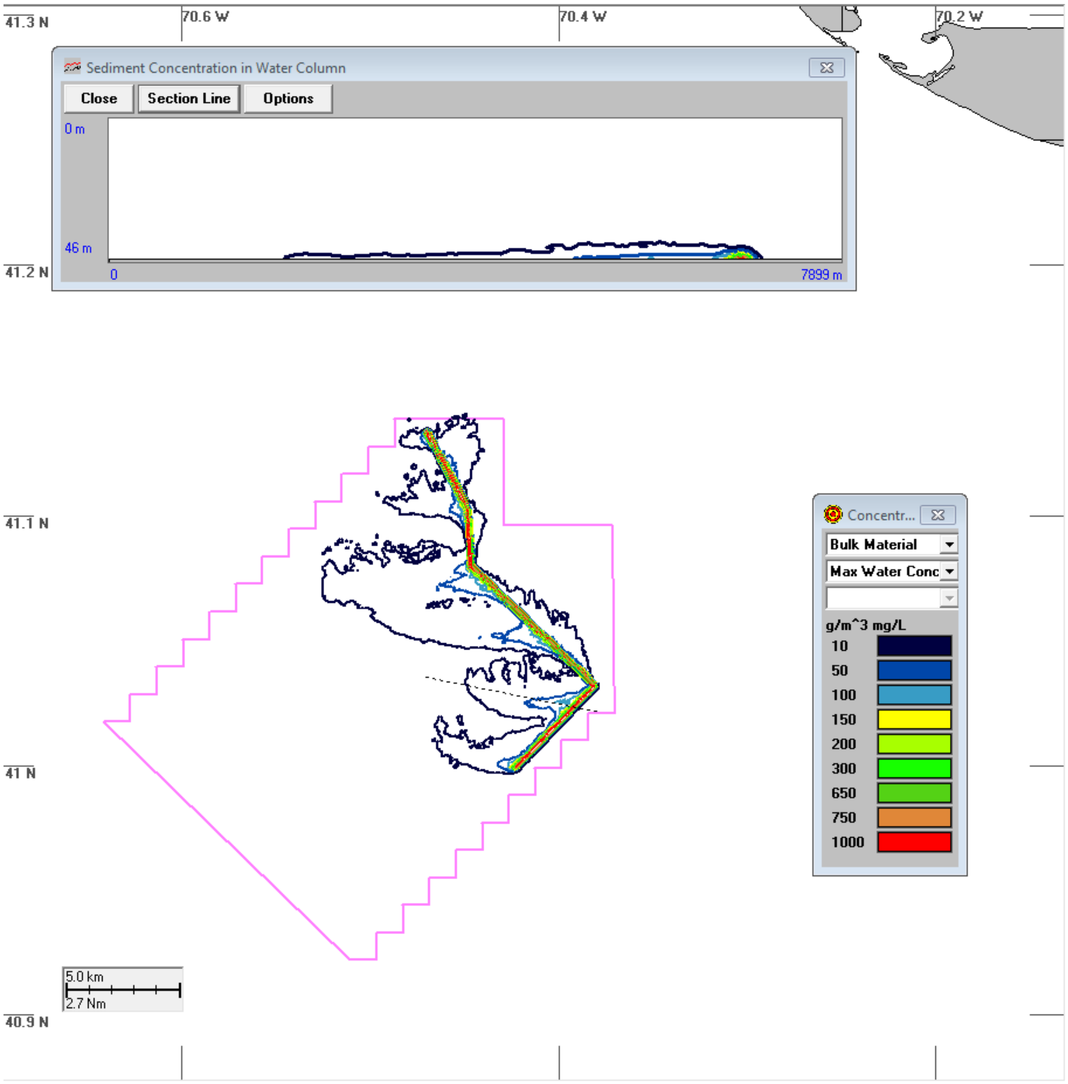


Figure 24. Map of time-integrated maximum concentrations associated with a representative inter-array cable installation simulation using maximum impact cable burial parameters. The upper panel shows the vertical cross section of a line that runs through the plume (the line is 4,097 m long and 46 m deep in this instance). The pink outline depicts the outline of the WDA.

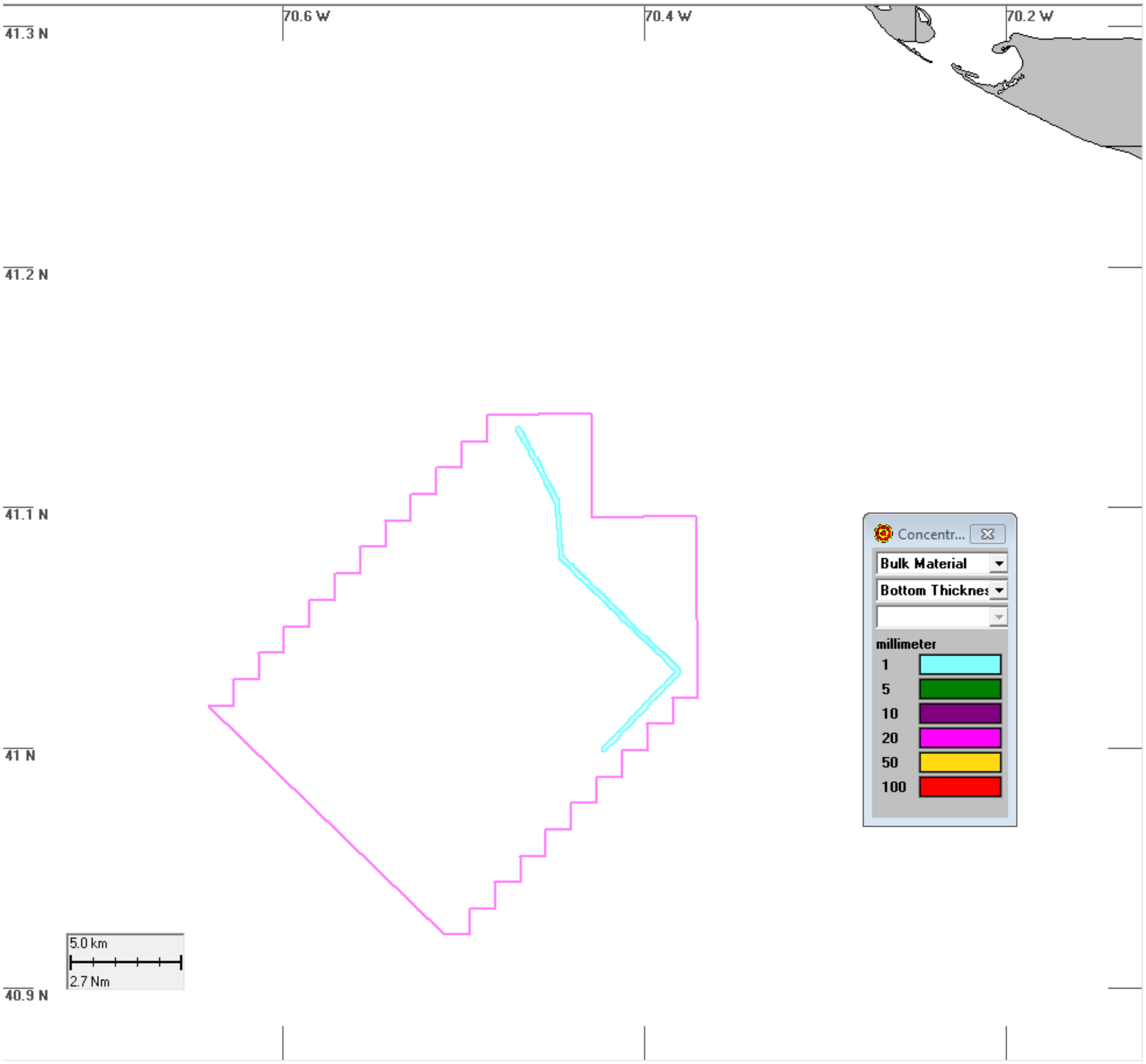


Figure 25. Map of deposition thickness associated with a representative Inter-array cable installation simulation using maximum impact cable burial parameters. The pink outline depicts the outline of the WDA.

4.7 SSFATE Application to the Offshore Export Cable Corridor

This section presents results for the simulation OECC pre cable installation spot dredging (with overflow and disposal) and for the cable installation. The results are presented separately for the two distinct cable installation approaches of (1) TSHD Pre Dredge + Cable Installation and (2) Limited TSHD Pre Dredge + Cable installation Aided by Jetting.

Due to the similarities in the impacts between route variants and even between cable installation aided by jetting and not aided by jetting, the results from a single route and approach (TSHD Pre Dredge + Cable Installation [No Jetting]) have been presented in detail and then figures showing all variants for each approach are shown for reference. The results of the TSHD Pre Dredge + Cable Installation approach for the EM to NH Avenue have been chosen to be representative and are presented in detail. .

4.7.1 Approach 1: TSHD Pre Dredge + Cable Installation

TSHD Pre Dredge

The map of time-integrated maximum concentrations associated with the TSHD pre cable installation spot dredging of the EM to NH Avenue OECC is presented in Figure 26 and a zoomed in view of one portion of the footprint focused on a dredge disposal dump is shown in Figure 27. In viewing the entire footprint it can be seen that the plume is present adjacent to the areas where sand wave dredging will occur, which is intermittent along the route. Further it can be seen that the plume may be present at varying orientations relative to the route centerline in response to the prevailing direction of the oscillating current synchronous with the simulated activity; in that sense it is noted that this footprint corresponds to the modeled time period and multiple perturbations of the footprint are possible, though the general trends are expected to be the same. The footprint and contours for the dredging, overflow and disposal activity show that excess concentrations are expected throughout the water column. This is due to the overflow release located at the surface and therefore a plume is noted throughout the water column as the sediments settle. Similarly the dumping will initiate sediments approximately 6 m below the surface and therefore the resulting plume occupies waters throughout the majority of the water column. The plume of excess TSS at 10 mg/L and 750 mg/L extends up to 16 km and 5 km from the route centerline, though may be less extensive at varying locations along the route. Relatively high concentrations (>1000 mg/L) are predicted at distances up to 5 km in response to the relatively high loading of dumping and swift transport of the dumped sediments. A good example of such results is shown in Figure 27, which is a zoomed in view that shows the simultaneous downward and lateral transport of the dumped sediment plume to the eventual settling location approximately 5 km from the dump site.

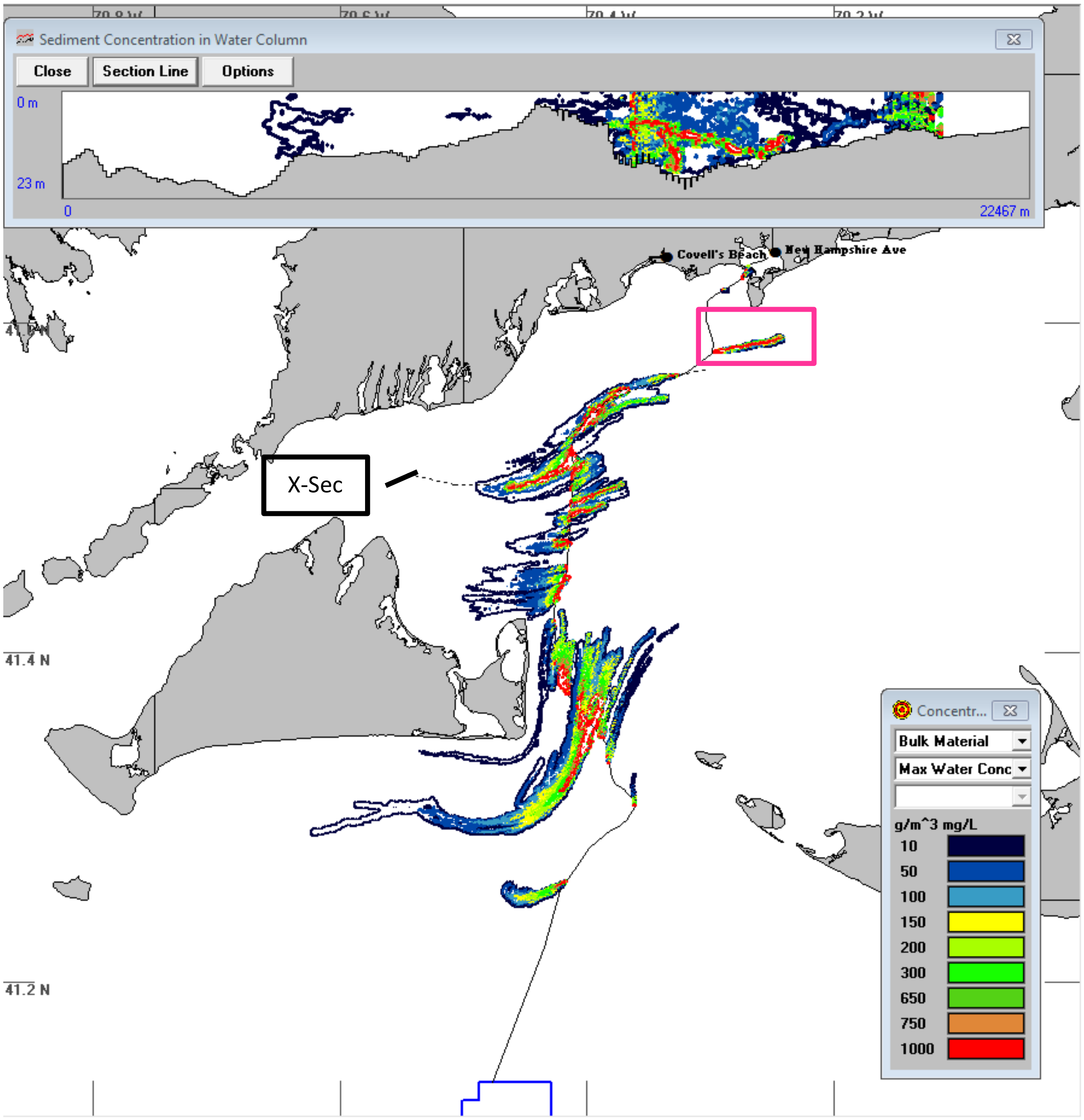


Figure 26. Map of time-integrated maximum concentrations associated with dredging, overflow and disposal operations for the EM to NH avenue OECC. The upper panel shows the vertical cross section of a line that runs through the plume (the line is 22,467 m long and 23 m deep in this instance). The blue outline at the bottom of the figure depicts the outline of the WDA. The pink box outlines a portion of the route that is presented in Figure 27 as a zoomed in view to show details.

