Sunrise Wind New York Cable Project

Appendix 4-H

Hydrodynamic and Sediment Transport Modeling Report – New York State Waters

Prepared for:

Sunrise Wind | Powered by Ørsted & Eversource

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Hydrodynamic and Sediment Transport Modeling
New York State Waters
Sunrise Wind New York Cable Project

December 2020

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
BOEM	Bureau of Ocean Energy Management
cy	cubic yards
DC	direct current
DOER	Dredging Operations and Environmental Research Program
FRONT	Front-Resolving Observation Network with Telemetry
FVCOM	Finite-Volume Community Ocean Model
Ha	Hectares
HDD	horizontal direction drilling
IAC	inter-array cable
in	inch
km	kilometer
m	meter
mi	statute miles
mm	millimeter
m/s	meters per second
nm	nautical miles
NCEI	National Center for Environmental Information
NECOFS	Northeast Coastal Ocean Forecast System
NERACOOS	Northeast Regional Association Coastal Ocean Observation System
NOAA	National Oceanic and Atmospheric Administration
NY	New York
NYS	New York State
NYSERDA	Ney York State Energy Research and Development Authority
OCS	Offshore Converter Station
OnCS	Onshore Converter Station
OREC	Offshore Wind Renewable Energy Certificate
OSAMP	Ocean Special Area Management Plan
PTM	Particle Tracking Model
Project	Sunrise Wind Farm Project
SMS	Surface-Water Modeling System
SRWF	Sunrise Wind Farm
SRWEC	Sunrise Wind Export Cable
SRWEC–NYS	Sunrise Wind Export Cable – NY State Waters
TJB	Transition Joint Bay
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WEA	Wind Energy Areas
WTG	wind turbine generator

1.0 EXECUTIVE SUMMARY

Sunrise Wind LLC (Sunrise Wind or the Applicant), a 50/50 joint venture between Orsted North America Inc. (Orsted NA) and Eversource Investment LLC (Eversource), proposes to construct, operate, and maintain the Sunrise Wind New York Cable Project (the Project). Sunrise Wind executed a 25-year Offshore Wind Renewable Energy Certificate (OREC) contract related to the Project with the New York State Energy Research and Development Authority (NYSERDA) in October 2019. The Project will deliver power from the Sunrise Wind Farm (SRWF), located in federal waters on the Outer Continental Shelf (OCS), to the existing electrical grid in New York. The Project includes offshore and onshore components within New York State (NYS) that are subject to PSL Article VII review and will interconnect at the existing Holbrook Substation, which is owned and operated by the Long Island Power Authority (LIPA).

Specifically, power from the SRWF will be delivered to the existing mainland electric grid via distinct transmission cable segments: the submarine segment of the export cable (SRWEC), the terrestrial underground segment of the transmission cable (Onshore Transmission Cable), the new Onshore Converter Station (OnCS–DC) and the underground terrestrial segment of the interconnection cable (Onshore Interconnection Cable). The Onshore Transmission Cable, the OnCS–DC, and the Onshore Interconnection Cable are all located in the Town of Brookhaven, Suffolk County, New York (NY).

Horizontal directional drilling (HDD) is expected to connect the SRWEC to onshore Project transmission components at Smith Point County Park in the Town of Brookhaven, NY. Hydrodynamic and sediment transport modeling was conducted to assess the sediment suspension and resulting deposition from proposed construction activities associated with the SRWEC in NYS waters.

The sediment disturbance was evaluated for:

1) excavation of HDD exit pits using a mechanical dredge in NYS waters, and
2) installation of the SRWEC using jet-plowing in NYS waters (SRWEC–NYS)

The hydrodynamic and sediment transport analysis utilized existing environmental data and models to assess sediment turbidity levels (presented as Total Suspended Sediment [TSS]) and resulting deposition (thickness above seafloor) at representative Project locations.

For characterizing the hydrodynamics within the Project area, the hind-cast results of the Northeast Coastal Ocean Forecast System (NECOFS) model (NERACOOS, UMass Dartmouth Massachusetts Fishery Institution, and MIT Sea Grant College), which uses the numerical scheme of the FV-COM (Finite-Volume Coastal Ocean Model), was utilized. The NECOFS hydrodynamic model output was then used as input for sediment transport modeling within the Project construction area.

The sediment transport model chosen was the Particle Tracking Model (PTM) in the Surface-Water Modeling System (SMS), which uses the equations for the movement of fluid on a rotating earth and integrates the properties of particles within that fluid to simulate resultant transport. This model has been developed by the Coastal Inlets Research Program (CIRP) and the Dredging Operations and Environmental Research Program (DOER) at the US Army Corps of Engineers (USACE) Research and Development Center for the transport and fate of suspended sediments surrounding dredging and sub-surface construction activity and is therefore suitable for this application.

The NECOFS model was first validated within the region of Project using comparisons made between the model output and available measurements. The model was first validated using measured currents from the University of Connecticut's National Oceanographic Partnership Front-Resolving Observation Network with Telemetry (FRONT) program. Three locations and two seasons were available for comparison between the measured current data and the NECOFS model output.

The NECOFS model was also evaluated using tidal constituents developed from available measurements within the region. Comparisons were made between the NECOFS model and tidal constituents from the Offshore Renewable Energy OSAMP buoys which collected data in 2009 - 2010. Additional comparisons were made between the NECOFS model and tidal constituents developed from water level measurements at NOAA station 8510560 located in Montauk, NY.

Once the model was validated, it was desired to select a year from the 39-year hindcast that was representative of average annual conditions. To select a representative average year, bulk current statistics were computed using the NECOFS model output at five (5) representative sites along the SRWEC. A ranking process resulted in the selection of 1997 as being the most representative of average annual conditions.

Surficial sediment characteristics in NYS waters were based on the U.S. Geological Survey (USGS) East Coast Sediment Texture Database (2014) and were used to define the surficial seafloor sediments along the SRWEC and at the HDD exit pit representative location.

A summary of the sediment transport model results is given in Table EX-1. Below are some general findings from the sediment transport analysis:

- The suspended sediment plume from the proposed construction activities is transient and its location in relation to the sediment disturbance varies with the tidal cycles. The sediment plume is shown to be larger in areas where there are higher percentages of fine-grained surficial seafloor sediments.

- The excavation of HDD pits resulted in peak TSS concentrations of 60 milligrams per Liter (mg/L) with concentrations exceeding 50 mg/L within 35 meters (m) of the sediment source. This activity resulted in a 0.07 hectares (ha) area on the seafloor where the deposition thickness was greater than 10 millimeters (mm), extending a maximum of 36 m from the source. The predicted time to return to ambient turbidity levels is 1.2 hours after completion.

- For SRWEC–NYS, peak TSS concentrations reached 141 mg/L with concentrations exceeding 100 mg/L within 120 m of the SRWEC route centerline. The maximum deposition thickness was 10.1 mm resulting in a small area (0.0015 ha) having a thickness greater than 10 mm with a maximum extent of 7.5 m from the route. While the time to return to ambient turbidity levels will vary along the SRWEC route, the time to return to ambient levels was 0.3 hours after completion.

- The cumulative impacts of installing two HDD pits sequentially were assessed. The results show the planned spacing between HDD pits is sufficient to avoid overlap of sediment deposition from the two sequential activities.

- Cumulative impacts were also evaluated for the short (~ 1 km) segment where two cables split to meet the HDD pits in NYS waters. Again, the results indicate there will not be overlap of sediment deposition from the installation of two SRWEC-NYS cables.

Table EX-1. Summary of sediment transport model results

Scenario	Total Sediment Volume Dispersed	Time for TSS to return to ambient	Max distance from source TSS plume exceeds ambient by		Peak TSS concentration	Max deposition thickness	Max distance from source deposition > 10 mm	Area of deposition > 10 mm
			50 mg/L	100 mg/L				
	[m^3]	[hrs]	[m]	[m]	[mg/L]	[mm]	[m]	[ha]
1 – Excavation of the HDD exit pits	760	1.2	35	0	60	216	36	0.07
2 – Installation of SRWEC–NYS	2,933	0.3	151	120	141	10.1	7.5	0.0015

2.0 PROJECT BACKGROUND

Sunrise Wind LLC (Sunrise Wind or the Applicant), a 50/50 joint venture between Orsted North America Inc. (Orsted NA) and Eversource Investment LLC (Eversource), proposes to construct, operate, and maintain the Sunrise Wind New York Cable Project (the Project). Sunrise Wind executed a 25-year Offshore Wind Renewable Energy Certificate (OREC) contract related to the Project with the New York State Energy Research and Development Authority (NYSERDA) in October 2019. The Project will deliver power from the Sunrise Wind Farm (SRWF), located in federal waters on the Outer Continental Shelf (OCS), to the existing electrical grid in New York. The Project includes offshore and onshore components within New York State (NYS) that are subject to PSL Article VII review and will interconnect at the existing Holbrook Substation, which is owned and operated by the Long Island Power Authority (LIPA).

Specifically, power from the SRWF will be delivered to the existing mainland electric grid via distinct transmission cable segments: the submarine segment of the export cable (SRWEC) in NYS waters (SRWEC-NYS), the terrestrial underground segment of the transmission cable (Onshore Transmission Cable), the new Onshore Converter Station (OnCS–DC) and the underground segment of the interconnection cable (Onshore Interconnection Cable). The Onshore Transmission Cable, the OnCS–DC and Onshore Interconnection Cable are all located in the Town of Brookhaven, Suffolk County, New York.

The Project's applicable components for this report are defined as:

- SRWEC–NYS:
    - One direct current (DC) submarine export cable bundle comprised of two cables (320kilovolt [kV]) approximately 6.2 miles (mi) (10.0 kilometers [km]) in NYS waters and 1,575 ft (480 m) located onshore (*i.e.*, above the Mean High Water Line [MHWL], as defined by the United States [US] Army Corps of Engineers [USACE] [33 CFR 329]) and underground, up to the transition joint bays (TJBs).

This Hydrodynamic and Sediment Transport Modeling report for the SRWEC–NYS considers the information available at this time; the precise locations and schedule of the construction and operation scenarios may be subject to change as the engineering design progresses.

2.1 Study Area and Construction Activities

The SRWEC–NYS will be comprised of one distinct cable bundle. A typical cable target burial depth of 1.0 to 2.0 m (3 to 7 ft)[1] is applicable for the SRWEC–NYS. The portion of the SRWEC in

[1] The Construction and Operations Plan (COP) describes the cable target burial depth as 1.0 to 2.0 m (3 to 7 ft) but for the purpose of this report the modeled SRWEC-NYS burial depth was 2.0 m (6.6 ft).

NYS waters is anticipated to be approximately 10 km (6.2 mi). The total width of the disturbance corridor for installation of the SRWEC–NYS will be up to 45 m (148 ft).

It is anticipated a cable laying vessel will move along the pre-determined SRWEC–NYS route within the established corridor towards the SRWF. The cable bundle will be laid on the seafloor and then trenched and installed post-lay. Alternatively, a trench may be pre-cut prior to cable installation.

As sediment conditions vary along the SRWEC–NYS, several different cable installation methodologies may be required during installation. For the purposes of characterizing the most conservative seafloor disturbance associated with the cable installation, jet-plowing was evaluated for the SRWEC–NYS installation. This technique involves the use of water jets to temporarily fluidize the sediment to create a trench that enables the cables to either be lowered under its own weight or be pushed to the bottom of the trench via a cable depressor.

To support the HDD installation for transition to the landfall area, up to three (3) HDD exit pits (one exit pit for each pole, and a fallback) may be excavated within the SRWEC–NYS corridor. The HDD exit pits will be located approximately 615 to 800 m (2,017 to 2,624 ft) from the shoreline at Smith Point County Park in the Town of Brookhaven, NY. The maximum HDD exit pit dimensions (length x width x depth) will be approximately 50 m x 15 m x 5 m (164 ft x 49 ft x 16 ft).

Hydrodynamics and sediment transport associated with the SRWEC–NYS installation were assessed to understand the most conservative potential seafloor impacts associated with proposed offshore Project construction activities. The construction activities evaluated include:

1) the use of a jet plow for the SRWEC–NYS,
2) dredging of HDD exit pits using a mechanical dredge (NYS waters)

The hydrodynamic and sediment transport analysis utilized existing environmental data and models to assess sediment turbidity levels (presented as Total Suspended Sediment [TSS]) and resulting deposition (thickness above seafloor) at representative Project locations.

3.0 AVAILABLE DATA

The following data and modeling sources were consulted and/or utilized for this study. The basis for selecting specific model assumptions from this available data to describe baseline conditions is presented in subsequent sections.

