TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F – HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING RESULTS – BASE CASE SIMULATIONS, ADDENDUM 1, ADDENDUM 2, ADDENDUM 3, AND CONTAMINANT TRANSPORT MODELING RESULTS

NORTHEAST SUPPLY ENHANCEMENT PROJECT

January 2020

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F-1 – HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING RESULTS – BASE CASE SIMULATIONS

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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Northeast Supply Enhancement Project:
Hydrodynamic and Sediment Transport Modeling Results – Base Case Simulations

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1 Introduction

1.1 Project Background

As part of its Northeast Supply Enhancement Project (Project), Transcontinental Gas Pipe Line Company, LLC (Transco) is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey, as well as its existing offshore natural gas pipeline system in New Jersey and New York. The Project capacity is fully subscribed by two entities of National Grid: Brooklyn Union Gas Company (doing business as National Grid NY) and KeySpan Gas East Corporation. To provide an incremental 400,000 dekatherms per day (Dth/d) of capacity, Transco plans to expand discrete segments of its system from the existing Station 195 in Lancaster, Pennsylvania, to the Rockaway Transfer Point. The Rockaway Transfer Point is the interconnection between the Project and Transco's existing Rockaway Delivery Lateral (RDL) subsea manifold in New York waters, approximately 3 miles seaward of Rockaway, New York.

A major portion of the Project includes the installation of a 26-inch outer diameter pipeline, referred to as the "Raritan Bay Loop" that will connect the Project's proposed "Madison Loop" (Middlesex County, NJ) to the Rockaway Transfer Point (Figure 1). The offshore portion of the Raritan Bay Loop will extend from the Sayreville, New Jersey shoreline (MP12.16) approximately 23.33 miles across Raritan Bay and Lower New York Bay to the Rockaway Transfer Point in the Atlantic Ocean. The proposed Raritan Bay Loop route crosses 5.95 miles of New Jersey waters and 17.38 miles of New York waters, and will cross multiple navigation channels and a wide range of water depths (0 to 75 ft below mean lower low water [MLLW]).

The pipeline installation will require a range of dredging and burial techniques (e.g. clamshell dredging, jet trenching, and backfilling) each of which has the potential to produce seabed disturbances, suspended sediment plume formation, and smothering due to sedimentation. Accordingly, hydrodynamic and sediment transport and dispersion simulations are being developed to help assess potential environmental impacts of Project-related activities. This report describes the computer modeling systems and approach being used to evaluate the Project, and provides predictions of suspended sediment concentrations and deposition from a set of initial "base case" construction scenarios.

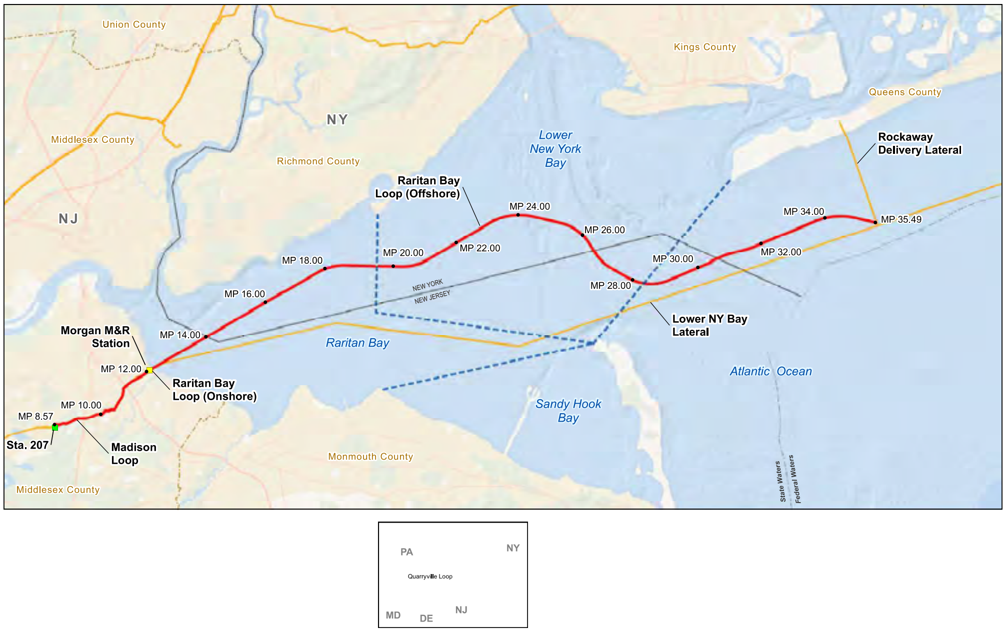

Figure 1. Offshore study area for the proposed Raritan Bay Loop (from Williams/Transco).

1.2 Study Area Description

The offshore portion of the Raritan Bay Loop will cross parts of three major water bodies that converge at the New York Bight Apex: Raritan Bay, Lower New York Bay, and the Atlantic Ocean. Collectively, these water bodies form a generally triangular-shaped embayment situated at the southern extent of the New York – New Jersey (NY/NJ) Harbor Estuary, a complex system of bays and tidal rivers where the Hudson, Hackensack, Passaic, and Raritan rivers meet the Atlantic Ocean. The embayment is bound to the south and west by New Jersey (Monmouth and Middlesex Counties), and to the north and northwest by New York (Richmond, Kings, and Queens Counties). The Sandy Hook peninsula extends approximately 5 miles into the embayment from the southeast, forming a partial barrier to waves and currents approaching from the Atlantic Ocean. Several major navigational channels cross the study area, connecting the New York Bight with Upper New York Bay – one of the largest and busiest harbors in the world.

Hydrodynamic circulation in the area is complex and is influenced by both the circulation of the NY/NJ Harbor Estuary and the large-scale shelf circulations of the New York Bight. Circulation in the NY/NJ Harbor Estuary is tidal with predominant semi-diurnal variability but is also influenced by fresh water outflow from the Hudson River and Raritan River, and surface winds including sea-breeze and land-breeze effects (Gopalakrishnan and Blumberg 2011). The mean tide range at the Sandy Hook, New Jersey NOAA station (Station ID: 8531680), near the center of the study area, is 4.7 feet (NOAA Tides and Currents 2017). Surface currents in this area have been shown to exhibit daily variation in flow direction, with flow mainly moving southwesterly during incoming tides and mixed flow direction occurring during outgoing tides (Bruno and Blumberg 2009). In Raritan Bay and Lower New York Bay, current patterns can be complex, but there is a general tendency for the outflowing Hudson River and Raritan River to veer south, creating an overall counter-clockwise gyre within the basin (Jeffries 1962; Gopalakrishnan and Blumberg 2011).

Water depths across the study area are relatively shallow, and deepen gradually from the Bay shoreline to the offshore extent. Depths in the central basin of Raritan and Lower New York Bay range from approximately 10 to 30 ft below MLLW, although greater water depths (up to 75 ft below MLLW) are present within the navigational channels. Depths offshore of the Rockaway Peninsula generally range from 20 to 30 ft below MLLW.

1.3 Objectives and Tasks

To address potential impacts from sediment resuspension during Project-related activities, RPS has been contracted to develop and apply customized hydrodynamic, and sediment transport and dispersion models to the study area. Specifically, the analysis includes two interconnected modeling tasks:

1. The development and calibration of a three-dimensional hydrodynamic model application for the NY/NJ Harbor Estuary, including waters of Raritan Bay, Lower New York Bay and nearby waters of the Atlantic Ocean using the WQMAP/BFHYDRO modeling system.
2. Simulations of the suspended sediment fate and transport (including evaluation of seabed deposition and sediment plumes) using the SSFATE modeling system. SSFATE is being applied to simulate a range of offshore construction activities including mechanical (clamshell) dredging, post-pipelay burial by jet trencher, hand-jetting, and suction dredging. Current fields developed using the BFHYDRO model are used as the primary forcing for the sediment dispersion model.

A description of the hydrodynamic model and its application to the Project area are presented in Section 2. Section 3 provides an overview of the SSFATE sediment model and results from the application of SSFATE for a range of base case construction scenarios. References for both modeling systems are provided in Section 4.

2 Hydrodynamic Modeling

The first modeling task was the development, validation, and application of a three-dimensional hydrodynamic model application for the NY/NJ Harbor Estuary, including waters of Raritan Bay, Lower New York Bay and nearby waters of the Atlantic Ocean. RPS' WQMAP model system, containing the BFHYDRO hydrodynamic model (Muin and Spaulding, 1997) 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.

WQMAP (Mendelsohn, et al., 1995) is a modeling system which integrates geographic information (land use, watersheds, topography/bathymetry etc.), environmental data (water quality parameters, surface elevations and velocities, stream flows, etc.) and models (analytical and numerical, hydrodynamic, pollutant transport, etc.). The WQMAP graphical user interface simplifies integration of inputs and provides a graphical display of model output making it a useful tool for scientists and regulators to undertake analyses such as this, where it can also be used for public presentation.

The WQMAP system contains multiple models and a graphical user interface for handling input and output. The computational engine is a family of general curvilinear coordinate system computer models including a boundary conforming gridding model (BFGRID), a hydrodynamic model (BFHYDRO), a single constituent mass transport model (BFMASS) and an eight-state variable water quality, eutrophication model (BFWASP). The output from BFHYDRO is seamlessly integrated as input in RPS' transport models including SSFATE (sediment transport and fates model).

2.1 WQMAP BFHYDRO Description

The BFHYDRO model is a general curvilinear coordinate, boundary-fitted hydrodynamic model (Muin and Spaulding, 1997; Mendelsohn et.al, 1995; Huang and Spaulding, 1995; Swanson et al., 1989) that can be used to generate tidal elevations, velocities, and salinity and temperature distributions. The model utilizes a boundary-fitting technique, which matches the grid coordinates with shoreline and bathymetric feature boundaries for highly accurate representations of areas with complex coastal geometry, such as the region surrounding the Raritan Bay Loop. This system also allows the modeling team to adjust the model grid resolution as desired (in this case, to a high resolution near the pipeline route) and introduce lower mesh resolution (larger cells) at locations several miles from the proposed route for computational efficiency. BFHYDRO may be applied in either two or three dimensions depending on the nature of the problem and the complexity of the study. A detailed description of the model with associated test cases is described in Muin and Spaulding (1997), which is included in Appendix A, and (Muin, 1993). The model has undergone extensive testing against analytical solutions and has been found to perform accurately and quickly. Specific model comparisons are found in Swanson et al. (2012), Mendelsohn et al. (2003), Muin and Spaulding (1997), Mendelsohn et al. (1995) and Huang and Spaulding, (1995). A brief description of the model follows.

2.1.1 Model Theory

The boundary-fitted method uses a set of coupled, quasi-linear, elliptic transformation equations to map an arbitrary horizontal multi-connected region from physical space to a rectangular mesh structure in the transformed horizontal plane (Spaulding, 1984). The three-dimensional conservation of mass and momentum equations, with approximations suitable for lakes, rivers, estuaries, and coastal oceans (Swanson, 1986; Muin, 1993) that form the basis of the model, are then solved in this transformed space. A sigma stretching system (Figure 2) is used in the vertical to map the free surface and bottom onto coordinate surfaces to resolve bathymetric variations. The vertical mesh stretches and shrinks with the changing tidal elevation, maintaining a constant number of layers, so that no interpolation is required to simulate the surface wave or the bathymetry. The velocities are represented in their contra-variant form, on an Arakawa-C grid.

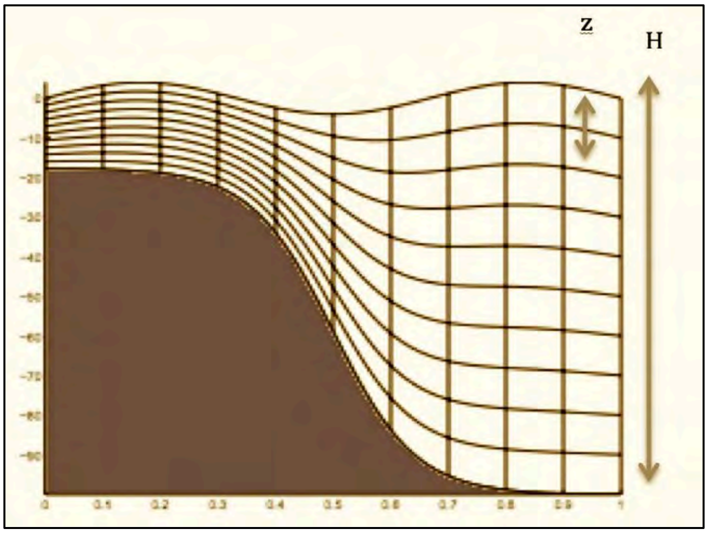

Figure 2. Illustration of sigma grid representation.

The basic equations are written in spherical coordinates to allow for accurate representation of large modeled areas without distortion. The conservation equations for water mass, momentum (in three dimensions) and constituent mass (temperature [heat] and salinity) form the basis of the model, and are well established. It is assumed that the flow is incompressible, that the fluid is in hydrostatic balance, the horizontal friction is not significant and the Boussinesq approximation applies; all customary assumptions.

The boundary conditions are as follows:

- At land, the normal component of velocity is zero.
- At open boundaries, the free surface elevation must be specified, and temperature (and salinity for estuarine and coastal applications) specified on inflow.
- On outflow, temperature (heat) (and salinity) is advected out of the model domain.
- At river boundaries, the volume flux must be specified, with positive flow into the model domain, and temperature and salinity must be specified.
- A bottom stress or a no slip condition can be applied at the bottom. No temperature (heat) is assumed to transfer to or from the bottom, a conservative assumption as some transfer of heat to the bottom is expected to occur.
- A wind stress, and appropriate heat transfer terms, are applied at the water surface. The surface heat balance includes all the primary heat transfer mechanisms for environmental interaction.

There are various options for specification of vertical eddy viscosity, Av, (for momentum) and vertical eddy diffusivity, Dv, (for constituent mass [temperature and salinity]). The simplest formulation is that both are constant, Avo and Dvo, throughout the water column. They can also be functions of the local Richardson number, which, in turn, is a function of the vertical density gradient and vertical gradient of horizontal velocity. A 1-equation or 2-equation turbulence closure model may also be used. This application used the spatially and temporally varying 1-equation model to predict the eddy viscosity and eddy diffusivity, consistent with estuarine application of this type.

The set of governing equations with dependent and independent variables transformed from spherical to curvilinear coordinates, in concert with the boundary conditions, is solved by a semi-implicit, split mode finite difference procedure (Swanson, 1986). The equations of motion are vertically integrated and, through simple algebraic manipulation, are recast in terms of a single Helmholtz equation in surface elevation. This equation is solved using a sparse matrix solution technique to predict the spatial distribution of surface elevation for each grid.

The vertically averaged velocity is then determined explicitly using the momentum equation. This step constitutes the external or vertically averaged mode. Vertical deviations of the velocity field from this vertically averaged value are then calculated, using a tridiagonal matrix technique. The deviations are added to the vertically averaged values to obtain the vertical profile of velocity at each grid cell thereby generating the complete current patterns. This constitutes the internal mode. The methodology allows time steps based on the advective, rather than the gravity, wave speed as in conventional explicit finite difference methods, and therefore results in a computationally efficient solution procedure (Swanson, 1986; Muin, 1993).

2.1.2 Previous BFHYDRO Applications Within the New York/New Jersey Harbor Estuary

BFHYDRO has been previously used to predict time varying currents for assessments of cable and pipeline crossings in the lower Hudson River (ASA, 2011a), and New York Harbor (between Bayonne, NJ and Brooklyn, NY) (ASA, 2009), as well as time varying currents, salinity and temperature for assessment of a thermal discharge from a power plant approximately 42 miles upstream of the Battery (ASA, 2011b) at the Indian Point Energy Center. Each of these applications used a modification of a NY/NJ Harbor Estuary and rivers grid developed over the many applications to the region.

Significant understanding of the important features that characterize the area, (e.g. the upstream penetration of the tidal response in the Hudson River) and affect the tidal elevations, currents and circulation patterns, was garnered from the previous, in-depth modeling studies. That understanding was employed to guide the present study, in the definition of the study area, definition of boundary conditions, and the values of important model parameters. The BFHYDRO general curvilinear coordinate, boundary conforming model system is ideally suited for the NY/NJ Harbor Estuary, with its ability to conform to the highly complex geometry of the numerous rivers and embayments, without the constraints of rectangular, orthogonal curvilinear or finite element systems.

2.2 BFHYDRO Application

2.2.1 Model Grid (Resolution/Bathymetry)

The gridding of the model domain began with the refinement of an existing, comprehensive model grid application to the NY/NJ Harbor Estuary. To appropriately capture the tides, currents and circulation patterns of the Raritan Bay system, the existing model domain was extended and refined to cover the study areas of Raritan Bay, Sandy Hook Bay, and Lower New York Bay. The larger domain of the grid extends several miles south and east into New York Bight, into Long Island Sound, and to the head of the tide in the Hudson, Raritan, and Passaic and Hackensack Rivers.

The grid was refined to a high resolution in the areas through which the pipeline route passes, and in other areas of specific interest (e.g. bathymetric features and channels, which affect circulation). A coarser grid resolution was maintained at distances away from the pipeline. The grid cells range in size from approximately 140 x 140 m (460 x 460 ft) in Raritan Bay to 2.4 x 3.2 km (1.5 x 2.0 mi.) offshore in the NY Bight. Note that the water column sediment concentrations do not depend on the hydrodynamic model grid for calculations; there is a separate gridding and calculation method employed in the SSFATE model which will be discussed in a later section.

The bathymetry used in the hydrodynamic model grid was taken from three sources:

- Electronic NOAA NOS charts, CMAP database
- NOAA's "maintained channels" ENC layer database
- Swath bathymetry along the Project offshore route collected by Rogers Surveying in 2016

The bathymetry sources were combined to create a detailed database in the NY/NJ Harbor Estuary. The model gridding tool was then used to grid the bathymetry, assigning a unique depth value to each cell, either through averaging, for multiple values in a designated cell, or interpolating for the occasional cell where no depth data are available. The resulting grid and associated depths were then manually checked for outliers. The final model grid and bathymetry is shown in Figure 3.

2.2.2 Boundary Conditions

The edges of the model grid are designated as either closed boundaries, (land boundaries along the coast), or open boundaries. Open boundaries can be designated as either tidal or riverine, for elevation or volume flow driven, respectively. A map of the model grid, showing the location of the open tidal and riverine boundaries, is presented in Figure 4. The Hudson River boundary, at Green Island (north of Albany), is significantly farther upstream than the map allows for visualization.

Tidal Boundary Conditions

Tidal boundaries require the specification of the water surface elevation, which can be done in one of two ways in the model: specification of tidal harmonic constituents (e.g. M2, K1, O1, S2, etc.) amplitude and phase, or application of a tidal time series. The harmonic constituents can be obtained from NOAA at tide stations near the open boundary, or specified from larger scale tidal models. The harmonic constituents are then used to generate a tidal elevation each time step at each open boundary cell during the model simulation, providing a very efficient and easily implemented approach. The drawback of the harmonic constituents approach is that they do not capture larger scale offshore pressure system or wind setup or set down along the coast.

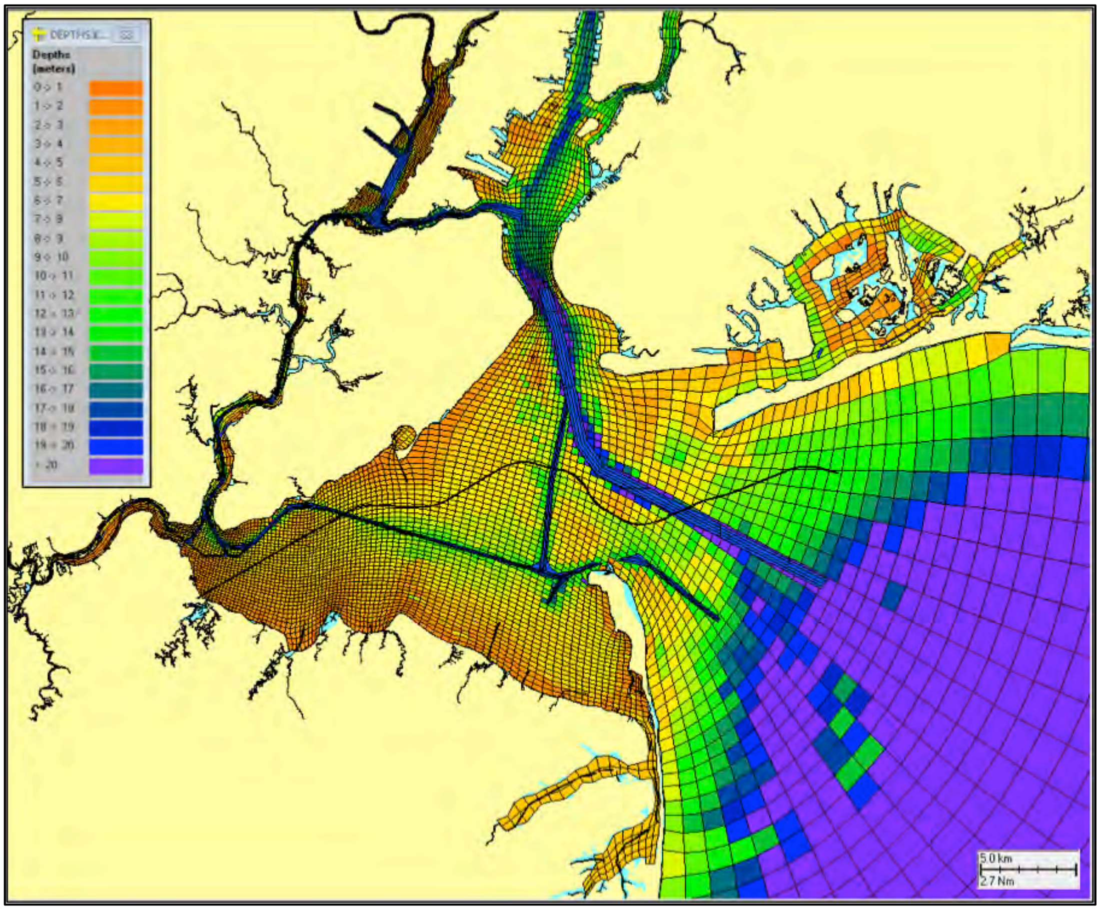

Figure 3. BFHYDRO, boundary conforming grid and bathymetry for NY/NJ Harbor Estuary and the New York Bight.

To better compare the model-predicted currents with observations of the surface elevation and currents in the study domain over a definite time period, RPS chose to use a detailed time series of tidal elevation from a NOAA station close to the open boundary. The tidal elevation time series from NOAA Stations 8531680 (Sandy Hook) and 8516945 (Kings Point) available at a 6-minute time step, were used to drive the open boundaries in the New York Bight and Long Island Sound, respectively. Data was downloaded from the NOAA NOS website for all of 2011 and 2012, which has verified data until near the end of October when hurricane Sandy disabled the station for several months. These dates were selected to overlap with the deployment of a series of current meters in Raritan Bay so the data could be used for comparison with model predictions. (Current meter data used for model validation are discussed in greater detail in the following sections.) The offshore open boundary was forced with the data obtained from Sandy Hook, though it was adjusted by offsetting the time by 30 minutes to align the model-predicted time series at the Sandy Hook location with the original observed timing.

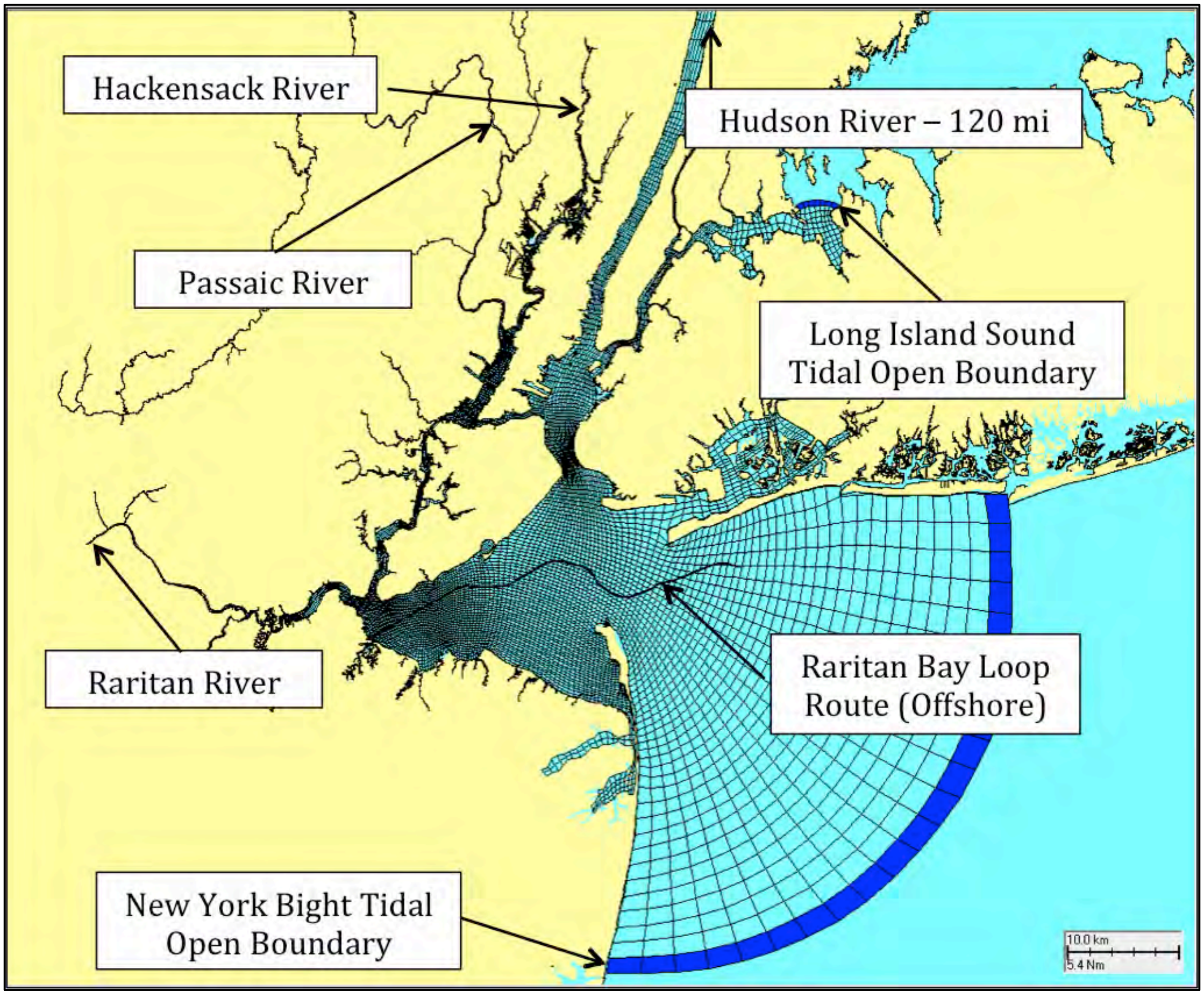

Figure 4. BFHYDRO, boundary conforming grid showing river boundaries for the Raritan, Passaic, Hackensack and Hudson Rivers and open boundaries for the New York Bight and the connection between the NY/NJ Harbor Estuary and Long Island Sound, at Kings Point.

River Boundary Conditions

The river flow rate for the 2011 – 2012 period was specified for the major inputs to the NY/NJ Harbor Estuary, based on USGS Station Gauge data. The major rivers included were the Raritan, Hudson, Passaic and Hackensack, where a number of tributaries to each were also included as the watershed drainage areas for many of the rivers are large (particularly the Hudson). The following specific USGS station data were employed in the modeling:

- Raritan
  - 01403060 Raritan River below Calco Dam at Bound Brook NJ
  - 01405030 Lawrence Brook at Westons Mills NJ
- Passaic
  - 01389890 Passaic River at Dundee Dam at Clifton NJ
  - 01391500 Saddle River at Lodi NJ
- Hackensack
  - 01378500 Hackensack River at New Milford NJ
- Hudson
  - 01358000 Hudson River at Green Island NY
  - 01361000 Kinderhook Creek at Rossman NY
  - 01364500 Esopus Creek at Mount Marion NY
  - 01367500 Rondout Creek at Rosendale NY
  - 01371500 Wallkill River at Gardiner NY
  - 01372500 Wappinger Creek Near Wappingers Falls NY

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 NOAA NWS Station 8531680, also located at Sandy Hook, which is representative of the Raritan Bay area, just to the west.

2.2.3 Set-up and Calibration

The model was set up and run in three-dimensional mode, using the boundary conditions described in the previous section. The simulation period was chosen to match the period of available in-situ current data identified during the preliminary phases of the modeling task. A summary of other input parameters, specific to the model application are listed in Table 1.

The Rutgers Marine & Coastal Sciences department had deployed a series of Acoustic Doppler Current Profiler (ADCP) moorings at five sites in Raritan Bay, spanning the period of September 2011 through October 2012. The mooring locations, noted as RB1, RB2, RB3, RB4 and AK1, are shown in Figure 5. A complete set of currents from the five locations was available during the second of four deployments over that period. The ADCP mooring second deployment began in December 2011 and continued through April 2012. The model was run for that period, and tidal elevation and current predictions from the model were compared to observations recorded at various NOAA station locations and at each of the five ADCP mooring locations.

Table 1. BFHYDRO input parameters.

Parameter	Value	Units
System Metrics		
IMAX - Nominal E-W grid dimension	150	(-)
JMAX - Nominal N-S grid dimension	261	(-)
KMAX - Vertical Layers	11	(-)
Number of sequential cells	7468	(-)
Open Boundary Cells	16	(-)
River Boundary Cells	8	(-)
Number of Time Series Locations	31	(-)
Time Parameters		
Hydro time step	300	(sec)
Open boundary ramp time	1440	(min)
Wind forcing ramp time	1400	(min)
Turbulence ramp time	0	(min)
Residual calculation delay	1440	(min)
Physical Parameters		
Drag coefficient, Cd	0.0015	(-)
1-eqn Turbulence Closure Model	(-)	(-)
Average water density	1025	(kg/m3)
Average air density	1.3	(kg/m3)
Surface, wind Cd	0.0014	(-)

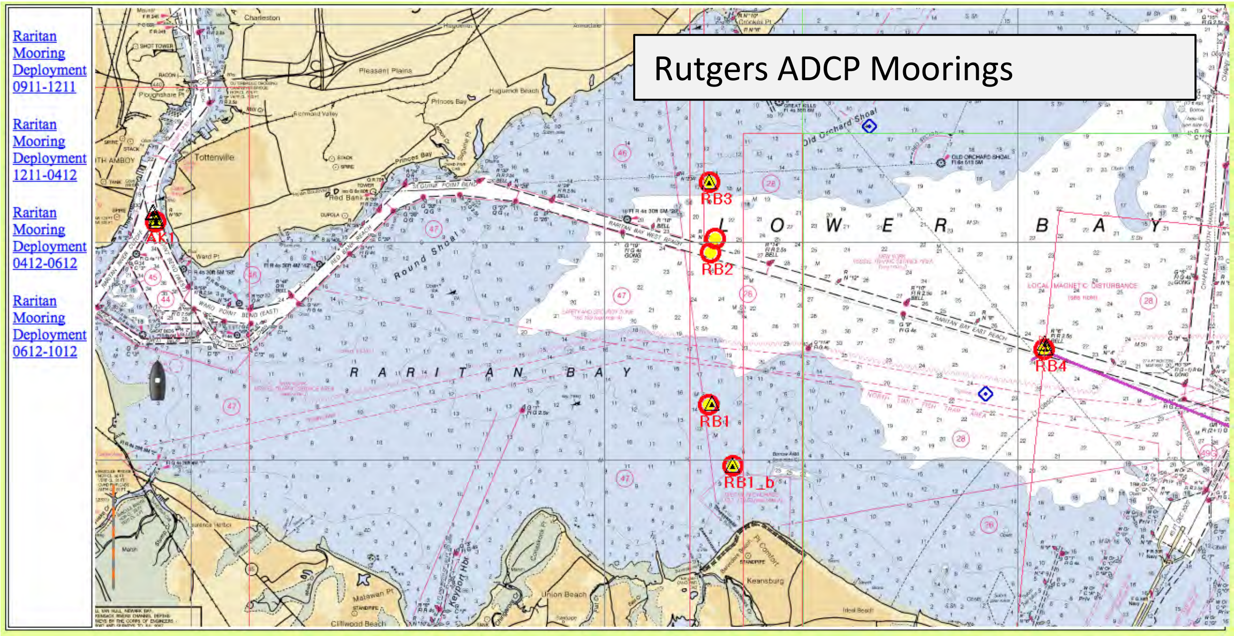

Figure 5. Map of Raritan Bay showing the locations of the Rutgers ADCP mooring sites. The dates of each of the four mooring deployment periods is presented in the column to the left of the map.

Model-predicted surface elevations, and current speeds at multiple water depths, were compared to available observations to ensure the modeling was adequately reproducing tidal amplitude, current velocity, and vertical structure of the water column. Standard quantitative metrics for model calibration and validation, were calculated for the time series, as well as a comparison of the model-predicted and observed harmonic constituents.

An example of the model-predicted tidal time series compared to the observations at Sandy Hook for the month of January, 2012, is presented in Figure 6. The top plot represents the wind vector during that period, and aligns with the tidal elevation in the lower plot. The elevation presents a complex response to tides, winds and set up and set down at various times. An example of this is seen beginning around 11 January, when an east and north wind appears to push water into the bay, increasing tidal elevations. Shortly thereafter, on 13 January, the wind comes around to the west and northwest, pushing water out of the bay and depressing elevations, all the while responding to tidal forcing as can be seen in the predominant semi-diurnal signal. The model predictions match the observations well, and the signal is well recreated, suggesting that the boundary condition application was effective.

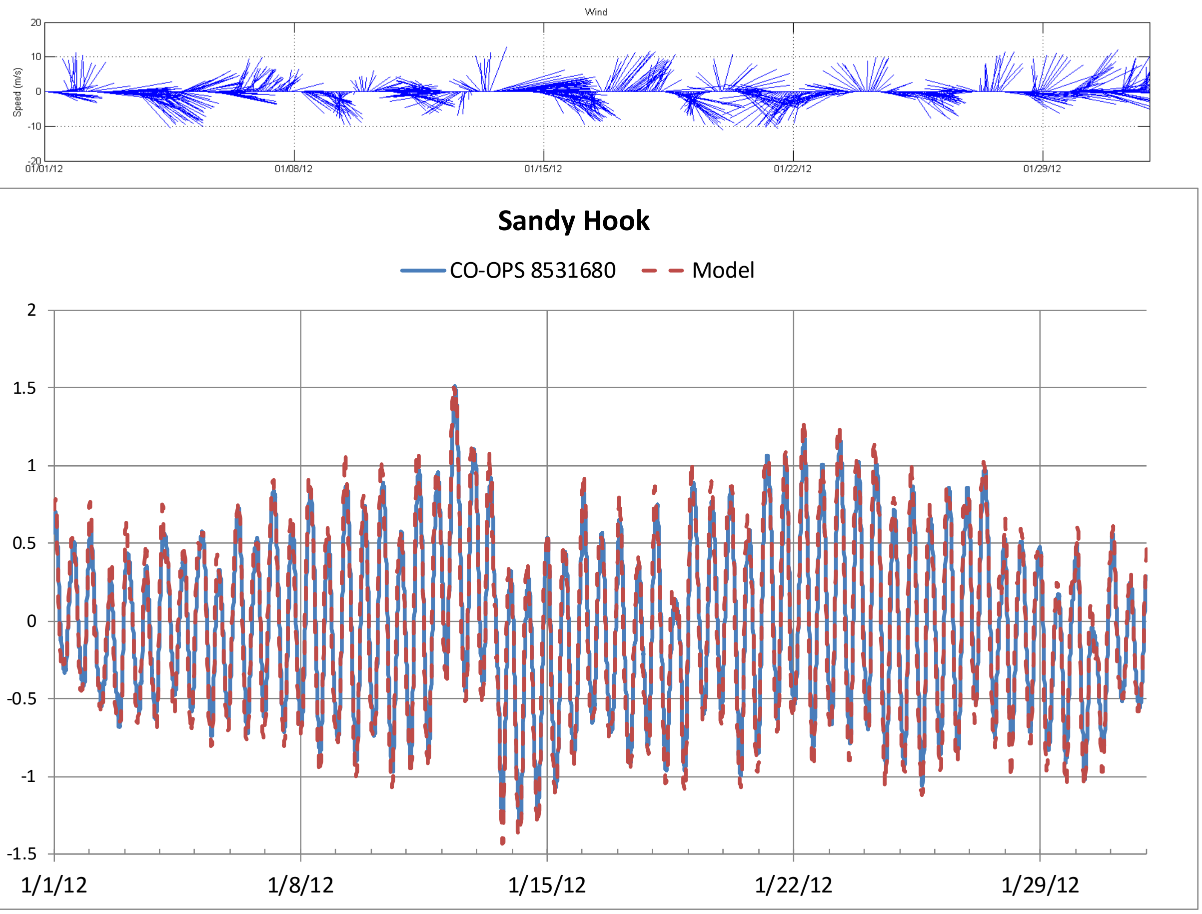

Figure 6. Time series of model-predicted versus observed tidal elevation for NOAA NOS Tide Station 8531680 at Sandy Hook, January 2012, lower plot. Upper plot shows the concurrent wind speed and direction at Sandy Hook, January 2012. The wind stick vectors on the wind plot show the wind speed as the length of the vector, and the direction as the direction towards which the wind is blowing.

The model-predicted tidal elevation signal was analyzed at several NOAA subordinate tide station locations in the model domain (see Figure 7), generating the major tidal harmonic constituents, to assess the time propagation through the system. A comparison of the model-predicted to observed (NOAA calculated) harmonic tidal elevation constituents, is presented in Figure 8, for the M2 and K1, which are the major semi-diurnal and diurnal constituents in the domain.

The bar chart comparison of the M2 constituent shows that the tides propagate through the domain in significantly different ways, depending on the location, and that the model could successfully recreate that difference. For example, there is a decrease in the M2 amplitude between Sandy Hook and the Battery, and a greater decrease still at the George Washington Bridge, moving up the Hudson River.

Figure 7. Map of the NOAA tide station locations in the Project area, for comparison of model-predicted and observed tidal elevation harmonic constituents.

Conversely, there is an increase in the M2 amplitude between Sandy Hook and the Raritan River, just a few miles to the west. The K1 response is less noticeable, but the diurnal response is characteristically smaller than the M2, as seen in the observations and predicted by the model. Table 1 presents the full set of calculated tidal harmonic constituents for the model-predicted and observed surface elevations at various stations around the NY/NJ Harbor Estuary.

The model's ability to predict the currents in the study domain is of primary interest in the model application. Model predictions and observations of the surface and bottom currents at Rutgers mooring RB1 location during January 2012, are presented in Figure 9. Mooring RB1 is located south of the Raritan Bay West Reach Channel, just north of Pt. Comfort. The top 2 plots are the E-W and N-S current vector components at the surface (surface = uppermost layer of model solution and uppermost bin of the ADCP data), and the 3rd and 4th plots are the bottom currents in the E-W and N-S directions, respectively (bottom = lowest layer of the model predictions, and first bin of the ADCP observations, which come from bottom mounted instruments).

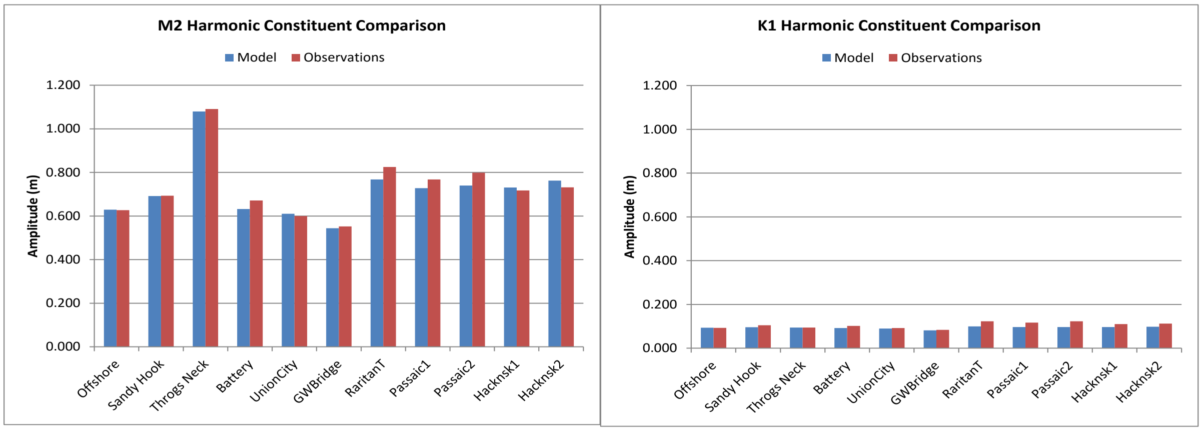

Figure 8. Comparison of model-predicted and observed M2 and K1 tidal elevation harmonic constituents, at various NOAA tide station in and around the NY/NJ Harbor Estuary area.

Table 2. Model-predicted and observed tidal harmonic constituents at various stations in the NY/NJ Harbor Estuary, for the 5 major components.

	Model Predicted									
Location	M2 AMP (m)	M2 PHASE	S2 AMP (m)	S2 PHASE	N2 AMP (m)	N2 PHASE	K1 AMP (m)	K1 PHASE	O1 AMP (m)	O1 PHASE
Offshore	0.629	240	0.132	228	0.139	245	0.094	88	0.050	133
Sandy Hook	0.692	249	0.146	238	0.151	255	0.096	92	0.052	138
Throgs Neck	1.079	10	0.187	356	0.238	11	0.094	117	0.065	192
Battery	0.632	266	0.133	253	0.139	270	0.092	99	0.051	147
UnionCity	0.610	270	0.129	258	0.134	275	0.090	104	0.050	152
GWBridge	0.544	282	0.114	270	0.117	287	0.082	115	0.046	166
RaritanT	0.768	255	0.163	246	0.167	263	0.099	95	0.054	139
Passaic1	0.728	262	0.154	252	0.158	269	0.097	99	0.053	145
Passaic2	0.740	279	0.152	274	0.158	289	0.097	109	0.057	151
Hacknsk1	0.731	261	0.155	250	0.159	267	0.097	98	0.053	144
Hacknsk2	0.763	262	0.163	251	0.166	268	0.098	98	0.053	144
	Observed									
Location	**M2 AMP (m)**	**M2 PHASE**	**S2 AMP (m)**	**S2 PHASE**	**N2 AMP (m)**	**N2 PHASE**	**K1 AMP (m)**	**K1 PHASE**	**O1 AMP (m)**	**O1 PHASE**
Open Boundary	0.627	203	0.131	225	0.138	190	0.093	91	0.05	93
Sandy Hook	0.693	223	0.137	245	0.157	208	0.105	100	0.054	102
Throgs Neck	1.091	333	0.189	354	0.240	316	0.094	120	0.065	152
Battery	0.671	235	0.133	255	0.149	219	0.102	105	0.054	107
UnionCity	0.600	251	0.125	272	0.134	234	0.092	113	0.048	117
GWBridge	0.552	261	0.115	282	0.123	244	0.084	119	0.045	122
RaritanT	0.825	243	0.173	265	0.182	230	0.123	112	0.066	113
Passaic1	0.768	240	0.153	261	0.171	224	0.117	108	0.062	110
Passaic2	0.799	246	0.161	267	0.180	230	0.123	111	0.065	113
Hacknsk1	0.717	249	0.150	271	0.161	233	0.110	113	0.058	117
Hacknsk2	0.732	274	0.152	296	0.163	257	0.112	125	0.059	128

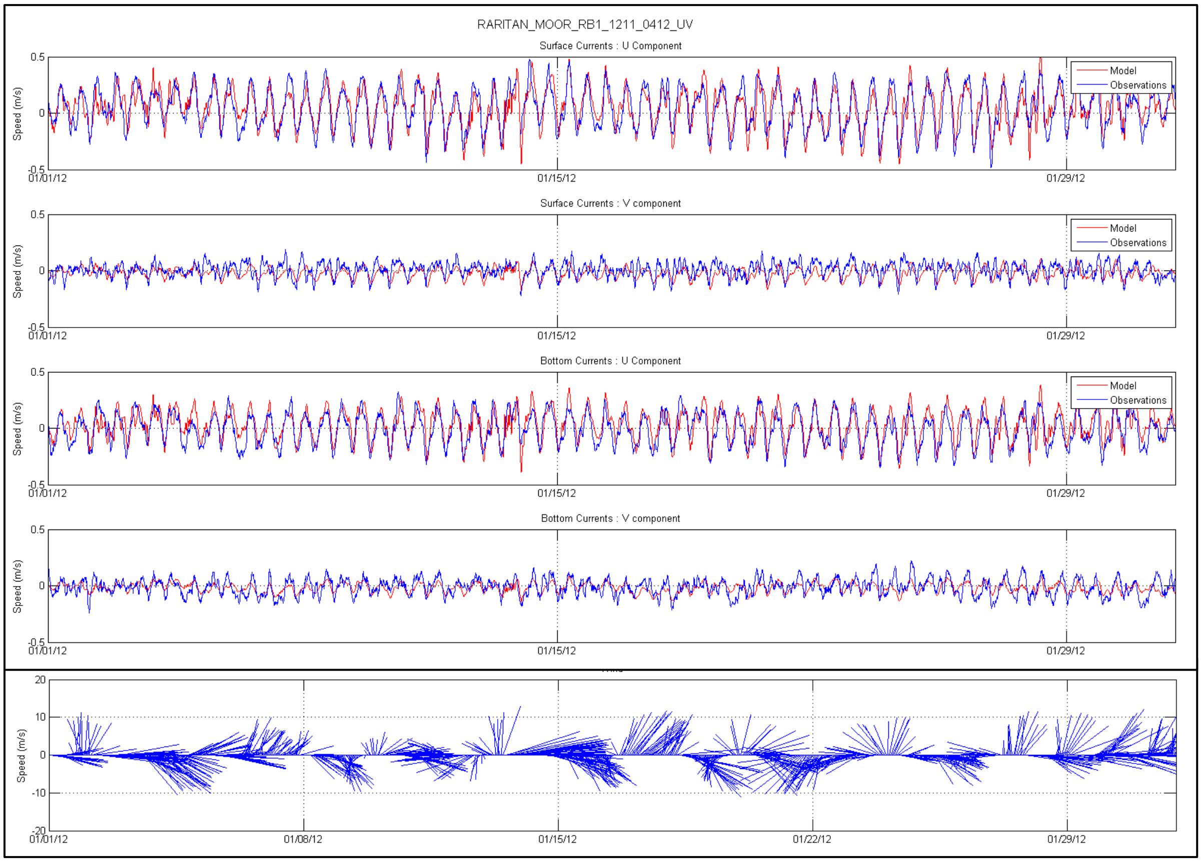

Figure 9. Model-predicted versus observed tidal currents at Rutgers ADCP mooring RB1, January 2012. The upper 2 plots show the model-predicted and observed E-W and N-S current vector components, respectively, at the surface. The 3rd and 4th plots show the model-predicted and observed E-W and N-S current vector components, respectively, at the bottom. The lower plot shows the concurrent wind speed and direction at Sandy Hook, January 2012.

There are two important features to be noted in the currents; the first is that the currents ebb and flood primarily in the E-W direction and have very little N-S movement. The second is that the bottom currents are not much smaller than the surface currents, as might be expected in a well-mixed estuary. The model predictions picked up the variability noted, and follow the trends and magnitudes of the observed currents well, clearly exhibiting the semi-diurnal tidal response as well as the wind induced offsets around mid-January at the surface and bottom.

As another example, the model current predictions are compared to observations at the Rutgers mooring RB2, in the Raritan Bay West Reach Channel, directly north of RB1, over the same period in January 2012 (Figure 10). The response here is similar if not more pronounced in the difference between the E-W and N-S vector components.

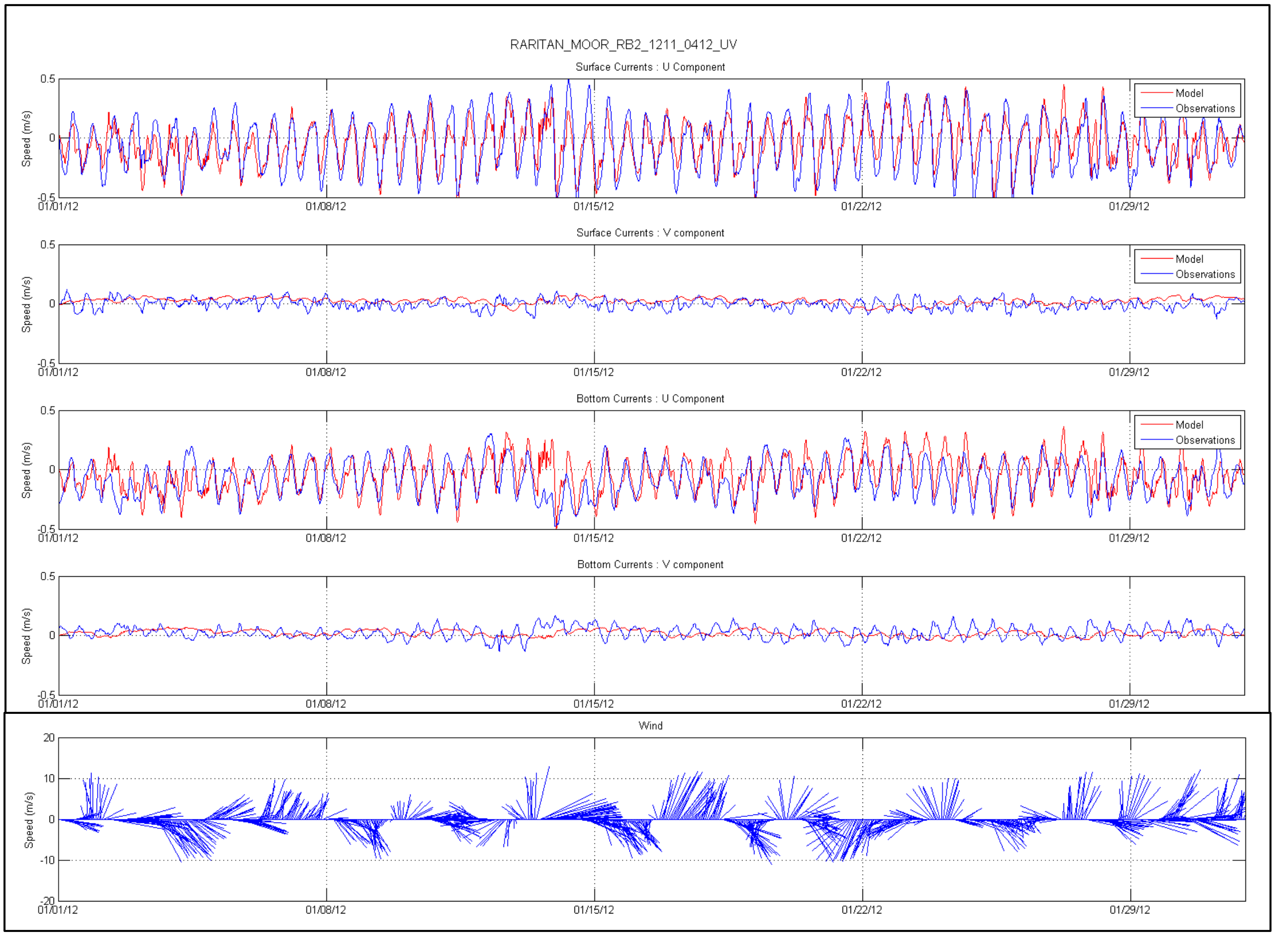

Figure 10. Model-predicted versus observed tidal currents at Rutgers ADCP mooring RB2, in the Raritan Bay West Reach Channel, January 2012. The upper 2 plots show the model-predicted and observed E-W and N-S current vector components, respectively, at the surface. The 3rd and 4th plots show the model-predicted and observed E-W and N-S current vector components, respectively, at the bottom. The lower plot shows the concurrent wind speed and direction at Sandy Hook, January 2012.

The surface currents show a strong semi-diurnal response, with the model able to recreate the strength and timing of the signal well. The surface predictions capture the response of the event in mid-January, as do the bottom predictions, apart from a brief anomalous behavior in the bottom current during that time. The N-S component strength is nearly non-existent both at the surface and bottom, though a little under-predicted by the model.

Examples of the model-predicted maximum flood and ebb tide current fields, on January 9th, 2012 are presented in Figure 11 and Figure 12, respectively. The currents are represented by vectors at each grid cell in the model domain, where the size of the vector represents the current speed, and the arrow head points in the direction of current flow. Referring to Figure 11, strong flood tide currents can be seen, on the right side of the map, to enter the bay through the reach just north of Sandy Hook, and head into Raritan Bay and curl southward into Sandy Hook bay as well. The flood tide currents diminish somewhat as they enter Raritan Bay proper, but accelerate around the two points on the south shore and again at the entrance to the Raritan River, at the left side of the map.

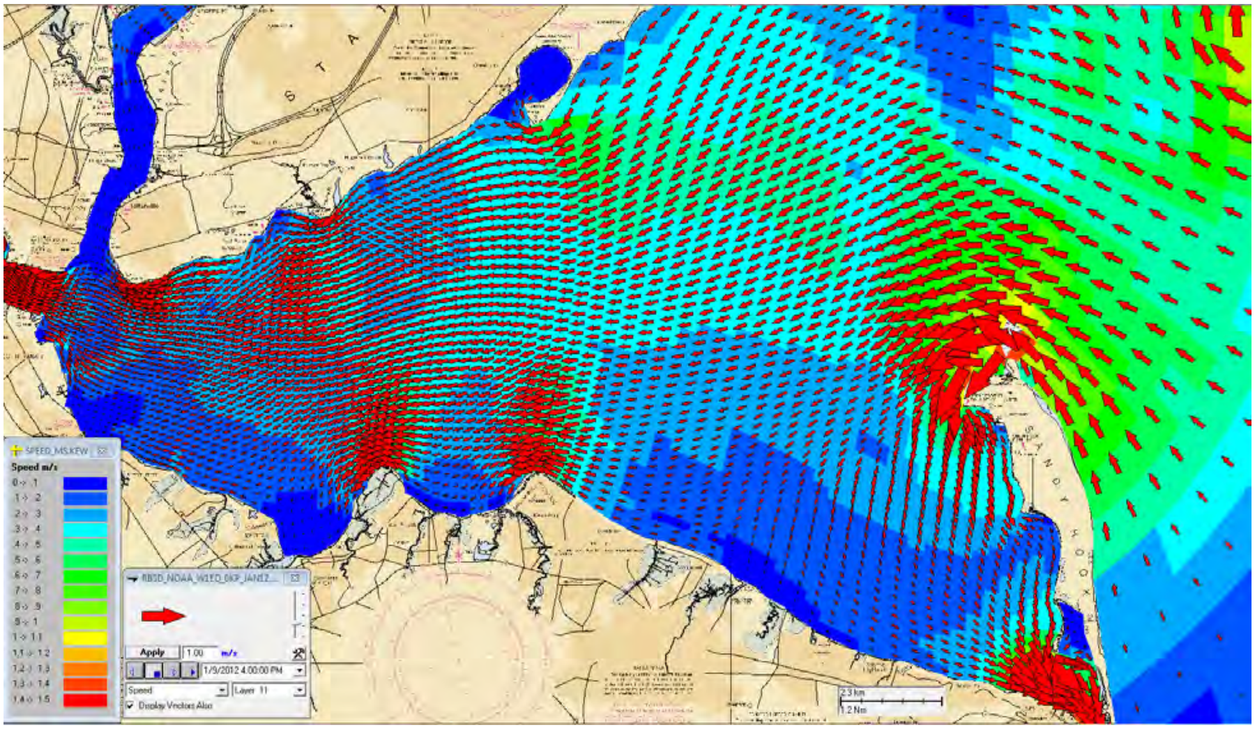

Figure 11. Example model-predicted maximum flood tide currents in the Raritan Bay study area, January 9th, 2012. The current vectors (red arrows) are plotted over color-coded current speed contours.

The currents in the Arthur Kill can be seen to have a different phase than those in the Raritan Bay, starting shortly after, and are not flooding at the time of maximum flood in the Bay, though wind influence may also play a part. The ebb tide currents show a similar picture though in reverse, as can be seen in Figure 12.

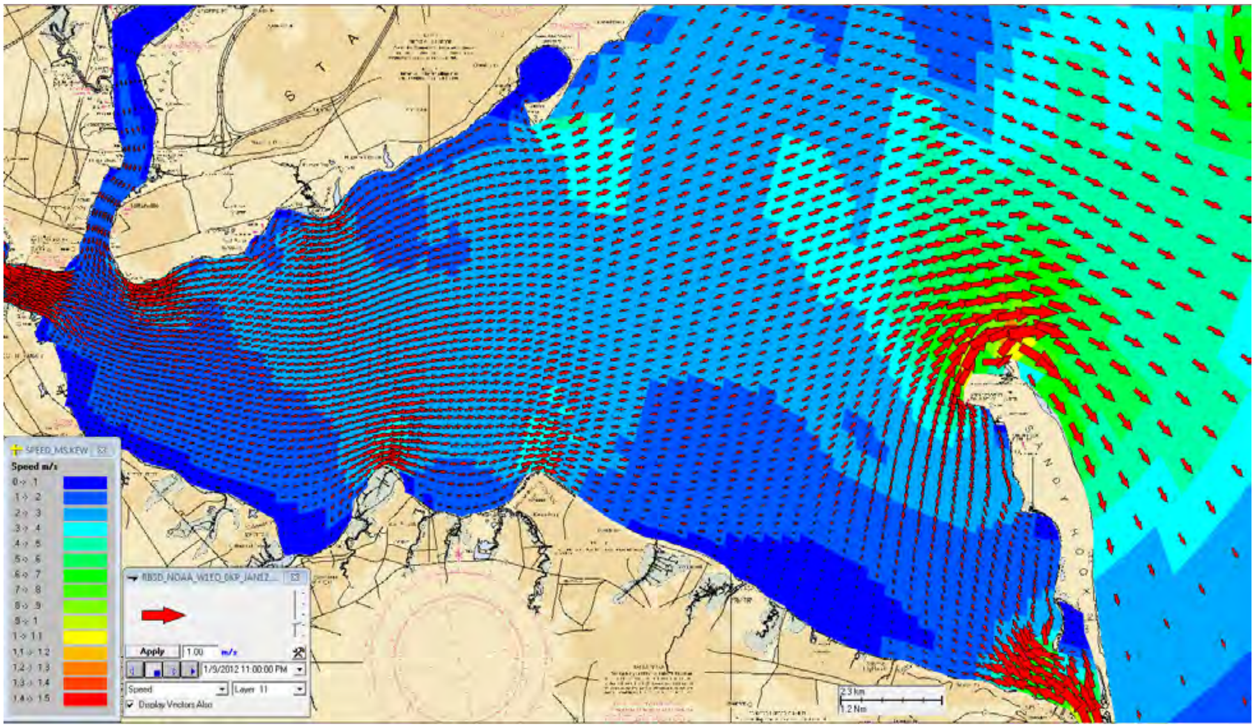

Figure 12. Example model-predicted maximum ebb tide currents in the Raritan Bay study area, January 9th, 2012. The current vectors (red arrows) are plotted over color coded current speed contours.

2.2.4 BFHYDRO Results

With the model application and calibration complete and acceptable, a series of long-term simulations were set up and executed. The simulations used the 2011 and 2012 forcing data set described in the previous sections, as that is the period over which the calibration was performed. Each simulation covered a 6 month time period, to correspond with the dredging and pipe burial schedule planned for the Project. A list of the scenarios with start and end dates is presented in Table 3.

Table 3. Hydrodynamic model simulations for the sediment transport and dispersion study

Run #	Run Name	Start Date	End Date
1	RB3D_NOAA_W1EQ_LIS_2011B.BPC	7/1/2011	12/31/2011
2	RB3D_NOAA_W1EQ_LIS_2011W.BPC	10/1/2011	3/31/2012
3	RB3D_NOAA_W1EQ_LIS_2012A.BPC	1/1/2012	6/30/2012
4	RB3D_NOAA_W1EQ_LIS_2012S.BPC	4/1/2012	9/30/2012

The simulations were confined to the 6-month span to reduce the overall size of the hydrodynamics model output, and facilitate ease of use and general manageability. The 4 scenarios were stored in a hydrodynamic ‘library’ for use in the sediment transport model application. The 6-month run time spans overlap, to allow long dredging scenarios to continue, start to finish without changing inputs, by selecting the appropriate input file. The overlapping periods are identical.

Results from the simulations were reviewed and a statistical analysis of the full span of the time period (all 4 output spans) in the form of current roses, was performed at selected locations along the proposed pipeline path, to better understand the forces acting on the suspended sediments. The surface and bottom current roses at stations along the route are presented in Figure 13 and Figure 14, respectively. There are 8 total stations (locations) where the analysis was performed, with station 1 just offshore of the pipeline entry point into the bay at South Amboy, NJ, and station 8 at the far end of the pipeline in the waters south of the Rockaway Peninsula. The stations are between 3.5 – 7 km apart, with closer spacing within Raritan Bay.

The current rose plots show the percentage of time that each 0.1 m/s range of current speeds goes in each direction (towards). The directional distribution is broken out into 16 points of the compass, (e.g. N, NNE, NE, ENE, E, etc.), and the circular bands represent 15%, 30%, and 45% (at the outside ring). The total length of a directional band represents the total percentage of time that the currents go in that particular direction. The current speed distribution in that particular direction is shown as color sections, along the band corresponding to the color-coded speed scale.

Referring to Figure 13, for the surface currents, the rose plots for stations 1, 3, 5 and 7 are presented along the lower part of the figure, and stations 2, 4, 6 and 8 are across the top. The rose patterns show that for the majority of the stations, the currents are tidal, and nearly rectilinear, i.e. in one direction and out in the opposite direction. The larger the band is in a particular direction, the more frequently the currents flow (toward) that direction. For example, station 2 currents are east approximately 40% of the time and west about 30%, with small variability to the NE and SW. The blue colors suggest that the tides are less than 0.3 m/s. In comparison, the currents at station 6, are directed in a ESE and WNW pattern, (>45% and 30% of the time, respectively), and considerably stronger than currents at station 2, with speeds that exceed 1 m/s.

The larger speeds at station 5 and 6, correspond to the high volume NY Harbor entrance flow, that must feed the entire system, including the Hudson and other tidal rivers. Station 7 is in the deep, entrance channel, and therefore a little slower, and station 8 is outside the entrance area, and also slower and more variable.

In Raritan Bay the current speeds are generally less than 0.5 m/s and follow the general flow pathways in and out of the bay. Station 1, which is out of the major flow pathways, appears to be directed by the nearshore topography. This location exhibits lower speeds and is more directionally variable.

The bottom currents (Figure 14) show a similar pattern to the surface, with smaller magnitudes - as was also observed in the model calibration (Figure 10). This reduction in speeds can be seen by comparing the colors of each bottom and surface current rose plot pair. The directional distribution and percent occurrence does not vary noticeably between the surface and bottom however.

The current rose plots of the model predictions along the pipeline route give a better understanding of the forces that will be acting on the re-suspended sediments during the various dredging operations. The higher speeds will tend to transport the sediments farther, but will also serve to reduce the concentrations in the water column through increased dilution (water volume into which the sediments are injected). Conversely, the slower currents will tend to maintain the sediments around the resuspension zone, at higher concentrations.

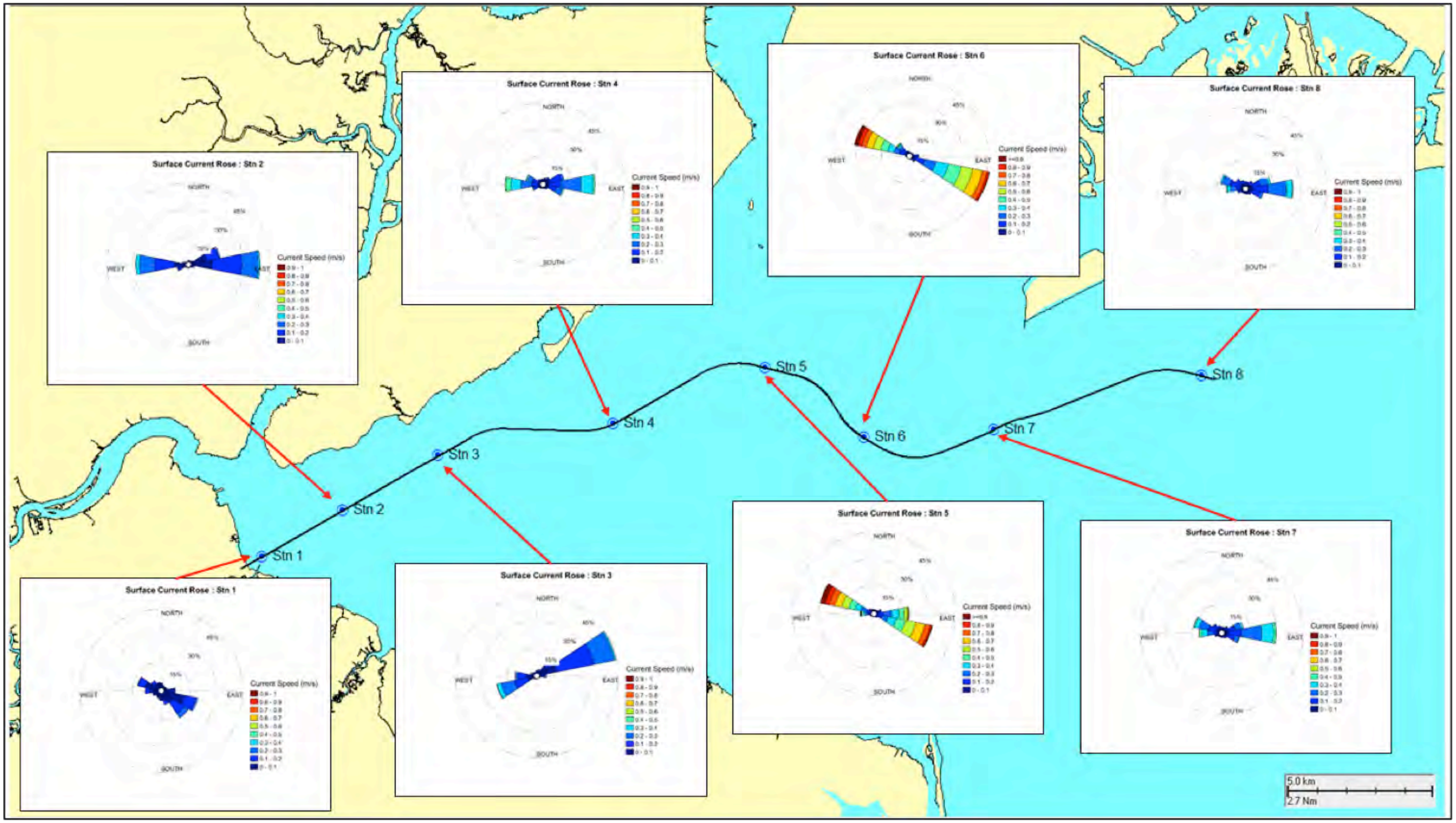

Figure 13. Model predicted surface current rose plots for 8 stations along the pipeline burial route in Raritan Bay.

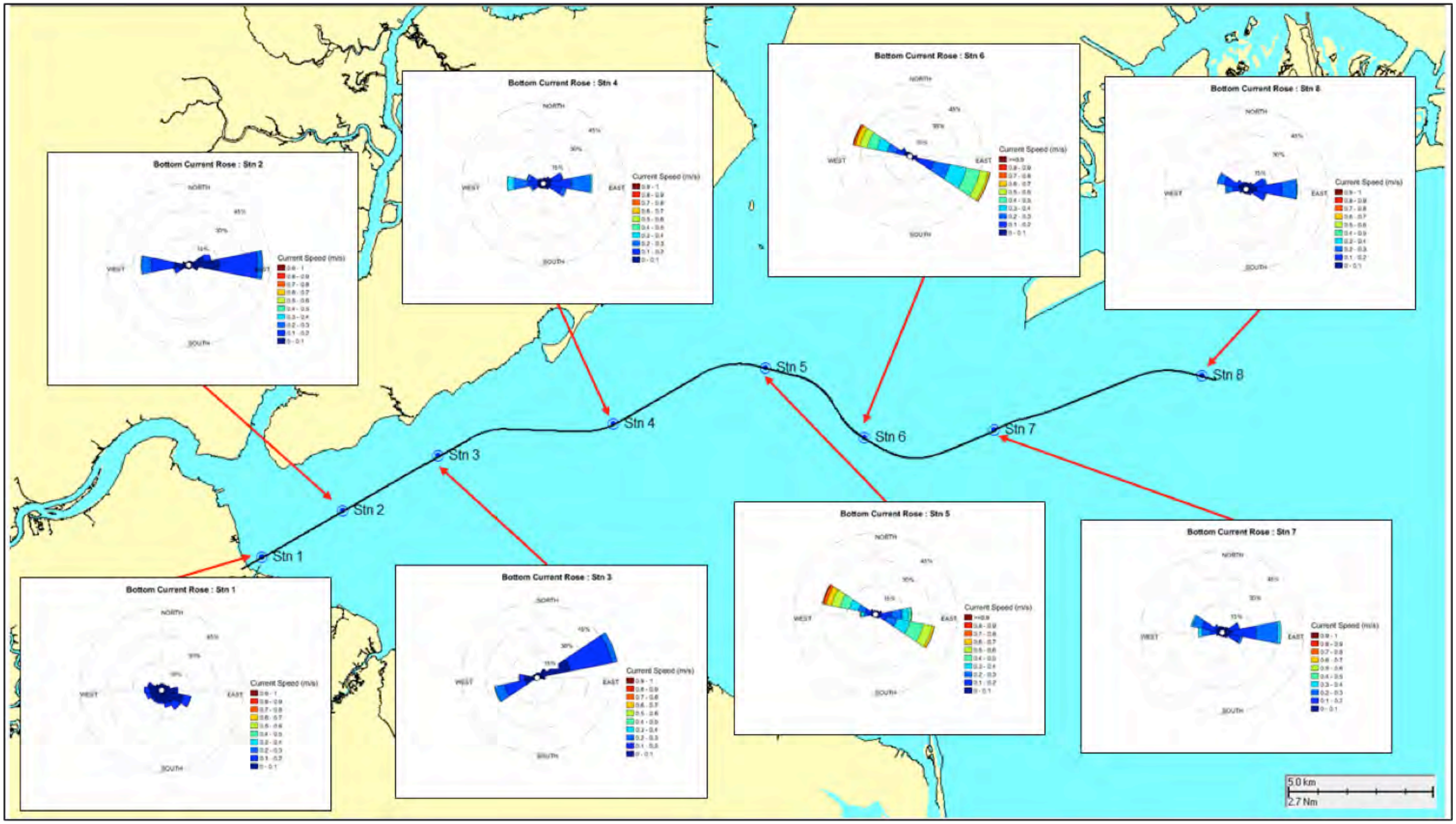

Figure 14. Model predicted bottom current rose plots for 8 stations along the pipeline burial route in Raritan Bay.

3 Suspended Sediment Modeling

3.1 SSFATE Description

SSFATE (Suspended Sediment FATE) is a three-dimensional Lagrangian (particle) model developed jointly by the U.S. Army Corps of Engineers (USACE) Environmental Research and Development Center (ERDC) and Applied Science Associates (now part of the RPS group) to simulate sediment resuspension and deposition 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 total suspended sediment (TSS) concentrations and sedimentation patterns resulting from sediment disturbing activities. The model requires a spatial and time varying circulation field (typically from hydrodynamic model output), definition of the water column bathymetry, and parameterization of the sediment disturbance (source) and 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 fate 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 losses (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.

As described below, SSFATE has been successfully applied to a number of recent modeling studies within the New York/New Jersey region and has received acceptance from Federal and State regulatory agencies (including FERC and NYSDEC).

3.1.1 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 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 represents 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 (Table 4.), each having unique behaviors for transport, dispersion, and settling. The model represents the total mass of sediments suspended over time by a defined sub-sample of Lagrangian particles, allocating an equal proportion of the mass to each particle (e.g. 1/1000th of the total release if 1000 particles are used). The initial size distribution of the sediments is used to apportion the sample of Lagrangian particles to size classes.

Table 4. Sediment size classes used in SSFATE

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

Horizontal transport, settling, and turbulence-induced suspension of each particle is computed independently by the model for each time step. Particle advection is based on the relationship that a particle moves linearly (in 3-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 the 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). Matter that is 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) summarizes 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 suspended 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 with user-specified cell size that 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 planes, 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. 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), which is attached as Appendix B.

3.1.2 Previous SSFATE Applications Within the New York/New Jersey Harbor Estuary

Since its development, SSFATE has been applied to over a dozen sediment dispersion modeling studies in and around the Project area including portions of the lower Hudson River, Upper New York Bay, Gowanus Bay, Arthur Kill, and adjacent environments of Long Island Sound and Great South Bay. Most of these previous applications have utilized a similar modeling approach to the present study – namely, the coupling of WQMAP/BFHYDRO and SSFATE models to evaluate impacts from mechanical dredging or subsea jetting. Examples of projects within the study domain include:

- Cross Hudson Project - Jet sled and pit excavation (dredging) associated with the burial of bundled electrical cable circuits between Manhattan, New York and Edgewater, New Jersey (ASA 2002).

- Spectra Energy NJ/NY Expansion – Mechanical dredging for placement of a buried natural gas pipeline between Jersey City, NJ and Manhattan, NY (ASA 2011).

- Bayonne Energy Center – Jet sled and cofferdam excavation for a 6.5 mile submarine electric transmission cable between Bayonne, NJ and the Gowanus Substation in Brooklyn, NY (ASA 2009).

- Arthur Kill Navigation Project – Simulations of sediment losses from maintenance dredging of the Arthur Kill Channel using a clamshell dredge (NYNJHP 2003).

In addition, SSFATE has been applied to evaluate impacts from recent gas pipeline installation projects in Massachusetts Bay, Tampa Bay, and Jobos Bay, Puerto Rico.

3.2 SSFATE Application for the Northeast Supply Enhancement Project

The offshore portion of the Raritan Bay Loop will extend approximately 23.3 miles between the Sayreville shoreline in Middlesex County, NJ (MP 12.16) to the Rockaway Transfer Point, south of the Rocakaway Peninsula in Queens County, NY (MP 35.49). Outside of the HDD crossings, the pipeline (including tie-in spools) will be buried to target depths between 4 and 7 below the seafloor along the pipeline route, and a minimum of 8 feet below authorized design depths at channel crossings. In addition, Transco plans to install an offshore anode sled approximately 1,200 feet from the pipe centerline seaward of the Morgan shoreline in Sayreville, New Jersey (near MP12.32) which will be buried below to a minimum depth of 4 feet.

SSFATE was used to perform a series of simulations to assess suspended sediment concentration and seabed deposition resulting from the pipeline installation and associated construction activities. The simulations presented within this report evaluate sediment releases from a range of "base case" construction activities that include:

1. Clamshell dredging of the horizontal directional drilling (HDD) entry and exit pits.
2. Excavation of the anode sled burial area by clamshell dredge.
3. Pre-lay trenching for pipeline burial (clamshell dredging).
4. Hand jetting at cable crossing point in Raritan Bay and offshore the Rockaway peninsula.
5. Post-lay trenching (by jet trencher) along four discrete pipeline segments (15.93 miles total).
6. Clamshell dredging for pipeline burial across navigational channels and anchorage areas.
7. Hand jetting and submersible pumping at the Rockaway Transfer Point (i.e., existing subsea manifold tie-in point).

Details describing the process by which each of the construction activities is implemented in the model are discussed below.

3.2.1 Description of SSFATE Model Set-up

Setup of the SSFATE model consists of defining how each construction activity will be parameterized and establishing the sediment source terms. For each scenario, this includes defining:

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

The model uses hydrodynamics, and bathymetry sources from the WQMAP/BFHYDRO application. As described above, concentration gridding in SSFATE is independent of the resolution of the hydrodynamic data used to calculate transport. Pipeline installation will include a range of sediment disturbing activities that occur as both point sources of sediment release (e.g. HDD pit excavation, hand jetting), as well as moving line sources (trenching by clamshell and jet trencher) across a wide range of spatial scales. Accordingly, a series of local grids were developed to efficiently compute concentrations while maintaining fine resolution in the vicinity of each Project activity.

Offshore construction for the Project is scheduled to begin in the third quarter of 2018 and continue for approximately twelve months. The general schedule for construction activities that involve sediment disturbance (as of March 2017) is presented in Table 5 and a map showing each phase within the construction sequence is shown in Figure 15.

Table 5. Estimated schedule for offshore construction activities associated with the Raritan Bay Loop.

Task	Start Date	Completion Date
Dredge Trench for Morgan Shore Approach HDD String and Exit Pit MP12.5	Q3 2018	Q3 2018
Lay Morgan Shore Approach HDD String	Q3 2018	Q3 2018
Morgan Shore Approach HDD Crossing (set-up, pull through, and hydrostatic test)	Q3 2018	Q4 2018
Neptune Cable Crossing Construction MP13.9	Q3 2018	Q3 2018
Neptune Cable Crossing Construction MP35.2	Q3 2018	Q3 2018
Dredge Ambrose HDD Crossing Entry and Exit Pits	Q3 2018	Q3 2018
Lay Ambrose HDD String	Q3 2018	Q3 2018
Ambrose HDD Crossing (set-up, pull through, and hydrostatic test)	Q3 2018	Q4 2018
Pre-lay Trench MP12.5 to MP16.6	Q3 2018	Q3 2018
Dredge and Subsea Tie-In Skid Installation	Q3 2018	Q3 2018
Valve Spool Installation on RDL Manifold	Q3 2018	Q4 2018
Pipe Lay from MP12.5 to MP16.6	Q3 2018	Q4 2018
Post Pipelay Burial and Backfill from MP12.5 to MP16.6	Q4 2018	Q4 2018
Pipe Lay from Ambrose HDD Entry MP30.4 to MP35.49	Q4 2018	Q4 2018
Pipe Lay from Ambrose HDD Exit MP29.5 to MP16.6	Q4 2018	Q1 2019
Post Pipelay Burial and Backfill Ambrose HDD Entry MP30.4 to MP35.49	Q4 2018	Q1 2019
Post Pipelay Burial and Backfill Ambrose HDD Exit MP29.5 to MP16.6	Q1 2019	Q1 2019
Hydrostatic Test and Pre-Commissioning MP12.0 to MP35.49	Q1 2019	Q1 2019
Complete Spool Installation from Subsea Tie-In Skid to RDL at MP35.49	Q1 2019	Q1 2019
Backfill RDL Manifold and Tie-in Skid at MP35.49	Q1 2019	Q2 2019

Hydrodynamic output from the years 2011-2012 are being used to represent currents for the construction period. This range of dates was selected as it corresponds to the deployment period of the ADCP instruments, which were used to validate the WQMAP/BFHYDRO model. The agreement between the model-predicted currents and observations over this period provides a high level of confidence in the model performance, and its ability to represent the conditions in study area over an extended period of time. Ocean and estuarine currents are the primary environmental forcing that affects the dispersion and transport of sediments re-suspended during the proposed construction activities. In the study area, currents vary primarily due to tides and winds, which do not change substantially on an interannual basis, as compared to episodic meteorological events or river flow. For these reasons, RPS chose to use a simulation period over which the currents in the study area were well characterized and represented (2011-2012), for predictive modeling of the sediment transport and dispersion associated with the Project.