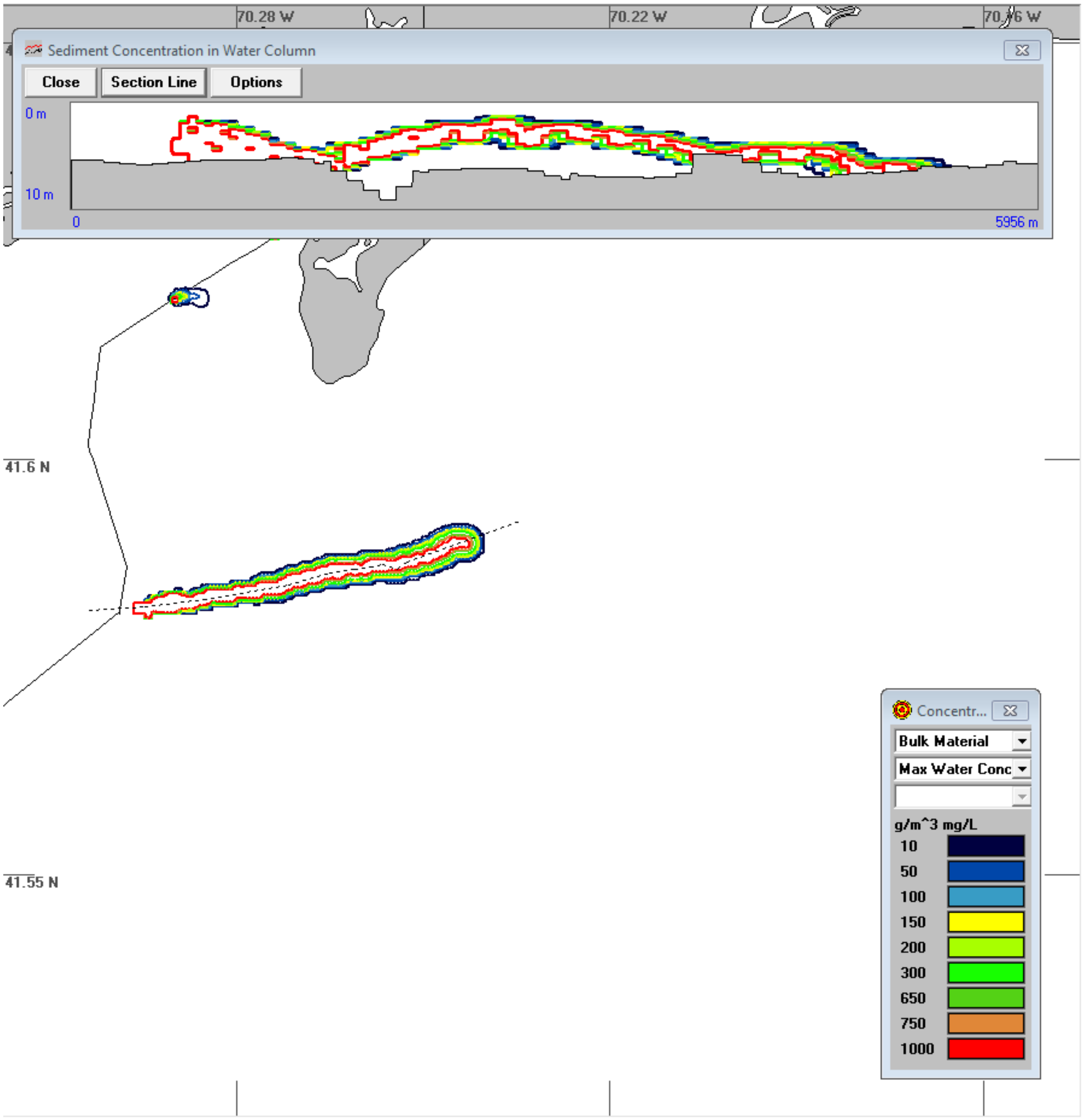


Figure 27. Zoomed in map of time-integrated maximum concentrations associated with dredging, overflow and disposal operations area within pink box outline as shown in Figure 26. The upper panel shows the vertical cross section of a line that runs through the plume (5,956 m long and 10 m deep in this instance).

In order to demonstrate the temporal nature of the excess concentrations, three additional figures (Figure 28 through Figure 30) of the map of maximum concentrations are presented for different locations (close to the outer extent of the 10 mg/L plume, close to the route centerline, and at a bottom dumping location). Each figure includes an inset plot showing the time history of excess TSS at a single point which is also identified in the figure.

- Figure 28 shows the time history at a location approximately 16 km west of the route centerline; close to the outer extent of one of the more extensive oscillations of the 10 mg/L plume from the route centerline. This figure shows that the concentrations are near zero until two separate peaks are observed, with the second peak reaching approximately 25 mg/L. The time step of this simulation was 2 minutes and each red dot on the time history represents the concentration at a time step; there are 8 dots over 10 mg/L indicating that the concentration is over 10 mg/L is predicted to be approximately 32 minutes at this location.
- Figure 29 shows the time history at a location close to the route centerline in a region with fairly constant sand wave dredging activity. This figure shows that the concentrations above zero are intermittent and concentrations greater than 10 mg/L are intermittent within a span of approximately .25 days (6 hours) from 0.39 – 0.61 days. The intermittent nature is a result of the individual plumes surrounding discrete sediment particles passing by this location, though in reality the plume may be more continuous in nature but would be attenuated in terms of concentration.
- Figure 30 shows the time history at the dumping location closest to the nearshore, which would be the location of dumping from any nearby dredging and from within Lewis Bay. The inset in this figure shows a very brief high concentration spike due to the transport of dumped sediments by this location. The plume passes by this location in approximately 16 minutes total and has a peak concentration greater than 1,750 mg/L.

The map of seabed deposition thickness associated with the TSHD dredging approach (dredging/overflow/dumping of pre-cable installation dredging of sand waves for the EM to NH Avenue OECC) is presented in Figure 31. This figure is demonstrates that the deposition above 1.0 mm is evident mainly in very close proximity to the dredge and dump sites. In most locations deposition greater than 1.0 mm is constrained to within 150 m from the route centerline or disposal site; however, there are some instances of deposition that extend up to a few kilometers from its source. Relatively larger amounts of deposition are located local to the disposal sites; these sites are evident in the yellow and red contours indicating deposition greater than 100 mm in small localized patches.

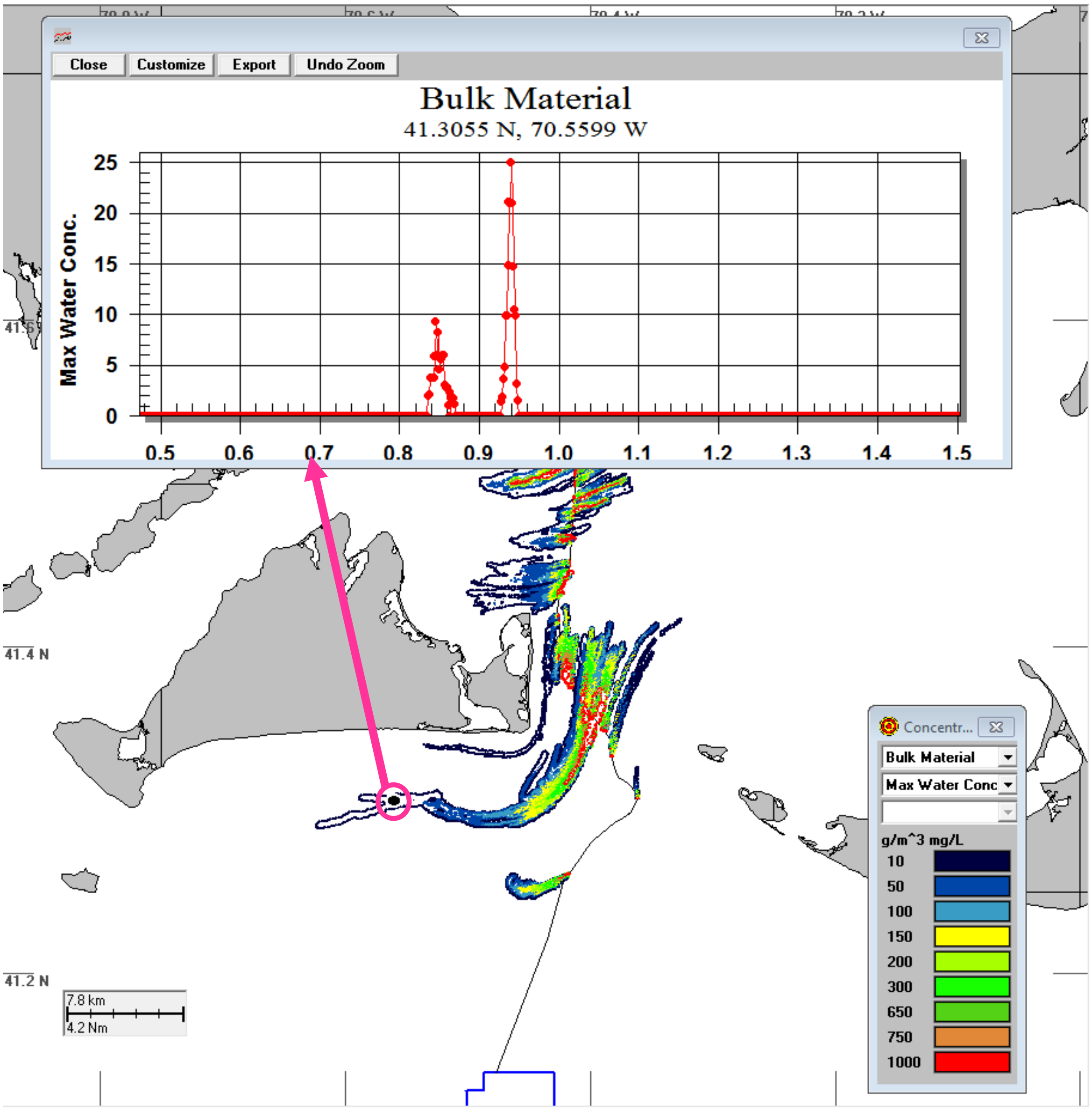


Figure 28. Map of time-integrated maximum concentrations associated with dredging, overflow and disposal operations for the EM to NH avenue OECC. The inset shows the time history of concentrations at the point indicated in the figure (circled in pink); y-axis is concentration in mg/L and x-axis is time in days. The blue outline at the bottom of the figure depicts the outline of the WDA.

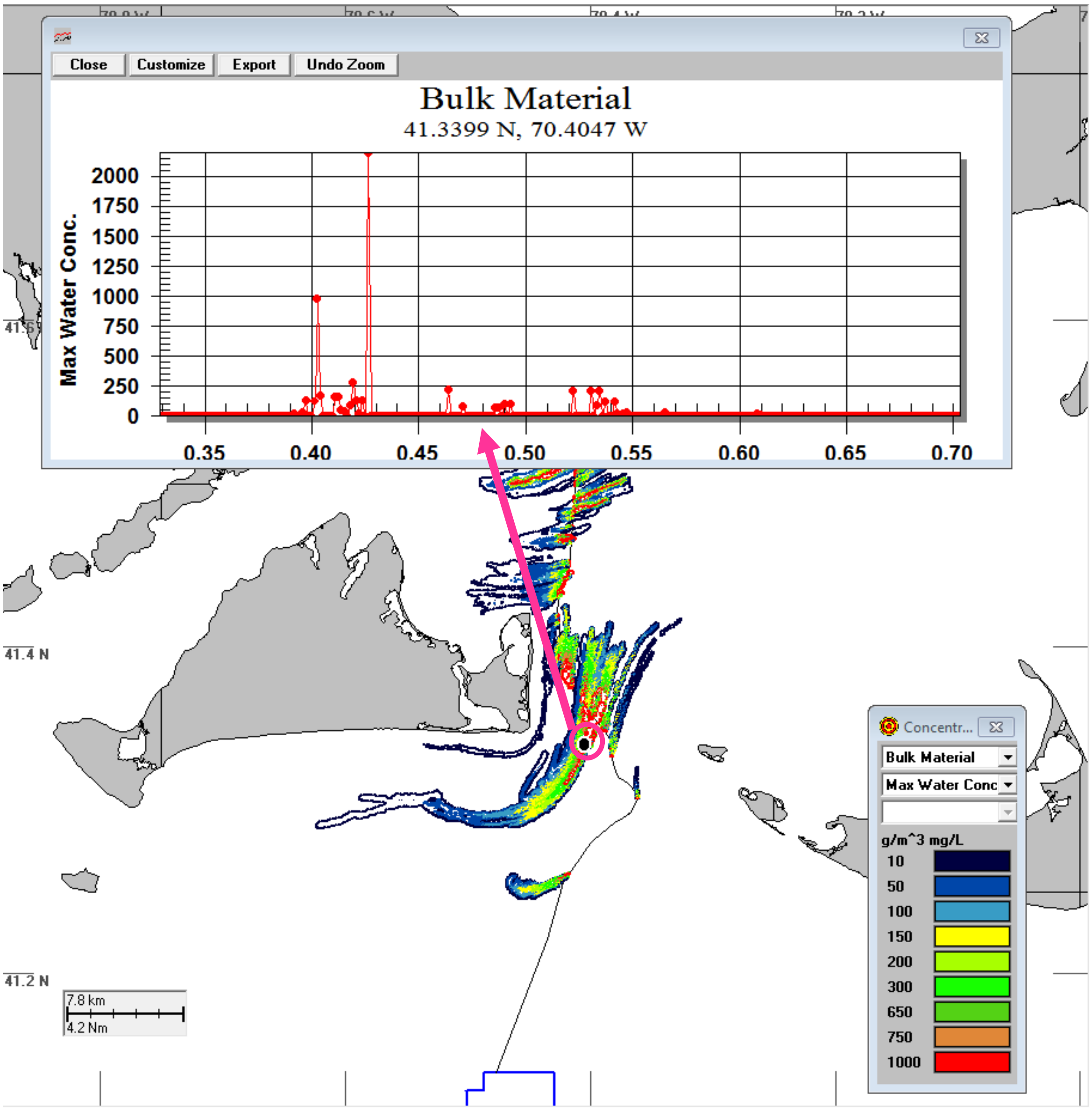


Figure 29. Map of time-integrated maximum concentrations associated with dredging, overflow and disposal operations for the EM to NH avenue OECC. The inset shows the time history of concentrations at the point indicated in the figure (circled in pink); y-axis is concentration in mg/L and x-axis is time in days. The blue outline at the bottom of the figure depicts the outline of the WDA.

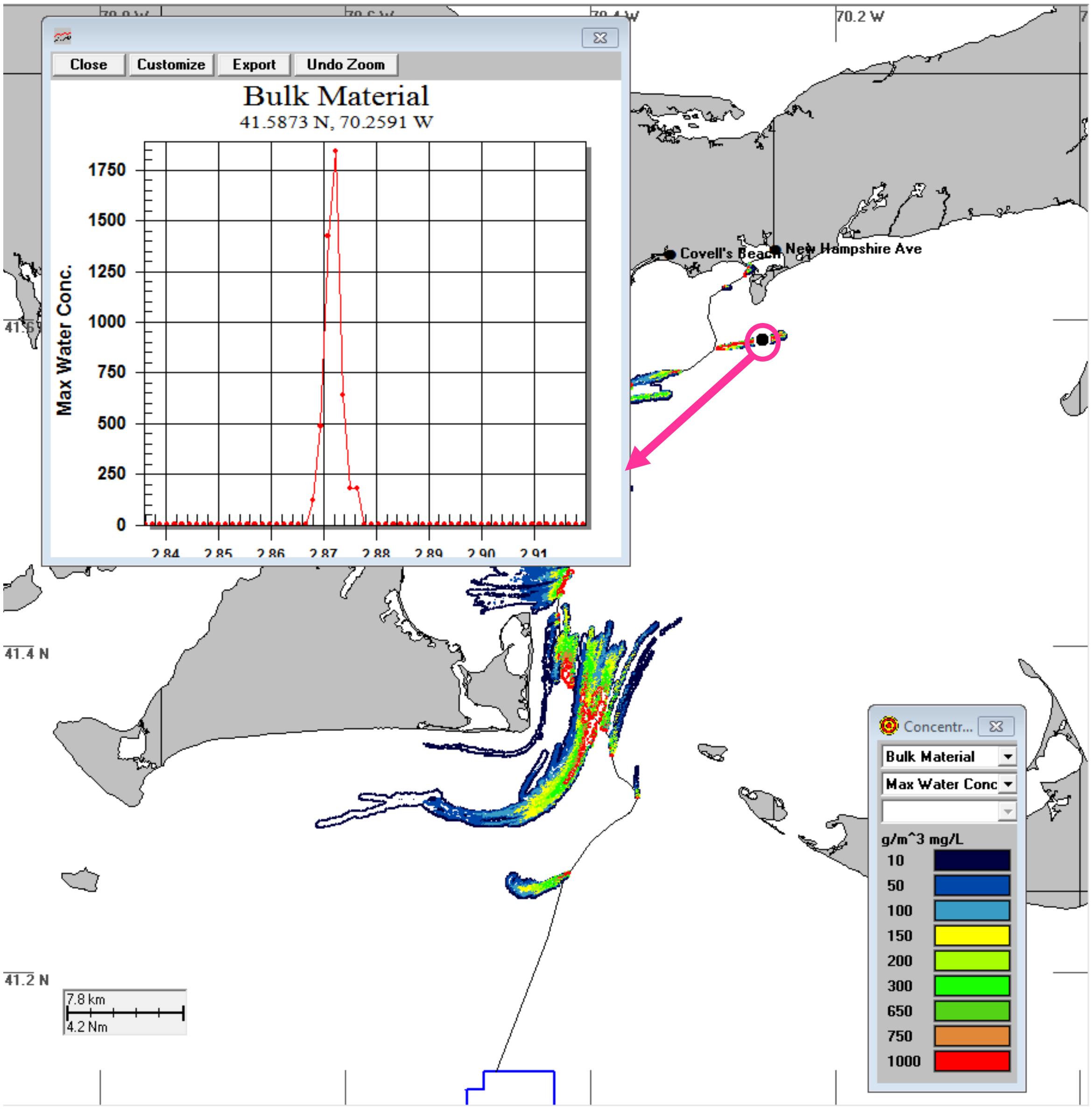


Figure 30. Map of time-integrated maximum concentrations associated with dredging, overflow and disposal operations for the EM to NH avenue OECC. The inset shows the time history of concentrations at the point indicated in the figure (circled in pink); y-axis is concentration in mg/L and x-axis is time in days. The blue outline at the bottom of the figure depicts the outline of the WDA.