- National Oceanic and Atmospheric Administration (NOAA) Tides and Currents
- NOAA/National Center for Environmental Information (NCEI) hydrographic surveys
- Currents from University of Connecticut's National Oceanographic Partnership Front-Resolving Observation Network with Telemetry (FRONT) Program (Codiga and Houk, 2002)

- Northeast Coastal Ocean Forecast System (NECOFS) 3-D forecast and hindcast model (NERACOOS, Massachusetts Fishery Institution, and MIT Sea Grant College)
- Rhode Island Ocean Special Area Management Plan (OSAMP) (Codiga and Ullman, 2010), (Grilli et. al., 2010)
- Us Army Corps of Engineers (USACE) Regional Sediment Management Plan
- Deepwater Wind South Fork Wind Farm: Hydrodynamic and Sediment Transport Modeling Results, RPS (2018)
- U.S. Geological Survey (USGS) East Coast Sediment Texture Database (2014)

4.0 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING APPROACH

The evaluation of hydrodynamic and sediment transport plays a critical role in evaluating potential temporary and/or permanent impacts to sensitive ecological resources within the vicinity of the disturbance of sediments associated with Project construction activities. These disturbed sediments can transport, mix, settle, deposit, and become re-suspended; their transport and fate being determined by local hydrodynamics. For characterizing the hydrodynamics within the Project area, the hind-cast results of the NECOFS model, which uses the numerical scheme of the FV-COM (Finite-Volume Coastal Ocean Model), was utilized. The NECOFS hydrodynamic model output was then used as input for sediment transport modeling within the Project construction area. The sediment transport model chosen for this application was the Particle Tracking Model (PTM) in the Surface-Water Modeling System (SMS), which uses the equations for the movement of fluid on a rotating earth and integrates the properties of particles within that fluid to simulate resultant transport. This model has been developed for the transport and fate of suspended sediments surrounding dredging and sub-surface construction activity and is therefore suitable for this application.

4.1 HYDRODYNAMIC MODEL DESCRIPTION

The NECOFS model is a forecast/hindcast coupled ocean and atmospheric forecasting model that covers the Northeast region from south of Nova Scotia to just south of Long Island (Beardsley and Chen, 2013). The modeling system is a coupling of the Weather Research and Forecasting model for atmospheric, Steady-State spectral WAVE for waves modeling and FV-COM for ocean modeling. NECOFS validation included the ability to reconstruct tidal constituents at 93 sites (Chen et al. 2011) as well as hind-cast experiments for water level, temperature, salinity, and currents covering the time-period of 1978 to present day (Chen et al., 2016). Model hindcast data from the regional FVCOM model covering the Gulf of Maine/Georges Bank/New England Shelf region (GOM3-FVCOM[2]) was utilized in this study.

Further details of the model theory are given in the FV-COM user manual (Chen et al., 2013).

[2] More information about the GOM3-FVCOM regional model structure and results at http://fvcom.smast.umassd.edu/necofs/. Accessed July 14, 2020.

4.2 Sediment Transport Model Description

The PTM is a Lagrangian particle tracking model that uses hydrodynamics to simulate particle transport processes. PTM was developed by the Coastal Inlets Research Program (CIRP) and the Dredging Operations and Environmental Research Program (DOER) at the USACE Research and Development Center (Demirbilek et al, 2008, 2012). The module is operated through the SMS 13.0 interface. The model's development included applications to dredging and coastal projects involving the disruption and transport of materials. The model accurately simulates the sediment transport, settling, suspension and re-suspension, deposition and mixing resulting from hydrodynamic and wave processes.

The governing equations for the 2-D PTM Model are provided in Appendix B.

5.0 HYDRODYNAMIC MODEL VALIDATION

In order to further validate the NECOFS model within the region of Project, comparisons were made between the model output and available measurements. The sections below detail the comparisons made with measured currents and measured tidal conditions for different historical periods.

5.1 NECOFS Model vs. FRONT Acoustic Doppler Current Profilers Data

The FRONT project (Codiga and Houk, 2002) was an effort to gain insight into the occurrence of surface frontal zones near the 50 m isobath at the eastern entrance to Long Island Sound. This was accomplished through the deployment of a moored array of Acoustic Doppler Current Profilers (ADCP) in the Fall, Winter and Spring seasons of 2000, 2001 and 2002. The locations of the ADCPs are clustered between Montauk Point on Long Island and Block Island, and regions just to the south.

Surface and bottom currents were collected at each of the following sites: FA00-W (Fall 2000), FA01-LI (Fall 2001), and SP-02 DP (Spring 2002). The locations of the sites are presented in Figure 1.

Three locations and two seasons were available for comparison between the ADCP data and the NECOFS model output. The time-period chosen for comparison was the entire ADCP deployment time-period for each instrument. The model vertical layer used for comparison was the closest corresponding model layer depth (meters) to the ADCP bin depth for the surface and bottom. For surface comparisons, the ADCP bins closest to the surface were disregarded due to potential contamination from surface reflection. In addition, ADCP bins at the very bottom of the water column were also disregarded due to the possibility of data contamination from bottom reflection. Unfiltered model and ADCP time-series data were used for the comparison of magnitude and direction of currents.

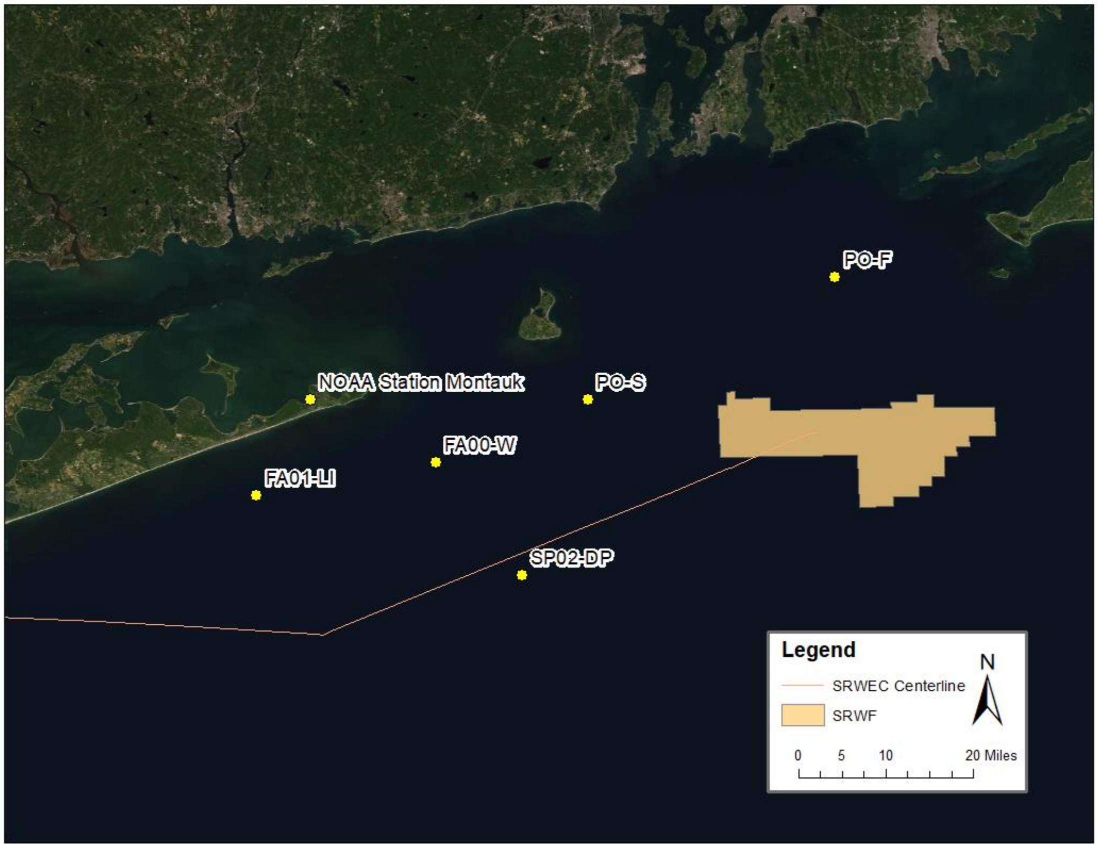

Figure 1. Locations of measured data available for model validation.

The comparisons are shown in Figures 2 through 4 in current roses for both the surface and bottom currents. Overall, the modeled currents are in close agreement with the measurements in terms of magnitude and directionality. The bottom current comparisons appear to be better aligned, particularly at station FA00-W where there are larger discrepancies seen in the surface currents. Since the bottom currents will be utilized from the model for the evaluation of sediment transport, these comparisons indicate the model does well at characterizing current speeds and directionality within the region and can be used to establish hydrodynamic conditions for this purpose.

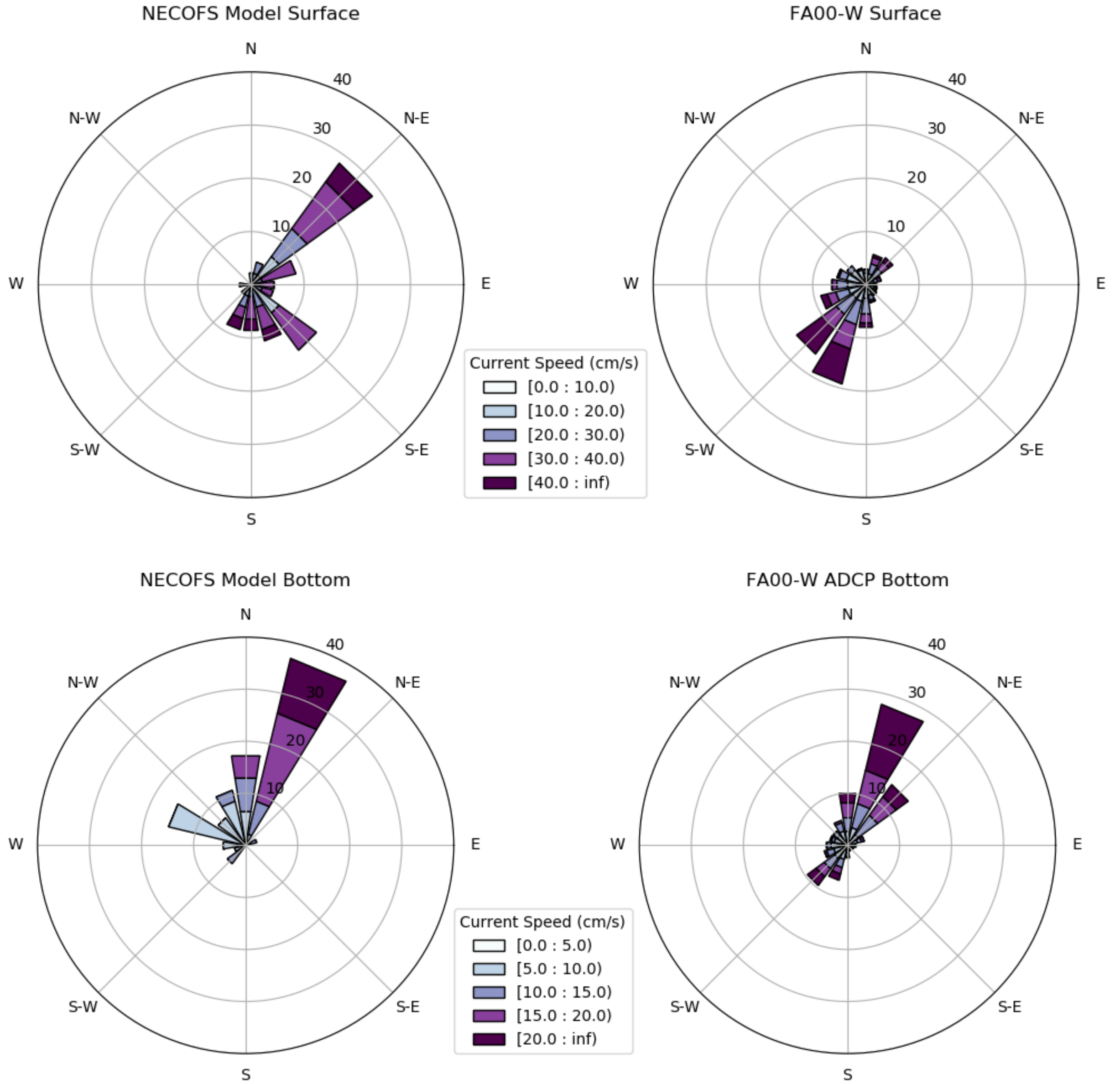

Figure 2. **Speed and direction of surface (top) and bottom (bottom) currents at the FA00-W ADCP. NECOFS model (left) and measurements (right).**