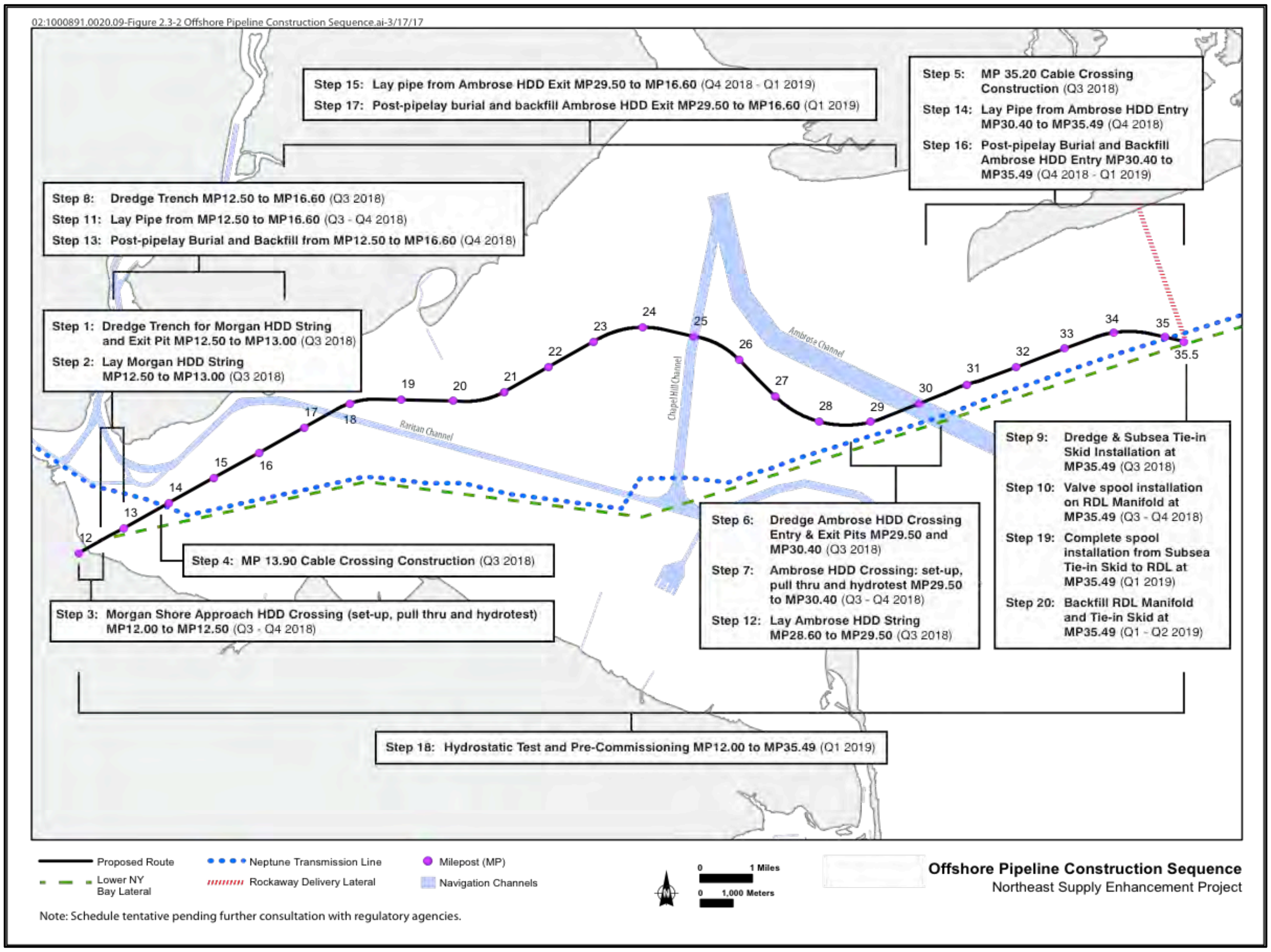

Figure 15. Offshore construction sequence by MP.

3.2.1.1 Sediment Source Terms

Four different subsea installation techniques are being employed for the construction activities shown in Figure 15. Sediment losses from each of these activities were represented in SSFATE by characterizing the source strength, vertical distribution, and grain-size distribution of the sediment load. Details describing the parameterization of each dredge method are provided below.

Clamshell dredging

Clamshell dredging will be used for a range of construction activities including (i) excavation of HDD entry and exit pits, (ii) offshore burial of the anode sled, (iii) excavation of subsea tie-in points, (iv) pre-lay trenching for pipeline burial (MP12.50 to MP16.60), and (v) backfilling of trenches and excavation pits as needed. For all clamshell dredging activities, the dredge advance rate was calculated based on a contractor provided production rate of 11,250 ft^3/hr. Losses from the clamshell dredge are assumed to be 10% of the total dredge volume for excavation activities. For clamshell excavation activities, sediment losses are distributed vertically throughout the water column, with the majority of the release at the surface, representing overflow from the receiving barge.

Hand jetting

Diver-assisted hand jets will be used to expose existing subsea infrastructure at cable crossings (MP13.88 and MP 35.19), and the subsea manifold (MP35.49). Production rates between 180-360 ft^3/hr are assumed for hand jetting scenarios based on historical estimates from offshore engineering contractors. (The production is variable and dependent on the seafloor compaction and sedimentology at the site.) Sediments excavated in this manner will be dispersed into the water column using water jets to completely clear the subsea infrastructure. For modeling, losses from hand jetting are assumed to be 100% of the excavation volume and are distributed vertically from a release height of 6 feet above the seafloor. All hand jetting scenarios are simulated as point sources.

Jet trencher

Transco is proposing to use a jet trencher to bury the pipeline over the majority of the route between MP16.60 and MP 35.19. The jet trencher is a hydraulically powered remotely operated vehicle (ROV) that straddles the pipeline. As the vehicle advances, two retractable cutting swords, one on each side of the pipeline, extend from the ROV beneath the seafloor. High-pressure seawater is pumped through a series of small diameter nozzles located on the front/forward side of each cutting sword to loosen the soils. Larger diameter nozzles located on the rear/trailing side of each cutting sword expels low pressure, high volume seawater that fluidizes the sediments, emulsifying the soils in order to lower the pipeline. This process allows the pipeline to lower under its own weight, eliminating the need to directly remove and/or displace the soils and minimizing sediment lost in the process. The modeling approach assumes that the final burial will require 2 passes of the jet trencher, which operates at an approximate production rate of 29,135 ft^3/hr (based on contractor estimates from average advance rates). Losses from the jet trencher are simulated as a moving line source and are assumed to be 5% of the excavation volume. The vertical distribution of the sediment release is partitioned within the lower 3 feet of the water column.

Submersible pump

A submersible pump will be used to fluidize and excavate sediments around the tie-in point at the Rockaway subsea manifold. The fluidized sediment is released through a discharge pipe to a spoil pile on the nearby seafloor. A production rate of 4,050 ft^3/hr for pumping was taken from contractor estimates. For implementation in the modeling, it is assumed that 100% of the fluidized sediment is lost to the water column as it is released from the discharge pipe. The sediment mass is distributed at depths between 0 and 10 feet above the seafloor.

3.2.1.2 Sediment Grain Size Distribution

A total of 87 vibracore samples were collected from the Project area as part of the geotechnical site investigation, of which 82 were used to characterize grain size distributions within the model. Figure 16 shows the location of each of the samples with respect to the proposed pipeline route and Figure 17 presents a graph of the relative size distributions (percent gravel, sand, fines) for the uppermost sample from each vibracore. The arrangement of the grain size data (west to east, along the pipeline route) reveals a shift in lithology along the bay axis. Mean grain size generally increases in the higher energy environments west of Raritan Bay and into the open Atlantic Ocean. An abrupt shift in the sediment fine fraction is noted near the confluence of Raritan Bay and Lower New York Bay.

A total of 263 sediment grain size samples, from 82 sediment cores are being used to develop the modeling input files. Figure 18 presents an example of grain size distribution curves within the Project area and the corresponding size classes that are used to parameterize the distribution in SSFATE. For each core, a unique size distribution was developed by a weighted averaging of the samples over a range excavation depths that are relevant to the Project activities (e.g. 7.5 ft for pre-lay trenching between MP 12.50 and MP 16.60, 20 ft for excavation of the Ambrose Channel HDD exit pit). SSFATE incorporates this spatially varying information and computes a unique grain size distribution for each location in the model domain using a distance weighted interpolation. In addition, the moisture content and specific gravity of the sediment samples are used to calculate the bulk density of the sediments along the pipeline route.

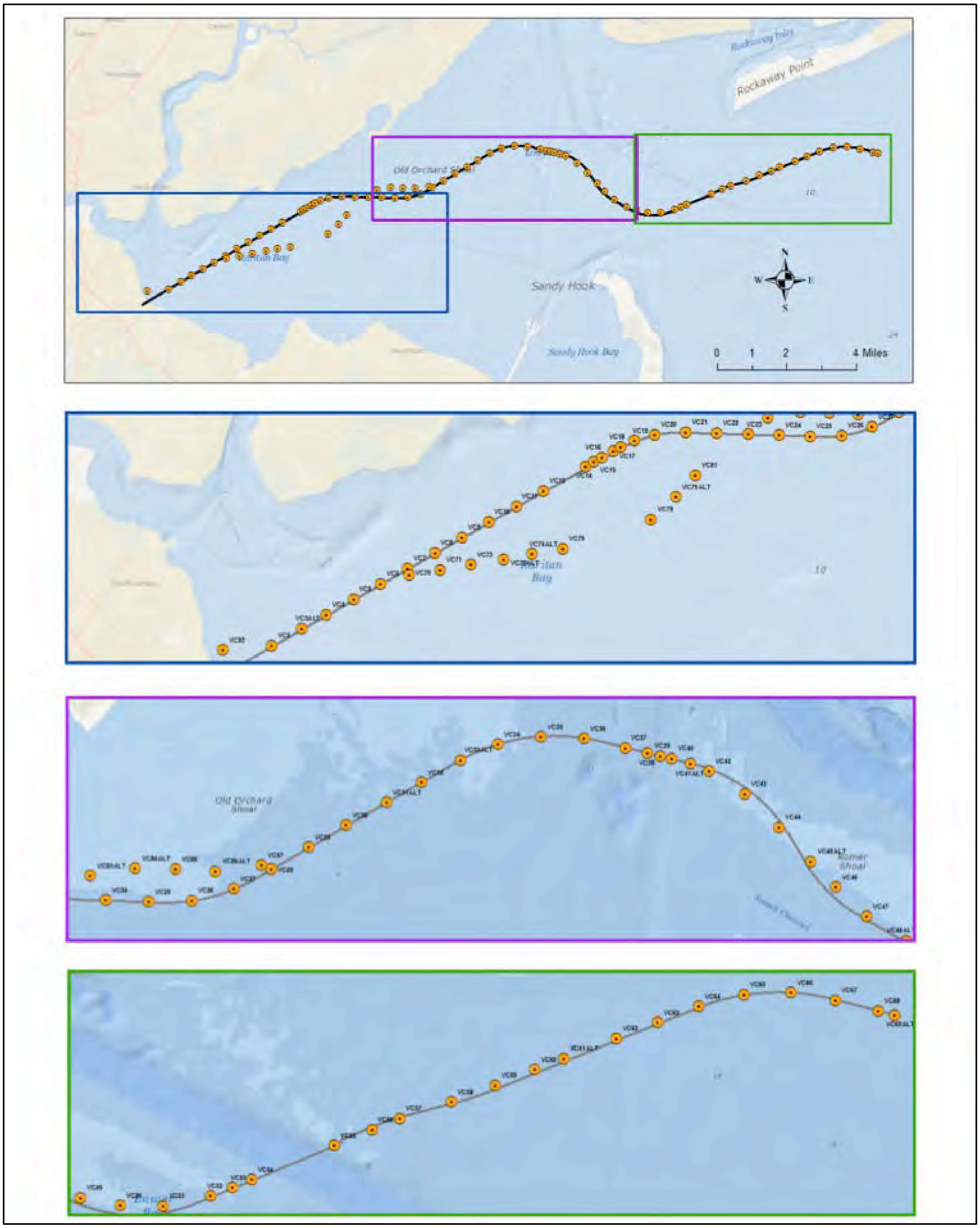

Figure 16. Location of vibracore samples along the pipeline route. Top figure shows full extent and bottom three plots show an expanded view based on the extents identified in top plot (west to east).

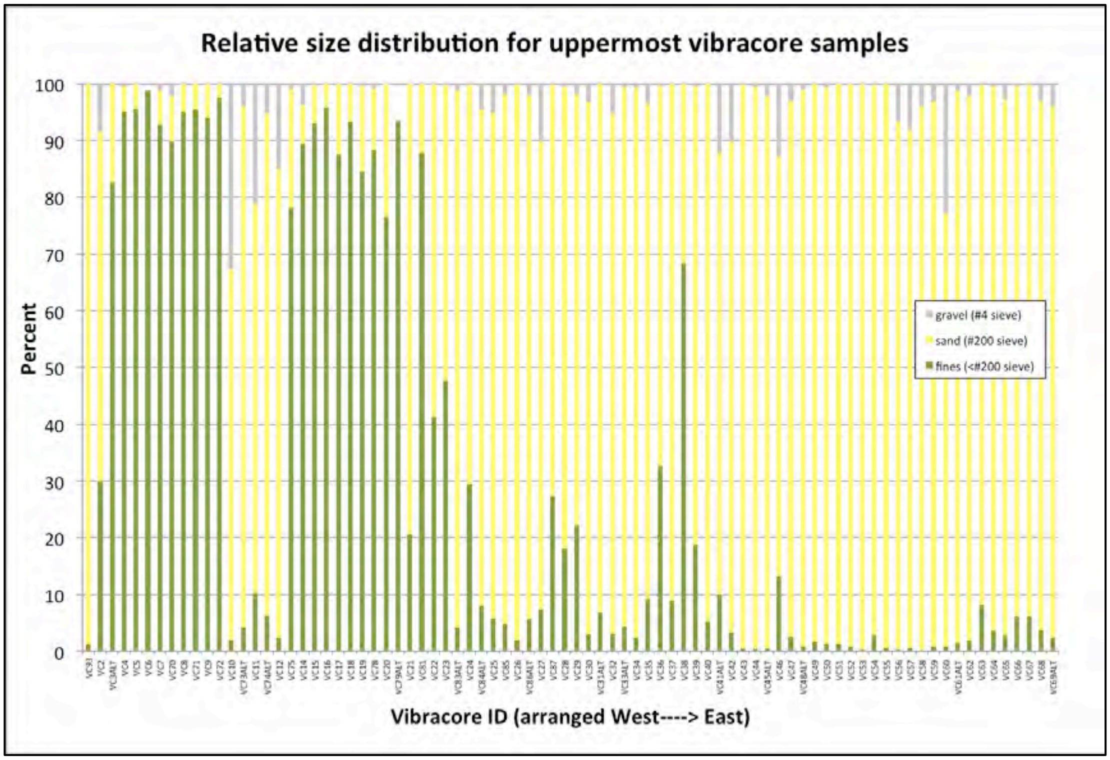

Figure 17. Near-surface sediment grain size distribution along the pipeline route (west to east).

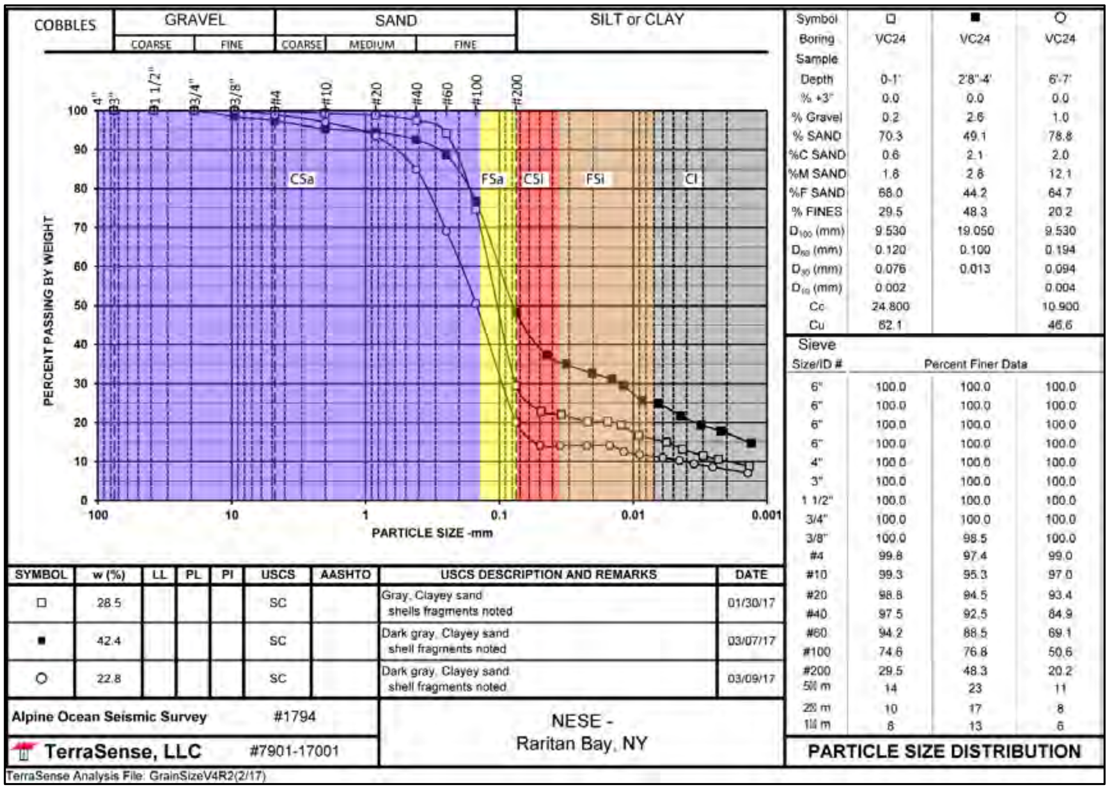

Figure 18. Size classes used by SSFATE overlain on grain size distribution curves from samples in the Project area. (CSa – coarse sand, FSa – fine sand, CSi – coarse silt, FSi – Fine silt, Cl – clay).

3.3 SSFATE Base Case Scenarios

Table 6 summarizes the current[1] ("base case") sediment modeling scenarios that RPS has developed in consultation with Transco and E&E. The simulations evaluate sediment releases for the construction activities associated with each stage of the offshore installation between MP 12.50 and the Rockaway tie-in point at MP 35.49. For stationary activities (point source releases), sediment volumes have been provided based on the construction plan for each stage of excavation. For non-stationary activities (line sources), volumes have been calculated from the trench cross-sectional area and the length over which the installation will occur. The duration of each activity is estimated from the production rates for each

[1] Parameters listed in the scenario table are based on construction rates and volumes provided to RPS as of July 25, 2017 and are subject to change upon further review. Currently the scenario list includes construction activities associated with the installation. Backfilling of the trench and excavation pits by clamshell dredge and side-casting of sediments was not modeled and will be included as needed in a subsequent modeling report addendum.

of the dredging methods as listed in Section 3.2.1. Figure 19 illustrates the location of each scenario in a map view.

Table 6. Description of activities being simulated for each modeling scenario.

Scenario	Construction Activity	Equipment Type	Point/Line Source	Location	Excavated Volume (ft^3)	Release Duration (day)
Scenario 1	Excavation of (i) Morgan Shore HDD pit, and (ii) anode sled burial area	Clamshell	Point	(i) MP 12.50, (ii) 1,200 ft north of MP12.32	281,319	1.04
Scenario 2	Pre-lay trenching between Morgan HDD exit and the Midline tie-in	Clamshell	Line	MP 12.50 - MP 16.60	5,780,244	21.41
Scenario 3	Jetting at the Neptune Cable crossing point in Raritan Bay	Hand Jet	Point	MP 13.88	53,694	6.21
Scenario 4	Post-lay trenching between Midline tie-in and Raritan Channel Transition (2 passes)	Jet Trencher	Line	MP 16.60 - MP 17.31	335,631	0.48
Scenario 5	Post-lay trenching between Curve 1 and Anchorage area (2 passes)	Jet Trencher	Line	MP 17.89 - MP 24.00	2,870,923	4.11
Scenario 6	Post-lay trenching between Curve 4 and Ambrose Channel (2 passes)	Jet Trencher	Line	MP 25.20 - MP 29.52	2,028,933	2.90
Scenario 7	Post-lay trenching between Ambrose Channel and Neptune Crossing 35 (2 passes)	Jet Trencher	Line	MP 30.40 - MP 35.19	2,241,033	3.21
Scenario 8	Pre-lay trenching across the Raritan Channel	Clamshell	Line	MP 17.31 - MP 17.89	5,138,432	19.03
Scenario 9	Pre-lay trenching between the anchorage area and the Chapel Hill Channel	Clamshell	Line	MP 24.00 - MP 25.20	3,374,322	12.50
Scenario 10	Excavation of Ambrose Channel HDD exit pit (West)	Clamshell	Point	MP 29.52	379,350	1.41
Scenario 11	Excavation of Ambrose Channel HDD entry pit (East) and tie-in	Clamshell	Point	MP 30.40	932,699	3.45
Scenario 12	Jetting at the Neptune Cable crossing offshore Rockaway	Hand Jet	Point	MP 35.19	50,252	11.63
Scenario 13	Pre-lay trenching between the Neptune crossing and end of pipeline	Clamshell	Line	MP 35.23 to MP 35.49	303,412	1.12
Scenario 14	Excavation of tie-in skid and manifold at Rockaway	Hand Jet and Submersible Pump	Point	MP 35.49	163,080	10.70

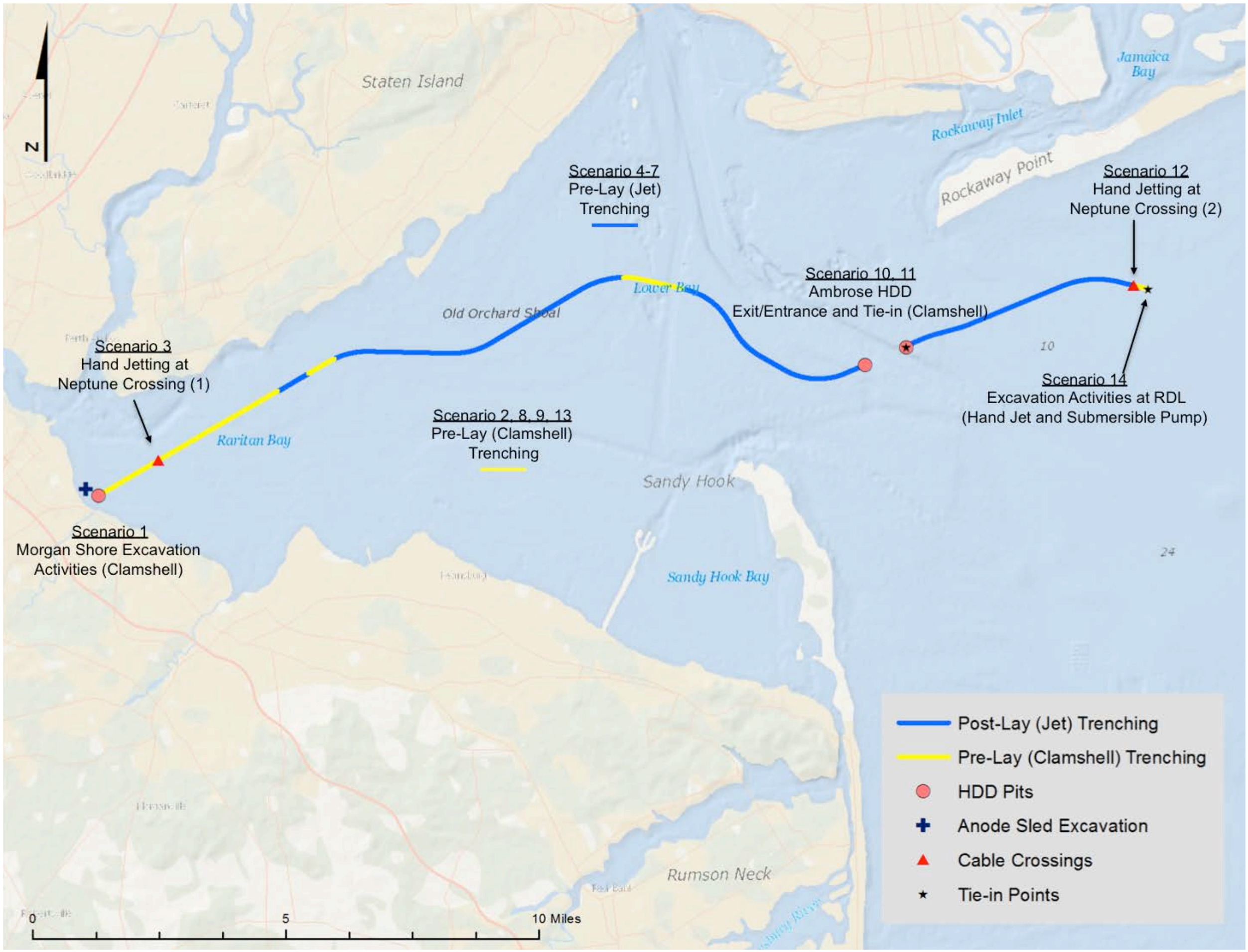

Figure 19. Map view showing sediment modeling scenario locations.

3.4 SSFATE Results for Base Case Scenarios

SSFATE simulations were performed for each construction activity in Table 6. All modeling assumed continuous operation for each phase of the construction, with short breaks for activities that involved multiple passes or changes in equipment. The model output was saved at a 10 minute time step for most activities, with the exception of clamshell (pre-lay trenching) which was saved at 20 minutes due to the duration of these simulations and slower advance speeds of the clamshell dredge. Sediment concentrations were computed on a grid with resolution of 20 m x 20 m (65 ft x 65 ft) in the horizontal dimension and 0.5 m (1.6 ft) in the vertical dimension. Note that reported concentrations are those predicted above the background concentration (i.e., a concentration of 0 mg/L equals the ambient concentration in the Project area).

The results from the model runs are presented below in maps showing the predicted TSS concentrations and subsequent deposition for each activity. Specifically, three sets of graphics were developed for each scenario:

(i) Instantaneous TSS concentrations (at the surface and throughout full water column) for representative tidal stages during the simulation.

(ii) Maximum TSS concentrations (at the surface and throughout full water column) predicted over the duration of the model run. (Labeled as "cumulative concentrations" within the graphics, where "cumulative" refers to the maximum TSS over all time steps, not the sum of TSS concentrations over time.)

(iii) Seabed deposition (thickness) following the modeled activity.

For comparison purposes, each set of figures maintains a consistent spatial scale. In addition, Table 7 presents a summary of the model results for each simulation, including:

- the maximum distances of TSS plumes at select concentration thresholds,
- time for TSS concentrations to return to ambient following the modeled activity,
- maximum distance of deposition contours that exceeds selected thicknesses,
- areal extent of the deposit that exceeds selected thicknesses.

Scenario-specific details describing the sediment release, timing, and other assumptions for each simulation are described below.

3.4.1 Scenario 1 – Morgan Shore Excavation Activities

The scenario includes two phases of construction associated with the Morgan Shore approach: (i) excavation of the Morgan Shore HDD pit to a depth of 14 ft, and (ii) installation of an offshore anode sled for cathode protection, buried to a minimum depth of 4 ft, approximately 1,200 feet northwest of the pipe centerline. Both activities were simulated as a stationary (point) source from their respective locations (Table 6). Both involve excavation by clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Morgan Shore campaign is scheduled for Q3 2018, and the simulation was performed based a start date of September 2. The dredge operates continuously for 23.8 hours during excavation of the HDD pit, and 1.2 hours for the anode sled area, with a break of approximately 24 hours between the two activities. Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). A total of 28,132 ft^3 (1,042 yd^3) of sediment is released from these two sources over the course of 2 days (1.04 days of active dredging).

Water column and sediment bed results from excavation at the Morgan Shore are presented in Figure 20 through Figure 22, and summarized in Table 7. The plume is oriented in a NW/SE configuration, generally reflecting the tidal current patterns near the site, which are aligned with the nearshore topography. Similarities between the surface and integrated water column plumes indicate that elevated TSS concentrations persist throughout the full water column, which is somewhat expected due to the shallow depths at this site. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,099 ft from the source and TSS concentrations remain elevated above ambient levels for 3.3 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 269 ft and covers 2.7 acres of the seabed.

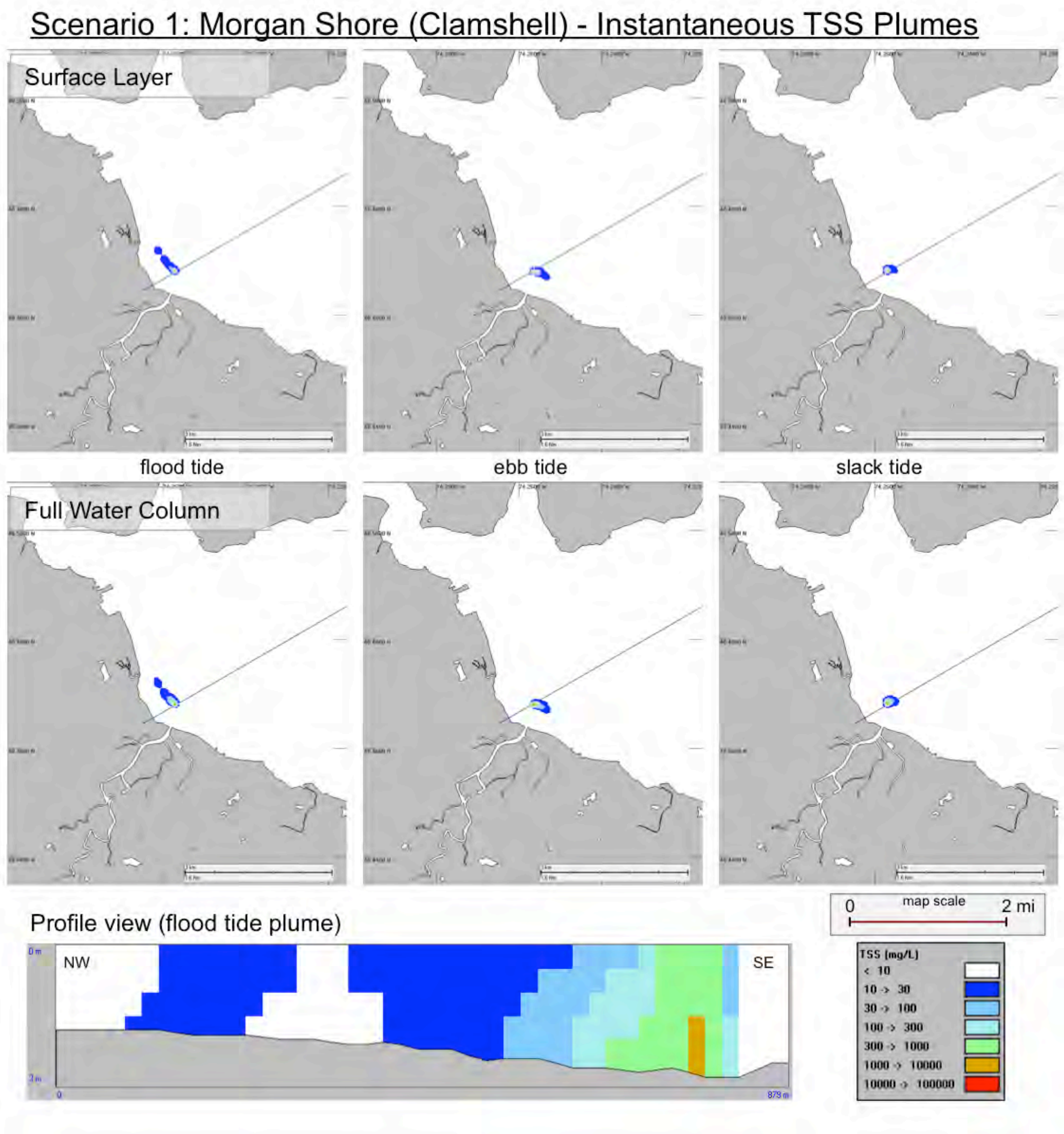

Figure 20. Instantaneous TSS concentrations at representative tide stages during excavation activities at the Morgan Shore. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the flood tide stage.

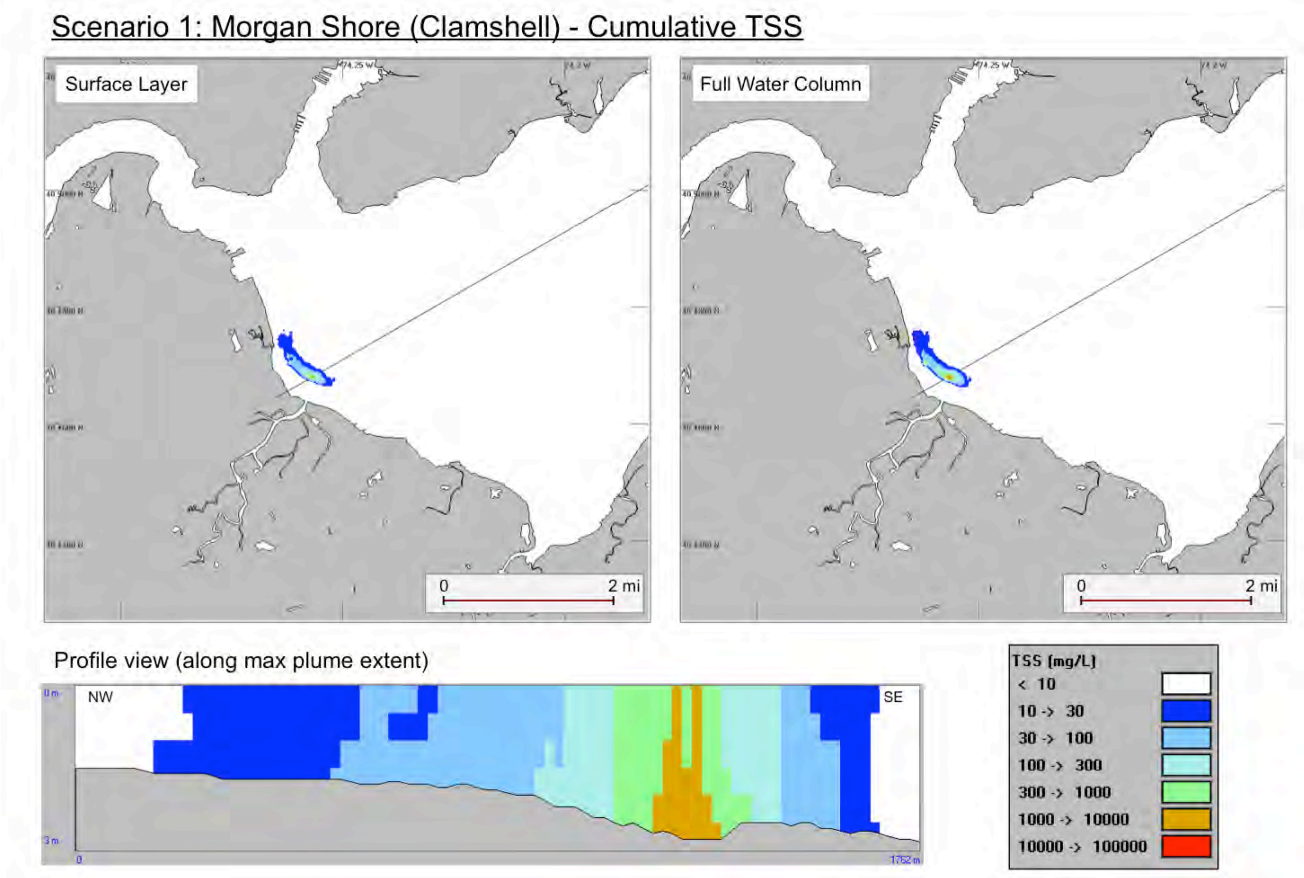

Figure 21. Cumulative TSS concentrations for Scenario 1 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

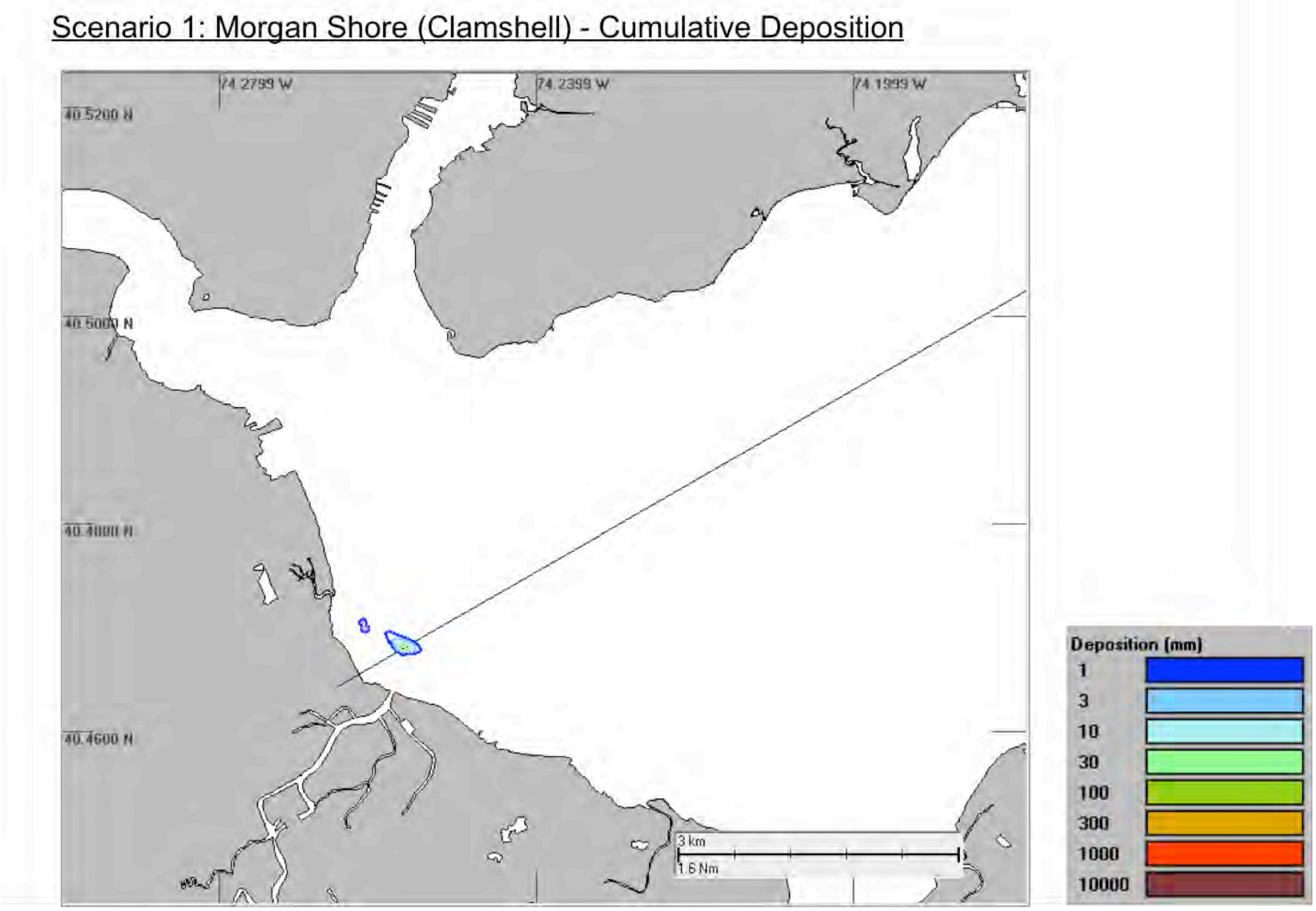

Figure 22. Extent of seabed deposition resulting from excavation activities at the Morgan Shore. Maximum predicted thickness = 3.9 in (99.1 mm).

3.4.2 Scenario 2 – Clamshell Trenching Between Morgan HDD and Midline Tie-in

Scenario 2 simulated releases associated with pre-lay trenching between MP 12.50 and MP 16.60. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total, 5,780,244 ft^3 of sediment will be removed by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredger in one direction (West to East) and a start date of September 27 (based on Q3 2018 construction schedule). Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 578,024 ft^3 (21,408 yd^3) of sediment over the course of 21.4 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 12.50 and MP 16.60 are presented in Figure 23 through Figure 25, and summarized in Table 7. During most of the run, the plume is oriented in a W/E configuration, oscillating back and forth with the tide along the primary axis of Raritan Bay. The maximum TSS concentrations are often seen to occur in the upper portions of the water column, presumably due to the higher losses at the surface. Water column concentrations of 100 mg/L are predicted to extend a maximum of 4,331 ft from the source and TSS concentrations remain elevated above ambient levels for 9.9 hours after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 108 ft from the source and covers a total of 16.9 acres of the seabed.

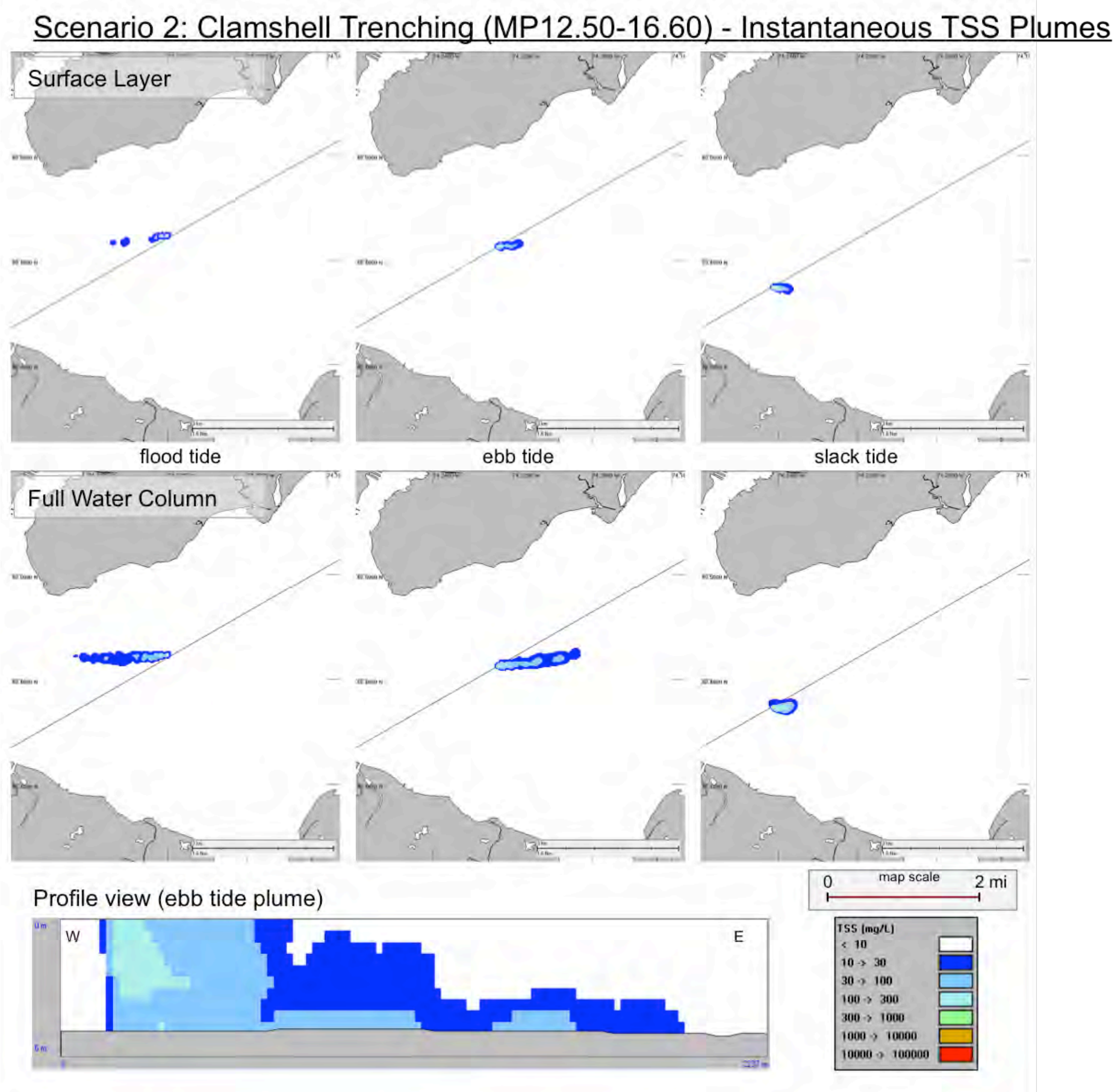

Figure 23. Instantaneous TSS concentrations at representative tide stages during pre-lay clamshell trenching between MP 12.50 and MP 16.60. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

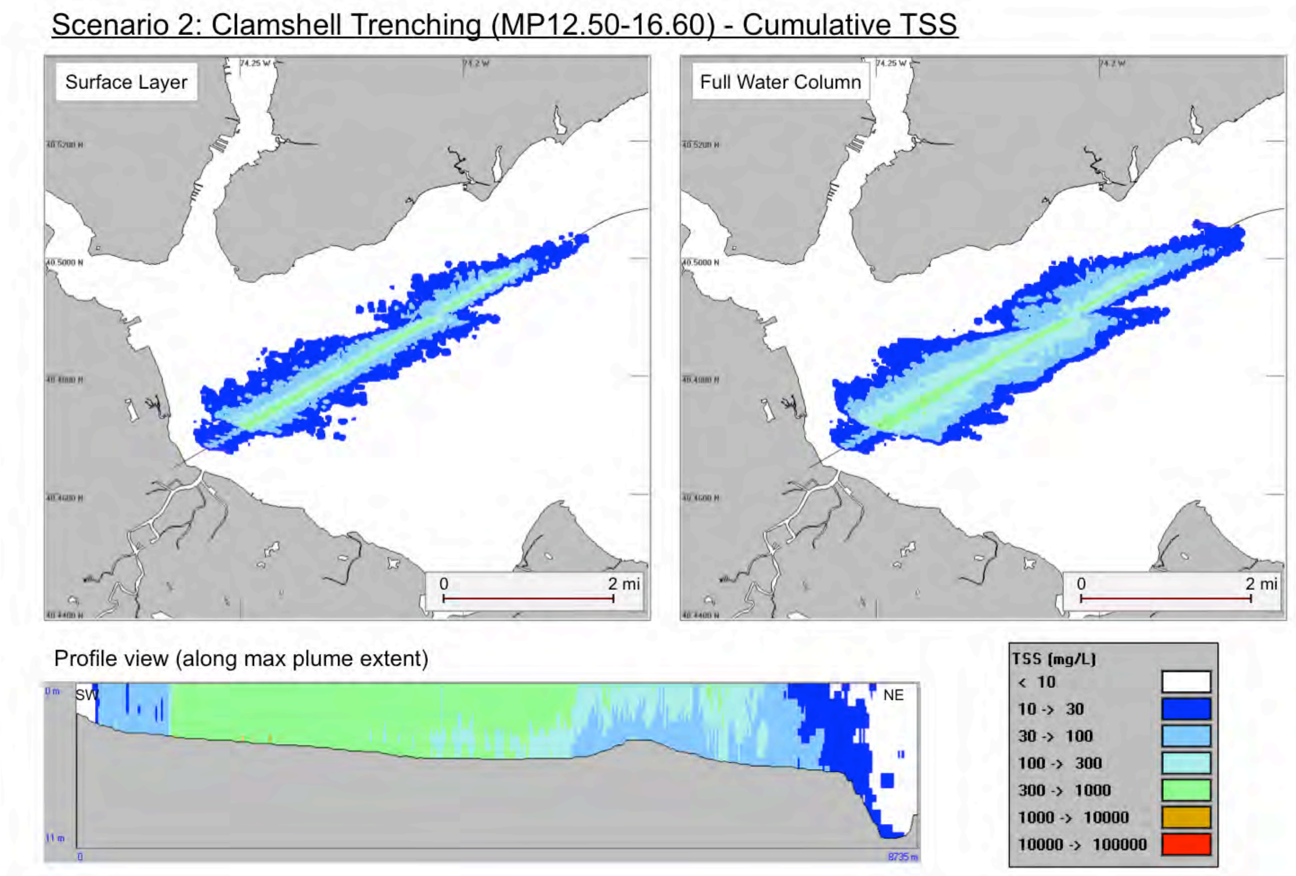

Figure 24. Cumulative TSS concentrations for Scenario 2 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

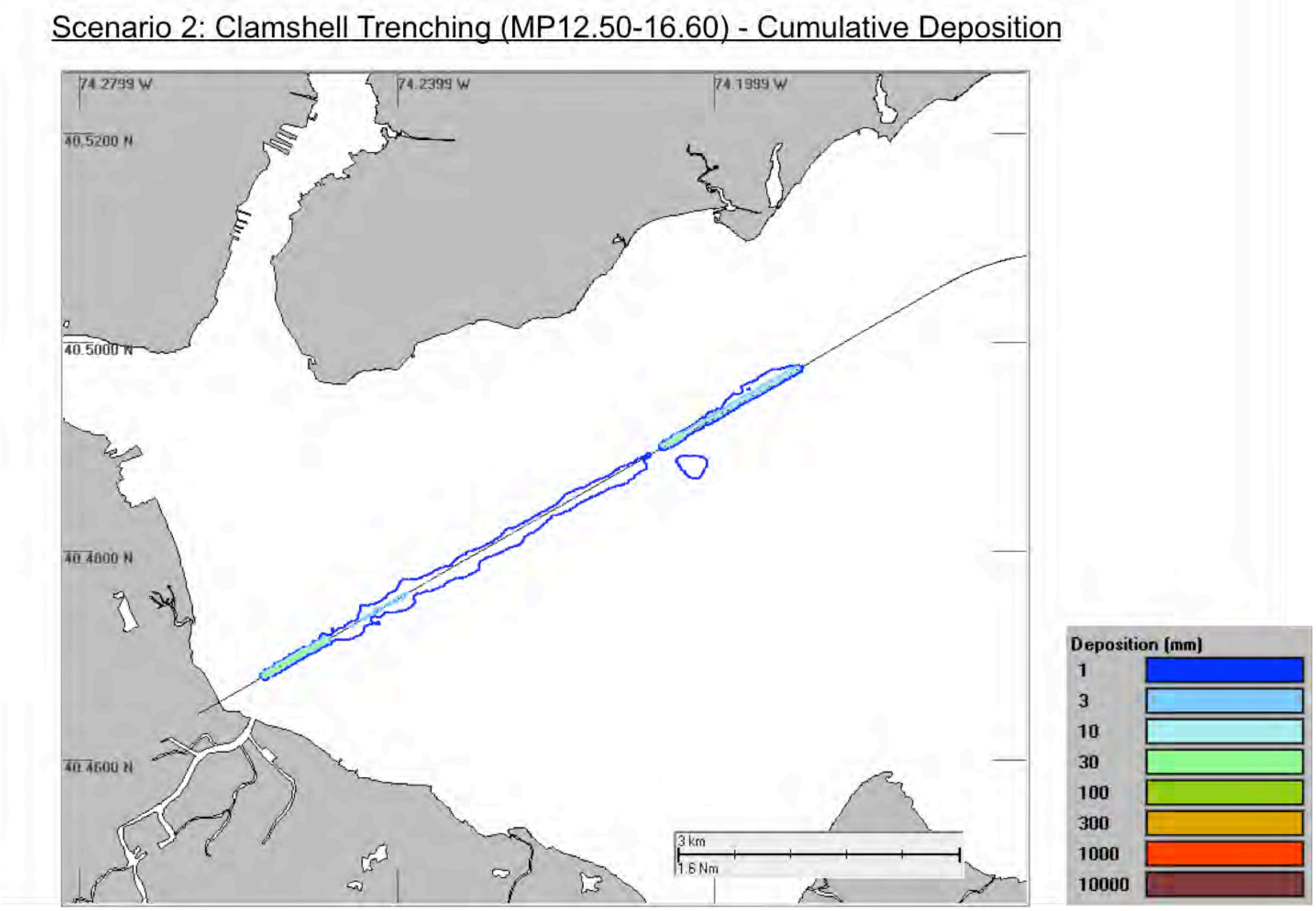

Figure 25. Extent of seabed deposition resulting from pre-lay clamshell trenching between MP 12.50 and MP 16.60. Maximum predicted thickness = 2.1 in (52.8 mm).

3.4.3 Scenario 3 – Jetting at the Neptune Cable Crossing in Raritan Bay

Scenario 3 simulated sediment disturbances associated with diver-assisted hand jets, which will be used to expose the Neptune Cable at its (western) crossing point at MP 13.88. Sediments excavated by hand jet (pressurized water jets) are completely dispersed into the water column; this type of excavation is used to clear sediments and expose subsea infrastructure. The jetting activity was simulated as a stationary (point) source from the crossing location, and was assumed to operate at a constant production rate of 360 ft^3/hr.

The excavation of the Neptune Cable at MP 13.88 is scheduled for Q3 2018, and the simulation was performed based a start date of September 20 (just prior to the pre-lay clamshell trenching along this section of the route). The hand jetting was assumed to take place continuously for 6.2 days. As the entirety of the disturbed sediment volume (100%) from hand jetting is considered lost to the water column, a total of 53,694 ft^3 (1,989 yd^3) of sediment was released over the duration of the simulation. In the model, sediment losses from hand jetting were released from a height of 6 ft above the seabed (at the location where the direct excavation is taking place).

Water column and sediment bed results from simulations of hand jetting at MP 13.88 are presented in Figure 26 through Figure 28, and summarized in Table 7. During most of the run, the plume is oriented in a W/E configuration, similar in shape to the plume that arises from clamshell trenching along this section of the route (Scenario 2) although notably, the maximum TSS concentrations from hand jetting at this site remained confined to the lower portions of the water column, close to the release point. As shown in Figure 26, the instantaneous plume at any given time exhibits limited surface expression. For Scenario 3, water column concentrations of 100 mg/L are predicted to extend a maximum of 1,378 ft from the source and TSS concentrations remain elevated above ambient levels for 3.4 hours after the conclusion of jetting activity. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 413 ft from the source and covers a total of 3.9 acres of the seabed.

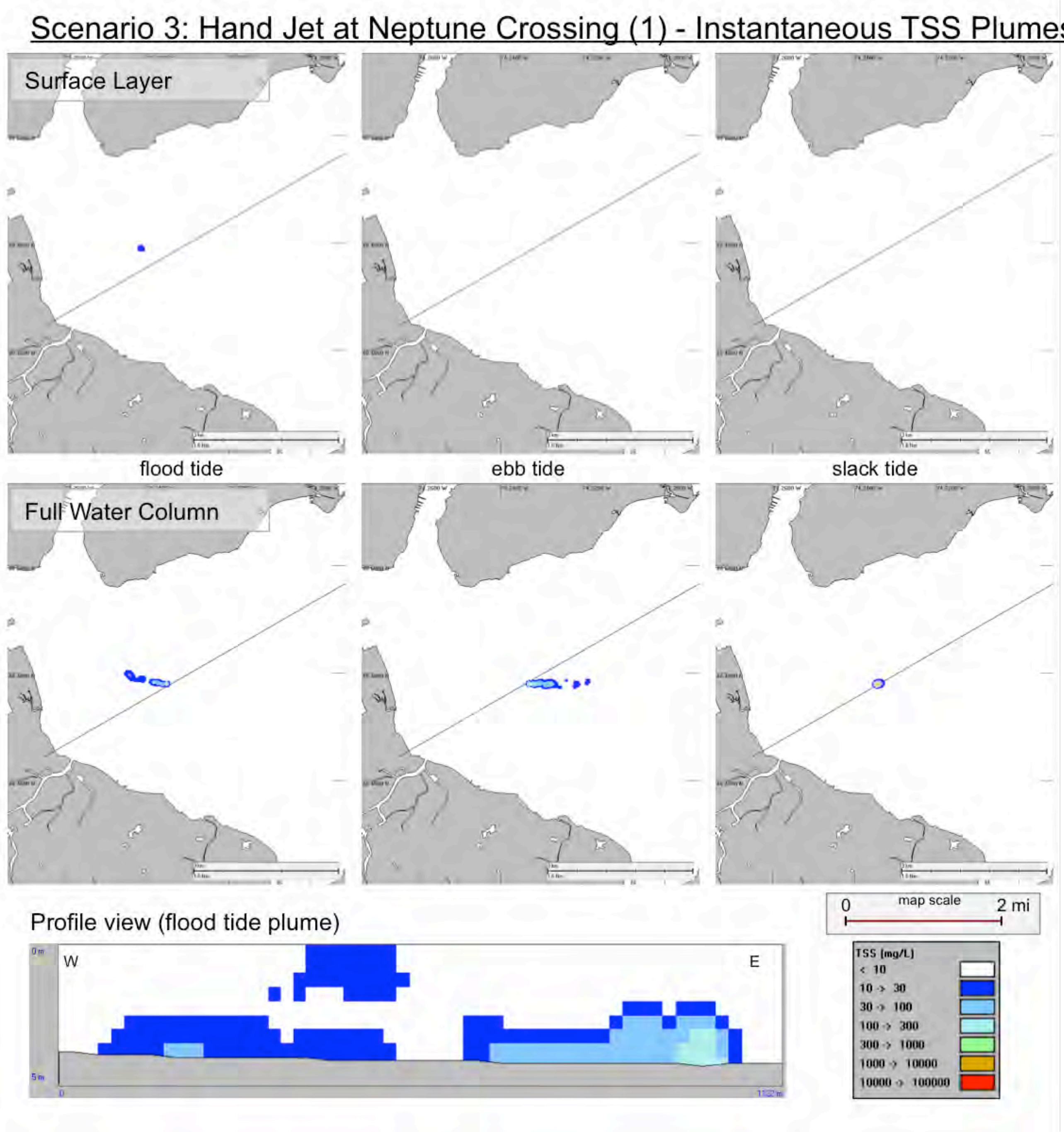

Figure 26. Instantaneous TSS concentrations at representative tide stages during hand jetting at MP 13.88. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

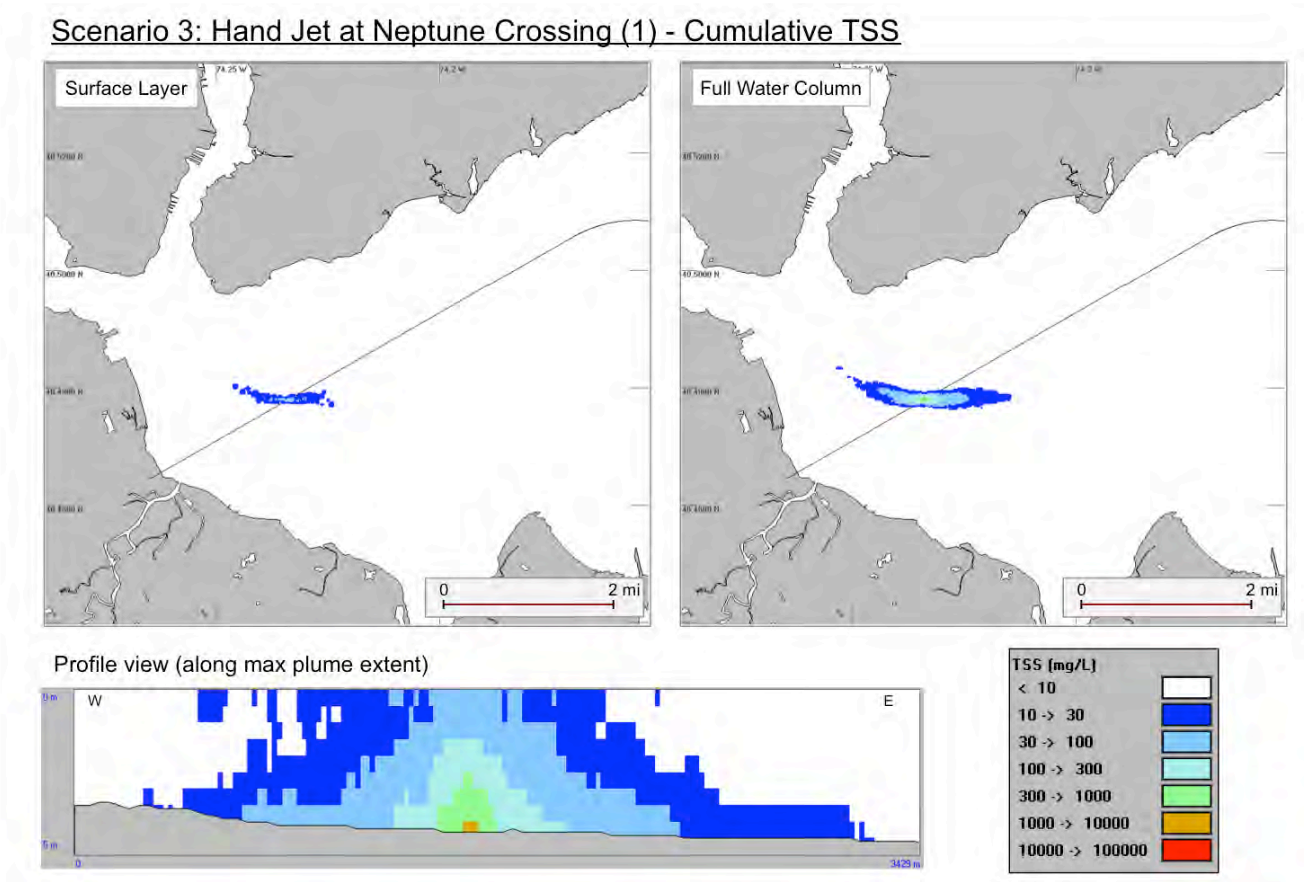

Figure 27. Cumulative TSS concentrations for Scenario 3 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

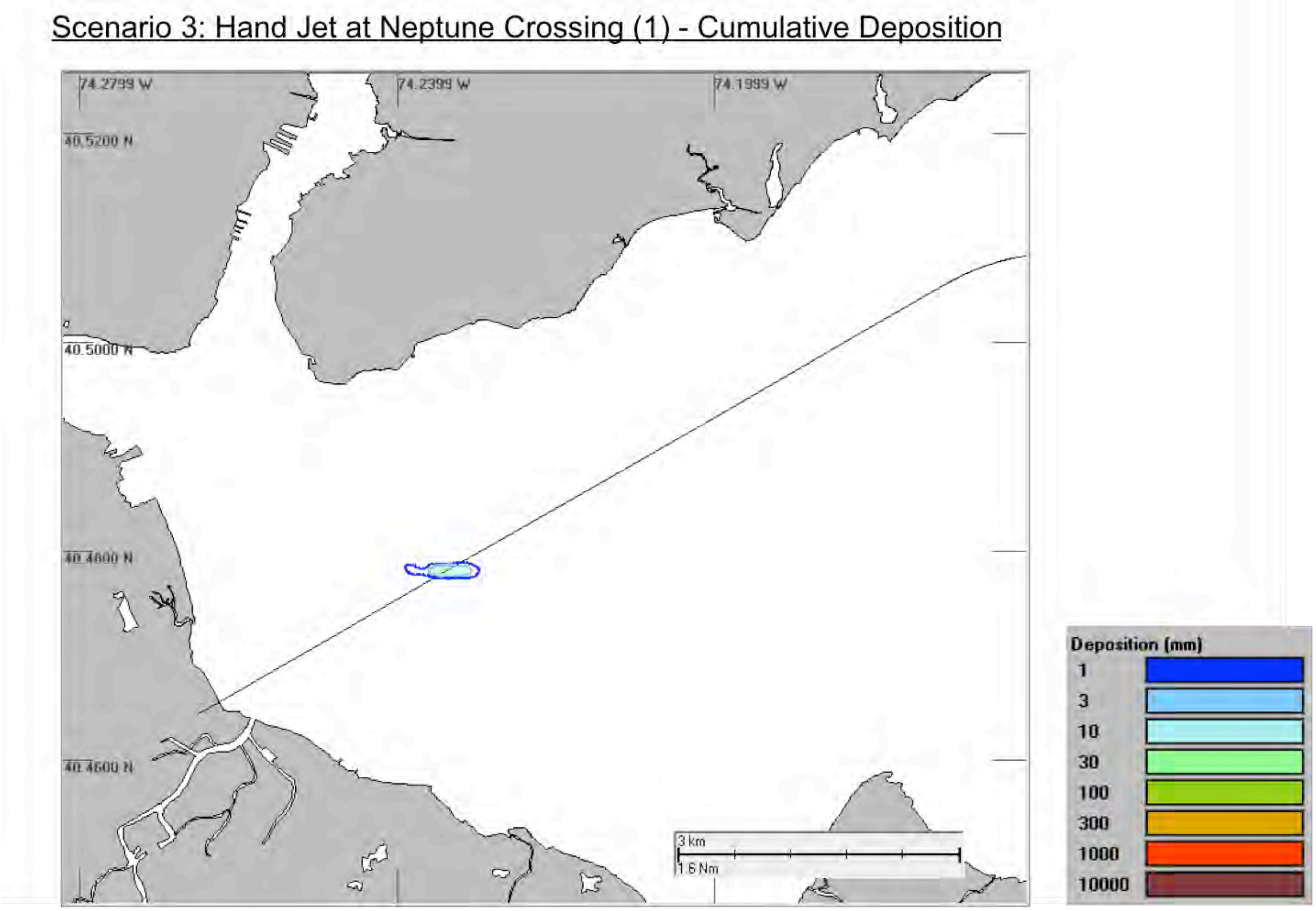

Figure 28. Extent of seabed deposition resulting from hand jetting at MP 13.88. Maximum predicted thickness = 2.5 in (64.4 mm).

3.4.4 Scenario 4 – Jet Trenching Between Midline Tie-in and Raritan Channel Transition

Scenario 4 simulated releases associated with post-lay jet trenching between MP 16.60 and MP 17.31. Transco is proposing to use a jet trencher along this section of the route, which is equipped with retractable cutting swords that straddle the pipeline and extend below the seabed. The jet trencher uses high volume seawater to fluidize the seabed and lower the pipeline to its burial depth (minimum 4 ft of cover) as the vehicle advances. The sediment volume along this section of the route is 335,631 ft^3, although most of this material will remain undisturbed at the seabed since the jet trencher does not directly excavate sediment from the trench. For modeling, it was assumed that the equipment operates at a constant production rate of 29,135 ft^3/hr (based on contractor estimates of 656 ft/hr [200 m/hr] advance rates).

The activity was modeled as a line source, assuming two passes of the jet trencher would be required to achieve full burial. The initial pass (West to East) was followed by a return pass in the opposite direction, with a break of approximately 6 hours between the two activities to account for equipment re-positioning and other operational factors. Jet trenching activities are planned for late Q4 2018 and a model start date of December 7 was selected based on the construction schedule. Losses from the jet trencher are assumed to be limited to 5% of the total excavation volume, with 3% distributed directly at the seafloor (0-1 ft above), 1.5% between 1 and 2 ft, and the remaining mass (0.5%) between 2 and 3 ft above the seabed. In total, the simulation included the release of 16,782 ft^3 (622 yd^3) of sediment over the course of 11.5 hours of active production.

Water column and sediment bed results from simulations of post-lay jet trenching between MP 16.60 and MP 17.31 are presented in Figure 29 through Figure 31, and summarized in Table 7. During most of the burial activity, the plume remains confined to the mid- and lower portions of the water column. The plume appears to oscillate with the tidal current, although this signal is not clearly seen in the TSS predictions due to the relatively short duration of the activity (< 6 hours for each pass). Maximum TSS concentrations occur at or near the seabed, and plumes above 10 mg/L do not reach the surface layer at any time during the simulation. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,001 ft from the source and TSS concentrations remain elevated above ambient levels for 6.9 hours after the conclusion of jet trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

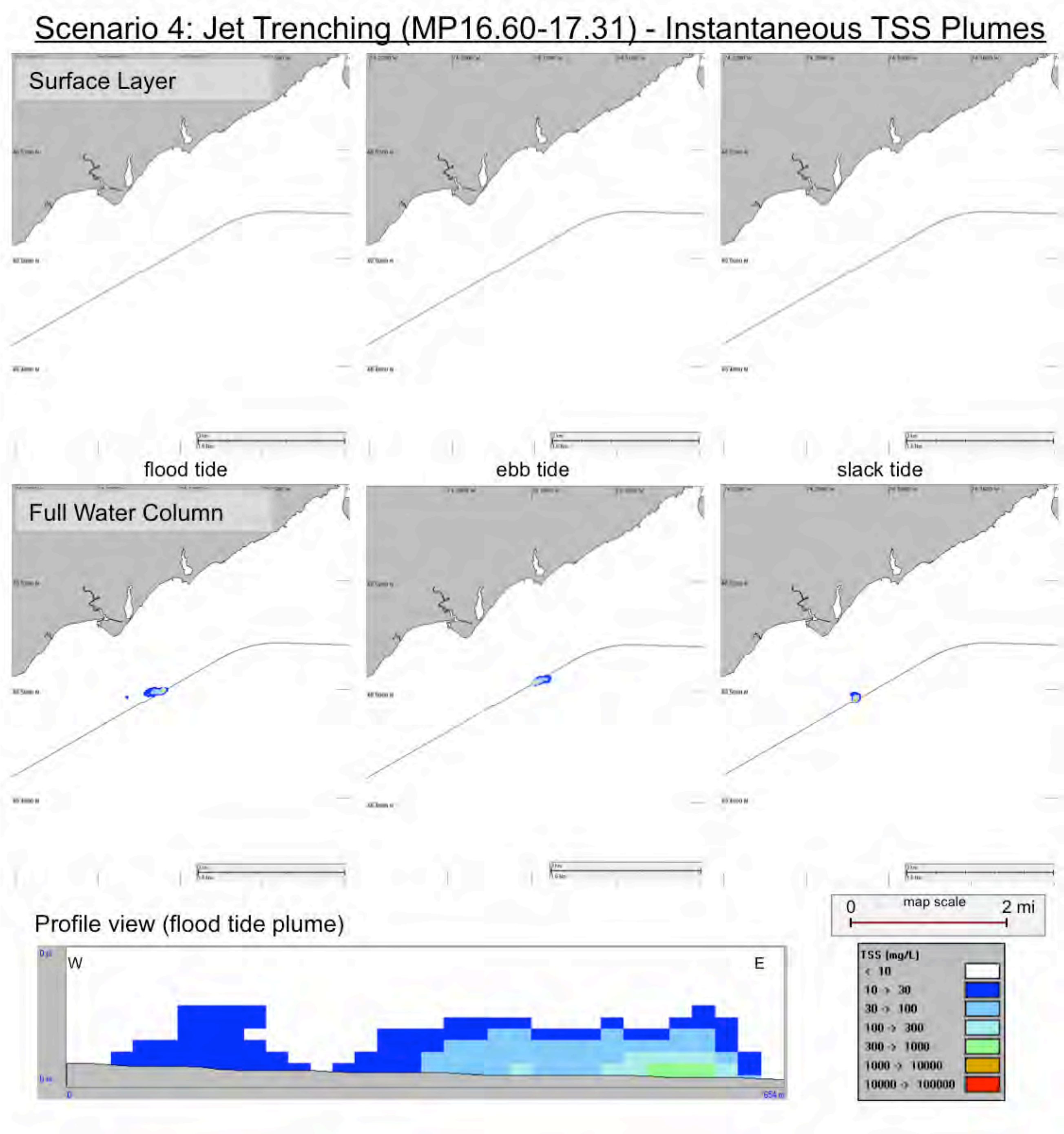

Figure 29. Instantaneous TSS concentrations at representative tide stages during post-lay jet trenching between MP 16.60 and MP 17.31. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the flood tide stage.

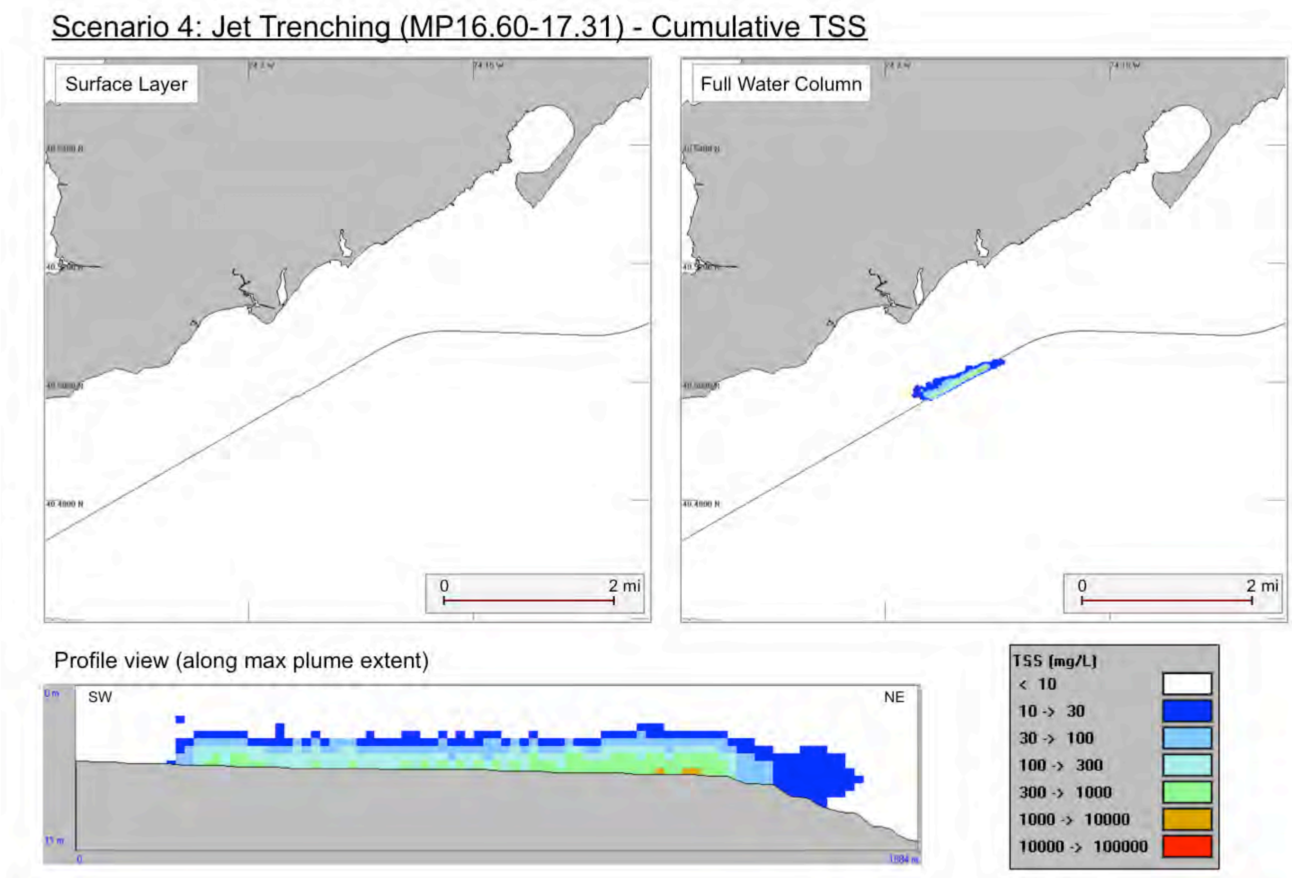

Figure 30. Cumulative TSS concentrations for Scenario 4 after a single pass of the jet trencher (W to E), shown for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

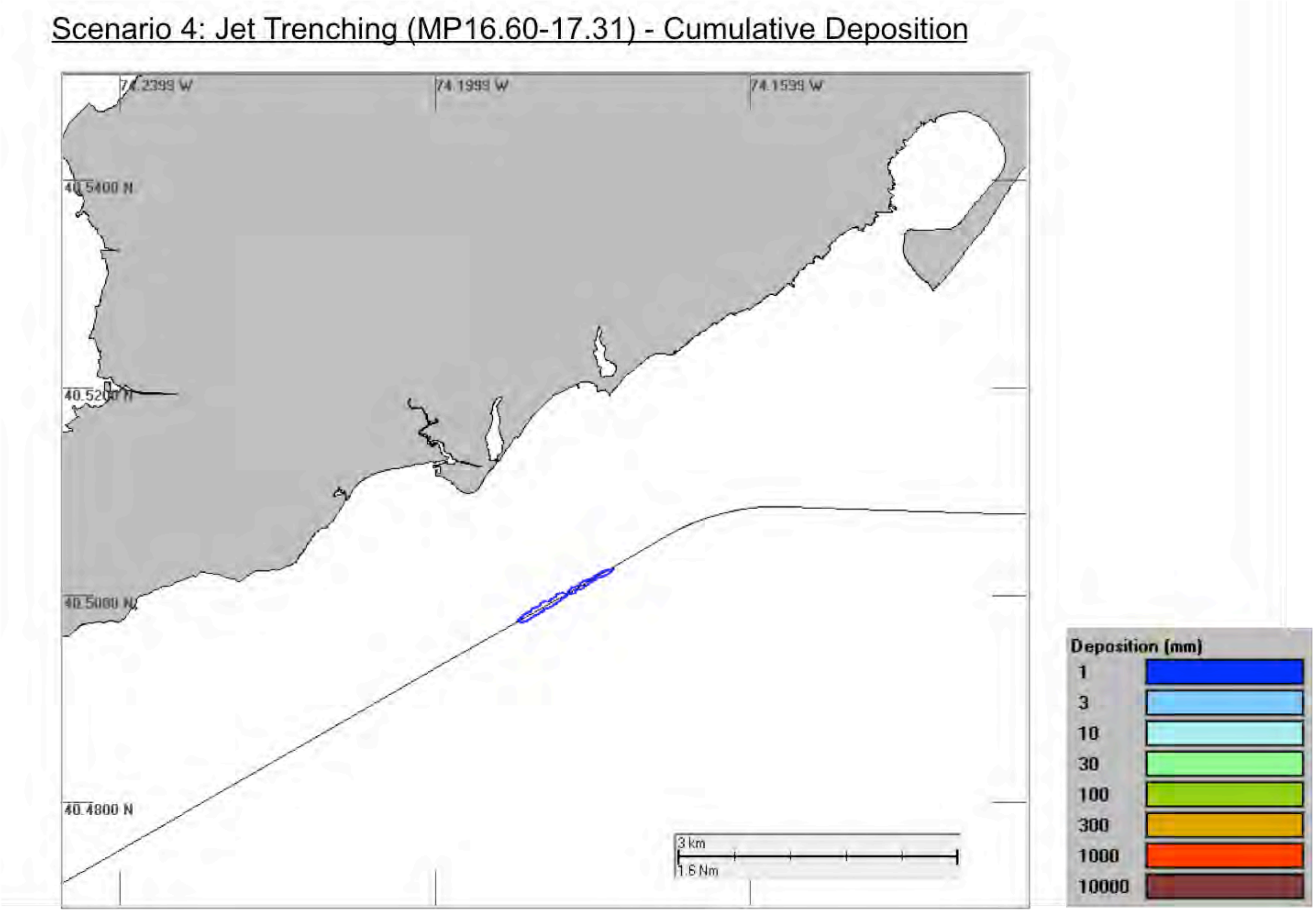

Figure 31. Extent of seabed deposition resulting from post-lay jet trenching between MP 16.60 and MP 17.31. Maximum predicted thickness = 0.1 in (3.0 mm).

3.4.5 Scenario 5 – Jet Trenching Between Curve 1 and Anchorage Area

Scenario 5 simulated releases associated with post-lay jet trenching between MP 17.89 and MP 24.00. As described above, the jet trencher is equipped with retractable cutting swords, which straddle the pipeline and extend below the seabed. The jet trencher uses high volume seawater to fluidize the seabed and lower the pipeline to its burial depth (minimum 4 ft of cover) as the vehicle advances. The sediment volume along this section of the route is 2,870,923 ft^3, although, as described earlier, most of this material will remain undisturbed at the seabed since the jet trencher does not directly excavate sediment from the trench. For modeling, it was assumed that the equipment operates at a constant production rate of 29,135 ft^3/hr (based on contractor estimates of 656 ft/hr [200 m/hr] advance rates).