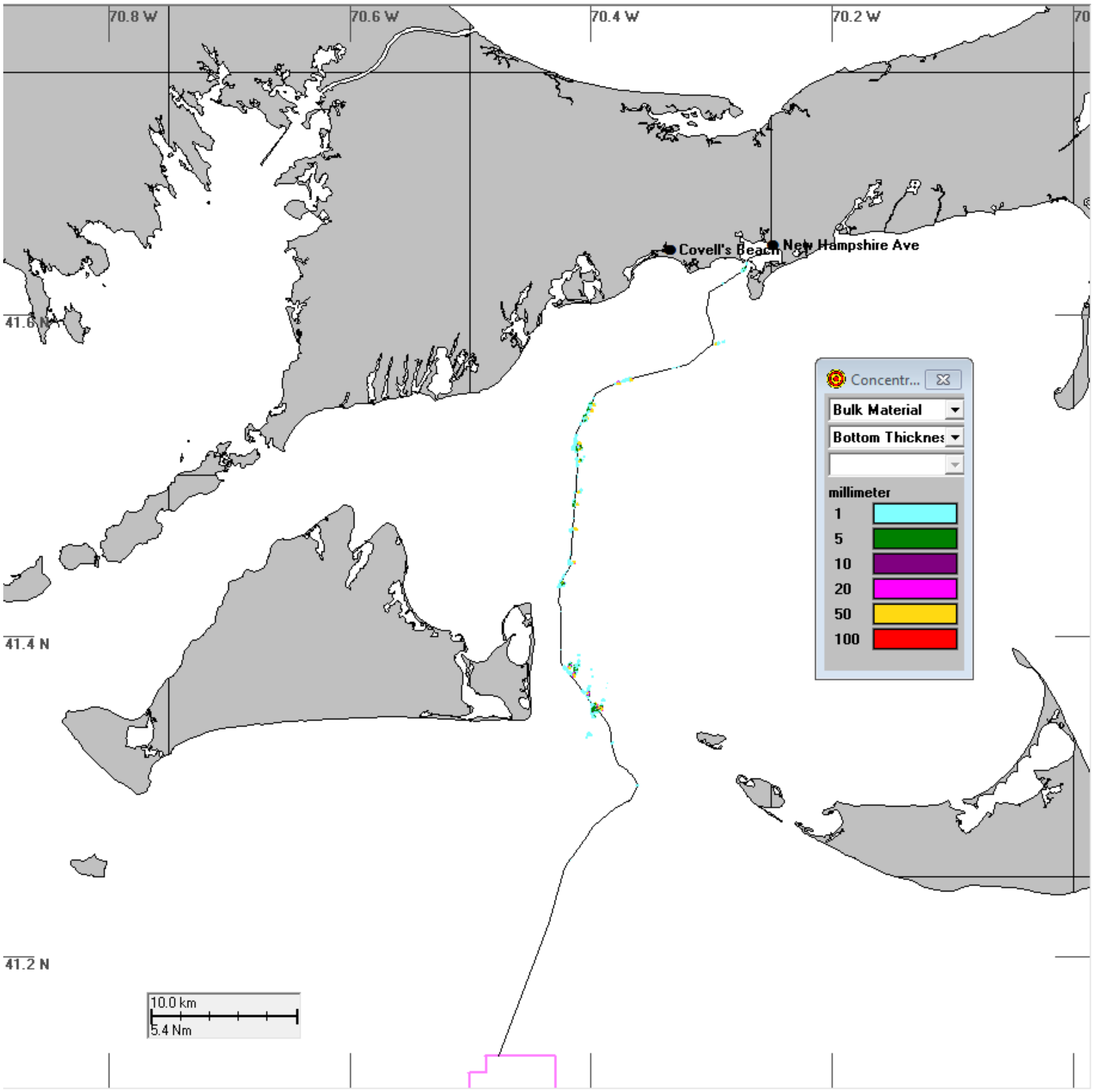


Figure 31. Map of deposition thickness associated with associated with dredging, overflow and disposal operations for the EM to NH avenue OECC. The pink outline at the bottom of the figure depicts the outline of the WDA.

Cable Installation

Subsequent to the pre-installation dredging via TSHD, cable installation will take place. The map of maximum concentrations of the corresponding cable installation using typical parameter for the EM to

NH Avenue OECC is presented in Figure 32. This figure shows the entire route with a cross section along the route centerline at the top. The overall footprint shows that the plume as delineated by excess concentrations of 10 mg/L and greater remains relatively close to the route centerline for the majority of the route with some areas with the plume as delineated by the 10 mg/L contour transported farther from the centerline in response to the currents or relatively higher volume of finer material within the sediments. The higher concentrations, above 10 mg/L, generally remain centered around the route centerline. The 10 mg/L contour has a maximum excursion of ~1.85 km from the centerline though typically remains within less than ~200 m from the centerline. In this figure, the main cross sectional view (top inset) runs along the centerline and shows that the plume is contained within the bottom of the water column close to the disturbance. The map of deposition thickness for this scenario is presented in Figure 33. This figure shows that deposition is mainly centered around the route centerline with deposition of 1.0 mm or greater limited to within ~100 m from the centerline and deposition does not reach 5 mm except in one small area just around the centerline. Both Figure 32 and Figure 33 indicate that most of the mass settles out quickly and is not transported for long by the currents.

A sensitivity run for the EM to NH Avenue OECC using maximum impact cable burial parameters was simulated to assess the impact of some of the uncertainties associated with the cable burial assumptions. The map of maximum concentrations associated with this maximum impact scenario is presented in Figure 34. This figure shows the entire route with a cross section along the route centerline at the top. The overall footprint shows that the plume as delineated by excess concentrations of 10 mg/L and greater remains relatively close to the route centerline for the majority of the route with some areas with the plume as delineated by the 10 mg/L contour transported farther from the centerline in response to the currents or relatively higher volume of finer material within the sediments. The higher concentrations, above 10 mg/L, generally remain centered around the route centerline. The 10 mg/L contour has a maximum excursion of ~2.8 km from the centerline though typically remains within less than ~200 m from the centerline. In this figure, the cross sectional view (top inset) runs along the centerline and shows that the plume is contained within the bottom of the water column close to the disturbance. The footprint is similar to that associated with the route simulated with typical parameters. Small differences between these two simulations of typical and maximum impact cable burial parameters exists, such as higher concentrations directly along the route and larger excursions of the 10 mg/L plume in places for the maximum impact parameters. Similarly the map of deposition associated with the maximum impact parameters is similar to that of typical parameters. The map of deposition for the maximum impact OECC is presented in Figure 35. This figure shows that deposition is mainly centered around the route centerline with deposition of 1.0 mm or greater limited to within ~140 m from the centerline and deposition does not reach 5 mm except in one small area just around the centerline. Both Figure 34 and Figure 35 indicate that most of the mass settles out quickly and is not transported for long by the currents.

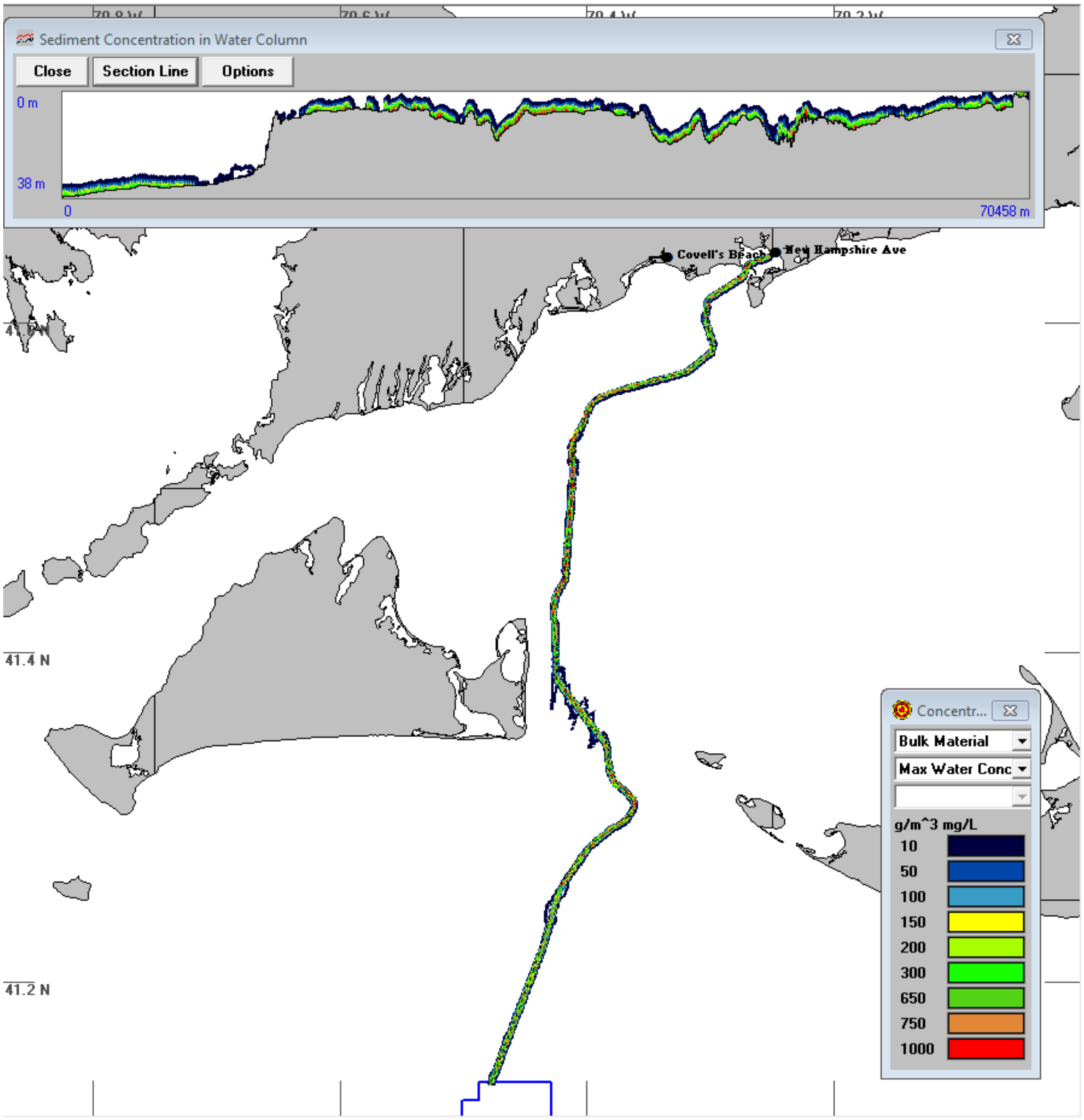


Figure 32. Map of time-integrated maximum concentrations associated with cable installation of one cable for the EM to NH avenue OECC using typical burial parameters. The upper panel shows the vertical cross section of a line that runs through the plume (70,458 m long and 38 m deep in this instance). The blue outline at the bottom of the figure depicts the outline of the WDA.

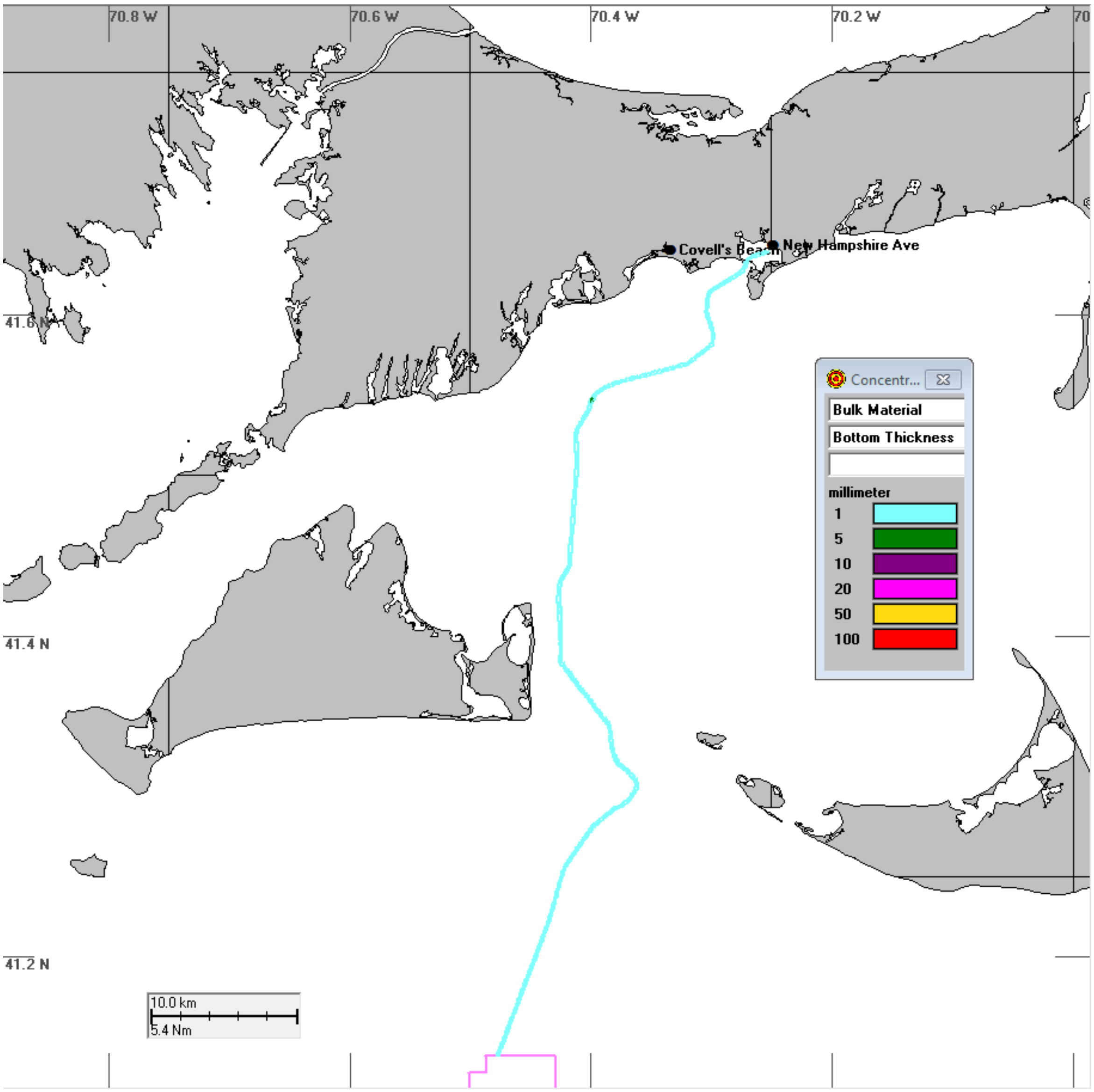


Figure 33. Map of deposition thickness associated with cable installation of one cable for the EM to NH avenue OECC from simulation using typical burial parameters. The pink outline near the bottom of the figure depicts the outline of the WDA.