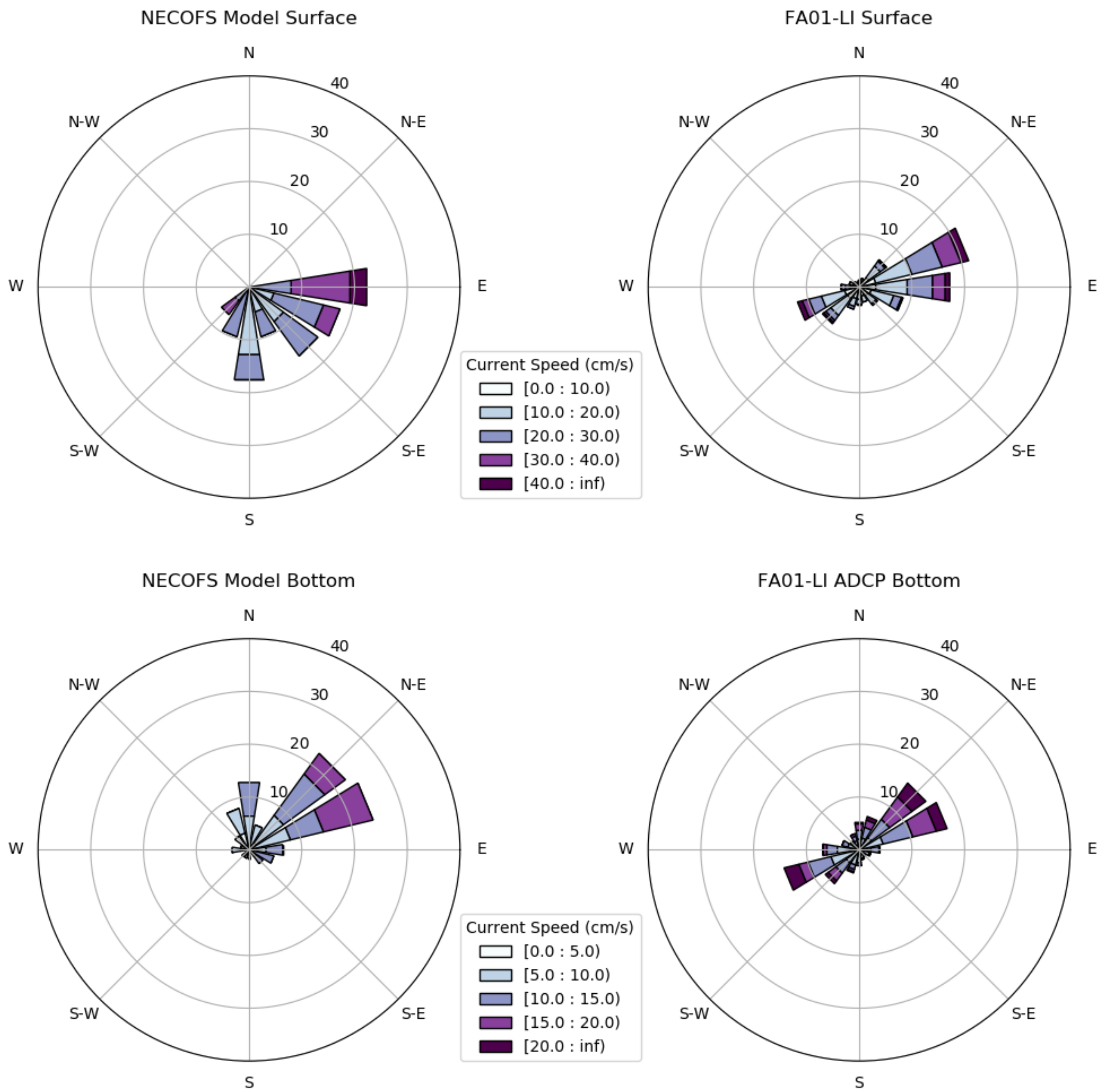

Figure 3. **Speed and direction of surface (top) and bottom (bottom) currents at the FA01-LI ADCP. NECOFS model (left) and measurements (right).**

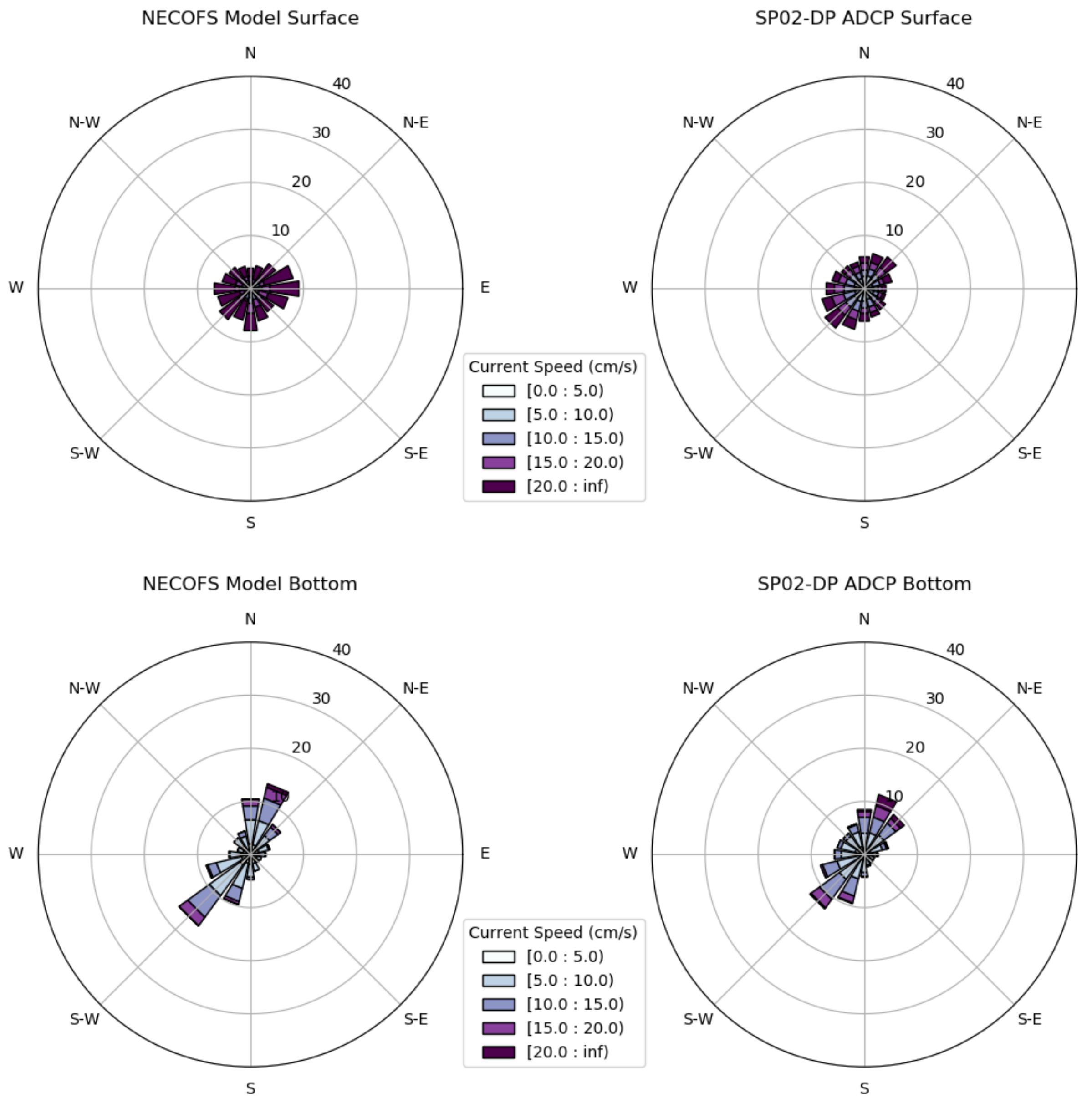

Figure 4. Speed and direction of surface (top) and bottom (bottom) currents at the SP02-DP ADCP from the FRONT Project. NECOFS model (left) and measurements (right).

5.2 NECOFS Model – Tidal Constituent Comparison

The NECOFS model was also evaluated using tidal constituents developed from available measurements within the region. Comparisons were made between the NECOFS model and tidal constituents from the Offshore Renewable Energy OSAMP buoys PO-S and PO-F which collected data in 2009 -2010. Additional comparisons were made between the NECOFS model and tidal constituents developed from water level measurements at NOAA station 8510560 located in Montauk, NY.

Modeled water levels for each time-period were analyzed using the T tide program (Pawlowicz et al., 2002) to conduct a constituent analysis and determine the primary tidal harmonics. The harmonic amplitude and phase were then compared to amplitude and phase of constituents given in the OSAMP report completed for Rhode Island Coastal Resources Management Council (Grilli et al., 2010) and those computed from NOAA water levels at Montauk.

The OSAMP buoy locations and NOAA station are shown in Figure 1, and details on the data collection at PO-F and PO-S buoys are provided in Table 1.

Table 1. Locations and dates for field buoys deployed in OSAMP study area (Grilli et al. 2010)

Buoy	Latitude	Longitude	Deployment Dates
PO-S	41.0482° N	71.5003° W	9-15-2009—1-15-2010
PO-F	41.2500° N	71.0917° W	9-15-2009—1-15-2010

Comparisons between the modeled constituents and those developed from measurements are provided for amplitude and phase in Tables 2 and 3, respectively. Additionally, Figures 5 to 10 show graphical comparisons of the computed constituents together with the calculation uncertainty (shown as error bars).

The comparisons show general agreement between constituent amplitudes (modeled and measured) with most amplitude differences being within the computed error. The exceptions are the M2 constituent at the PO-F and PO-S buoys where the model amplitude is less by approximately 0.1 to 0.15 m. The constituent phases (modeled and measured) compare reasonably well but show larger differences at Montauk. This is somewhat expected given the Montauk tide station is located in a nearshore area that is rather complex and is not as well defined in the NECOFS model.

Table 2. Summary of the comparison between harmonic constituent amplitude (m) from the model and observations.

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
Montauk	NOAA PORTS	0.0483	0.0577	0.0838	0.3037	0.0768	0.0181	0.0149
NECOFS	GOM3-FVCOM	0.0569	0.0994	0.0493	0.2706	0.0659	0.0350	0.0100

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
POS	Grilli et al. 2010	0.0466	0.0725	0.1035	0.4427	0.0945	0.0218	0.0107
NECOFS	GOM3-FVCOM	0.0456	0.0776	0.0765	0.3356	0.0815	0.0134	0.0008

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
POF	Grilli et al. 2010	0.0478	0.0684	0.1114	0.4517	0.0976	0.0335	0.0057
NECOFS	GOM3-FVCOM	0.0494	0.0600	0.0772	0.3228	0.0947	0.0252	0.0024

Table 3. Summary of the comparison between harmonic constituent phase (degrees) from the model and observations.

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
Montauk	NOAA PORTS	98.52	156.14	184.08	289.88	43.75	105.48	161.33
NECOFS	GOM3-FVCOM	311.64	143.87	213.83	155.84	43.15	181.36	118.61

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
POS	Grilli et al. 2010	193.33	166.82	350.54	3.92	18.70	16.31	201.29
NECOFS	GOM3-FVCOM	112.30	114.44	41.31	252.99	291.94	155.22	298.27

Location	Data Source	O1	K1	N2	M2	S2	M4	M6
POF	Grilli et al. 2010	194.82	167.2	334.74	0.92	18.23	7.41	180.12
NECOFS	GOM3-FVCOM	106.95	123.17	44.95	254.82	299.86	148.70	10.37

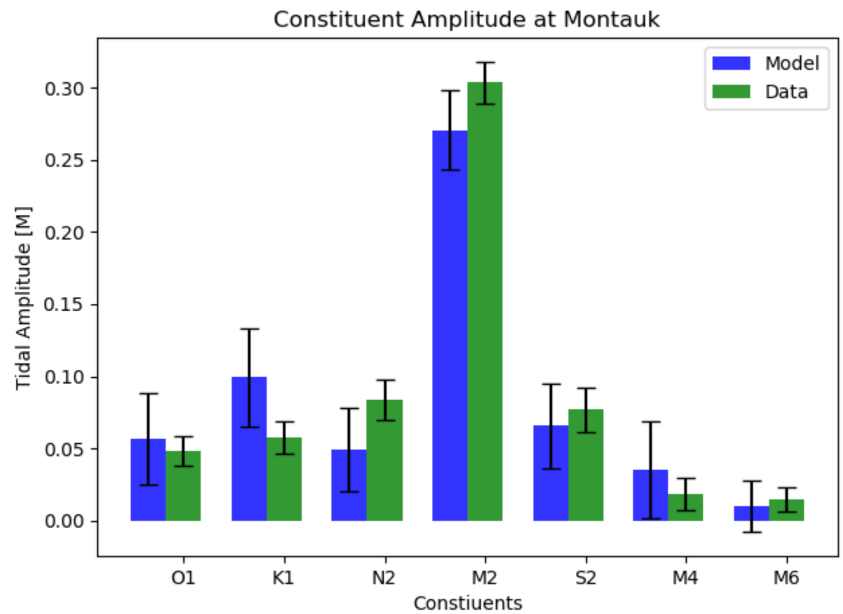

Figure 5. **Comparison of tidal amplitude (meters) for each of the major constituents extracted from the time-series 10/8/2001-11/7/2001 at Montauk Harbor. Modeled output is in blue and observations are in green. The error bar represents the computed amplitude error.**