The activity was modeled as a line source, assuming two passes of the jet trencher would be required to achieve full burial. The initial pass (West to East) was followed by a return pass in the opposite direction, with a break of approximately 6 hours between the two activities to account for equipment re-positioning and other operational factors. Jet trenching activities are planned for late Q4 2018 and a model start date of December 11 was selected based on the construction schedule, and assuming a brief (three day) break between the previous jet trenching section (Scenario 4). Losses from the jet trencher are assumed to be limited to 5% of the total excavation volume, with 3% distributed directly at the seafloor (0-1 ft above), 1.5% between 1 and 2 ft, and the remaining mass (0.5%) between 2 and 3 ft above the seabed. In total, the simulation included the release of 143,546 ft^3 (5,317 yd^3) of sediment over the course of 4.1 days of active production.

Water column and sediment bed results from simulations of post-lay jet trenching between MP 17.89 and MP 24.00 are presented in Figure 32 through Figure 34, and summarized in Table 7. As with Scenario 4, the plume remains confined to the mid- and lower portions of the water column during most of the burial activity. The plume typically oscillates back and forth with the tidal current along the release path, particularly in the western reaches of Raritan Bay, which display a sinuous plume pattern as shown in Figure 33. For Scenario 5, water column concentrations of 100 mg/L are predicted to extend a maximum of 853 ft from the source and TSS concentrations remain elevated above ambient levels for 7.9 hours after the conclusion of jet trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

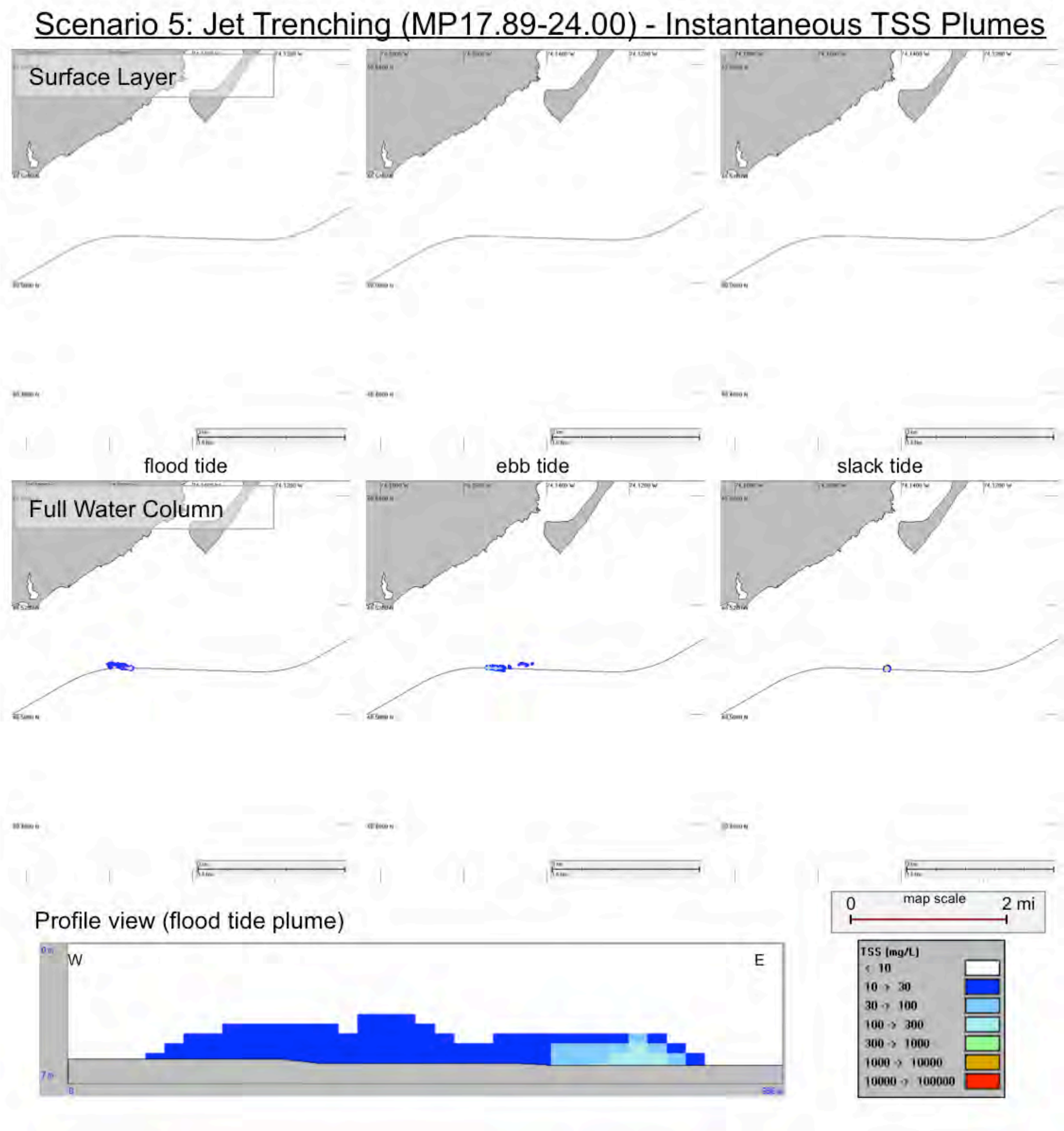

Figure 32. Instantaneous TSS concentrations at representative tide stages during post-lay jet trenching between MP 17.89 and MP 24.00. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the flood tide stage.

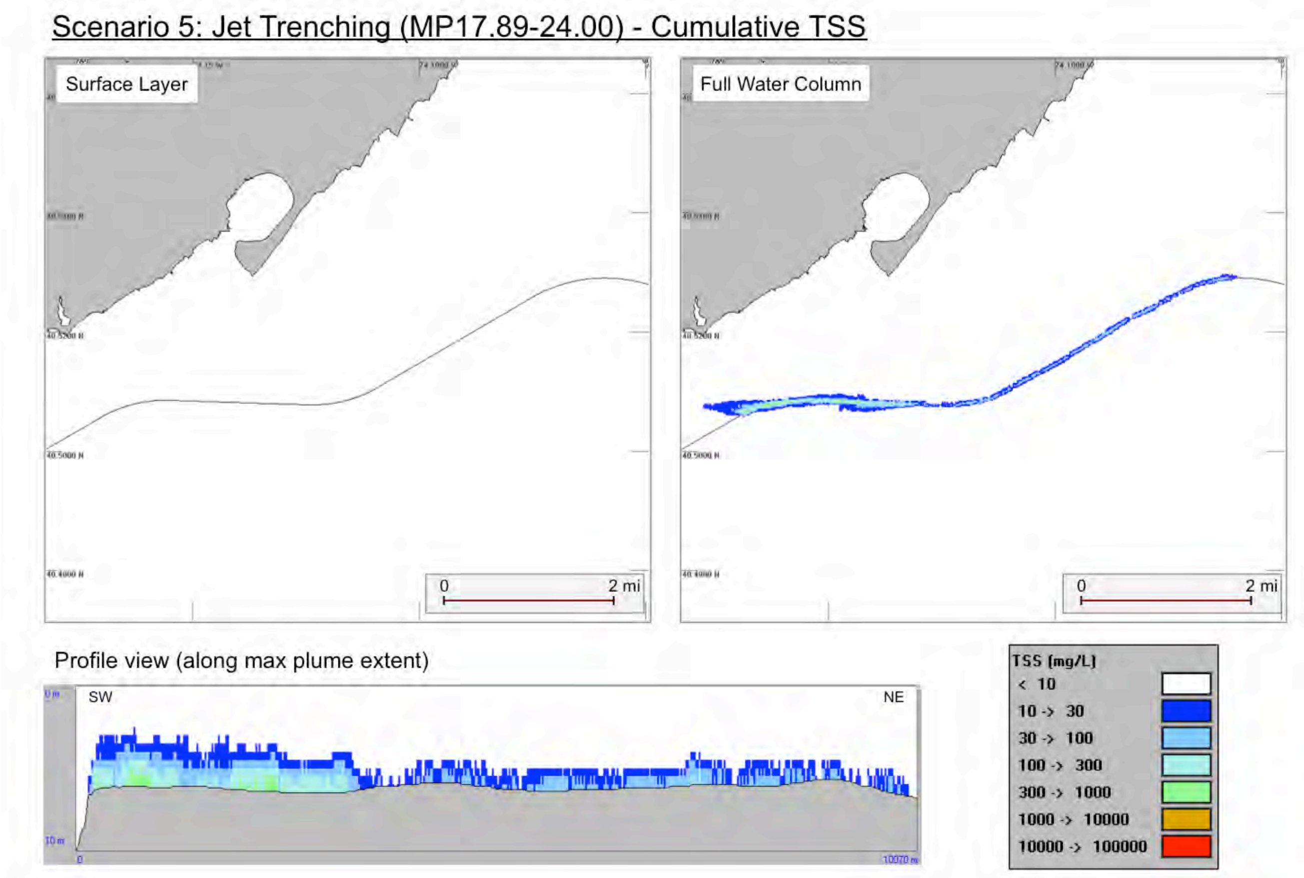

Figure 33. Cumulative TSS concentrations for Scenario 5 after a single pass of the jet trencher (W to E), shown for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

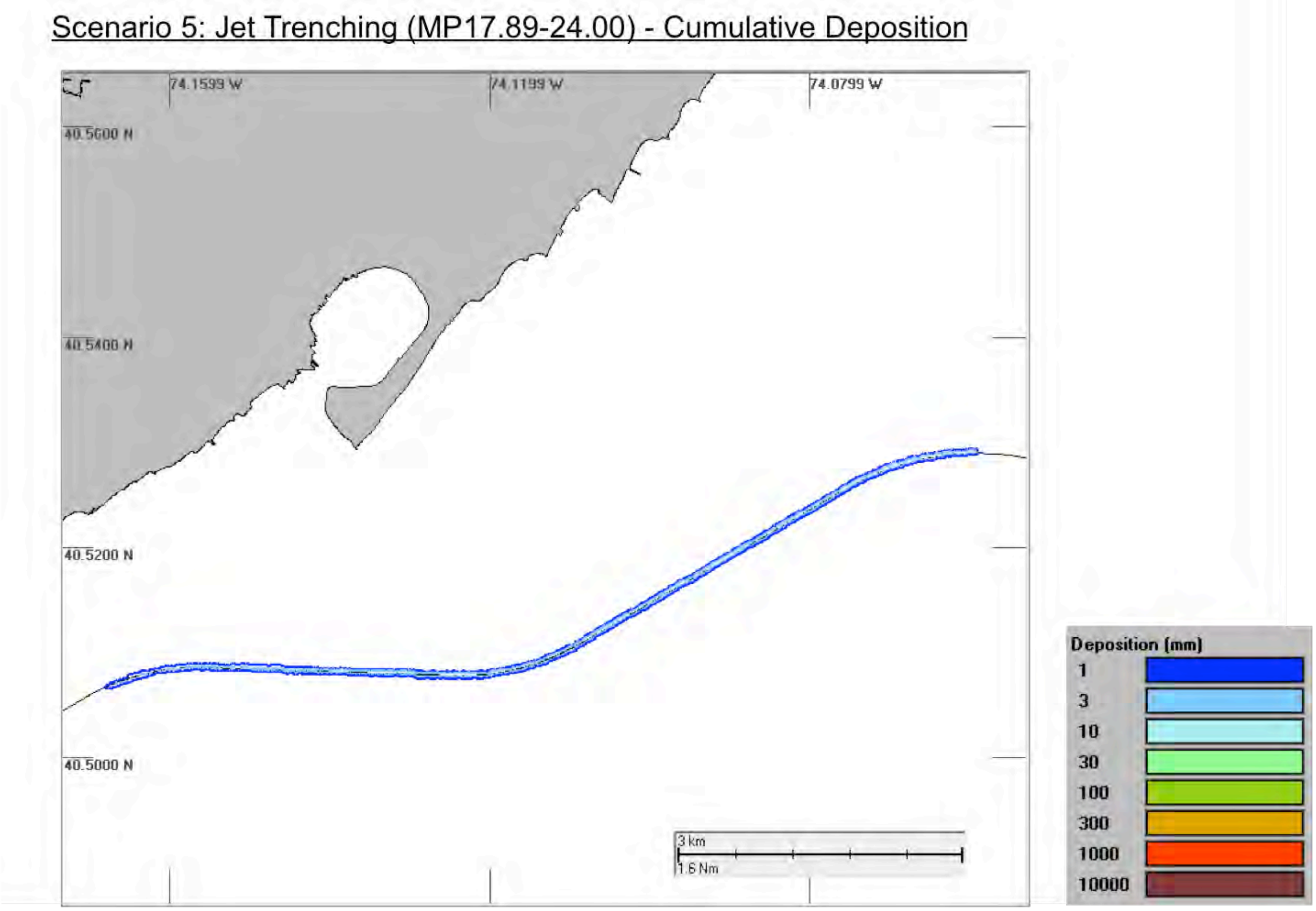

Figure 34. Extent of seabed deposition resulting from post-lay jet trenching between MP 17.89 and MP 24.00. Maximum predicted thickness = 0.3 in (8.4 mm).

3.4.6 Scenario 6 – Jet Trenching Between Curve 4 and Ambrose Channel

Scenario 6 simulated releases associated with post-lay jet trenching between MP 25.20 and MP 29.52. As described above, the jet trencher is equipped with retractable cutting swords, which straddle the pipeline and extend below the seabed. The jet trencher uses high volume seawater to fluidize the seabed and lower the pipeline to its burial depth (minimum 4 ft of cover) as the vehicle advances. The sediment volume along this section of the route is 2,028,933 ft^3, although, as described earlier, most of this material will remain undisturbed at the seabed since the jet trencher does not directly excavate sediment from the trench. For modeling, it was assumed that the equipment operates at a constant production rate of 29,135 ft^3/hr (based on contractor estimates of 656 ft/hr [200 m/hr] advance rates).

The activity was modeled as a line source, assuming two passes of the jet trencher would be required to achieve full burial. The initial pass (West to East) was followed by a return pass in the opposite direction, with a break of approximately 6 hours between the two activities to account for equipment re-positioning and other operational factors. Jet trenching activities are planned for late Q4 2018 and a model start date of December 19 was selected based on the construction schedule, and assuming a brief (three day) break between the previous jet trenching section (Scenario 5). Losses from the jet trencher are assumed to be limited to 5% of the total excavation volume, with 3% distributed directly at the seafloor (0-1 ft above), 1.5% between 1 and 2 ft, and the remaining mass (0.5%) between 2 and 3 ft above the seabed. In total, the simulation included the release of 101,447 ft^3 (3,757 yd^3) of sediment over the course of 2.9 days of active production.

Water column and sediment bed results from simulations of post-lay jet trenching between MP 25.20 and MP 29.52 are presented in Figure 35 through Figure 37, and summarized in Table 7. As with the previous jet trenching simulations, the sediment plume remains confined to the mid- and lower portions of the water column, producing almost no periods of elevated TSS concentrations in the upper half of the water column (Figure 36). Currents are particularly strong along this portion of the route and as a result, the sediment plume becomes rapidly diluted with distance from the source. As with Scenario 5, the plume oscillates back and forth with the tidal current along the release path, resulting in TSS plumes that alternate between either side of the route, as shown in Figure 36. Water column concentrations of 100 mg/L are predicted to extend a maximum of 262 ft from the source and TSS concentrations remain elevated above ambient levels for 1.4 hours after the conclusion of jet trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

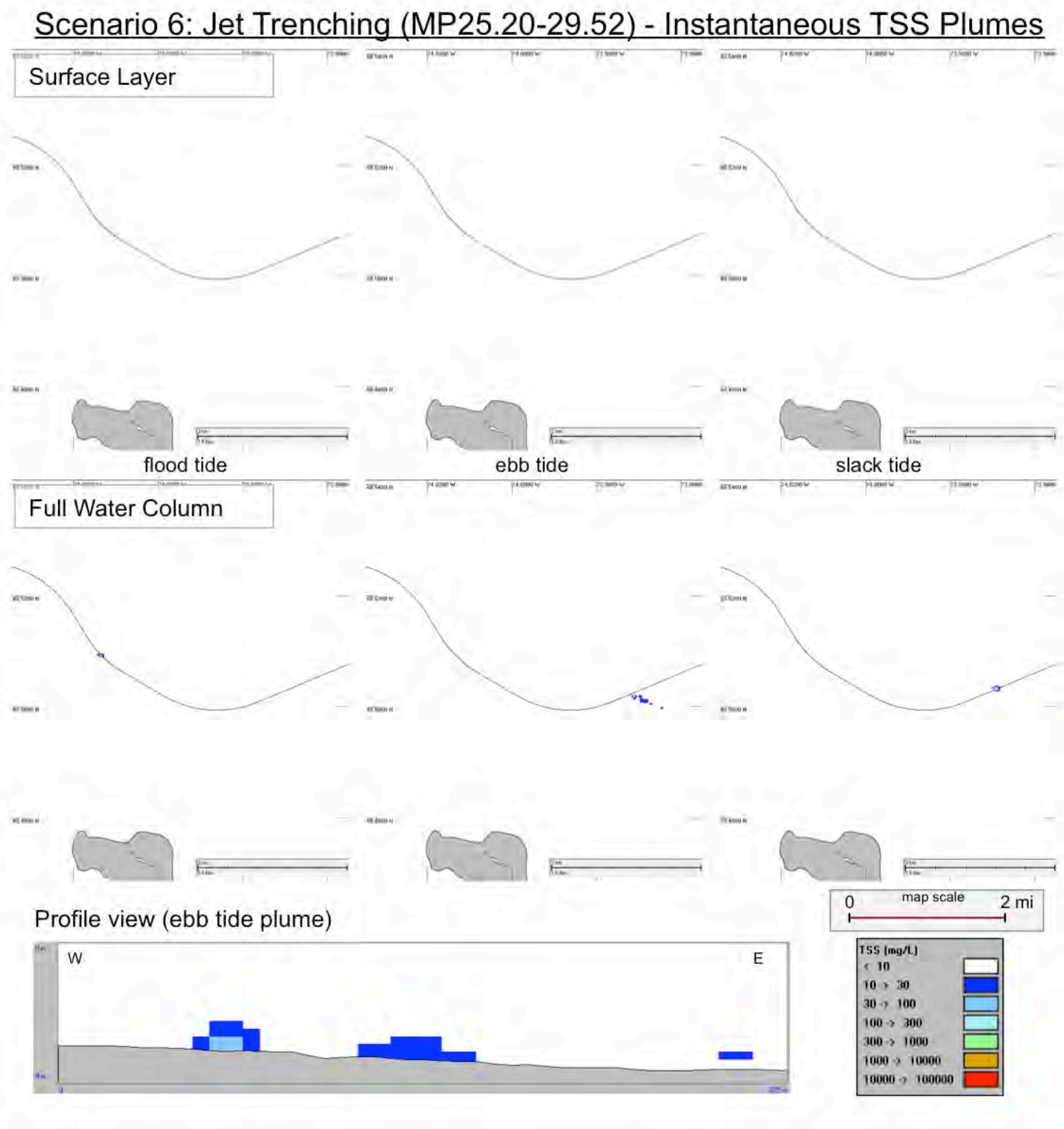

Figure 35. Instantaneous TSS concentrations at representative tide stages during post-lay jet trenching between MP 25.20 and MP 29.52. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

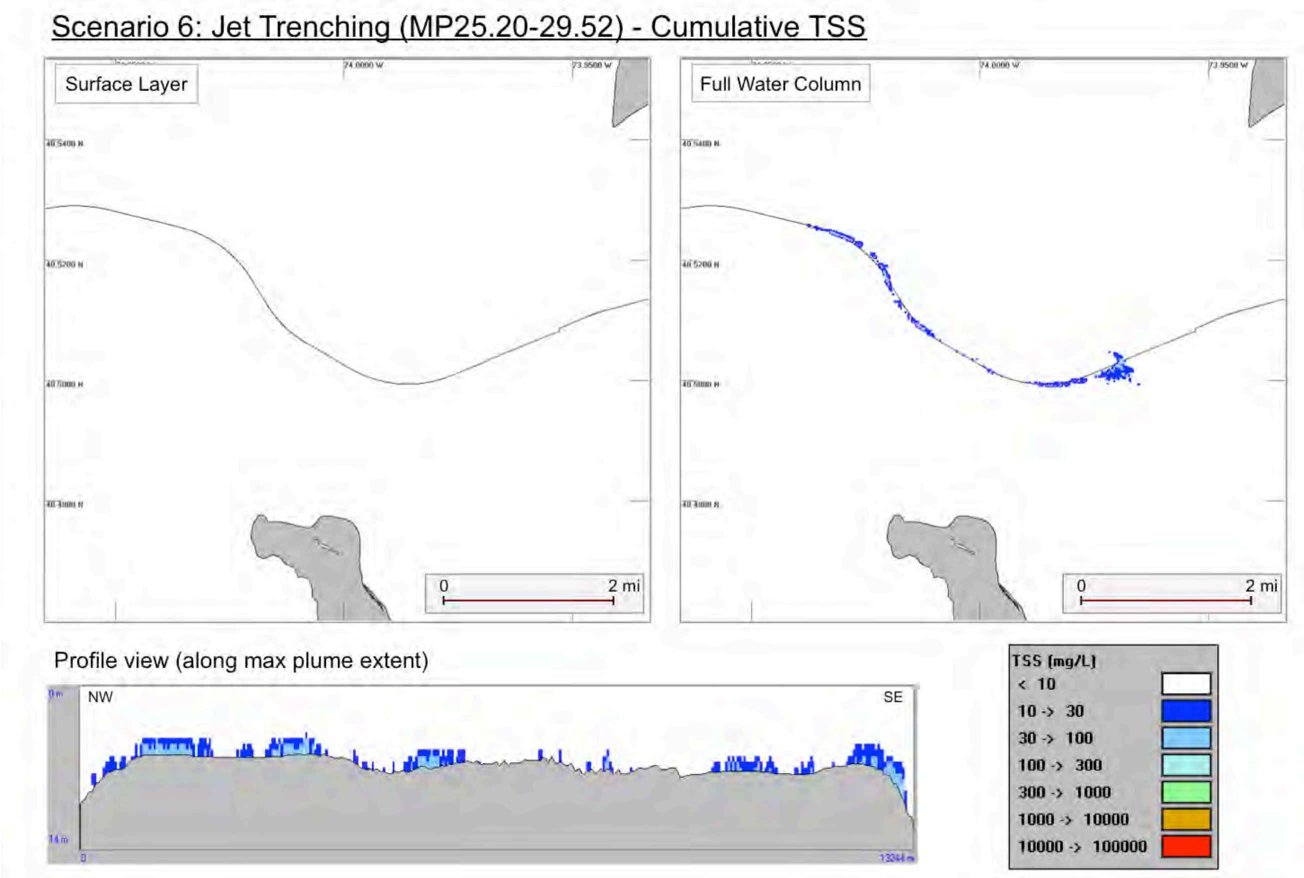

Figure 36. Cumulative TSS concentrations for Scenario 6 after a single pass of the jet trencher (W to E), shown for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

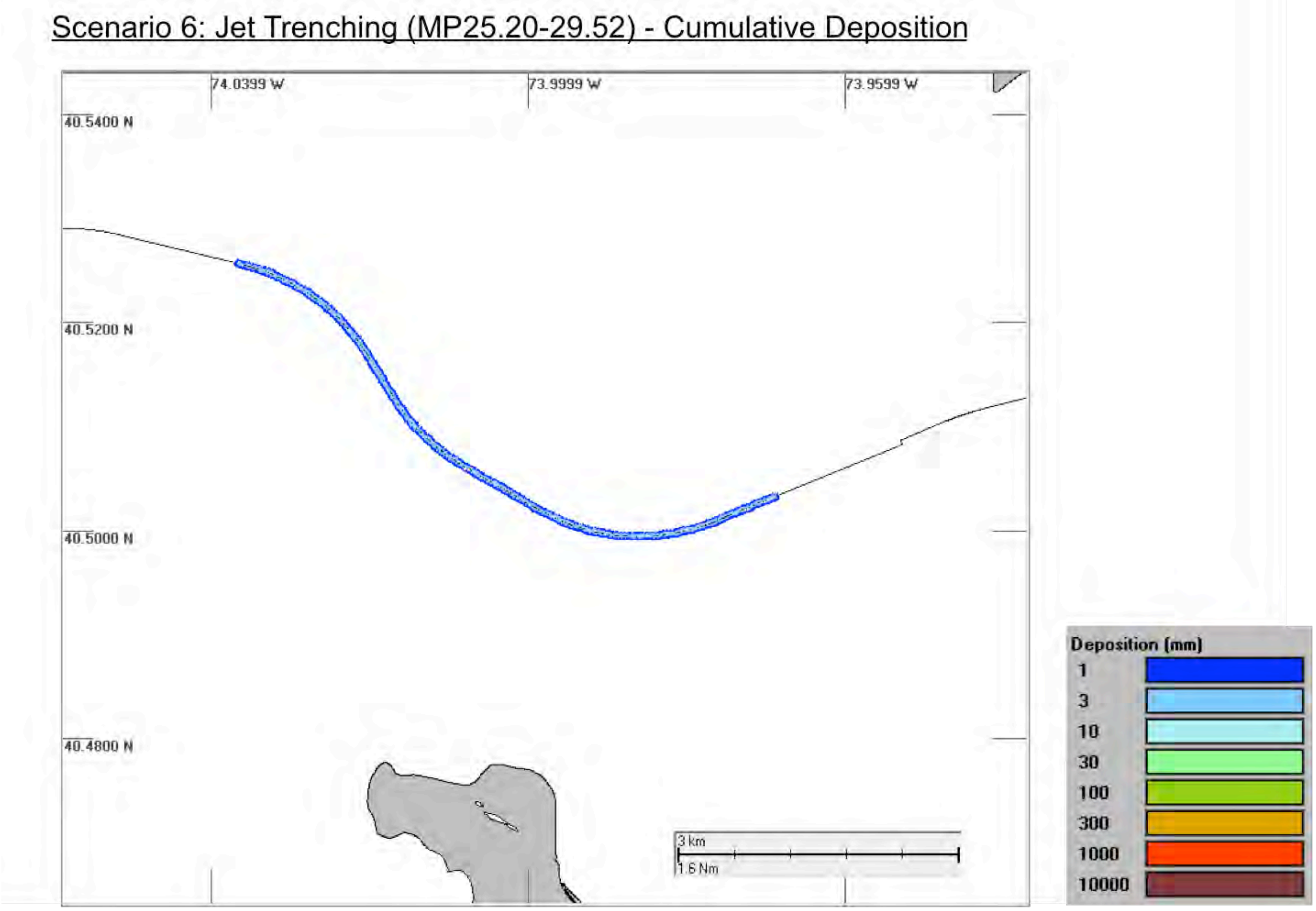

Figure 37. Extent of seabed deposition resulting from post-lay jet trenching between MP 25.20 and MP 29.52. Maximum predicted thickness = 0.3 in (6.7 mm).

3.4.7 Scenario 7 – Jet Trenching Between Ambrose Channel and Neptune Crossing 35

Scenario 7 simulated releases associated with post-lay jet trenching between MP 30.40 and MP 35.19, east of the Ambrose Channel. As described above, the jet trencher is equipped with retractable cutting swords, which straddle the pipeline and extend below the seabed. The jet trencher uses high volume seawater to fluidize the seabed and lower the pipeline to its burial depth (minimum 4 ft of cover) as the vehicle advances. The sediment volume along this section of the route is 2,242,033 ft^3, although, as described earlier, most of this material will remain undisturbed at the seabed since the jet trencher does not directly excavate sediment from the trench. For modeling, it was assumed that the equipment operates at a constant production rate of 29,135 ft^3/hr (based on contractor estimates of 656 ft/hr [200 m/hr] advance rates).

The activity was modeled as a line source, assuming two passes of the jet trencher would be required to achieve full burial. The initial pass (West to East) was followed by a return pass in the opposite direction, with a break of approximately 6 hours between the two activities to account for equipment re-positioning and other operational factors. Jet trenching activities are planned for late Q4 2018 and a model start date of December 26 was selected based on the construction schedule, and assuming a brief (three day) break between the previous jet trenching section (Scenario 6). Losses from the jet trencher are assumed to be limited to 5% of the total excavation volume, with 3% distributed directly at the seafloor (0-1 ft above), 1.5% between 1 and 2 ft, and the remaining mass (0.5%) between 2 and 3 ft above the seabed. In total, the simulation included the release of 112,052 ft^3 (4,150 yd^3) of sediment over the course of 3.2 days of active production.

Water column and sediment bed results from simulations of post-lay jet trenching between MP 30.40 and MP 35.19 are presented in Figure 38 through Figure 40, and summarized in Table 7. As with the previous jet trenching simulations, the sediment plume remains confined to the lower portions of the water column, with now sustained periods of elevated TSS concentrations predicted within the upper half of the water column. In comparison to the previous jet trenching scenarios, the cumulative plume is larger, presumably due to the dampening in current velocities east of the Ambrose Channel (Figure 13). For Scenario 7, water column concentrations of 100 mg/L are predicted to extend a maximum of 1,345 ft from the source and TSS concentrations remain elevated above ambient levels for 5.7 hours after the conclusion of jet trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

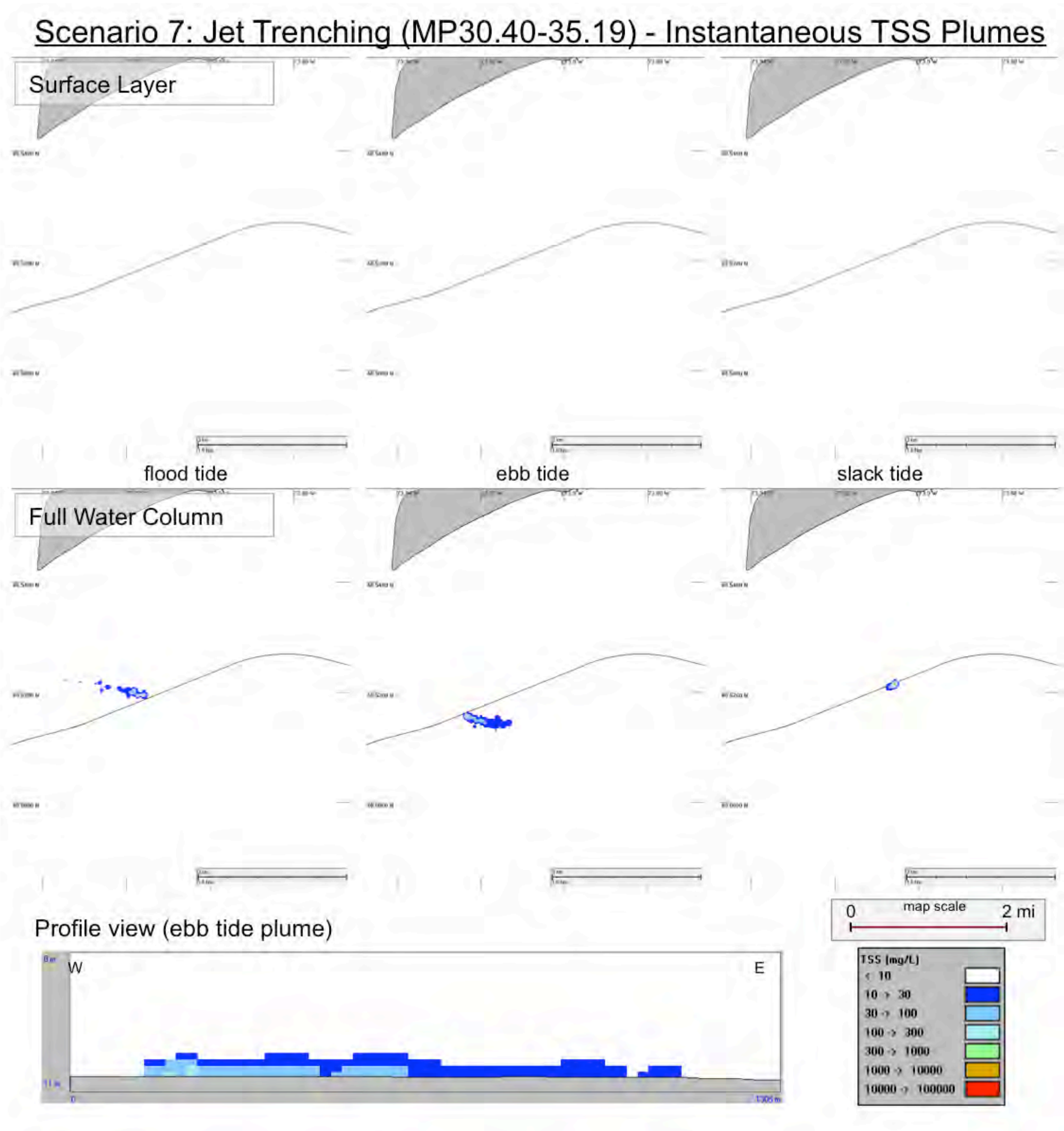

Figure 38. Instantaneous TSS concentrations at representative tide stages during post-lay jet trenching between MP 30.40 and MP 35.19. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

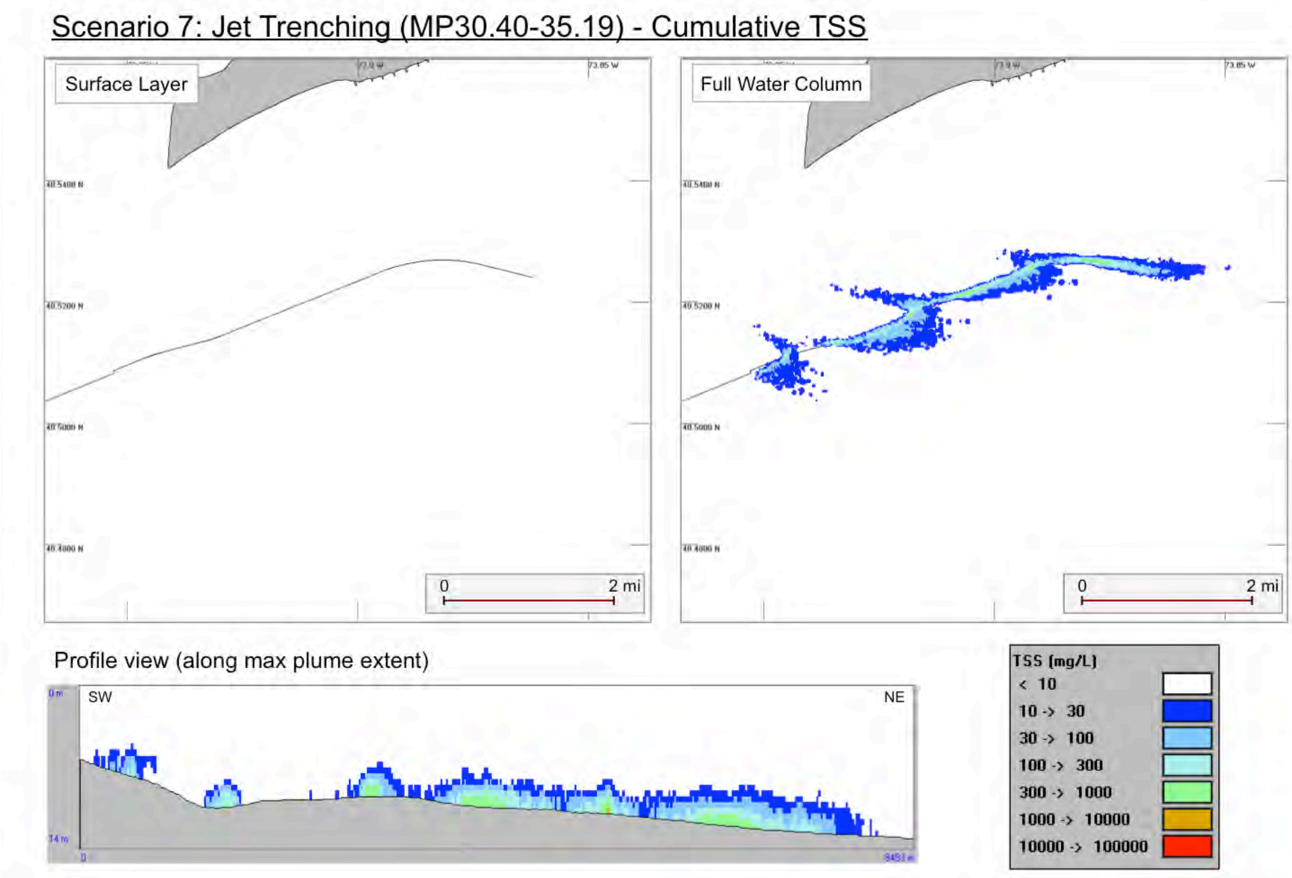

Figure 39. Cumulative TSS concentrations for Scenario 7 after a single pass of the jet trencher (W to E), shown for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

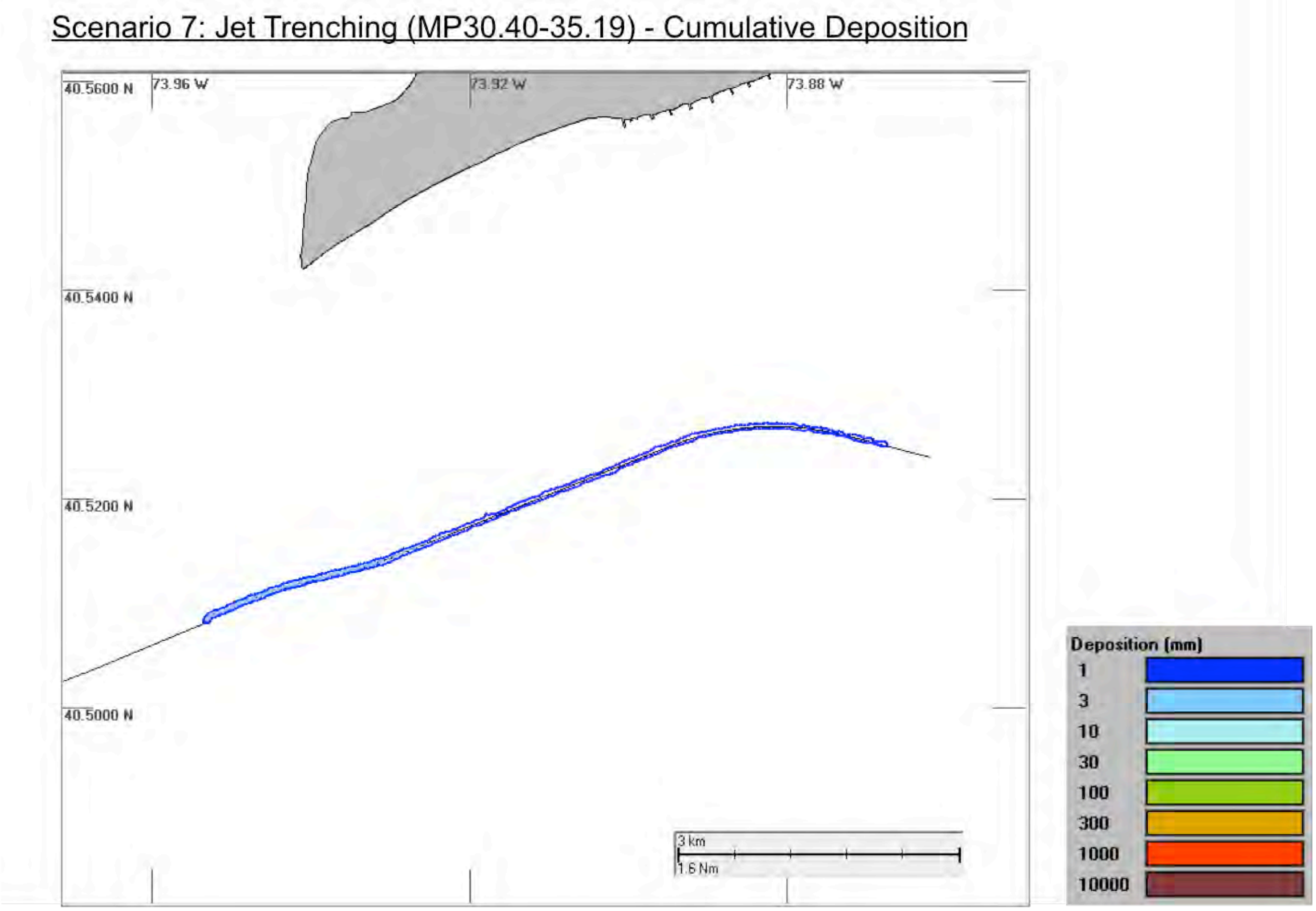

Figure 40. Extent of seabed deposition resulting from post-lay jet trenching between MP 30.40 and MP 35.19. Maximum predicted thickness = 0.2 in (4.6 mm).

3.4.8 Scenario 8 – Clamshell Trenching Across the Raritan Channel

Scenario 8 simulated releases associated with pre-lay (clamshell) trenching across the Raritan Channel (between MP 17.31 and MP 17.89). Along this reach, the pipeline will be buried to variable depths (between 4 and 8 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. In total, 5,138,432 ft^3 of sediment will be removed by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of November 6 (based on the Q4 2018 construction schedule for this activity). Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 513,843 ft^3 (19,031 yd^3) of sediment over the course of 19 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 17.31 and MP 17.89 are presented in Figure 41 through Figure 43, and summarized in Table 7. During most of the run, the plume is oriented in a W/E configuration, oscillating back and forth with the tide along the primary axis of Raritan Bay. The surface plume is sustained for most of the simulation and maximum TSS concentrations often occur in the mid- and upper portions of the water column, presumably due to the higher losses at the surface. Model results show that the highest TSS concentrations are expected to occur directly over the Raritan Channel (see cross-section within Figure 42). Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,822 ft from the source and TSS concentrations remain elevated above ambient levels for 7.6 hours after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 112 ft from the source and covers a total of 7.8 acres of the seabed.

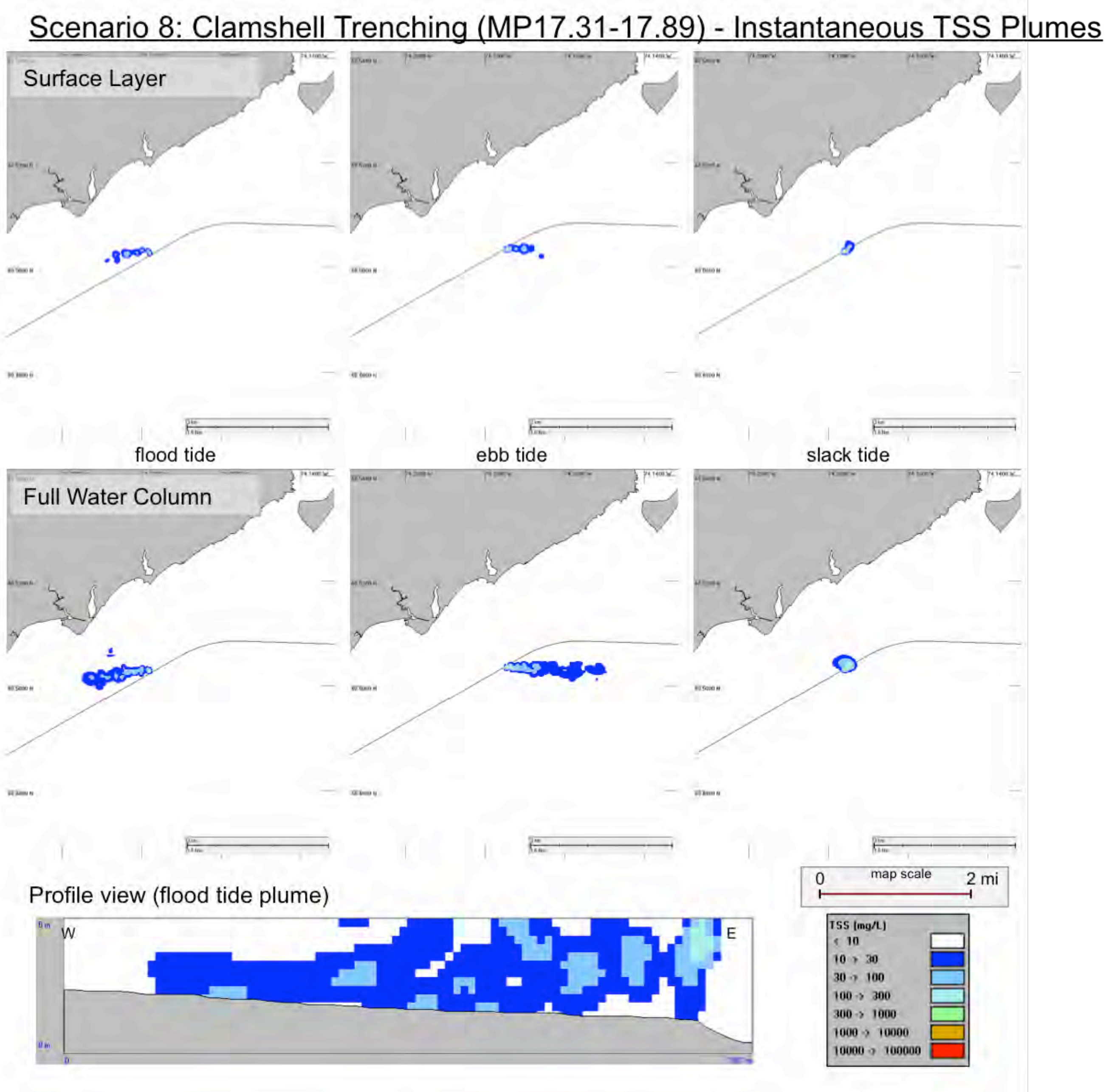

Figure 41. Instantaneous TSS concentrations at representative tide stages during pre-lay clamshell trenching across the Raritan Channel (between MP 17.31 and MP 17.89). Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the flood tide stage.

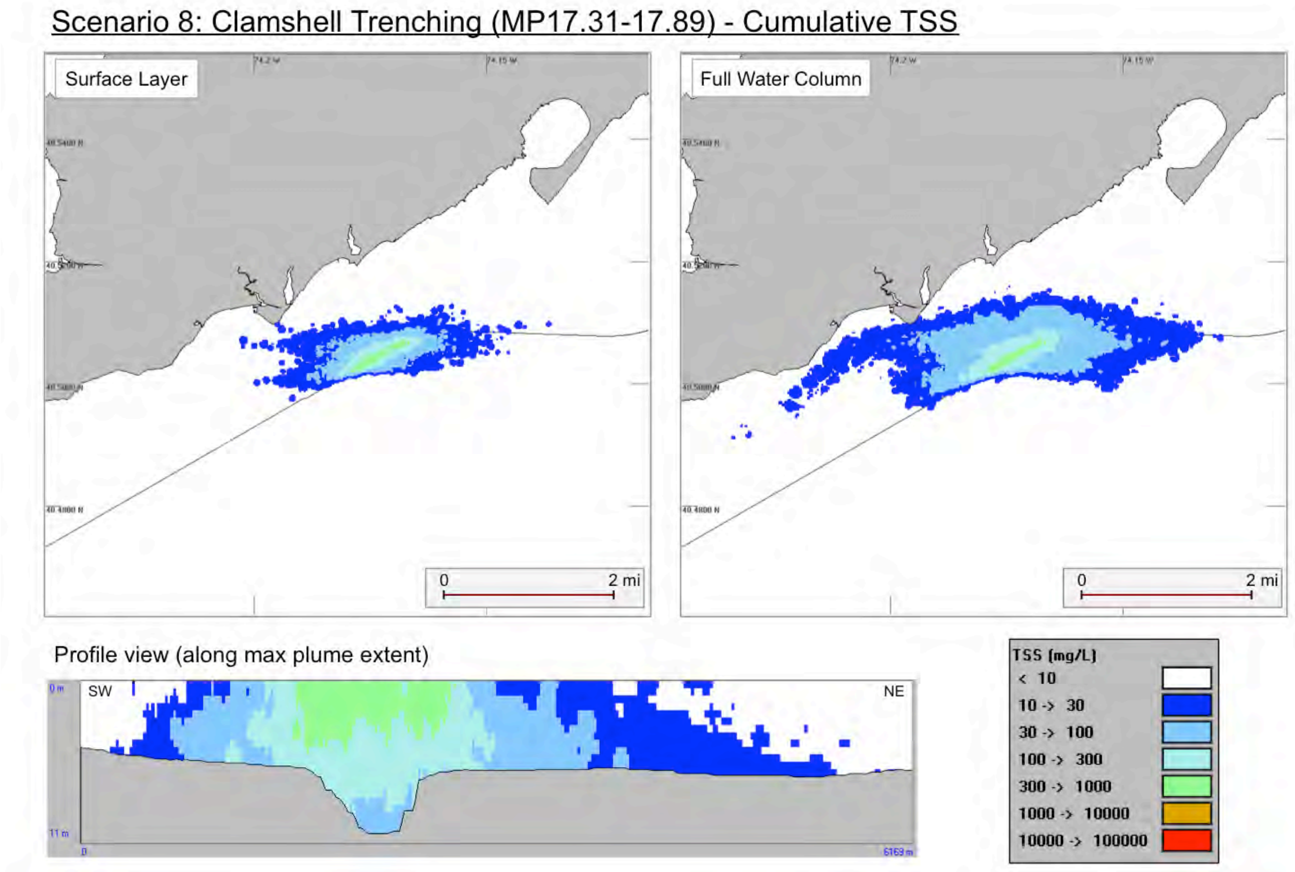

Figure 42. Cumulative TSS concentrations for Scenario 8 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

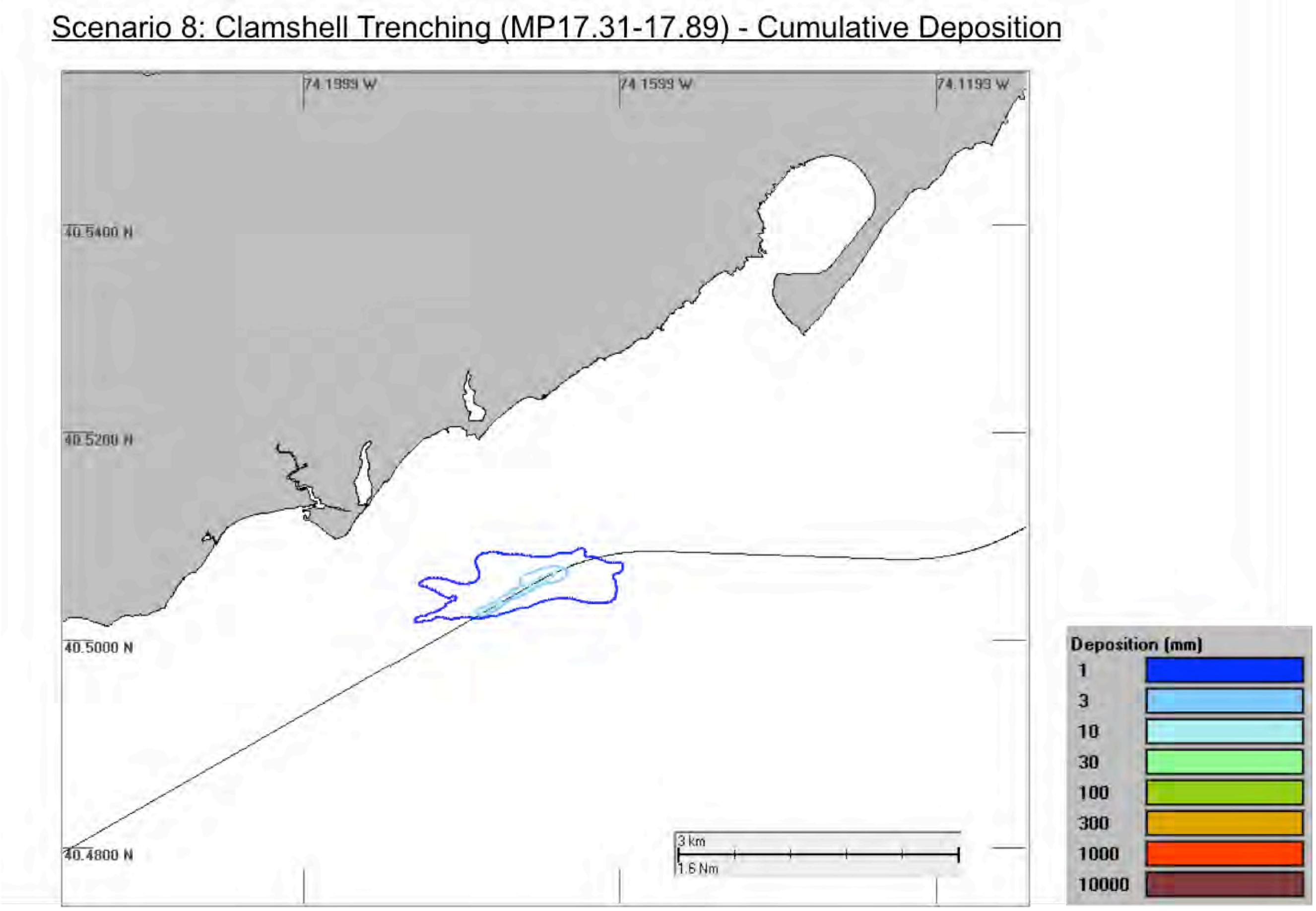

Figure 43. Extent of seabed deposition resulting from pre-lay clamshell trenching across the Raritan Channel (between MP 17.31 and MP 17.89). Maximum predicted thickness = 1.1 in (28.0 mm).

3.4.9 Scenario 9 – Clamshell Trenching Between the Anchorage Area and Chapel Hill Channel

Scenario 9 simulated releases associated with pre-lay (clamshell) trenching between MP 24.00 and MP 25.20. Along this reach, the pipeline will be buried to variable depths (between 4 and 7 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. In total, 3,374,322 ft^3 of sediment will be removed by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 (based on the Q3 2018 construction schedule for this activity). Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 337,432 ft^3 (12,497 yd^3) of sediment over the course of 12.5 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 24.00 and MP 25.20 are presented in Figure 44 through Figure 46, and summarized in Table 7. During most of the run, TSS plumes above 10 mg/L appear intermittently. When present, elevated TSS concentrations appear oriented in a W/E configuration, oscillating back and forth with the tide and in alignment with the primary flow pathway in and out of Raritan Bay. Sediment concentrations are far lower than those predicted from clamshell dredging further to the west, in Raritan Bay, reflecting the general shift in lithology (to coarser sediments) west of the Raritan Channel. Very little difference is noted between the surface and the integrated water column TSS concentrations in their cumulative extent, although higher concentrations are predicted to occur lower in the water column along the western portion of the route (Figure 45). Model results show that the highest TSS concentrations are expected to occur directly above the seabed, and directly below the surface (see cross-section within Figure 45). Water column concentrations of 100 mg/L are predicted to extend a maximum of 131 ft from the source and TSS concentrations remain elevated above ambient levels for 4.4 hours after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 148 ft from the source and covers a total of 35.3 acres of the seabed.

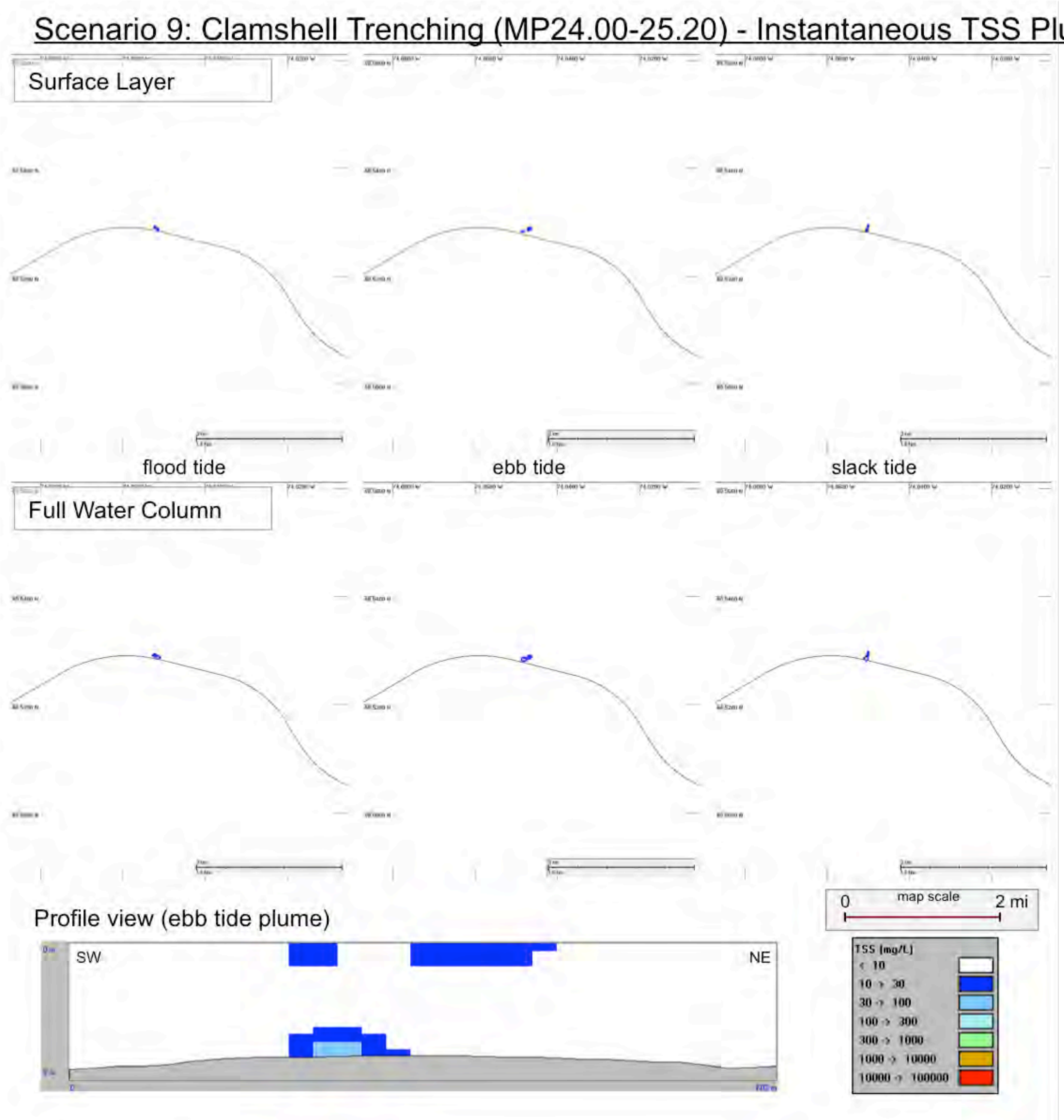

Figure 44. Instantaneous TSS concentrations at representative tide stages during pre-lay clamshell trenching between MP 24.00 and MP 25.20. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

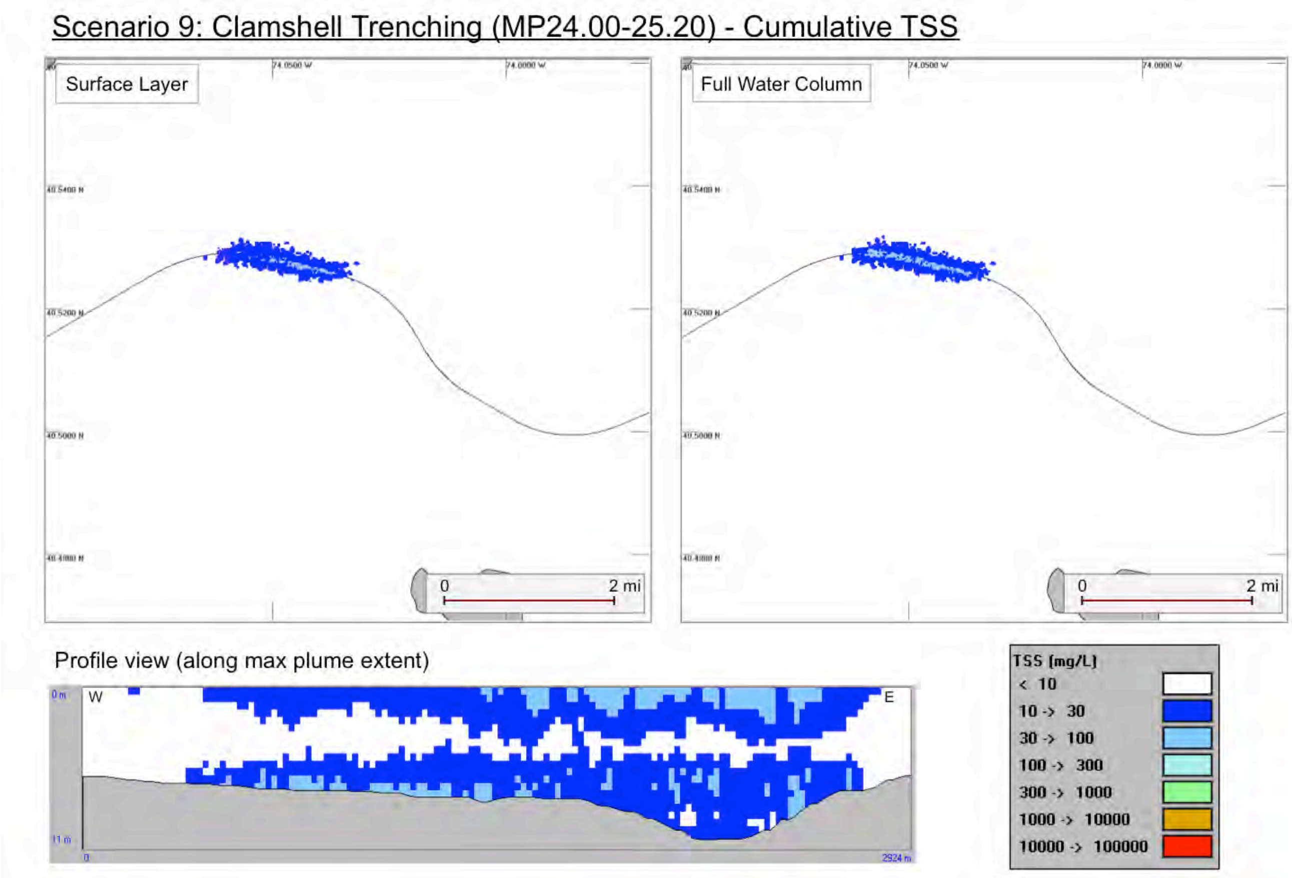

Figure 45. Cumulative TSS concentrations for Scenario 9 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

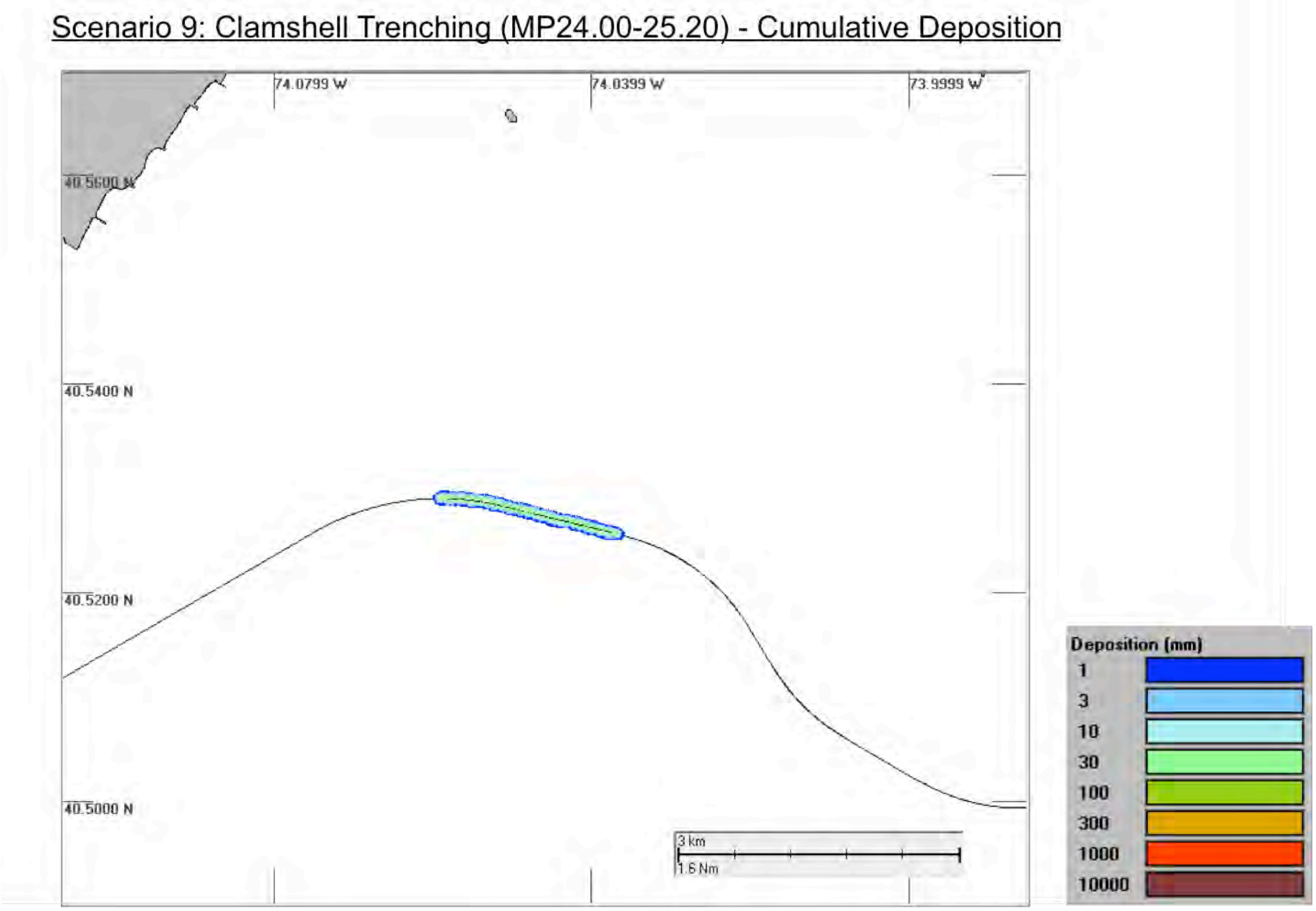

Figure 46. Extent of seabed deposition resulting from pre-lay clamshell trenching across the Raritan Channel (between MP 17.31 and MP 17.89). Maximum predicted thickness = 3.2 in (82.5 mm).

3.4.10 Scenario 10 – Excavation of Ambrose Channel HDD Exit Pit (West)

Scenario 10 includes simulations of sediment disturbance associated with excavation of the HDD exit pit at MP 29.52, west of the Ambrose Channel. The HDD pit will extend to a maximum of 20 ft below the grade of the seabed. During the excavation, approximately 379,350 ft^3 of sediment will be removed using a clamshell dredger. The dredging was simulated as a stationary (point) source from the HDD exit pit location, and was assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed based a start date of August 1. The modeling assumes the dredge operates continuously for the duration of the excavation activity (33.7 hours). Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). In total, the simulation included the release of 37,935 ft^3 (1,405 yd^3) of sediment over the course of 1.4 days of active dredge production.

Water column and sediment bed results from excavation at the Ambrose exit pit are presented in Figure 47 through Figure 49, and summarized in Table 7. The plume is clearly aligned with the strong tidal currents that flow in and out of the Bay entrance. Although present, elevated TSS concentrations at the surface rapidly dissipate with the strong currents speeds at this location. Maximum TSS concentrations are distributed vertically throughout the water column, and are predicted to occur in areas immediately adjacent to the dredge site. Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,756 ft from the source and TSS concentrations remain elevated above ambient levels for 12.5 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 397 ft and covers 3.8 acres of the seabed.

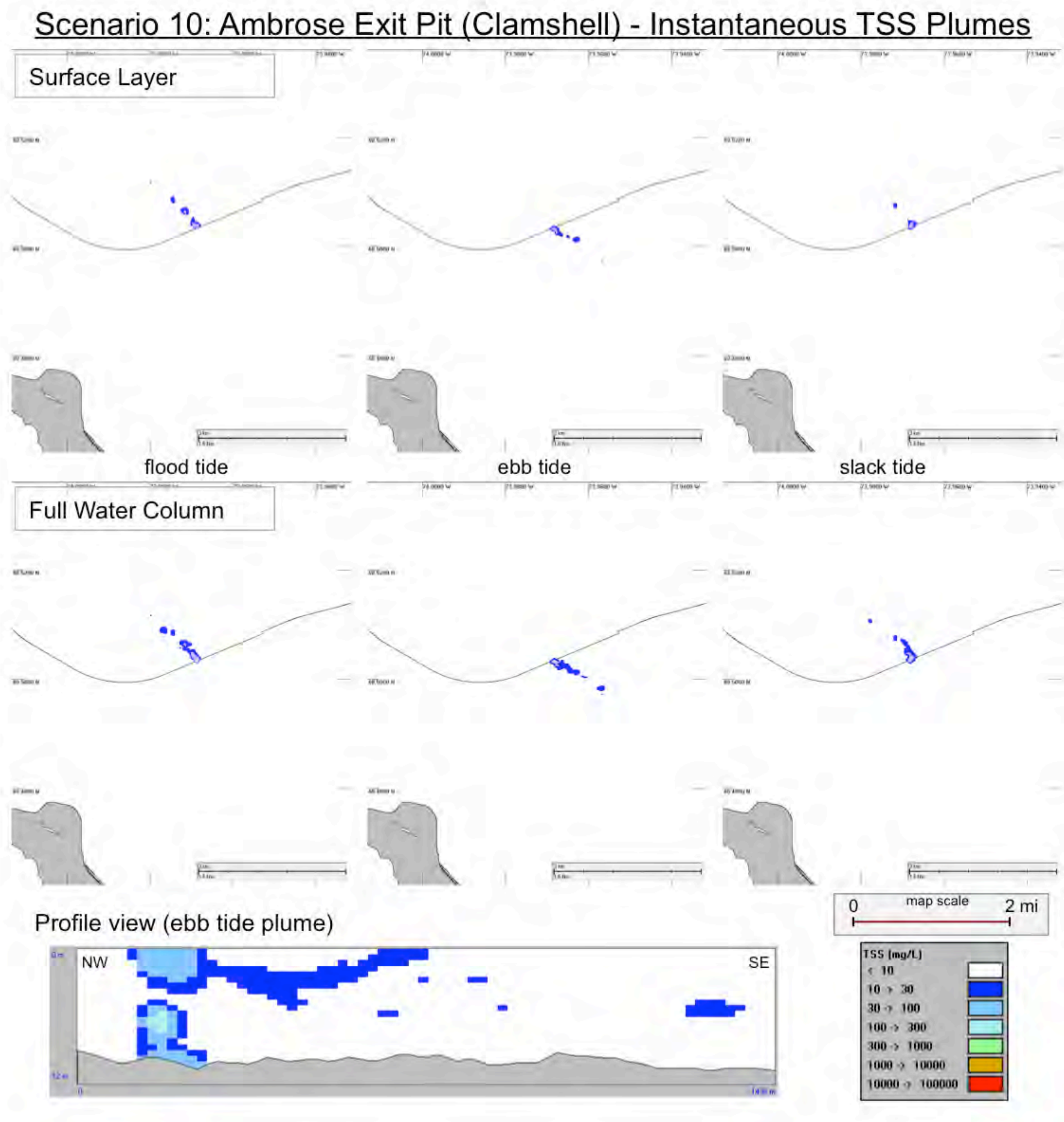

Figure 47. Instantaneous TSS concentrations at representative tide stages during excavation of the Ambrose Channel HDD exit pit at MP 29.52. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

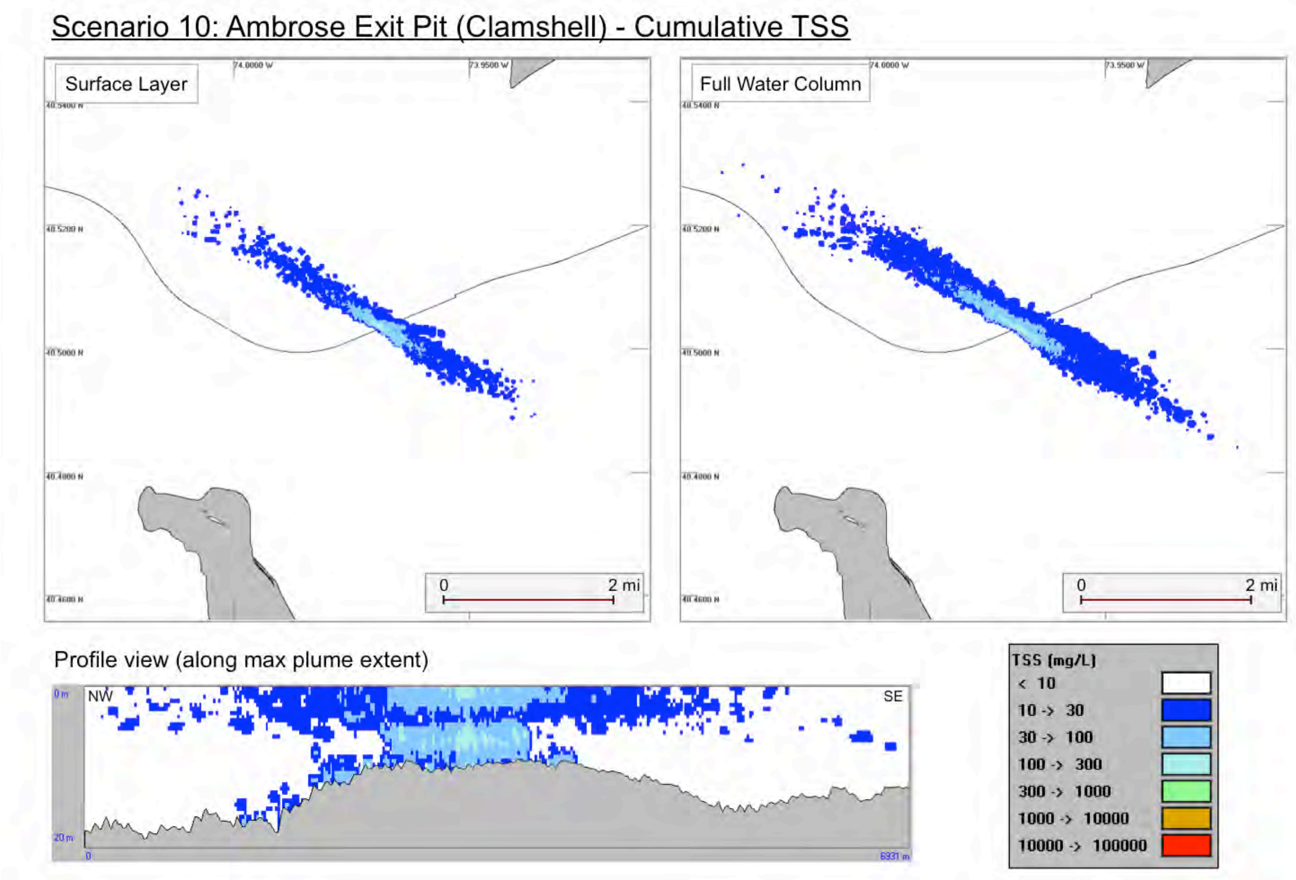

Figure 48. Cumulative TSS concentrations for Scenario 10 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

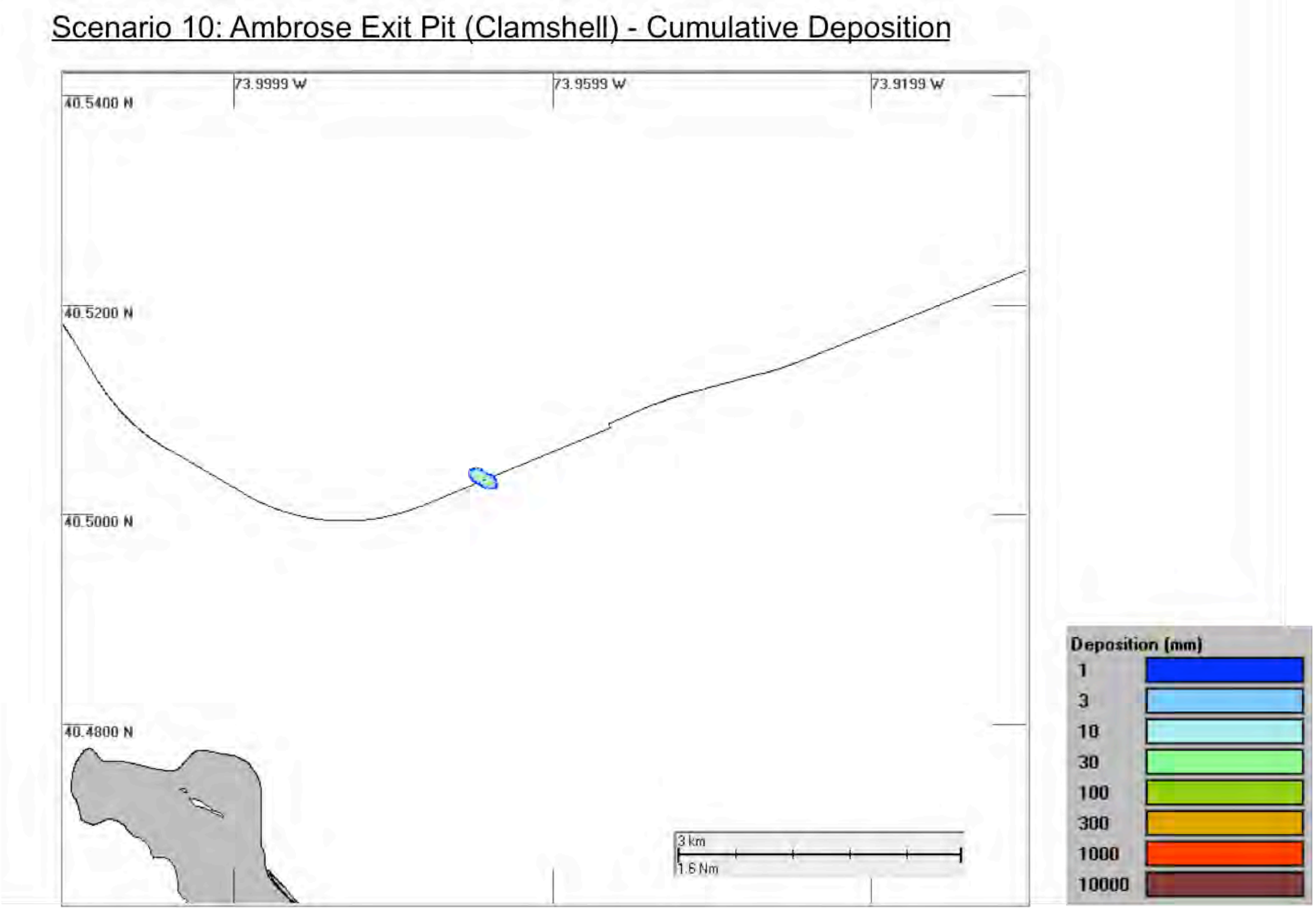

Figure 49. Extent of seabed deposition resulting from excavation of the Ambrose Channel HDD exit pit at MP 29.52. Maximum predicted thickness = 3.8 in (97.6 mm).

3.4.11 Scenario 11 – Excavation of Ambrose Channel HDD Entry Pit (East) and Tie-in

Scenario 11 includes two phases of construction associated with the Ambrose HDD campaign: (i) excavation of the Ambrose Channel HDD entry pit to a depth of 24 ft, and (ii) excavation of the tie-in point on the east side of the HDD to a depth of 7.5 ft. Both activities were simulated, in sequence as a stationary (point) source from the HDD entry point (MP30.40). Both involve excavation by clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed based a start date of August 4 (immediately following the HDD exit excavation west of the channel). The modeling assumes the dredge operates continuously for 77.9 hours during excavation of the HDD pit, breaks for approximately 18 hours between the two activities, and begins operations for the tie-in point excavation at the start of the next calendar day. Excavation for the tie-in point is simulated continuously for 5 hours. Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). A total of 93,270 ft^3 (3,454 yd^3) of sediment is released from these two sources over the course of 4 days (82.9 hours of active dredging).