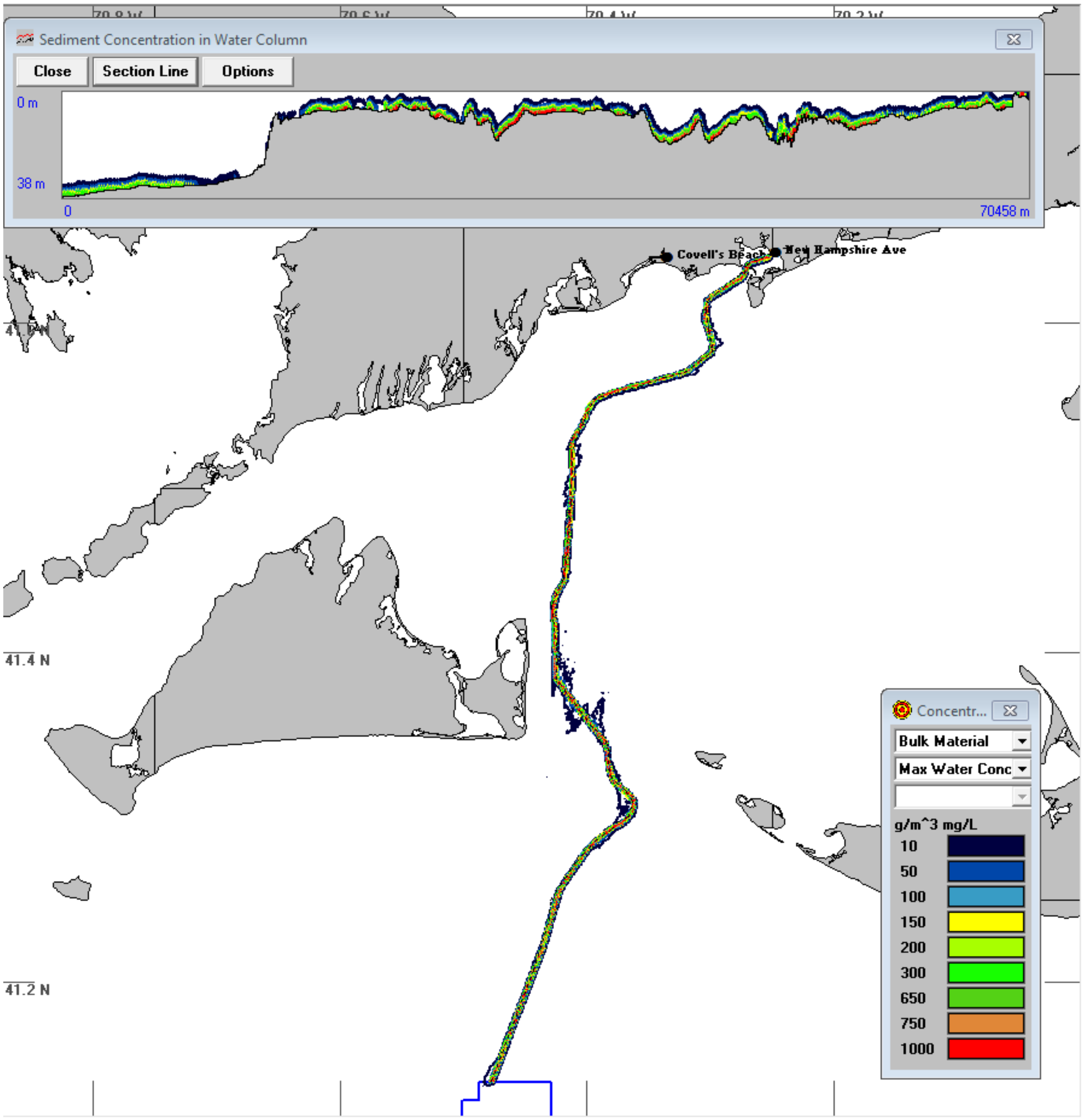


Figure 34. Map of time-integrated maximum concentrations associated with the EM to NH avenue OECC single cable installation using maximum impact cable burial parameters. The upper panel shows the vertical cross section of a line that runs along the route centerline (the line is 70,458 m long and 38 m deep in this instance). The blue outline at the bottom of the figure depicts the outline of the WDA.

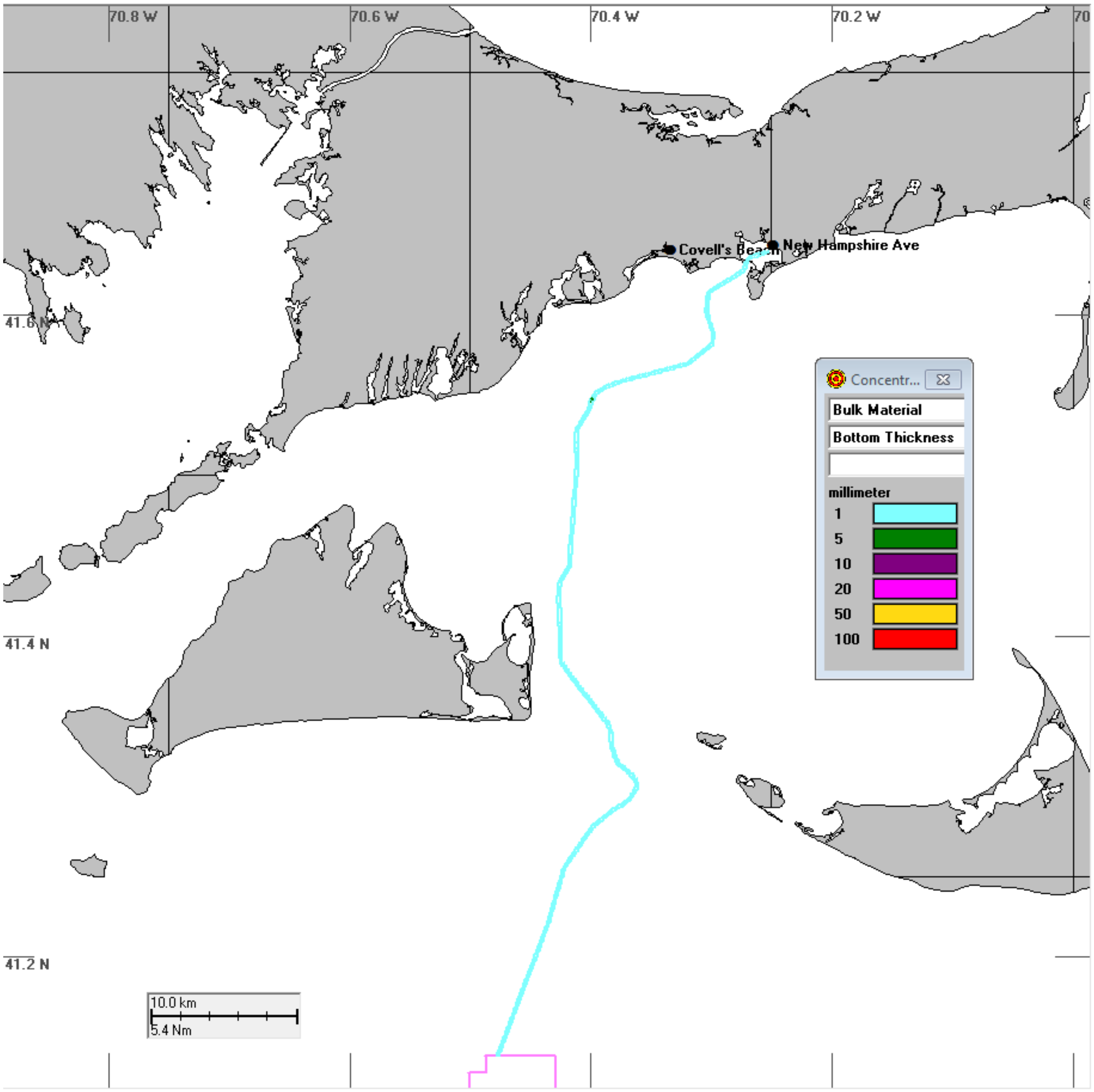


Figure 35. Map of deposition thickness associated with the EM to NH avenue OECC single cable installation using maximum impact cable burial parameters. The pink outline at the bottom of the figure depicts the outline of the WDA.

Figures Showing All Routes

Figure 36 and Figure 37 present the map of maximum concentrations and seabed deposition for the TSHD Pre Dredge + Cable Installation approach for all OECC variants, respectively. These results are discussed further in Section 4.7.2 below.

4.7.1 Approach 2: Limited TSHD Pre Dredge + Cable Installation aided by Jetting

Figures showing the map of maximum concentrations and seabed deposition for the Limited TSHD Pre Dredge + Cable Installation aided by Jetting for all OECC variants are presented in Figure 38 and

Figure 39. Figure 38 shows the map of maximum concentration for the limited TSHD pre dredge (top row) and the subsequent cable installation aided by jetting (bottom row).

Figure 39 shows the corresponding seabed deposition.

4.7.2 Discussion of Results

Two approaches - TSHD Pre Dredge + Cable Installation and Limited TSHD Pre Dredge + Cable Installation aided by Jetting – were modeled. Reviewing the set of figures 36-39 collectively it can be seen that the cable installation impacts are extremely similar across route variants and whether or not jetting for sand wave clearance is used in the cable installation. The largest difference between the figures is due to the extent of TSHD utilized. As expected, the dredging footprint for the Limited TSHD Pre Dredge + Cable Installation aided by Jetting approach is smaller than the dredging footprint for the TSHD Pre Dredge + Cable Installation approach.

The model results of simulations of the OECC show that the use of the TSHD for pre-cable installation dredging has the potential to generate temporary plumes that impact the entire water column and may extend several km from the route centerline. The cable installation activities may generate temporary plumes that are constrained to the bottom of the water column and do not extend far from the route centerline.

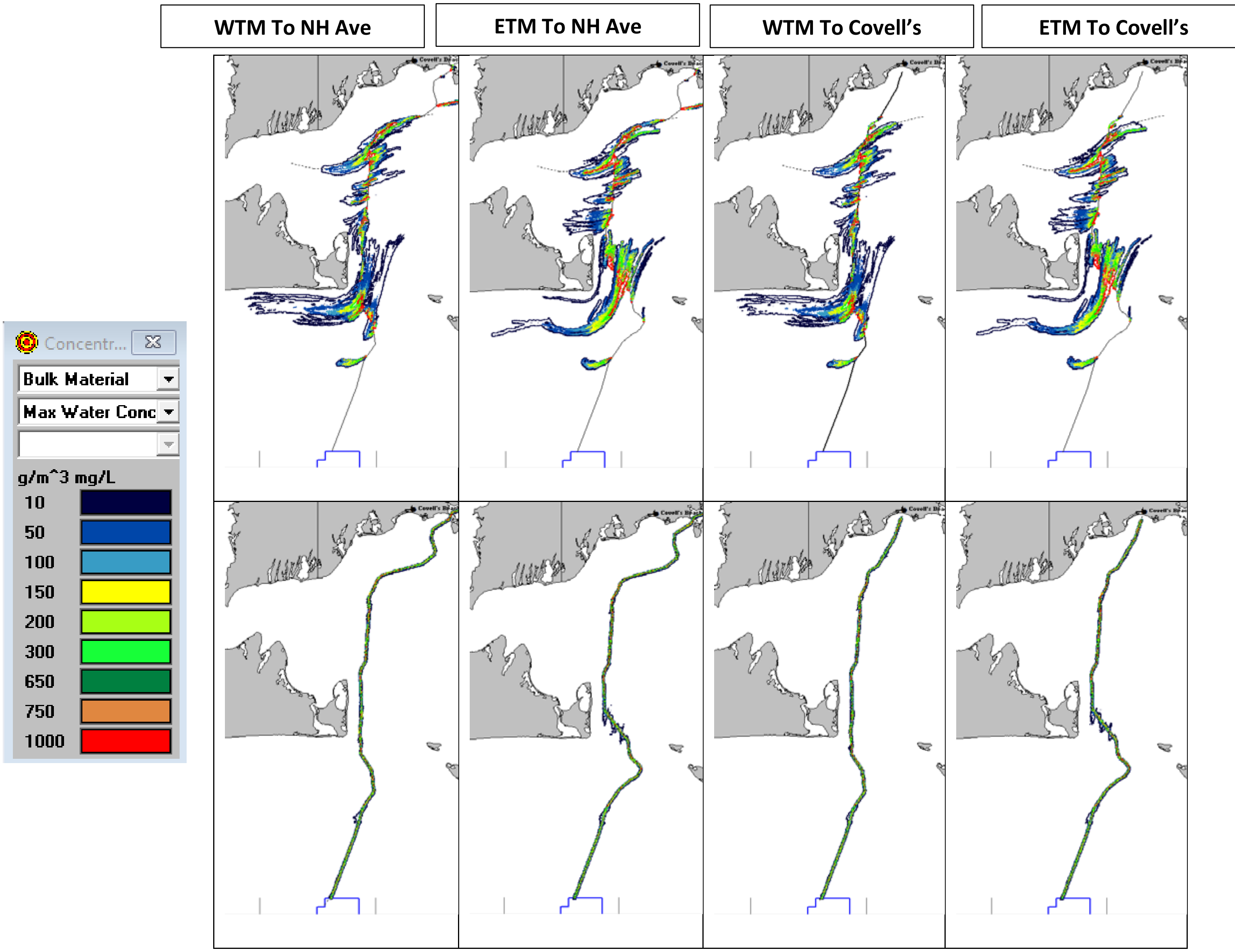


Figure 36. Map of time-integrated maximum concentrations for the OECC construction activities for TSHD Pre Dredge + Cable Installation. Top row shows results from simulation of dredging operations via TSHD only and bottom row shows results from cable installation (without jetting for sand wave clearance).