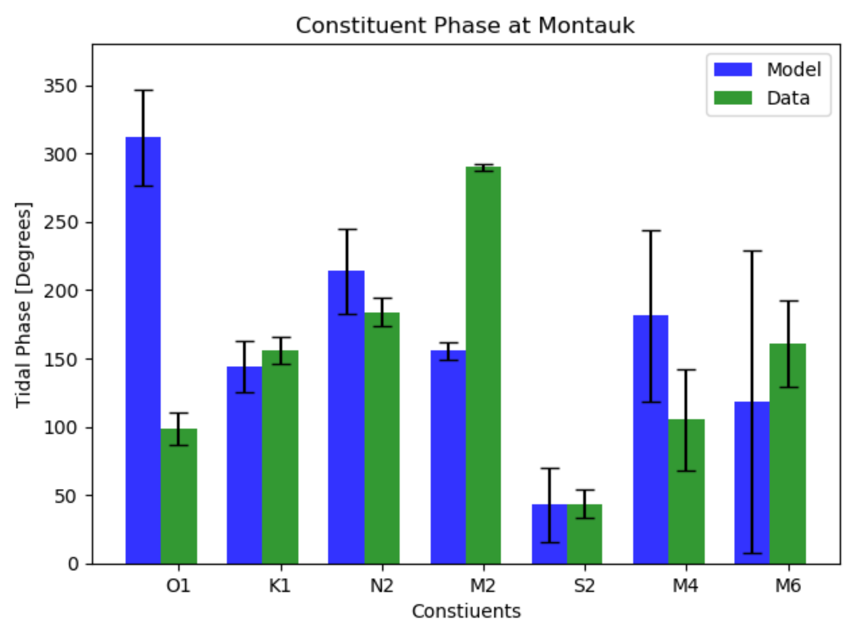

Figure 6. **Comparison of tidal phase (degrees) for each of the major constituents extracted from the time-series 10/8/2001-11/7/2001 at Montauk Harbor. Modeled output is in blue and observations are in green. The error bar represents the computed tidal phase error.**

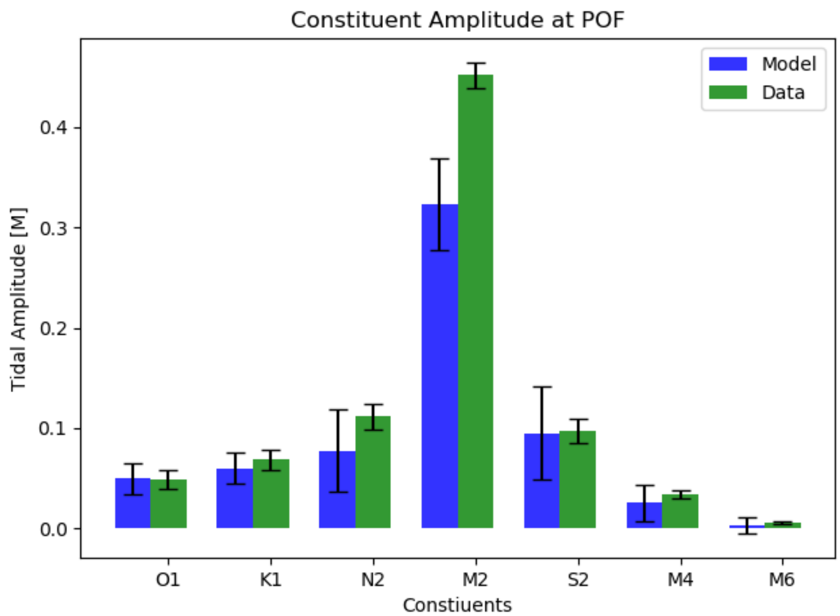

Figure 7. **Comparison of tidal amplitude (meters) for each of the major constituents extracted from the time-series 9/15/2009-1/15/2010 at observation buoy POF. Modeled output is in blue and observations are in green. The error bar represents the computed amplitude error.**

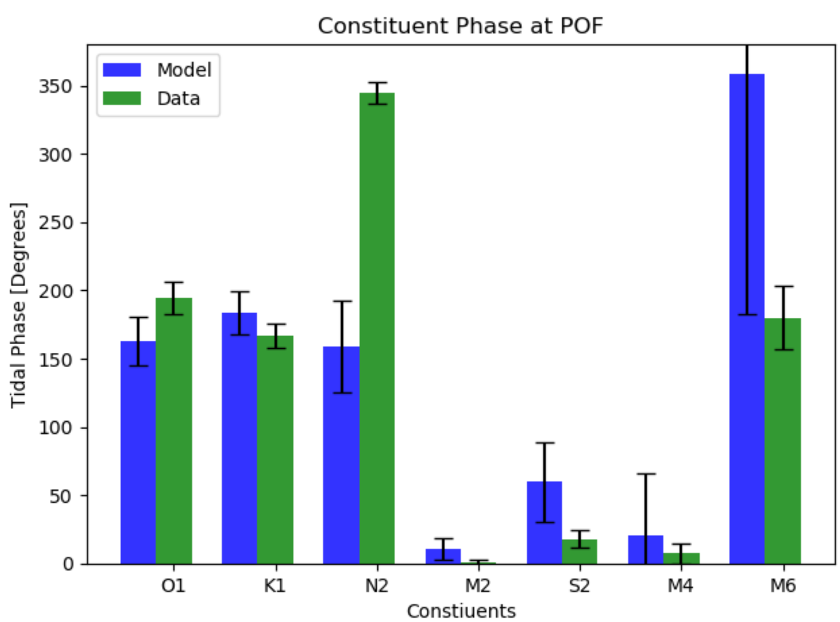

Figure 8. **Comparison of tidal phase (degrees) for each of the major constituents extracted from the time-series 9/15/2009-1/15/2010 at observation buoy POF. Modeled output is in blue and observations are represented in green. The error bar represents the computed tidal phase error.**

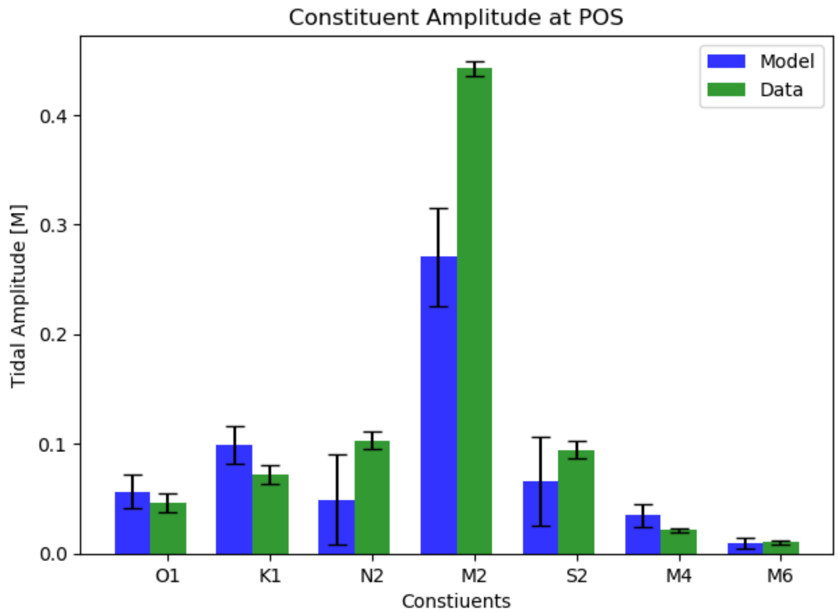

Figure 9. **Comparison of tidal amplitude (meters) for each of the major constituents extracted from the time-series 9/15/2009-1/15/2010 at observation buoy POS. Modeled output is in blue and observations are in green. The error bar represents the computed amplitude error.**

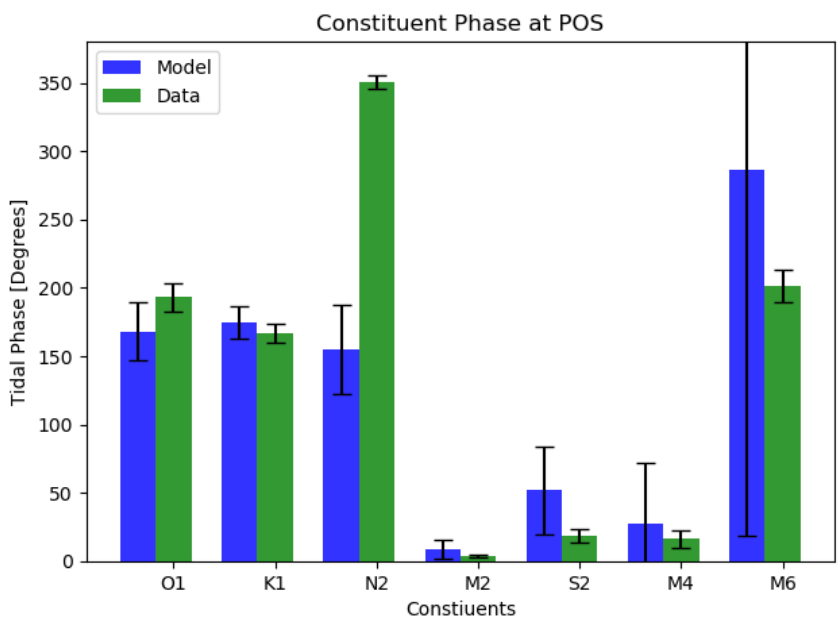

Figure 10. **Comparison of tidal phase (degrees) for each of the major constituents extracted from the time-series 9/15/2009-1/15/2010 at observation buoy POS. Modeled output is in blue and observations are represented in green. The error bar represents the computed tidal phase error.**

6.0 SELECTION OF REPRESENTATIVE HYDRODYNAMIC CONDITIONS

6.1 Average Year

A 39-year hourly hindcast product is available from the regional NECOFS model that provides both meteorological and oceanic model outputs. For this study, it was desired to select a year from the 39-year hindcast that was representative of average annual conditions.

To select a representative average year, bulk statistics were computed using the model's current output at five (5) representative sites along the SRWEC shown in Figure 11. A short list of years (8 in total: 1978, 1991, 1992, 1994, 1997, 2012, 2013, 2015) were identified for which statistics were similar to statistics computed from 39-years of data. Current roses were developed for each shortlisted year at each site and the years were then ranked based on visual inspection/comparison with the 39-year period. Four (4) years were identified as being potential representative years between the different sites. The year rankings were compiled for each site and an overall ranking was developed based on the combined site rankings.

This process resulted in the selection of 1997 as being the most representative of average annual conditions. Comparisons of current roses developed from the 39-year dataset and the year 1997 for the five (5) sites are shown in Figures 12 and 13.

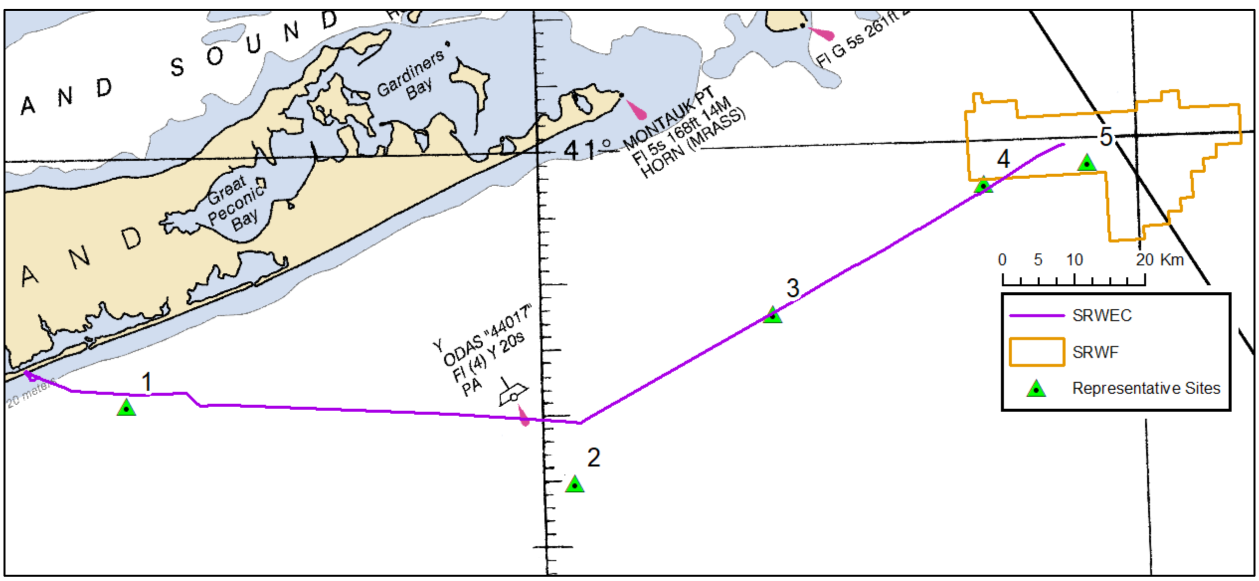

Figure 11. Sites selected along proposed SRWEC for evaluation of representative hydrodynamic conditions (average year).