Water column and sediment bed results from excavation at the Ambrose Channel HDD east entry pit are presented in Figure 50 through Figure 52, and summarized in Table 7. Overall, elevated TSS concentrations from the above activities are ephemeral due in large part to the coarser sediment grain sizes in the area, which lead to rapid settling. Similarly, sedimentation is substantially higher at this location than the adjacent (west) HDD entry pit location. In part, this is expected due to greater excavation volumes, although faster settling rates also contribute to the overall thickness of the deposit, which is confined to the area within 600 ft from the construction site. Water column concentrations are not predicted to exceed 100 mg/L at any point during the model simulation. TSS concentrations remain elevated above ambient levels for 2.0 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 299 ft and covers 4.0 acres of the seabed.

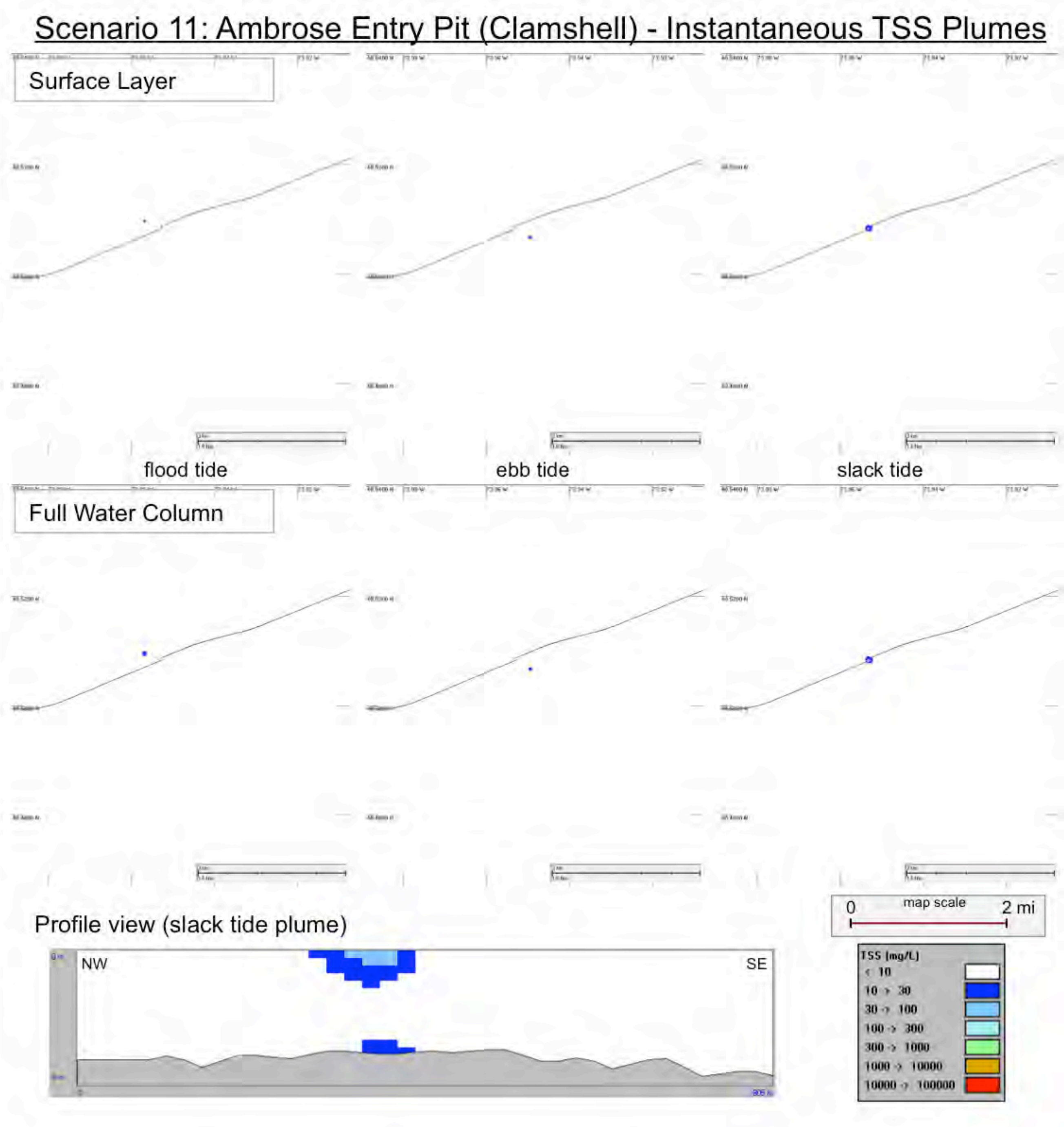

Figure 50. Instantaneous TSS concentrations at representative tide stages during excavation activities at the Ambrose Channel HDD (east) location. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during slack tide conditions.

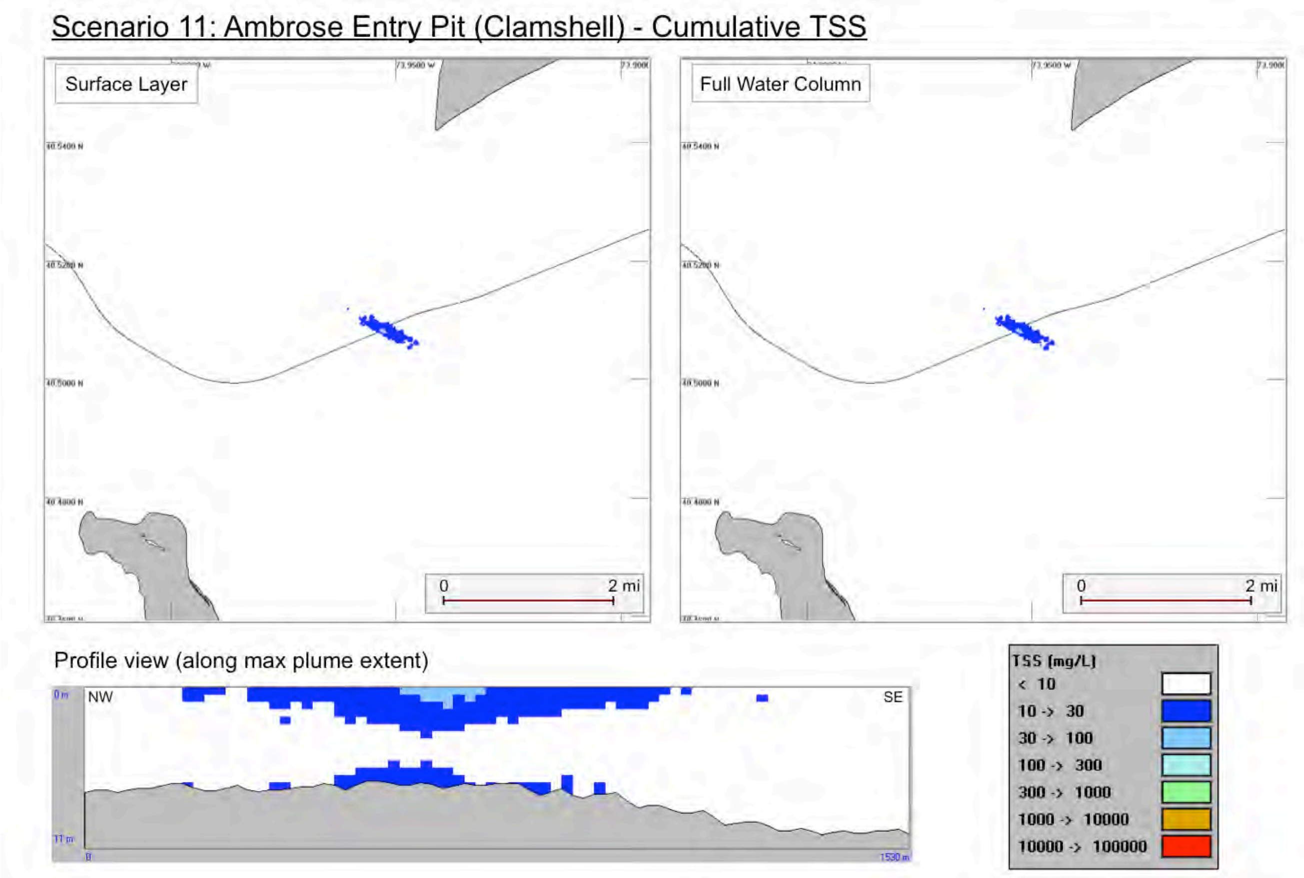

Figure 51. Cumulative TSS concentrations for Scenario 11 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

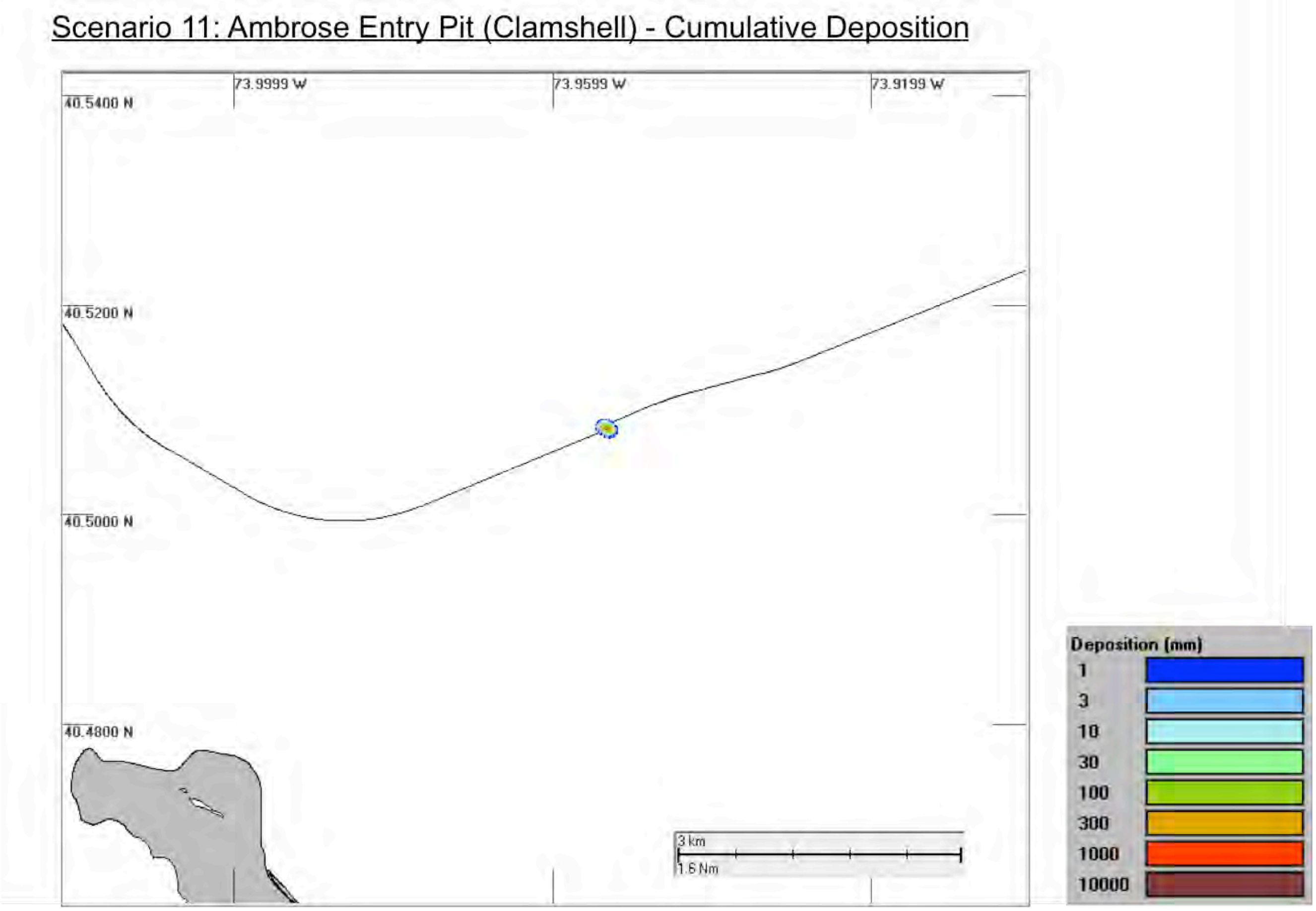

Figure 52. Extent of seabed deposition resulting from excavation activities at the Ambrose Channel HDD (east) location. Maximum predicted thickness = 16.9 in (429.0 mm).

3.4.12 Scenario 12 – Jetting at the Neptune Cable Crossing Offshore Rockaway

Scenario 12 simulated sediment disturbances associated with diver-assisted hand jets, which will be used to expose the Neptune Cable at its (eastern) crossing point at MP 35.19. Sediments excavated by hand jet (pressurized water jets) are completely dispersed into the water column; this type of excavation is used to clear sediments and expose subsea infrastructure. The jetting activity was simulated as a stationary (point) source from the crossing location, and was assumed to operate at a constant production rate of 180 ft^3/hr (approximately half the production rate of the Raritan Bay crossing).

The excavation of the Neptune Cable at MP 35.19 is scheduled for Q3 2018, and the simulation was performed based a start date of September 27 (immediately following hand jetting at the western cable crossing presented in Scenario 3). The hand jetting was assumed to take place continuously for 11.6 days. As the entirety of the disturbed sediment volume (100%) from hand jetting is considered lost to the water column, a total of 50,252 ft^3 (1,861 yd^3) of sediment was released over the duration of the simulation. In the model, sediment losses from hand jetting were released from a height of 6 ft above the seabed (at the location where the direct excavation is taking place).

Water column and sediment bed results from simulations of hand jetting at MP 35.19 are presented in Figure 53 through Figure 55, and summarized in Table 7. During most of the run, the plume remains compact around the release point (rarely extending beyond 500 ft even at the lowest thresholds) and confined to the lower depths of the water column (~5 ft above the seafloor). And as with simulations of other (stationary) construction activities east of the Ambrose Channel, sedimentation is more pronounced at this location (Figure 55). Water column concentrations of 100 mg/L are predicted to extend a maximum of 197 ft from the hand jet source and TSS concentrations remain elevated above ambient levels for 0.7 hours after the conclusion of jetting activity. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 394 ft from the source and covers a total of 2.9 acres of the seabed.

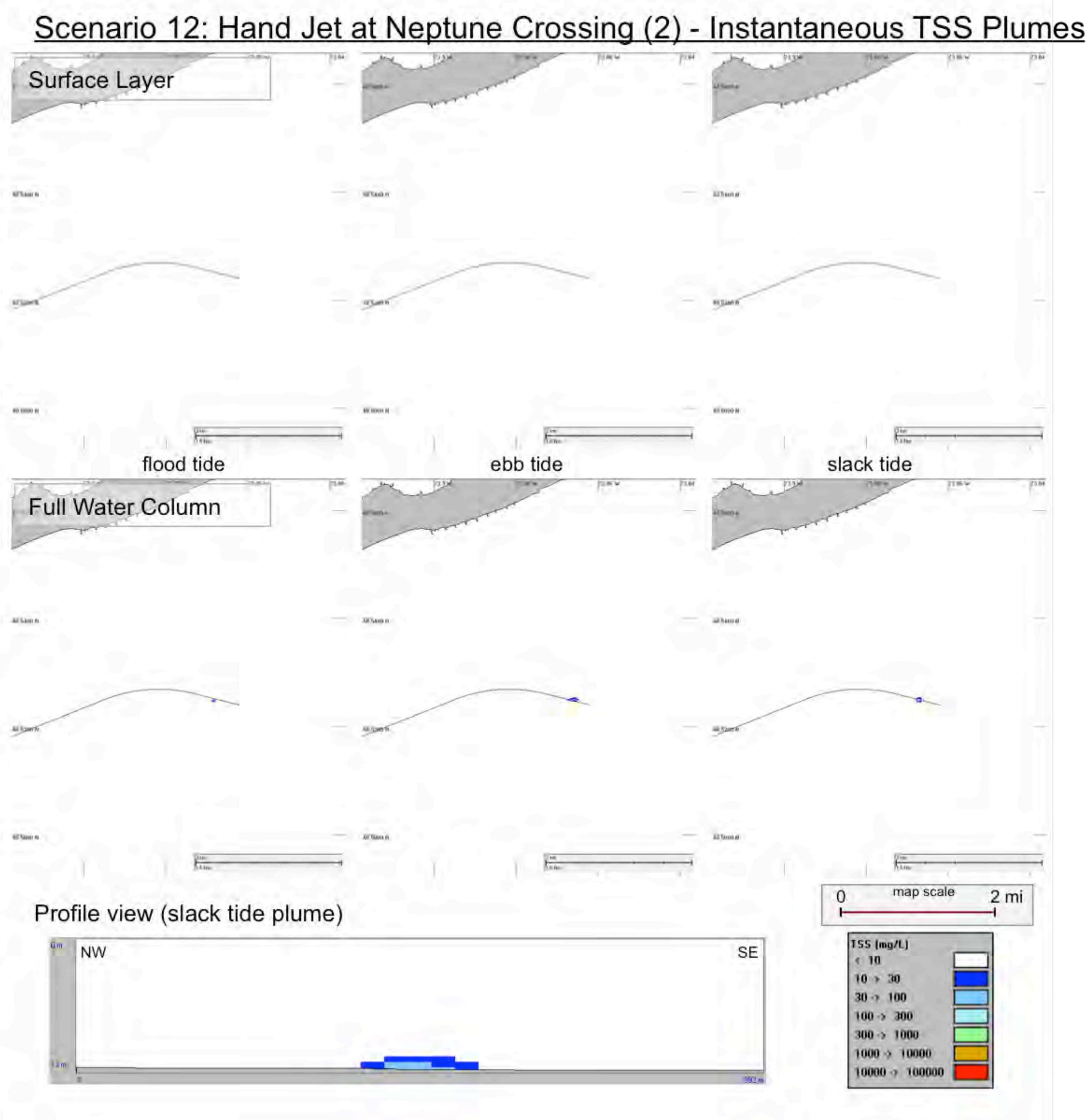

Figure 53. Instantaneous TSS concentrations at representative tide stages during hand jetting at MP 35.19. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

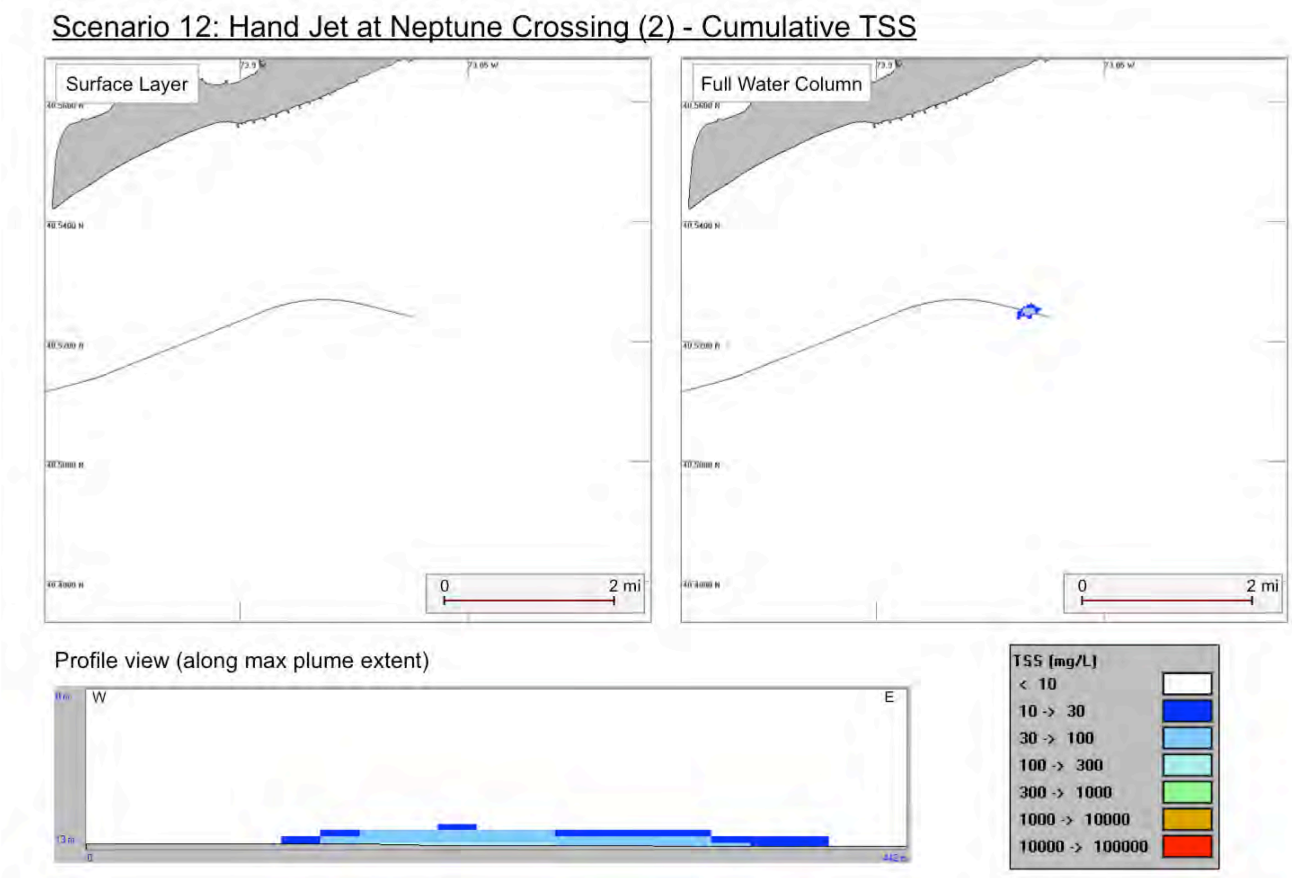

Figure 54. Cumulative TSS concentrations for Scenario 12 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

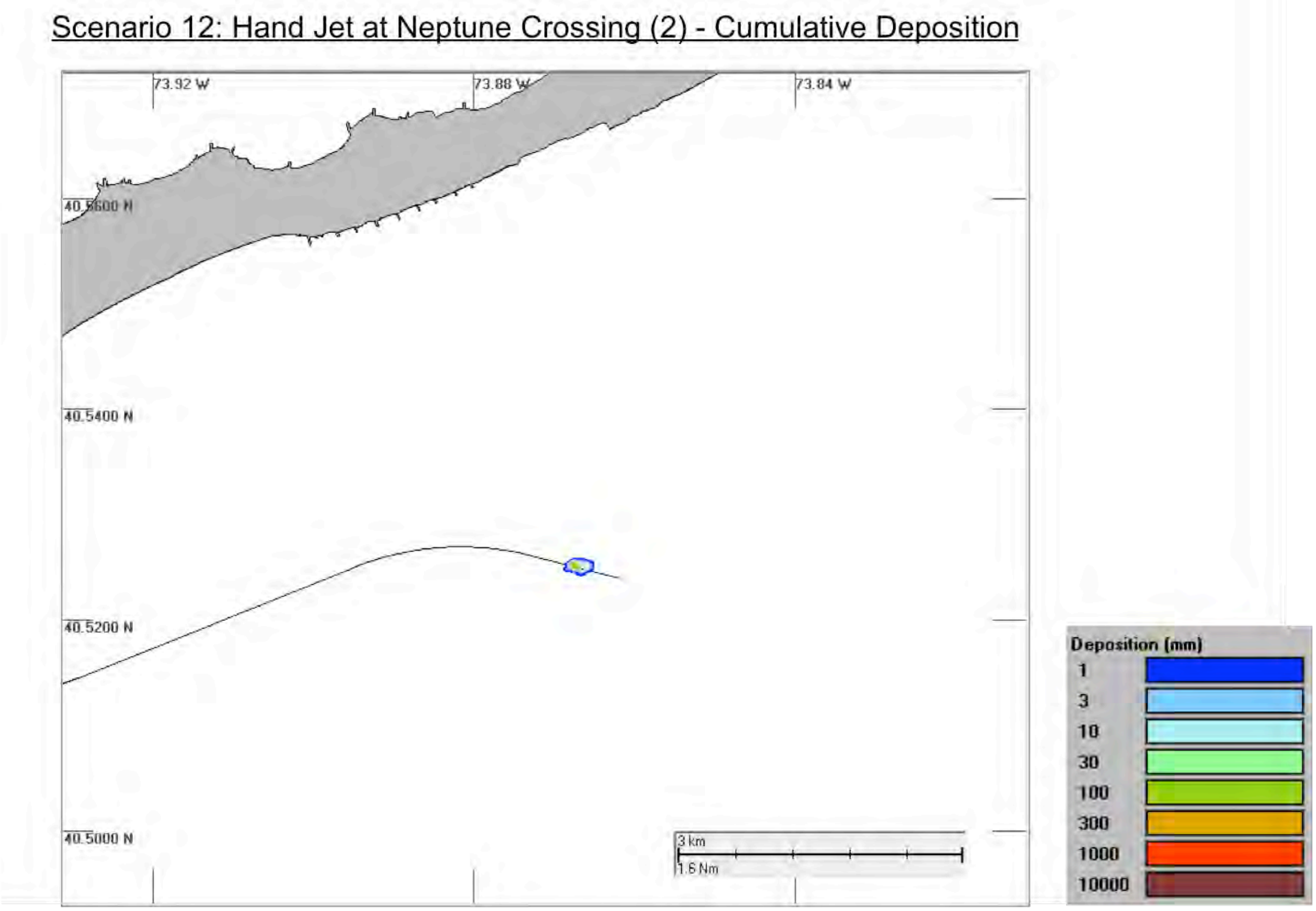

Figure 55. Extent of seabed deposition resulting from hand jetting at MP 35.19. Maximum predicted thickness = 15.5 in (392.7 mm).

3.4.13 Scenario 13 – Clamshell Trenching Between the Neptune Crossing and RDL Manifold

Scenario 13 simulated releases associated with pre-lay (clamshell) trenching between MP 35.23 and the RDL tie-in point at MP 35.49. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total 303,412 ft^3 of sediment will be removed by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of February 6 (based on the Q1 2019 construction schedule for this activity). Losses from the clamshell bucket are assumed to be 10% of the total excavation volume, with 8% released at the sea surface (representing barge overflow) and the remaining 2% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 30,341 ft^3 (1,124 yd^3) of sediment over the course of 1.1 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 35.23 and MP 35.49 are presented in Figure 56 through Figure 58, and summarized in Table 7. During most of the run, the plume is oriented in a NW/SE configuration, oscillating back and forth with the primary flow pathway south of the Rockaway Peninsula. The maximum TSS concentrations occur at or just below the sea surface due to the higher concentration of sediment losses from the clamshell bucket as it breaks the water surface. Lower current velocities east of the Ambrose Channel also contribute to the elevated TSS surface concentrations along this portion of the route. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,198 ft from the dredge source and TSS concentrations remain elevated above ambient levels for 8.0 hours after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

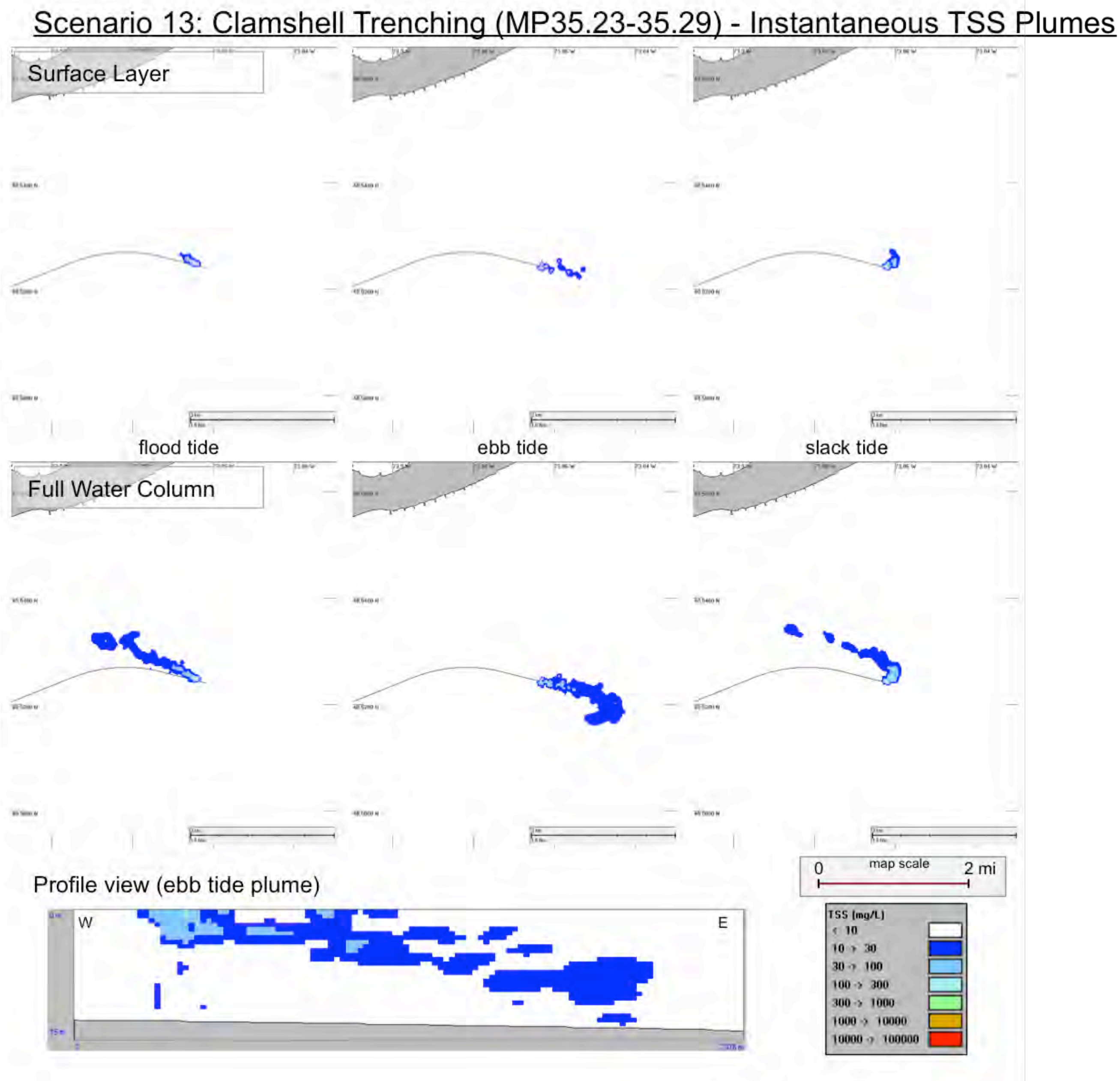

Figure 56. Instantaneous TSS concentrations at representative tide stages during pre-lay clamshell trenching between MP 35.23 and MP 35.29. Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during the ebb tide stage.

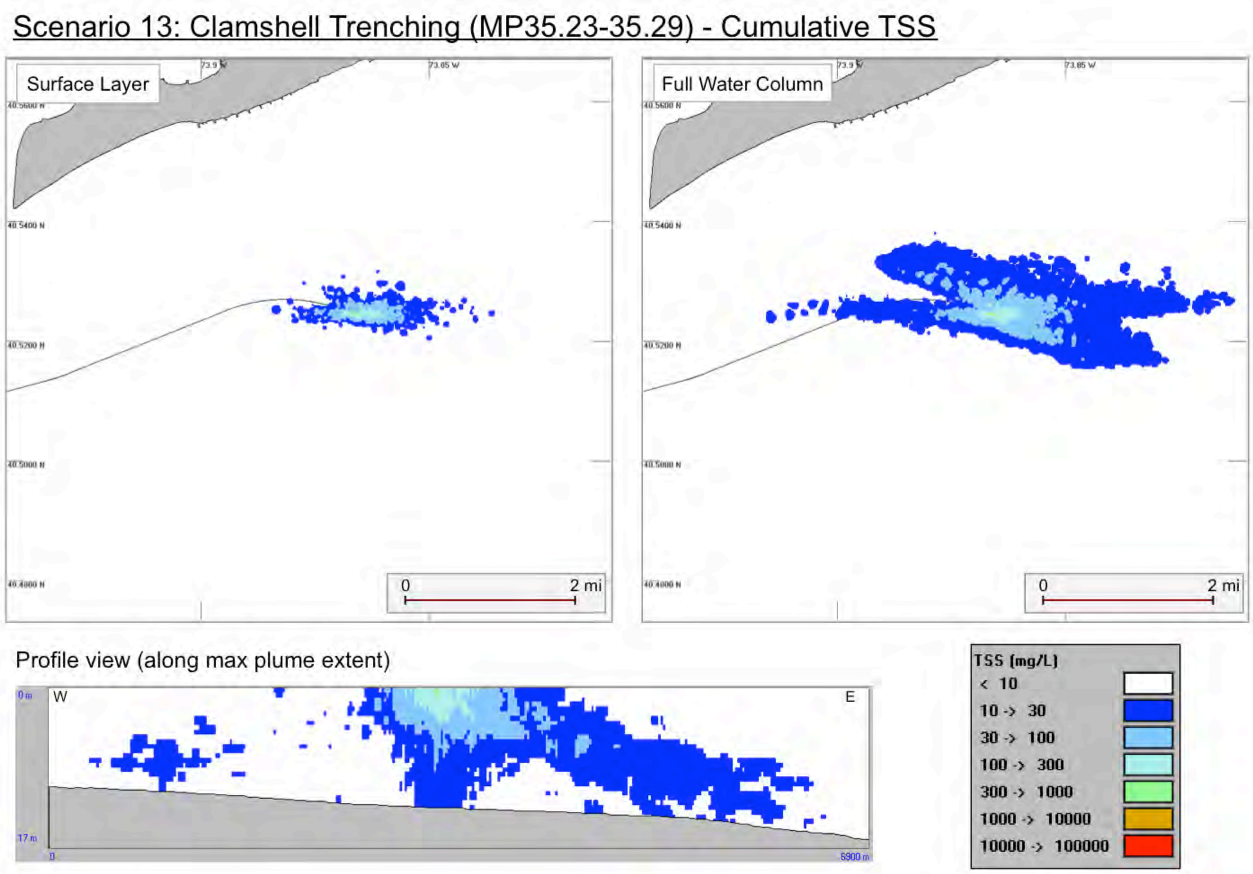

Figure 57. Cumulative TSS concentrations for Scenario 13 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

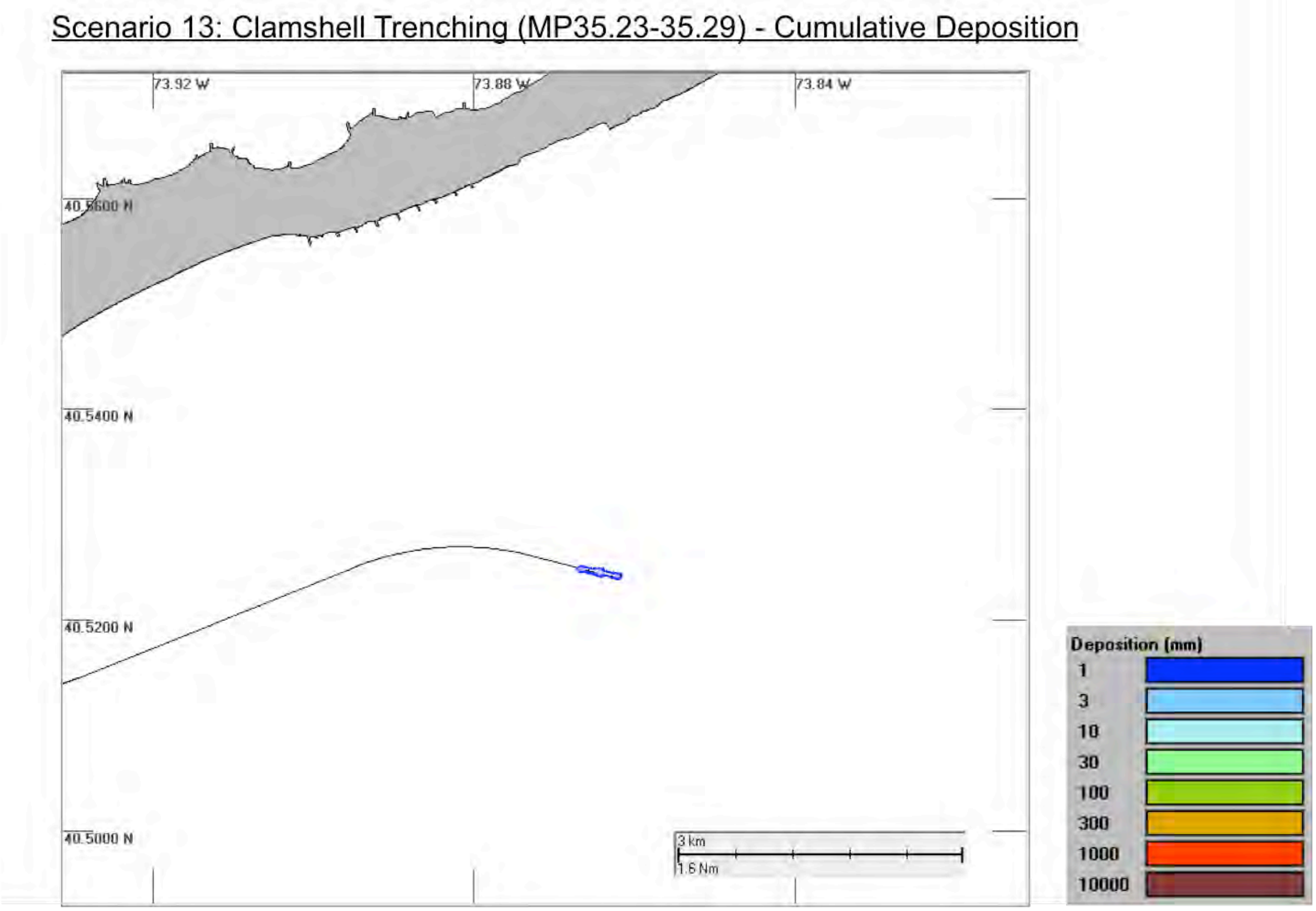

Figure 58. Extent of seabed deposition resulting from pre-lay clamshell trenching between MP 35.23 and MP 35.29. Maximum predicted thickness = 0.2 in (5.6 mm).

3.4.14 Scenario 14 – Excavation the Tie-in Skid and Manifold at Rockaway

Scenario 14 included simulating two different methods for the excavation associated with uncovering the tie-in skid and manifold at the Rockaway Delivery Lateral at MP 35.49. A total of 163,080 ft^3 of sediment will be excavated from the site - approximately 75% will be dispersed using a submersible pump, and the remaining 25% will be excavated by hand jetting. The submersible pump fluidizes and excavates the sediments, releasing them through a discharge pipe to a spoil pile on the nearby seafloor, whereas the hand jet uses water jets to clear away sediment surrounding the subsea infrastructure. Both types of equipment release 100% of the excavated sediment directly into the water column. Losses from the submersible pump are distributed between 0 and 10 ft above the seabed (45% between 0-1 ft, 25% between 1-2 ft, and the remaining 30% distributed equally between 2-10 ft). Losses from hand jetting are released from a single point, 6 ft above the seabed.

The Rockaway tie-in campaign is scheduled for Q2 2019, and the simulation was performed using a start date of April 30. The modeling assumes the submersible pump will operate continuously for 30.2 hours followed by a break for approximately 18 hours between the two activities. Hand jetting operations begin at the start of the next calendar day and continue uninterrupted for 226.5 hours (9.4 days). A total of 163,080 ft^3 (6,040 yd^3) of sediment is released from these two sources over the course of the model run (11.4 days; 10.7 days of active excavation).

Water column and sediment bed results from excavation at the RDL tie-in point are presented in Figure 59 through Figure 61, and summarized in Table 7. Overall, elevated TSS concentrations from the above activities remain confined to the lower portions of the water column. At no point during the entire simulation are elevated TSS concentrations predicted in the upper half of the water column. Relatively high sedimentation levels are predicted from these activities (maximum deposition thickness of 57.5 in), owing mainly to the large volume and fraction of sediment being directly released at or near the seabed. Water column concentrations of 100 mg/L are predicted to extend a maximum of 722 ft from the dredge source and TSS concentrations remain elevated above ambient levels for 0.7 hours after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 456 ft from the source and covers a total of 6.3 acres of the seabed.

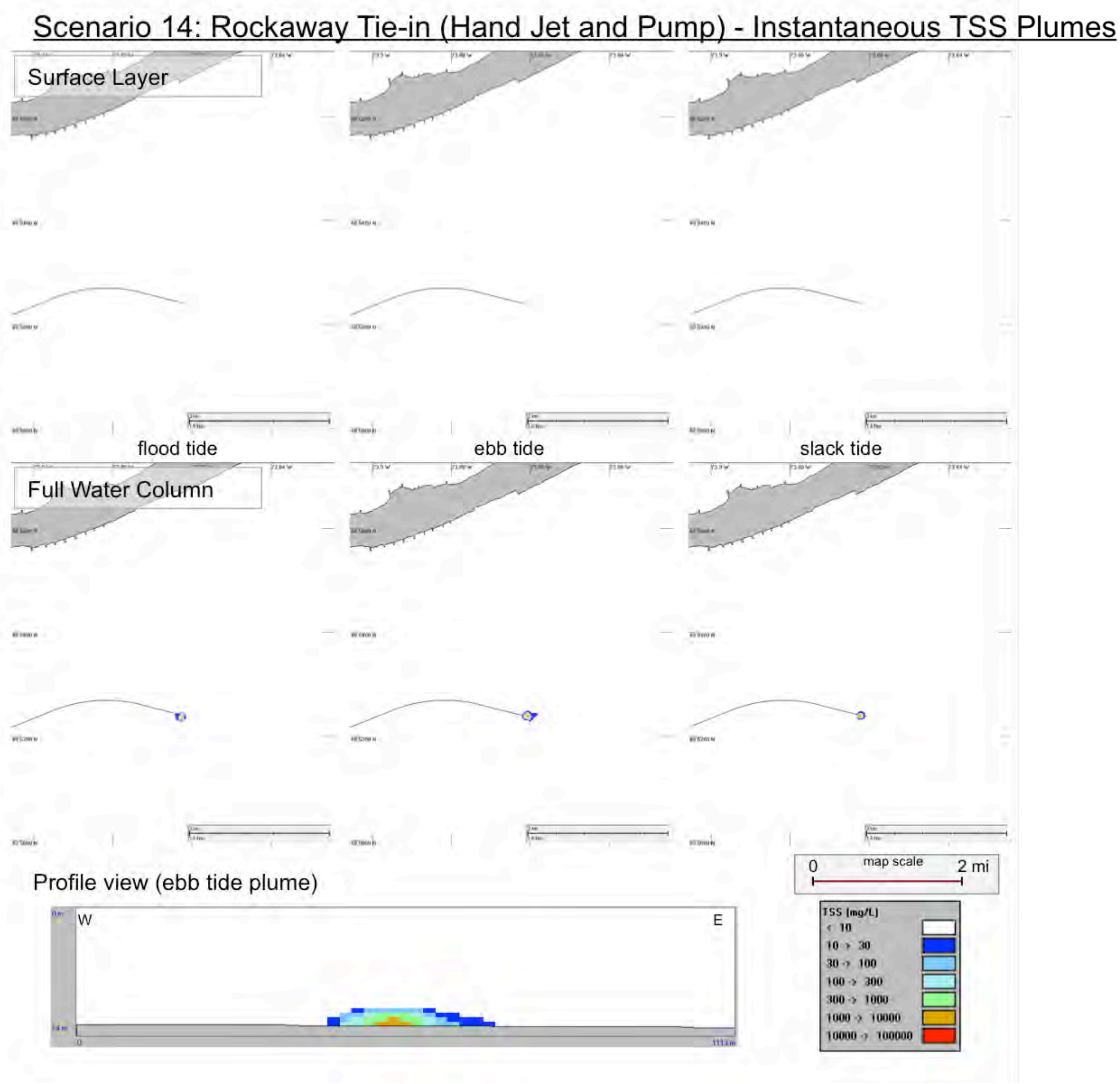

Figure 59. Instantaneous TSS concentrations at representative tide stages during excavation activities at the RDL tie-in location (MP 35.49). Top figures show concentrations in the surface layer (0-1.6 ft below the sea surface) and bottom figures show maximum concentrations at all depths. The profile view shows a cross-section of TSS concentrations along the main plume axis during ebb tide conditions.

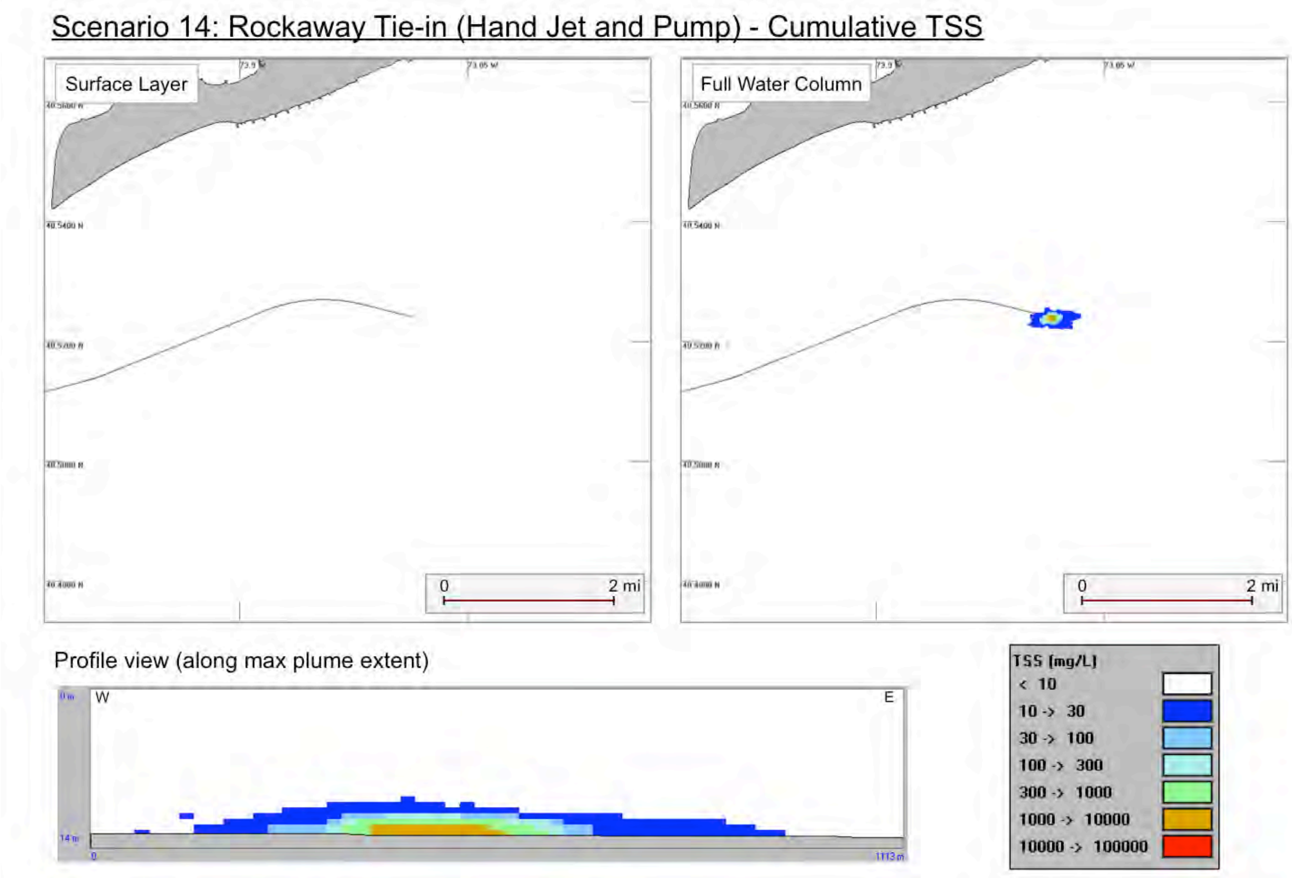

Figure 60. Cumulative TSS concentrations for Scenario 14 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

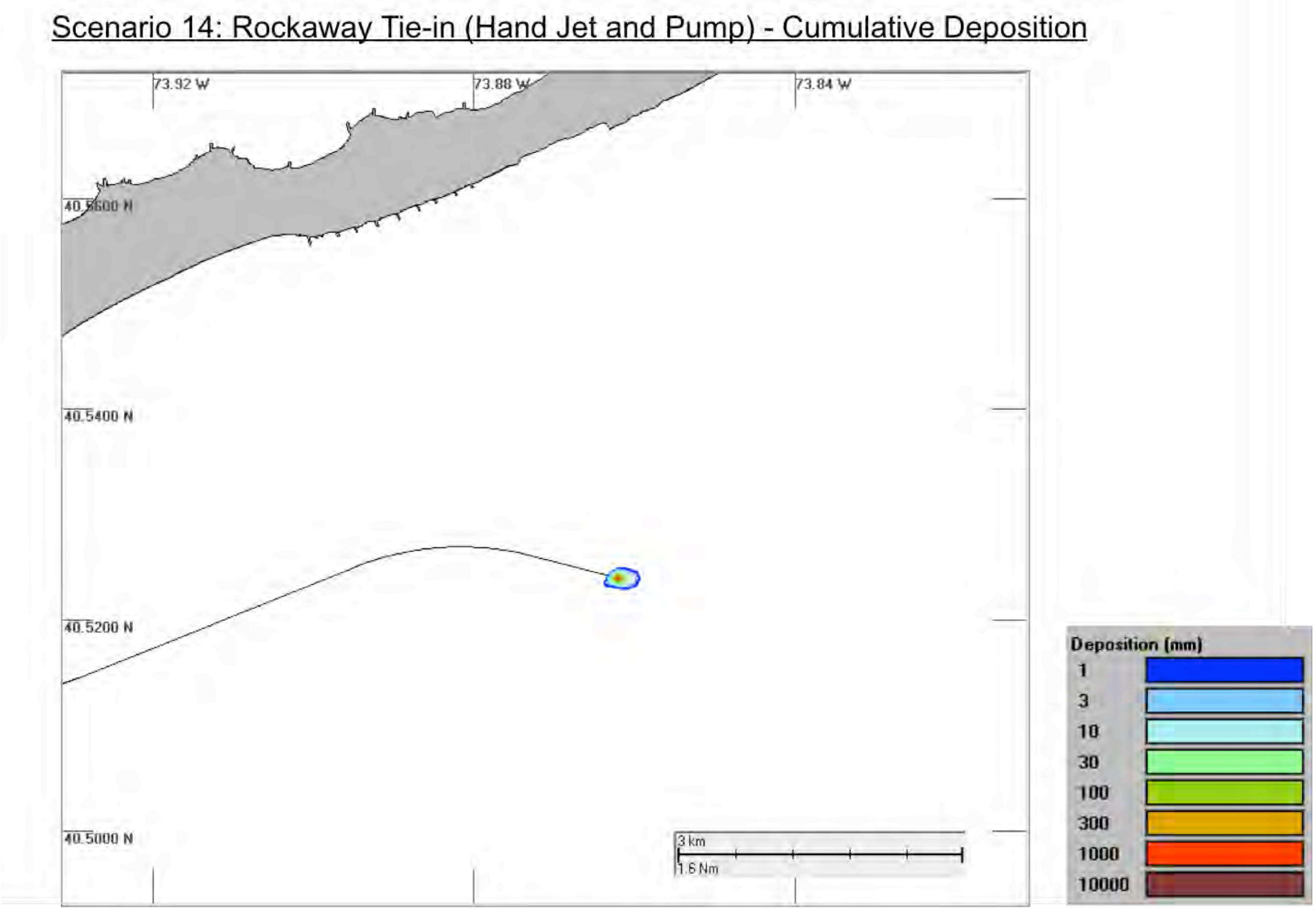

Figure 61. Extent of seabed deposition resulting from excavation activities at the RDL tie-in (MP 35.49). Maximum predicted thickness = 57.5 in (1460.0 mm).

Table 7. Summary of "base case" simulation results.

Scenario	Construction Activity	Phase	Equipment Type	Location	Production rate (ft3/hr)	Duration of modeled activity (hr)	Equipment Loss Rate (%)	Total volume released (yd3)	Time For TSS to return to ambient (hrs)	Max Distance of TSS Plume exceeding ambient (ft)		Max Distance of deposition exceeding (ft)			Area of deposition exceeding (acres)		
										50 mg/L	100 mg/L	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]
Scenario 1	Excavation activities at Morgan Shore	Excavation of Morgan Shore HDD pit	Clamshell	MP 12.50	11,250	23.8	10	993	3.33	1,969	1,099	482	269	154	7.4	2.7	0.9
		Excavation of anode sled burial area	Clamshell	~1,200 ft north of MP 12.30	11,250	1.2	10	49									
Scenario 2	Pre-lay trenching between Morgan HDD exit and the Midline tie-in	–	Clamshell	MP 12.50 - MP 16.60	11,250	513.8	10	21,408	9.87	5,233	4,331	148	108	62	39.9	16.9	5.2
Scenario 3	Jetting at the Neptune Cable crossing point in Raritan Bay	–	Hand Jet	MP 13.88	360	149.2	100	1,989	3.35	2,592	1,378	958	413	236	10.7	3.9	1.1
Scenario 4	Post-lay trenching between Midline tie-in and Raritan Channel Transition (2 passes)	Pass 1 (W to E)	Jet Trencher	MP 16.60 - MP 17.31	29,135	5.8	5	311	6.91	1,591	1,001	36	0	0	0.1	0.0	0.0
		Pass 2 (E to W)	Jet Trencher	MP 17.31 - MP 16.60	29,135	5.8	5	311									
Scenario 5	Post-lay trenching between Curve 1 and Anchorage area (2 passes)	Pass 1 (W to E)	Jet Trencher	MP 17.89 - MP 24.00	29,135	49.3	5	2,658	7.90	1,329	853	99	0	0	69.3	0.0	0.0
		Pass 2 (E to W)	Jet Trencher	MP 24.00 - MP 17.89	29,135	49.3	5	2,658									
Scenario 6	Post-lay trenching between Curve 4 and Ambrose Channel (2 passes)	Pass 1 (W to E)	Jet Trencher	MP 25.20 - MP 29.52	29,135	34.8	5	1,879	1.35	410	262	79	0	0	52.1	0.0	0.0
		Pass 2 (E to W)	Jet Trencher	MP 29.52 - MP 25.20	29,135	34.8	5	1,879									
Scenario 7	Post-lay trenching between Ambrose Channel and Neptune Crossing 35 (2 passes)	Pass 1 (W to E)	Jet Trencher	MP 30.40 - MP 35.19	29,135	38.5	5	2,075	5.71	2,346	1,345	66	0	0	10.9	0.0	0.0
		Pass 2 (E to W)	Jet Trencher	MP 35.19 - MP 30.40	29,135	38.5	5	2,075									
Scenario 8	Pre-lay trenching across the Raritan Channel	–	Clamshell	MP 17.31 - MP 17.89	11,250	456.8	10	19,031	7.58	5,446	2,822	427	112	23	29.7	7.8	0.0
Scenario 9	Pre-lay trenching between the anchorage area and the Chapel Hill Channel	–	Clamshell	MP 24.00 - MP 25.20	11,250	299.9	10	12,497	4.39	722	131	197	148	109	49.4	35.3	19.2
Scenario 10	Excavation of Ambrose Channel HDD exit pit (West)	–	Clamshell	MP 29.52	11,250	33.7	10	1,405	12.45	9,039	2,756	502	397	289	6.4	3.8	1.6
Scenario 11	Excavation of Ambrose Channel HDD entry pit (East)	–	Clamshell	MP 30.40	11,250	77.9	10	3,245	1.97	0	0	341	299	256	5.3	4.0	2.9
	Excavation of Ambrose Channel tie-in	–	Clamshell	MP 30.40	11,250	5.0	10	209									
Scenario 12	Jetting at the Neptune Cable crossing offshore Rockaway	–	Hand Jet	MP 35.19	180	279.2	100	1,861	0.66	591	197	548	394	171	5.4	2.9	1.2
Scenario 13	Pre-lay trenching between the Neptune crossing and end of pipeline	–	Clamshell	MP 35.23 to MP 35.49	11,250	27.0	10	1,124	8.03	3,330	1,198	92	0	0	1.0	0.0	0.0
Scenario 14	Excavation of tie-in skid and manifold at Rockaway	Tie-In Skid and Manifold Excavation (75% Submersible Pump)	Submersible Pump	MP 35.49	4,050	30.2	100	4,530	0.67	787	722	591	456	328	9.8	6.3	3.7
		Tie-In Skid and Manifold Excavation (25% Hand Jet)	Hand Jet	MP 35.49	180	226.5	100	1,510									

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F-2 – HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING RESULTS – ADDENDUM 1

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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Northeast Supply Enhancement Project:
Hydrodynamic and Sediment Transport Modeling Results: Addendum 1

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1 Introduction

1.1 Project Background

As part of its Northeast Supply Enhancement Project (Project), Transcontinental Gas Pipe Line Company, LLC (Transco) is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey, as well as its existing offshore natural gas pipeline system in New Jersey and New York. A major portion of the Project includes the installation of a 26-inch outer diameter pipeline, referred to as the "Raritan Bay Loop" that will extend from the Sayreville, New Jersey shoreline (MP12.16) approximately 23.33 miles across the Raritan Bay and Lower New York Bay to the Rockaway Transfer Point in the Atlantic Ocean. The pipeline installation will require a range of dredging and burial techniques (e.g. clamshell dredging, jet trenching, submersible pumping, and backfilling) each of which has the potential to produce seabed disturbances, suspended sediment plume formation, and smothering due to sedimentation. RPS has been contracted to develop and apply customized hydrodynamic, and sediment transport and dispersion models to help assess the potential environmental impacts of these Project-related activities.

1.2 Objectives and Tasks

Results from an initial set of "base case" excavation activities were completed by RPS in August 2017. The base case modeling report described the development and calibration of a three-dimensional hydrodynamic model for the New York/New Jersey Harbor Estuary (NY/NJ Harbor Estuary), using the Water Quality Model and Analysis Package / Boundary-Fitted Hydrodynamics (WQMAP/BFHYDRO) modeling system and application of the Suspended Sediment Fate (SSFATE) sediment model to simulate offshore construction activities including mechanical (clamshell) dredging, post-pipelay burial by jet trencher, hand-jetting, and suction dredging (submersible pumping).

This report (Addendum 1) describes new application of the modeling systems to predict suspended sediment concentrations and deposition from additional Project-related activities that include dredging of navigation channels and backfilling for portions of the pipeline route. An overview of the additional SSFATE scenarios and model results are provided in Sections 2 and 3. The reader is directed to the base case modeling report for a complete description of the modeling systems, model theory, validation of the hydrodynamic predictions, and references for each model (RPS 2017).

2 SSFATE Model Setup

2.1 Description of SSFATE Scenarios

The additional sediment modeling scenarios that RPS has developed in consultation with Transco and E&E are summarized in Table 1 and presented graphically in Figure 1. The new SSFATE scenarios (13 total) were developed to simulate sediment releases for two types of construction activities associated with different stages of the offshore installation between MP 12.50 and the Rockaway tie-in point at MP 35.49. Specifically, these include:

1. Predictions of losses to the water column from dredging of navigation channels as a source of backfill material (Scenarios A-1 through A-3).
2. Simulations of placement of backfill materials for segments of the pipeline route excavated using clamshell dredges, hand-jets, and submersible pumps (Scenarios A-4 through A-13).

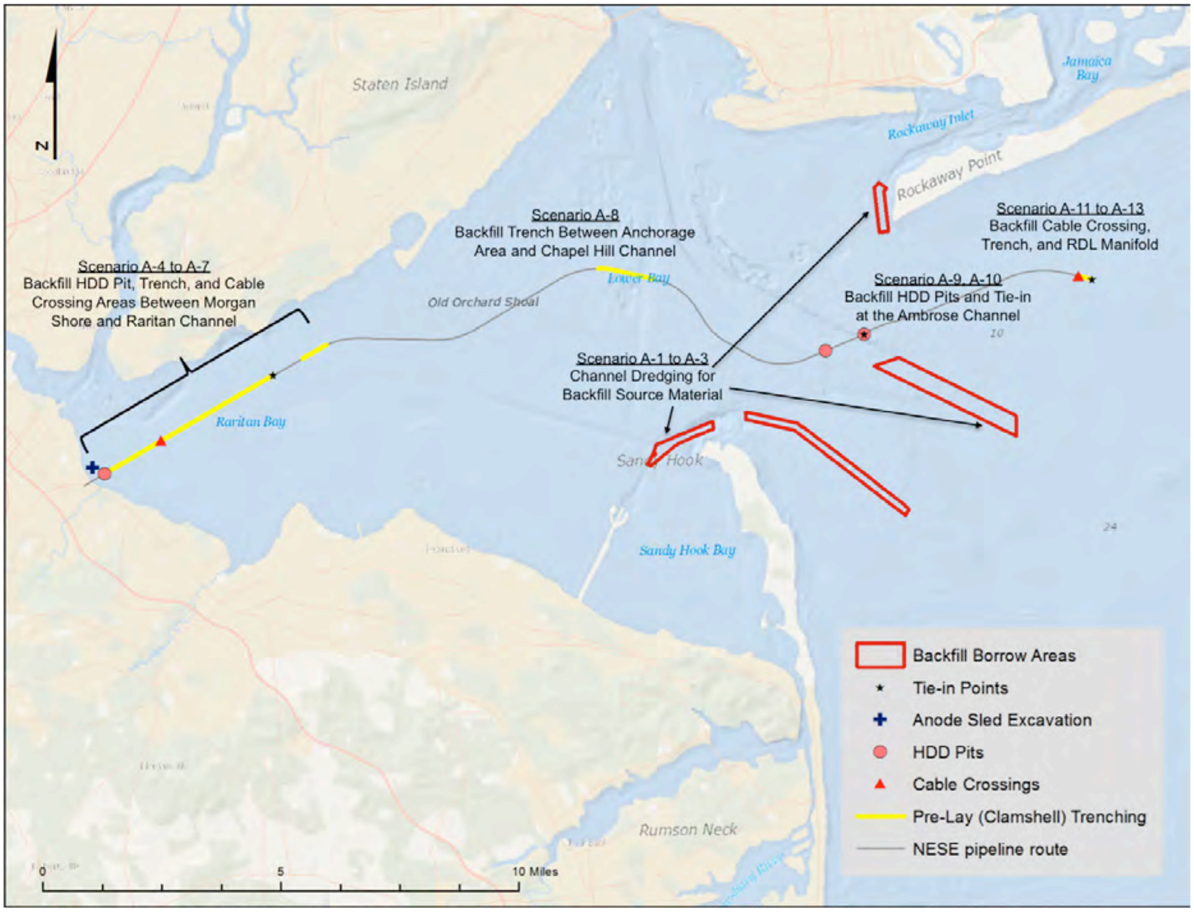

Figure 1. Map view showing sediment modeling scenario locations.

Table 1. Description of activities being simulated for each modeling scenario included in Addendum 1.

Scenario	Construction Activity	Equipment Type	Point/Line Source	Location	Excavation/Backfill Volume (yd^3)	Duration (day)
Scenario A-1	Dredging of backfill source material from Ambrose Channel	Clamshell	Line	Ambrose Channel	222,216	22.2
Scenario A-2	Dredging of backfill source material from Rockaway Inlet	Clamshell	Line	Rockaway Inlet	222,216	22.2
Scenario A-3	Dredging of backfill source material from Earle Channel	Clamshell	Line	Earle Channel	222,216	22.2
Scenario A-4	Backfilling of (i) Morgan Shore HDD pit and (ii) anode sled burial area	Clamshell	Point	(i) MP 12.50 (ii) 1,200 ft north of MP 12.32	13,205	1.3
Scenario A-5	Backfill of trench between Morgan HDD exit and the Midline tie-in	Clamshell	Line	MP 12.50 - MP 16.60	219,591	22.0
Scenario A-6	Backfill of the Neptune Cable crossing point in Raritan Bay	Clamshell	Point	MP 13.88	2,095	0.2
Scenario A-7	Backfill of trench across the Raritan Channel	Clamshell	Line	MP 17.31 - MP 17.89	167,025	16.7
Scenario A-8	Backfill of trench between the anchorage area and the Chapel Hill Channel	Clamshell	Line	MP 24.00 - MP 25.20	140,590	14.1
Scenario A-9	Backfilling of Ambrose Channel HDD exit pit (West)	Clamshell	Point	MP 29.52	17,563	1.8
Scenario A-10	Backfilling of Ambrose Channel HDD entry pit (East) and tie-in	Clamshell	Point	MP 30.40	40,563	4.1
Scenario A-11	Backfill at the Neptune Cable crossing offshore Rockaway	Clamshell	Point	MP 35.19	2,606	0.3
Scenario A-12	Backfilling between the Neptune crossing and end of pipeline	Clamshell	Line	MP 35.23 to MP 35.49	14,197	1.4
Scenario A-13	Backfill tie-in skid and manifold at Rockaway	Clamshell	Point	MP 35.49	7,550	0.8

2.2 Sediment Source Terms

Transco plans to use a mechanical (clamshell) dredge for all of the Project-related activities listed in Table 1. Sediment volumes for each scenario were provided by Transco and E&E, and are based on the construction plan for each stage of the Project. Losses from each of the excavation/backfilling activities were represented in SSFATE by characterizing the source strength, vertical distribution, and grain-size distribution of the sediment load. Details describing the model parameterization for each activity are provided below.

Dredging of backfill source material (Scenario A-1 through A-3)

Three navigational channels within the New York/New Jersey Harbor Estuary – Ambrose Channel, Rockaway Inlet (i.e., Jamaica Bay Entrance Channel), and Earle Channel (including portions of Sandy Hook Channel) – have been identified as potential sources of sediment for portions of the pipeline route that will require backfilling. These areas will be excavated using a clamshell dredge, and losses during dredging were assumed to be 5% of the total dredge volume with 4% released at the sea surface (representing scow overflow) and the remaining 1% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The total volume of sediment to be dredged is the sum of all areas requiring backfill with additional volume to account for losses during dredging (5%) and an “overfill” factor for material that may be dispersed or off-target during backfill placement (20%). The total volume of 666,649 yd^3 was divided equally between each of the three dredge areas. For each scenario, the clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Placement of backfill material (Scenario A-4 through A-13)

Areas requiring backfill include portions of the pipeline route that will be excavated by pre-lay trenching (4), cable crossings (2), HDD pits (3), anode sled burial area (1), and tie-in locations (2) (Figure 1). These areas represent both point and line sources within the model. For linear features (trenches), backfilling is expected take place in the same direction (West to East) as the trench excavation. The backfill volume for each section is equal to the original trench/excavation volume plus a 20% “overfill” factor to account for material that may be dispersed or off-target during the backfilling. Placement of backfill material will require a clamshell dredge, which will release 100% of the backfill volume into the water column at a fixed height of approximately 5 feet above the seafloor. As above, the clamshell dredge is expected to advance at a constant production rate of 11,250 ft^3/hr.

2.3 Sediment Grain Size Distributions

SSFATE incorporates spatially varying sediment data from surface samples and sediment cores and computes a unique grain size distribution for each location in the model domain using a distance-weighted interpolation. (Further description of the sediment size classes assigned by SSFATE is provided in the base case modeling report [RPS 2017].) For this Addendum, two new sets of sediment grain size data were developed to characterize sediment releases associated with the SSFATE scenarios in Table 1.

Scenarios A-1 through A-3 (dredging of backfill source areas) were assigned grain size distributions using sediment core and stockpile samples collected from each channel area during previous dredging projects. The data are summarized in a series of permit applications to the US Army Corps of Engineers (USACE, 2011; 2015) and in a feasibility study for storm damage reduction for Raritan Bay (USACE, 2000). Data include 6 samples collected in the vicinity of the Earle Channel, three samples within the Ambrose Channel (presented as a single [average] size distribution), and one sample from the Rockaway Inlet. The sediment sourced from these locations is predominantly sand and gravel (Figure 2).

Scenarios A-4 through A-13 (backfilling operations) will involve placement of a mixture of sediment from the different source areas. Approximately 1/3 of the total volume needed for backfill was assumed to be sourced from each of the three channels. Accordingly, the scenarios were developed using a composite grain size distribution, representing an equally weighted average of the (3) borrow areas.

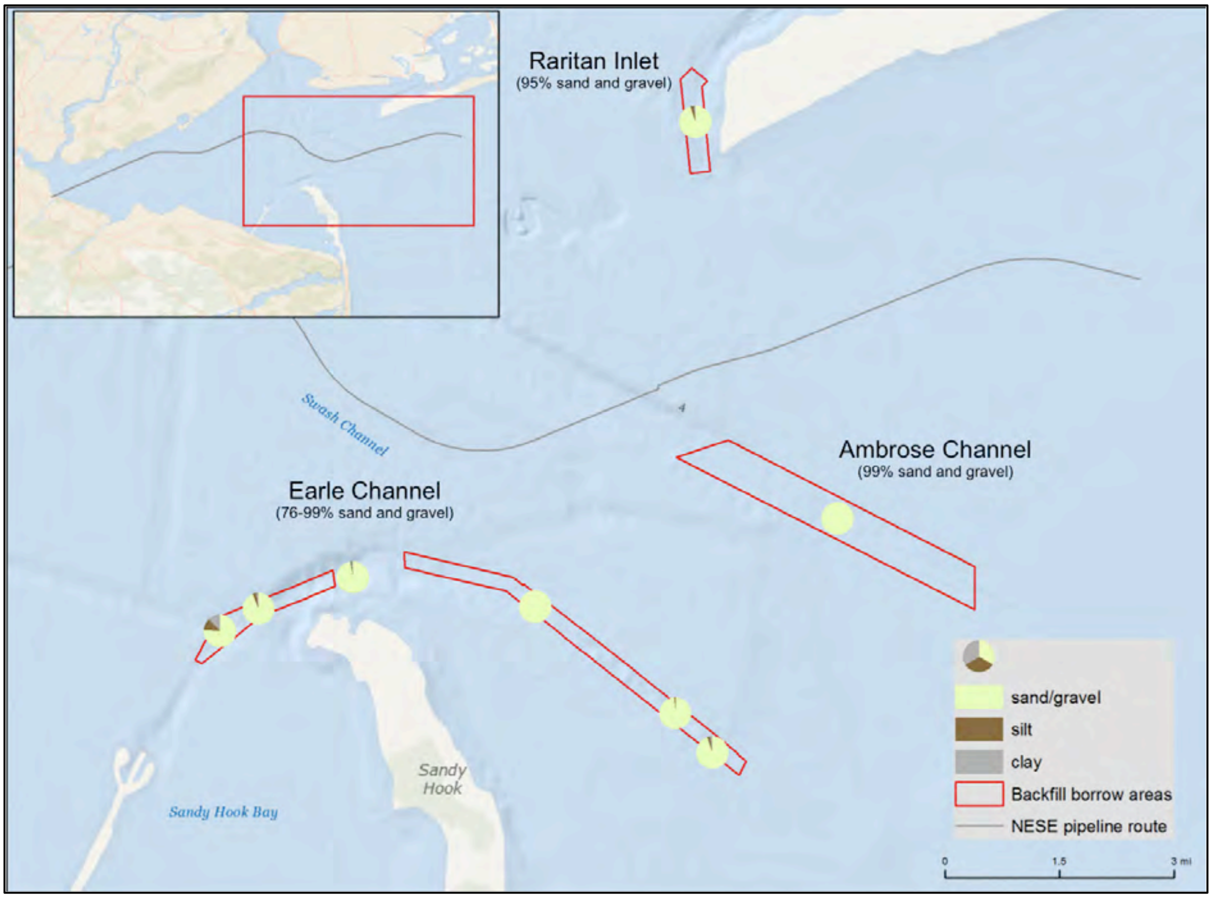

Figure 2. General location and classification of sediment samples used to characterize backfill source material. Ambrose Channel samples have been averaged to a single size distribution (>99% sand and gravel). For modeling, the sample locations were assigned to the centroid of each respective dredge area.

2.4 Construction Schedule

Offshore construction for the Project is scheduled to begin in the third quarter of 2018 and continue for approximately twelve months. The final segments of pipe installation and testing are scheduled to be complete by May 2019 and backfilling is expected to commence as soon as possible once the pipe-laying process is complete. To reproduce these activities in SSFATE, both dredging and placement of the backfill source material were assumed to begin immediately after the final pipe-laying section in Q2 2019 and proceed continuously until all of the dredged sediment has been placed. (Pre-lay trenching between the Morgan Shore and the Midline tie-in will follow the schedule described in the base case modeling report - Q3 2018.)

3 SSFATE Results

SSFATE simulations were performed for each construction activity in Table 1. All modeling assumed continuous operation for each phase of the activity and sediment concentrations were computed on a grid with resolution of 20 m x 20 m (65 ft x 65 ft) in the horizontal dimension and 0.5 m (1.6 ft) in the vertical dimension. Note that the concentrations reported below are those predicted above the background concentration (i.e., a concentration of 0 mg/L equals the ambient concentration in the Project area).

The results from the model runs are presented below in maps showing the predicted TSS concentrations and subsequent deposition for each activity. Specifically, two sets of graphics were developed for each scenario:

(i) Maximum TSS concentrations (at the surface and throughout full water column) predicted over the duration of the model run. (Labeled as “cumulative concentrations” within the graphics, where “cumulative” refers to the maximum TSS over all time steps, not the sum of TSS concentrations over time.)

(ii) Seabed deposition (thickness) following the modeled activity.

For comparison purposes, each set of figures maintains a consistent spatial scale. TSS concentrations are shown as filled cells at the resolution of the concentration grid, while deposition results are presented as contour lines. In addition, Table 2 presents a summary of the model results for each simulation, including:

- the maximum distances of TSS plumes at select concentration thresholds,
- time for TSS concentrations to return to ambient following the modeled activity,
- maximum distance of deposition contours that exceeds selected thicknesses,
- areal extent of the deposit that exceeds selected thicknesses.

Reported thicknesses include deposition within the construction footprint for each activity (i.e. maximum deposition from backfilling occurs inside the trench/excavation area and includes deposition of the sediments required to return the seabed to grade). Similarly, areas and distances to various thickness contours are measured from the center of the trench and include areas disturbed by each activity. Scenario-specific details describing the sediment release, timing, and other assumptions for each simulation are described below.

3.1 Scenario A-1 – Dredging of Backfill Material from the Ambrose Channel

Scenario A-1 simulated releases associated with the dredging of backfill source material from the Ambrose Channel. A total of 666,649 yd^3 of sediment may be needed to backfill portions of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Ambrose Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill purposes. Transco plans to use a clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (away from Raritan Bay) and a start date of May 1 (based on Q2 2019 construction schedule). Losses from the clamshell bucket were assumed to be 5% of the total excavation volume, with 4% released at the sea surface (representing barge overflow) and the remaining 1% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 11,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Ambrose Channel are presented in Figure 3 and Figure 4, and summarized in Table 2. Elevated TSS concentrations are predicted throughout most of the water column, with the notable exception of the surface layers where concentrations do not exceed ambient levels. This observation is likely the result of (i) rapid settling of the coarse-grained sediments within the channel, and (ii) strong current velocities that rapidly disperse overflow sediments at the sea surface. Water column concentrations of 100 mg/L are predicted to extend a maximum of 6,365 ft from the source and TSS concentrations remain elevated above ambient levels for 1.0 hour after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 92 ft from the source and covers a total of 2.3 acres of the seabed.

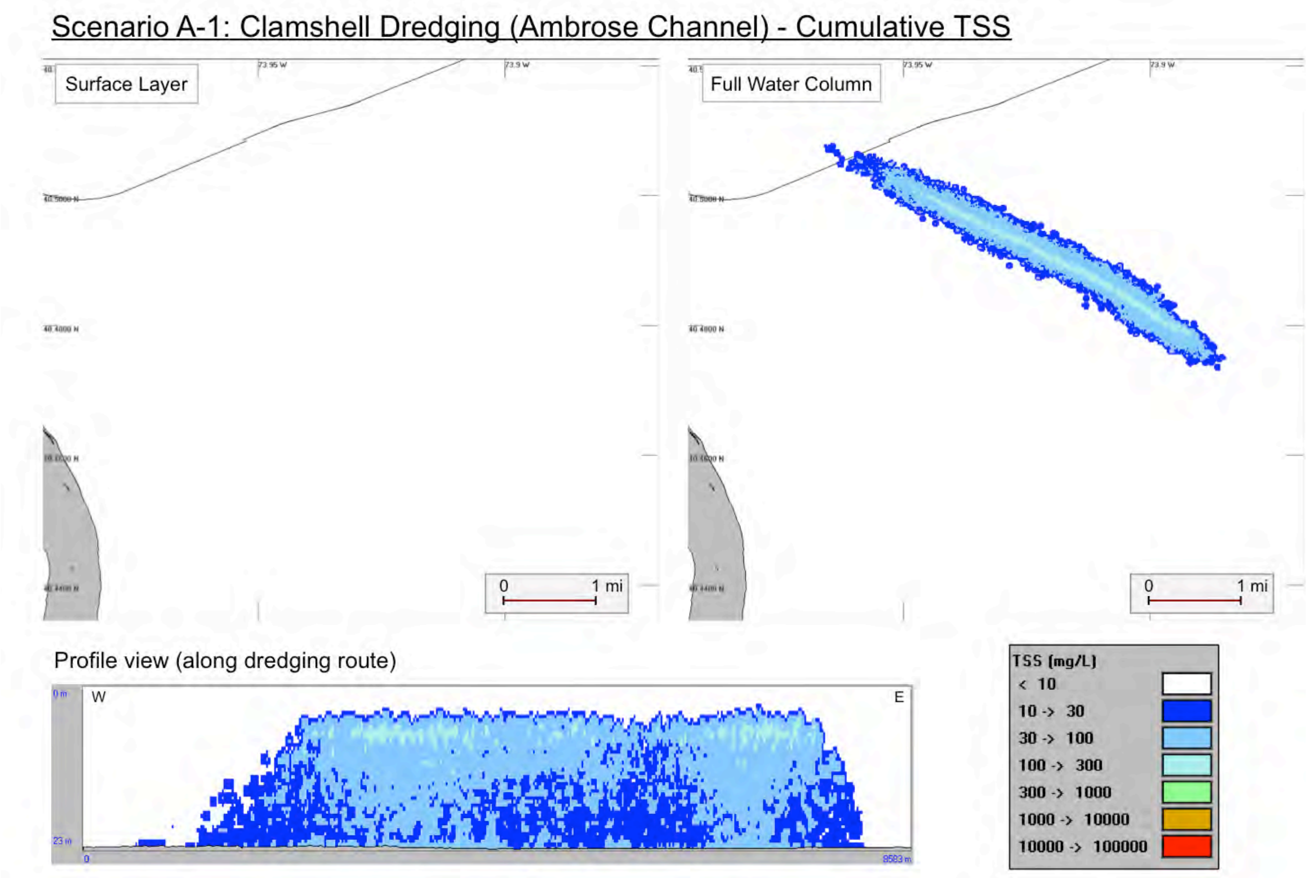

Figure 3. Cumulative TSS concentrations for Scenario A-1 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route. Maximum predicted concentration = 278.4 mg/L.