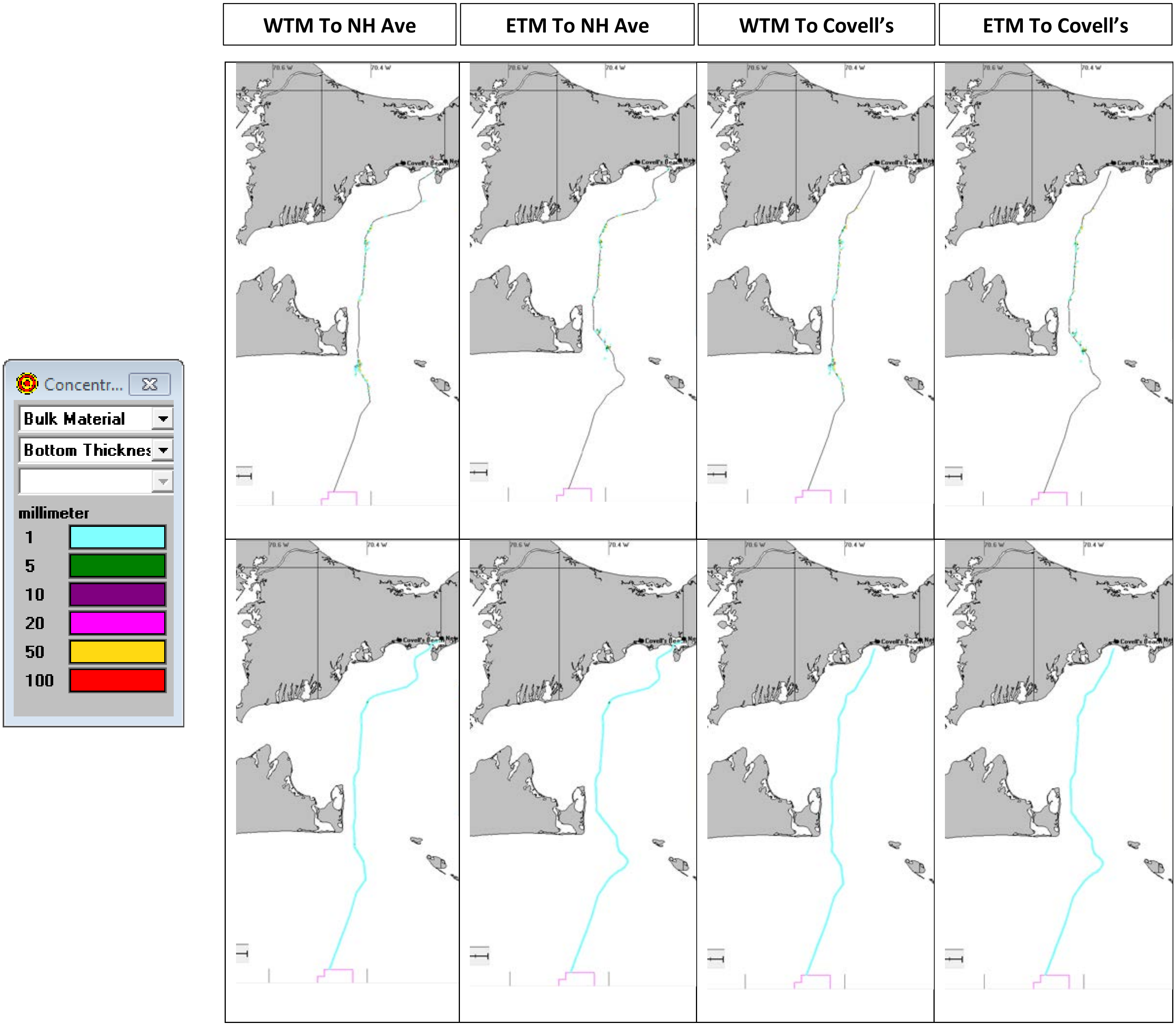

WTM To NH Ave | ETM To NH Ave | WTM To Covell’s | ETM To Covell’s

Figure 37. Map of deposition for the OECC construction activities for TSHD Pre Dredge + Cable Installation. Top row shows results from simulation of dredging operations via TSHD only and bottom row shows results from cable installation (without jetting for sand wave clearance).

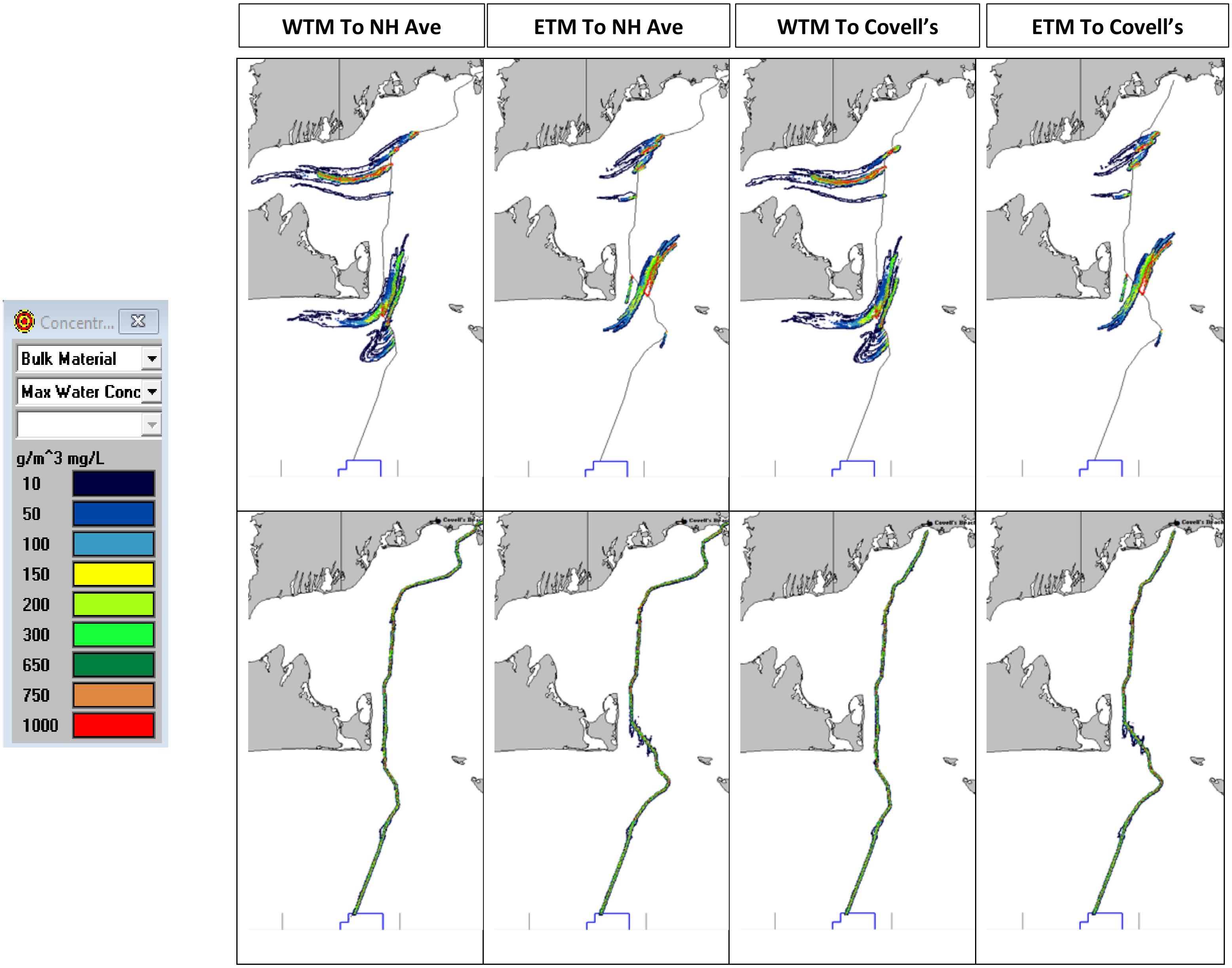


Figure 38. Map of time-integrated maximum concentrations for the OECC construction activities for Limited TSHD Pre Dredge + Cable Installation aided by Jetting. Top row shows results from simulation of limited TSHD dredging operations prior to cable installation and bottom row shows results from cable installation aided by jetting.

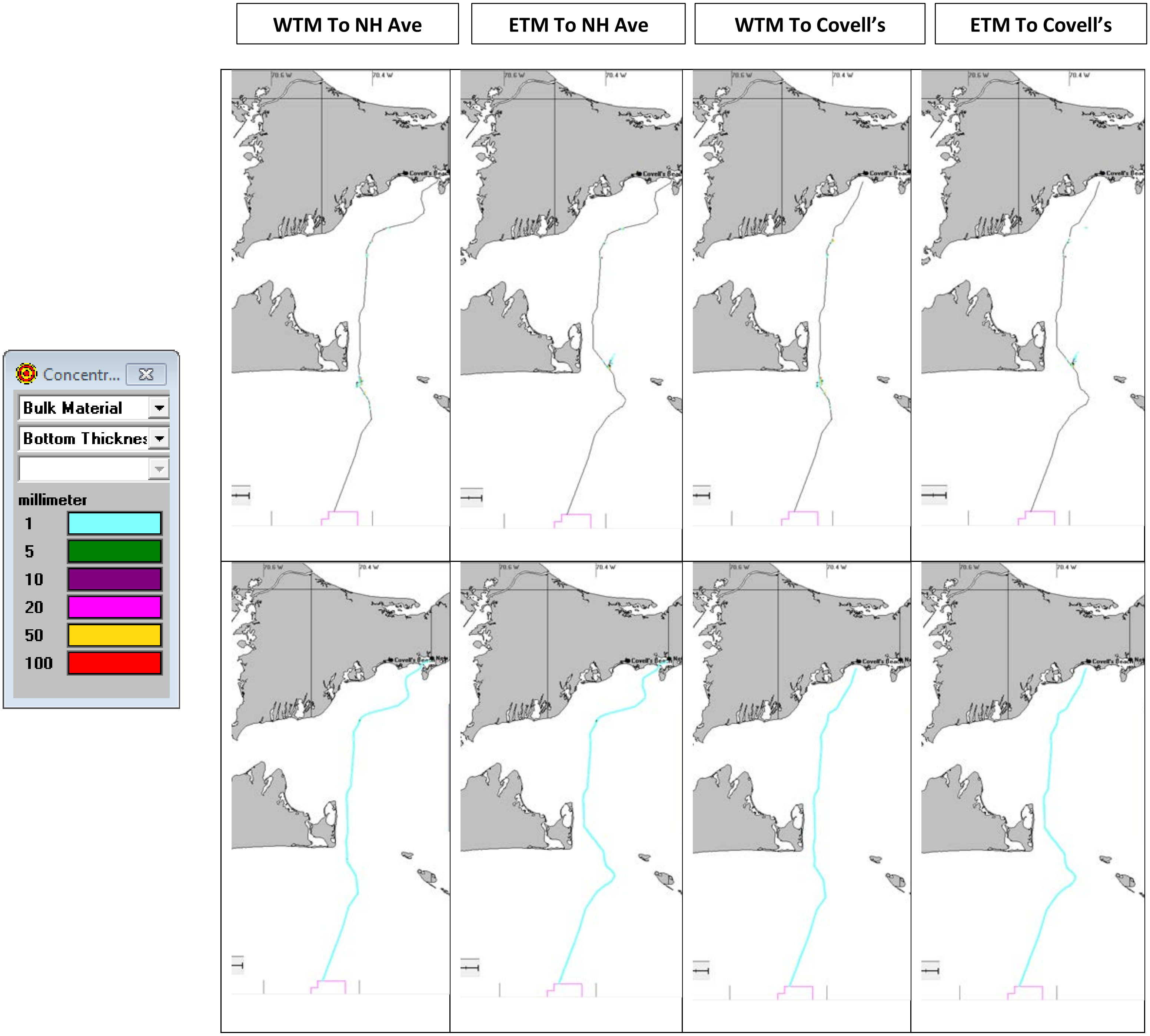


Figure 39. Map of deposition for the OECC construction activities for Limited TSHD Pre Dredge + Cable Installation aided by Jetting. Top row shows results from simulation of limited TSHD dredging operations prior to cable installation and bottom row shows results from cable installation aided by jetting.

The results from all scenarios were analyzed to determine the area over specific thresholds for various durations. The areas are not contiguous but a sum of all individual concentration grid cells that exceed the threshold anywhere in the water column for the duration of interest. Table 15 through Table 19 provide a summary of these areas for durations of 60 minutes, 120 minutes, 180 minutes, and 360 minutes, respectively. The durations were based on a combination of timeframes of biological significance and values that would help demonstrate the transient nature of the physical impacts. The post processing included hourly calculations up to 6 hours (360 minutes) and then 12 hours, 24 hours, and 48 hours; however, there were no areas over the thresholds for the 12 hour, 24 hour, or 48 hour duration. In reviewing these tables and areas it is helpful to keep in mind that the concentration grid resolution is 50 m in the horizontal plane and that for a route of 60 km in length the area covered by the grid cells along the route would be (60,000 m x 50 m = 3 km^2). Further when the source is introduced to the concentration grid, the mass is spread out across a central cell and four neighboring cells and therefore the cell footprint of initial loading is close to 5 x 3 km^2 or 15 km^2. The dredge source is introduced in a smaller footprint since the dredging is intermittent and does not take place along the entire route.

From this set of four tables it can be seen that the areas above 10 mg/L are the greatest and they drop off rapidly with increasing concentration threshold and with increasing duration. For example, the WM to Covell's OECC for Cable Installation aided by Jetting (# 9) has 12.3 km^2 over 10 mg/L for over 60 minutes, which reduces to 0.01 km^2 over 650 mg/L for over 60 minutes (Table 15). The concentrations along this route similarly reduce quickly with time: the concentrations over 10 mg/L reduce from 16.6 km^2 for 60 minutes (Table 15) to 1.06 km^2 for 120 minutes (Table 16), to 0.15 km^2 for 180 minutes (Table 17) to zero for 240 minutes. Also for this route, concentrations above 100 mg/L do not endure for 120 minutes. Similar trends are noted for all other routes presented.

The representative inter-array cable and the EM to NH Avenue OECC were run for both typical and maximum impact installation parameters. The change in parameters results in a relatively large (~4X) increase in area of over 10 mg/L for the 60 minute duration (Table 15), and similarly increases in area over each threshold value for the inter-array simulations. For durations longer than 60 minutes (Table 16 through Table 19), concentrations above the 10 mg/L only persist for the maximum impact simulation. Further the areas over 10 mg/L that persist are greater for the maximum impact parameters simulation as compared to the typical parameter simulation. The trend of increasing area does not follow for the comparison of the typical to maximum impact parameters for the simulations of the EM – NH Avenue route; the reason for this is due to the faster loading and swift currents which combine to reduce the duration that concentrations in a given area stay above particular thresholds.

A summary of the area of deposition over thickness thresholds is provided in Table 20. The cable installation scenarios result in a maximum thickness less than 10 mm whereas the TSHD scenarios result in small areas with a thickness of 100 mm or greater. For both the inter-array and OECC maximum impact cable installation scenarios, the areas are greater for each thickness level as compared to the simulation with typical parameters.