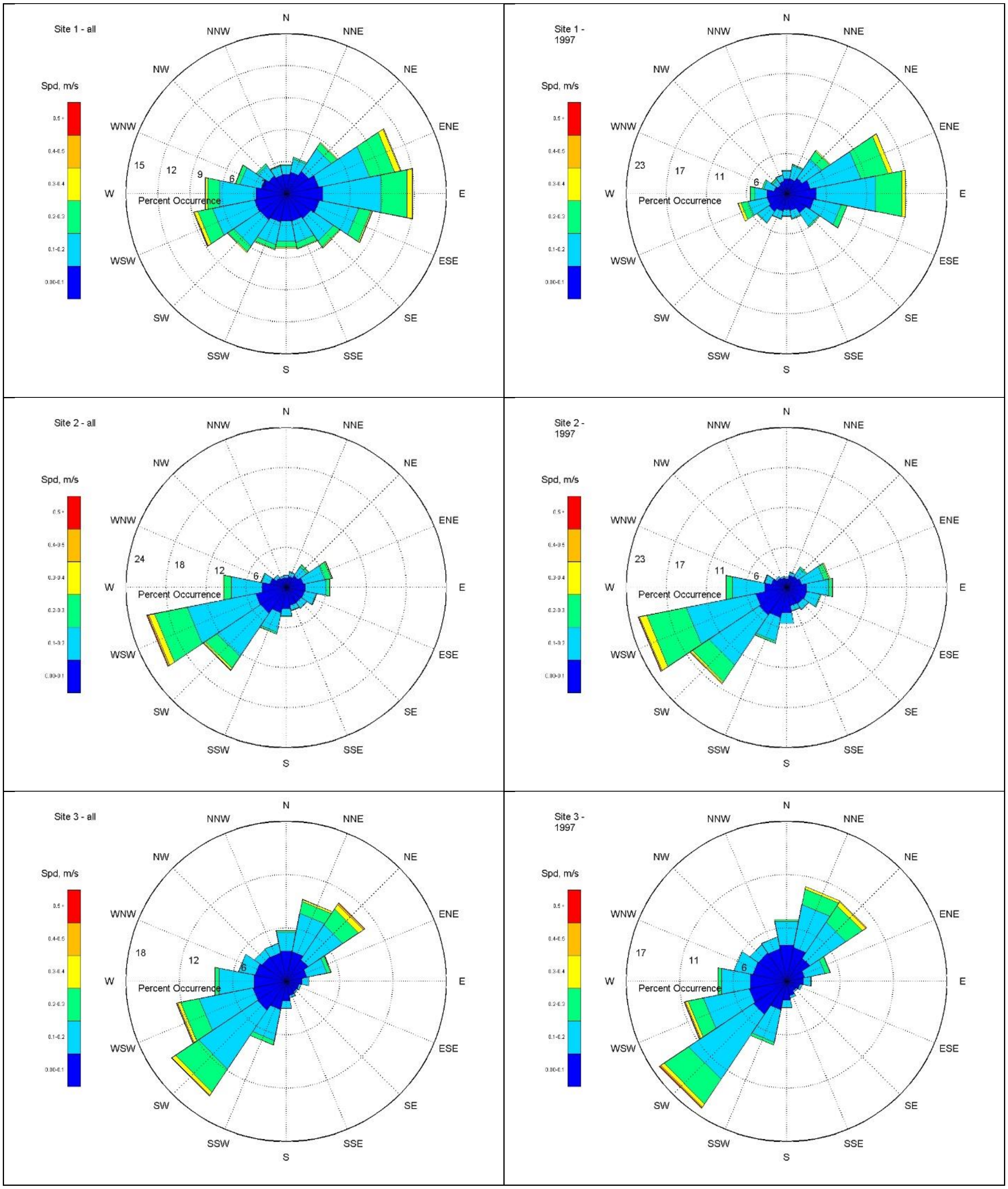

Figure 12. Current rose comparisons between 39-year dataset (left) and the representative year 1997 (right) at sites 1 (top), 2 (middle), and 3 (bottom).

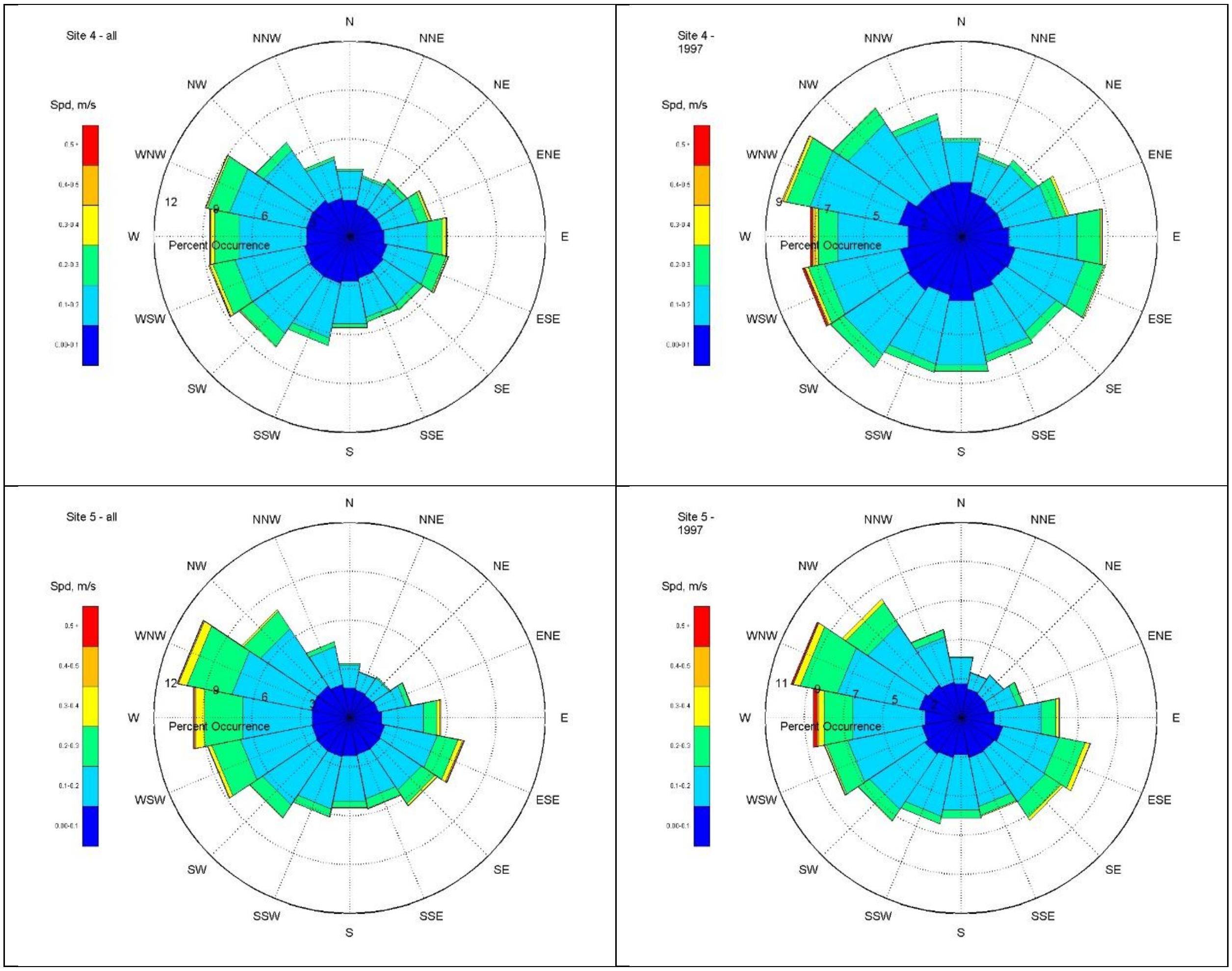

Figure 13. Current rose comparisons between 39-year dataset (left) and the representative year 1997 (right) at sites 4 (top) and 5 (bottom).

6.2 CHARACTERISTIC CURRENTS

The sediment transport model requires input bottom currents (velocity and direction) from the NECOFS hydrodynamic model. For the representative year of 1997, a 70-day period beginning on September 1st and ending on November 10th was selected for providing currents from NECOFS. This was based on most proposed construction activities having operations in the Fall season and the occurrence of meteorological events in the Fall season that produce higher currents. Currents were separated into u- and v- velocity components and extracted for the bottom portion of the water column. The bottom 15 sigma-layers from the NECOFS model were used to represent roughly the bottom one-third of the water column (total of 45 vertical layers). This was considered sufficient for the representative currents capable of initiating sediment transport along the SRWEC–NYS.

7.0 SEDIMENT CHARACTERISTICS

Publicly available sediment characteristics (USGS, 2014) were used to define the surficial seafloor sediments along SRWEC–NYS and at the HDD exit pit representative location for sediment transport modeling.

Figure 14 indicates the proposed SRWEC–NYS route and the representative point source sediment transport model location for the HDD exit pit.

The SRWEC–NYS was modeled as a moving point source, utilizing sediment data that is available along the route. Also shown in Figure 14 are the surficial grab sample locations in NYS waters from the USGS sediment characterization database. Table 4 lists the sediment charateristics derived from the USGS samples for the HDD pit excavation located in NYS waters.

Since in-situ bulk sediment density was not available, the values assigend for the sand fraction and fines/silt fraction were 1700 kg/m^3 and 1150 kg/m^3, respectively. These values are typical within the range of other reported measurements (van Rijn, 2007).

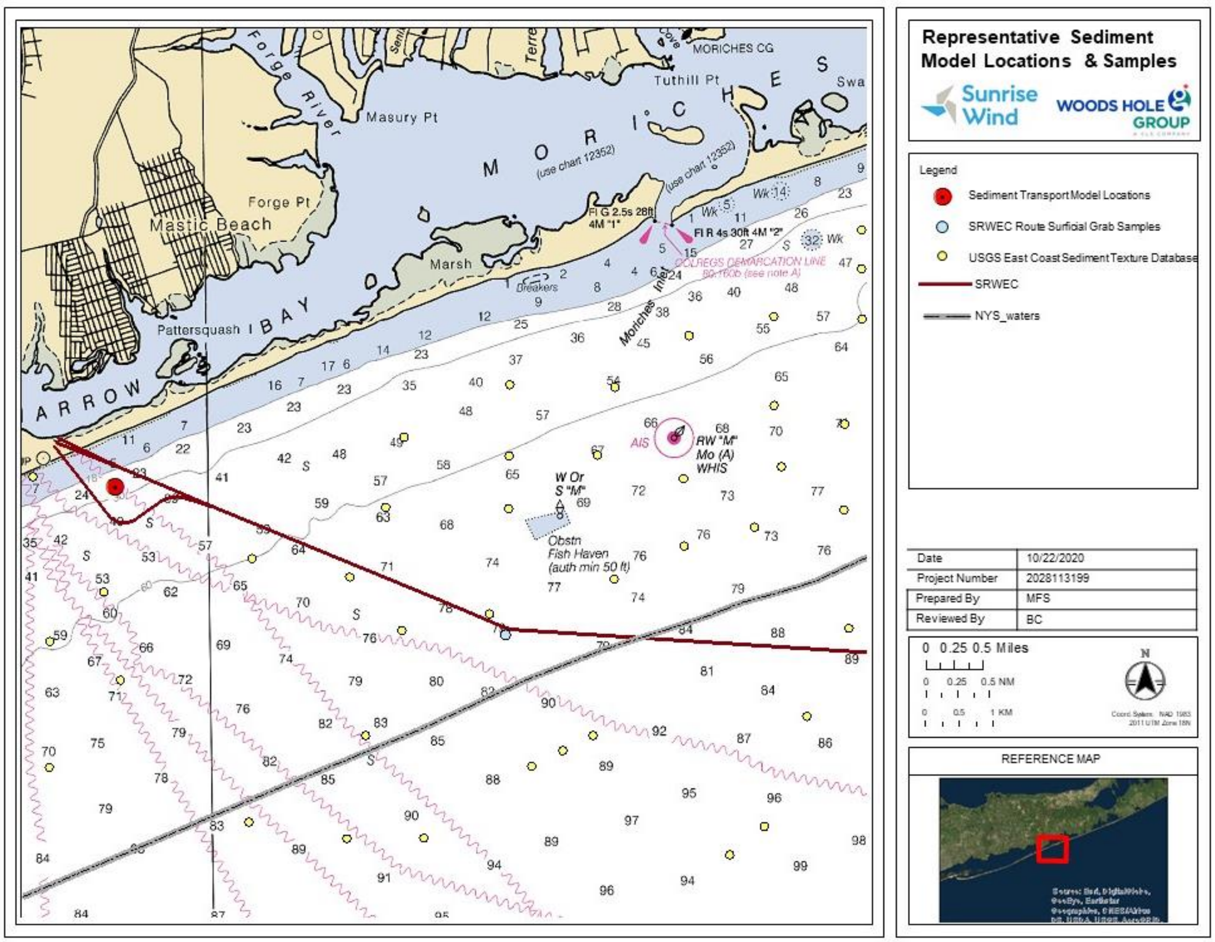

Figure 14. Sediment sample and representative model locations

Table 4. Sediment grain size characteristics at HDD pit (USGS)

D50 (mm)	Gravel %	Sand %	Fines %
0.1927	0.00	99.5	0.5

8.0 MODEL SCENARIOS AND CONFIGURATION

Model scenarios were developed for each proposed construction activity. As discussed in Section 2, multiple installation methods are being considered and the model scenario assumed the method that would create the most sediment disturbance.

Table 5 lists the model scenarios, the model's start time within the representative average year (1997), and the model duration. For the installation of the SRWEC–NYS, two different advance speeds/production rates were considered which resulted in two durations for scenario 2. Model simulations for both scenarios were of sufficient duration to adequately characterize conditions expected over the anticipated duration of construction and after construction until sediment concentrations return to ambient levels. For all scenarios, a continuous construction operation was assumed (7 days a week, 24 hours a day,).