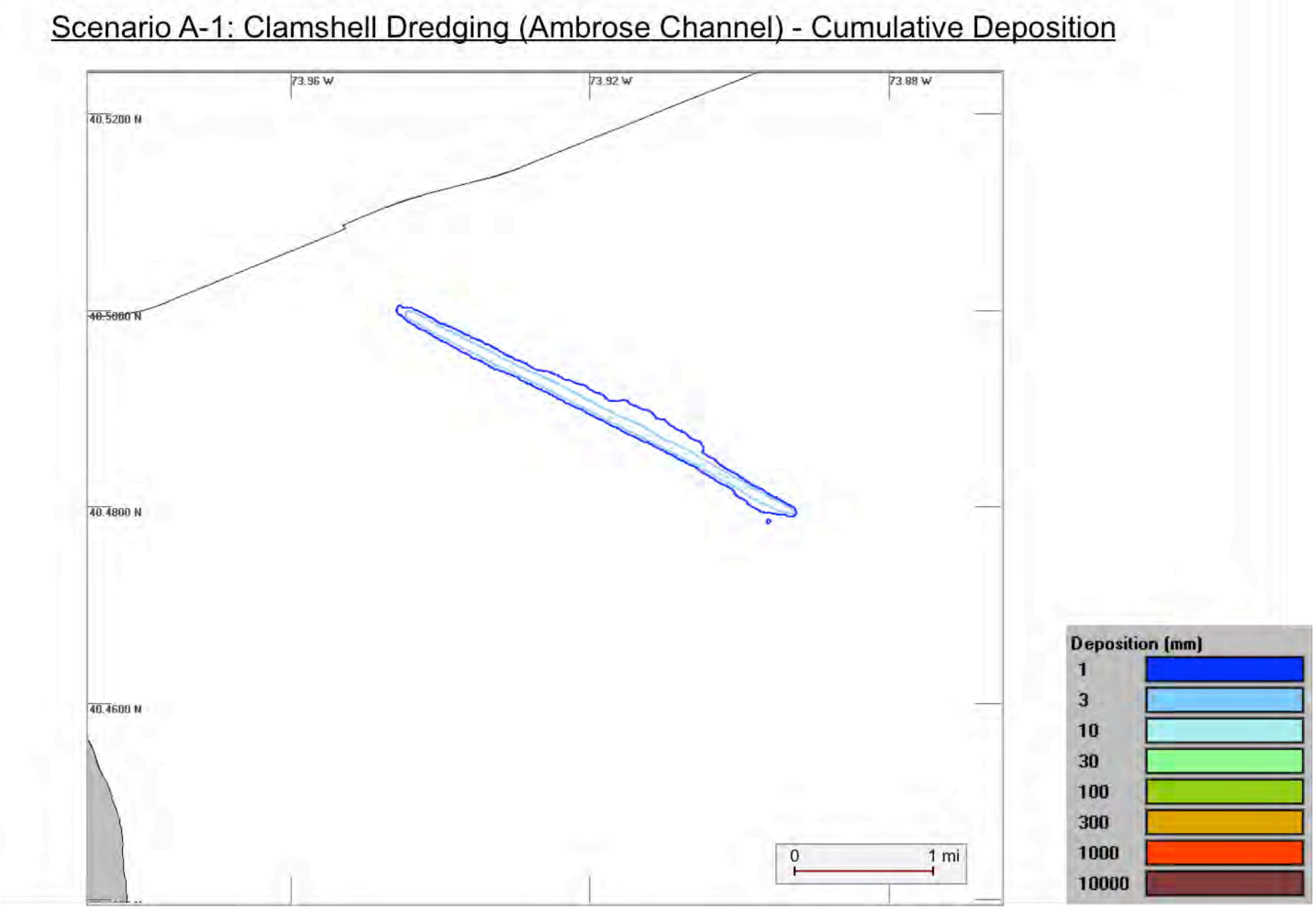

Figure 4. Extent of seabed deposition resulting from clamshell dredging of backfill material at the Ambrose Channel. Maximum predicted thickness = 0.5 in (11.6 mm).

3.2 Scenario A-2 – Dredging of Backfill Material from the Rockaway Inlet

Scenario A-2 simulated releases associated with the dredging of backfill source material from the Rockaway Inlet. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Rockaway Inlet (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. Transco plans to use a clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (South to North) and a start date of May 1 (based on Q2 2019 construction schedule). Losses from the clamshell bucket were assumed to be 5% of the total excavation volume, with 4% released at the sea surface (representing barge overflow) and the remaining 1% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 11,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Rockaway Inlet are presented in Figure 5 and Figure 6, and summarized in Table 2. Elevated TSS levels are predicted throughout the entire water column, but concentrations notably increase with depth at this location. As with Scenario A-1 the results are influenced by rapid settling of the coarse-grained sediments within the channel, but the shallow depths at this location result in peak concentrations just above the seabed. Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,526 ft from the source and TSS concentrations remain elevated above ambient levels for 0.6 hour after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 197 ft from the source and covers a total of 34.6 acres of the seabed.

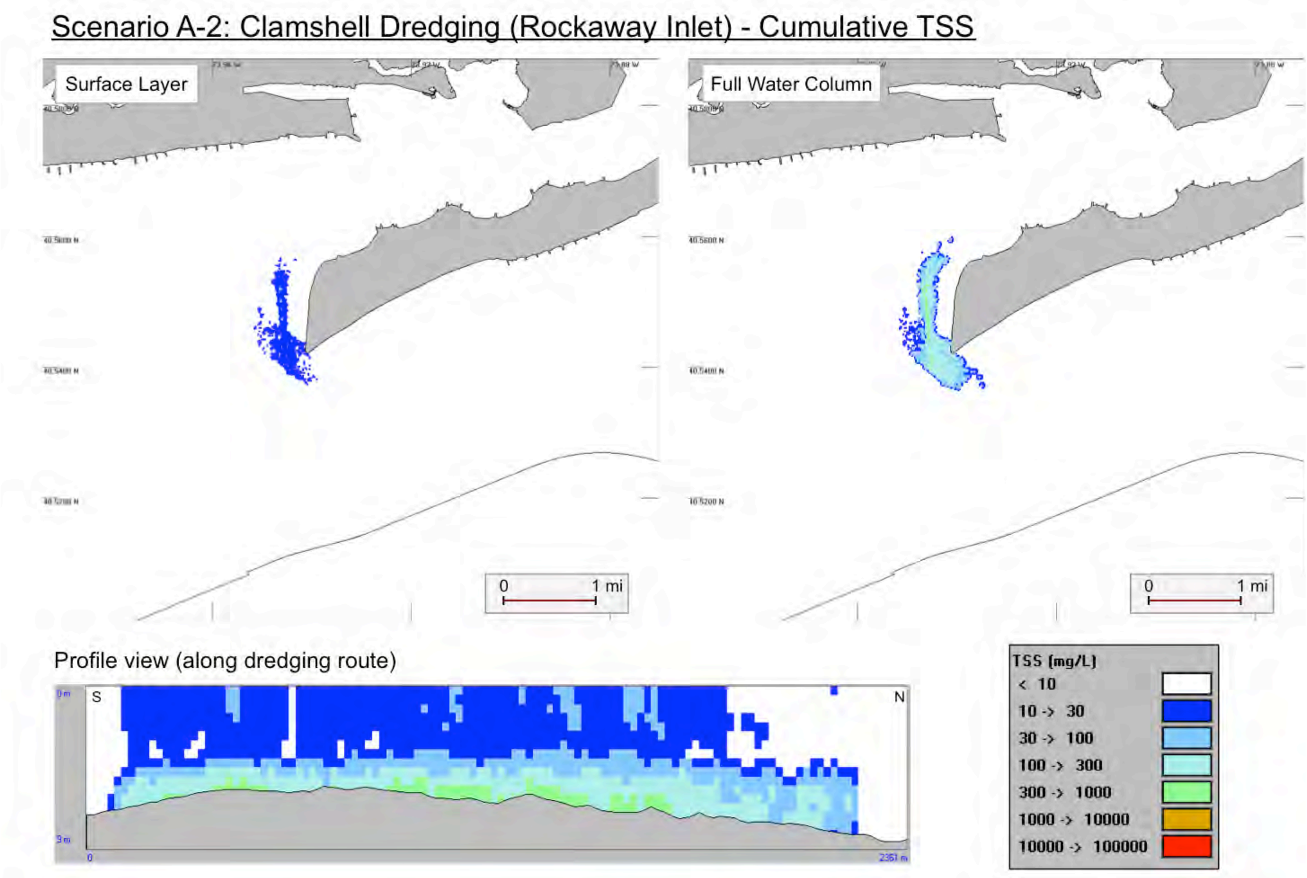

Figure 5. Cumulative TSS concentrations for Scenario A-2 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route. Maximum predicted concentration = 1,004.8 mg/L.

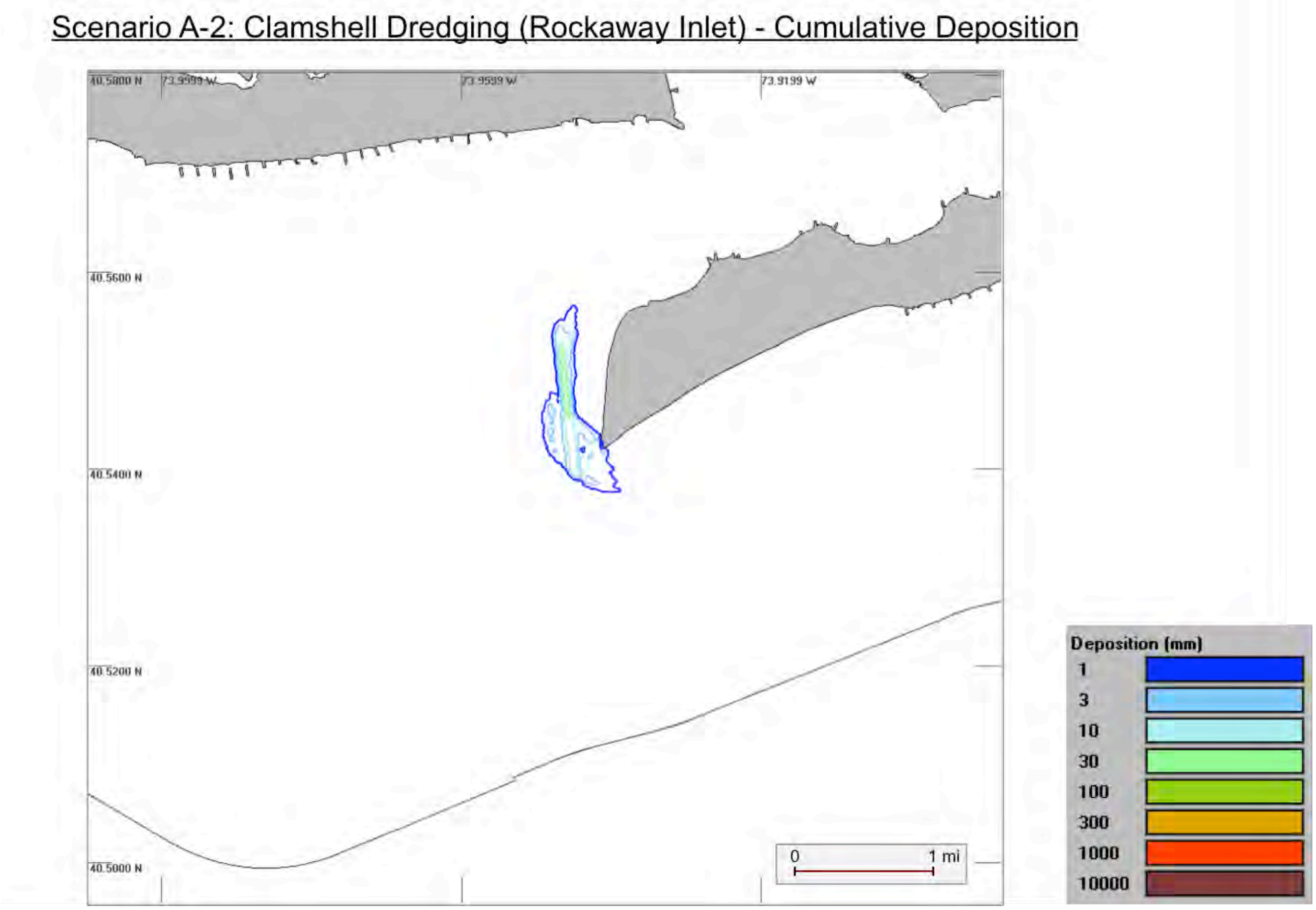

Figure 6. Extent of seabed deposition resulting from clamshell dredging of backfill material at the Rockaway Inlet. Maximum predicted thickness = 2.0 in (49.6 mm).

3.3 Scenario A-3 – Dredging of Backfill Material from the Earle Channel

Scenario A-3 simulated releases associated with the dredging of backfill source material from the Earle Channel. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Earle Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. Transco plans to use a clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of May 1 (based on Q2 2019 construction schedule). Although the Earle Channel is separated into two distinct dredge areas (Figure 2), the model was run as a single uninterrupted dredge operation, with an instantaneous transition between the two dredge areas. Losses from the clamshell bucket were assumed to be 5% of the total excavation volume, with 4% released at the sea surface (representing barge overflow) and the remaining 1% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 11,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Earle Channel are presented in Figure 7 and Figure 8, and summarized in Table 2. Similar to Scenario A-1, the plume has limited surface expression and peak TSS levels are predicted several feet below the surface. Higher concentrations are predicted toward the start and end of the dredge route, where mean grain sizes are slightly finer (Figure 2). Water column concentrations of 100 mg/L are predicted to extend a maximum of 3,888 ft from the source and TSS concentrations remain elevated above ambient levels for 0.8 hour after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 59 ft from the source and covers a total of 3.0 acres of the seabed.

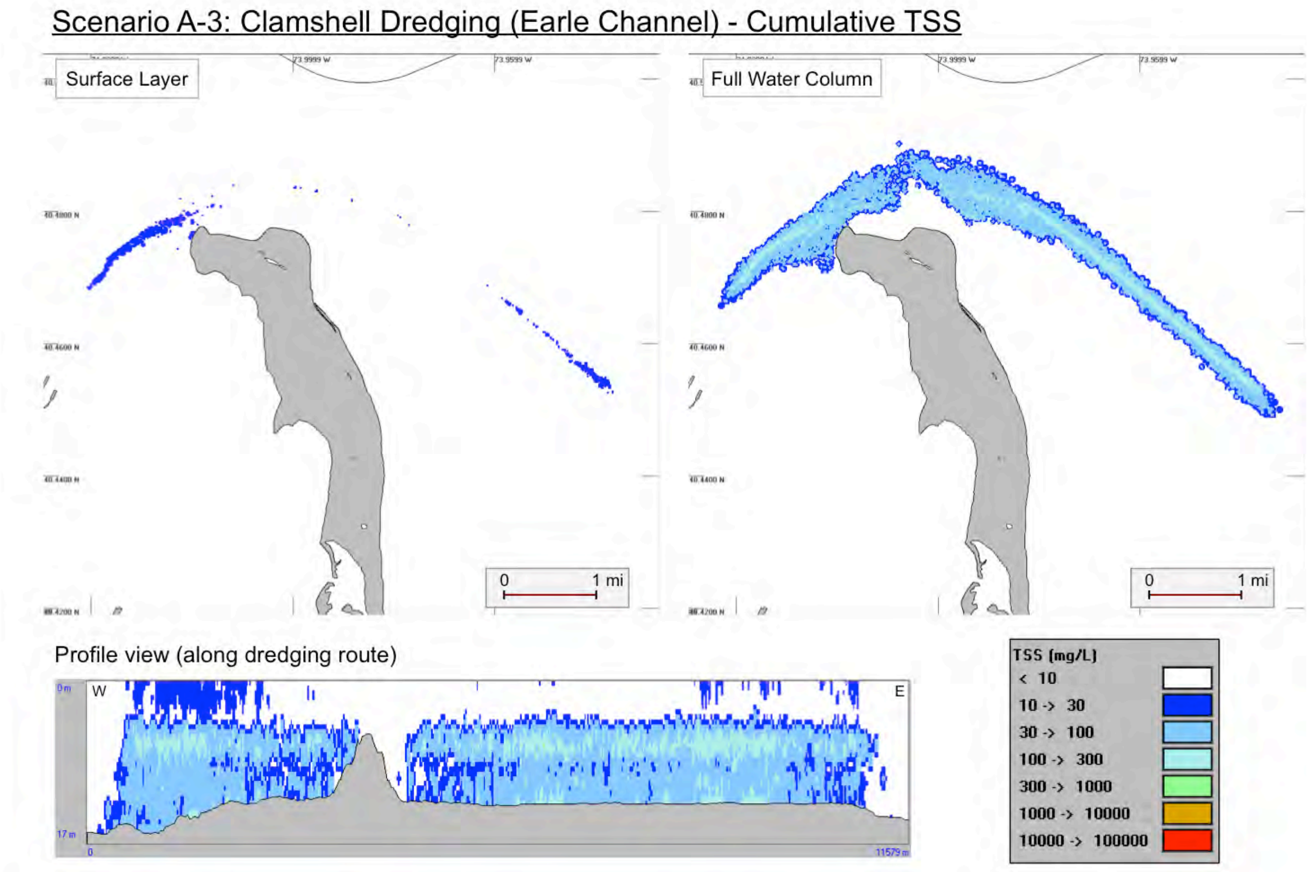

Figure 7. Cumulative TSS concentrations for Scenario A-3 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route. Maximum predicted concentration = 312.3 mg/L.

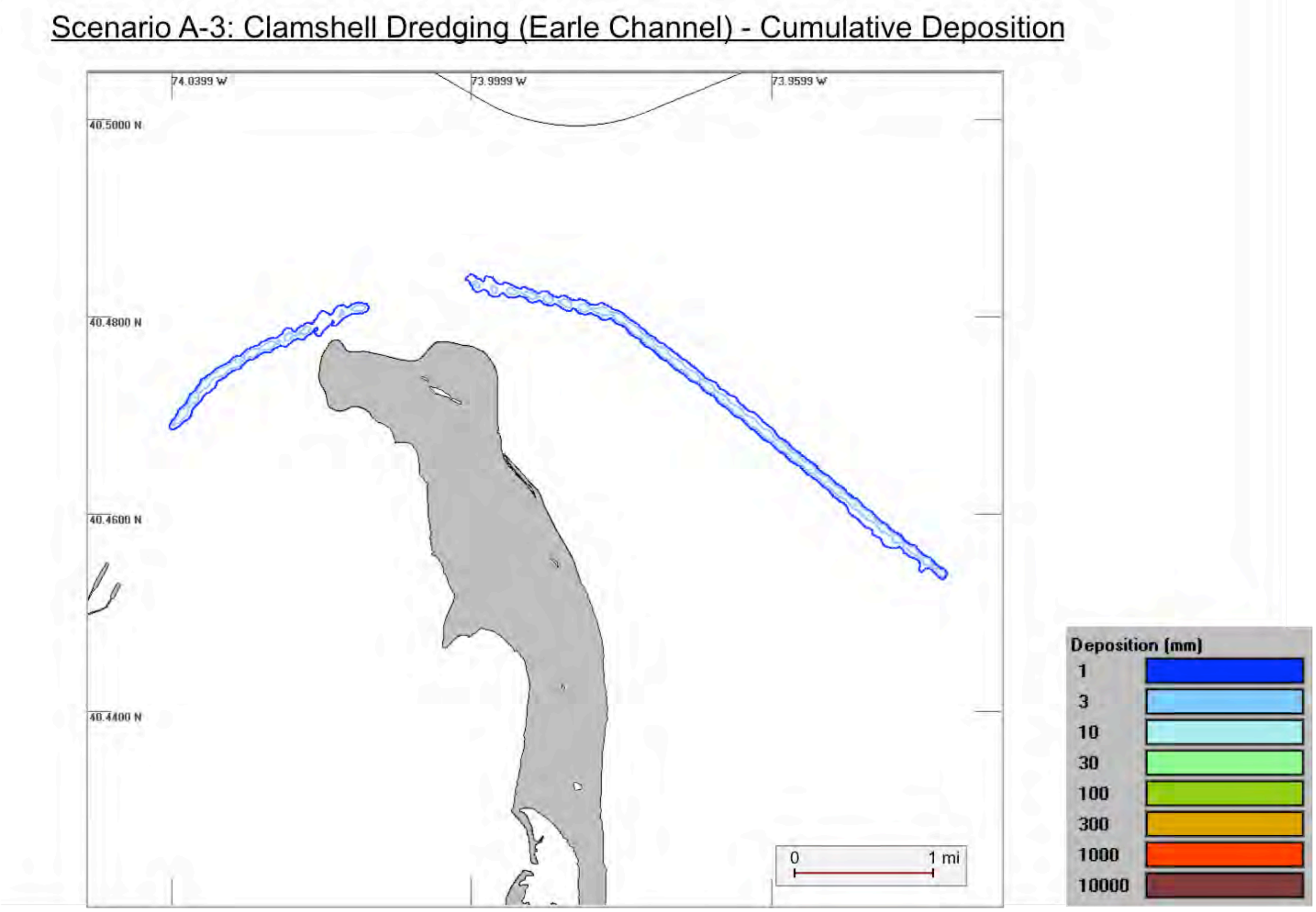

Figure 8. Extent of seabed deposition resulting from clamshell dredging of backfill material at the Earle Channel. Maximum predicted thickness = 0.5 in (13.0 mm).

3.4 Scenario A-4 – Backfilling of the Morgan Shore Excavation Areas

Scenario A-4 simulated the placement of backfill material at two locations that will require excavation for the Morgan Shore approach: (i) the Morgan Shore HDD pit, which will be dredged to a depth of 14 ft, and (ii) the offshore anode sled, which will be buried to a minimum depth of 4 ft, approximately 1,200 feet northwest of the pipe centerline. Both locations will require backfilling by clamshell dredge to return the seabed to grade once the pipe-laying is complete. Backfilling activities were simulated as a stationary (point) source from their respective locations and both assumed the dredge operates at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For the Morgan Shore areas, the simulation was performed using a start date of May 1. The clamshell dredge operates continuously for 29.8 hours during backfilling of the HDD pit, and for 1.9 hours at the anode sled area immediately afterward. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 13,205 yd^3 of sediment was placed at these two locations, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for these locations is 10,564 yd^3.

Water column and sediment bed results from simulations of backfilling at the Morgan Shore are presented in Figure 9 and Figure 10, and summarized in Table 2. The sediment plume that emerges during backfill operations is oriented in a Northwest/Southeast configuration, generally reflecting the tidal current patterns near the site, which are aligned with the nearshore topography. Peak concentrations occur at or below the placement depth, but the shallow water depths and mixing near the site result in elevated TSS concentrations throughout the water column. Water column concentrations of 100 mg/L are predicted to extend a maximum of 886 ft from the source and TSS concentrations remain elevated above ambient levels for 2.0 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 305 ft from the source and covers a total of 6.6 acres of the seabed.

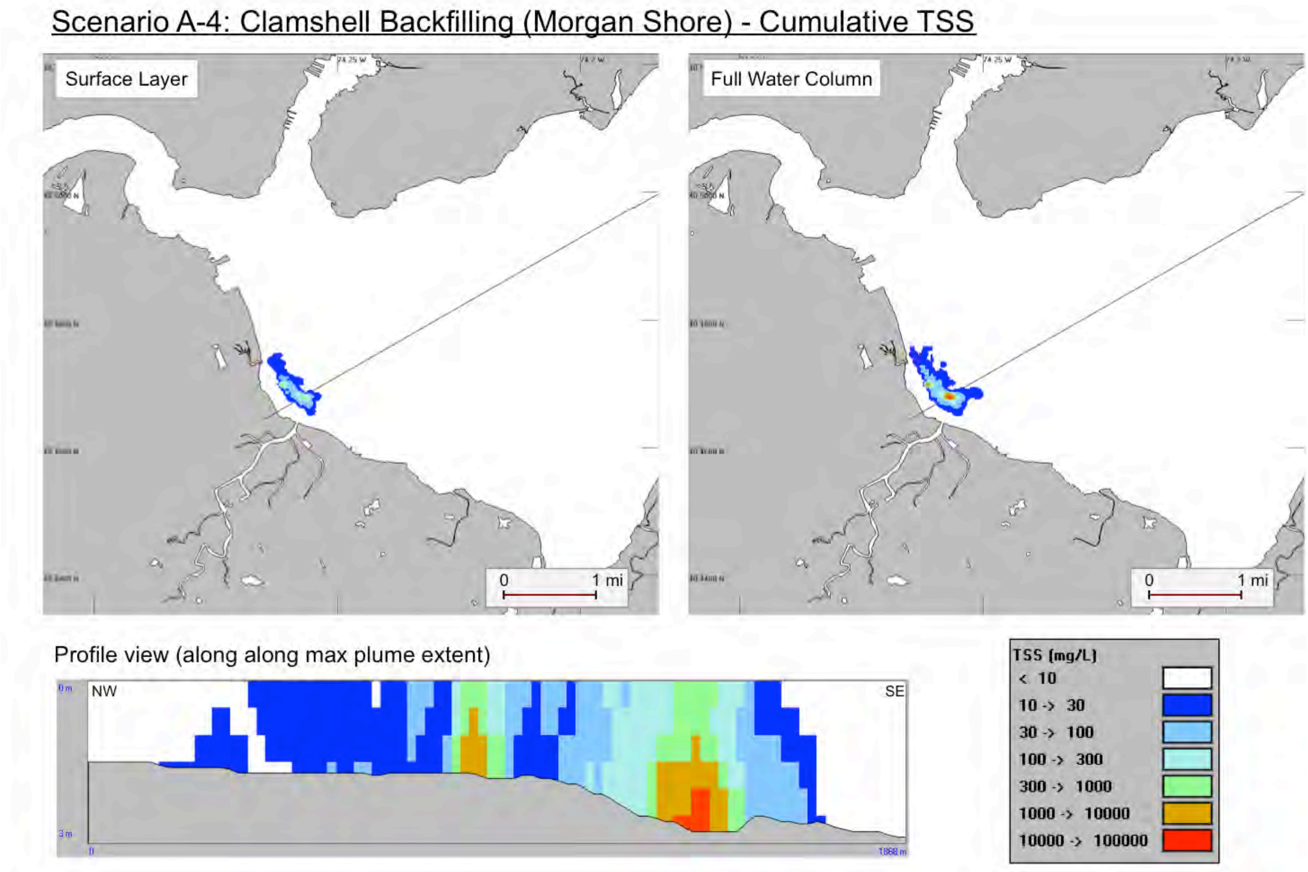

Figure 9. Cumulative TSS concentrations for Scenario A-4 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 13,691.6 mg/L.

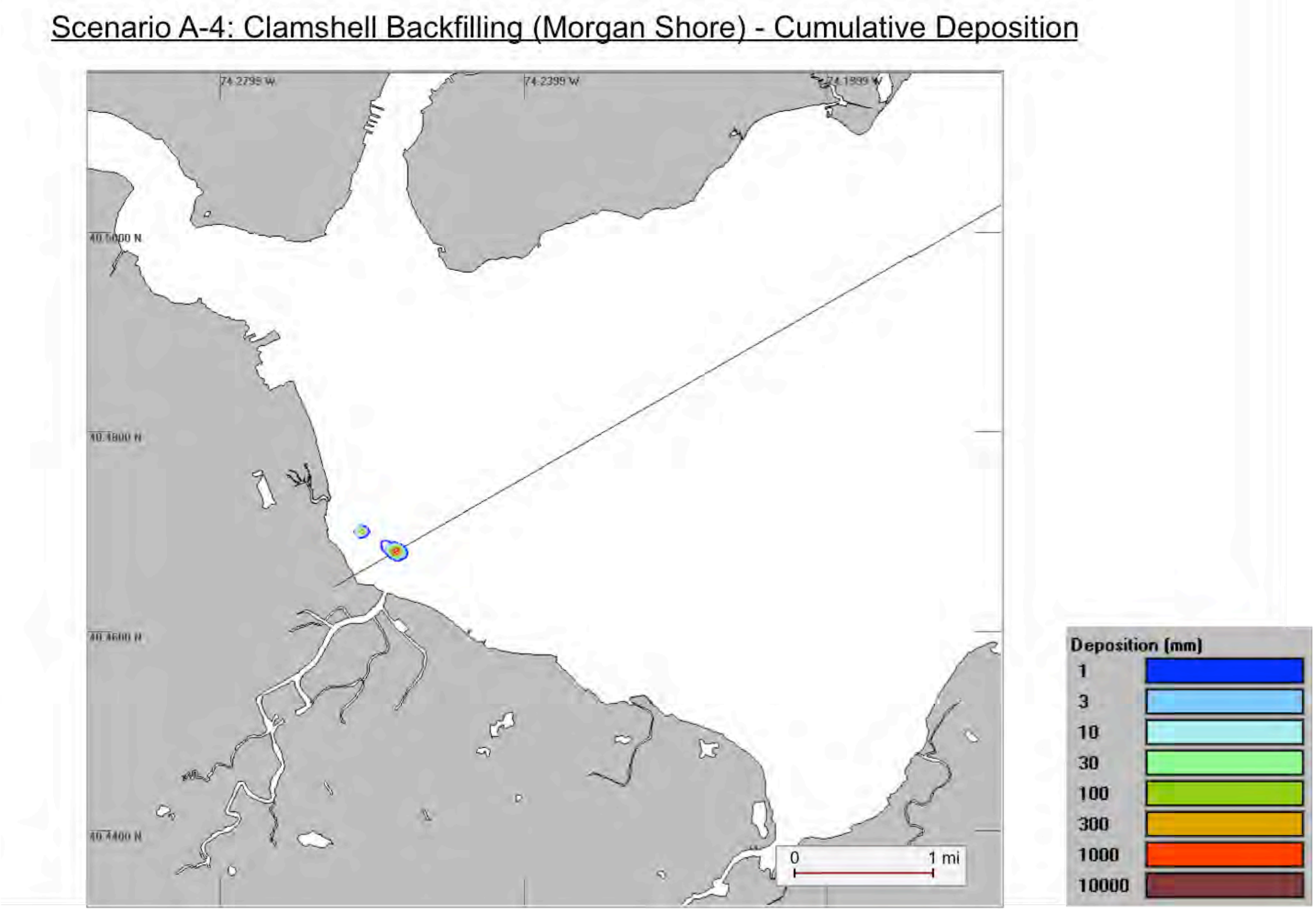

Figure 10. Extent of seabed deposition resulting from placement of backfill material at the Morgan Shore excavation areas. Maximum predicted thickness = 115.5 in (2,930.0 mm).

3.5 Scenario A-5 – Backfilling Between Morgan HDD and Midline Tie-in

Scenario A-5 simulated the placement of backfill material within the excavated trench extending between MP 12.50 and MP 16.60. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. Backfilling of the trench was simulated as a line source, and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-5, the simulation was performed using a start date of May 2 (immediately following backfill activities at the Morgan Shore). The clamshell dredge operates continuously for 527 hours (22 days) while placing backfill sediments over approximately 4.1 miles. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 219,591 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 175,673 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 12.50 and MP 16.60 are presented in Figure 11 and Figure 12, and summarized in Table 2. During most of the run, the plume is oriented in a West/East configuration, oscillating back and forth with the tide along the primary axis of Raritan Bay. Peak TSS concentrations are predicted to occur at or just above the seabed; surface TSS concentrations decrease and become more intermittent as the backfilling route advances into deeper water. Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,444 ft from the source and TSS concentrations remain elevated above ambient levels for 1.5 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 440 ft from the source and covers a total of 220.9 acres of the seabed.

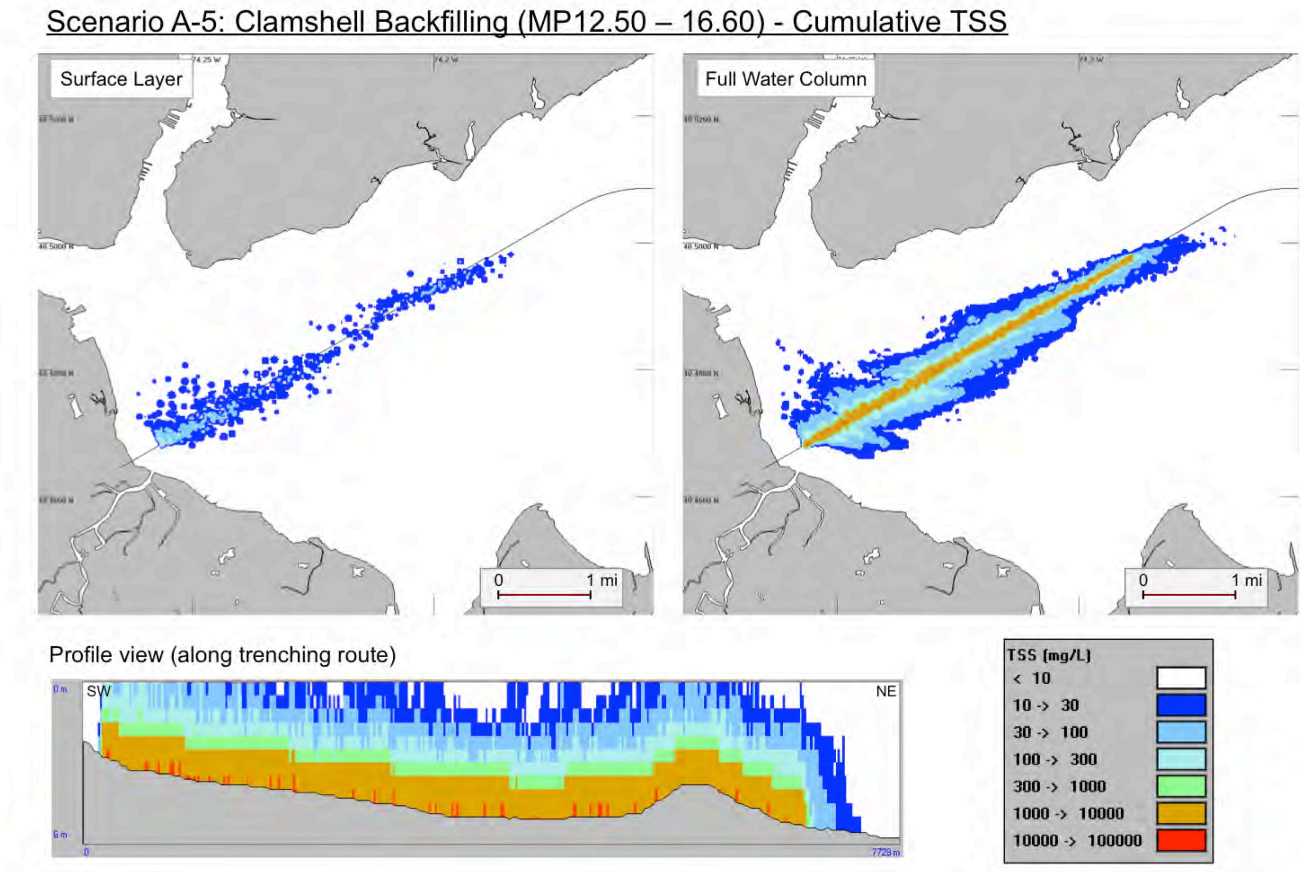

Figure 11. Cumulative TSS concentrations for Scenario A-5 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the backfilling route. Maximum predicted concentration = 17,083.9 mg/L.

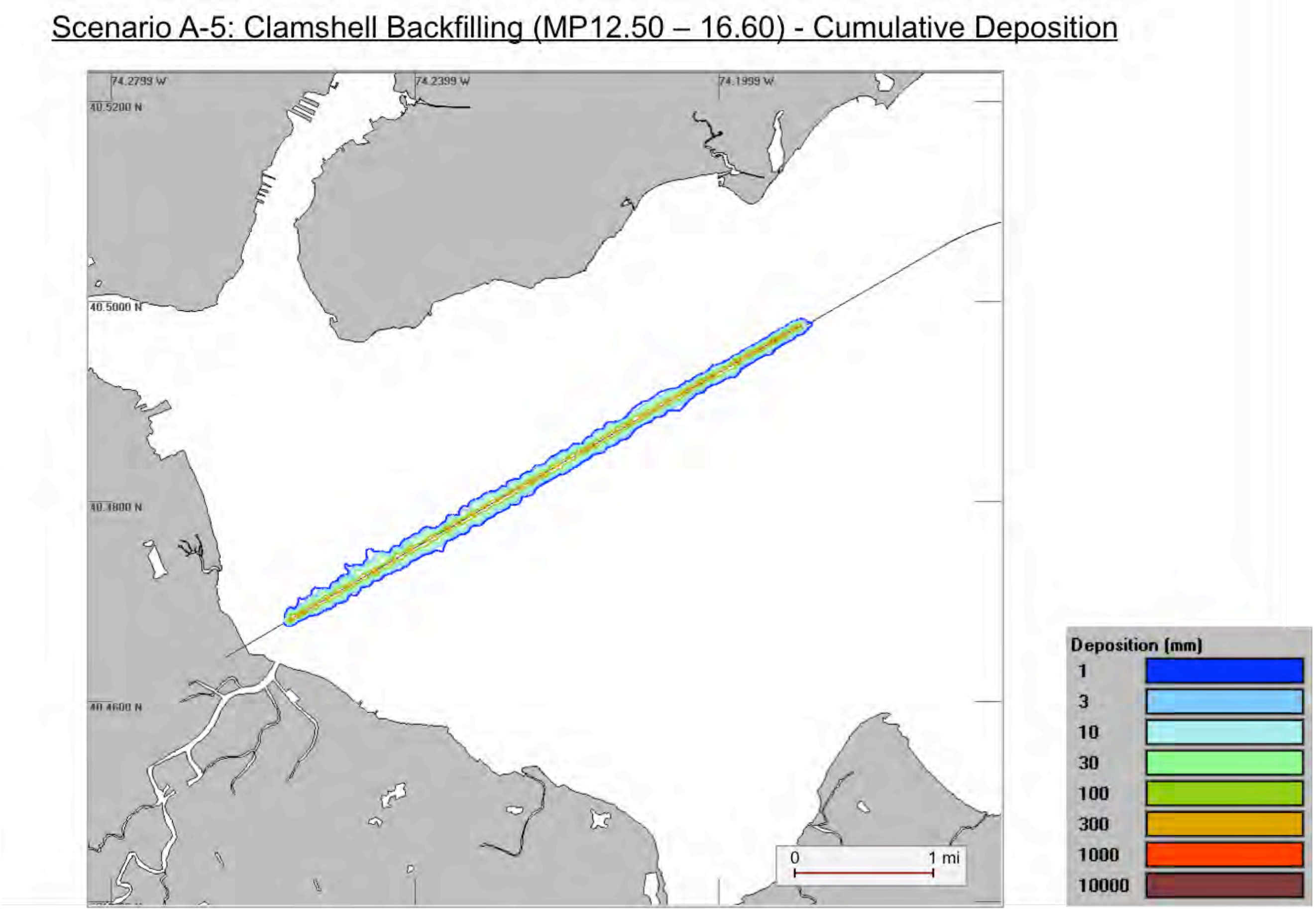

Figure 12. Extent of seabed deposition resulting from placement of backfill material between MP 12.50 and MP 16.60. Maximum predicted thickness = 30.4 in (771.7 mm).

3.6 Scenario A-6 – Backfilling at the Neptune Cable Crossing in Raritan Bay

Scenario A-6 simulated the placement of backfill material at the (western) Neptune Cable crossing location at MP 13.88. Prior to the pipeline installation, Transco plans to use diver-assisted hand jets to expose the Neptune Cable, which rests approximately 7.5 ft below the seafloor. Backfilling by clamshell dredge will be required to cover the cable and return the seabed to grade once the pipe-laying is complete. The backfilling activity was simulated as a stationary (point) source at MP 13.88. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For the Neptune Cable crossing in Raritan Bay, the simulation was performed using a start date of May 1. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 2,095 yd^3 of sediment was placed at the site, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 1,676 yd^3.

Water column and sediment bed results from simulations of backfilling at the (western) Neptune crossing are presented in Figure 13 and Figure 14, and summarized in Table 2. During most of the simulation, the plume is confined to the lower half of the water column and oscillates with the tide (West/East orientation), similar to the plume that arises from backfilling along this portion of the pipeline route in Scenario A-5. Peak concentrations are predicted to occur directly at the placement site above the cable. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,247 ft from the source and TSS concentrations remain elevated above ambient levels for 3.5 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 371 ft from the source and covers a total of 2.9 acres of the seabed.

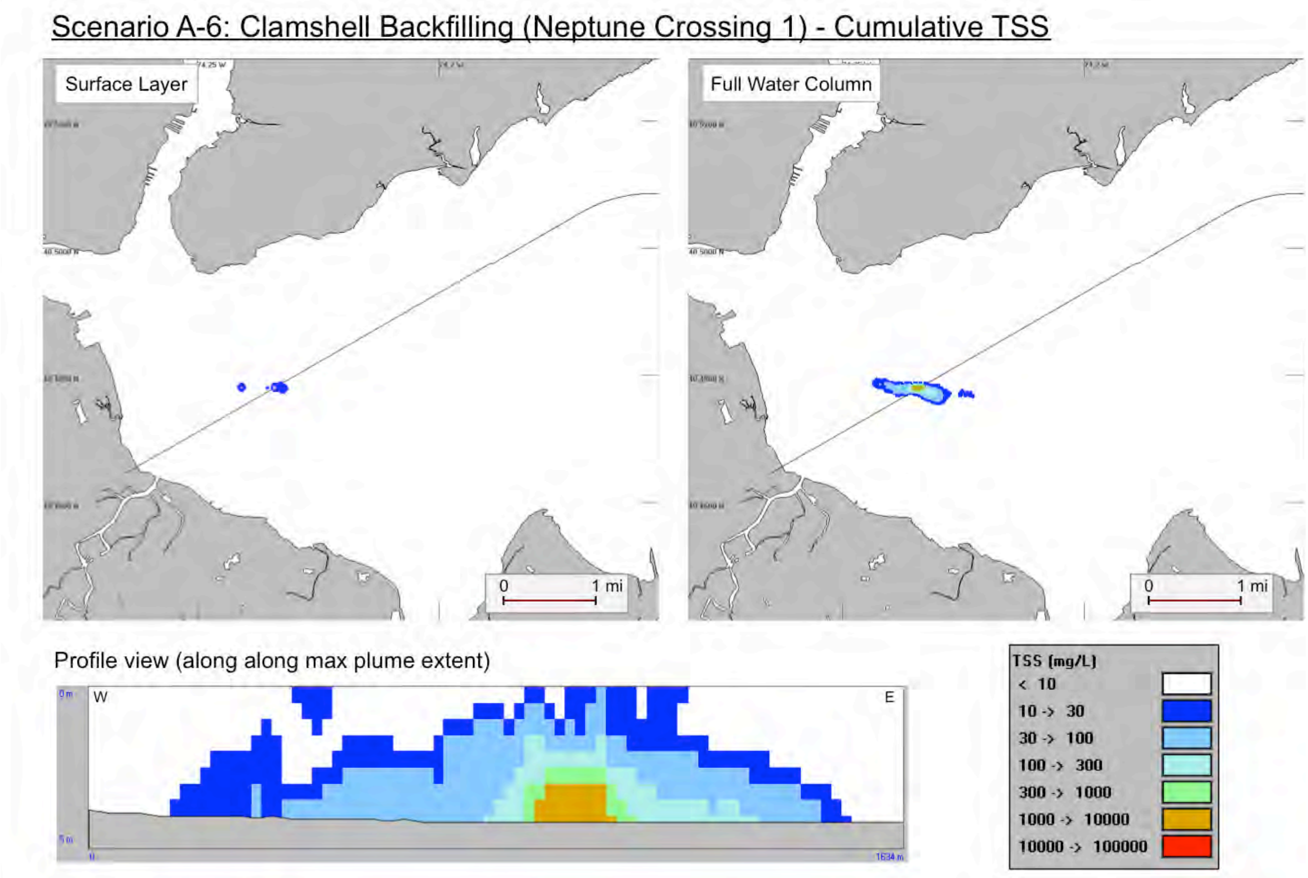

Figure 13. Cumulative TSS concentrations for Scenario A-6 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 12,052.1 mg/L.

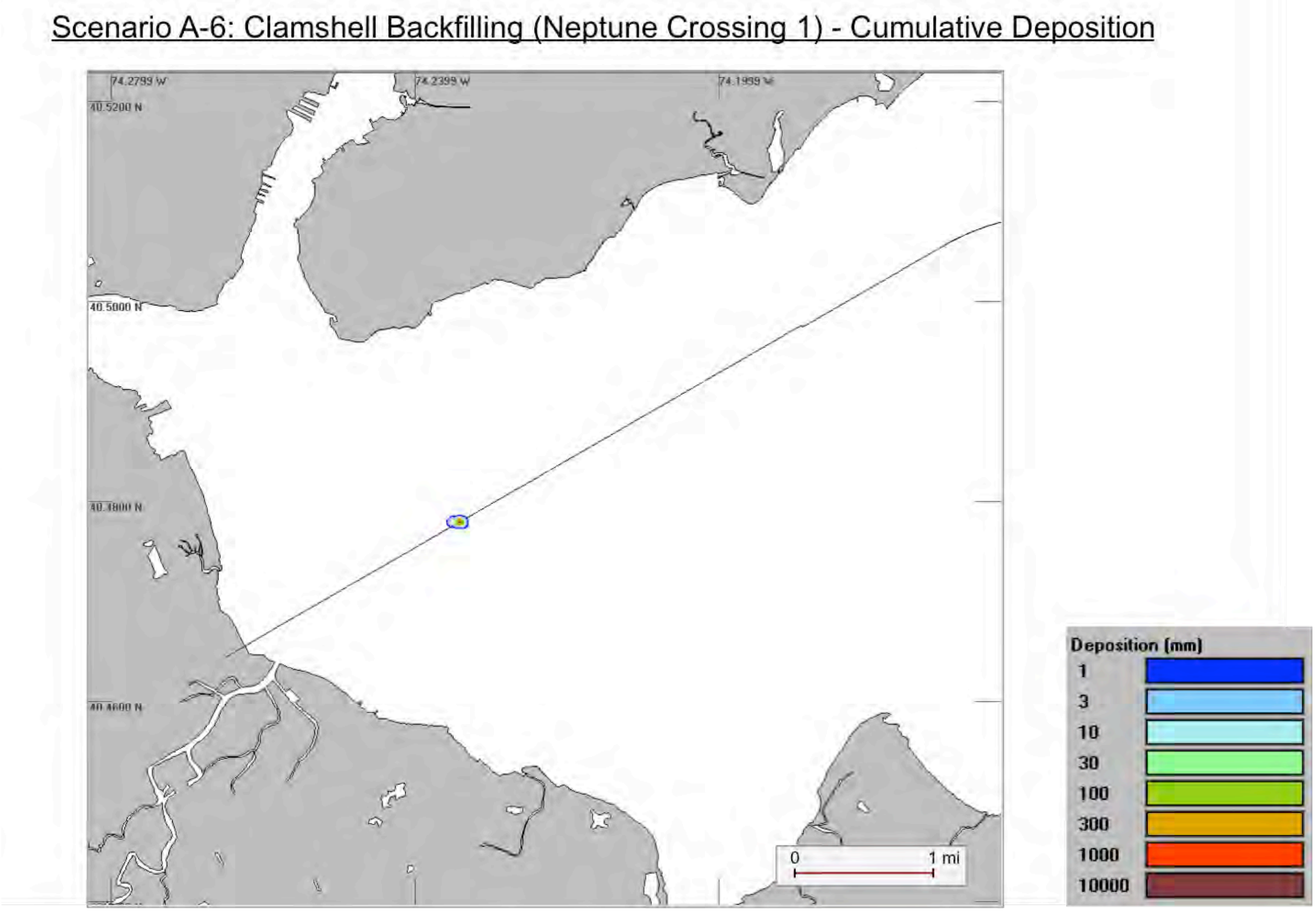

Figure 14. Extent of seabed deposition resulting from placement of backfill material at the Neptune crossing in Raritan Bay. Maximum predicted thickness = 20.0 in (508.1 mm).

3.7 Scenario A-7 – Backfilling Across the Raritan Channel

Scenario A-7 simulated the placement of backfill material to fill the excavated trench extending across the Raritan Channel (between MP 17.31 and MP 17.89). Along this reach, the pipeline will be buried to variable depths (between 4 and 8 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. Backfilling of the trench was simulated as a line source, and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-7, the simulation was performed using a start date of May 1 (immediately following backfill activities at the Neptune Cable crossing in Raritan Bay). The clamshell dredge operates continuously for 401 hours (16.7 days) while placing backfill sediments over approximately 0.58 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 167,025 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 133,620 yd^3.

Water column and sediment bed results from simulations of backfilling across the Raritan Channel are presented in Figure 15 and Figure 16, and summarized in Table 2. Overall, elevated TSS concentrations remain confined to the mid- and lower portions of the water column as the plume oscillates back and forth (in a W/E orientation) with the tide. Water depths along this reach of the pipeline route exceed 15 ft and because the sediment is released close to the seabed, at no point during the simulation does the sediment plume exhibit a surface expression. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,509 ft from the source and TSS concentrations remain elevated above ambient levels for 1.9 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 591 ft from the source and covers a total of 43.7 acres of the seabed.

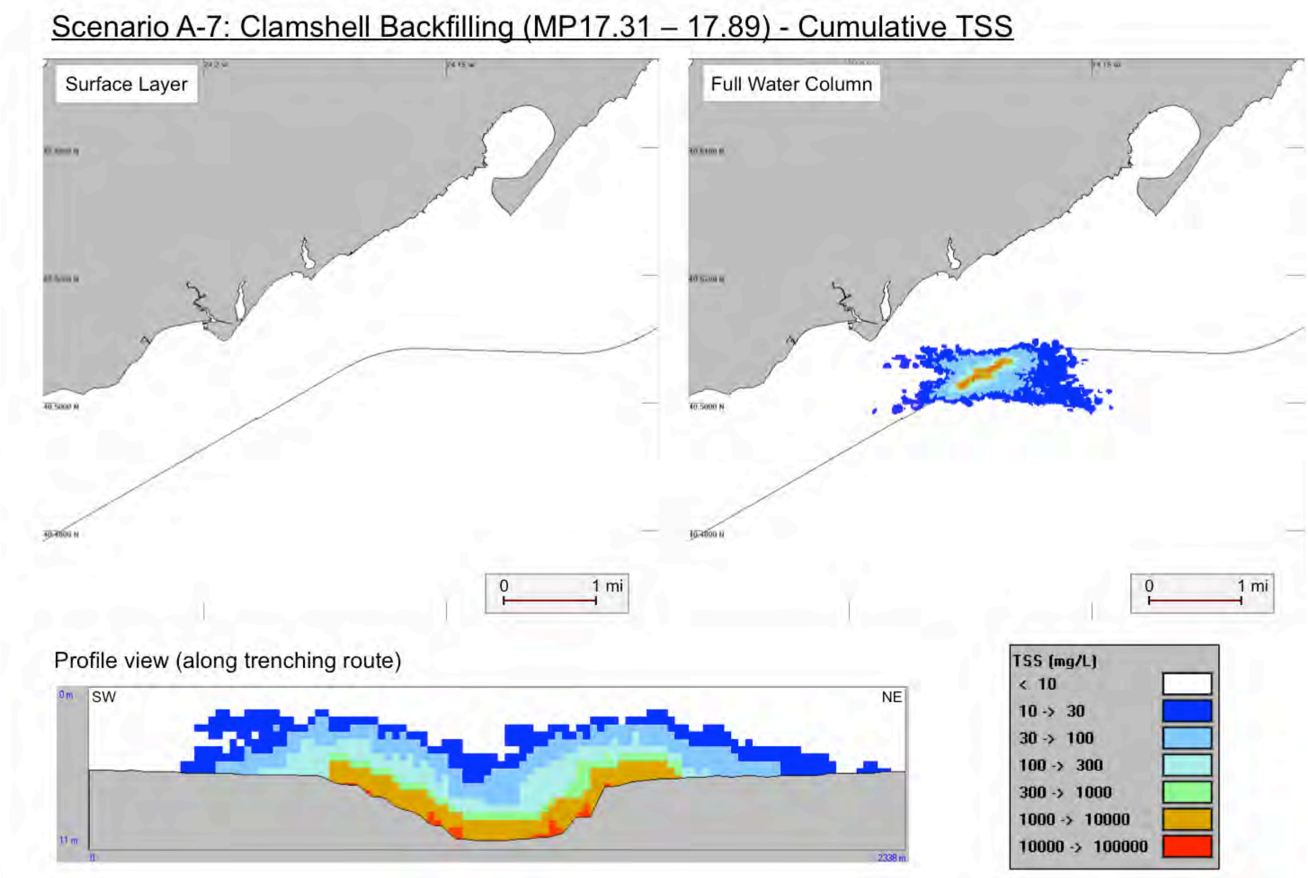

Figure 15. Cumulative TSS concentrations for Scenario A-7 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the backfilling route. Maximum predicted concentration = 23,447.9 mg/L.

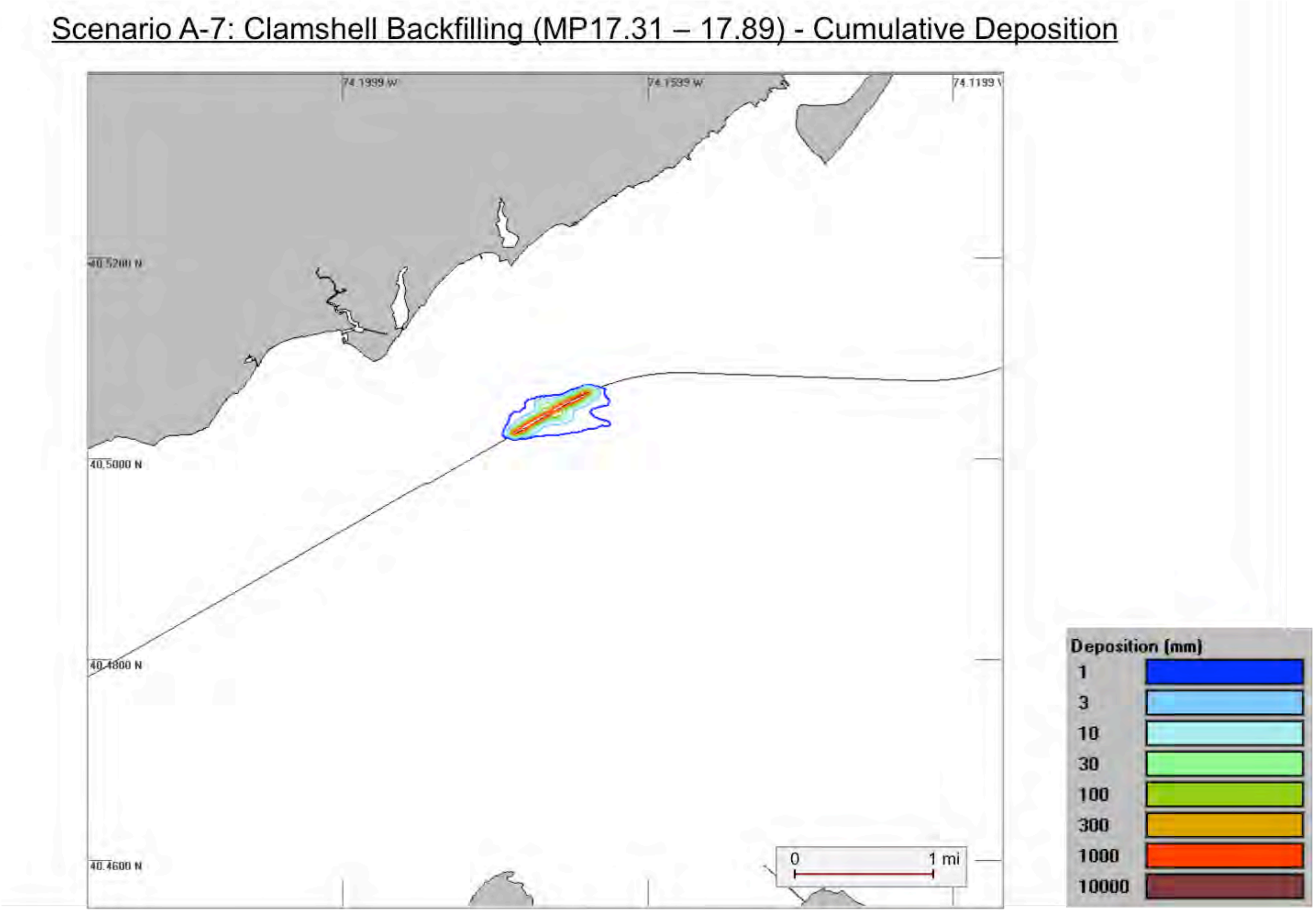

Figure 16. Extent of seabed deposition resulting from placement of backfill material across the Raritan Channel. Maximum predicted thickness = 94.3 in (2,349.4 mm).

3.8 Scenario A-8 – Backfilling Between the Anchorage Area and Chapel Hill Channel

Scenario A-8 simulated the placement of backfill material to fill the excavated trench extending between the Anchorage Area and Chapel Hill Channel (between MP 24.00 and MP 25.20). Along this reach, the pipeline will be buried to variable depths (between 4 and 7 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. Backfilling of the trench was simulated as a line source, and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-8 the simulation was performed using a start date of May 1. The clamshell dredge operates continuously for 338 hours (14.1 days) while placing backfill sediments over approximately 1.2 miles. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 140,590 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 112,472 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 24.00 and MP 25.20 are presented in Figure 17 and Figure 18, and summarized in Table 2. Elevated TSS concentrations are generally confined to the lower half of the water column as the plume oscillates back and forth (West/East) with the tide. TSS concentrations of 10 mg/L appear only intermittently in the surface layers, and peak concentrations remain within the lowermost portions of the water column, as the backfill sediments settle following their release. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,690 ft from the source and TSS concentrations remain elevated above ambient levels for 2.8 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 292 ft from the source and covers a total of 68.5 acres of the seabed.

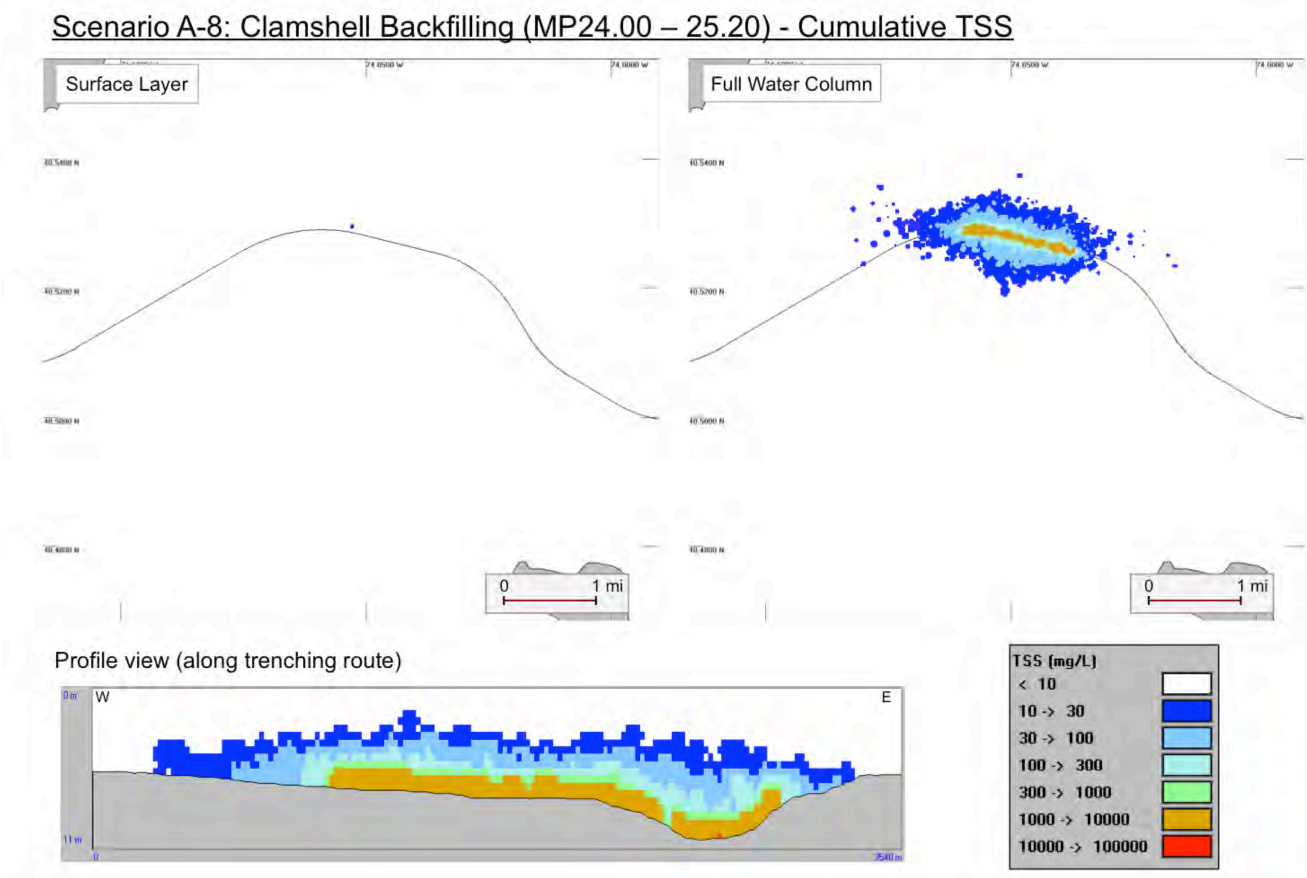

Figure 17. Cumulative TSS concentrations for Scenario A-8 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the backfilling route. Maximum predicted concentration = 12,344.5 mg/L.

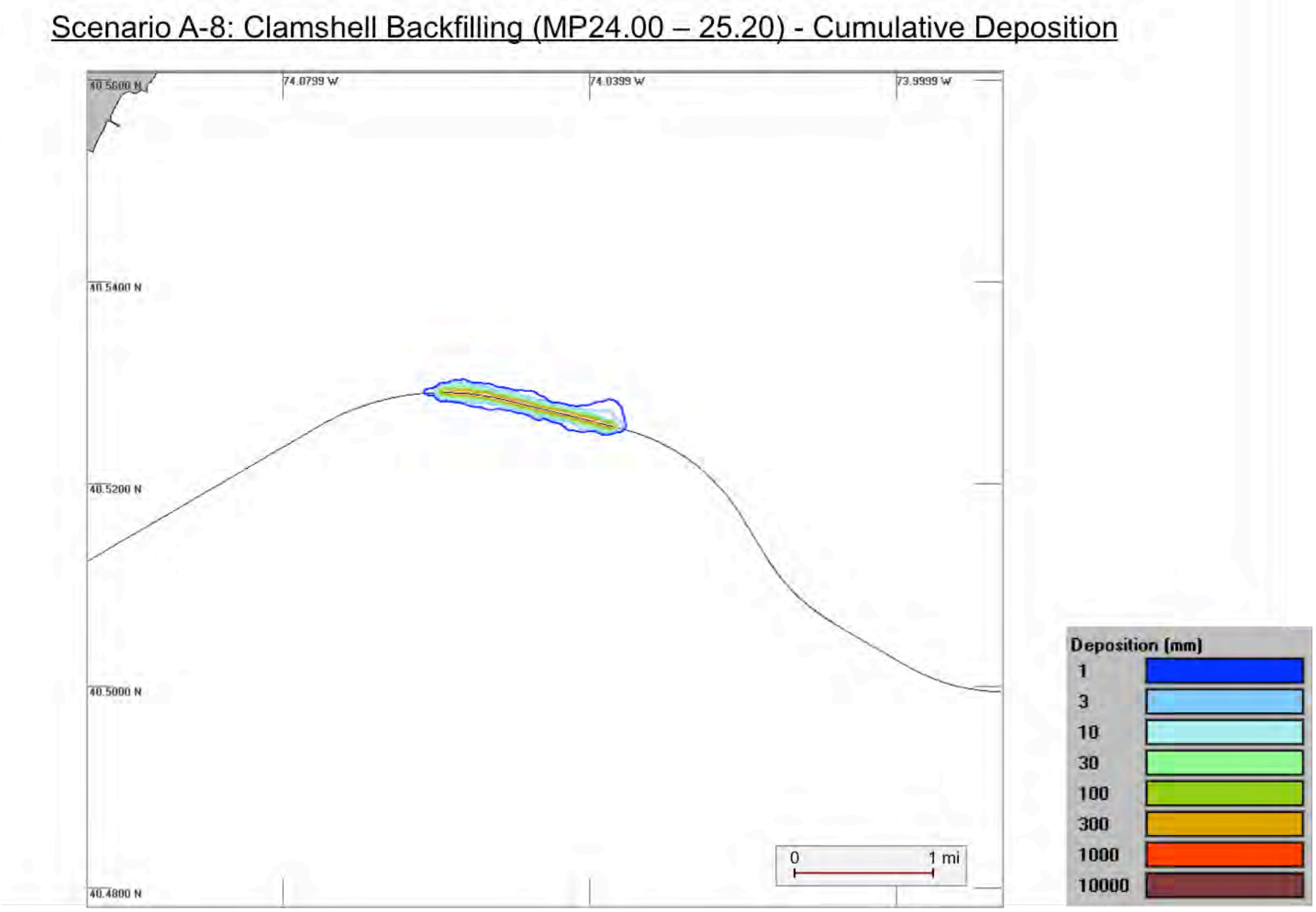

Figure 18. Extent of seabed deposition resulting from placement of backfill material between the Anchorage Area and the Chapel Hill Channel. Maximum predicted thickness = 42.7 in (1,084.3 mm).

3.9 Scenario A-9 – Backfilling of the Ambrose Channel HDD Exit Pit

Scenario A-9 simulated the placement of backfill material at the HDD exit pit at MP 29.52, directly west of the Ambrose Channel. The HDD pit will extend to a maximum of 20 ft below the seabed and backfilling by clamshell dredge will be required to return the seabed to grade once the pipe has been installed beneath the Ambrose Channel. The backfilling activity was simulated as a stationary (point) source at MP 29.52. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-9, the simulation was performed using a start date of May 15 (immediately following backfilling of the trench up to the Chapel Hill Channel). The clamshell dredge operates continuously for 42.2 hours, during which time the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 17,563 yd^3 of sediment was placed at the HDD pit, which includes an “overfill” factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 14,050 yd^3.

Water column and sediment bed results from simulations of backfilling at the Ambrose exit pit are presented in Figure 19 and Figure 20, and summarized in Table 2. The predicted sediment plume from backfilling at this site shows a distinct alignment with the strong tidal currents that flow in and out of the entrance to Raritan Bay. Overall, elevated TSS concentrations are confined to the lower half of the water column and decrease with distance from the backfilling site. At no point during the entire simulation are TSS concentrations above 10 mg/L predicted in the surface, or near-surface layers (e.g. within 13 ft of the sea surface). Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,952 ft from the source and TSS concentrations remain elevated above ambient levels for 3.3 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 804 ft from the source and covers a total of 8.5 acres of the seabed.

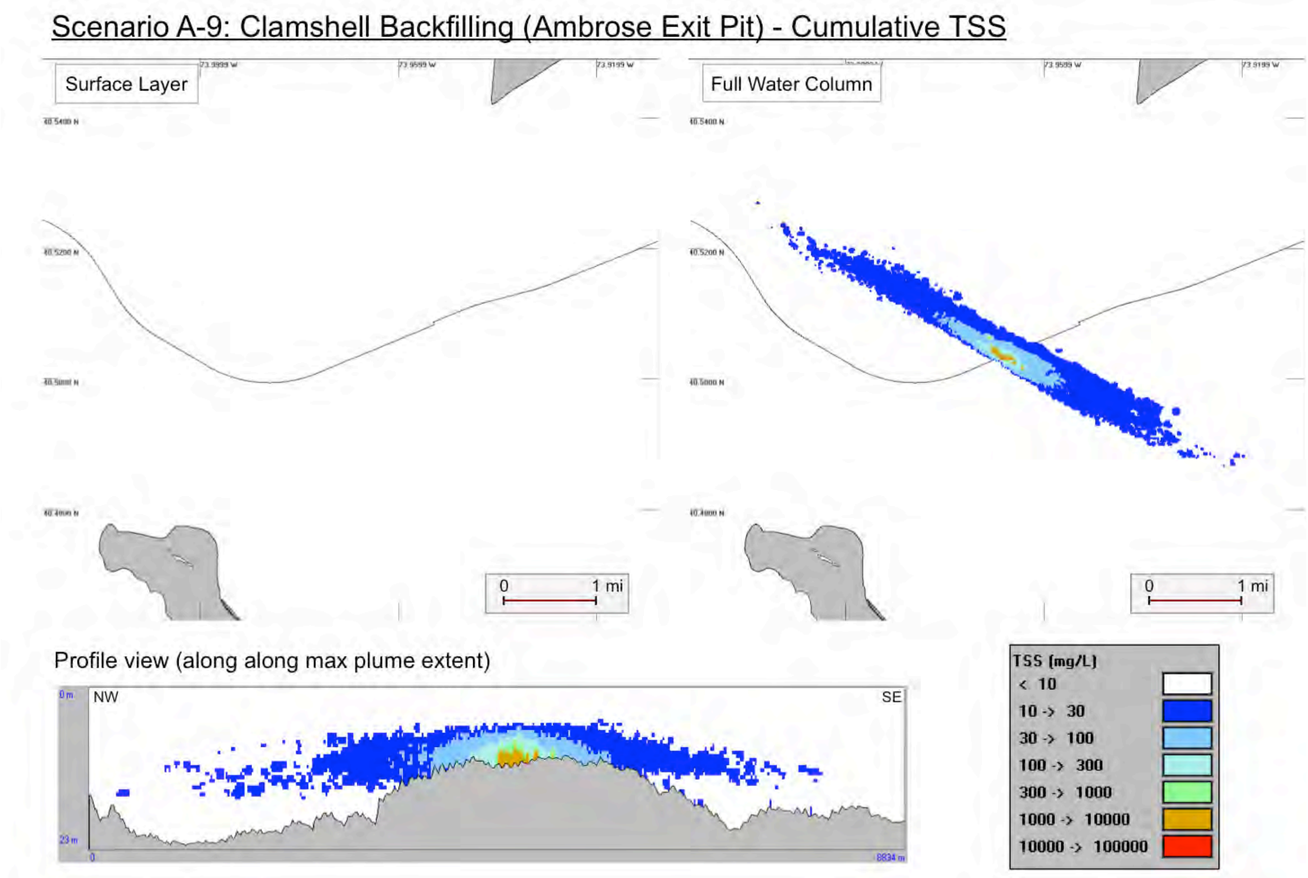

Figure 19. Cumulative TSS concentrations for Scenario A-9 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 8,652.8 mg/L.

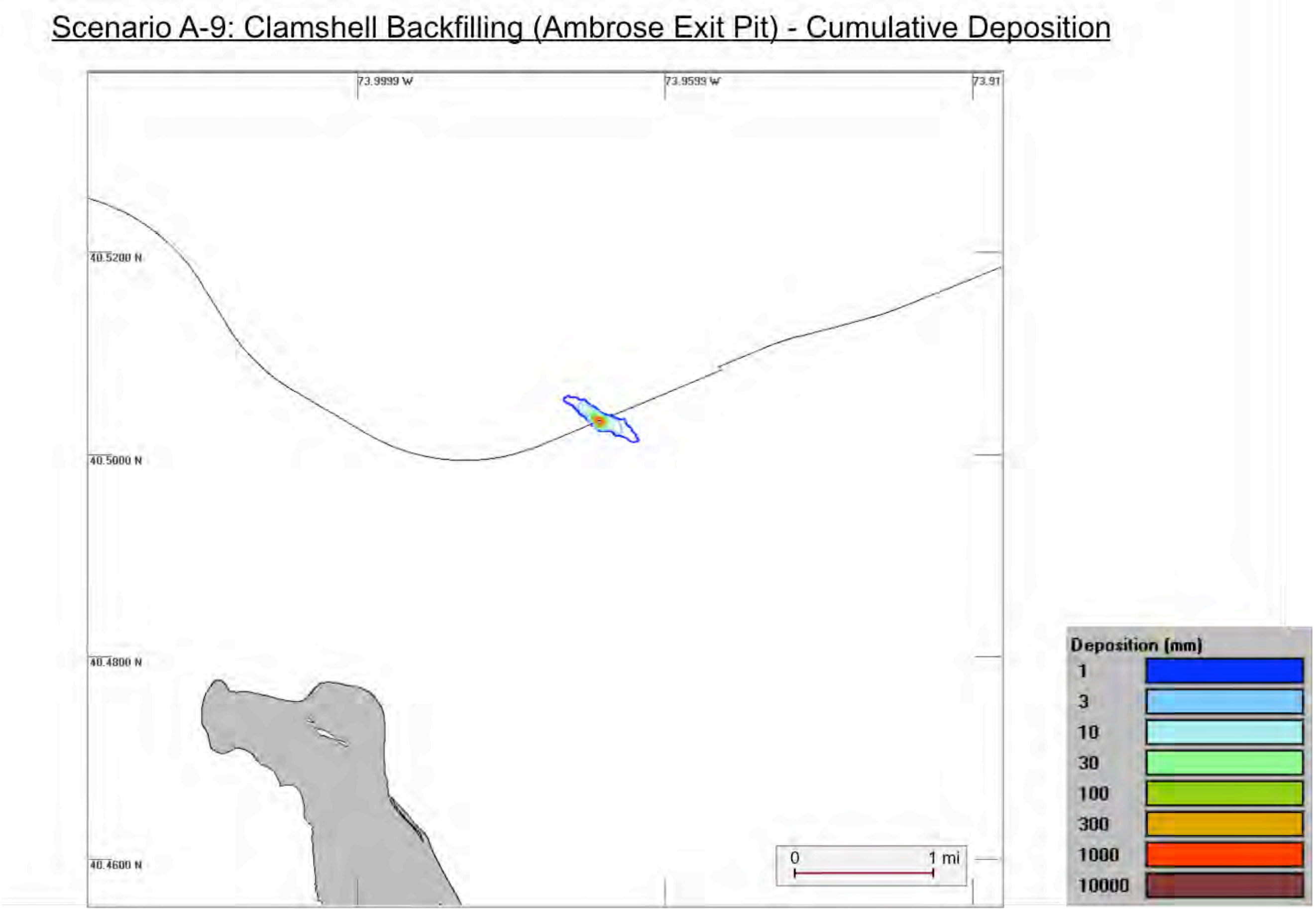

Figure 20. Extent of seabed deposition resulting from placement of backfill material at the Ambrose exit pit. Maximum predicted thickness = 127.6 in (3,242.1 mm).

3.10 Scenario A-10 – Backfilling of the Ambrose Channel HDD Entry Pit and Tie-in

Scenario A-10 simulated the placement of backfill material at MP 30.40, directly east of the Ambrose Channel. At this location backfill will be required for two excavation areas associated with the Ambrose HDD campaign: (i) the Ambrose Channel HDD entry pit, which will extend to a depth of 24 ft, and (ii) the tie-in point on the east side of the HDD, which will be excavated to 7.5 ft. Both backfilling activities were simulated, in sequence as a stationary (point) source from the HDD entry point (MP30.40). Both involve backfill by clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-10, the simulation was performed using a start date of May 16 (immediately following backfilling of the Ambrose exit pit). The clamshell dredge operates continuously for 97.4 hours, during which time 100% of the source sediment is released directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 40,563 yd^3 of sediment was placed at this location, which includes an “overfill” factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 32,450 yd^3.

Water column and sediment bed results from simulations of backfilling at the Ambrose Channel entry pit and tie-in are presented in Figure 21 and Figure 22, and summarized in Table 2. As with backfilling at the exit pit, the predicted sediment plume shows clear alignment with the currents that flow in and out of the entrance to Raritan Bay. (Due to the longer duration for this activity, the cumulative plume extends farther from the placement site.) The vertical structure of the plume also shows similarities with Scenario A-9, although elevated TSS concentrations are present intermittently in the surface layers. Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,231 ft from the source and TSS concentrations remain elevated above ambient levels for 3.0 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 702 ft from the source and covers a total of 9.7 acres of the seabed.

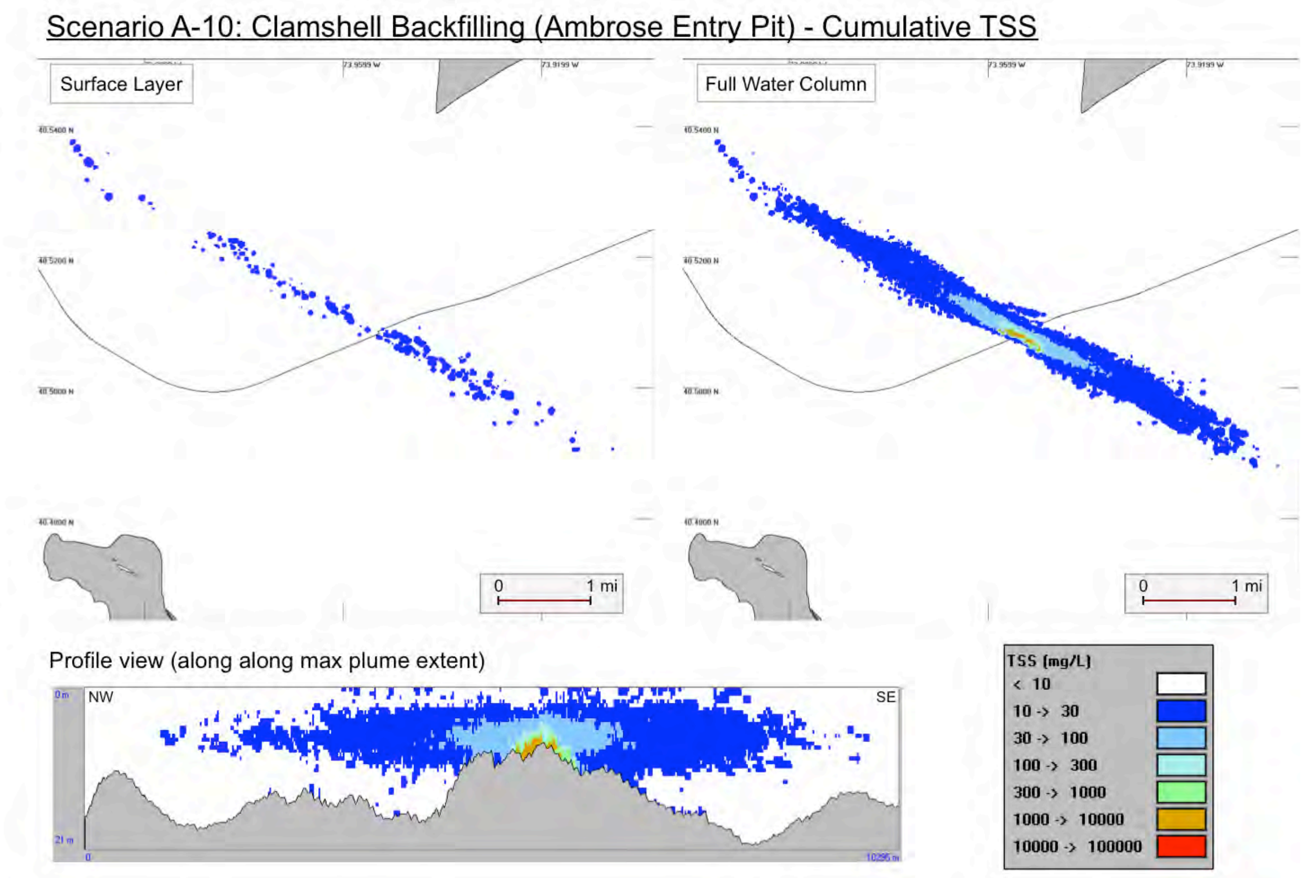

Figure 21. Cumulative TSS concentrations for Scenario A-10 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 20,538.2 mg/L.