Table 15. Summary of area over threshold concentrations for 60 minutes or longer for all complete routes. Typical (“Typ”) and maximum impact (“Max”) are presented where applicable. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	**Comp.**	**Route**	**Activity**	**Typ or Max**	**Concentration Thresholds in mg/L**								
					10	**50**	**100**	**150**	**200**	**300**	**650**	**750**	**1000**
					Areas above Concentration Threshold (km^2)								
1	WDA	Inter-Array	Cable Installation	Typ	9.73	3.01	0.95	0.59	0.02				
2	WDA	Inter-Array	Cable Installation	Max	36.40	5.62	1.92	0.29	0.06				
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ	2.36	0.11	0.07	0.05	0.04	0.03	0.01	0.01	0.01
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ	5.27	0.75	0.21	0.09	0.06	0.02	0.01	0.01	0.01
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ	2.26	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	OECC	EM – Covell’s	Limited TSHD Pre Dredge	Typ	5.27	0.75	0.21	0.09	0.06	0.02	0.01	0.01	0.01
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ	13.70	6.55	2.79	0.79	0.19	0.06	0.01		
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ	14.80	7.08	2.86	0.90	0.22	0.04	0.01		
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ	12.30	5.82	2.38	0.62	0.13	0.04	0.01		
10	OECC	EM – Covell’s	Cable Installation aided by Jetting	Typ	13.30	6.38	2.52	0.76	0.14	0.02			
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	19.70	2.55	0.95	0.46	0.27	0.19	0.05	0.03	0.02
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	19.70	4.27	1.38	0.51	0.30	0.20	0.04	0.03	0.02
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ	17.40	1.67	0.75	0.33	0.17	0.11	0.04	0.03	0.02
14	OECC	EM – Covell’s	TSHD Pre Dredge	Typ	17.20	3.64	1.00	0.30	0.19	0.13	0.03	0.03	0.01
15	OECC	WM - NH Ave	Cable Installation	Typ	13.50	6.34	2.49	0.60	0.10	0.02			
16	OECC	EM - NH Ave	Cable Installation	Typ	14.70	7.05	2.78	0.77	0.15	0.01			
17	OECC	WM - Covell's	Cable Installation	Typ	12.10	5.62	2.14	0.47	0.04				
18	OECC	EM – Covell’s	Cable Installation	Typ	13.30	6.21	2.37	0.63	0.08				
19	OECC	EM - NH Ave	Cable Installation	Max	9.94	1.16	0.12	0.03	0.01	0.01			

Table 16. Summary of area over threshold concentrations for 120 minutes or longer for all complete route. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	**Comp.**	**Route**	**Activity**	**Typ or Max**	**Concentration Thresholds in mg/L**								
					10	**50**	**100**	**150**	**200**	**300**	**650**	**750**	**1000**
					Areas above Concentration Threshold (km^2)								
1	WDA	Inter-Array	Cable Installation	Typ	4.67								
2	WDA	Inter-Array	Cable Installation	Max	21.40	0.55	0.01						
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ	0.17								
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ	0.88								
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ	0.18								
6	OECC	EM – Covell's	Limited TSHD Pre Dredge	Typ	0.88								
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ	1.51	0.01							
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ	1.14	0.01							
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ	1.06								
10	OECC	EM – Covell's	Cable Installation aided by Jetting	Typ	0.72								
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	5.94	0.47	0.09	0.02	0.01	0.01			
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	7.12	0.78	0.06	0.03	0.02	0.01			
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ	3.85	0.37	0.07	0.01	0.01				
14	OECC	EM – Covell's	TSHD Pre Dredge	Typ	5.70	0.67	0.01						
15	OECC	WM - NH Ave	Cable Installation	Typ	1.45	0.01							
16	OECC	EM - NH Ave	Cable Installation	Typ	1.09	0.01							
17	OECC	WM - Covell's	Cable Installation	Typ	1.06								
18	OECC	EM – Covell's	Cable Installation	Typ	0.71								
19	OECC	EM - NH Ave	Cable Installation	Max	0.65								

Table 17. Summary of area over threshold concentrations for 180 minutes or longer for all complete routes. Typical (“Typ”) and maximum impact (“Max”) are presented where applicable. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	**Comp.**	**Route**	**Activity**	**Typ or Max**	**Concentration Thresholds in mg/L**								
					10	**50**	**100**	**150**	**200**	**300**	**650**	**750**	**1000**
					Areas above Concentration Threshold (km^2)								
1	WDA	Inter-Array	Cable Installation	Typ	1.30								
2	WDA	Inter-Array	Cable Installation	Max	12.10	0.05							
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ									
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ	0.11								
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ									
6	OECC	EM – Covell’s	Limited TSHD Pre Dredge	Typ	0.11								
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ	0.18								
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ	0.10								
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ	0.15								
10	OECC	EM – Covell’s	Cable Installation aided by Jetting	Typ	0.07								
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	1.69	0.02							
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	3.87	0.07							
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ	0.83	0.01							
14	OECC	EM – Covell’s	TSHD Pre Dredge	Typ	2.78	0.05							
15	OECC	WM - NH Ave	Cable Installation	Typ	0.18								
16	OECC	EM - NH Ave	Cable Installation	Typ	0.08								
17	OECC	WM - Covell's	Cable Installation	Typ	0.15								
18	OECC	EM – Covell’s	Cable Installation	Typ	0.06								
19	OECC	EM - NH Ave	Cable Installation	Max	0.14								

Table 18. Summary of area over threshold concentrations for 240 minutes or longer for all complete routes. Typical ("Typ") and maximum impact ("Max") are presented where applicable. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	Comp.	Route	Activity	Typ or Max	Concentration Thresholds in mg/L								
					10	50	100	150	200	300	650	750	1000
					Areas above Concentration Threshold (km^2)								
1	WDA	Inter-Array	Cable Installation	Typ	0.27								
2	WDA	Inter-Array	Cable Installation	Max	6.88	0.05							
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ									
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ									
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ									
6	OECC	EM – Covell's	Limited TSHD Pre Dredge	Typ									
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ									
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ									
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ									
10	OECC	EM – Covell's	Cable Installation aided by Jetting	Typ	0.01								
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	0.45	0.02							
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	1.90	0.07							
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ	0.09	0.01							
14	OECC	EM – Covell's	TSHD Pre Dredge	Typ	1.18	0.05							
15	OECC	WM - NH Ave	Cable Installation	Typ	0.02								
16	OECC	EM - NH Ave	Cable Installation	Typ									
17	OECC	WM - Covell's	Cable Installation	Typ	0.02								
18	OECC	EM – Covell's	Cable Installation	Typ									
19	OECC	EM - NH Ave	Cable Installation	Max	0.01								

Table 19. Summary of area over threshold concentrations for 360 minutes or longer for all complete routes. Typical ("Typ") and maximum impact ("Max") are presented where applicable. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	Comp.	Route	Activity	Typ or Max	Concentration Thresholds in mg/L								
					10	**50**	**100**	**150**	**200**	**300**	**650**	**750**	**1000**
					Areas above Concentration Threshold (km^2)								
1	WDA	Inter-Array	Cable Installation	Typ									
2	WDA	Inter-Array	Cable Installation	Max	1.33								
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ									
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ									
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ									
6	OECC	EM – Covell's	Limited TSHD Pre Dredge	Typ									
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ									
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ									
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ									
10	OECC	EM – Covell's	Cable Installation aided by Jetting	Typ									
11	OECC	WM - NH Ave	TSHD Pre Dredge	Typ									
12	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	0.06								
13	OECC	WM - Covell's	TSHD Pre Dredge	Typ									
14	OECC	EM – Covell's	TSHD Pre Dredge	Typ									
15	OECC	WM - NH Ave	Cable Installation	Typ									
16	OECC	EM - NH Ave	Cable Installation	Typ									
17	OECC	WM - Covell's	Cable Installation	Typ									
18	OECC	EM – Covell's	Cable Installation	Typ									
19	OECC	EM - NH Ave	Cable Installation	Max									

Table 20. Summary of deposition area over threshold concentrations for all complete routes. Typical ("Typ") and maximum impact ("Max") are presented where applicable. Violet shading used for Inter-Array and OECC simulations with corresponding typical and maximum impact parameters. White (no) shading used for all THSD simulations and grey shading used for OECC cable installation scenarios, with the exception of the variant which was run with both typical and maximum impact parameters.

#	Comp.	Route	Activity	Typ or Max	1 mm	5 mm	10 mm	20 mm	50 mm	100 mm
					Areas of Deposition above Threshold (km^2)					
1	WDA	Inter-Array	Cable Installation	Typ	2.42					
2	WDA	Inter-Array	Cable Installation	Max	3.66					
3	OECC	WM - NH Ave	Limited TSHD Pre Dredge	Typ	0.48	0.11	0.08	0.06	0.05	0.05
4	OECC	EM - NH Ave	Limited TSHD Pre Dredge	Typ	0.26	0.10	0.06	0.03	0.02	0.02
5	OECC	WM - Covell's	Limited TSHD Pre Dredge	Typ	0.42	0.11	0.08	0.06	0.05	0.05
6	OECC	EM - Covell's	Limited TSHD Pre Dredge	Typ	0.26	0.10	0.06	0.03	0.02	0.02
7	OECC	WM - NH Ave	Cable Installation aided by Jetting	Typ	9.82	0.03				
8	OECC	EM - NH Ave	Cable Installation aided by Jetting	Typ	10.30	0.03				
9	OECC	WM - Covell's	Cable Installation aided by Jetting	Typ	8.68	0.01				
#	OECC	EM - Covell's	Cable Installation aided by Jetting	Typ	9.10					
#	OECC	WM - NH Ave	TSHD Pre Dredge	Typ	1.33	0.30	0.18	0.14	0.13	0.13
#	OECC	EM - NH Ave	TSHD Pre Dredge	Typ	1.20	0.41	0.17	0.11	0.10	0.10
#	OECC	WM - Covell's	TSHD Pre Dredge	Typ	1.23	0.29	0.17	0.13	0.12	0.12
#	OECC	EM - Covell's	TSHD Pre Dredge	Typ	1.06	0.37	0.14	0.10	0.08	0.08
#	OECC	WM - NH Ave	Cable Installation	Typ	9.80	0.02				
#	OECC	EM - NH Ave	Cable Installation	Typ	10.20	0.03				
#	OECC	WM - Covell's	Cable Installation	Typ	8.64					
#	OECC	EM - Covell's	Cable Installation	Typ	9.08					
#	OECC	EM - NH Ave	Cable Installation	Max	10.50	0.03				

Simulations of pre-cable installation dredging using a TSHD along the OECC show that plumes originating from the source are intermittent along the route, due to the intermittent need for dredging. The plume of excess TSS at 10 mg/L and 750 mg/L extends up to 16 km and 5 km from the route centerline for 2-3 hours, respectively, though may be less extensive at varying locations along the route. Relatively high concentrations (>1000 mg/L) are predicted at distances up to 5 km from the route centerline in response to the relatively high loading of dumping and swift transport of the dumped sediments, but this high concentration only persists for <2 hours. In general, the excess concentrations over 10 mg/L from dredging can extend several km from the route centerline and may be present throughout the entire water column but are temporary and typically dissipate within about 6 hours. The deposition greater than 1.0 mm associated with the TSHD drag arm is mainly constrained to within 150 m from the route centerline whereas the deposition greater than 1.0 mm associated with overflow and disposal extends to greater distances from the source, mainly within 1 km though such deposition can extend up to 2.3 km in isolated patches when subject to swift currents through Muskeget Channel.

The simulations of the cable installation showed that both the footprint of the 10 mg/L excess concentration plume and the footprint of deposition over 1.0 mm stayed close to the route centerline. The maximum excursion of the 10 mg/L excess plume extended up to ~2 km, though typically less than 200 m from the route centerline. The excess concentrations stemming from cable installation, both with and without jetting for sand wave clearance, remain relatively close to the route centerline, are constrained to the bottom of the water column, and are also short-lived (typically dissipating within 4-6 hours). Deposition greater than 1.0 mm was limited to within 100 m from the route centerline for typical installation parameters.

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MEMORANDUM

RPS |Ocean Science Division

55 Village Square Drive
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TO: Maria Hartnett, Epsilon Associates
FROM: Deborah Crowley, RPS
DATE: 18 October 2018
RE: Updated Sediment Dispersion Modeling in Lewis Bay

1 Background

Vineyard Wind, LLC (“Vineyard Wind”) is proposing an ~800 megawatt (“MW”) wind energy project within BOEM Lease Area OCS-A 0501, consisting of offshore wind turbine generators (“WTGs”) each placed on a foundation support structure, electrical service platforms (“ESPs”), an Onshore Substation, offshore and onshore cabling, and onshore Operations & Maintenance Facilities (these facilities will hereafter be referred to as the “Project”). RPS previously completed a sediment dispersion modeling study of sediment disturbing construction activities associated with the Project (namely offshore cable installation and pre cable installation spot dredging of sand waves) that was included in the Project’s Construction and Operations Plan (“COP”) and Supplemental Draft Environmental Impact Report (“SDEIR”). This previous study included the entire length of the Offshore Export Cable Corridor (“OECC”) from the Wind Development Area in federal waters to the two potential Landfall Sites at Covell’s Beach and New Hampshire Avenue in Lewis Bay. The modeling incorporated grain size data collected during Vineyard Wind’s 2017 survey program from regularly spaced vibracores along the entire OECC. The previous report contained details on assumptions, inputs and outputs associated with hydrodynamic and sediment dispersion modeling.

Since the initial sediment dispersion modeling study was completed, Vineyard Wind completed its 2018 survey program and more sediment samples have been obtained and analyzed and a high resolution bathymetric survey has been completed in Lewis Bay. Additionally, there has been a very minor shift to the OECC alignment within Lewis Bay. Accordingly, updated sediment dispersion modeling has been conducted that is specific to Lewis Bay. This memo documents the new sediment data made available within and just outside Lewis Bay and provides updated sediment dispersion modeling of the cable installation based on the new sediment data. Also included is a summary of new site specific hydrodynamics that were generated with the same model and approach as the previous effort; however, the hydrodynamics were refined for a smaller region with higher resolution using the recently acquired high resolution bathymetry to better capture the features within Lewis Bay.

The sections of this memo include Section 2: Updated Sediment Characterization within Lewis Bay, Section 3: Hydrodynamic modeling of Lewis Bay and Section 4: Updated Sediment Dispersion Modeling of Lewis Bay.

2 Updated Sediment Characterization

As part of Vineyard Wind's 2018 survey program, additional vibracore samples were obtained, including five vibracore samples within Lewis Bay . The samples were sent to Alpha Analytical for analysis and the results of the analysis (sieve analysis) were provided to RPS. The sediment grain size distributions were assessed to develop the percentages within the five classes (bins) of sediment used in the sediment dispersion modeling in the same manner as for the previous modeling. For any given vibracore location, the sediment grain size characteristics from all available samples within the target cable installation depths (2 m for typical and 3 m for maximum impact) were used to establish a singular depth weighted grain size distribution at a given location. Additionally the percent solid (by mass) obtained as part of the laboratory analysis via standard operating protocol (SOP) 2540G was used to calculate the percent solids by volume at each sample site. The percent solid by volume represents the percent of the volume that is sediment as opposed to water which fills the interstitial voids; high percent solid (by volume) numbers reflect more sediments being introduced to the water column.

Figure 1 shows the sediment characterizations used in the previous modeling and Figure 2 shows the sediment characterizations used in the present updated modeling; both figures show sediment characterization for the typical cable installation simulation which has a target depth of 2 m. Also shown in these figures is the route section (red) that was modeled in this present analysis along with the previous route (light grey). The pink labels are the vibracore IDs and the white numbers located to the bottom right of each sample are the percent solid by volume. A summary of the characterizations as used by the model for the 2 m and 3 m depths are presented in Table 1 and Table 2 respectively.

Tables 1 and 2 indicate that the vibracores within Lewis Bay have a relatively higher percent of fine material and most samples have a higher percent solid (by volume) than what was used in the previous modeling from the closest vibracore sample located just outside Lewis Bay (VC 49). However, the general sediment classification is similar to what was used previously in that both sample sets (the 2018 Lewis Bay vibracores and the 2017 vibracore outside Lewis Bay [VC 49] used in the previous modeling) are predominately coarse sand.

Figure 1 Sediment characterizations used in the previous modeling.

Figure 2 Sediment characterizations used in the present modeling.

Table 1 Sediment characterization used in modeling for typical installation simulations (Target Depth 2m).