Table 5. List of model scenarios and timing

Model Scenario	Model Start Date	Model Duration (days)
1 – Excavation of the HDD exit pit (NYS waters)	September 1, 1997	2.6
2 – Installation of SRWEC–NYS	September 1, 1997	1.1 to 2.6

Table 6 summarizes the sediment transport model parameters for the different model scenarios and data sources used. These parameters were developed based on anticipated construction methods being considered.

For the excavation of the HDD exit pit (Scenario 1), the trench volume was estimated based on a 5.0 m (16 ft) depth and a dredging area of 750 m^2 (15 m by 50 m) and an excavation volume of approximately 3,800 m^3 (4,970 cubic yards [cy]). This scenario assumed a clamshell bucket size of 4 cy operating on a 3-minute cycle (20 cycles per hour). This equates to a production rate of 60 m^3 (80 cy) per hour. The sediment loss percentage was set conservatively high at 20% (16 cy/hr) for this scenario. The modeled HDD location was selected at a representative centralized location between the proposed HDD pits (preferred and fallback).

For the SRWEC–NYS installation scenario using the jet-plow methodology, two different production rates were considered: 1) high production of 600 m^3 (785 cy) per hour for a sled advance speed of 300 m/hr (984.3 ft/hr), and 2) low production of 250 m^3 (327 cy) per hour for a sled advance speed of 125 m/hr (410.1 ft/hr). The sediment loss percentage for both the low and high production rates (25%) was based on prior studies (RPS, 2018). The construction parameters used in each modeling scenario are detailed in Table 6.

Table 6. Parameters used in sediment transport model scenarios

Model Scenario 1 – Excavation of the HDD exit pit (NYS waters), annual average conditions	
Location (UTM coordinates, m)	19 N 174421 E, 4515659 N
Hydrodynamics	FVCOM model output
Sediment Characteristics	USGS, 2014
Sediment source / classification	Point source / sand (< 1% fines)
Equipment Type	Mechanical (clamshell) dredge
Trench Volume (m^3)	3800
Production Rate (m^3/hr)	60
Vertical distribution above seabed (m)	2
Sediment loss (%)	20
Anticipated construction season	Fall to Winter
Construction duration (hrs / days)	63.3 /2.6 days
Model Scenario 2 – Installation of SRWEC–NYS, annual average conditions	
Location	Along cable route (approximately 10 km)
Hydrodynamics	FVCOM model output
Sediment Characteristics	USGS, 2014
Sediment source	Moving point source
Equipment Type	Jet-plow
Trench Volume (m^3)	2.0 (2.0 m deep by 1.0 m wide)
Production Rate (m^3/hr)	600 to 250
Advance Speed (m/hr)	300 to 125
Vertical distribution above seabed (m)	1
Sediment loss (%)	25
Anticipated construction season	Spring
Construction duration (hrs / days)	26 to 62.5 / 1.1 to 2.6

9.0 MODELING RESULTS AND DISCUSSION

9.1 SEDIMENT TRANSPORT MODELING RESULTS

Scenario 1 – HDD Exit Pit

This scenario included the release of 760 m^3 (994 cy) of sediment to the water column over the duration of the HDD pit excavation using a mechanical clamshell dredge (duration of over 63 hrs). The modeling was conducted assuming a continuous operation. Maximum suspended sediment concentrations in excess of ambient levels (> 10 mg/L) occurring over the duration of the HDD pit excavation are shown in Figure 15. The sediment deposition that results from this activity are shown in Figure 16.

The results indicate maximum suspended sediment concentrations in excess of 100 mg/L do not occur, with the peak TSS concentration reaching 60 mg/L. Concentrations above 50 mg/L are within 35 m (115 ft) of the HDD pit. The TSS plume is contained within the lower half of the water column, approximately 3.9 m (12.8 ft) above the seafloor. TSS concentrations are predicted to return to ambient levels (<10 mg/L) at the HDD location within 1.2 hours after completing the excavation.

The maximum predicted deposition thickness is 216 mm (8.5 inches [in]). Sedimentation at or above 10 mm (0.4 in) extends a maximum of 36 m (118 ft) from the HDD exit pit and covers an area of 0.07 hectares (ha) (0.17 acres) of the seafloor.

The cumulative deposition from multiple proposed HDD exit pits was assessed and is further detailed in Section 9.2.

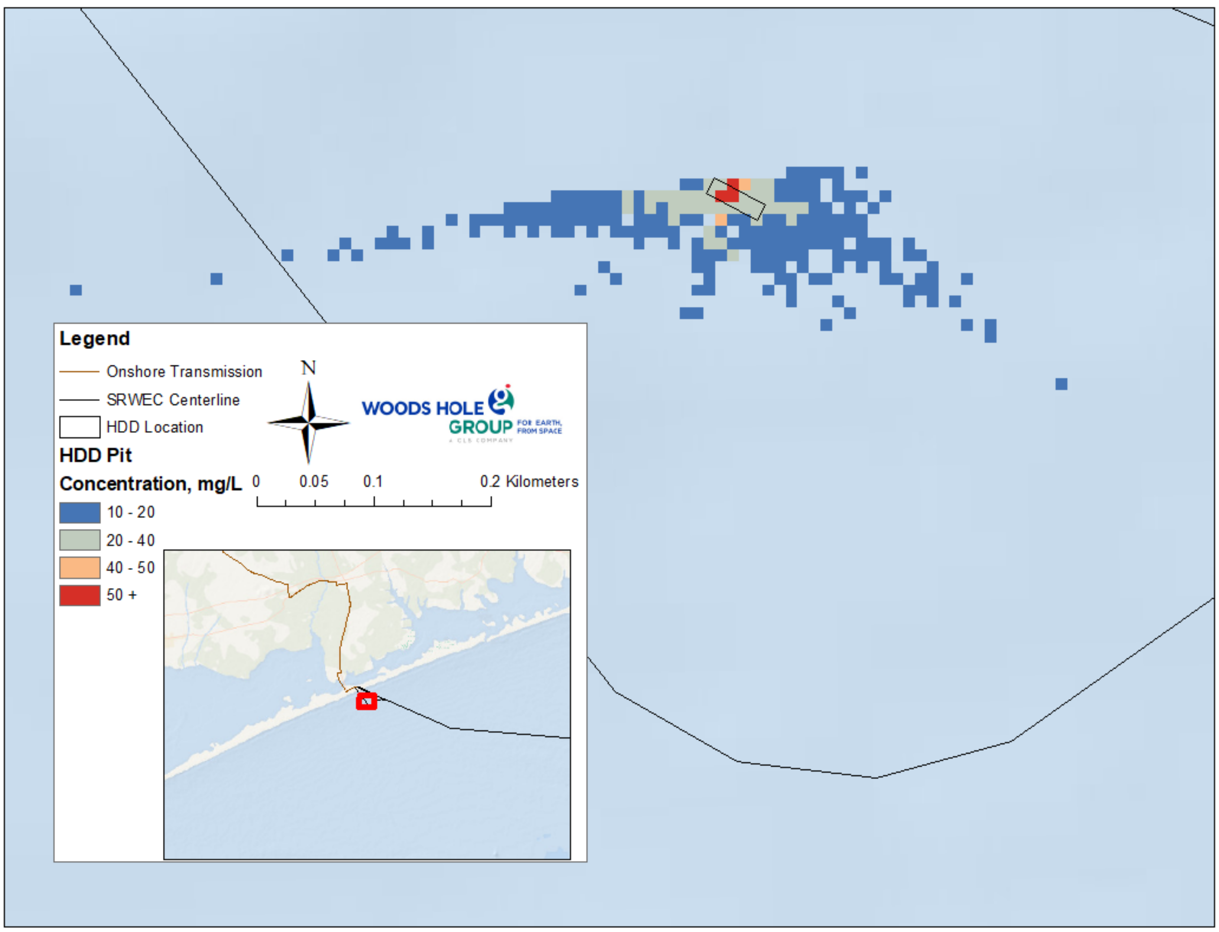

Figure 15. **Maximum TSS concentrations occurring during HDD exit pit**

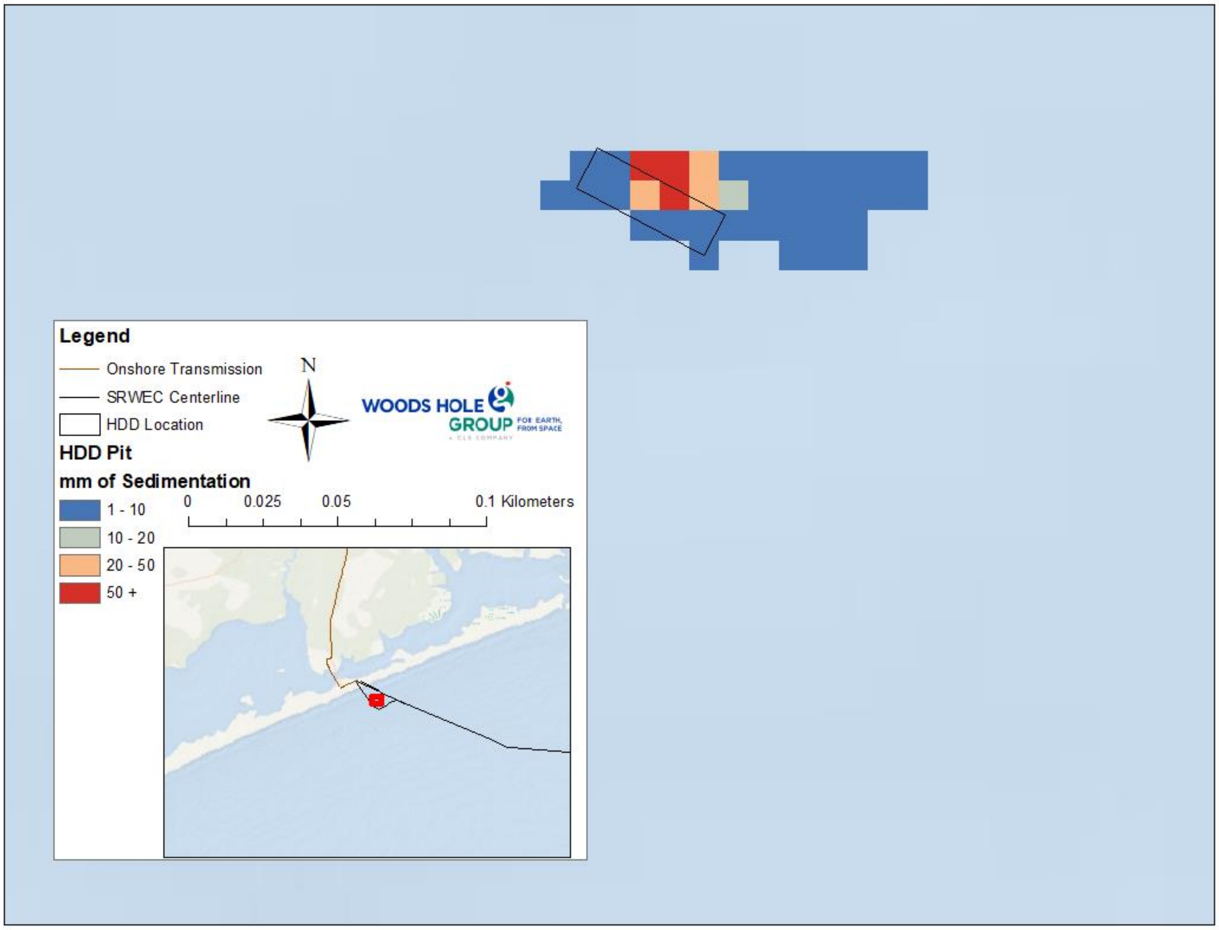

Figure 16. Sediment deposition on seafloor after HDD exit pit excavation

Scenario 2 – SRWEC–NYS Installation

This scenario included the release of 3,907 m^3 (5,110 cy) of sediment to the water column over the SRWEC-NYS route. The duration of the SRWEC–NYS installation is 26.1 hours using the high production rate and 62.5 hours using the slow production rate. Maximum suspended sediment concentrations in excess of 10 mg/L occurring over the duration of the SRWEC–NYS waters are shown in Figure 17 for the high production rate (600 m^3/h). The sediment deposition that results from this activity is shown in Figure 18.

Figures showing suspended sediment concentrations and sediment deposition for the low production rate (250 m^3/hr) are included in Appendix A.

The results shown in Figures 18 indicate maximum suspended sediment concentrations in excess of 100 mg/L occur with the high production rate, within 120 m (394 ft) of the cable centerline. The TSS plume is primarily contained within the lower portion of the water column, approximately 2.0 m (6.6 ft) above the seafloor. TSS concentrations are predicted to return to ambient levels (<10 mg/L) within 0.3 hours from completing the installation, giving an indication of how long it might take to return to ambient levels at any location along the SRWEC–NYS route after sediment suspension.