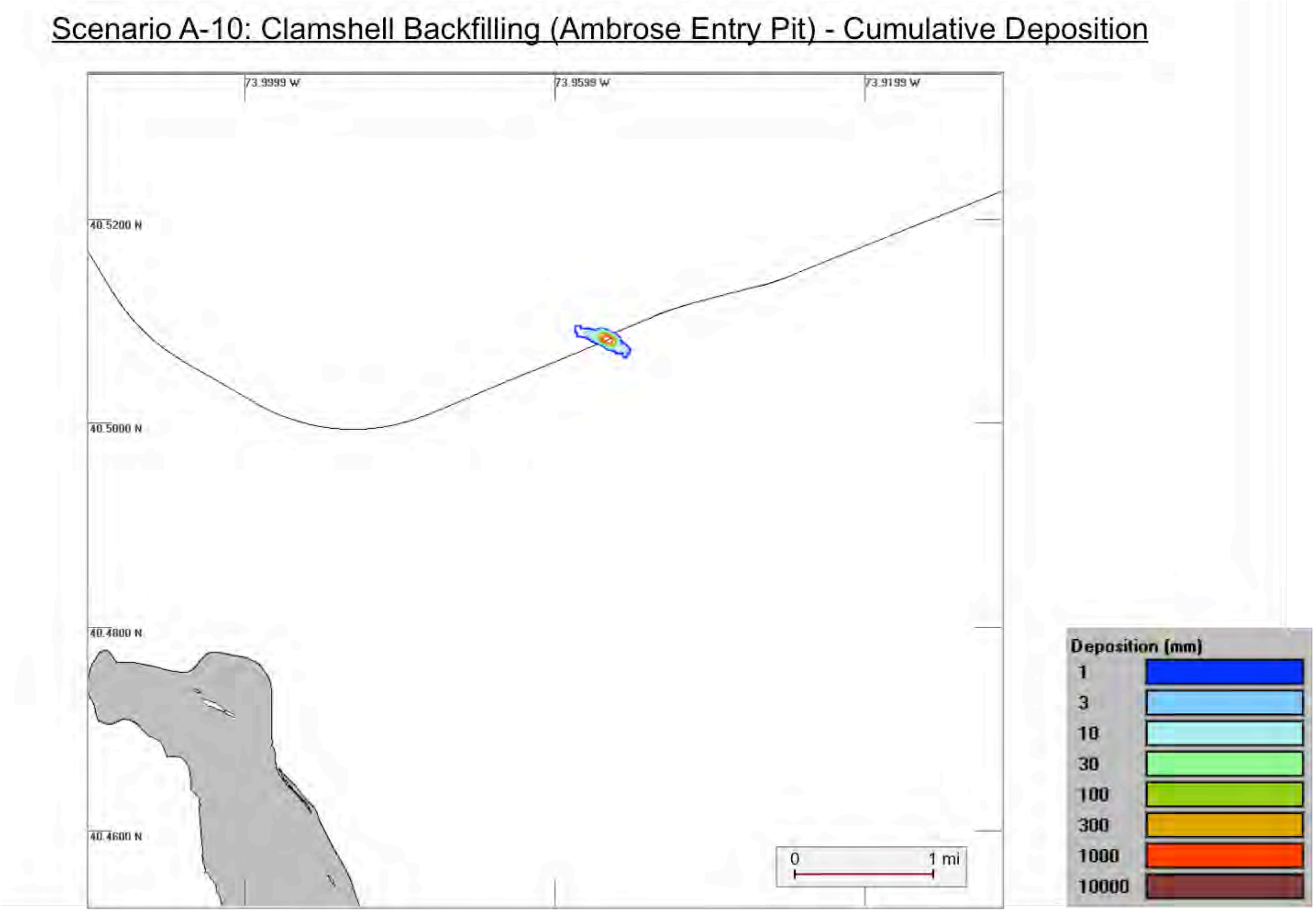

Figure 22. Extent of seabed deposition resulting from placement of backfill material at the Ambrose Channel HDD entry pit. Maximum predicted thickness = 334.6 in (8,500.0 mm).

3.11 Scenario A-11 – Backfilling at the Neptune Cable Crossing Offshore Rockaway

Scenario A-11 simulated the placement of backfill material at the (eastern) Neptune Cable crossing location at MP 35.19. Prior to the pipeline installation, Transco plans to use diver-assisted hand jets to expose the Neptune Cable, which rests approximately 7.5 ft below the seafloor. Backfilling by clamshell dredge will be required to cover the cable and return the seabed to grade once the pipe-laying is complete. The backfilling activity was simulated as a stationary (point) source at MP 35.19. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For the Neptune Cable crossing in Raritan Bay, the simulation was performed using a start date of May 20 (immediately following backfilling at the Ambrose entry pit). The clamshell dredge operates continuously for 6.3 hours, during which time the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 2,606 yd^3 of sediment was placed at the site, which includes an “overfill” factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 2,085 yd^3.

Water column and sediment bed results from simulations of backfilling at the (eastern) Neptune crossing are presented in Figure 23 and Figure 24, and summarized in Table 2. At this location the plume is confined to the lowest portions of the water column and remains relatively compact around the placement site. Sediment concentrations exceeding 10 mg/L are not predicted to occur within 25 ft of the sea surface, at any location within the model domain. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,476 ft from the source and TSS concentrations remain elevated above ambient levels for 2.1 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 443 ft from the source and covers a total of 4.9 acres of the seabed.

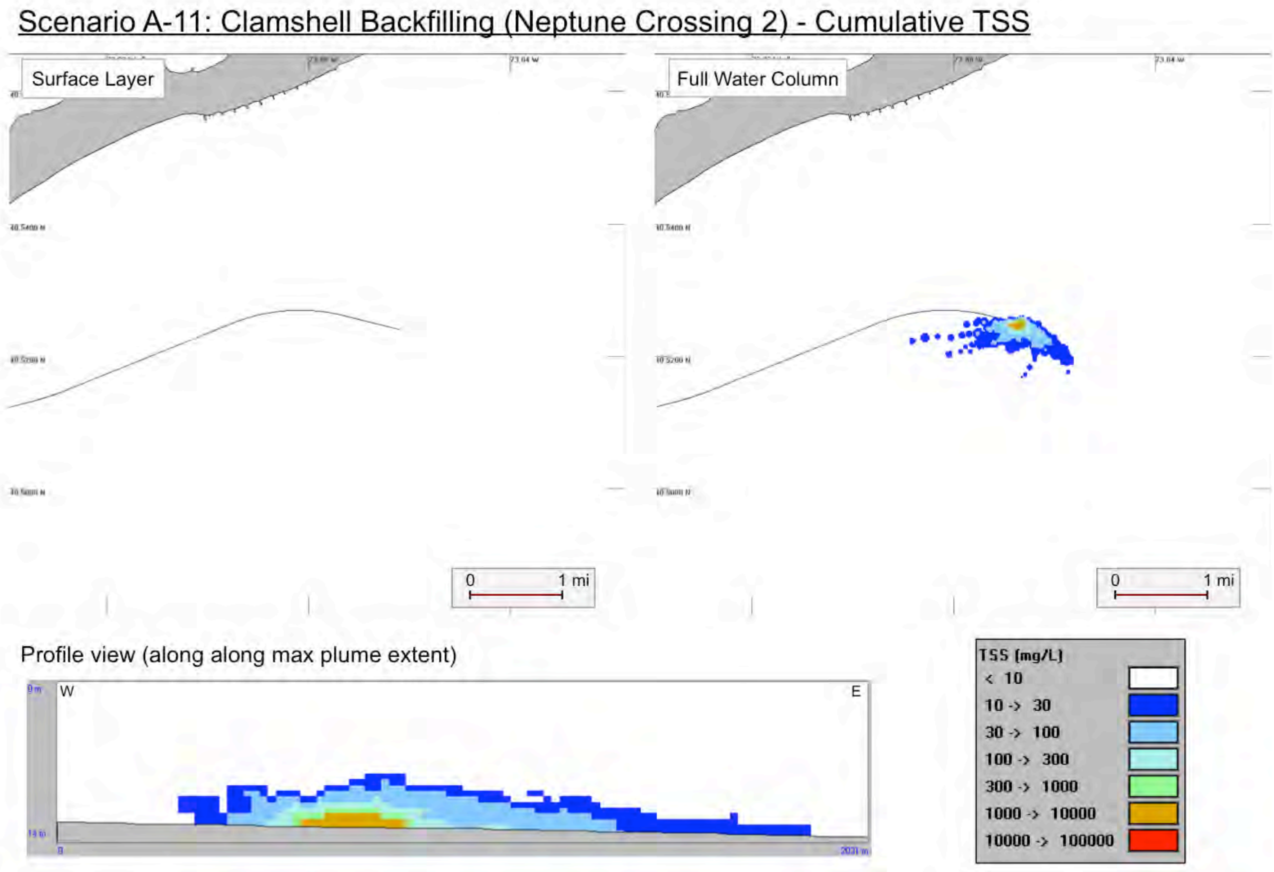

Figure 23. Cumulative TSS concentrations for Scenario A-11 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 9,120.1 mg/L.

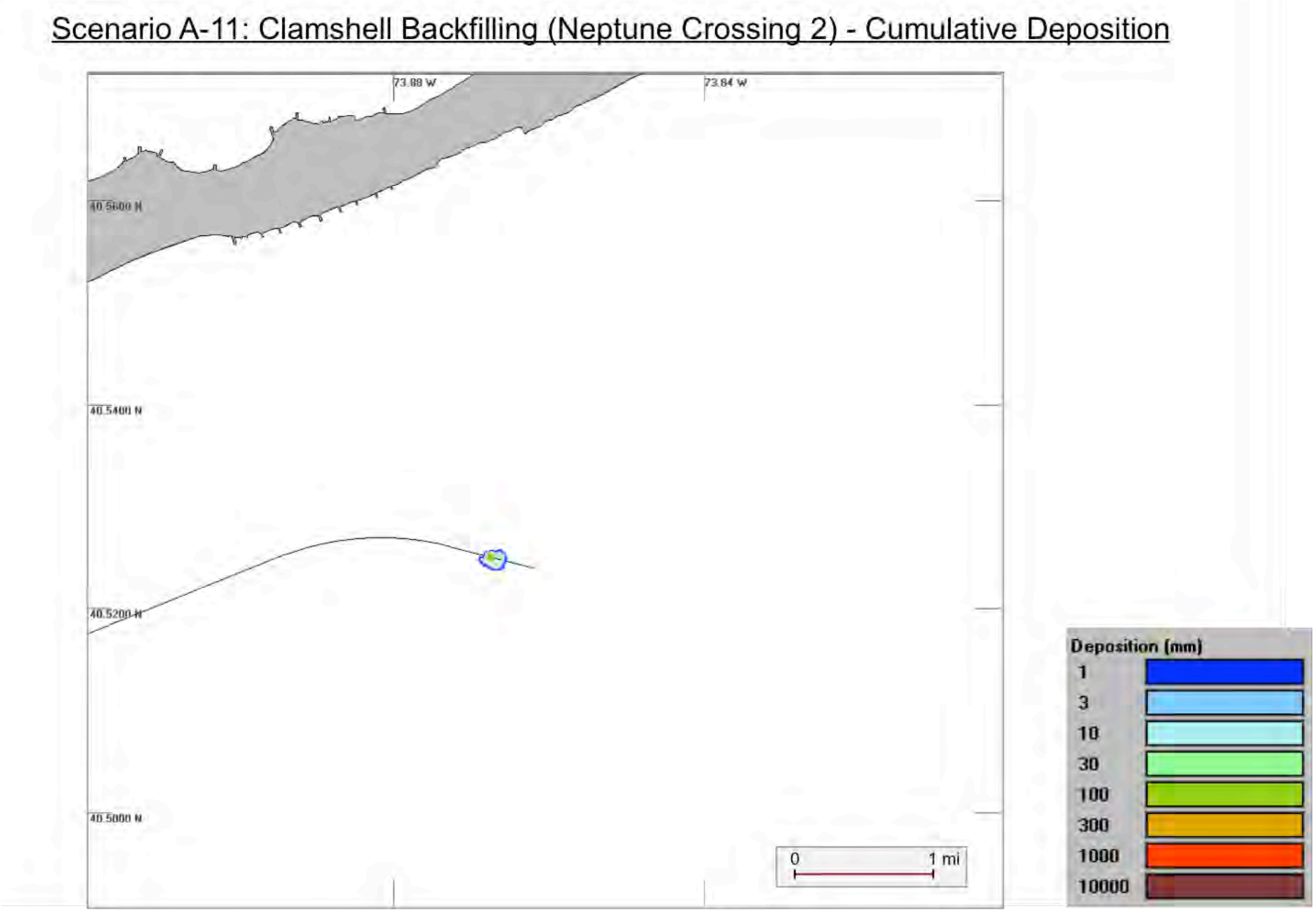

Figure 24. Extent of seabed deposition resulting from placement of backfill material at the Neptune crossing offshore Rockaway. Maximum predicted thickness = 20.1 in (509.9 mm).

3.12 Scenario A-12 – Backfilling Between the Neptune Crossing and RDL Manifold

Scenario A-12 simulated the placement of backfill material to fill the excavated trench extending between the Neptune Cable crossing offshore Rockaway and the Rockaway Delivery Lateral (RDL) tie-in point (from MP 35.23 to MP 35.49). Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. Backfilling of the trench was simulated as a line source, and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-12 the simulation was performed using a start date of May 21 (immediately following backfilling activities at the Neptune cable crossing offshore Rockaway). The clamshell dredge operates continuously for 34.0 hours while placing backfill sediments over approximately 0.26 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 14,197 yd^3 of sediment was placed along the route, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 11,358 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 35.23 and MP 35.49 are presented in Figure 25 and Figure 26, and summarized in Table 2. Along this reach of the route, the excess TSS plume generally extends south of the placement site, and oscillates slightly between south and west as the dredge advances. Peak TSS concentrations occur in the immediate vicinity of the backfilling route, and concentrations above 10 mg/L are predicted to remain at depths between the seabed and 19 ft from the water surface. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,493 ft from the source and TSS concentrations remain elevated above ambient levels for 2.3 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 531 ft from the source and covers a total of 19.6 acres of the seabed.

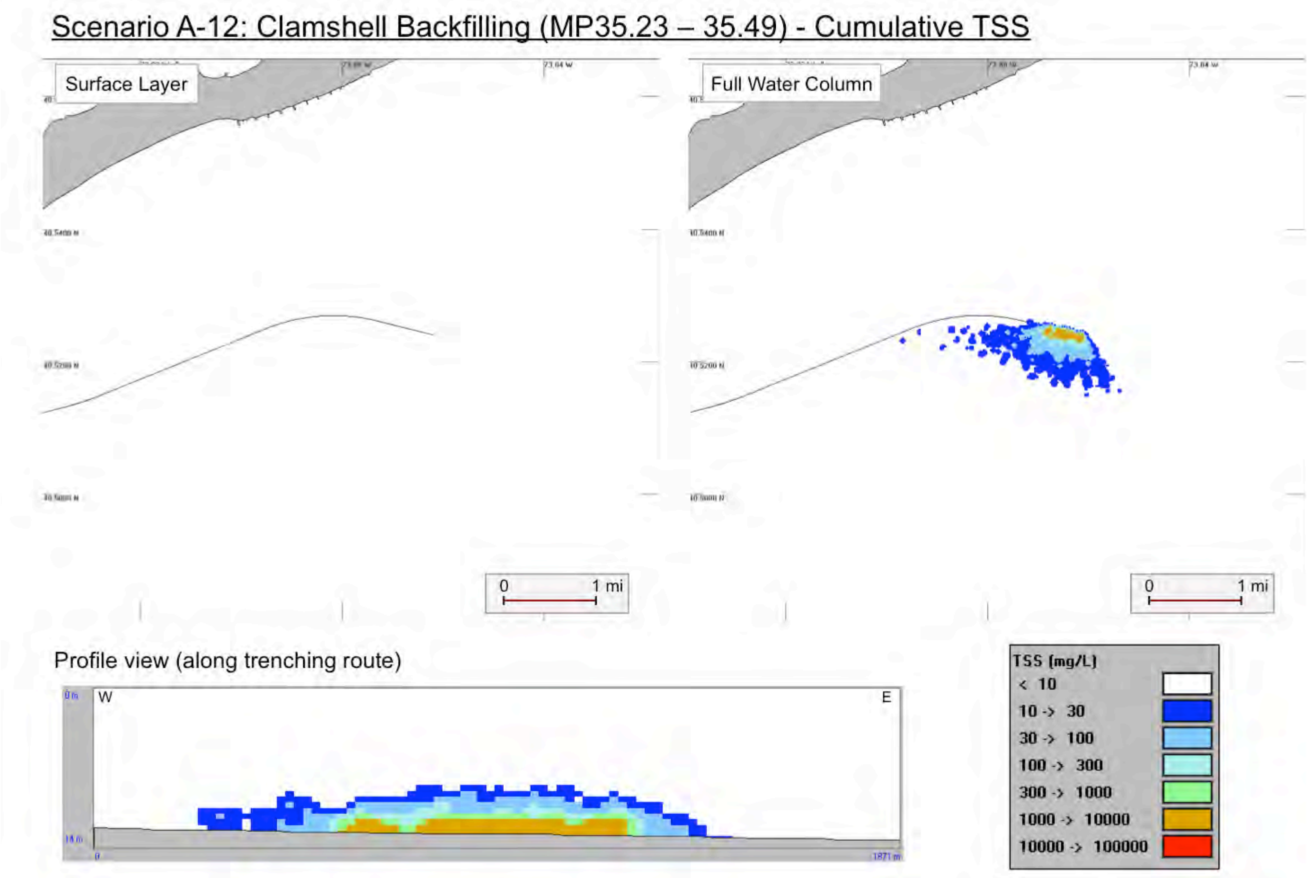

Figure 25. Cumulative TSS concentrations for Scenario A-12 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the backfilling route. Maximum predicted concentration = 7,503.9 mg/L.

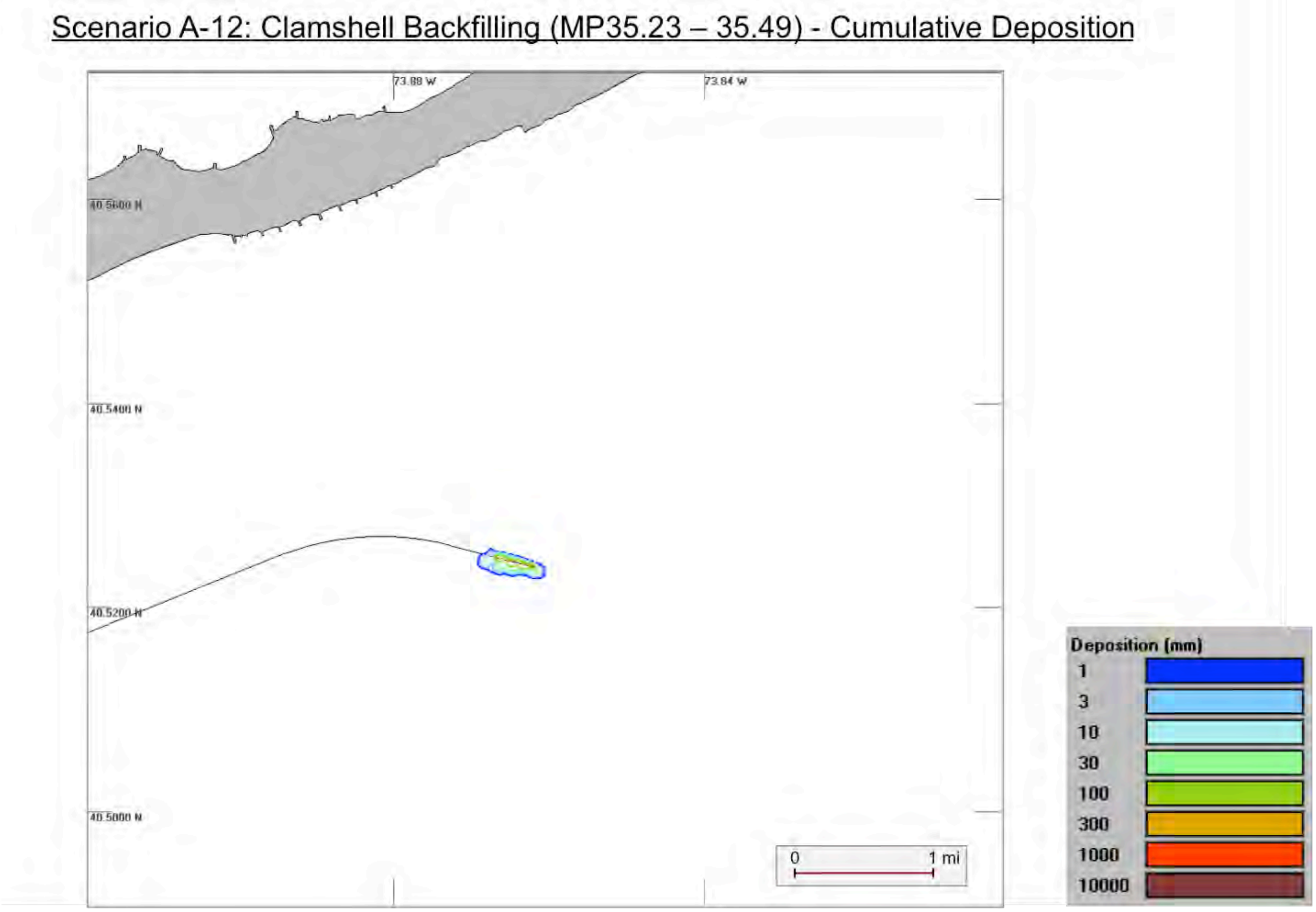

Figure 26. Extent of seabed deposition resulting from placement of backfill material between the Neptune Cable crossing and RDL. Maximum predicted thickness = 14.3 in (362.3 mm).

3.13 Scenario A-13 – Backfilling of the Tie-in Skid and Manifold at Rockaway

Scenario A-13 simulated the placement of backfill material at the tie-in skid and manifold at the Rockaway Delivery Lateral at the end of the pipeline route. Prior to the pipeline installation, these features will be uncovered using diver-assisted hand jets and submersible pumps to jet/excavate sediment away from the site. Backfilling by clamshell dredge will then be required to return the seabed to grade once the pipe has been installed and tie-in to the RDL manifold is complete. The backfilling activity was simulated as a stationary (point) source at MP 35.49. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

Backfilling operations are expected to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3. For Scenario A-13, the simulation was performed using a start date of May 22 (immediately following backfilling of the pipeline trench up to the RDL). The clamshell dredge operates continuously for 18.1 hours, during which time the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 7,550 yd^3 of sediment was placed at the RDL tie-in site, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 6,040 yd^3.

Water column and sediment bed results from simulations of backfilling at MP 35.49 are presented in Figure 27 and Figure 28, and summarized in Table 2. As with the adjacent backfilling activities described in Scenario A-12, the excess TSS plume at the RDL tie-in generally extends south and west of the placement site and concentrations above 10 mg/L remain in the lower portion of the water column (depths below 23 feet from the surface). Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,739 ft from the source and TSS concentrations remain elevated above ambient levels for 3.0 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 607 ft from the source and covers a total of 9.0 acres of the seabed.

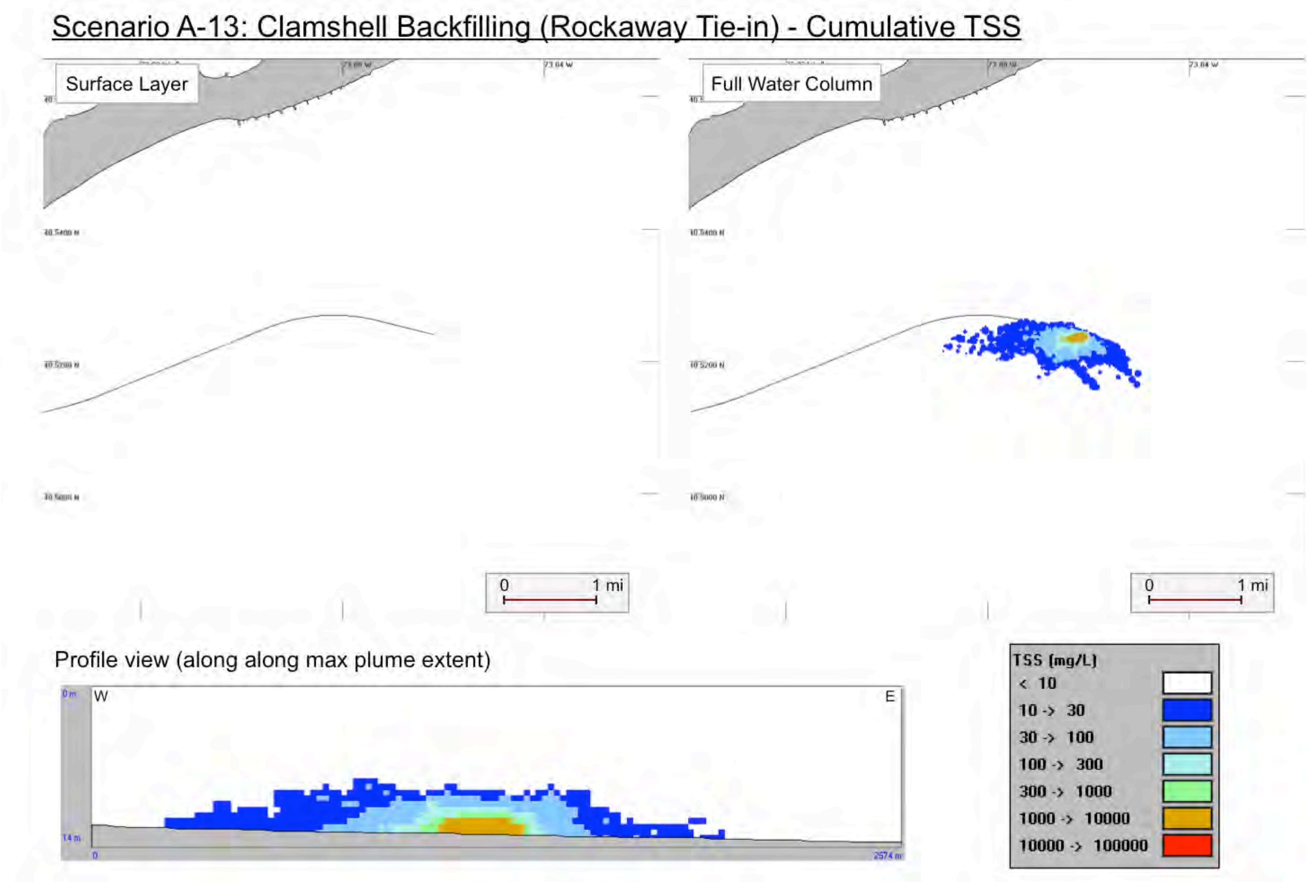

Figure 27. Cumulative TSS concentrations for Scenario A-13 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 10,070.2 mg/L.

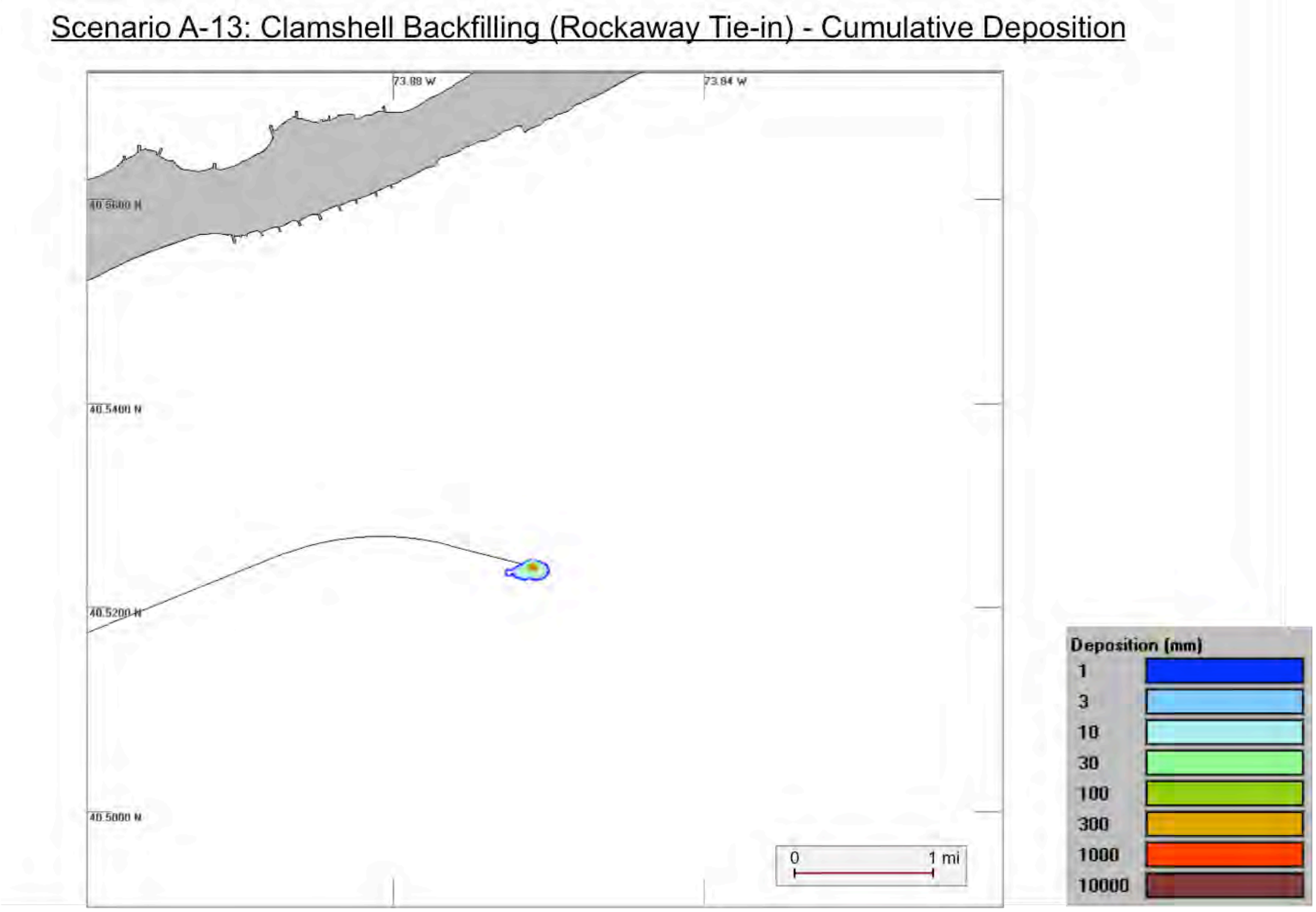

Figure 28. Extent of seabed deposition resulting from placement of backfill material at the RDL tie-in. Maximum predicted thickness = 56.2 in (1,427.6 mm).

Table 2. Summary of Addendum 1 simulation results.

Scenario	Construction Activity	Equipment Type	Location	Production rate (ft3/hr)	Duration of modeled activity (hr)	Equipment Loss Rate (%)	Total volume released (yd3)	Time For TSS to return to ambient (hrs)	Max Distance of TSS Plume exceeding ambient (ft)		Max Distance of deposition exceeding (ft)			Area of deposition exceeding (acres)		
									50 mg/L	100 mg/L	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]
Scenario A-1	Dredging of backfill source material from Ambrose Channel	Clamshell	Ambrose Channel	11,250	533.0	5	11,111	1.0	7,661	6,365	279	92	0	119.6	2.3	0.0
Scenario A-2	Dredging of backfill source material from Rockaway Inlet	Clamshell	Rockaway Inlet	11,250	533.0	5	11,111	0.6	3,478	2,526	1,247	197	72	78.5	34.6	7.2
Scenario A-3	Dredging of backfill source material from Earle Channel	Clamshell	Earle Channel	11,250	533.0	5	11,111	0.8	6,365	3,888	187	59	0	114.9	3.0	0.0
Scenario A-4	Backfilling of (i) Morgan Shore HDD pit and (ii) anode sled burial area	Clamshell	(i) MP 12.50 (ii) 1,200 ft north of MP 12.32	11,250	31.7	100	13,205	2.0	1,362	886	404	305	253	9.4	6.6	4.8
Scenario A-5	Backfill of trench between Morgan HDD exit and the Midline tie-in	Clamshell	MP 12.50 - MP 16.60	11,250	527.0	100	219,591	1.5	4,331	2,444	545	440	381	281.9	220.9	158.7
Scenario A-6	Backfill of the Neptune Cable crossing point in Raritan Bay	Clamshell	MP 13.88	11,250	5.0	100	2,095	3.5	1,903	1,247	427	371	197	4.4	2.9	1.6
Scenario A-7	Backfill of trench across the Raritan Channel	Clamshell	MP 17.31 - MP 17.89	11,250	401.0	100	167,025	1.9	3,150	1,509	715	591	472	60.7	43.7	33.6
Scenario A-8	Backfill of trench between the anchorage area and the Chapel Hill Channel	Clamshell	MP 24.00 - MP 25.20	11,250	338.0	100	140,590	2.8	4,265	1,690	522	292	249	92.8	68.5	52.3
Scenario A-9	Backfilling of Ambrose Channel HDD exit pit (West)	Clamshell	MP 29.52	11,250	42.2	100	17,563	3.3	3,871	1,952	945	804	525	16.5	8.5	5.1
Scenario A-10	Backfilling of Ambrose Channel HDD entry pit (East) and tie-in	Clamshell	MP 30.40	11,250	97.4	100	40,563	3.0	4,495	2,231	915	702	453	14.9	9.7	7.0
Scenario A-11	Backfill at the Neptune Cable crossing offshore Rockaway	Clamshell	MP 35.19	11,250	6.3	100	2,606	2.1	2,182	1,476	489	443	377	7.6	4.9	3.0
Scenario A-12	Backfilling between the Neptune crossing and end of pipeline	Clamshell	MP 35.23 to MP 35.49	11,250	34.0	100	14,197	2.3	2,493	1,493	633	531	335	26.8	19.6	12.0
Scenario A-13	Backfill tie-in skid and manifold at Rockaway	Clamshell	MP 35.49	11,250	18.1	100	7,550	3.0	2,395	1,739	709	607	476	12.0	9.0	5.4

4 References

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F-3 – HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING RESULTS – ADDENDUM 2

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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Northeast Supply Enhancement Project:
Hydrodynamic and Sediment Transport Modeling Results: Addendum 2

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1 Introduction

1.1 Project Background

As part of its Northeast Supply Enhancement Project (Project), Transcontinental Gas Pipe Line Company, LLC (Transco) is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey, as well as its existing offshore natural gas pipeline system in New Jersey and New York. A major portion of the Project includes the installation of a 26-inch outer diameter pipeline, referred to as the "Raritan Bay Loop" that will extend from the Sayreville, New Jersey shoreline (MP12.16) approximately 23.33 miles across the Raritan Bay and Lower New York Bay to the Rockaway Transfer Point in the Atlantic Ocean. The pipeline installation will require a range of dredging and burial techniques (e.g. clamshell dredging, jet trenching, submersible pumping, and backfilling) each of which has the potential to produce seabed disturbances, suspended sediment plume formation, and smothering due to sedimentation. RPS has been contracted to develop and apply customized hydrodynamic, and sediment transport and dispersion models to help assess the potential environmental impacts of these Project-related activities.

1.2 Objectives and Tasks

Results from an initial set of "base case" construction activities were completed by RPS in August 2017. The base case modeling report described the development and calibration of a three-dimensional hydrodynamic model for the New York/New Jersey Harbor Estuary (NY/NJ Harbor Estuary), using the Water Quality Model and Analysis Package / Boundary-Fitted Hydrodynamics (WQMAP/BFHYDRO) modeling system and application of the Suspended Sediment Fate (SSFATE) sediment model to simulate offshore construction activities including mechanical (clamshell) dredging, post-pipelay burial by jet trencher, hand-jetting, and suction dredging (submersible pumping). A report addendum completed in September 2017 (Addendum 1) described predictions of suspended sediment concentrations and deposition from additional Project-related activities, which included dredging of navigation channels and backfilling for portions of the pipeline route

This report (Addendum 2) describes new applications of the modeling systems to simulate the use of environmental buckets for dredging (to limit sediment losses to the water column), and side-casting of dredged sediments to the seabed during certain phases of the installation. An overview of the additional SSFATE scenarios and model results are provided in Sections 2 and 3. The reader is directed to the base case modeling report for a complete description of the modeling systems, model theory, validation of the hydrodynamic predictions, and references for each model (RPS 2017).

2 SSFATE Model Setup

2.1 Description of SSFATE Scenarios

The additional sediment modeling scenarios that RPS has developed in consultation with Transco and E&E are summarized in Table 1 and presented graphically in Figure 1. The new SSFATE scenarios (22 total) were developed to simulate sediment releases for five types of construction activities associated with different stages of the offshore installation between MP 12.50 and the Rockaway tie-in point at MP 35.49. Specifically, these include:

1. Clamshell dredging with an "environmental" bucket where sediment is lost as the bucket ascends through the water column, and from overflow of the scow barge at the sea surface (2.5% sediment loss).
2. Clamshell dredging with an "environmental" bucket where sediment is lost as the bucket ascends through the water column (0.5% sediment loss). No overflow of the scow barge is permitted.
3. Post-lay trenching (by jet trencher) to achieve pipeline burial (5% sediment loss).
4. Clamshell dredging and subsequent side-casting of dredged materials to the seabed at four locations along the pipeline route (100% sediment loss).
5. Simulations of placement of backfill materials for two segments of the pipeline route excavated using clamshell dredges.

Table 1. Description of activities being simulated for each modeling scenario included in Addendum 2.

Scenario	Construction Activity	Equipment Type	Point/Line Source	Location	Excavation Volume (yd^3)	Duration (day)
Scenario B-1	Pre-lay trenching between Morgan HDD pit and the Midline tie-in (2.5% loss)	Clamshell	Line	MP 12.50 - MP 16.60	175,673	17.6
Scenario B-2	Pre-lay trenching between Morgan HDD pit and the Midline tie-in (0.5% loss; no scow overflow)	Clamshell	Line	MP 12.50 - MP 16.60	175,673	17.6
Scenario B-3	Post-lay trenching between Morgan HDD pit and the Midline tie-in (2 passes; 5% loss)	Jet Trencher	Line	MP 12.50 - MP 16.60	71,176	2.8
Scenario B-4	Excavation activities at Morgan Shore (0.5% loss)	Clamshell	Point	(i) MP 12.50 (ii)~1,200 ft north of MP 12.30	10,392	1.0
Scenario B-5	Pre-lay trenching across the Raritan Channel (0.5% loss)	Clamshell	Line	MP 17.31 - MP 17.89	133,620	13.4
Scenario B-6	Pre-lay trenching between the anchorage area and the Chapel Hill Channel (0.5% loss)	Clamshell	Line	MP 24.00 - MP 25.20	112,472	11.2
Scenario B-7	Excavation of Ambrose Channel HDD pit (West) (2.5% loss)	Clamshell	Point	MP 29.52	14,050	1.4
Scenario B-8	Excavation of Ambrose Channel HDD pit (West) (0.5% loss)	Clamshell	Point	MP 29.52	14,050	1.4
Scenario B-9	Excavation at the Ambrose HDD pit (East) and Ambrose Channel tie-in (2.5% loss)	Clamshell	Point	MP 30.40	34,777	3.5
Scenario B-10	Pre-lay trenching between the Neptune crossing and end of pipeline (2.5% loss)	Clamshell	Line	MP 35.19 to MP 35.49	13,152	1.3
Scenario B-11	Dredging of backfill source material from Ambrose Channel (2.5% loss)	Clamshell	Line	Ambrose Channel (W to E)	222,216	22.2

Table 1 (cont.)

Scenario	Construction Activity	Equipment Type	Point/Line Source	Location	Excavation Volume (yd^3)	Duration (day)
Scenario B-12	Dredging of backfill source material from Rockaway Inlet (2.5% loss)	Clamshell	Line	Rockaway Inlet (S to N)	222,216	22.2
Scenario B-13	Dredging of backfill source material from Earle Channel (2.5% loss)	Clamshell	Line	Earle Channel (W to E)	222,216	22.2
Scenario B-14	Dredging of backfill source material from Ambrose Channel (0.5% loss)	Clamshell	Line	Ambrose Channel (W to E)	222,216	22.2
Scenario B-15	Dredging of backfill source material from Rockaway Inlet (0.5% loss)	Clamshell	Line	Rockaway Inlet (S to N)	222,216	22.2
Scenario B-16	Dredging of backfill source material from Earle Channel (0.5% loss)	Clamshell	Line	Earle Channel (W to E)	222,216	22.2
Scenario B-17	Side-cast across the Anchorage area (100% loss)	Clamshell	Line	MP 24.00 to MP 24.78	64,311	6.4
Scenario B-18	Side-cast at the Ambrose HDD pit (West) (100% loss)	Clamshell	Point	MP 29.52	14,050	1.4
Scenario B-19	Side-cast at the Ambrose HDD pit (East) and Ambrose Channel tie-in (100% loss)	Clamshell	Point	MP 30.40	34,777	3.5
Scenario B-20	Side-cast between the Neptune crossing and RDL	Clamshell	Line	MP 35.19 to MP 35.49	13,152	1.3
Scenario B-21	Backfill of trench between Morgan HDD exit and the Midline tie-in	Clamshell	Line	MP 12.50 - MP 16.60	219,591	33.1
Scenario B-22	Backfilling of Ambrose Channel HDD Pit (West)	Clamshell	Point	MP 29.52	17,563	2.6

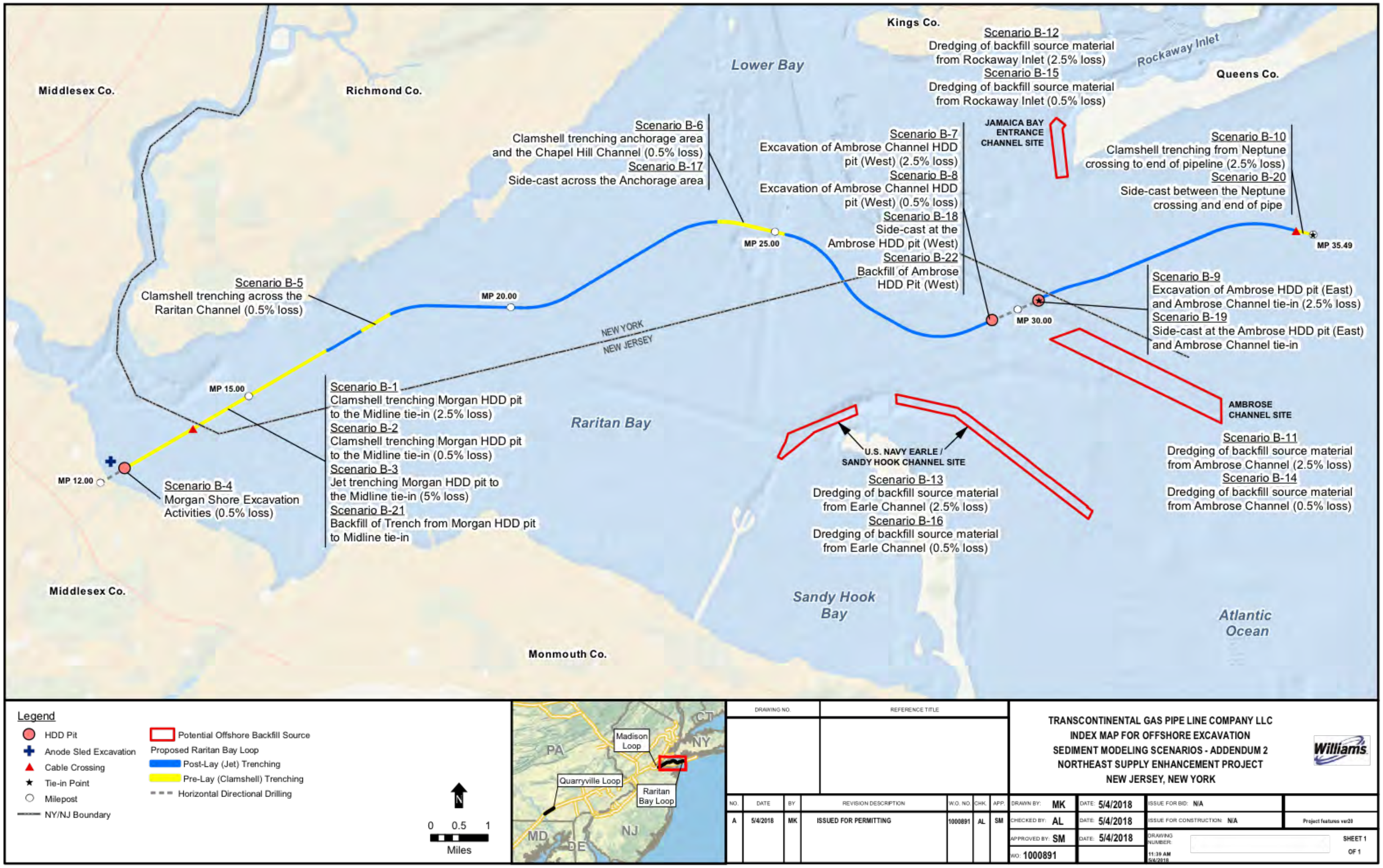

Figure 1. Map view showing sediment modeling scenario locations (from E&E).

3 SSFATE Results

3.1 Scenario B-1 – Clamshell Trenching Between Morgan HDD and Midline Tie-in (2.5% loss)

Scenario B-1 simulated releases associated with pre-lay trenching between MP 12.50 and MP 16.60 under the assumption that total sediment losses would be limited to 2.5% of the trench volume through use of an environmental bucket. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total, 175,673 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredger in one direction (West to East) and a start date of September 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 4,392 yd^3 of sediment over 17.6 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 12.50 and MP 16.60 are presented in Figure 2 and Figure 3, and summarized in Table 2. As with previous clamshell trenching scenarios along this range of MPs, the highest plume concentrations are predicted within the upper portions of the water column and over the western half of the trenching route. Water column concentrations of 100 mg/L are predicted to extend a maximum of 591 ft from the source and TSS concentrations remain elevated above ambient levels for 1.7 hours after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) remains within 26 ft from the source and covers a total of 0.5 acres of the seabed.

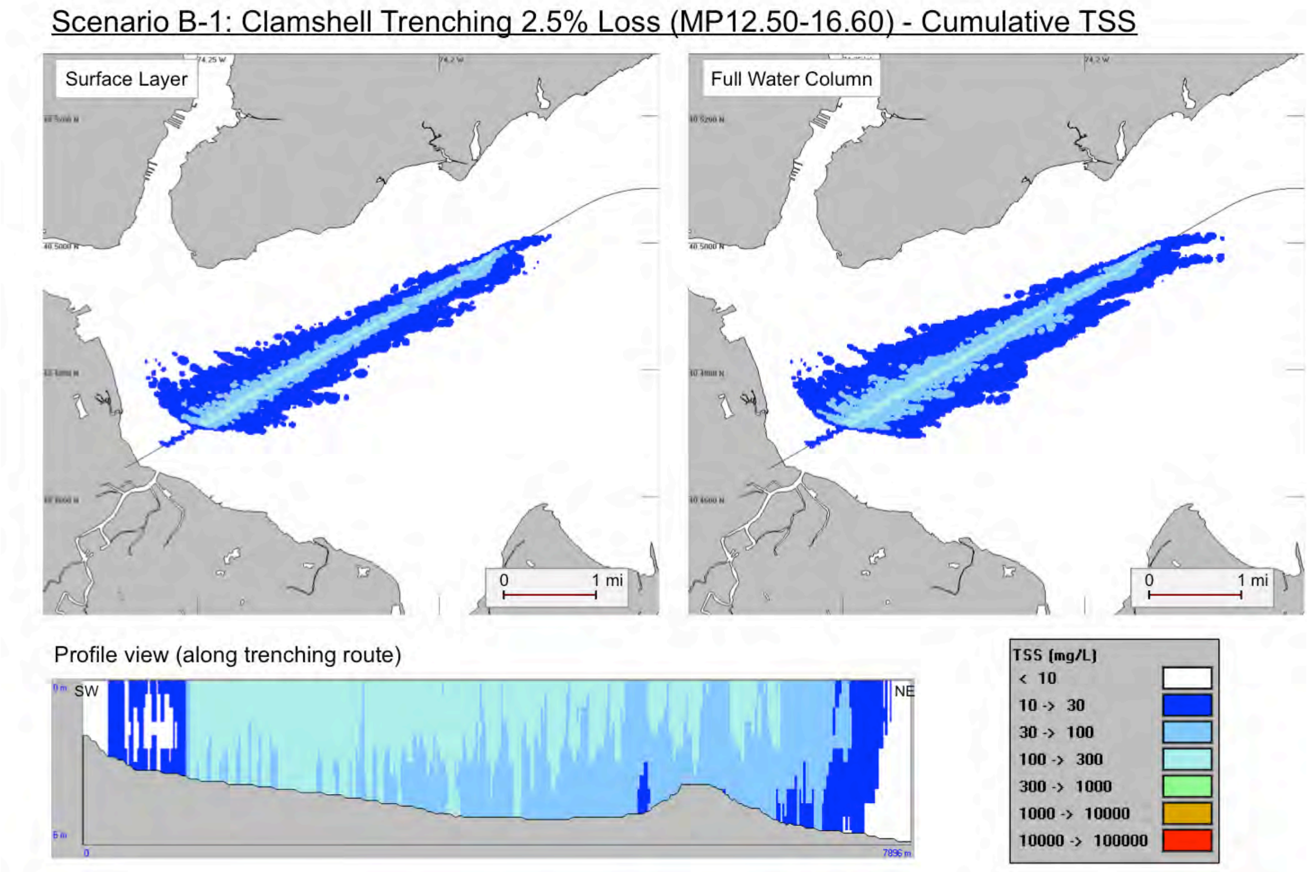

Figure 2. Cumulative TSS concentrations for Scenario B-1 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

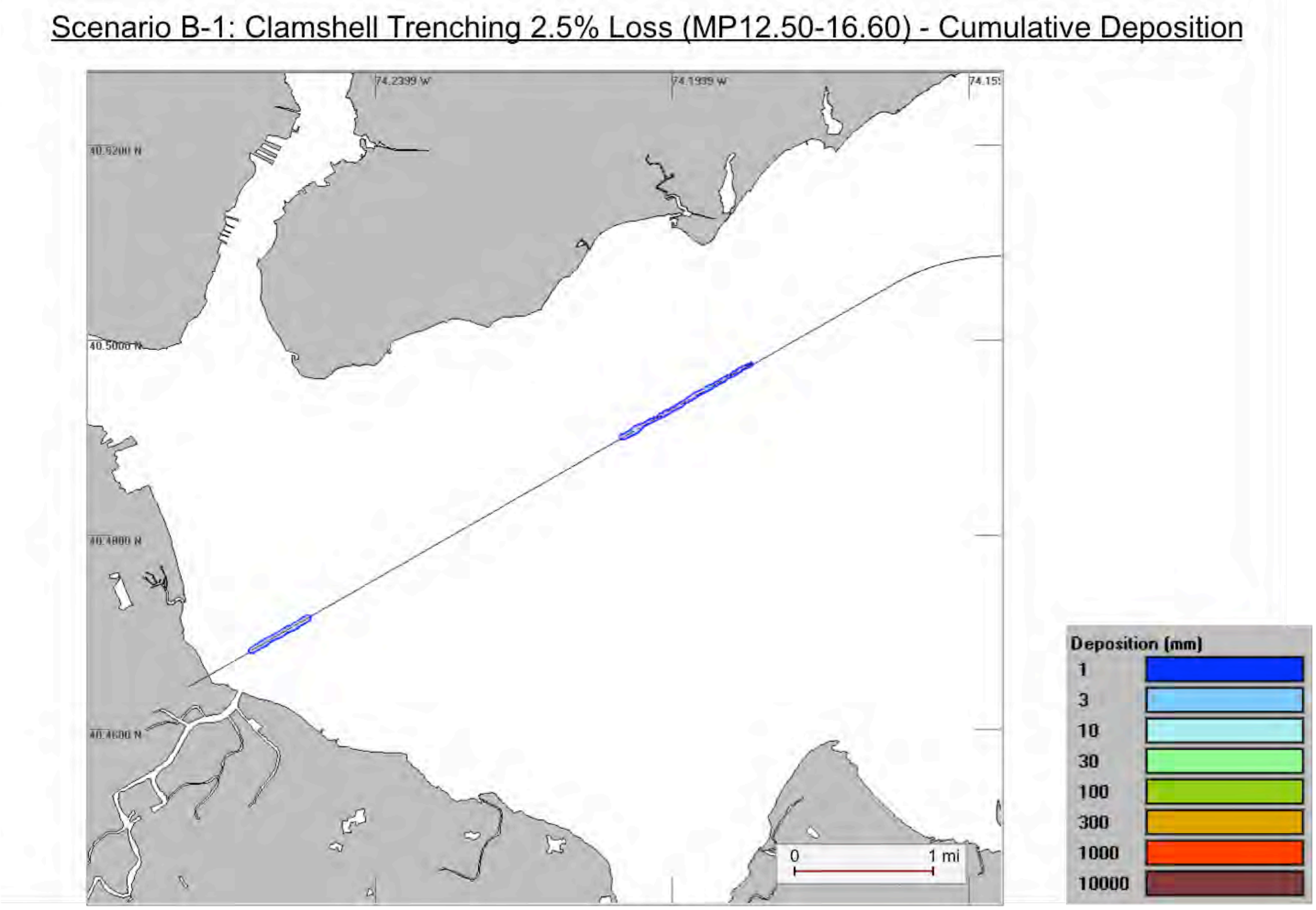

Figure 3. Extent of seabed deposition resulting from pre-lay clamshell trenching (2.5% loss) between MP 12.50 and MP 16.60. Maximum predicted thickness = 0.5 in (13.9 mm).

3.2 Scenario B-2 – Clamshell Trenching Between Morgan HDD and Midline Tie-in (0.5% loss)

Scenario B-2 simulated releases associated with pre-lay trenching between MP 12.50 and MP 16.60 under the assumption that total sediment losses would be limited to 0.5% of the trench volume through use of an environmental bucket and no scow overflow. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total, 175,673 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredger in one direction (West to East) and a start date of September 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 878 yd^3 of sediment over 17.6 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 12.50 and MP 16.60 are presented in Figure 4 and Figure 5, and summarized in Table 2. As with Scenario B-1, the cumulative TSS plume is more pronounced through the upper portions of the water column and over the western half of the trenching route, although peak concentrations are notably lower. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L; TSS concentrations are expected to return to ambient levels approximately 0.4 hours (25 minutes) after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

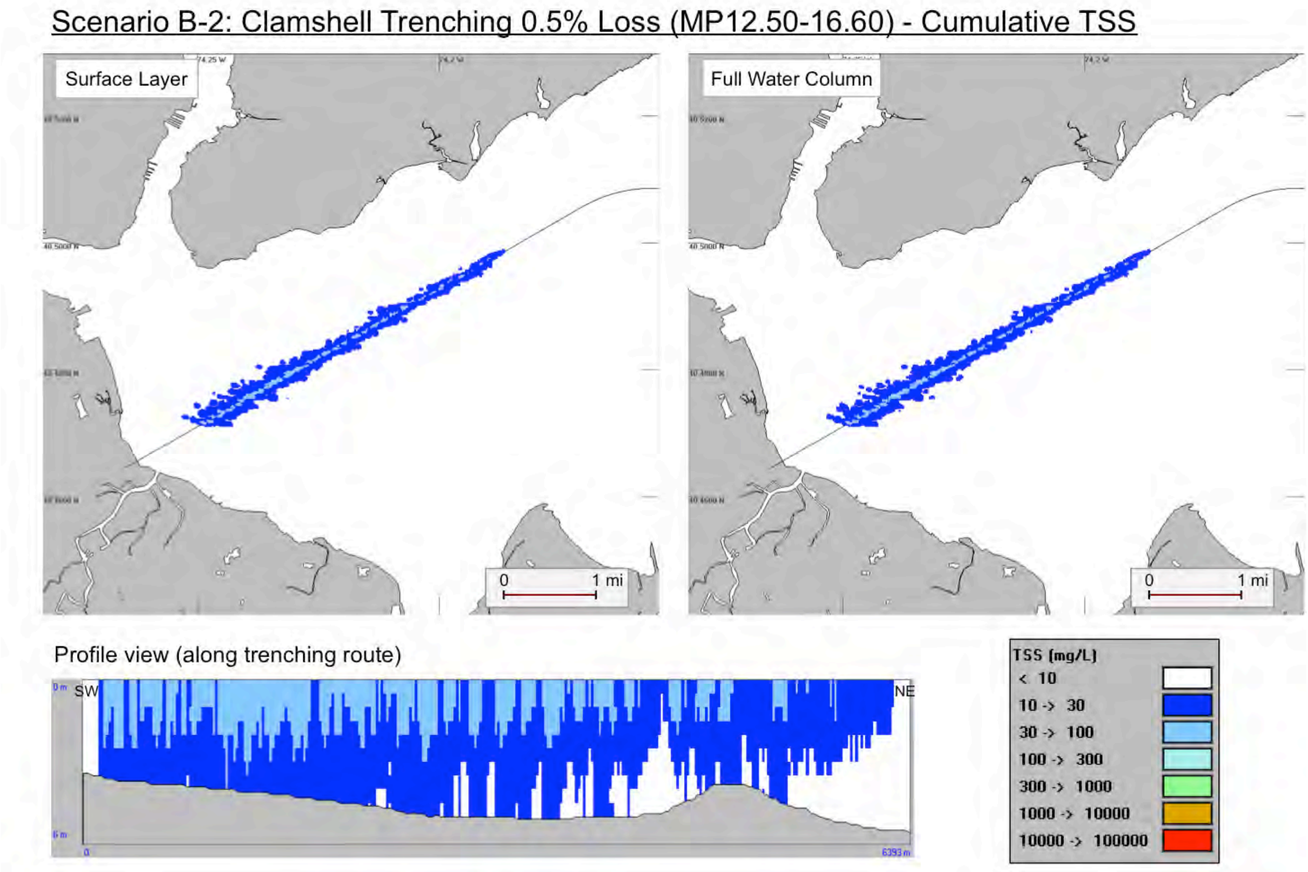

Figure 4. Cumulative TSS concentrations for Scenario B-2 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

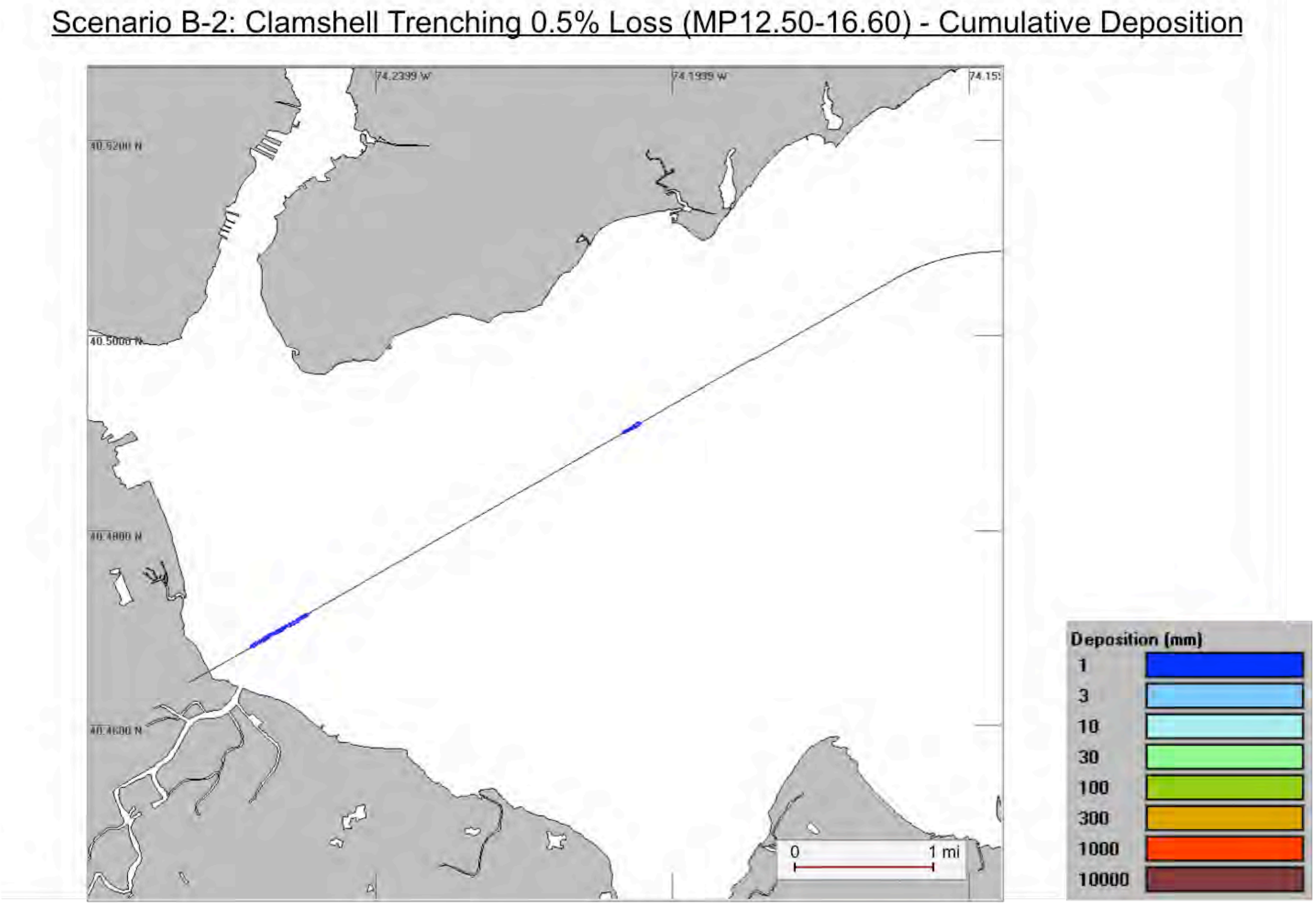

Figure 5. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) between MP 12.50 and MP 16.60. Maximum predicted thickness = 0.1 in (2.8 mm).

3.3 Scenario B-3 – Jet Trenching Between Morgan HDD and Midline Tie-in

Scenario B-3 simulated releases associated with post-lay jet trenching between MP 12.50 and MP 16.60. The jet trencher is equipped with retractable cutting swords that straddle the pipeline and extend below the seabed. High volume seawater is used to fluidize the seabed and lower the pipeline to its burial depth (minimum 4 ft of cover) as the jet trencher advances. The trench volume along this section of the route is 71,176 yd^3, although most of this material will remain undisturbed at the seabed since the jet trencher does not directly excavate sediment from the trench. For modeling, it was assumed that the equipment operates at a constant production rate of 29,135 ft^3/hr (based on contractor estimates of 656 ft/hr [200 m/hr] advance rates).

The activity was modeled as a line source, assuming two passes of the jet trencher would be required to achieve full burial. The initial pass (West to East) was followed by a return pass in the opposite direction, with a break of approximately 6 hours between the two activities to account for equipment re-positioning and other operational factors. A model start date of September 27 was selected to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the jet trencher are assumed to be limited to 5% of the total excavation volume, with 3% distributed directly at the seafloor (0-1 ft above), 1.5% between 1 and 2 ft, and the remaining mass (0.5%) between 2 and 3 ft above the seabed. In total, the simulation included the release of 3,559 yd^3 of sediment over the course of 2.8 days of active production.

Water column and sediment bed results from simulations of jet trenching between MP 12.50 and MP 16.60 are presented in Figure 6 and Figure 7, and summarized in Table 2. During most of the burial activity, the plume remains confined to the mid- and lower portions of the water column. The plume migrates with the tidal current as evidenced by the oscillatory pattern of cumulative TSS concentrations. The maximum TSS concentrations remain at or near the seabed, and plumes above 10 mg/L reach the surface layer only intermittently during the simulation. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,476 ft from the source and TSS concentrations remain elevated above ambient levels for 0.2 hours (12 minutes) after the conclusion of jet trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during this simulation.

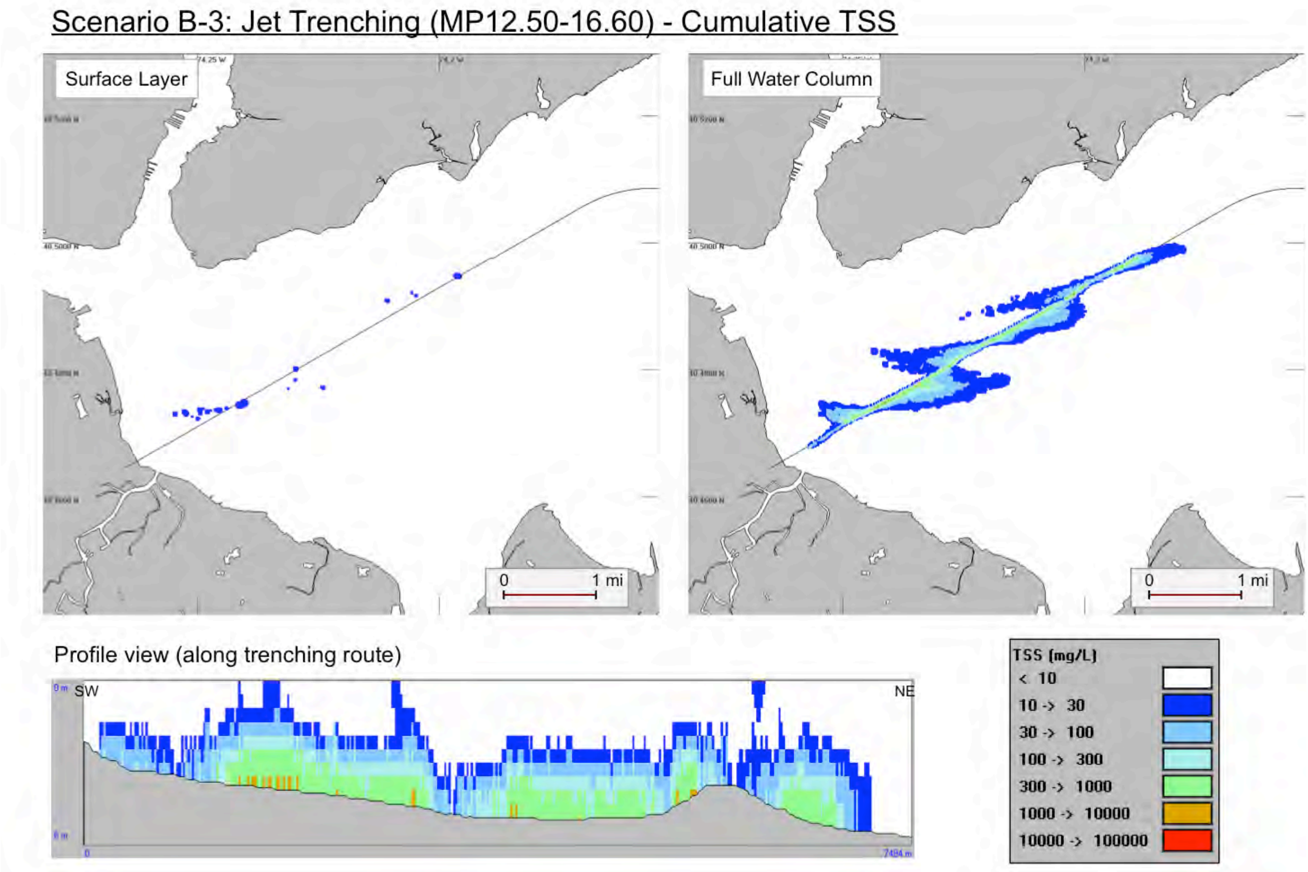

Figure 6. Cumulative TSS concentrations for Scenario B-3 after a single pass of the jet trencher (W to E), shown for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

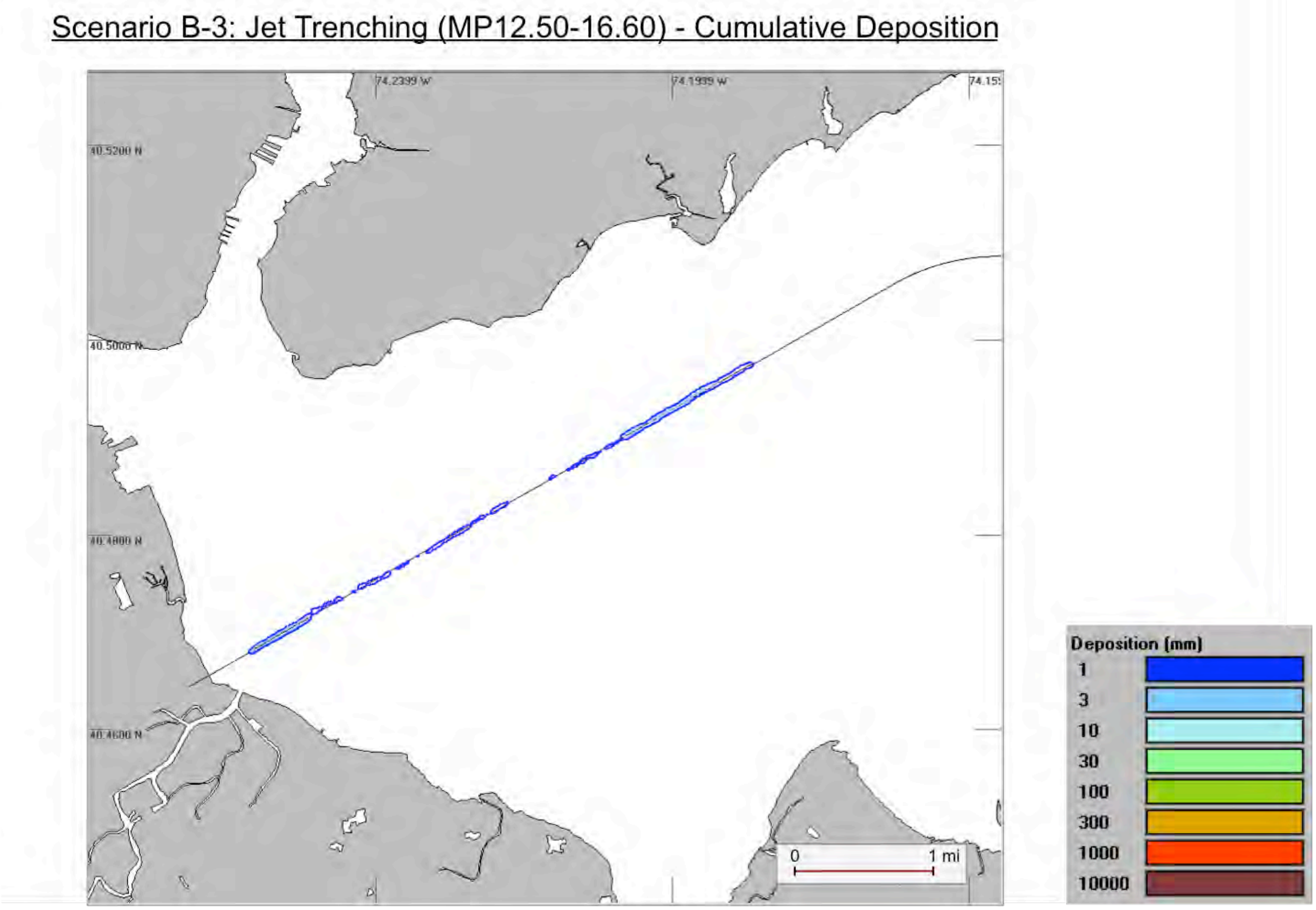

Figure 7. Extent of seabed deposition resulting from post-lay jet trenching between MP 12.50 and MP 16.60. Maximum predicted thickness = 0.3 in (6.9 mm).

3.4 Scenario B-4 – Excavation Activities at the Morgan Shore (0.5% loss)

Scenario B-4 includes two phases of construction associated with the Morgan Shore approach: (i) excavation of the Morgan Shore HDD pit to a depth of 14 ft, and (ii) installation of an offshore anode sled for cathode protection, buried to a minimum depth of 4 ft, approximately 1,200 feet northwest of the pipe centerline. Both activities were simulated as a stationary (point) source from their respective locations, with the assumption that total sediment losses would be limited to 0.5% of the trench volume through use of an environmental bucket and no overflow from the scow barge. Both involve excavation by clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Morgan Shore campaign is scheduled for Q3 2018, and the simulation was performed with a start date of September 2 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The dredge operates continuously for 23.8 hours during excavation of the HDD pit, and 1.2 hours for the anode sled area, with a break of approximately 24 hours between the two activities. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). A total 52 yd^3 of sediment is released from these two sources over the course of 2 days (1.04 days of active dredging).

Water column and sediment bed results from excavation at the Morgan Shore are presented in Figure 8 and Figure 9, and summarized in Table 2. The plume orientation (NW/SE), generally reflects the tidal current patterns near the site, which are aligned with the nearshore topography. Use of an environmental bucket limits the peak TSS levels predicted for this activity to 119 mg/L. Water column concentrations of 100 mg/L are predicted to extend a maximum of 148 ft from the source and TSS concentrations return to ambient levels within 0.4 hours (24 minutes) of the conclusion of dredging. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

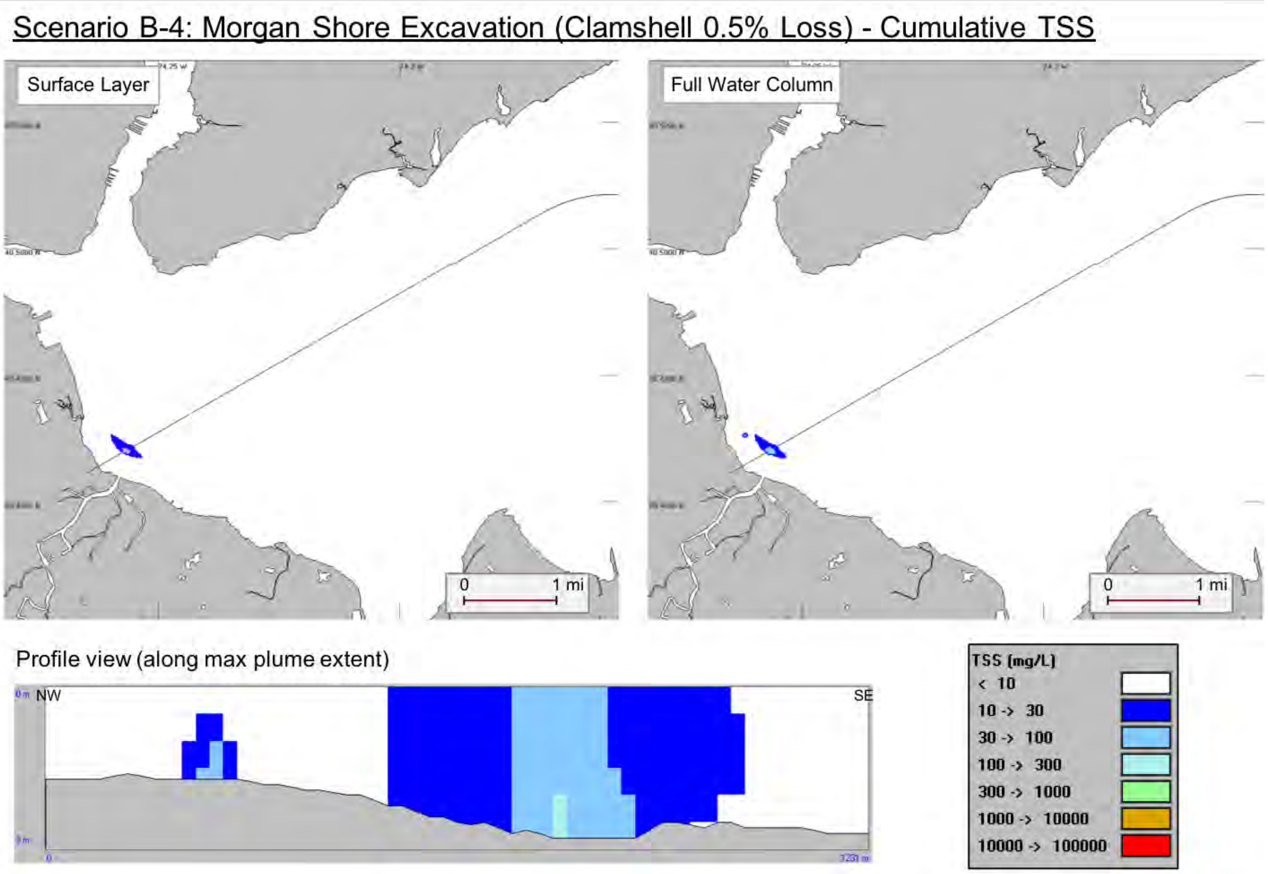

Figure 8. Cumulative TSS concentrations for Scenario B-4 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the maximum plume extent.

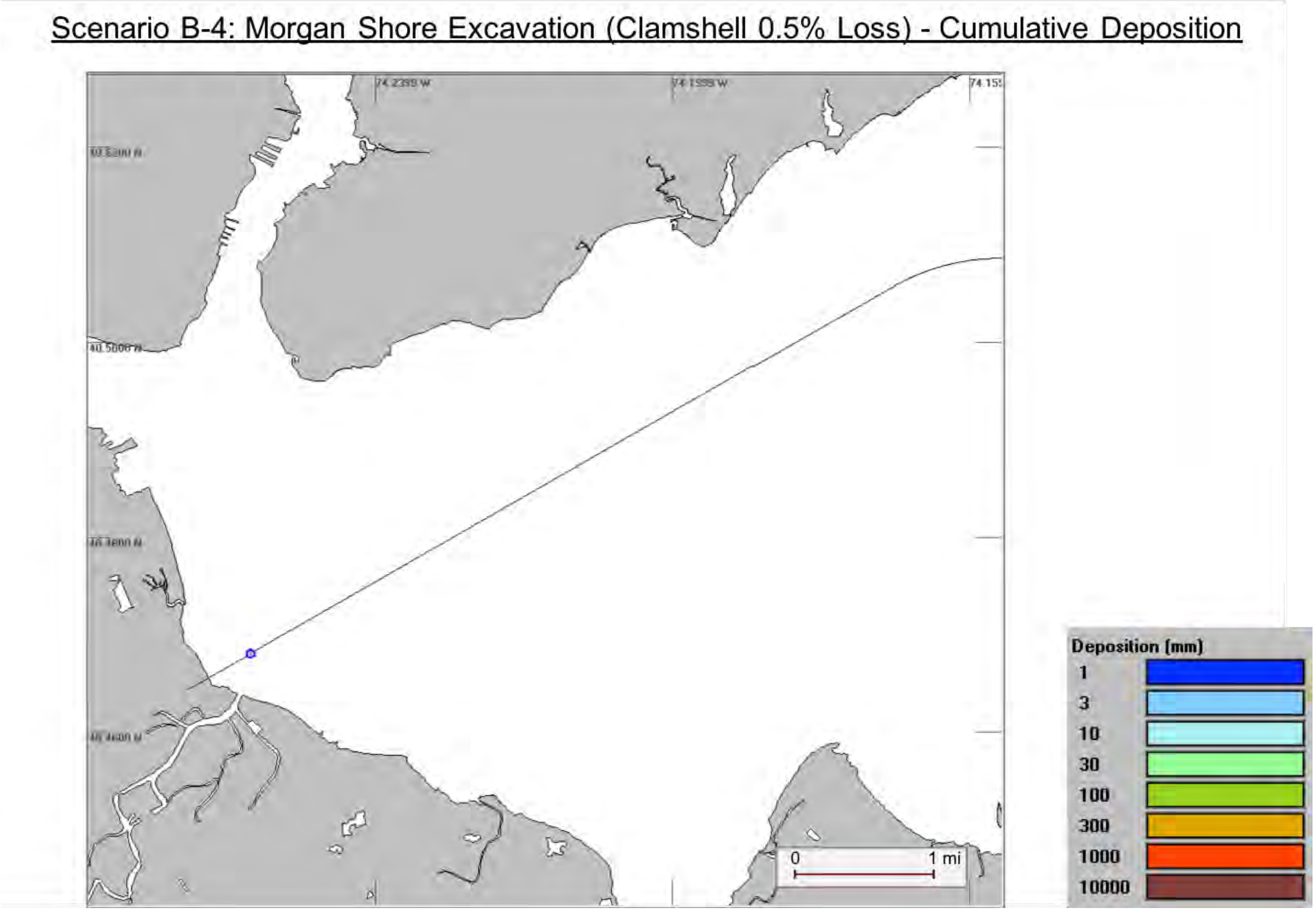

Figure 9. Extent of seabed deposition resulting from clamshell dredging activities (0.5% loss) at the Morgan Shore. Maximum predicted thickness = 0.2 in (6.2 mm).