Previous vs Present	ID - Target Depth	Clay 0 -7 um	Fine silt 8 -35 um	Coarse silt 36-74 um	Fine sand 75-130 um	Coarse sand >130 um	Percent Solid by Volume
		Percentages (The Five Bins Sum to 100%)					%
Previous	VC49 -2M	1.22	1.15	0.92	0.52	96.19	70.00
Present	VC99-2M	6.77	6.77	6.77	7.77	71.93	88.60
Present	VC100-2M	2.73	2.73	2.73	16.46	75.37	81.57
Present	VC102 -2M	8.03	8.03	8.03	4.71	71.19	48.00
Present	VC101-2-2M	2.47	2.47	2.47	9.42	83.18	78.20
Present	VC103-2M	1.18	1.18	1.18	11.32	85.14	85.21
Present	VC112-2M	0.99	0.99	0.99	3.00	94.02	86.44

Table 2 Sediment characterization used in modeling for maximum impact installation simulations (Target Depth 3m).

Previous vs Present	ID - Target Depth	Clay 0 -7 um	Fine silt 8 - 35 um	Coarse silt 36 -74 um	Fine sand 75 - 130 um	Coarse sand >130 um	Percent Solid by Volume
		Percentages (The Five Bins Sum to 100%)					%
Previous	VC49 -3M	0.96	0.91	0.75	0.53	96.85	70.00
Present	VC99-3M	7.51	7.51	7.51	7.81	69.66	88.60
Present	VC100-3M	2.29	2.29	2.29	17.07	76.05	82.02
Present	VC102 -3M	8.03	8.03	8.03	4.71	71.19	48.00
Present	VC101-2-3M	2.47	2.47	2.47	9.42	83.18	78.20
Present	VC103-3M	1.10	1.10	1.10	11.42	85.29	85.57
Present	VC112-3M	0.96	0.96	0.96	2.65	94.46	86.53

3 Hydrodynamic Modeling of Lewis Bay

A new hydrodynamic model application was generated that integrated the 2018 bathymetry survey and was a smaller domain with higher grid resolution to better capture the features of Lewis Bay. The same hydrodynamic model (HYDROMAP) and approach was taken; however, the modeling was refined to focus on Lewis Bay and incorporate additional information available from Vineyard Wind's 2018 survey:

- The model grid extent was focused on Lewis Bay and extended to the adjacent waters in Hyannis Harbor.
- The grid resolution was finer than the previous grid within Lewis Bay.
- The grid bathymetry was updated to reflect the most recent (2018) bathymetric survey
- The open boundary tidal forcing was adjusted based on the updated position of the open boundaries.

Figure 3 shows the model grid used in the present modeling and Figure 4 shows the gridded bathymetry that reflects soundings from the recent survey. A summary of the tidal constituents used at the open boundaries is presented in Table 3; these values were based on data from a regional model of tides.

Table 3. Summary of tidal boundary conditions.

Tidal Constituent	Amplitude (m)	Phase (Degrees Relative to GMT)
M2	0.594	135.0
S2	0.055	170.6
N2	0.127	96.3
K1	0.191	207.3
O1	0.095	211.6
Q1	0.018	190.91

Snapshots of the model predicted flood and ebb currents (near peak) are presented in Figure 5 and Figure 6 respectively. These show that the currents are relatively weak in most locations and are greater at the entrance to the bay.

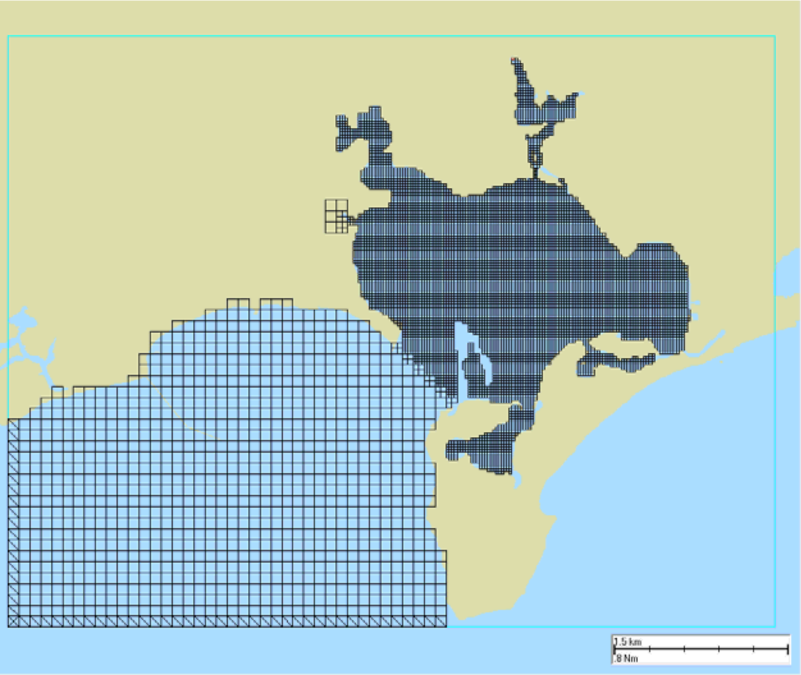

Figure 3. Model grid.

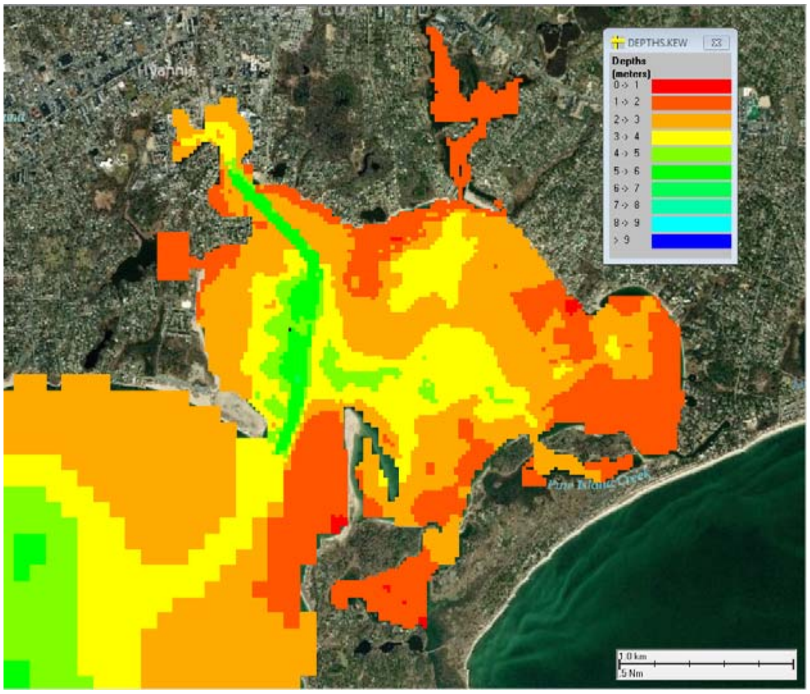

Figure 4. Model grid bathymetry, zoomed in to Lewis Bay.

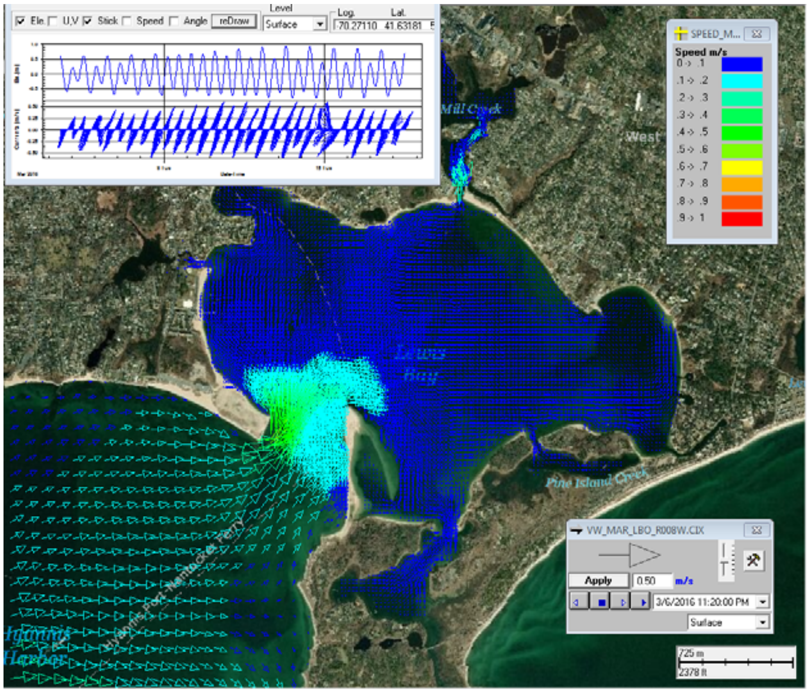

Figure 5. Snapshot of flood currents. Inset (upper left) shows a time series of water surface elevation (top) and a stick plot of currents (bottom) at the inlet. Colored arrows represent current speeds in accordance to the legend (upper right inset)

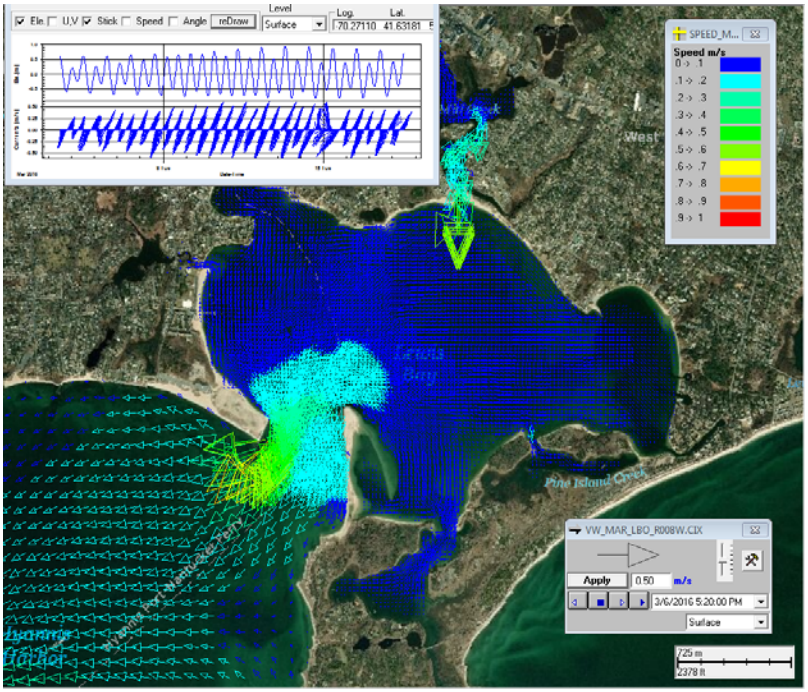

Figure 6. Snapshot of ebb currents. Inset (upper left) shows a time series of water surface elevation (top) and a stick plot of currents (bottom) at the inlet. Colored arrows represent current speeds in accordance to the legend (upper right inset)

4 Updated Sediment Dispersion Modeling of Cable Installation in Lewis Bay

Sediment dispersion modeling of the cable installation in Lewis Bay was performed using the same model (SSFATE) and approach as previously documented. The modeling approach was refined to focus on Lewis Bay as follows:

- Only that portion of the route within Lewis Bay and a portion of the adjacent waters of Hyannis Harbor was modeled.
- The model was updated to reflect the new sediment characterizations available within the bay.
- The depth grid reflected the soundings available from the recent bathymetric survey.

The model was run to simulate the route portion shown in Figure 1 and Figure 2 for both typical and maximum impact conditions. The same assumptions regarding trench cross sectional area (volume), production rate, sediment loss rate and initialization profile that were used in the previous modeling effort were also used in the present modeling. The maximum impact condition is a conservative scenario that is unlikely to be used in Lewis Bay but is included for completeness.

The modeling was used to predict the spatially and temporally varying excess water column concentrations of total suspended solids (TSS) as well as the seabed deposition thicknesses. The time integrated map of maximum concentrations for the typical scenario are presented in Figure 7 and Figure 8. These figures show the same results in the plan view; however, Figure 7 contains a vertical cross section as an inset and Figure 8a and 8b include a time series at a point as an inset. Figure 8b is overlaid on a map showing the aquaculture lease areas within Lewis Bay. The associated seabed deposition for the typical scenario is presented in Figure 9. The time integrated map of maximum concentrations for the maximum impact scenario are presented in Figure 10 and Figure 11. These figures show the same results in the plan view; however, Figure 10 contains a vertical cross section as an inset and Figure 11a and 11b include a time series at a point as an inset. Figure 11b is overlaid on a map showing the aquaculture lease areas within Lewis Bay. The associated seabed deposition for the typical scenario is presented in Figure 12. A summary of areas over specific thresholds (e.g. 10 mg/L) for specific durations (e.g. 1 hr.) is presented in Table 4 and a summary of areas over specific deposition thresholds is presented in Table 5. Following is a summary of these results.

For typical installation parameters:

- The extent of the 10 mg/L excess concentration extended up to 512 m from the route centerline as measured perpendicular from the centerline. The extent was typically less than this (on the order of 180 m); however, close to the termination point near the shore the plume is larger than the along the rest of the route.
- The inset on Figure 8 with the time history of concentration shows that concentrations above 10 m/gL at the location queried in the figure persist for less than an hour.
- The extent of deposition of 1 mm thickness was 90 m from the route centerline.
- With respect to the aquaculture lease areas, deposition >1 mm does not reach the aquaculture areas and the predicted sediment plume (as delineated by concentrations of 10 mg/L or greater) likewise does not reach the aquaculture areas.

For maximum impact installation parameters:

- The extent of the 10 mg/L excess concentration extended up to 635 m from the route centerline as measured perpendicular from the centerline. The extent was typically less than this (on the order of 200 m); however close to the termination point near the shore the plume is larger than the along the rest of the route.
- The inset on Figure 11 with the time history of concentration shows that concentrations above 10 mg /L at the location queried in the figure persist for less than an hour.
- The extent of deposition of 1 mm thickness was 100 m from the route centerline.
- With respect to the aquaculture lease areas, deposition >1 mm does not reach the aquaculture areas and the predicted sediment plume (as delineated by concentrations of 10 mg/L or greater) does not reach the aquaculture areas, though the boundary of the 10 mg/L contour, which persists for less than 1-2 hours, does approach the aquaculture areas.

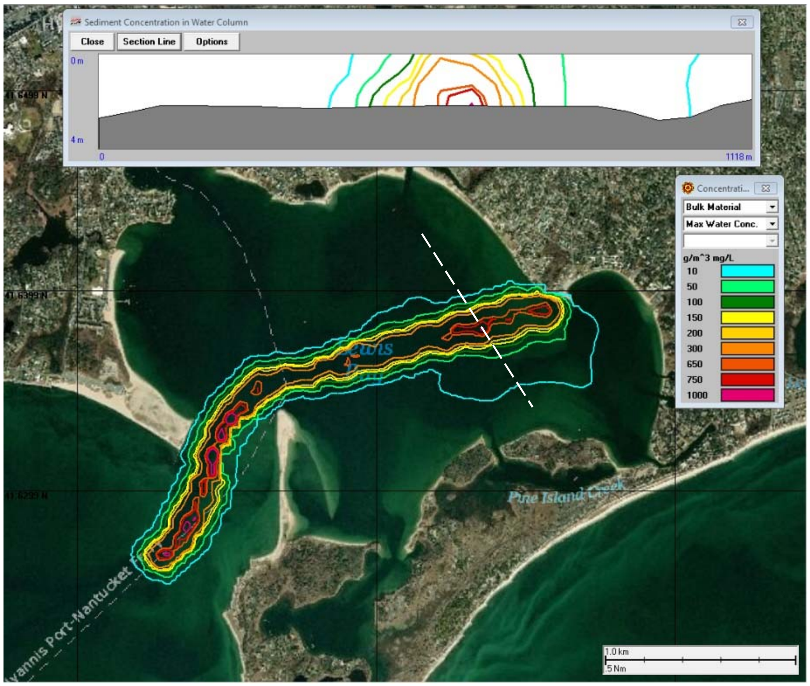

Figure 7. Map of time integrated maximum concentrations for typical installation parameters. Upper inset shows vertical cross section along the white dashed line (approximately).