The maximum predicted deposition thickness is 10.1 mm (0.4 in). Sedimentation at or above 10 mm (0.4 in) extends a maximum of 7.5 m (25 ft) from the cable centerline and covers an area of 0.0015 ha (0.0037 acres) of the seafloor.

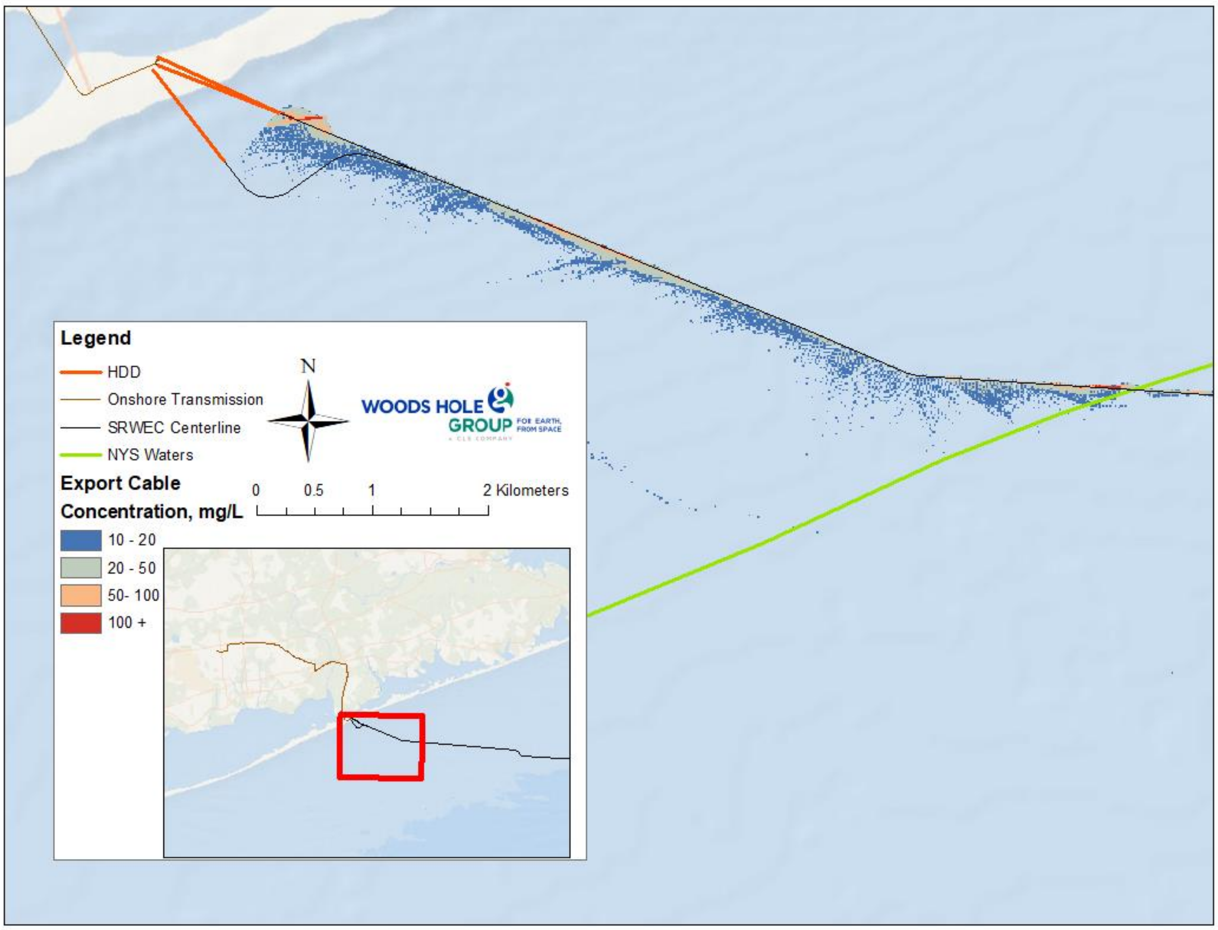

Figure 17. Maximum TSS concentrations occurring during SRWEC–NYS installation with high production rate (600 m3/hr)

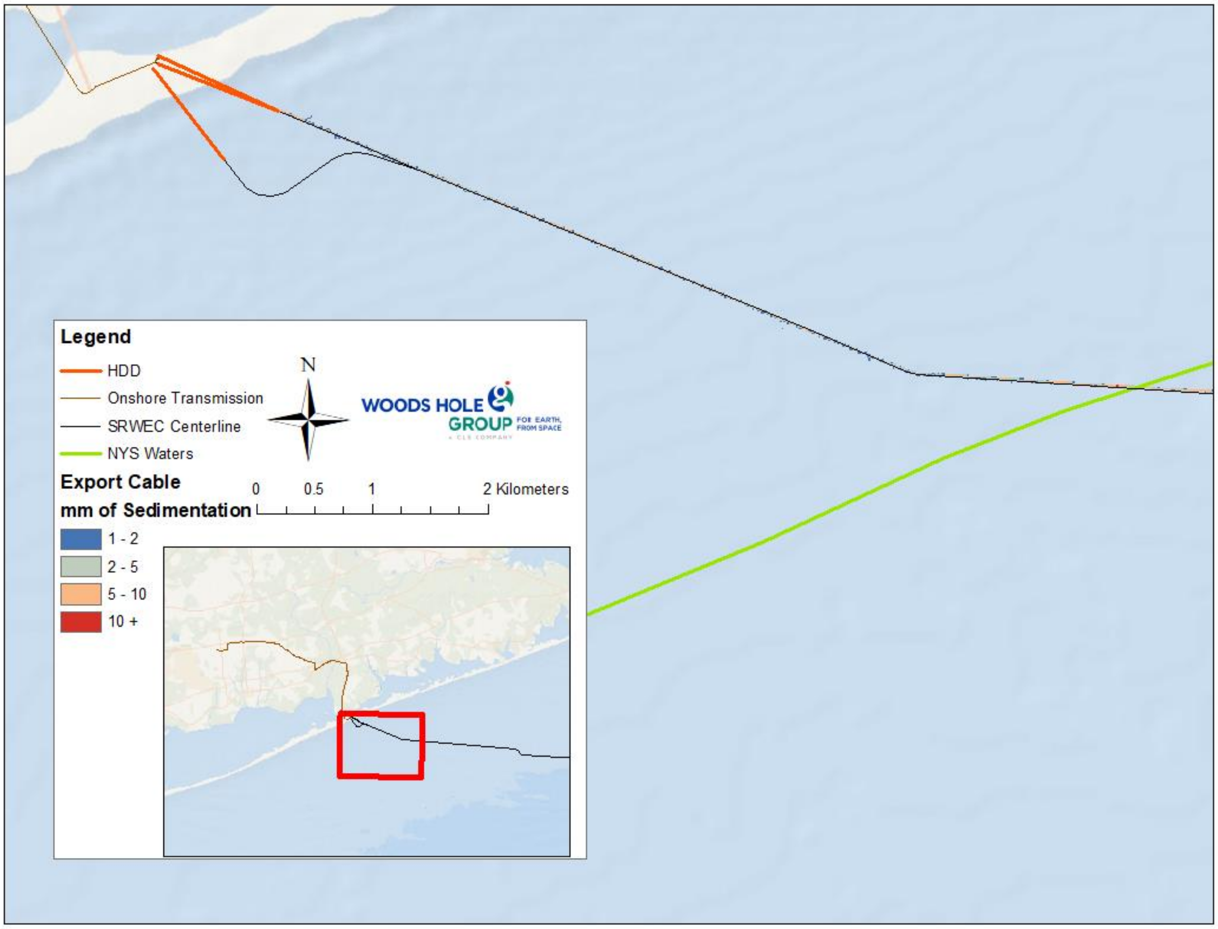

Figure 18. Sediment deposition on seafloor after SRWEC–NYS installation with high production rate (600 m3/hr)

9.2 Combined Effects of Multiple HDD Pits

The preferred HDD exit pits to link the SRWEC–NYS cables to the proposed landfall locations were evaluated (HDD fallback location not evaluated). The distance between the preferred HDD exit pits is approximately 105 m (345 ft). Excavation of the HDD pits will not be conducted simultaneously, however there could be cumulative effects from the sediment disturbances. An analysis of cumulative sediment deposition associated with the preferred HDD pits was conducted. The analysis involved first translating the representative sediment deposition model results to the HDD exit pit locations and then combining the results to obtain the cumulative deposition. Figure 19 shows the combined sediment deposition from the HDD excavations at the preferred locations. The results show there is sufficient distance between the preferred HDD pit locations to avoid cumulative impacts (i.e. there is not significant overlap of sediment deposition from the paired HDD exit pit excavations).

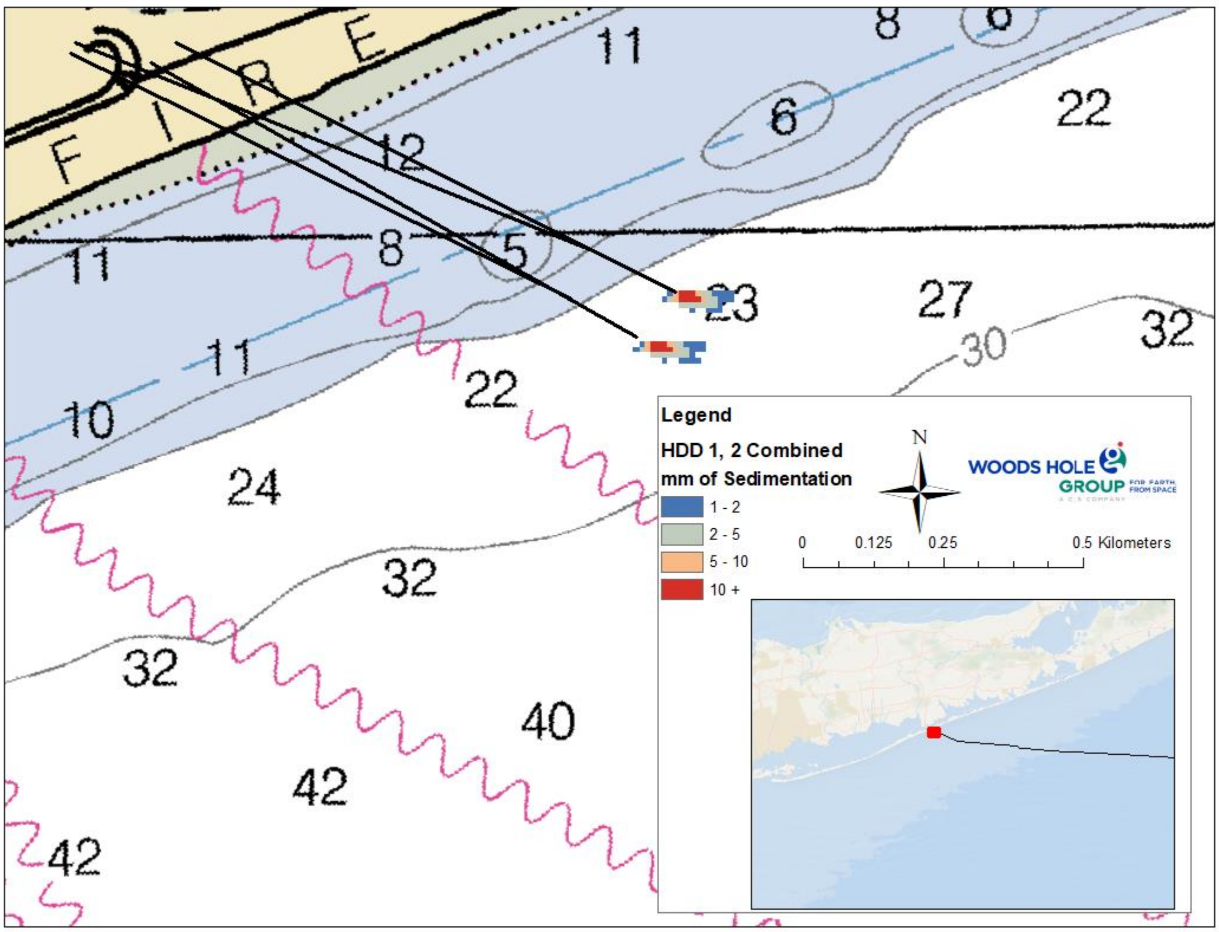

Figure 19. Cumulative sediment deposition on seafloor after sequential excavation of multiple HDD exit pits (preferred locations)

9.3 Combined Effects of Multiple Export Cables

There is one main SRWEC–NYS cable, however, the two poles split before meeting the two HDD exit pits, so there will be a short section (~ 1 km) of two cables in NYS waters, installed in two separate trenches. The two cables will not be simultaneously installed, however there could be cumulative effects from the sediment disturbances. An analysis of cumulative sediment deposition associated with the sequential installation of both cables was conducted.

An analysis of cumulative sediment deposition was conducted using a representative cable spacing in NYS waters (100 m [329 ft]). The analysis involved first translating the representative sediment deposition model results to the proposed SRWEC-NYS routes and then adding the results to obtain the cumulative deposition. The results indicated there will not be overlap of sediment deposition from the installation of two separate SRWEC-NYS cables along this short segment.