3.5 Scenario B-5 – Clamshell Trenching Across the Raritan Channel (0.5% loss)

Scenario B-5 simulated releases associated with pre-lay trenching across the Raritan Channel (between MP 17.31 and MP 17.89) under the assumption that total sediment losses would be limited to 0.5% of the trench volume through use of an environmental bucket and no scow overflow. Along this reach, the pipeline will be buried to variable depths with a minimum 4 ft of cover. In total, 133,620 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of November 6 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 668 yd^3 of sediment over 13.4 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 17.31 and MP 17.89 are presented in Figure 10 and Figure 11, and summarized in Table 2. The plume is predicted to remain in close proximity to the dredge during most of the simulation, and as a result the cumulative plume footprint closely matches the trenching route. Instantaneous TSS concentrations remain below 30 mg/L throughout the simulation, with lowest values near the deepest sections of the channel. TSS concentrations rise toward either bank of the channel. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L; TSS concentrations are expected to return to ambient levels approximately 0.5 hours (27 minutes) after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

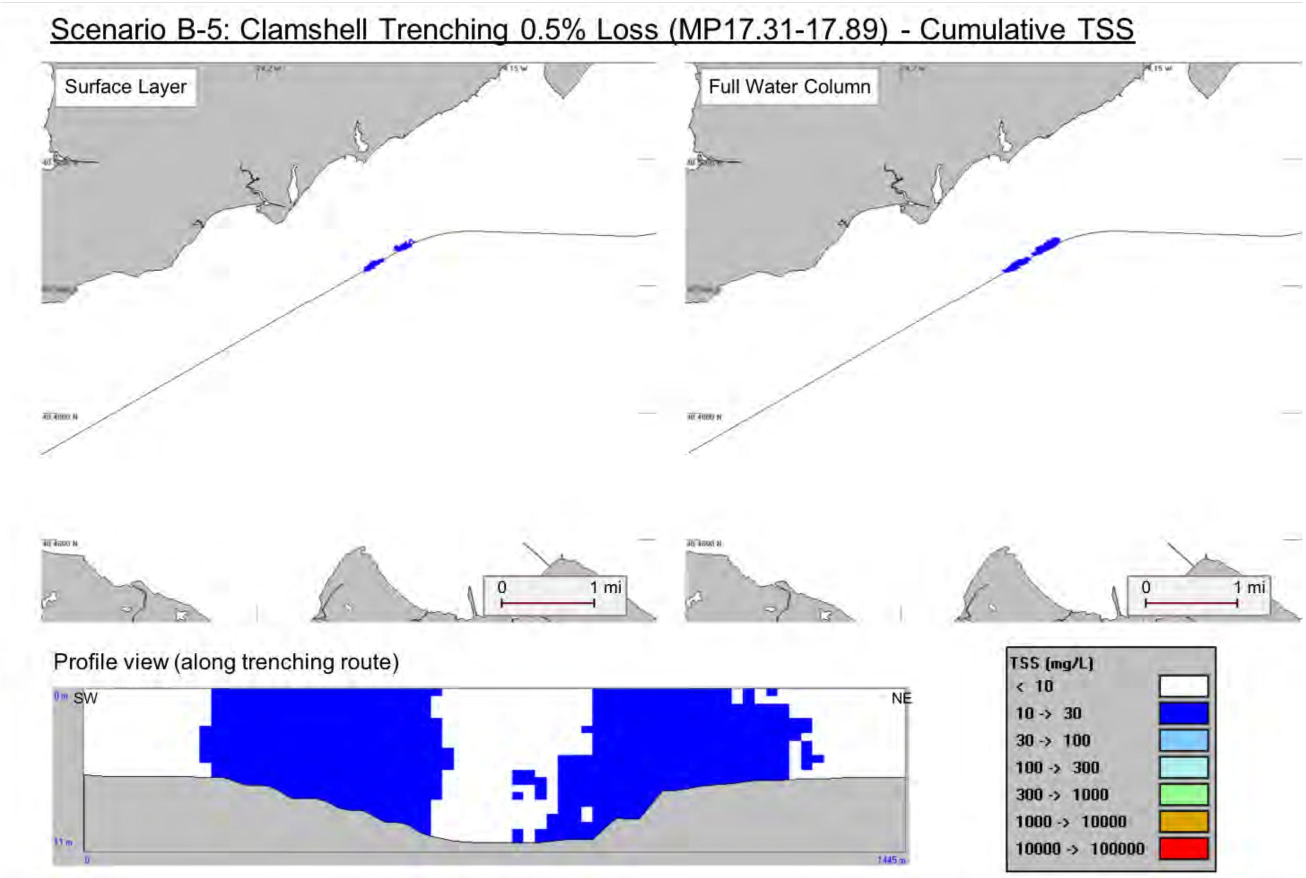

Figure 10. Cumulative TSS concentrations for Scenario B-5 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

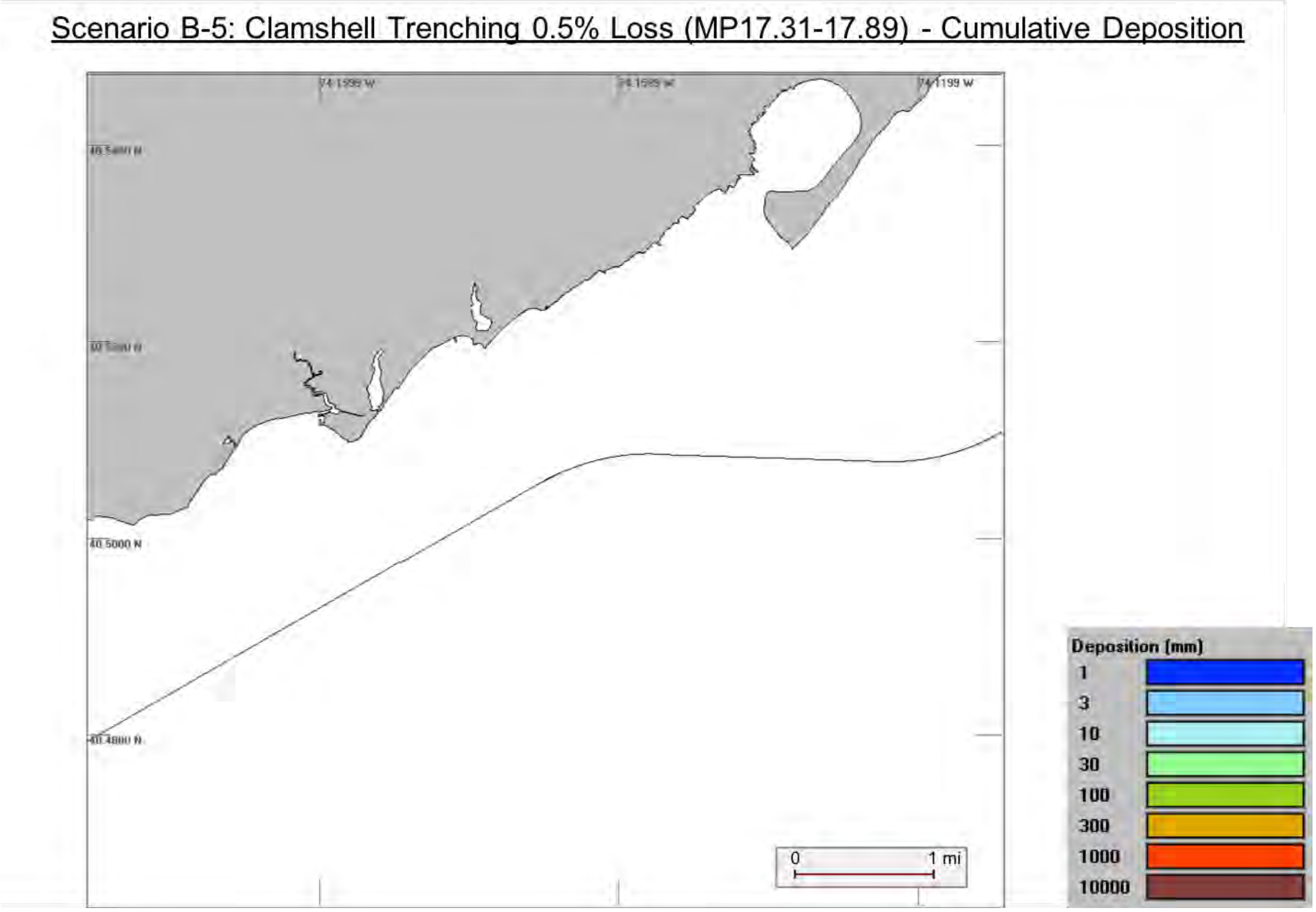

Figure 11. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) across the Raritan Channel between MP 17.31 and MP 17.89. Maximum predicted thickness = 0.03 in (0.7 mm).

3.6 Scenario B-6 – Clamshell Trenching Between the Anchorage Area and Chapel Hill Channel (0.5% loss)

Scenario B-6 simulated releases associated with pre-lay trenching between MP 24.00 and MP 25.22 (Anchorage Area through the Chapel Hill Channel), under the assumption that total sediment losses would be limited to 0.5% of the trench volume through use of an environmental bucket and no scow overflow. Along this reach, the pipeline will be buried to variable depths (between 4 and 7 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. In total, 112,472 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 562 yd^3 of sediment over 11.2 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 17.31 and MP 17.89 are presented in Figure 12 and Figure 13, and summarized in Table 2. As with Scenario B-5, the use of an environmental bucket and prevention of scow overflow is predicted to reduce TSS concentrations to very low levels throughout the simulation. At no point during the simulation are water column concentrations predicted to exceed 10 mg/L and TSS concentrations are expected to return to ambient levels immediately after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

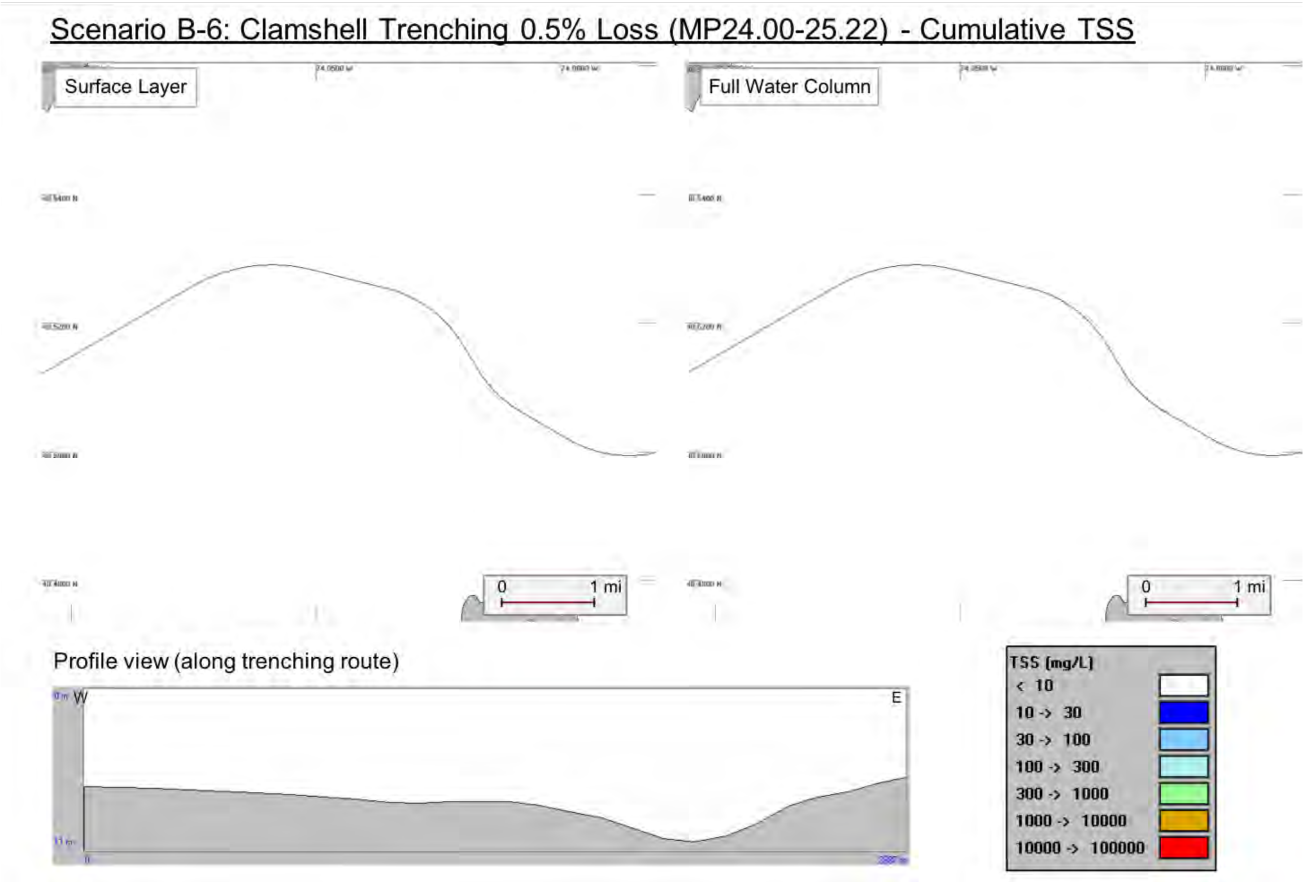

Figure 12. Cumulative TSS concentrations for Scenario B-6 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

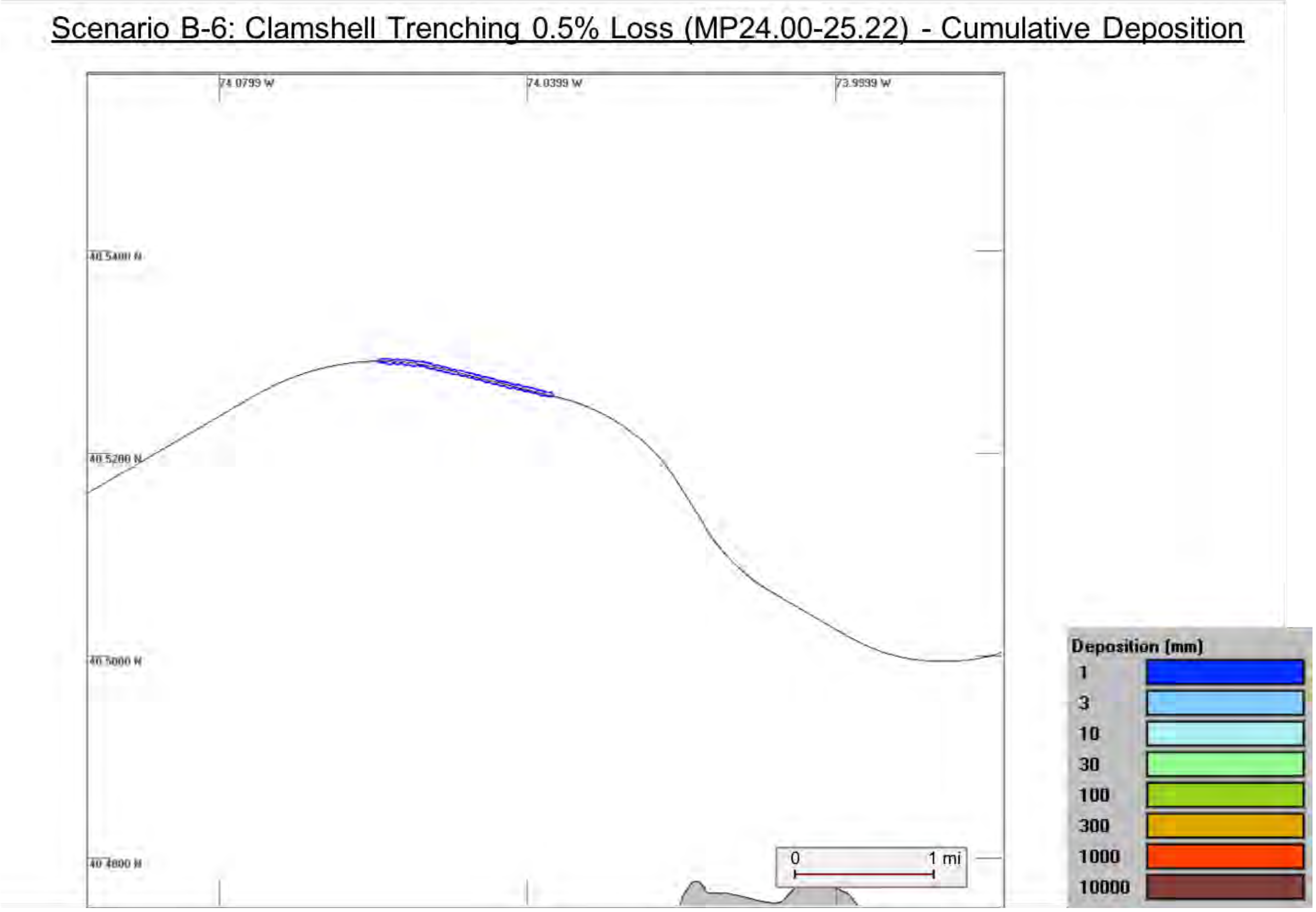

Figure 13. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) MP 24.00 and MP 25.22. Maximum predicted thickness = 0.1 in (3.2 mm).

3.7 Scenario B-7 – Excavation of the Ambrose Channel HDD Pit (West) (2.5% loss)

Scenario B-7 includes simulations of sediment disturbance associated with excavation of the HDD pit at MP 29.52, west of the Ambrose Channel, under the assumption that total sediment losses would be limited to 2.5% of the pit volume through use of an environmental bucket. The HDD pit will extend to a maximum of 20 ft below the grade of the seabed. During the excavation, approximately 14,050 yd^3 of sediment will be removed using a clamshell dredger and placed on a scow barge. The dredging was simulated as a stationary (point) source from the HDD pit location, and was assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed with a start date of August 1 to be consistent with the schedule applied for the “Base Case” (August 2017) and Addendum 1 (September 2017) modeling scenarios. The modeling assumes the dredge operates continuously for the duration of the excavation activity (33.7 hours) and losses from the clamshell bucket were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 351 yd^3 of sediment over 1.4 days of active dredge production.

Water column and sediment bed results from excavation at the Ambrose HDD pit (west) are presented in Figure 14 and Figure 15, and summarized in Table 2. At this location the TSS plume is notably aligned with the strong tidal currents that flow in and out of the Bay entrance. Peak concentrations occur directly above the HDD pit location, both at the surface (due to overflow) and at mid-depths (see cross-section of Figure 14). The plume extends laterally Northwest and Southeast from the release site, with slight elongation in the direction of the flood tide. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L; TSS concentrations remain elevated above ambient levels for 1.1 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 253 ft and covers 1.2 acres of the seabed.

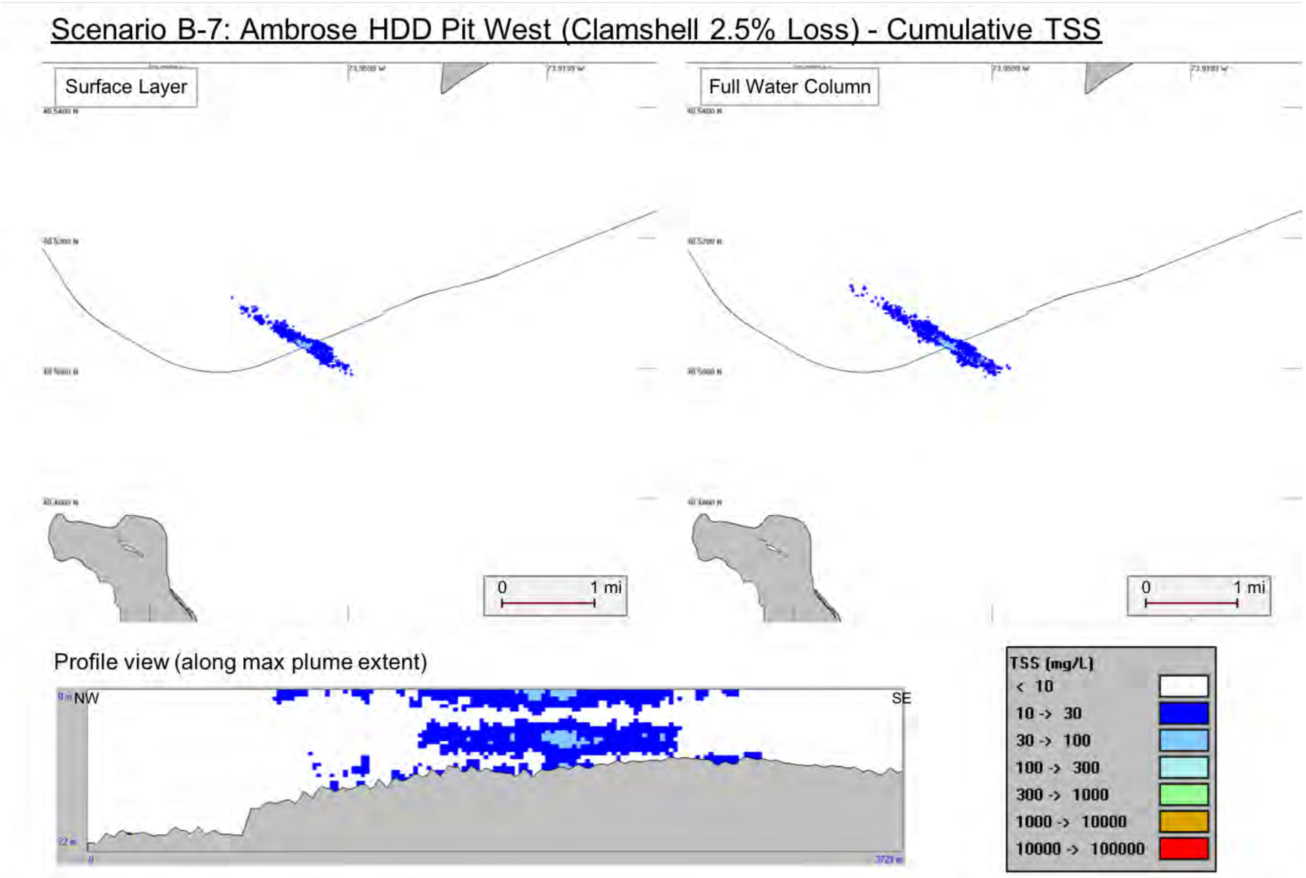

Figure 14. Cumulative TSS concentrations for Scenario B-7 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

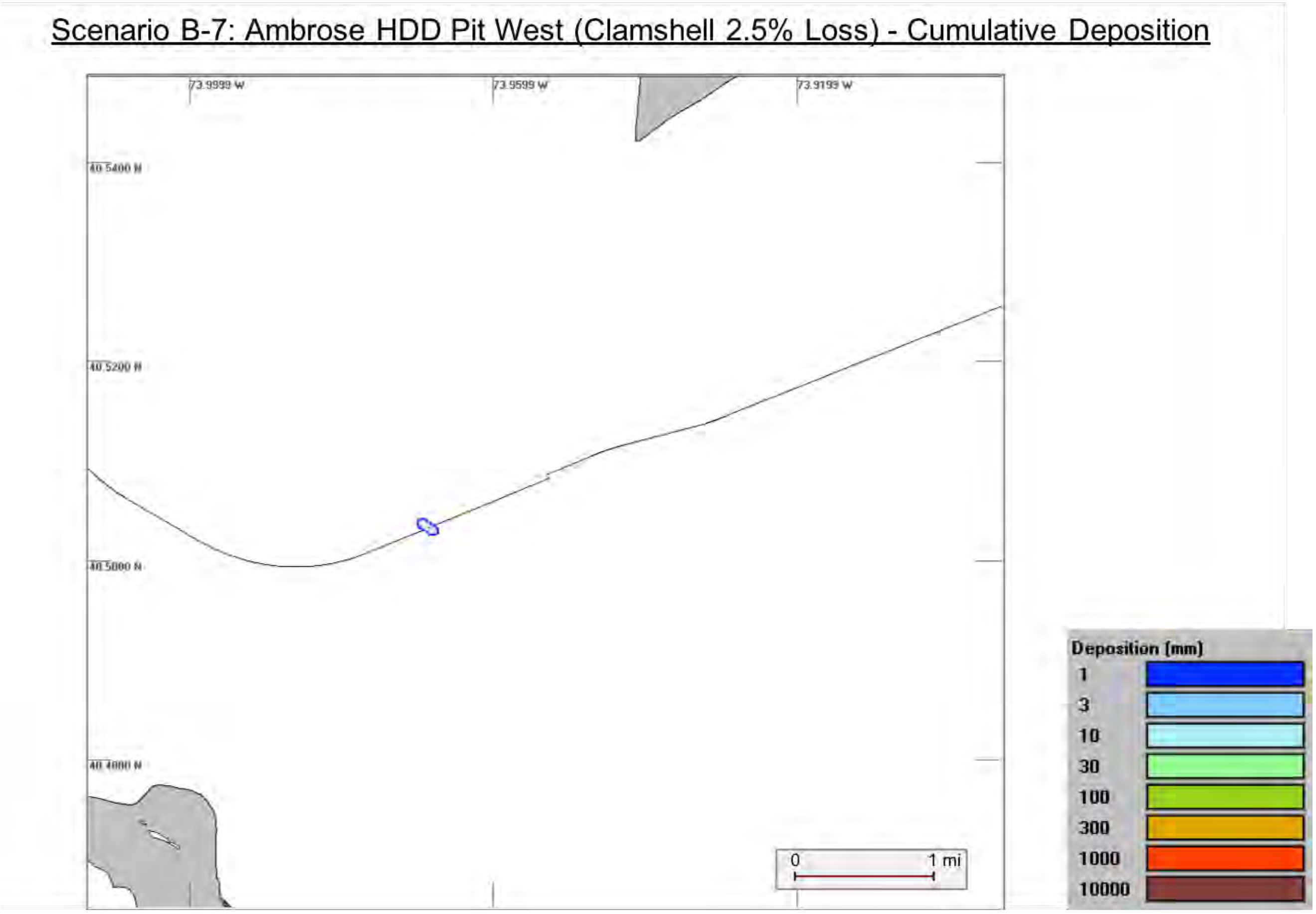

Figure 15. Extent of seabed deposition resulting from excavation of sediments at the Ambrose Channel HDD pit at MP 29.52. Maximum predicted thickness = 0.9 in (23.8 mm).

3.8 Scenario B-8 – Excavation of the Ambrose Channel HDD Pit (West) (0.5% loss)

Scenario B-8 includes simulations of sediment disturbance associated with excavation of the HDD pit at MP 29.52, west of the Ambrose Channel, under the assumption that total sediment losses would be limited to 0.5% of the pit volume through use of an environmental bucket and no scow overflow. The HDD pit will extend to a maximum of 20 ft below the grade of the seabed. During the excavation, approximately 14,050 yd^3 of sediment will be removed using a clamshell dredger and placed on a scow barge. The dredging was simulated as a stationary (point) source from the HDD pit location, and was assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed with a start date of August 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The modeling assumes the dredge operates continuously for the duration of the excavation activity (33.7 hours) and losses from the clamshell bucket were limited to 0.5% of the total excavation volume distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 70 yd^3 of sediment over 1.4 days of active dredge production.

Water column and sediment bed results from excavation at the Ambrose HDD pit (west) are presented in Figure 16 and Figure 17, and summarized in Table 2. Through most of the simulation, the use of an environmental bucket and prevention of scow overflow is predicted to limit excess TSS concentrations to levels below 10 mg/L. Portions of the model domain directly adjacent to the dredge location experience intermittent pulses of turbidity, although peak TSS remains below 15 mg/L for the duration of the simulation. TSS concentrations return to ambient levels immediately after the conclusion of dredging``. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

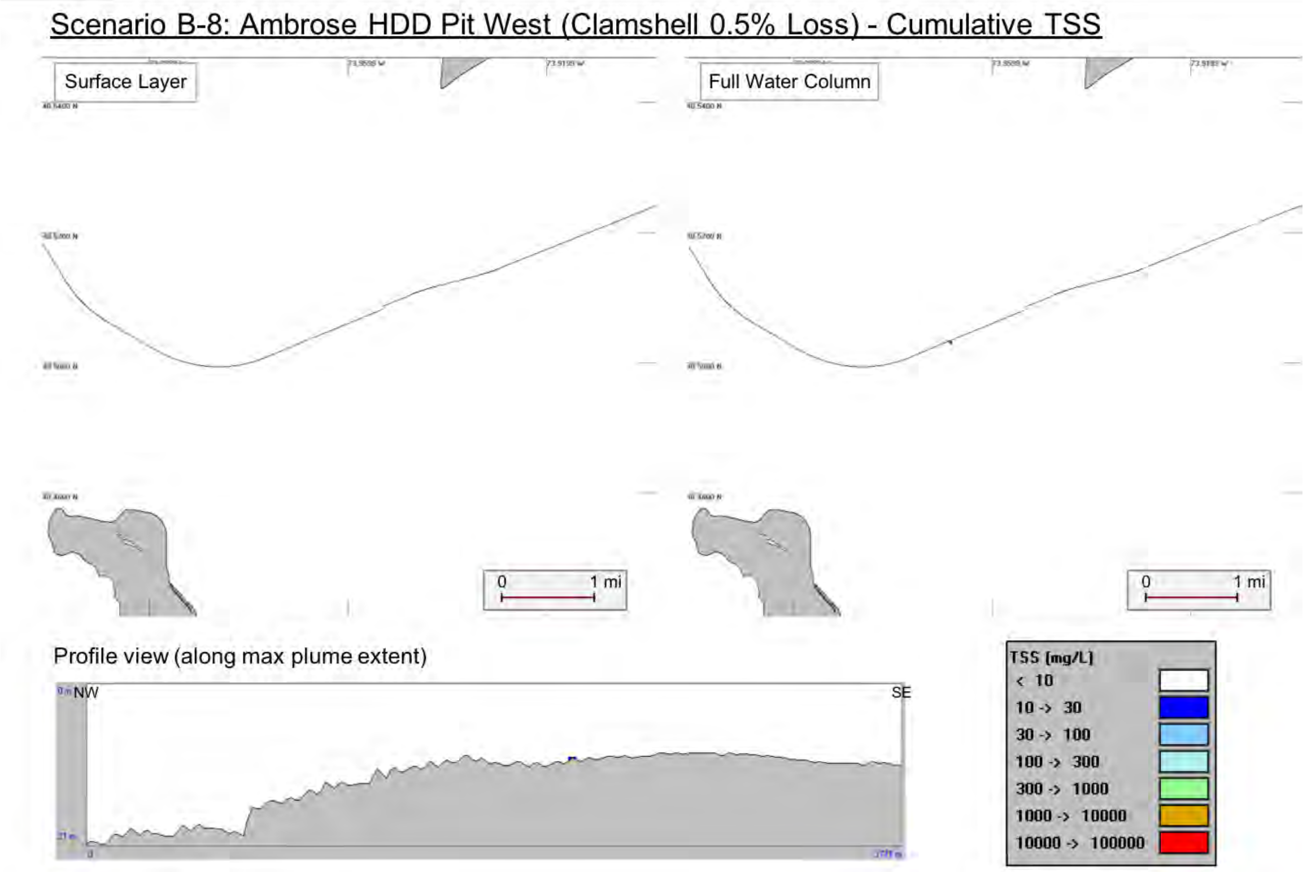

Figure 16. Cumulative TSS concentrations for Scenario B-8 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

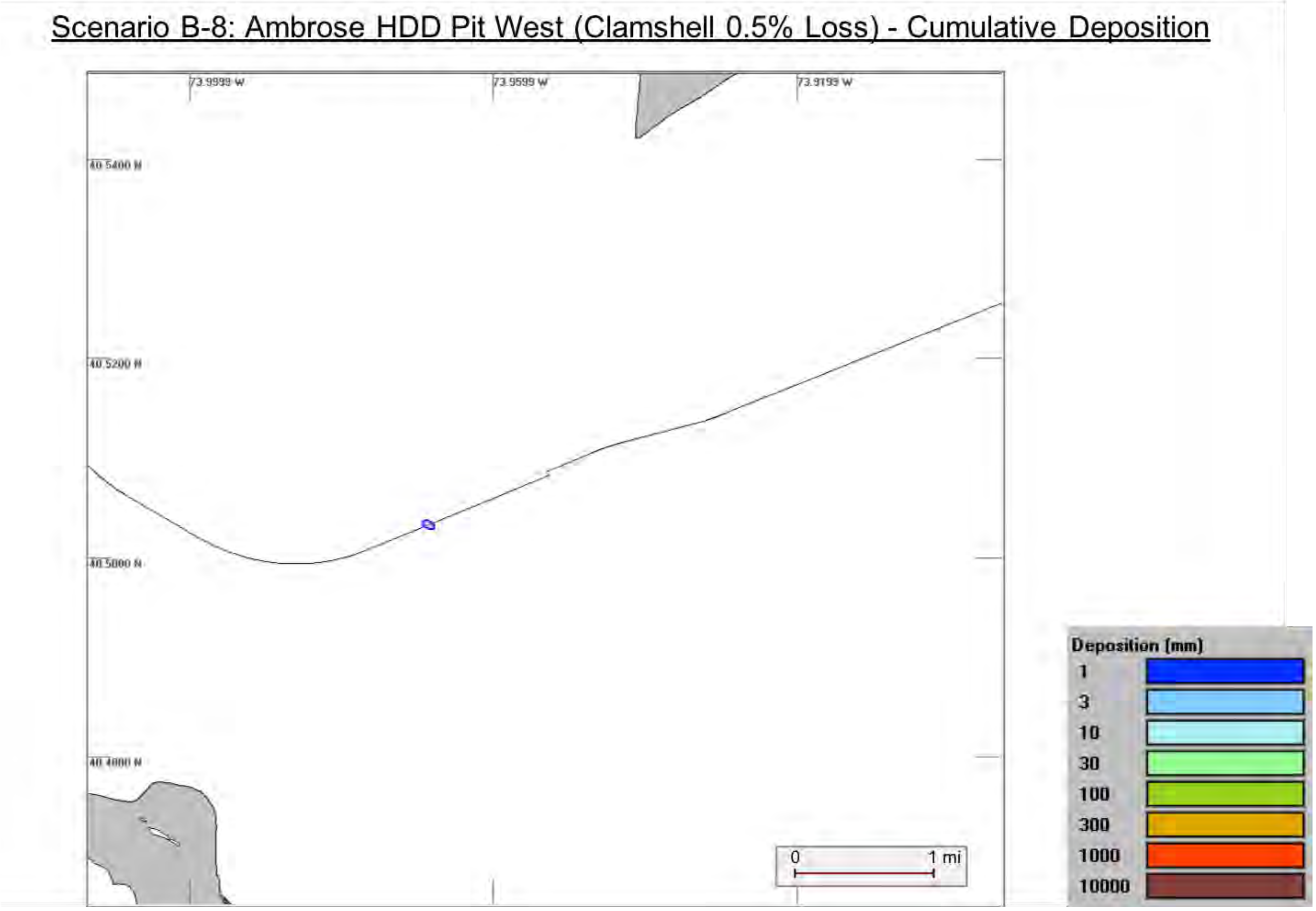

Figure 17. Extent of seabed deposition resulting from excavation of sediments at the Ambrose Channel HDD pit at MP 29.52. Maximum predicted thickness = 0.3 in (7.6 mm).

3.9 Scenario B-9 – Excavation of Ambrose Channel HDD Pit (East) and Tie-in (2.5% loss)

Scenario B-9 includes simulations of sediment disturbance associated with two phases of construction associated with the Ambrose HDD campaign: (i) excavation of the Ambrose Channel HDD pit (east) to a depth of 24 ft, and (ii) excavation of the tie-in point on the east side of the HDD to a depth of 7.5 ft. Both activities were simulated, in sequence as a stationary (point) source from the HDD pit location (MP 30.40) with the assumption that total sediment losses would be limited to 2.5% of the excavation volume through use of an environmental bucket. Both involve excavation by clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed with a start date of August 4 (immediately following the HDD pit excavation west of the channel) to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The modeling assumes the dredge operates continuously for 77.9 hours during excavation of the HDD pit, breaks for approximately 18 hours between the two activities, and begins operations for the tie-in point excavation at the start of the next calendar day. Excavation for the tie-in point is simulated continuously for 5.6 hours. Losses from the clamshell bucket were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 869 yd^3 of sediment over 3.4 days of active dredge production.

Water column and sediment bed results from excavation at the Ambrose Channel HDD (east) pit are presented in Figure 18 and Figure 19, and summarized in Table 2. Overall, TSS concentrations remain near background levels throughout the simulation, and plumes are notably reduced when compared to activities on the west bank of the channel modeled with comparable loss assumptions (Scenario B-7). Greater levels of sedimentation are also predicted at this location, in part due to larger excavation volumes, and also because of the coarse sediments present at this location. Water column concentrations are not predicted to exceed 100 mg/L during any part of the simulation and TSS concentrations return to ambient levels immediately after the conclusion of dredging (0 minutes). Sediment deposition at or above 0.4 in (1.0 cm) extends up to 243 ft and covers 2.7 acres of the seabed

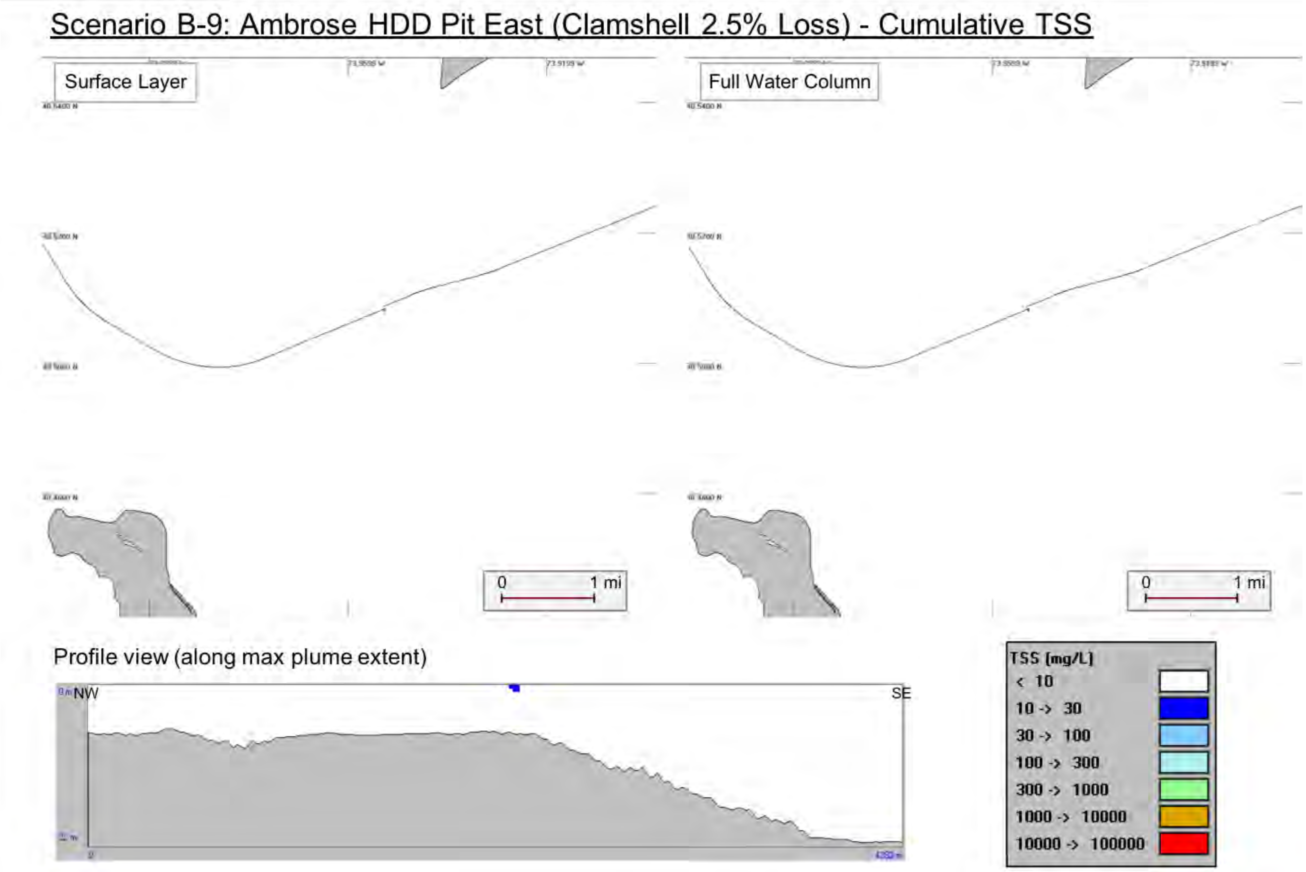

Figure 18. Cumulative TSS concentrations for Scenario B-9 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

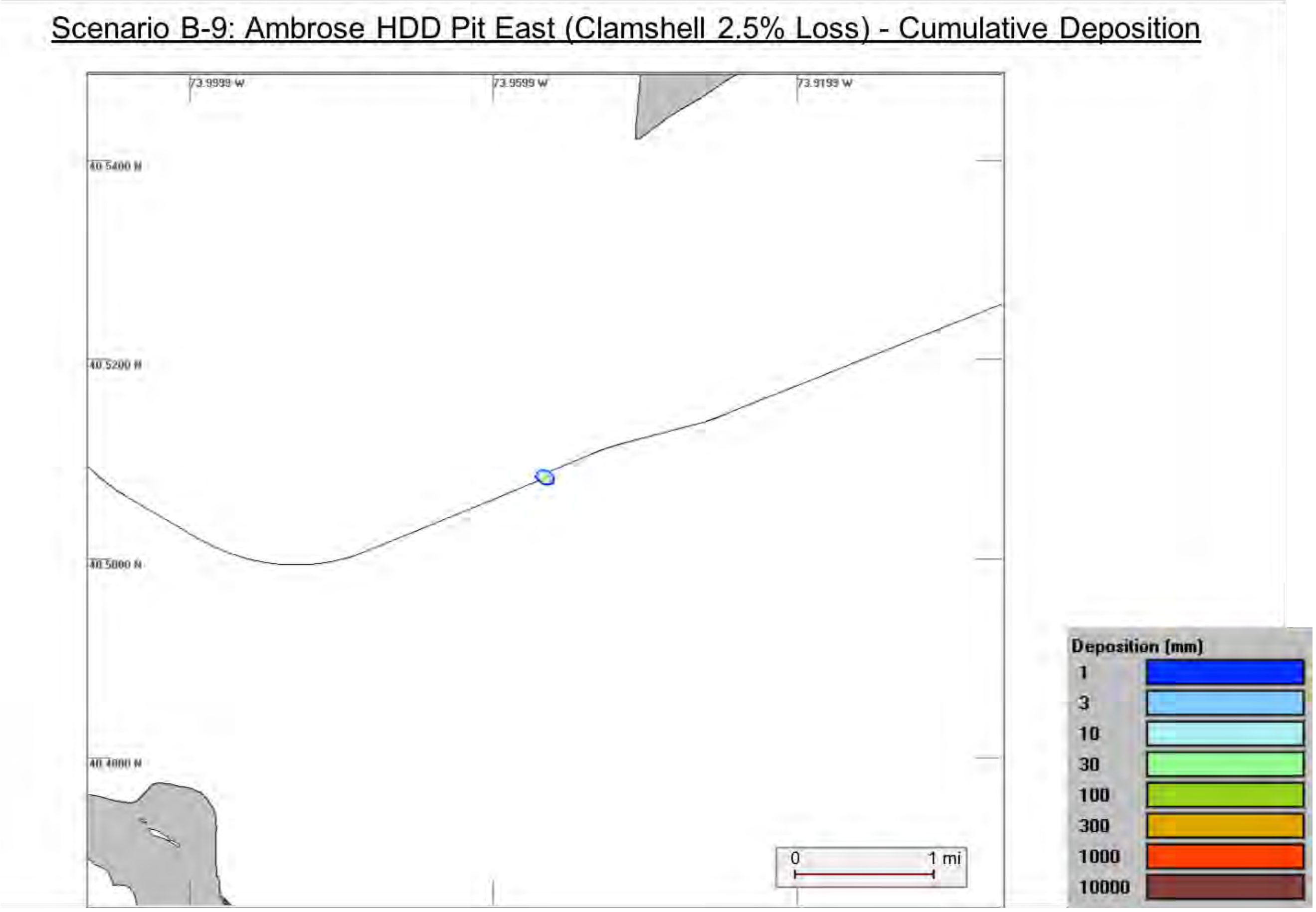

Figure 19. Extent of seabed deposition resulting from excavation of sediments at the Ambrose Channel HDD pit at MP 30.40. Maximum predicted thickness = 4.3 in (109.0 mm).

3.10 Scenario B-10 – Clamshell Trenching Between the Neptune Crossing and RDL Manifold (2.5% loss)

Scenario B-10 simulated releases associated with pre-lay trenching between MP 35.19 and the RDL tie-in point at MP 35.49 under the revised assumption that total sediment losses would be limited to 2.5% of the trench volume through use of an environmental bucket. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total, 13,152 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of February 6 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 329 yd^3 of sediment over 1.3 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 35.19 and MP 35.49 are presented in Figure 20 and Figure 21, and summarized in Table 2. A combination of strong surface currents offshore the Rockaway Peninsula and coarse sediments along this section of the route limit the formation of plumes in the upper water column. Excess TSS concentrations generally remain confined to the lower half of the water column, with peak concentrations found at mid-depths. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L; TSS concentrations are expected to return to ambient levels approximately 0.6 hours (35 minutes) after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

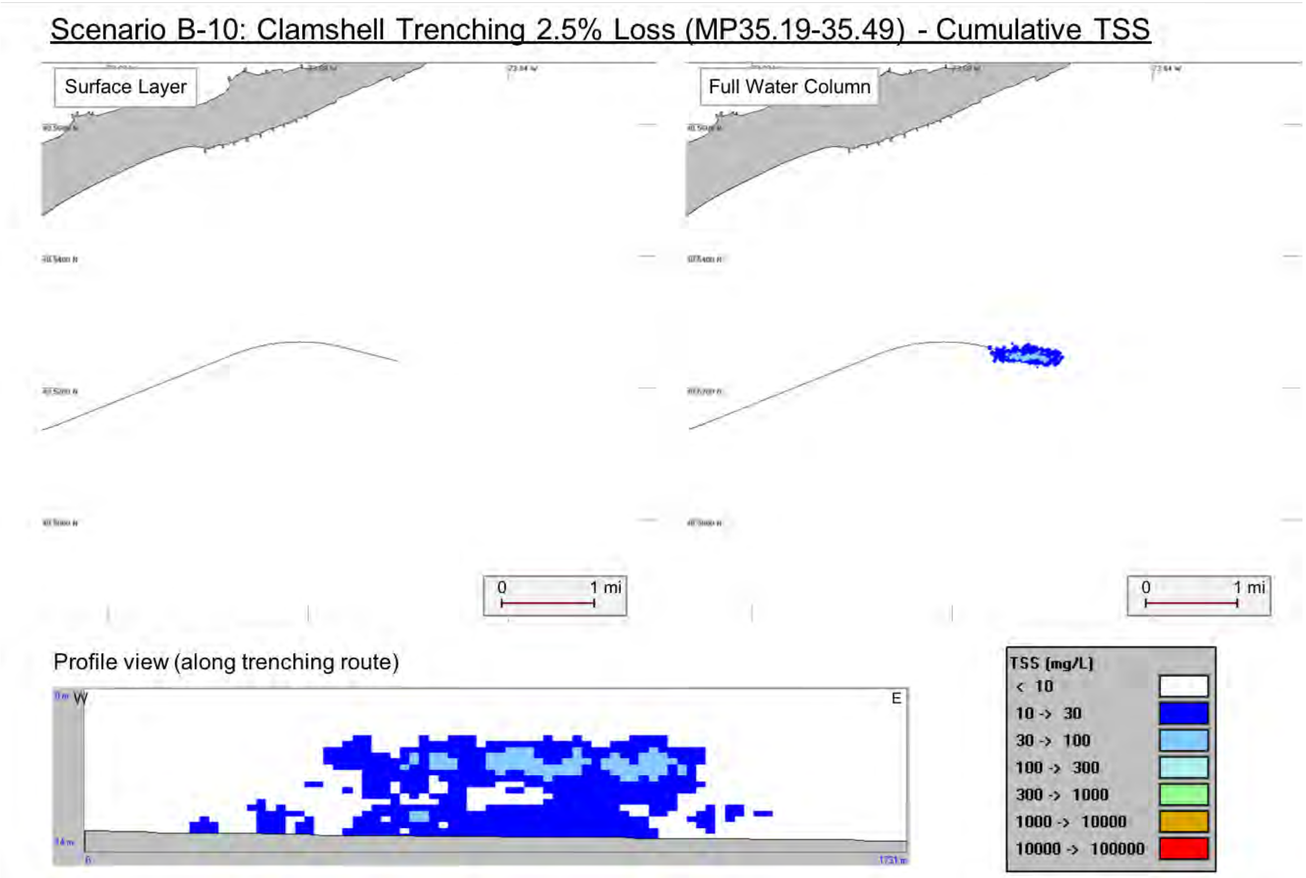

Figure 20. Cumulative TSS concentrations for Scenario B-10 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

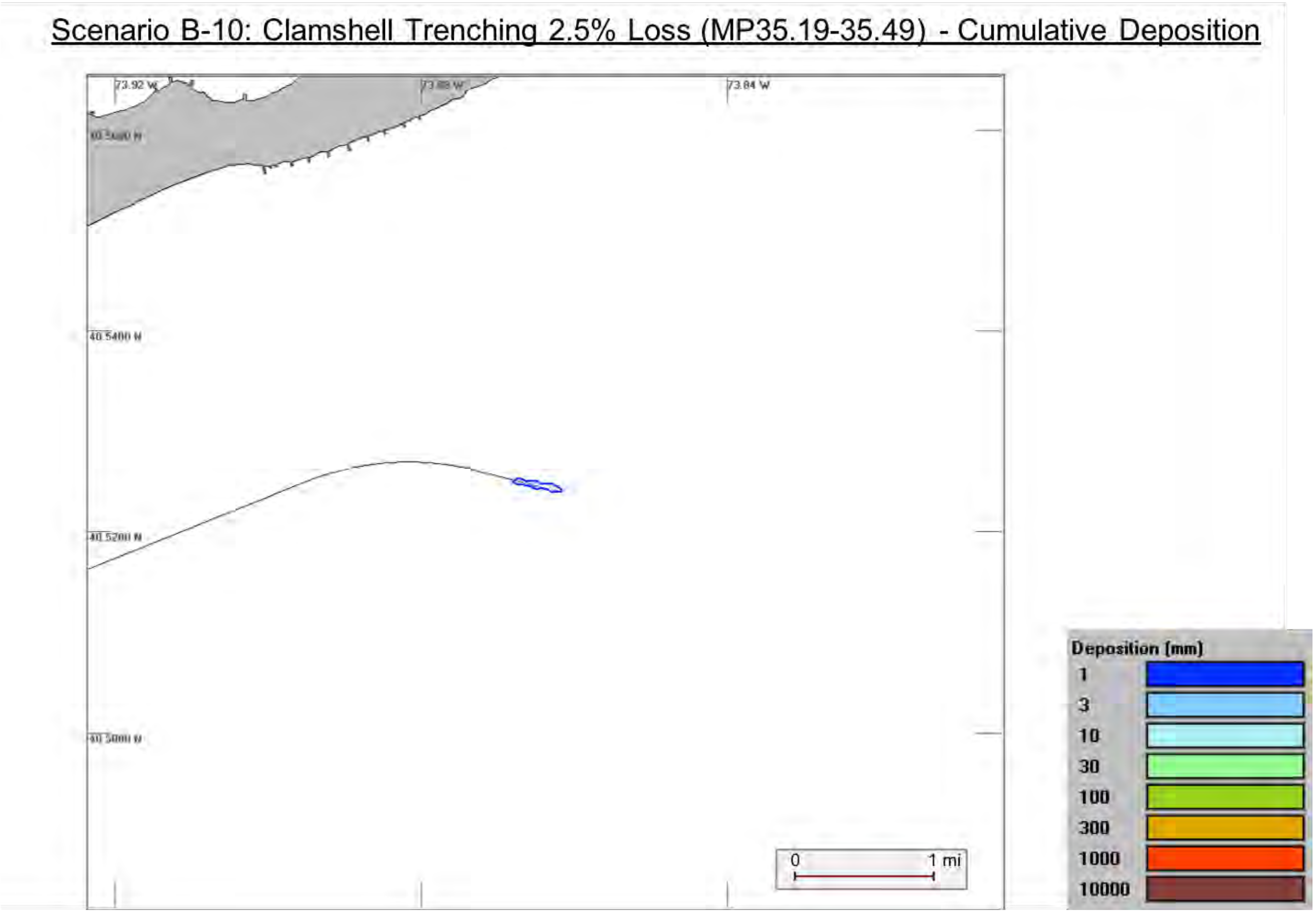

Figure 21. Extent of seabed deposition resulting from pre-lay clamshell trenching (2.5% loss) between MP 35.19 and MP 35.49. Maximum predicted thickness = 0.3 in (8.4 mm).

3.11 Scenario B-11 – Dredging of Backfill Material from the Ambrose Channel (2.5% loss)

Scenario B-11 simulated releases associated with the dredging of backfill source material from the Ambrose Channel under the assumption that total sediment losses would be limited to 2.5% of the dredging volume through use of an environmental bucket. A total of 666,649 yd^3 of sediment may be needed to backfill portions of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Ambrose Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill purposes. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (away from Raritan Bay) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from dredging were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 5,555 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Ambrose Channel are presented in Figure 22 and Figure 23, and summarized in Table 2. Elevated TSS concentrations are predicted throughout most of the water column along the dredge route, with the notable exception of the surface layers where concentrations do not exceed ambient levels. This presentation is likely the result of (i) rapid settling of coarse-grained sediments from within the channel, and (ii) strong current velocities that rapidly disperse overflow sediments at the sea surface. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,033 ft from the source and TSS concentrations remain elevated above ambient levels for 1.0 hour after the conclusion of dredging. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

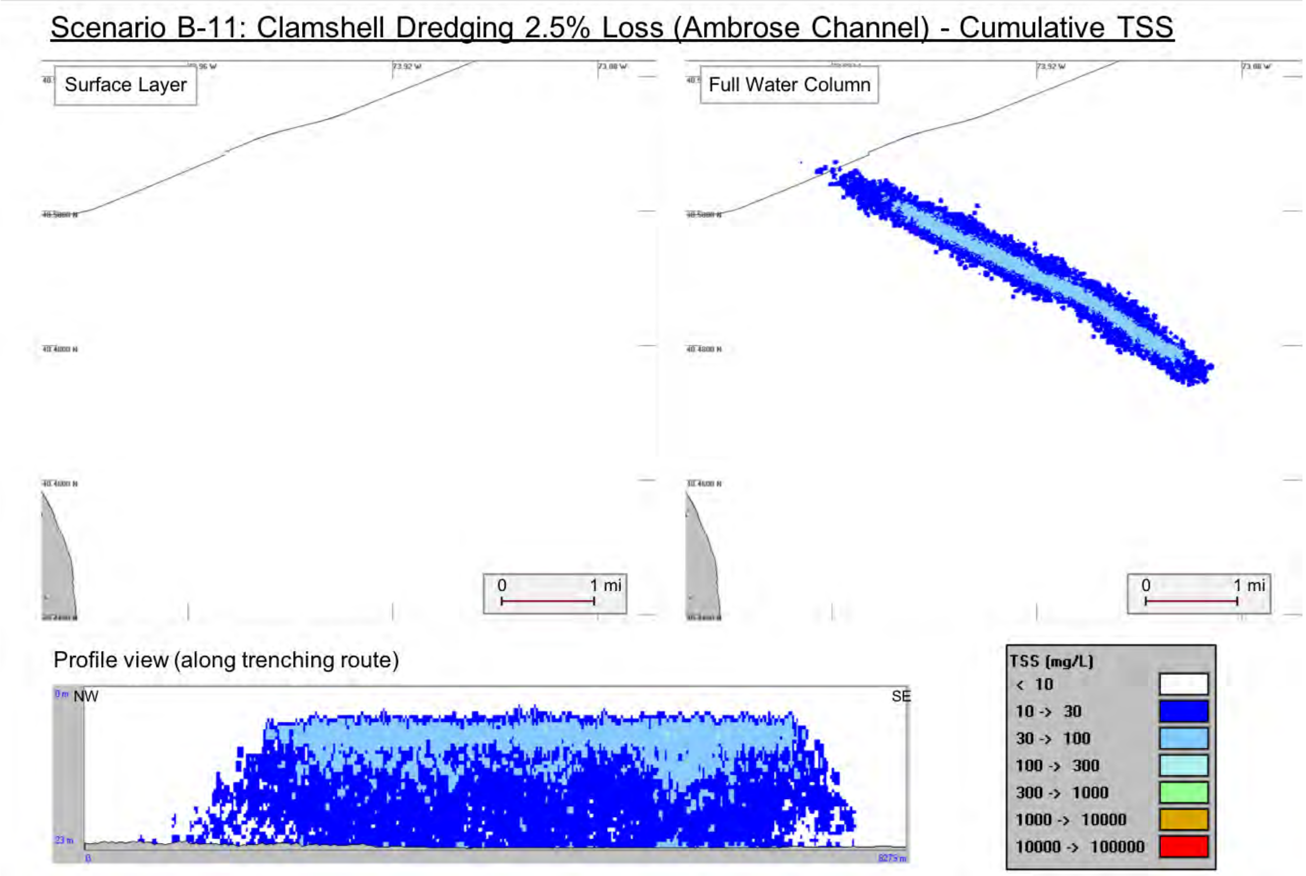

Figure 22. Cumulative TSS concentrations for Scenario B-11 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

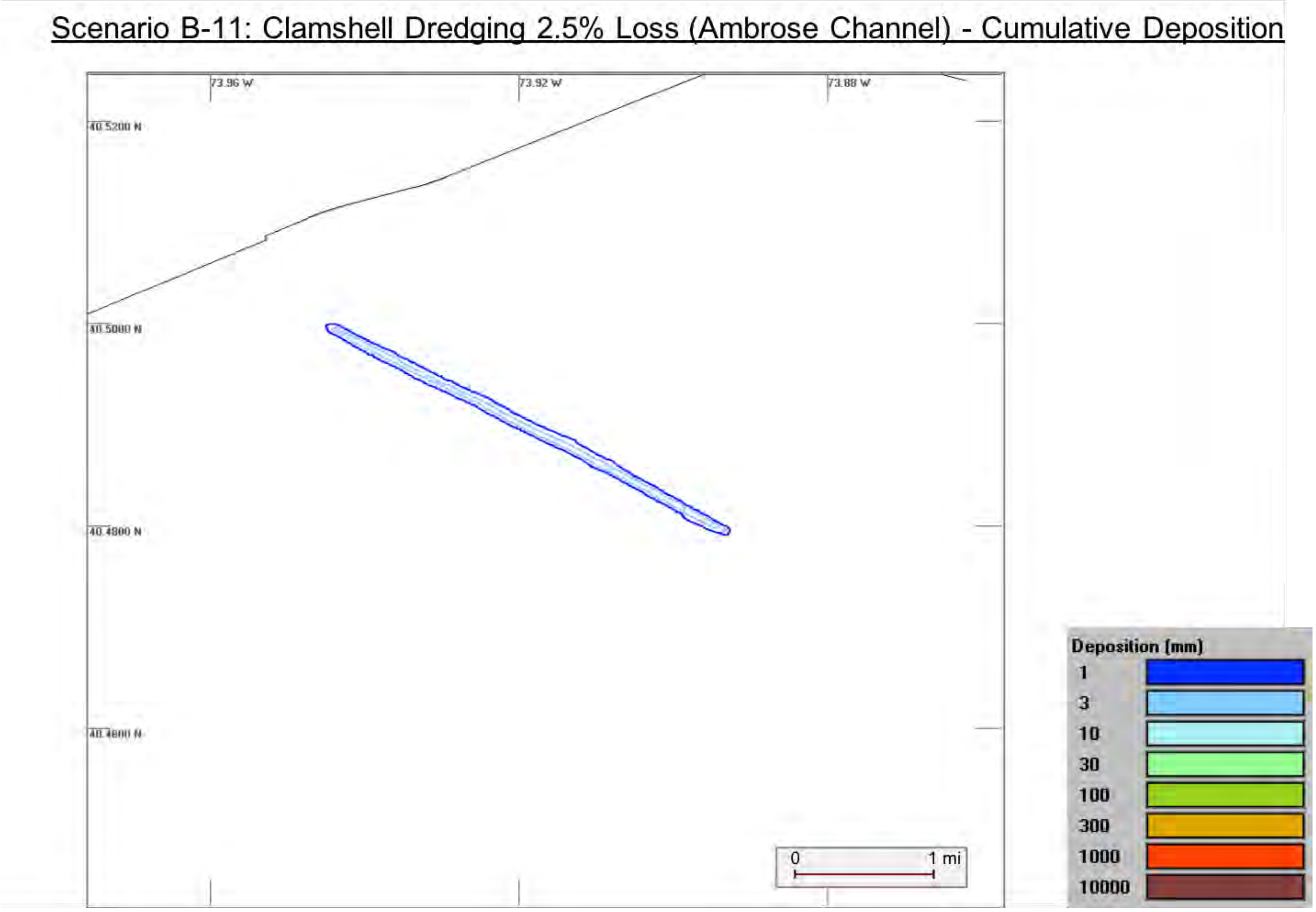

Figure 23. Extent of seabed deposition resulting from dredging of backfill material at the Ambrose Channel. Maximum predicted thickness = 0.2 in (5.6 mm).

3.12 Scenario B-12 – Dredging of Backfill Material from the Rockaway Inlet (2.5% loss)

Scenario B-12 simulated releases associated with the dredging of backfill source material from the Rockaway Inlet under the assumption that total sediment losses would be limited to 2.5% of the dredging volume through use of an environmental bucket. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Rockaway Inlet (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (South to North) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from dredging were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 5,555 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Rockaway Inlet are presented in Figure 24 and Figure 25, and summarized in Table 2. Elevated TSS levels increase with depth at this location. As with Scenario B-11 the results are influenced by rapid settling of coarse-grained sediments within the channel, although the relatively shallow depths at this location result in peak concentrations just above the seabed. Water column concentrations of 100 mg/L are predicted to extend a maximum of 2,116 ft from the source and TSS concentrations remain elevated above ambient levels for 0.2 hours (14 minutes) after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 131 ft from the source and covers a total of 15.6 acres of the seabed.

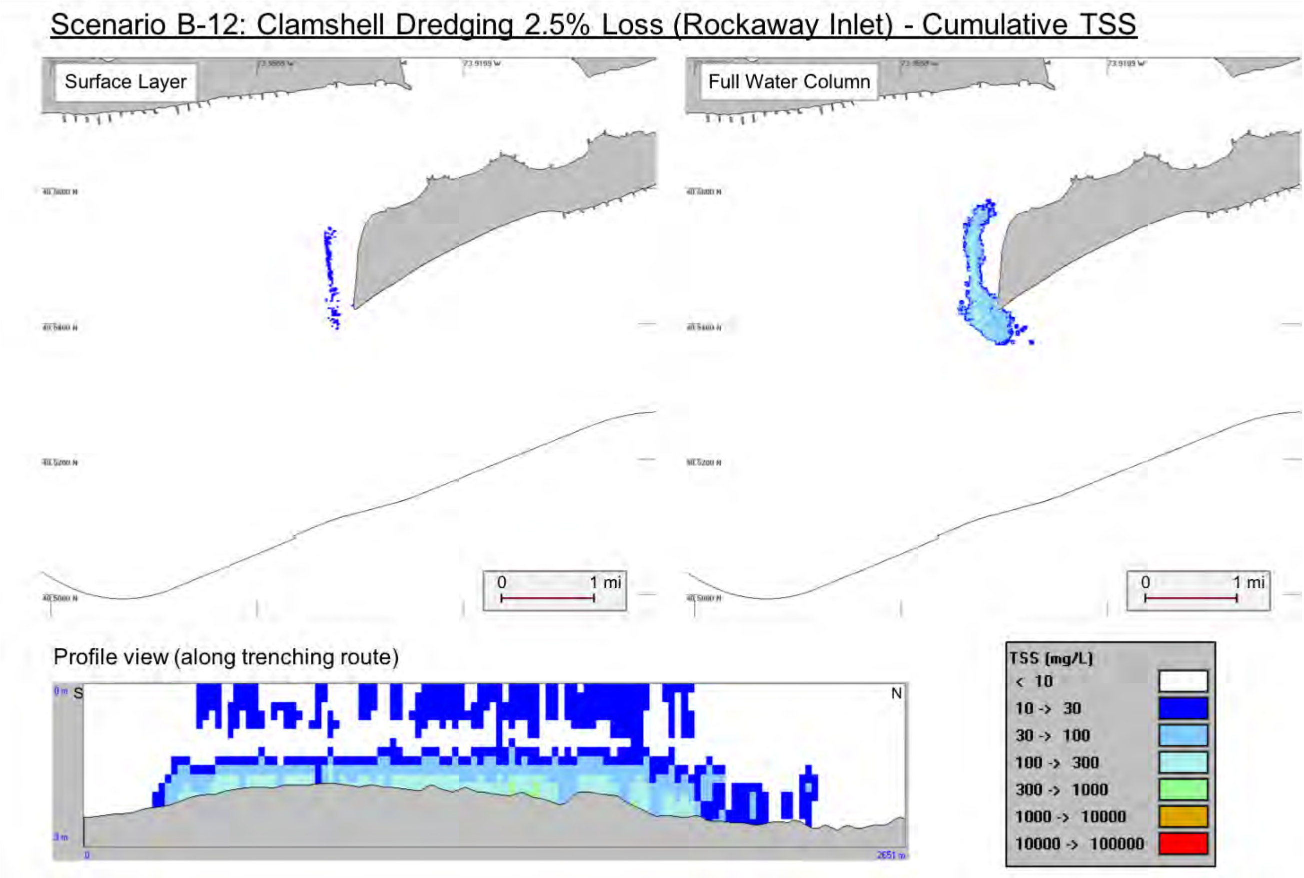

Figure 24. Cumulative TSS concentrations for Scenario B-12 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

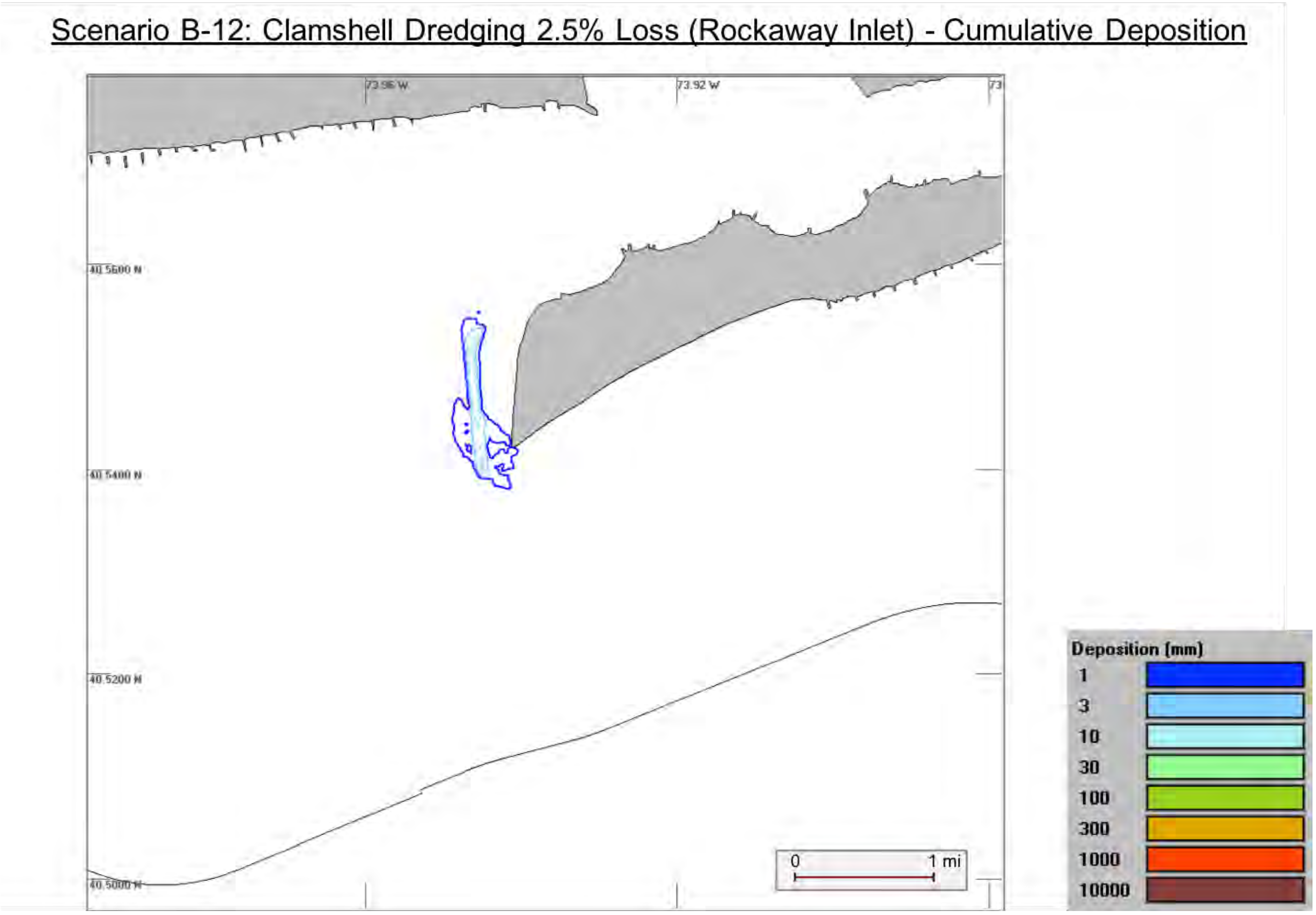

Figure 25. Extent of seabed deposition resulting from dredging of backfill material at the Rockaway Inlet. Maximum predicted thickness = 1.0 in (26.4 mm).

3.13 Scenario B-13 – Dredging of Backfill Material from the Earle Channel (2.5% loss)

Scenario B-13 simulated releases associated with the dredging of backfill source material from the Earle Channel under the assumption that total sediment losses would be limited to 2.5% of the dredging volume through use of an environmental bucket. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Earle Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Although the Earle Channel is separated into two distinct dredge areas, the model was run as a single uninterrupted dredge operation, with an instantaneous transition between the two dredge areas. Losses from the dredge were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 5,555 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Earle Channel are presented in Figure 26 and Figure 27, and summarized in Table 2. Similar to B-11, the plume has limited surface expression and peak TSS levels are predicted at mid-depths. Minor increases in TSS concentrations (up to 30 mg/L above ambient) are predicted at the surface along the inner end of the channel segment that may be dredged, west of the Sandy Hook Peninsula, where mean grain sizes are finer. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,099 ft from the source and TSS concentrations remain elevated above ambient levels for 0.8 hours after the conclusion of dredging. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

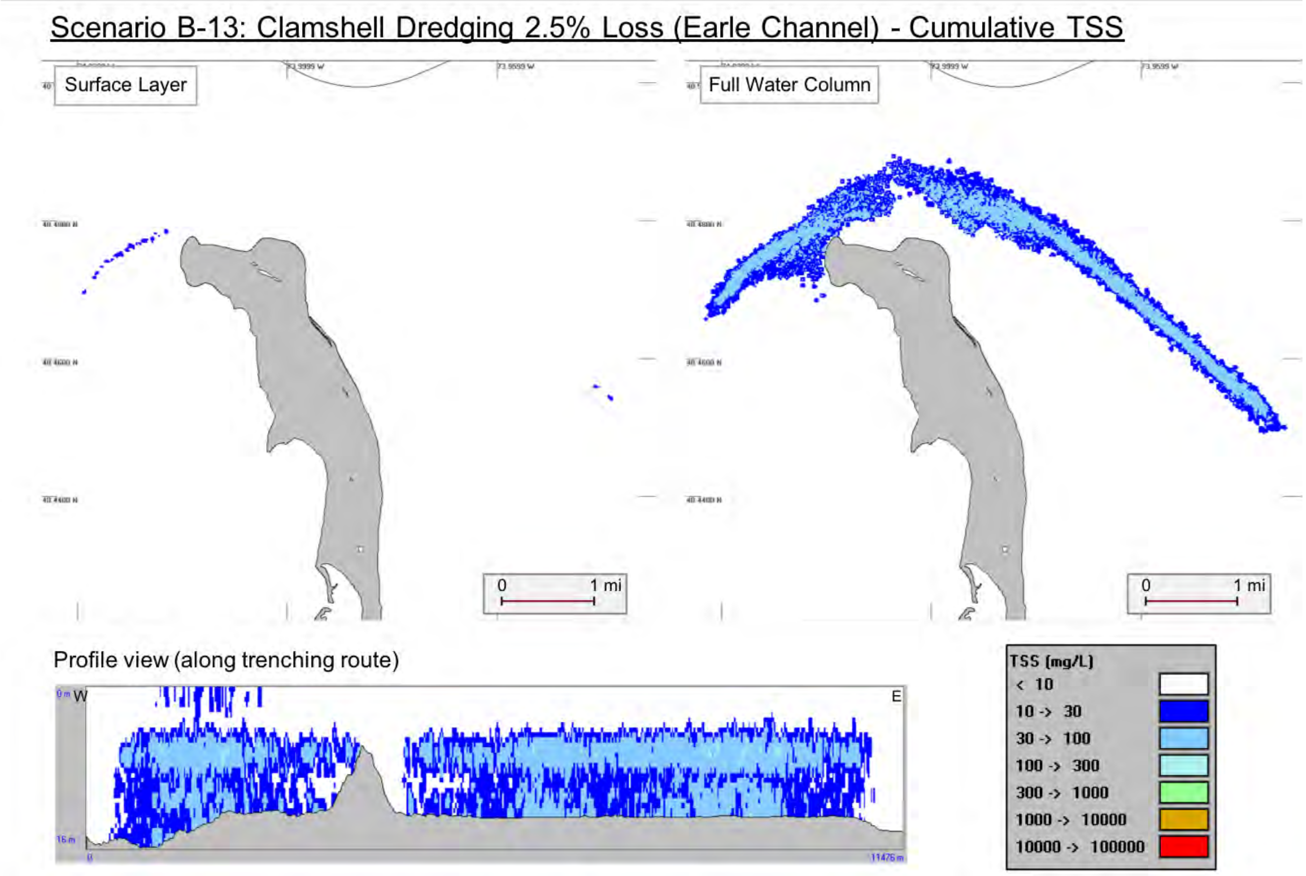

Figure 26. Cumulative TSS concentrations for Scenario B-13 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

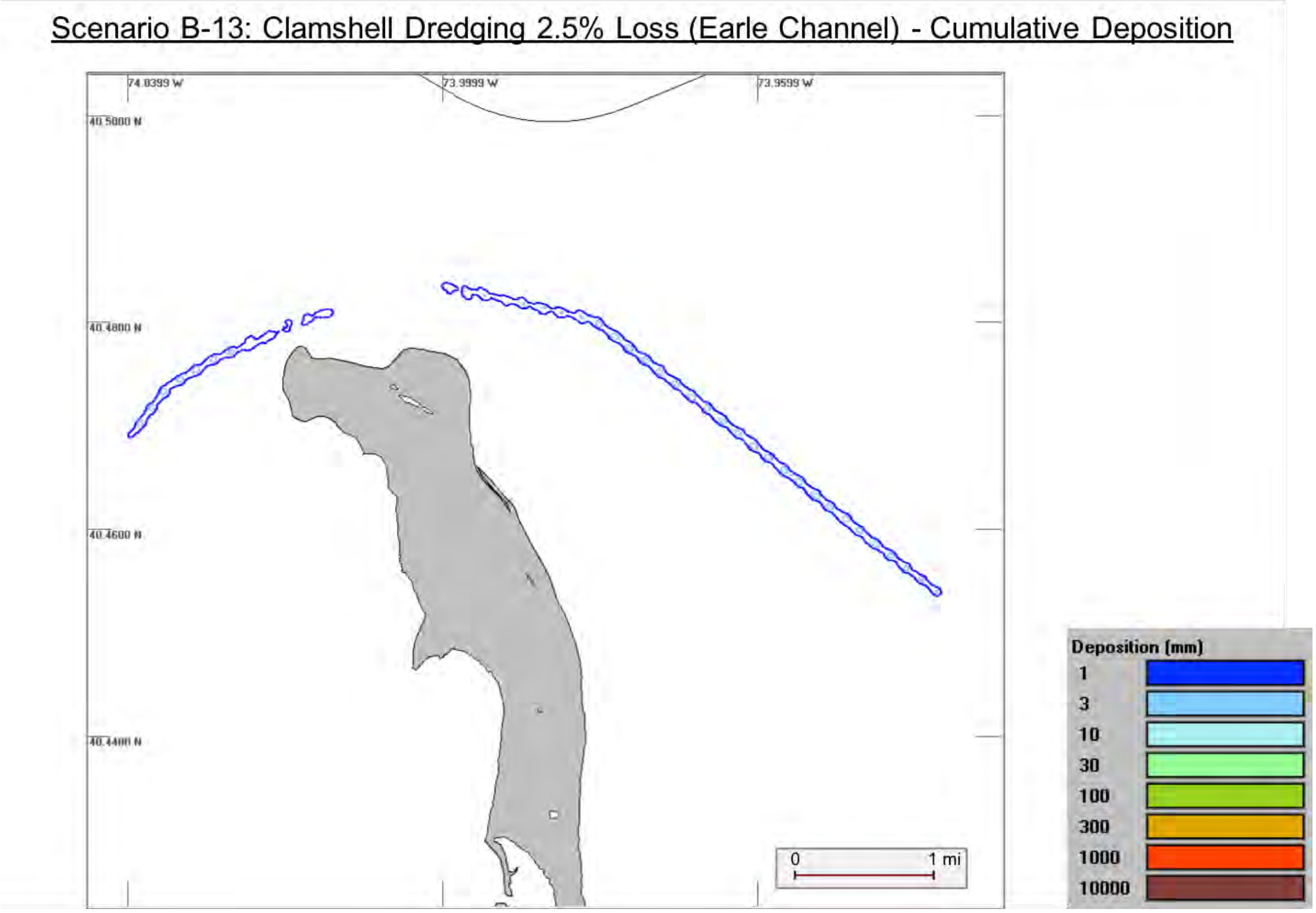

Figure 27. Extent of seabed deposition resulting from dredging of backfill material at the Earle Channel. Maximum predicted thickness = 0.2 in (6.3 mm).