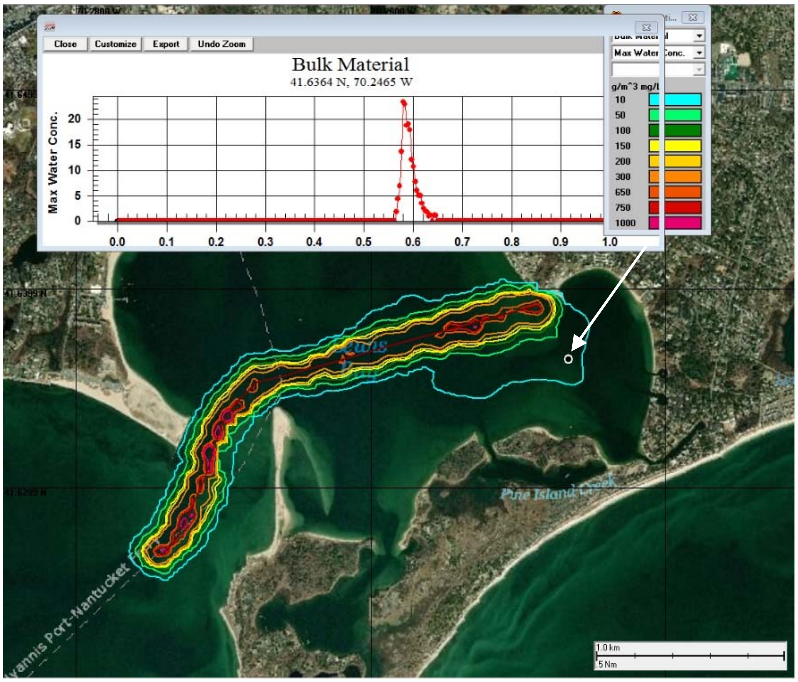

Figure 8a. Map of time integrated maximum concentrations for typical installation parameters. Upper inset shows time history at the point identified in the figure. The red markers are plotted at 5 minute intervals.

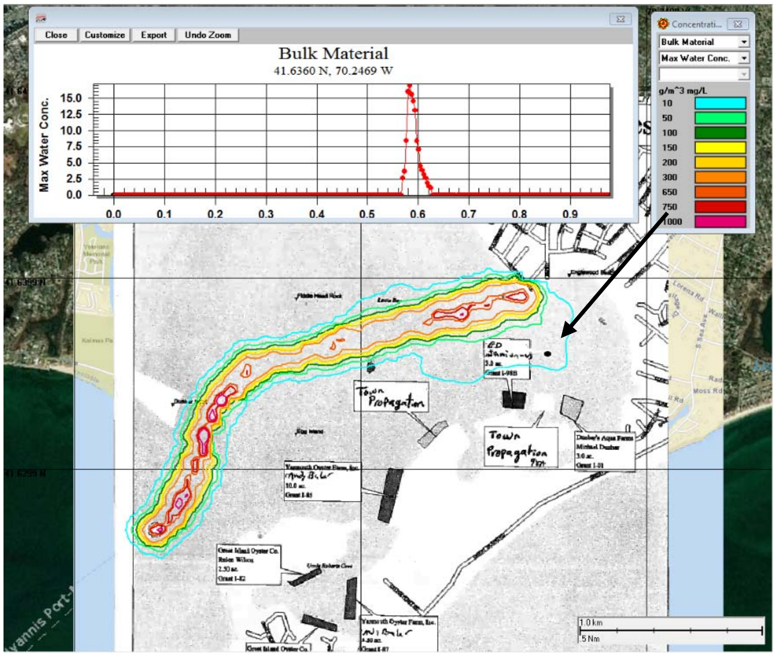

Figure 8b. Map of time integrated maximum concentrations for typical installation parameters. Upper inset shows time history at the point identified in the figure. The red markers are plotted at 5 minute intervals. Overlaid on Yarmouth aquaculture lease map.

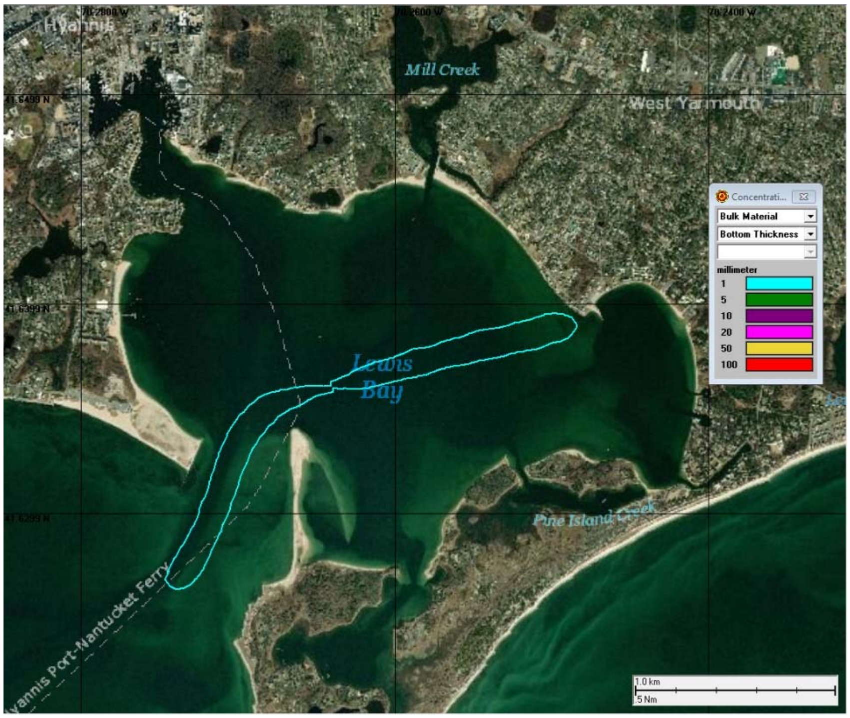

Figure 9. Map of seabed deposition thickness for typical installation parameters.

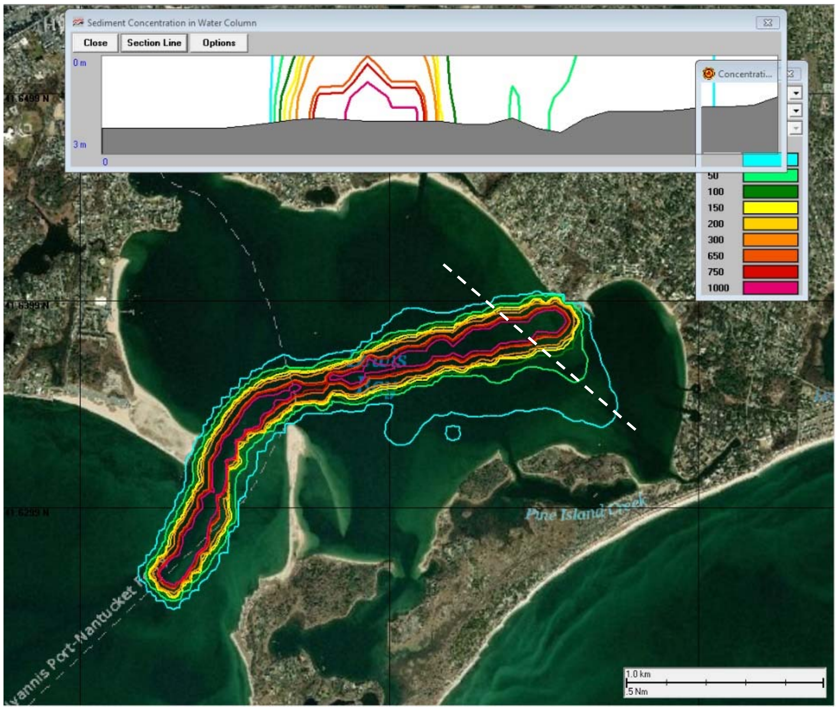

Figure 10. Map of time integrated maximum concentrations for maximum impact installation parameters. Upper inset shows vertical cross section along the white dashed line (approximately).

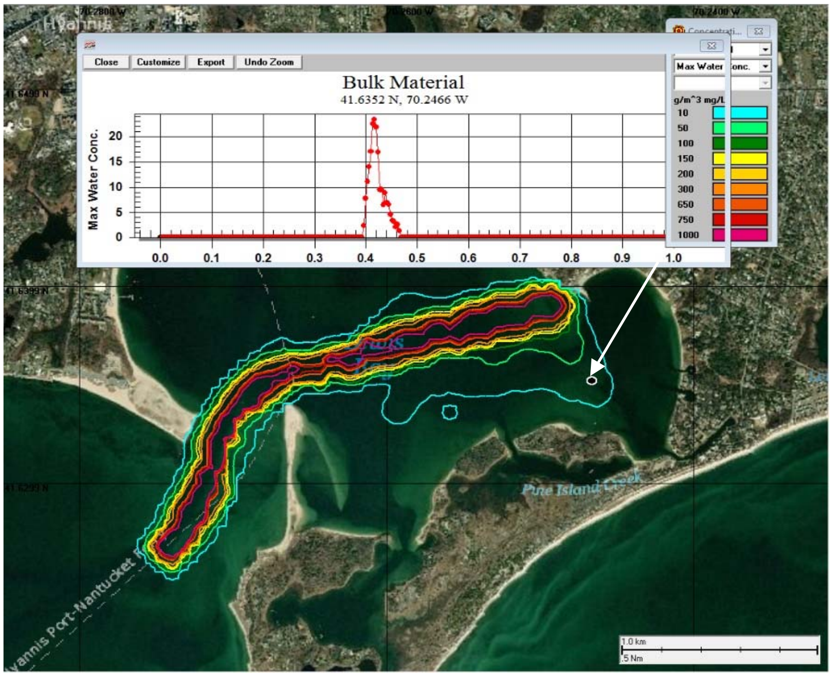

Figure 11a. Map of time integrated maximum concentrations for maximum impact installation parameters. Upper inset shows time history at the point identified in the figure, the red markers are plotted at 5 minute intervals.

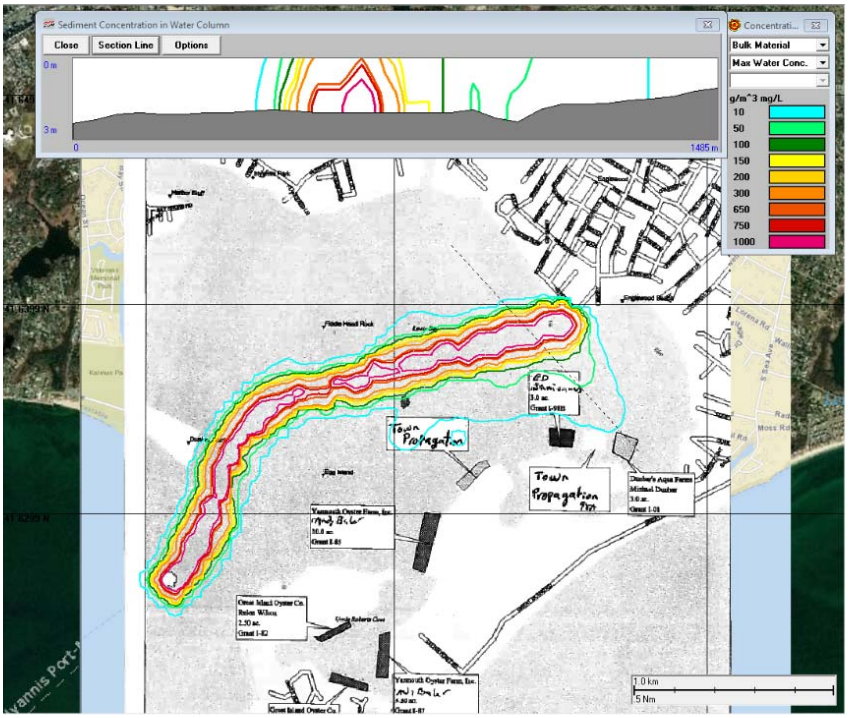

Figure 11b. Map of time integrated maximum concentrations for maximum impact installation parameters. Upper inset shows vertical cross section along the dashed line. Overlaid on Yarmouth aquaculture lease map.

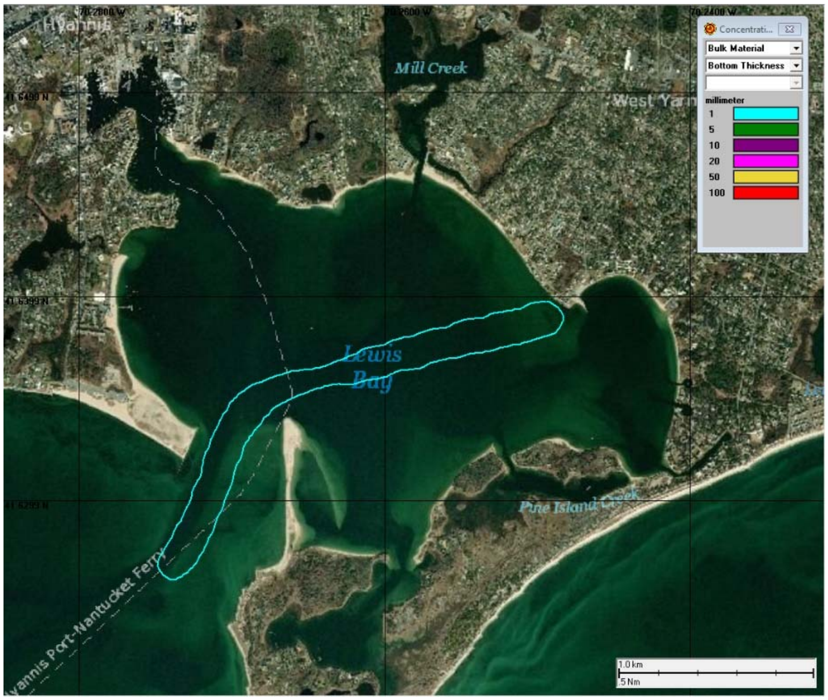

Figure 12. Map of seabed deposition thickness for maximum impact installation parameters.

Table 4. Summary of area over specific concentration thresholds for various durations.

Water Column Thresholds (mg/L)	**Typical Installation**		**Maximum Impact Installation**	
	1 hr.	**2 hr.**	**1 hr.**	**2 hr.**
	Area in km^2 Over Threshold (Left) for Duration (Above)		**Area in km^2 Over Threshold (Far Left) for Duration (Above)**	
10	0.636		0.601	0.035
50	0.247		0.107	
100	0.0923		0.015	
150	0.0175		0.003	
200				
300				
650				
750				
1000				
2000				

Table 5. Summary of area of deposition greater than specific thickness thresholds.

Typical or Maximum Impact	**1 mm**	**5 mm**	**10 mm**	**20 mm**	**50 mm**	**100 mm**
	Areas of Deposition above Threshold (km2)					
Typical	0.367					
Maximum	0.459					