9.4 Summary of Results

Hydrodynamic and sediment transport modeling were conducted to assess the sediment suspension and resulting deposition from proposed construction activities associated with the SRWEC–NYS and HDD exit pit locations. The sediment transport model provided sediment turbidity levels (presented as TSS), and sediment deposition (thickness above seafloor).

Table 7 provides a summary of the sediment transport model results. The following are some general findings from the sediment transport analysis:

- The suspended sediment plume from the proposed construction activities is transient and its location in relation to the sediment disturbance varies with the tidal cycles. The sediment plume is shown to be larger in areas where there are higher percentages of fine-grained surficial seafloor sediments.

- The excavation of HDD pits resulted in peak TSS concentrations of 60 milligrams per Liter (mg/L) with concentrations exceeding 50 mg/L within 35 meters (m) of the sediment source. This activity resulted in a 0.07 hectares (ha) area on the seafloor where the deposition thickness was greater than 10 millimeters (mm), extending a maximum of 36 m from the source. The predicted time to return to ambient turbidity levels is 1.2 hours after completion.

- For the SRWEC–NYS installation, peak TSS concentrations reached 141 mg/L with concentrations exceeding 100 mg/L within 120 m of the SRWEC route centerline. The maximum deposition thickness was 10.1 mm resulting in a small area (0.0015 ha) having a thickness greater than 10 mm with a maximum extent of 7.5 m from the route. While the time to return to ambient turbidity levels will vary along the SRWEC route, the time to return to ambient levels was 0.3 hours after completion.

- The cumulative impacts of installing two HDD pits sequentially were assessed. The results show the planned spacing between HDD pits is adequate to avoid overlap of sediment deposition from the two sequential activities.

- Cumulative impacts were also evaluated for the short (~ 1 km) SRWEC segment where two cables split to meet the HDD pits in NYS waters. Again, the results indicate there will not be overlap of sediment deposition from the installation of two SRWEC-NYS cables.

Table 7. Summary of sediment transport model results

Scenario	Total Sediment Volume Dispersed	Time for TSS to return to ambient	Max distance from source TSS plume exceeds ambient by		Peak TSS concentration	Max deposition thickness	Max distance from source deposition > 10 mm	Area of deposition > 10 mm
			50 mg/L	100 mg/L				
	[m^3]	[hrs]	[m]	[m]	[mg/L]	[mm]	[m]	[ha]
1 – Excavation of the HDD exit pit	760	1.2	35	0	60	216	36	0.07
2 – Installation of SRWEC–NYS	2,933	0.3	151	120	141	10.1	7.5	0.0015

10.0 REFERENCES

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APPENDIX A – ADDITIONAL MODEL RESULT FIGURES

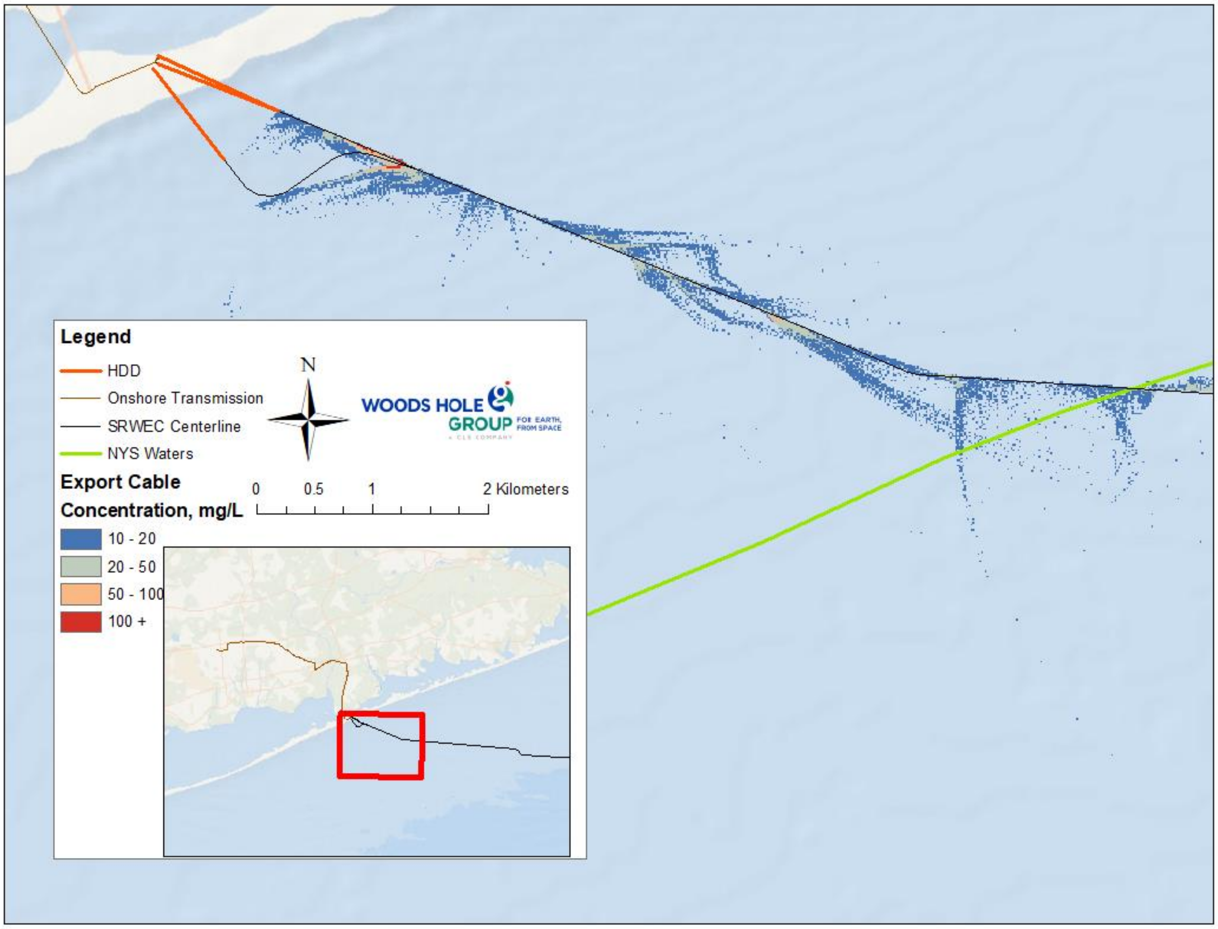

Figure A1. **Maximum TSS concentrations occurring during SRWEC–NYS installation with low production rate (250 m3/hr)**

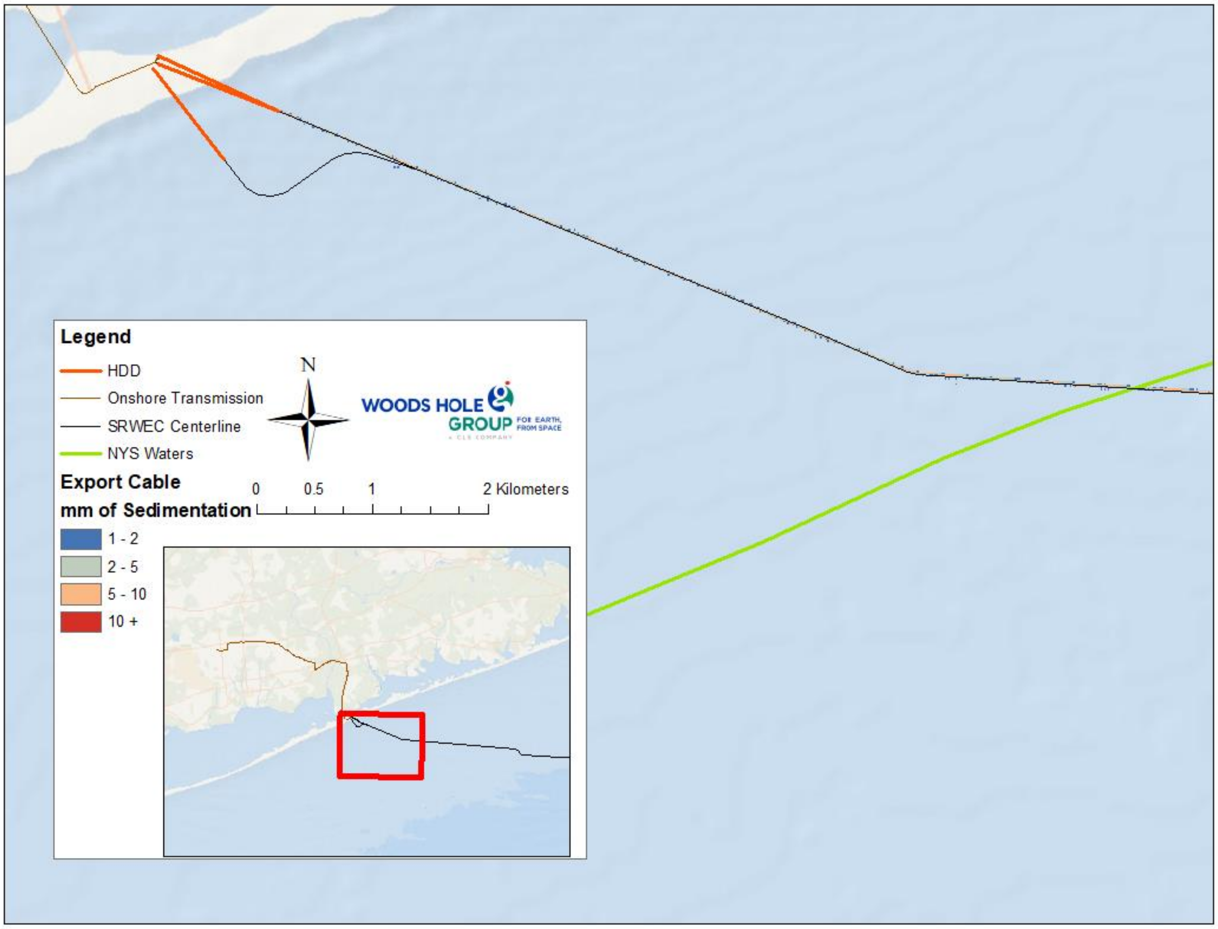

Figure A2. **Sediment deposition on seafloor after SRWEC–NYS installation with low production rate (250 m3/hr)**

APPENDIX B – GOVERNING EQUATIONS FOR 2-D PTM MODEL

A large proportion of the sediment transport models available are developed based on obtaining a solution from a single point in space, or a Eulerian framework. In these models, transport rates of change are calculated over the entire modeling domain for a time-step to set up the condition for the next time-step. This computes the evolution of the sediment field in the water column. PTM is developed under a Lagrangian framework, where sediment is discretized instead to a finite number of particles with properties (i.e. grain size, specific gravity), and this particle field moves and evolves with the flow. The Lagrangian modeling framework favors modeling situations with a sharp gradient in the suspended sediment load, which is characteristic of a plume created because of suction dredging or jet trenching. In addition to situational specialization, Lagrangian particle tracking models are higher in computational efficiency than their Eulerian counterparts.

The version of PTM that is used for this application is the 2-dimensional mode of operation. This method provides an analysis of transport pathways and processes while excluding interaction with the native sediment, vertical advection, and settling. Vertical movement of particles is understood as the vertical elevation of the particle cloud's centroid above the seafloor. Erosion and deposition of particles are both determined by a threshold set by the user (Shield's curve, or user-defined). A critical shear stress value is set by the user, and particles are assumed to be removed from the seafloor when that critical shear stress value is reached. This 2-dimensional method is commonly used for identifying key sediment transport pathways and provides an analysis of potential erosional and accretional regions, while remaining computationally efficient.

The governing equations for the 2-Dimensional Lagrangian particle tracking model are as follows:

Shear stress is a function of the flow and sediment bed conditions. Four shear stress components are calculated in the PTM:

1. Current-induced shear stress due to skin friction, τ'_c.
2. Current-induced shear stress due to form drag, τ''_c.
3. Wave-induced shear stress due to skin friction, τ'_w.
4. Wave-induced shear stress due to form drag, τ''_w.

For the current-induced shear stress due to form drag, τ''_c, the form roughness height, k''_s, is estimated using a combination of the bed form length and steepness. The PTM implements methods described in van Rijn (1993) to calculate shear stress. An overview of these methods follows.
The bed shear stress (Pa) can be calculated from the depth-averaged velocity, $\bar{U}$, as:

$$\tau''_c = \frac{\rho \ \bar{U}^2}{C''^2}$$

Where rho (ρ) is the water density and C’’ is the dimensionless Chezy coefficient, which for rough turbulent flow is approximated by:

$$C'' = 2.5 \ln\left[11 \frac{h}{k_s''}\right]$$

Where *h* = depth of flow (m).
The bed shear velocity (U*) in meters/second, is calculated from:

$$u_* = \sqrt{\frac{\tau_c''}{\rho}} = \frac{\bar{U}}{C''}$$

The dimensionless critical Shields parameter, θ_{cr}, is that value of θ at which the start of sediment transport occurs and is given as:

$$\theta_{cr} = \frac{\tau_{cr}}{\rho g (s-1) D}$$

This relationship signifies the shear stress necessary to remove sediment from the bed and into suspension in the water column.