3.14 Scenario B-14 – Dredging of Backfill Material from the Ambrose Channel (0.5% loss)

Scenario B-14 simulated releases associated with the dredging of backfill source material from the Ambrose Channel under the assumption that total sediment losses would be limited to 0.5% of the dredging volume through use of an environmental bucket and no scow overflow. A total of 666,649 yd^3 of sediment may be needed to backfill portions of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Ambrose Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill purposes. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (away from Raritan Bay) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 1,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Ambrose Channel are presented in Figure 28 and Figure 29 and summarized in Table 2. Elevated TSS concentrations occur intermittently during the simulation at mid-depths, though sustained concentrations rarely exceed 10 mg/L. As with Scenario B-11, TSS concentrations within the surface layers do not exceed ambient levels. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations return to ambient levels immediately after the conclusion of dredging (0 minutes). Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

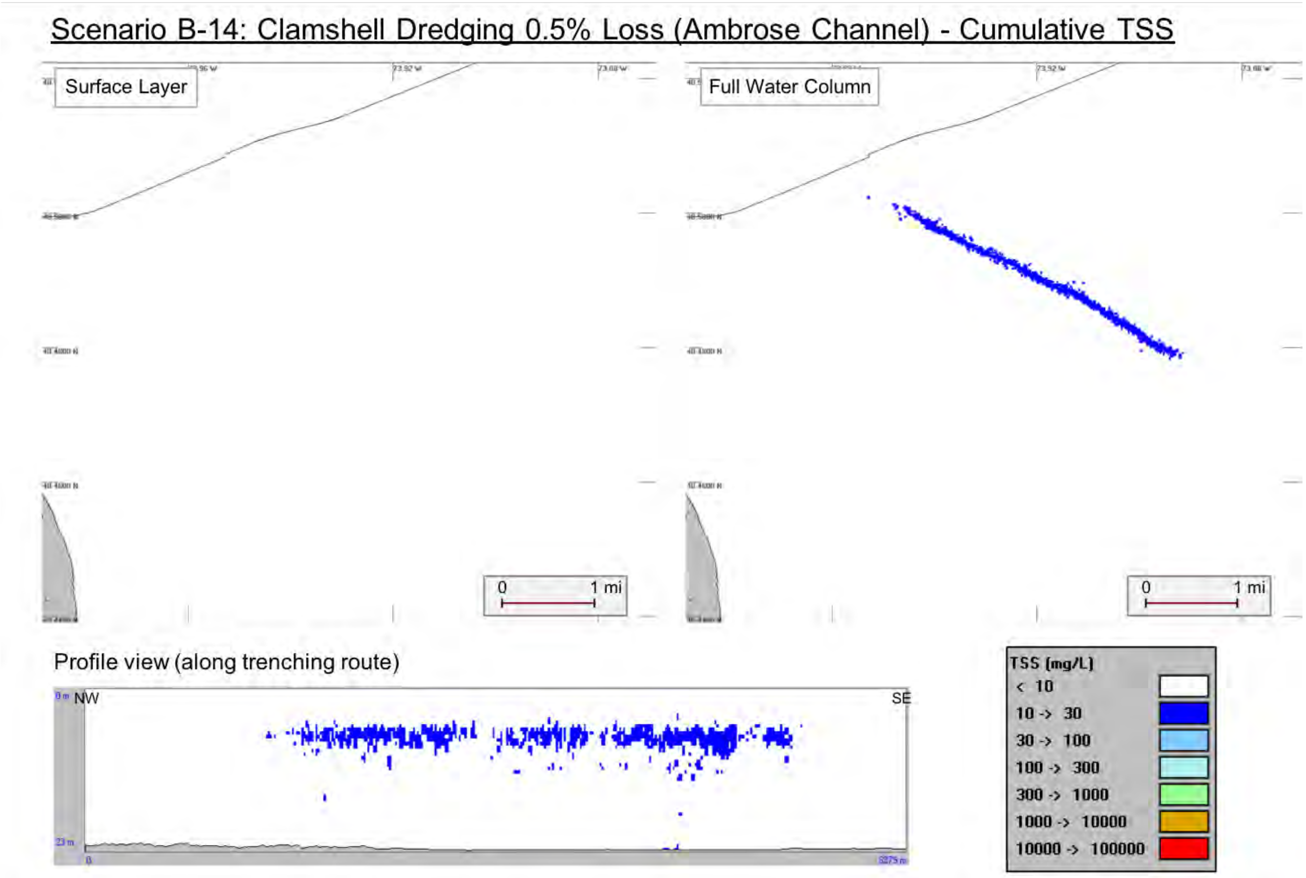

Figure 28. Cumulative TSS concentrations for Scenario B-14 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

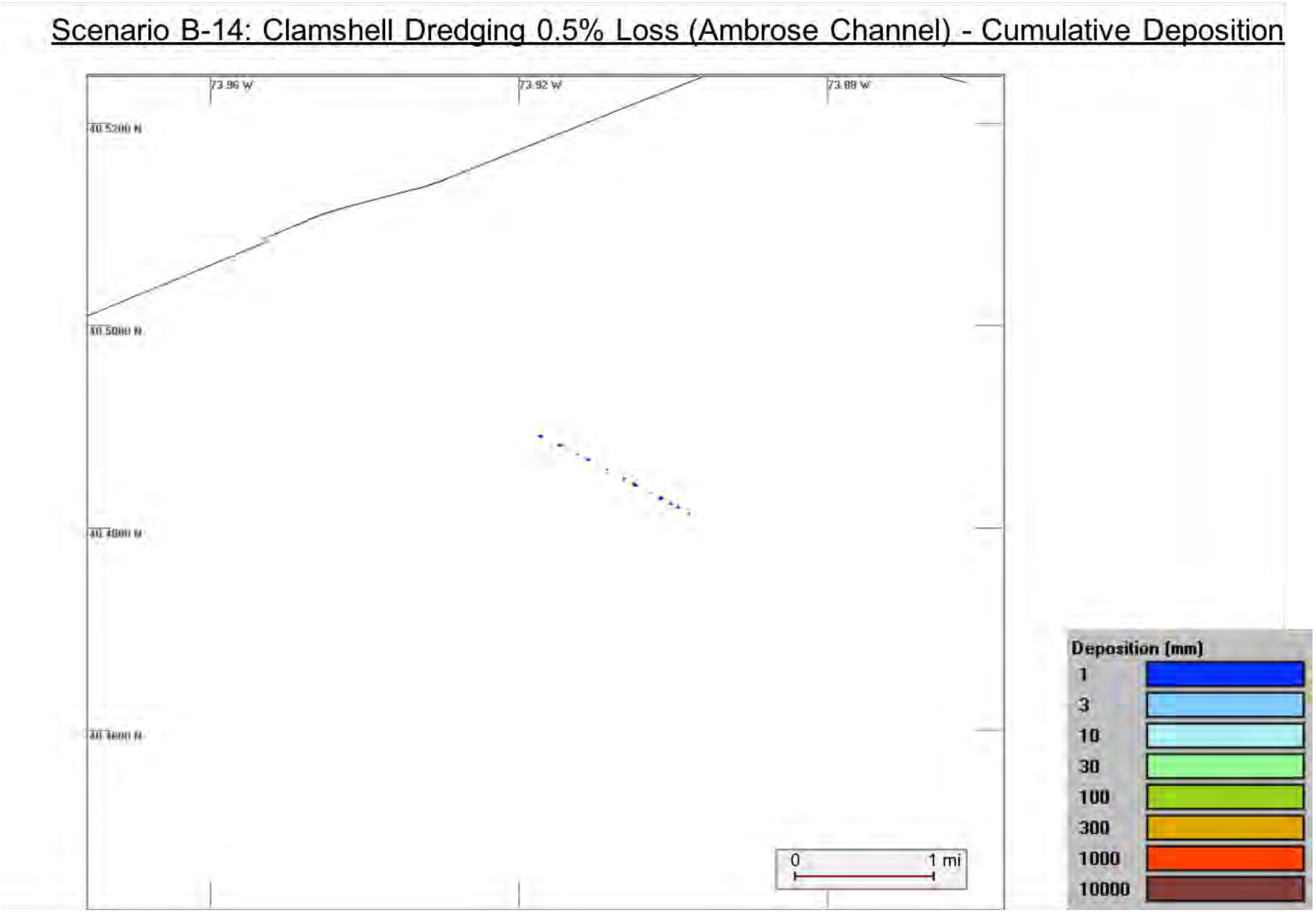

Figure 29. Extent of seabed deposition resulting from dredging of backfill material at the Ambrose Channel. Maximum predicted thickness = 0.04 in (1.1 mm).

3.15 Scenario B-15 – Dredging of Backfill Material from the Rockaway Inlet (0.5% loss)

Scenario B-15 simulated releases associated with the dredging of backfill source material from the Rockaway Inlet under the assumption that total sediment losses would be limited to 0.5% of the dredging volume through use of an environmental bucket and no scow overflow. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Rockaway Inlet (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (South to North) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 1,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Rockaway Inlet are presented in Figure 30 and Figure 31, and summarized in Table 2. Elevated TSS levels (above 10 mg/L) are confined to the lower portions of water column (0-5 ft above the seabed), directly along the dredge route. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations return to ambient levels within 0.2 hours (14 minutes) after the conclusion of dredging. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

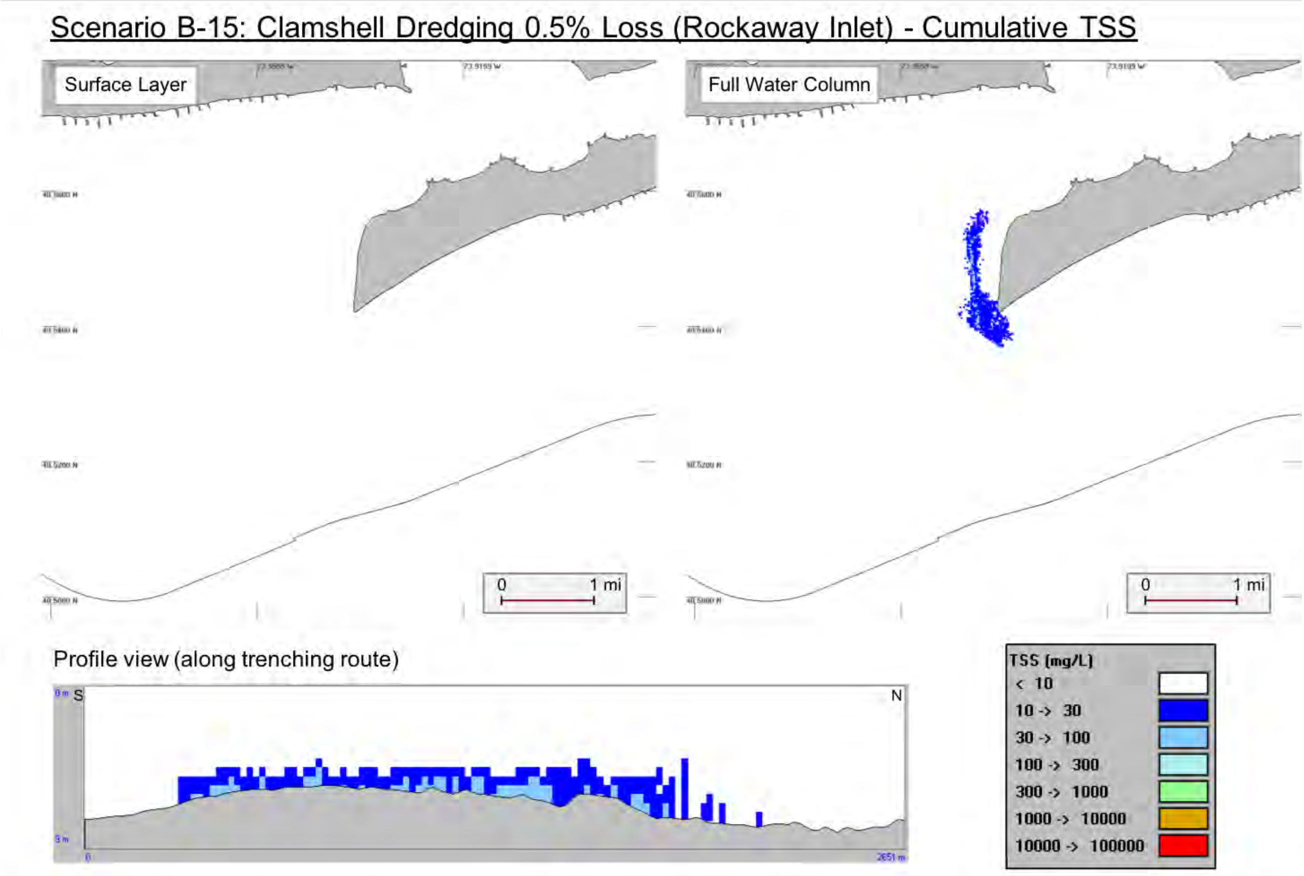

Figure 30. Cumulative TSS concentrations for Scenario B-15 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

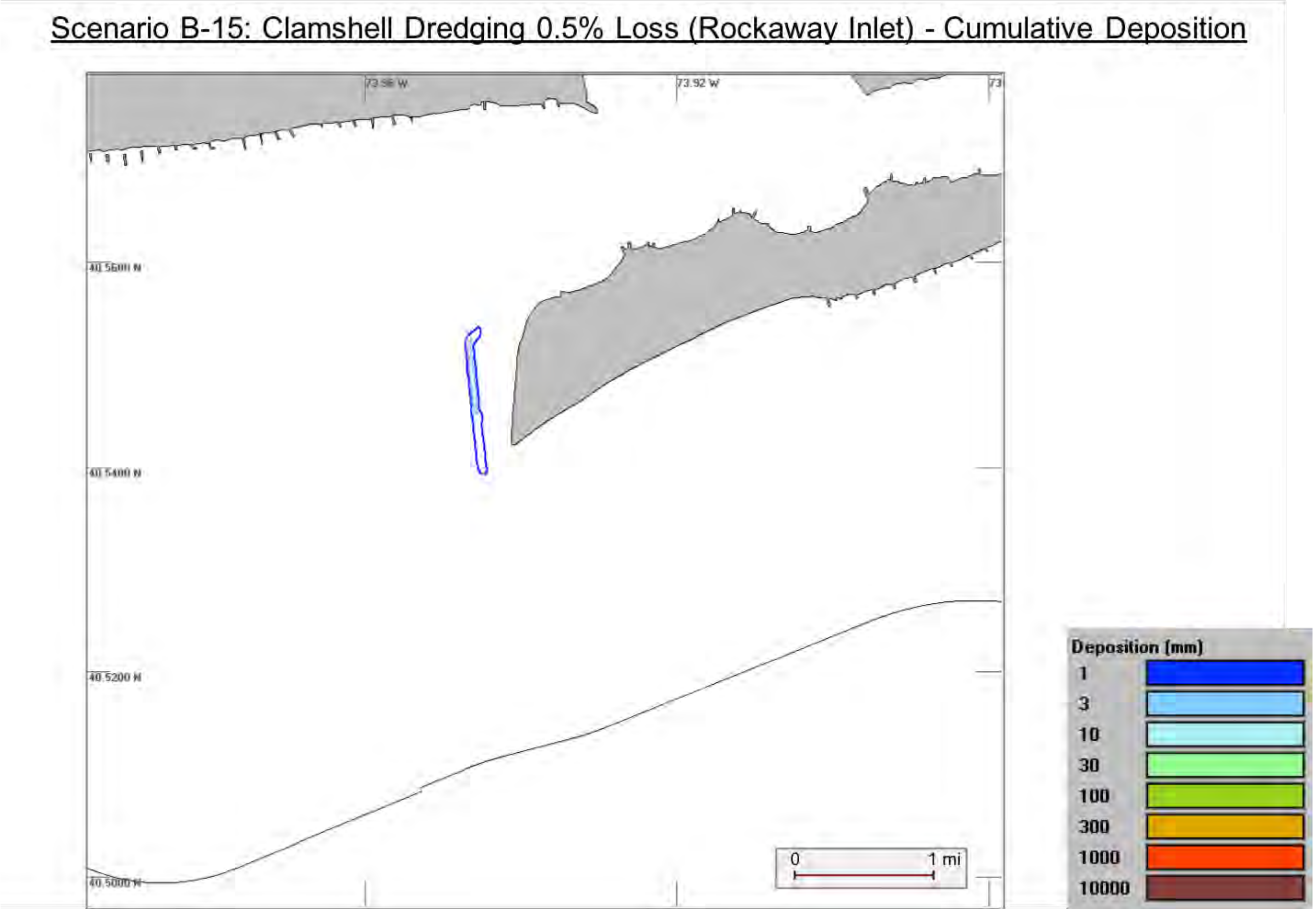

Figure 31. Extent of seabed deposition resulting from dredging of backfill material at the Rockaway Inlet. Maximum predicted thickness = 0.2 in (5.2 mm).

3.16 Scenario B-16 – Dredging of Backfill Material from the Earle Channel (0.5% loss)

Scenario B-16 simulated releases associated with the dredging of backfill source material from the Earle Channel under the assumption that total sediment losses would be limited to 0.5% of the dredging volume through use of an environmental bucket and no scow overflow. A total of 666,649 yd^3 of sediment may be needed to backfill several reaches of the pipeline route that are excavated using clamshell dredgers, hand-jets, and submersible pumps. For the purposes of modeling, it was assumed that this volume would be sourced from three navigation channels within the Project area – Ambrose Channel, Rockaway Inlet, and Earle Channel. Sediment dredged from the Earle Channel (222,216 yd^3) represents 1/3 of the material that would be excavated for backfill. A clamshell dredge will be used, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of May 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. Although the Earle Channel is separated into two distinct dredge areas, the model was run as a single uninterrupted dredge operation, with an instantaneous transition between the two dredge areas. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 1,111 yd^3 of sediment over the course of 22.2 days.

Water column and sediment bed results from simulations of clamshell dredging of the Earle Channel are presented in Figure 32 and Figure 33, and summarized in Table 2. As with B-13 (where scow overflow is included in the simulation), the plume within the Earle Channel has limited surface expression and maximum TSS levels are predicted at mid-depths and along portions of the dredging route where grain sizes become finer. However, at no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations return to ambient levels within 0.5 hours (28 minutes) of the conclusion of dredging. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation

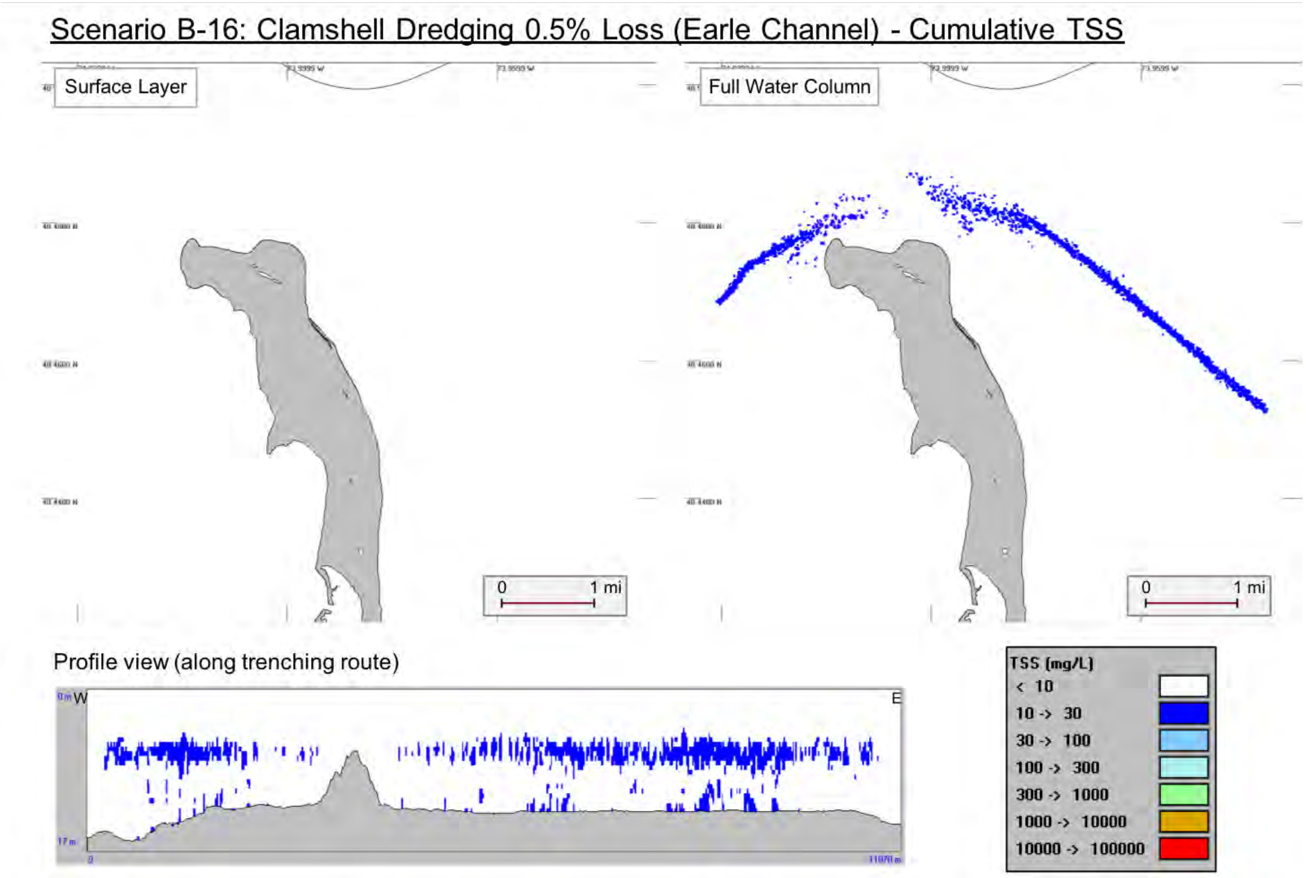

Figure 32. Cumulative TSS concentrations for Scenario B-16 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

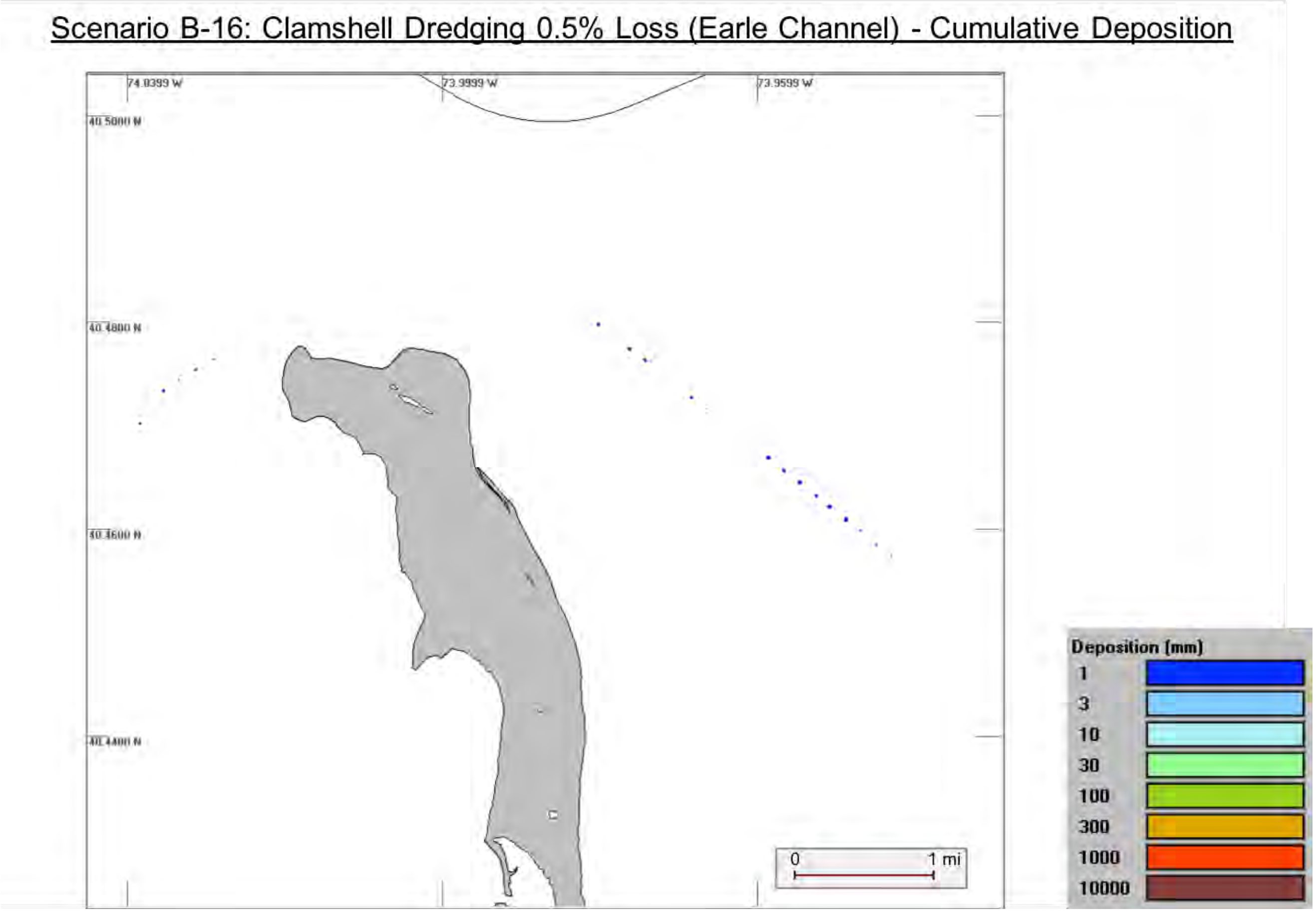

Figure 33. Extent of seabed deposition resulting from dredging of backfill material at the Earle Channel. Maximum predicted thickness = 0.05 in (1.3 mm).

3.17 Scenario B-17 – Clamshell Trenching (Side-Casting) Between the Anchorage Area and Chapel Hill Channel

Scenario B-17 simulated releases associated with pre-lay (clamshell) trenching and the simultaneous side-casting of sediment excavated from the trench between the Anchorage area and the western boundary of Chapel Hill Channel (MP 24.00 to MP 24.78). Along this reach the pipeline will be buried to a minimum 7 ft of cover, requiring trench excavation of 10.5 ft below the seabed. In total, 64,311 yd^3 of sediment will be removed using a clamshell dredge and side-cast directly adjacent to the trench as the dredge advances. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 to be consistent with the schedule applied for the “Base Case” (August 2017) and Addendum 1 (September 2017) modeling scenarios. As the entirety of the disturbed sediment volume (100%) will be side-cast, the simulation included the release of all 64,311 yd^3 of sediment over the course of 6.4 days. In the model, sediment losses from side-casting were released from a fixed height of 5 ft above the seabed (directly adjacent to the location where the excavation is taking place).

Water column and sediment bed results from simulations of clamshell trenching between MP 24.00 and MP 24.78 are presented in Figure 34 and Figure 35, and summarized in Table 2. Elevated TSS concentrations are mostly confined to the lower half of the water column as the plume oscillates back and forth (West/East) with the tide. Peak TSS concentrations occur directly above the seafloor and decline with height in the water column. TSS concentrations exceeding 10 mg/L are predicted to occur only intermittently in the surface layer. Water column concentrations of 100 mg/L are predicted to extend a maximum of 3,084 ft from the source and TSS concentrations return to ambient levels within 0.9 hours (53 minutes) of the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 259 ft from the source and covers a total of 36.0 acres of the seabed.

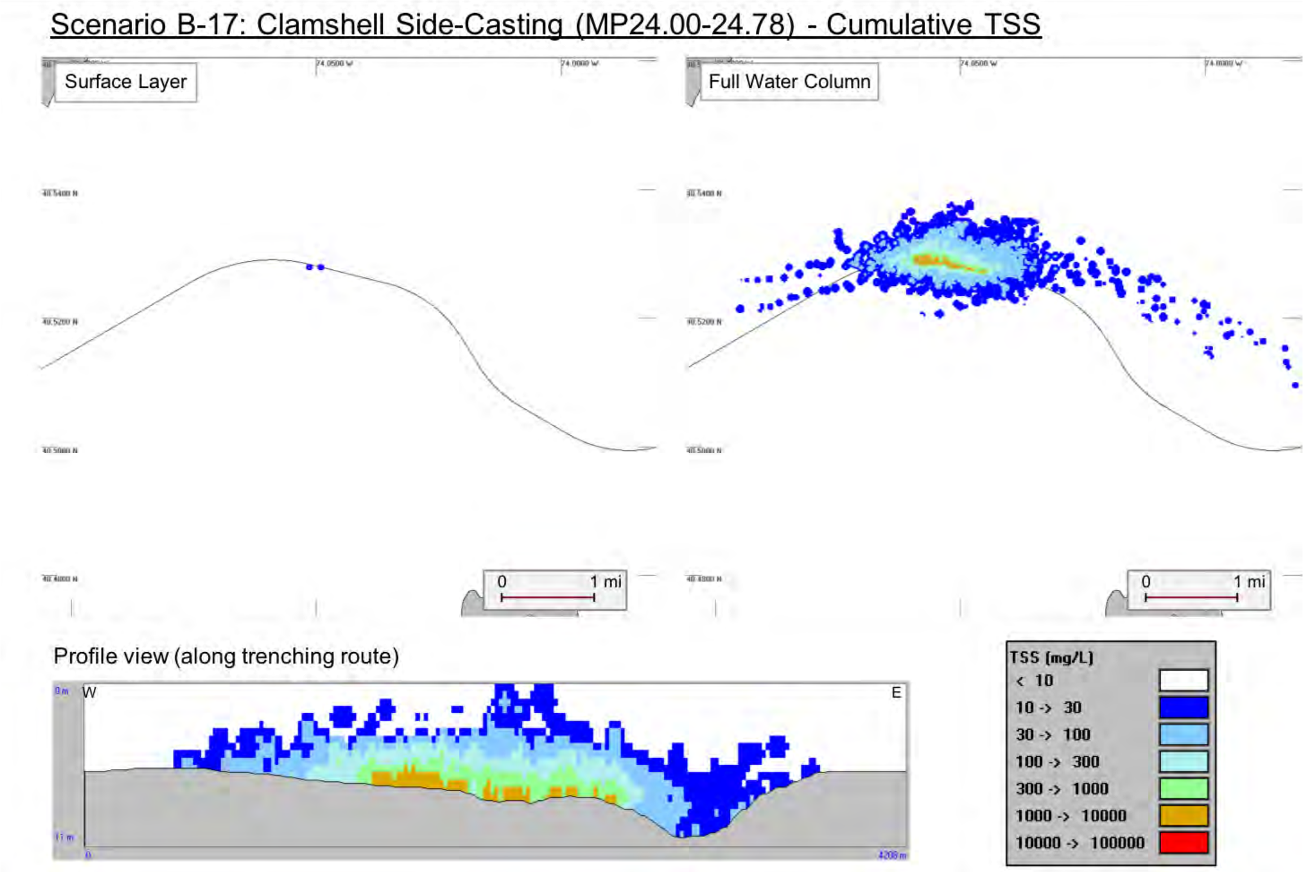

Figure 34. Cumulative TSS concentrations for Scenario B-17 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

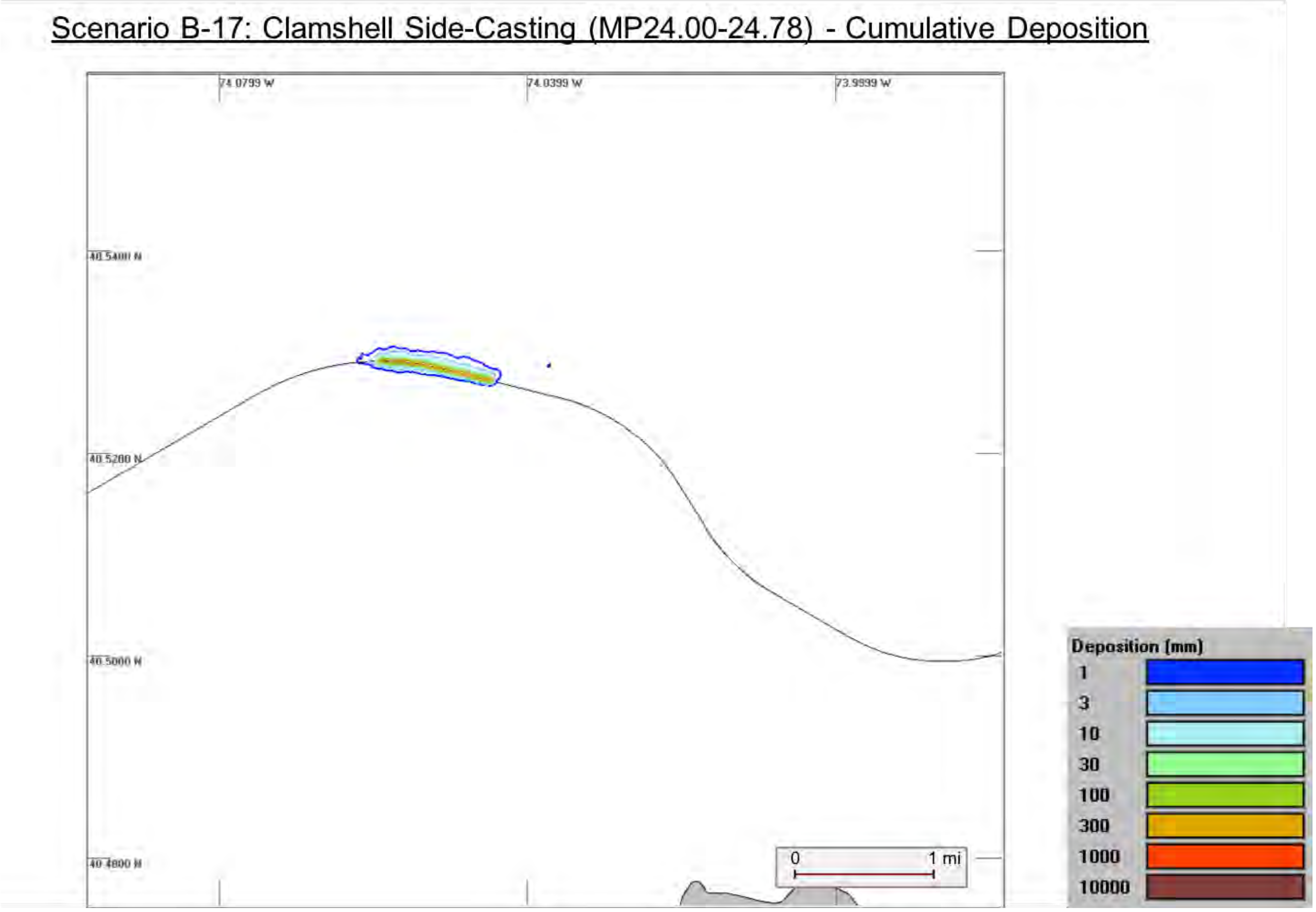

Figure 35. Extent of seabed deposition resulting from pre-lay clamshell trenching and side-casting between MP 24.00 and MP 24.78. Maximum predicted thickness = 31.7 in (805.8 mm).

3.18 Scenario B-18 – Excavation and Side-Casting of the Ambrose Channel HDD Pit (West)

Scenario B-18 includes simulations of sediment disturbance associated with excavation of the HDD pit at MP 29.52, west of the Ambrose Channel. The HDD pit will extend to a maximum of 20 ft below the grade of the seabed. During the excavation, approximately 14,050 yd^3 of sediment will be excavated using a clamshell dredger and side-cast directly adjacent to the HDD pit. The dredging was simulated as a stationary (point) source from the HDD pit location, and was assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed with a start date of August 1 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The modeling assumes the dredge operates continuously for the duration of the excavation activity (33.7 hours) and as the entirety of the disturbed sediment volume will be side-cast, losses from the clamshell bucket are assumed to be 100% of the total excavation volume. In the model, sediment losses from side-casting were released from a fixed height of 5 ft above the seabed (directly adjacent to the location where the excavation is taking place).

Water column and sediment bed results from excavation at the Ambrose HDD pit (west) are presented in Figure 36 and Figure 37, and summarized in Table 2 (note that Figure 36 is shown at a scale that differs from other TSS figures within this report). The plume is notably aligned with the strong tidal currents that flow in and out of the Bay entrance. Peak TSS concentrations occur directly at the side-casting location (approximately 30 ft below the surface) and extend laterally Northwest and Southeast from the release site, with slight elongation in the direction of the flood tide. The plume cross-section (Figure 36) indicates TSS concentrations exceeding 100 mg/L remain at depths below 15 ft from the surface and at no point during the simulation are TSS concentrations exceeding 10 mg/L predicted in the surface layer. Water column concentrations of 100 mg/L are predicted to extend up to 17,684 ft from the source and TSS concentrations remain elevated above ambient levels for 7.3 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 787 ft and covers 6.4 acres of the seabed.

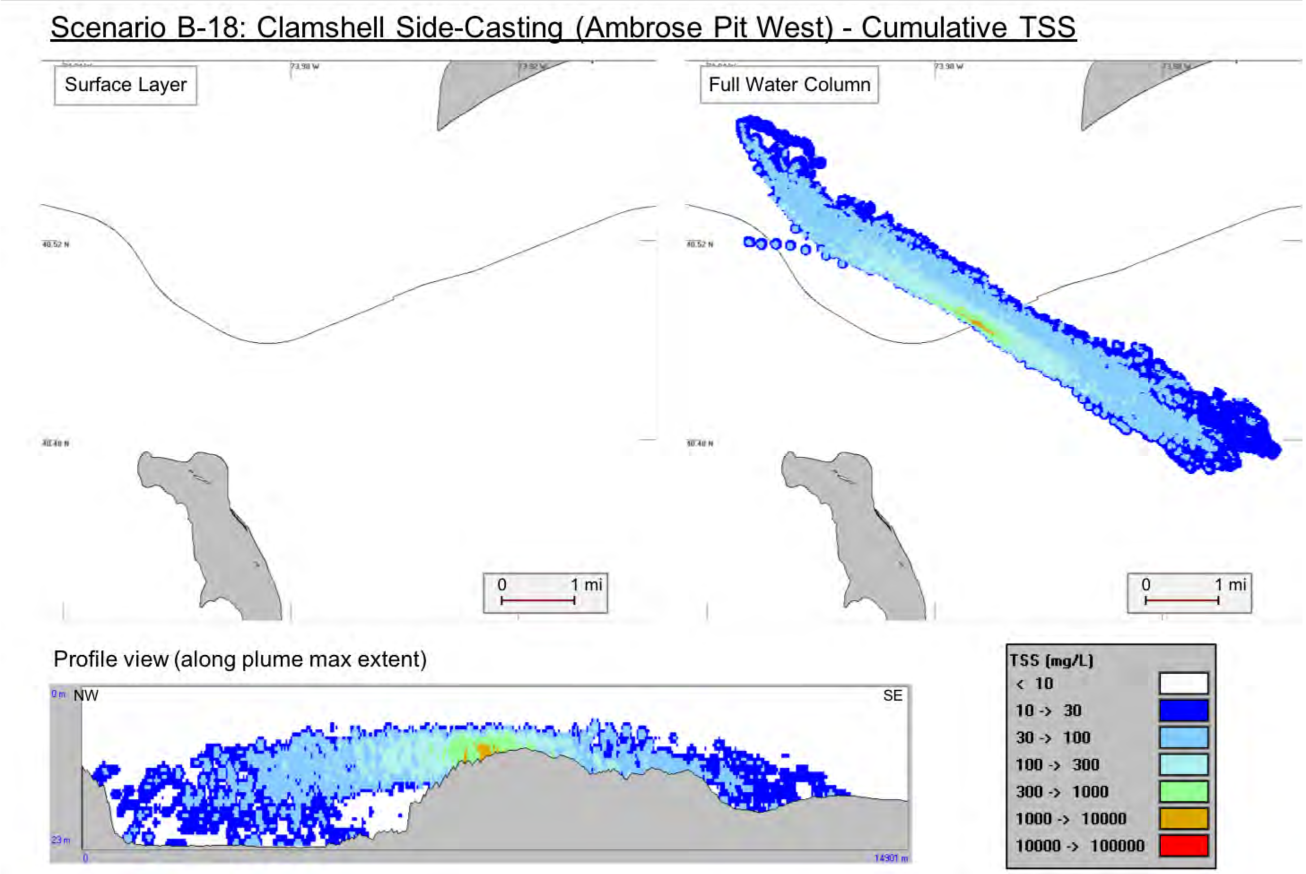

Figure 36. Cumulative TSS concentrations for Scenario B-18 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis. **This figure is presented at a map scale that differs from the other cumulative TSS figures in this report.**

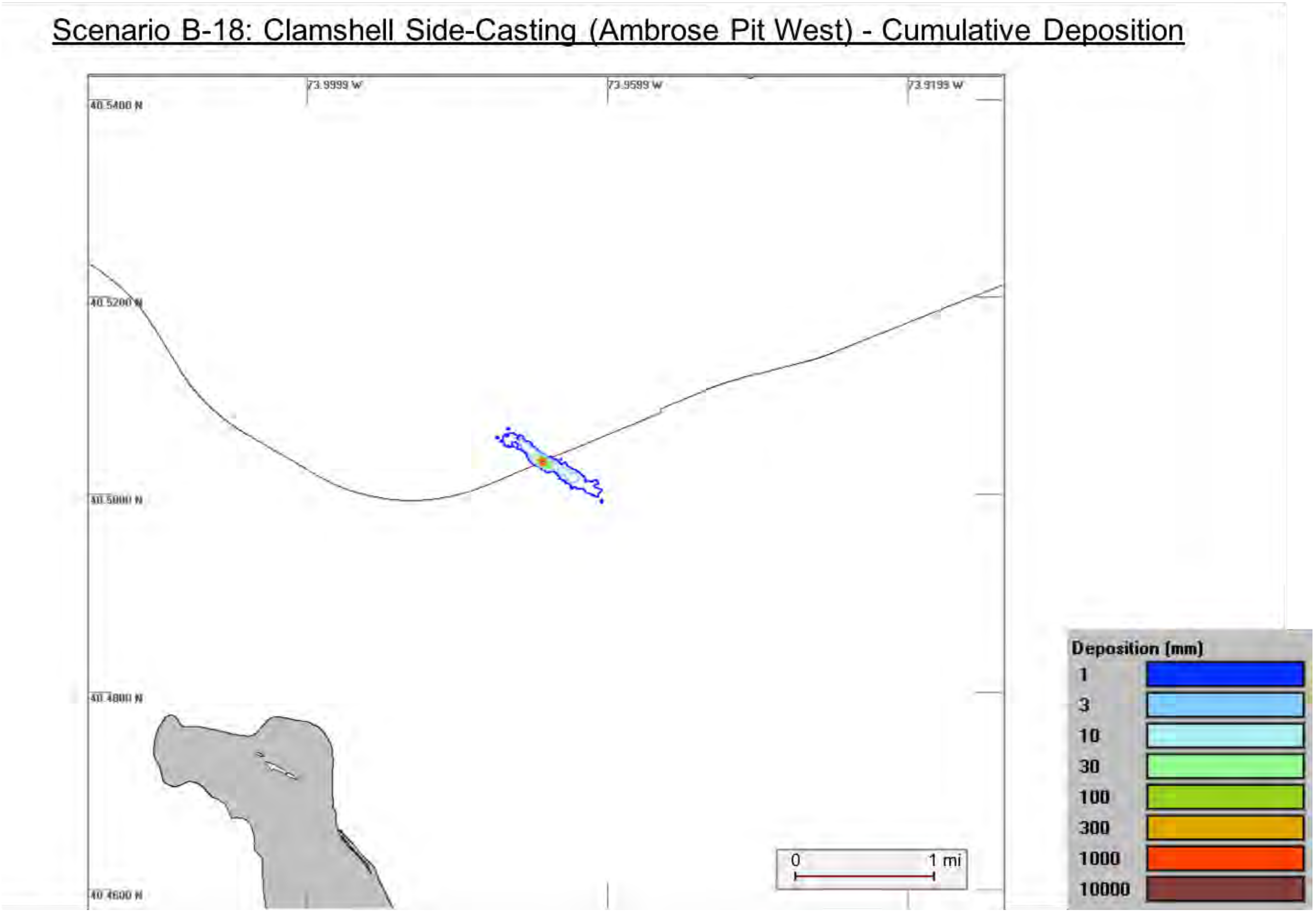

Figure 37. Extent of seabed deposition resulting from excavation and side-casting of sediments at the Ambrose Channel HDD pit at MP 29.52. Maximum predicted thickness = 129.9 in (3,070.5 mm).

3.19 Scenario B-19 – Excavation and Side-Casting of the Ambrose Channel HDD Pit (East) and Tie-in

Scenario B-19 includes two phases of construction associated with the Ambrose HDD campaign: (i) excavation of the Ambrose Channel HDD pit (east) to a depth of 24 ft, and (ii) excavation of the tie-in point on the east side of the HDD to a depth of 7.5 ft. Both activities were simulated, in sequence as a stationary (point) source from the HDD pit location (MP 30.40). Both involve excavation by clamshell dredger and the simultaneous side-casting of sediment onto the seabed. The clamshell dredger is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The Ambrose HDD campaign is scheduled for Q3 2018, and the simulation was performed with a start date of August 4 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The modeling assumes the dredge operates continuously for 77.9 hours during excavation of the HDD pit, breaks for approximately 18 hours between the two activities, and begins operations for the tie-in point excavation at the start of the next calendar day. Excavation for the tie-in point is simulated continuously for 5.6 hours. As the entirety of the disturbed sediment volume will be side-cast, losses from the clamshell bucket are assumed to be 100% of the excavation volume. In total, 34,777 yd^3 of sediment will be released from these two sources over the course of 4.2 days (83.5 hours of active dredging). In the model, sediment losses from side-casting were released from a fixed height of 5 ft above the seabed (directly adjacent to the location where the excavation is taking place).

Water column and sediment bed results from excavation at the Ambrose HDD (east) pit are presented in Figure 38 and Figure 39, and summarized in Table 2. When compared to excavation/side-casting activities at the adjacent (west) HDD pit location, TSS plumes at the HDD pit are both smaller and are characterized by lower concentrations throughout the simulation. Presumably, this is due to the coarse sediment grain sizes east of the Ambrose Channel, which lead to rapid settling and less sustained sediment plumes. Sedimentation is also substantially higher at this location because of (i) the larger excavation volumes, and (ii) decreased transport of relatively coarser sediments. Water column concentrations of 100 mg/L are predicted to extend up to 2,789 ft from the source and TSS concentrations remain elevated above ambient levels for 1.6 hours after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 305 ft and covers 4.4 acres of the seabed.

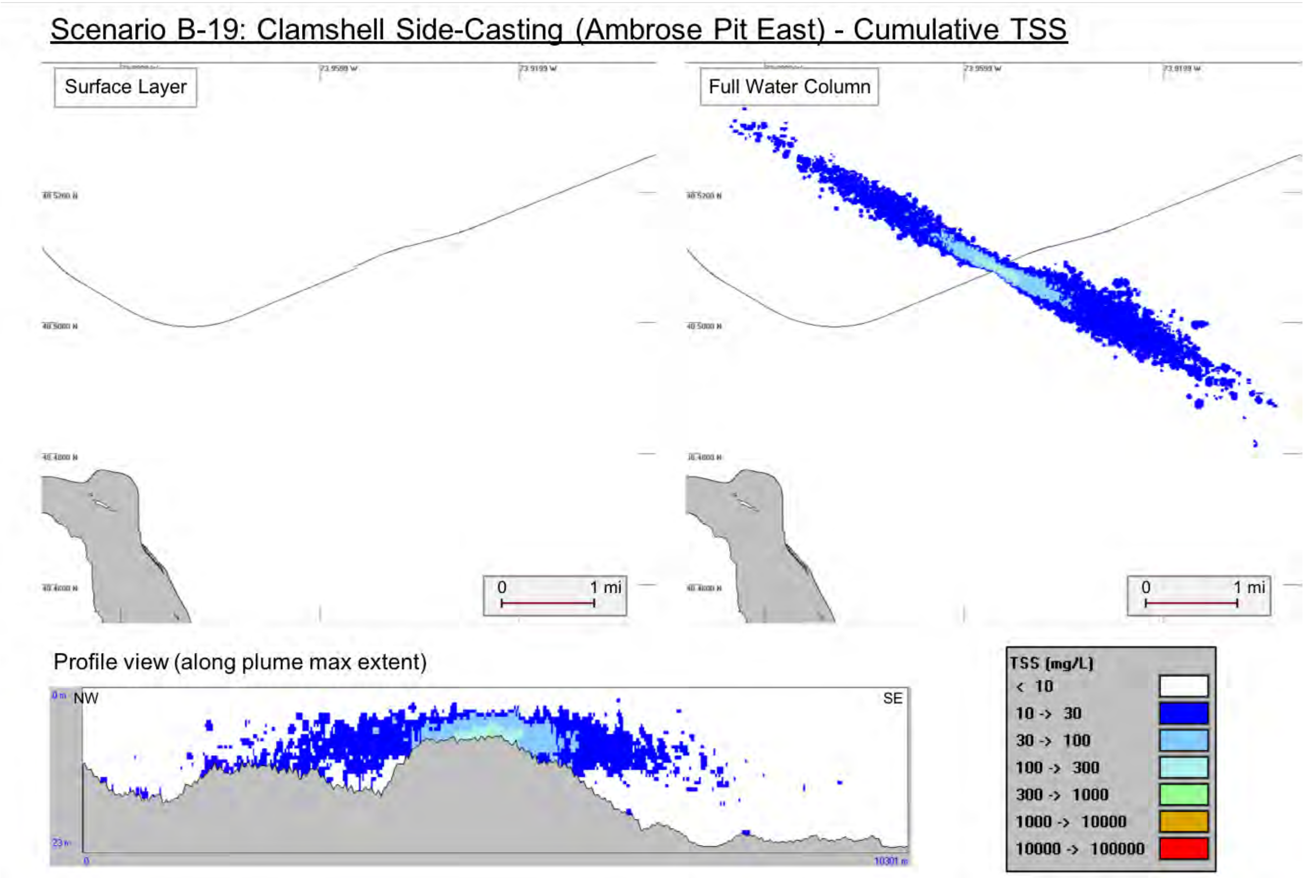

Figure 38. Cumulative TSS concentrations for Scenario B-19 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

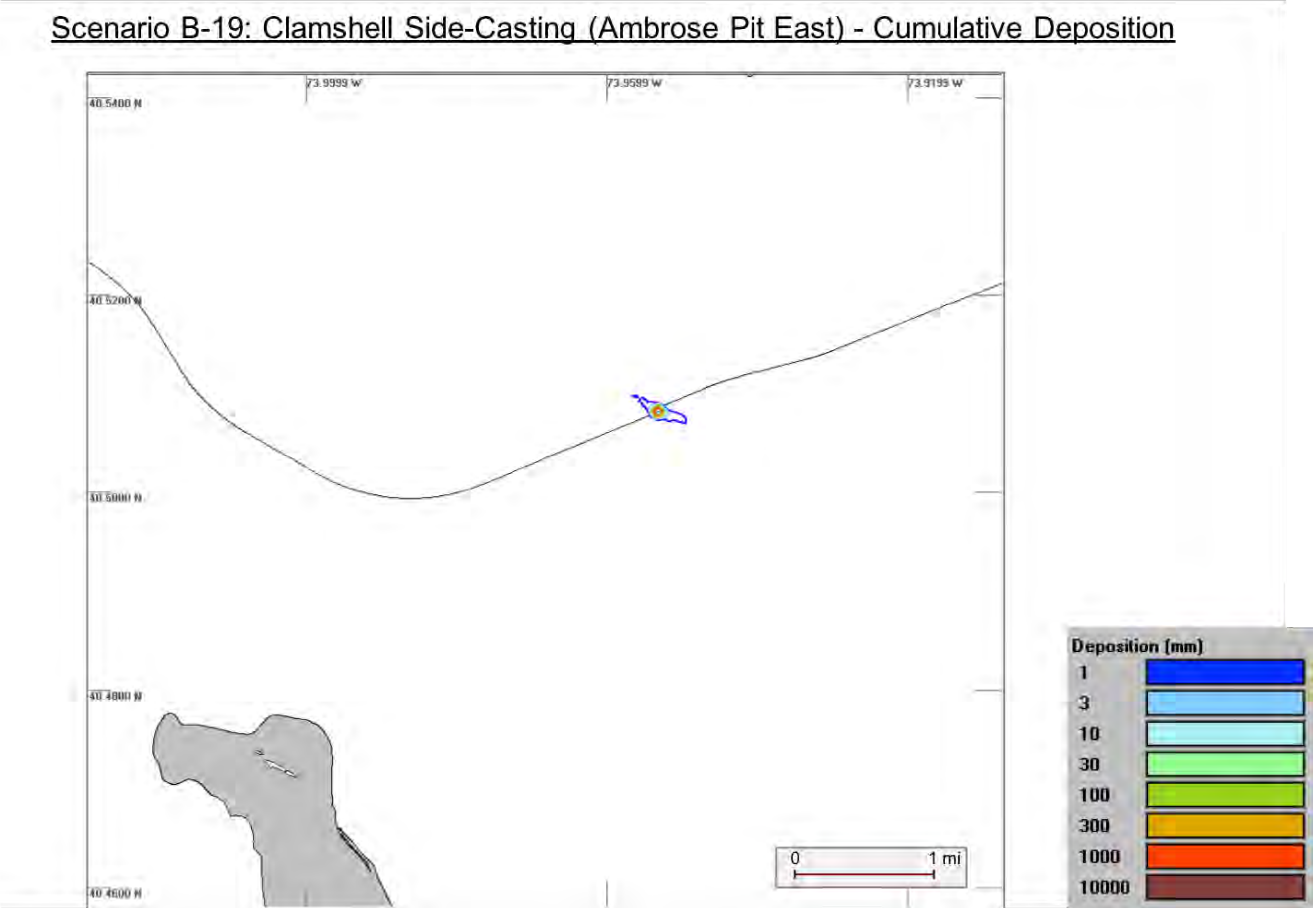

Figure 39. Extent of seabed deposition resulting from excavation and side-casting of sediments at the Ambrose Channel HDD pit at MP 30.40. Maximum predicted thickness = 245.7 in (6,240.0 mm).

3.20 Scenario B-20 – Clamshell Trenching (Side-Casting) Between the Neptune Crossing and RDL Manifold

Scenario B-20 simulated releases associated with pre-lay (clamshell) trenching and side-casting of sediment onto the seafloor between the Neptune Cable crossing offshore Rockaway and the Rockaway Delivery Lateral (RDL) tie-in point (from MP 35.19 to MP 35.49). Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. In total, 13,152 yd^3 of sediment will be removed using a clamshell dredge and side-cast directly adjacent to the trench as the dredge advances. The clamshell dredge is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of February 6 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. As the entirety of the disturbed sediment volume (100%) will be side-cast, the simulation included the release of all 13,152 yd^3 of sediment over the course of 1.3 days. In the model, sediment losses from side-casting were released from a fixed height of 5 ft above the seabed (directly adjacent to the location where the excavation is taking place).

Water column and sediment bed results from simulations of clamshell trenching between MP 35.19 and MP 35.49 are presented in Figure 40 and Figure 41, and summarized in Table 2. Elevated TSS concentrations largely remain confined to lower portions of the water column as the plume oscillates back and forth with the tide (concentrations exceeding background levels are only predicted at depths below 20 ft). Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,296 ft from the source and TSS concentrations return to ambient levels within 1.9 hours of the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 348 ft from the source and covers a total of 14.9 acres of the seabed.

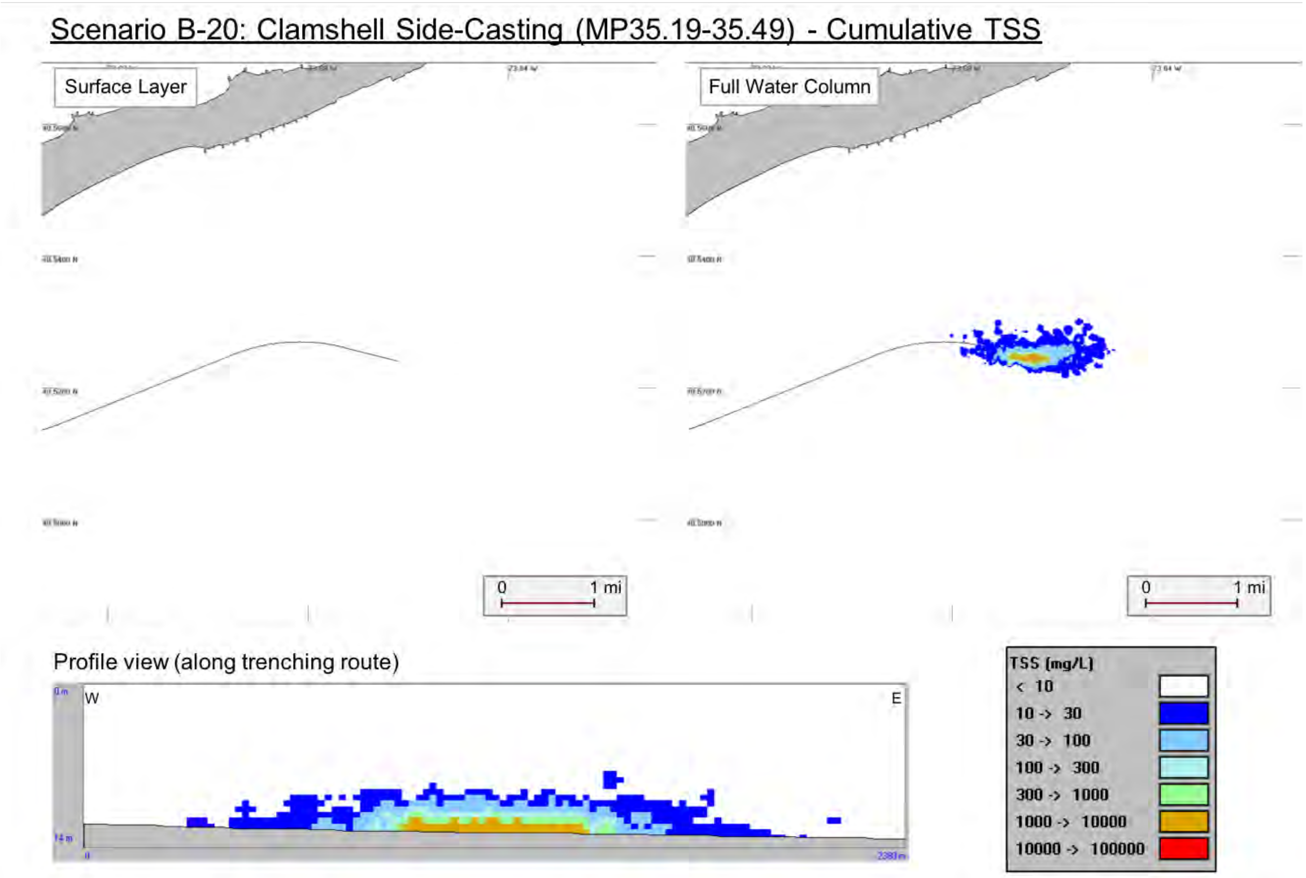

Figure 40. Cumulative TSS concentrations for Scenario B-20 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

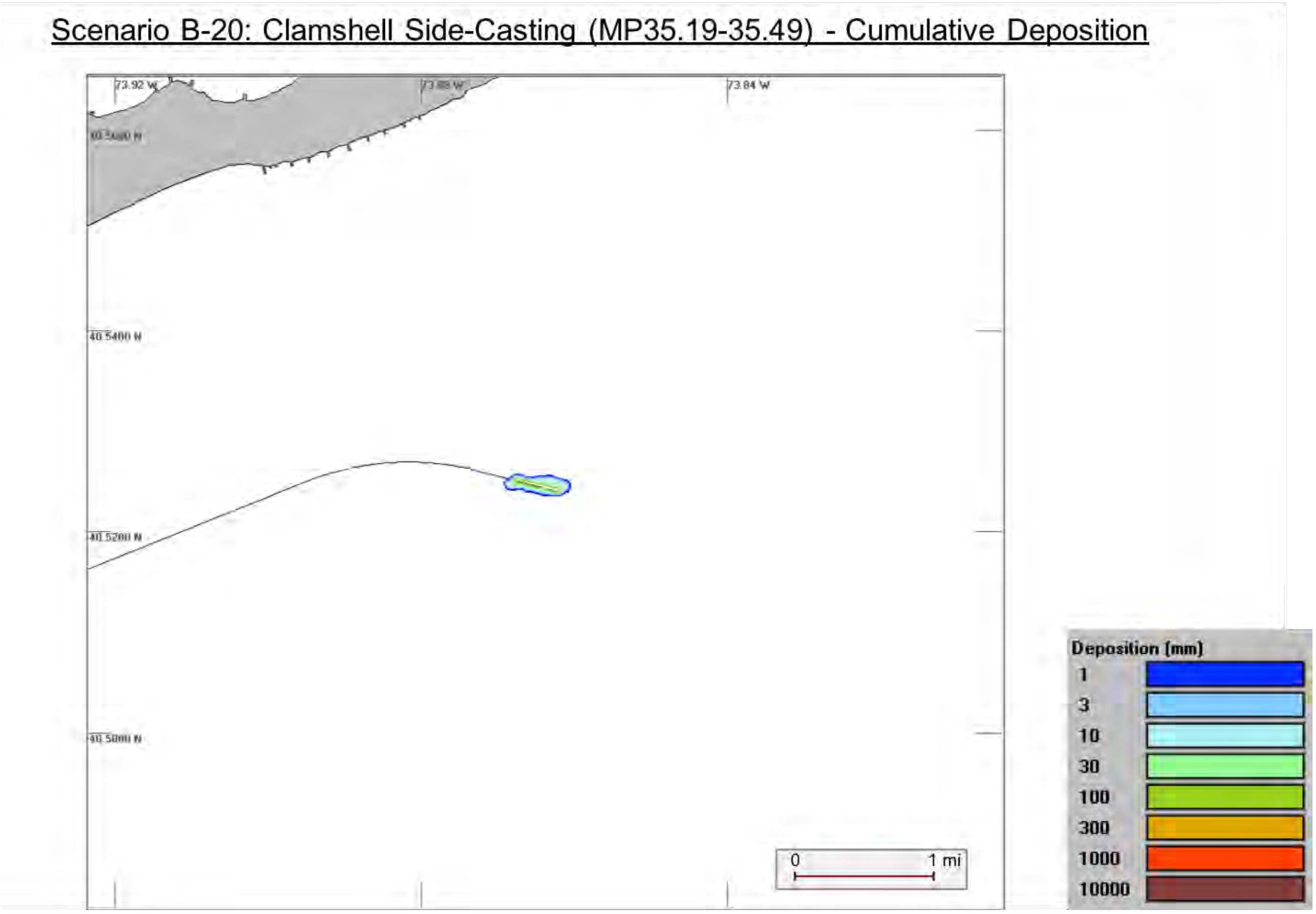

Figure 41. Extent of seabed deposition resulting from pre-lay clamshell trenching and side-casting between MP 35.19 and MP 35.49. Maximum predicted thickness = 11.7 in (296.3 mm).

3.21 Scenario B-21 – Backfilling Between Morgan HDD and Midline Tie-in

Scenario B-21 simulated the placement of backfill material within the excavated trench extending between MP 12.50 and MP 16.60. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 7,500 ft^3/hr.

Backfilling operations are expected to occur concurrent with the dredging of source material (see Addendum 1, Scenarios A-1 through A-3). For Scenario B-21, the simulation was performed using a start date of May 2 (immediately following backfill activities at the Morgan Shore) to be consistent with the schedule applied for the “Base Case” (August 2017) and Addendum 1 (September 2017) modeling scenarios. The clamshell dredge operates continuously for 794 hours (33.1 days) while placing backfill sediments over approximately 4.1 miles. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 219,591 yd^3 of sediment was placed along this section of the trench, which includes an “overfill” factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 175,673 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 12.50 and MP 16.60 are presented in Figure 42 and Figure 43, and summarized in Table 2. During most of the run, the plume is oriented in a West/East configuration, oscillating back and forth with the tide along the primary axis of Raritan Bay. Peak TSS concentrations are predicted to occur at or just above the seabed; surface TSS concentrations decrease and become more intermittent as the backfilling route advances into deeper water. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,329 ft from the source and TSS concentrations remain elevated above ambient levels for 1.2 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 364 ft from the source and covers a total of 222.6 acres of the seabed.

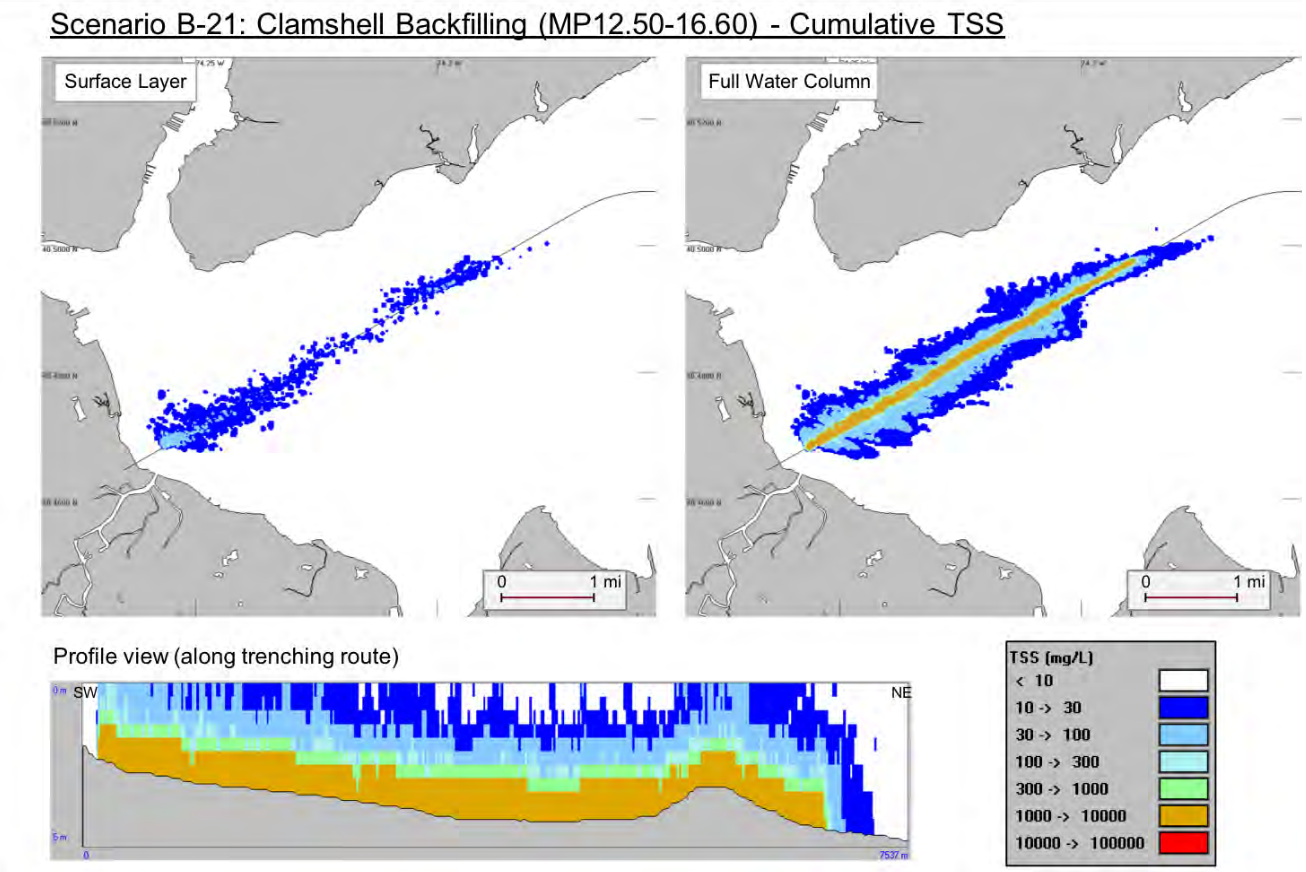

Figure 42. Cumulative TSS concentrations for Scenario B-21 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the backfilling route. Maximum predicted concentration = 13,275.9 mg/L.

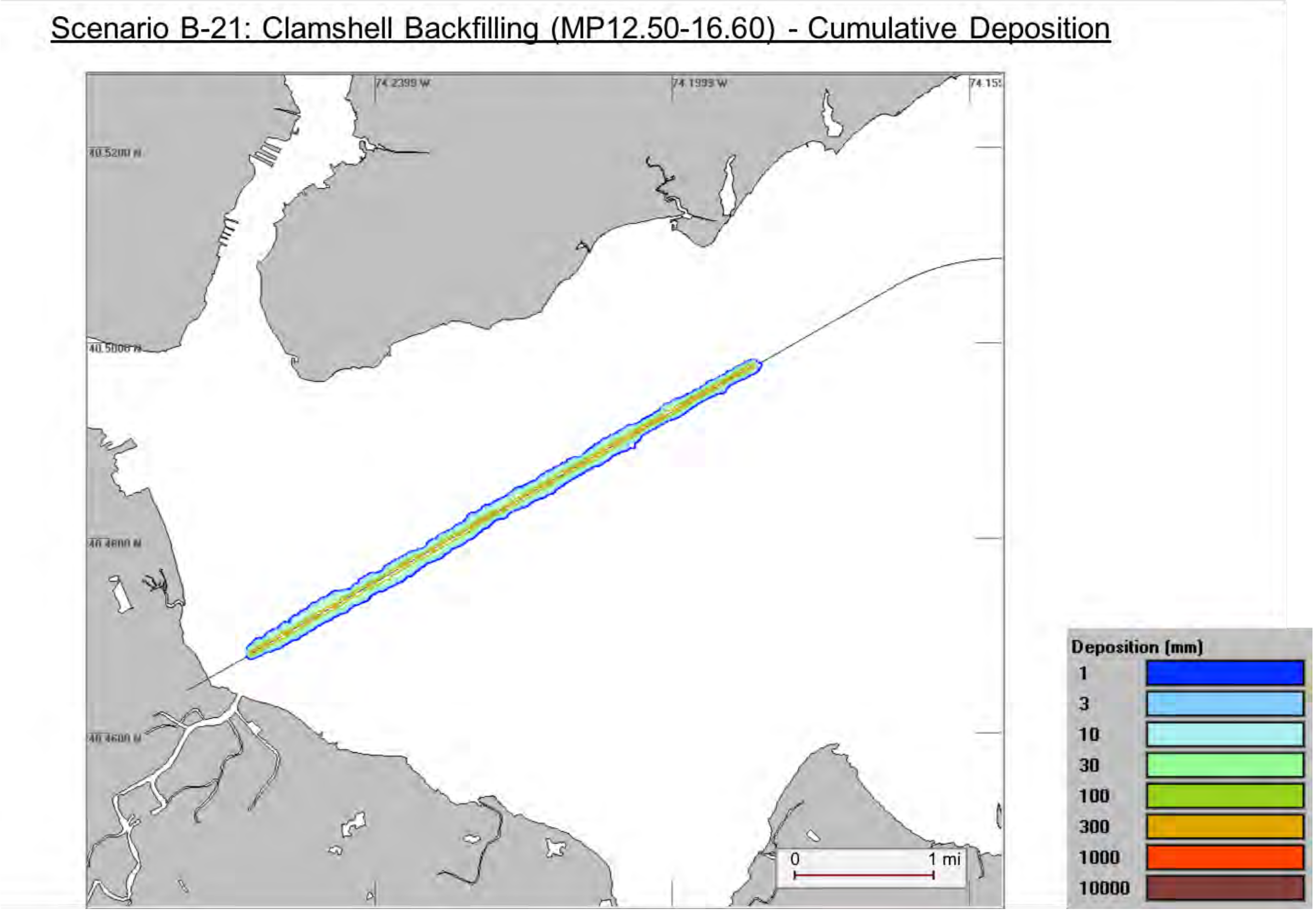

Figure 43. Extent of seabed deposition resulting from placement of backfill material between MP 12.50 and MP 16.60. Maximum predicted thickness = 24.6 in (624.5 mm).

3.22 Scenario B-22 – Backfilling of the Ambrose Channel HDD West Pit

Scenario B-22 simulated the placement of backfill material at the HDD pit at MP 29.52, directly west of the Ambrose Channel. The HDD pit will extend to a maximum of 20 ft below the seabed and backfilling by clamshell dredge will be required to return the seabed to grade once the pipe has been installed beneath the Ambrose Channel. The backfilling activity was simulated as a stationary (point) source at MP 29.52. The clamshell dredge is assumed to operate at a constant production rate of 7,500 ft^3/hr.

Backfilling operations are expected to occur concurrent with the dredging of source material (see Addendum 1, Scenarios A-1 through A-3). The simulation was performed using a start date of May 15 (immediately following backfilling of the trench up to the Chapel Hill Channel) to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The clamshell dredge operates continuously for 63.2 hours, during which time the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. A total of 17,563 yd^3 of sediment was placed at the HDD pit, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 14,050 yd^3.

Water column and sediment bed results from simulations of backfilling at the Ambrose (West) pit are presented in Figure 44 and Figure 45, and summarized in Table 2. The predicted sediment plume from backfilling at this site shows a distinct alignment with the strong tidal currents that flow in and out of the entrance to Raritan Bay. Overall, elevated TSS concentrations are confined to the lower half of the water column and decrease with distance from the backfilling site. Peak concentrations are predicted to occur at depths between 30 and 35 ft, close to the bucket release site. At no point during the entire simulation are TSS concentrations above 10 mg/L predicted in the surface, or near-surface layers (e.g. within 15 ft of the sea surface). Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,526 ft from the source and TSS concentrations remain elevated above ambient levels for 1.3 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 755 ft from the source and covers a total of 8.9 acres of the seabed.

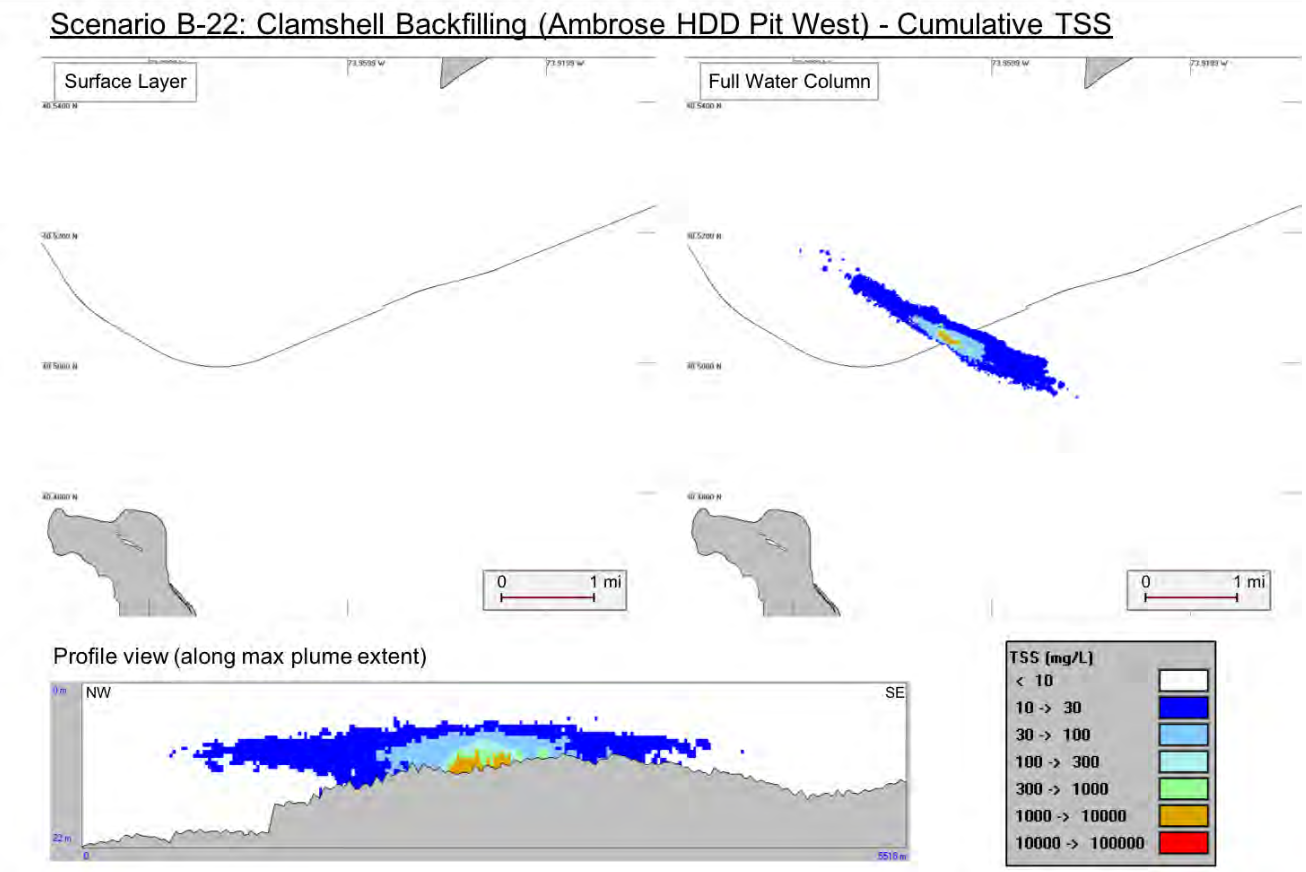

Figure 44. Cumulative TSS concentrations for Scenario B-22 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the plume axis. Maximum predicted concentration = 7,228.4 mg/L.

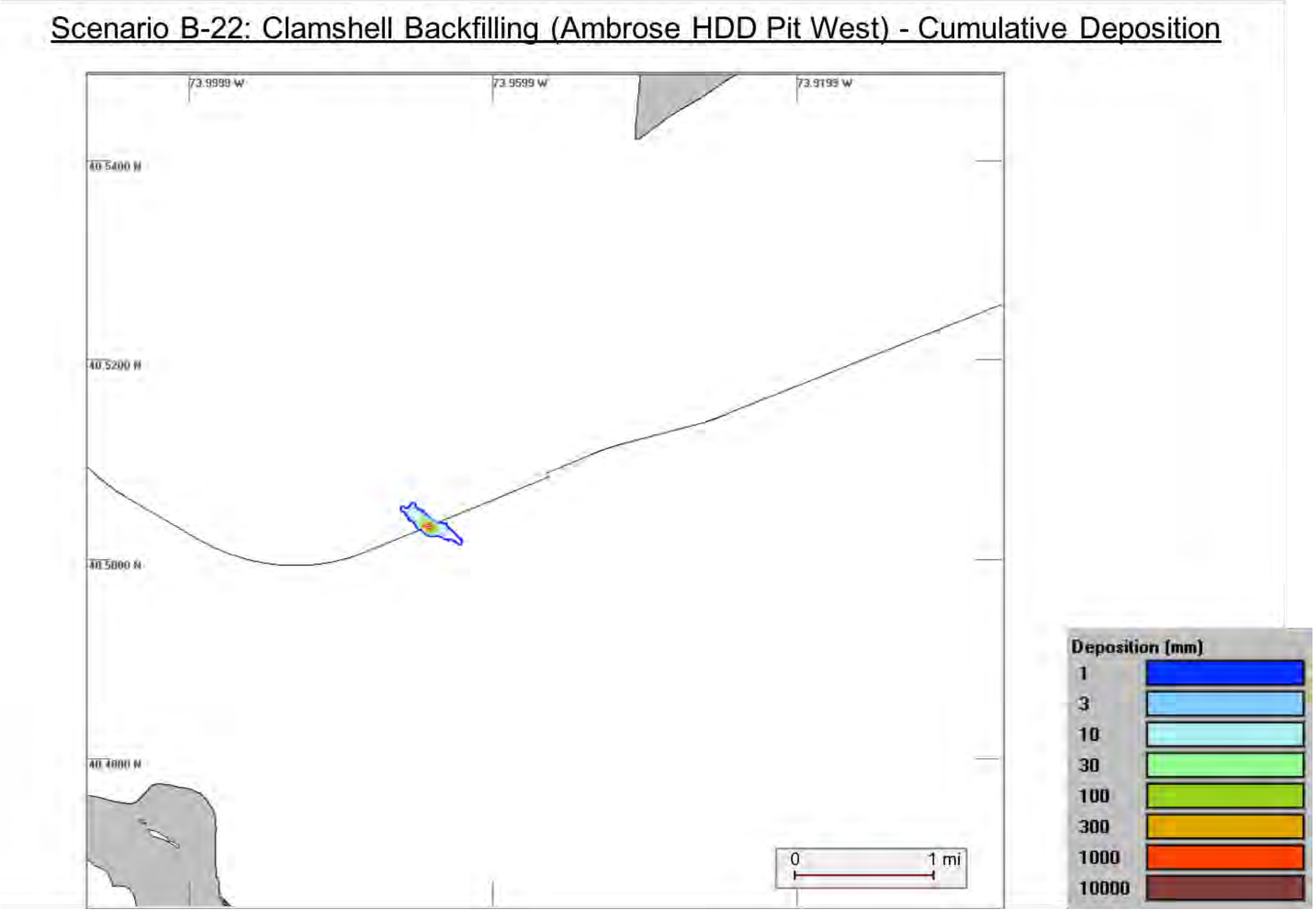

Figure 45. Extent of seabed deposition resulting from placement of backfill material at the Ambrose (West) HDD pit. Maximum predicted thickness = 126.9 in (3,223.3 mm).

Table 2. Summary of Addendum 2 simulation results.

Scenario	Construction Activity	Equipment Type	Location	Production rate (ft3/hr)	Duration of modeled activity (hr)	Equipment Loss (%)	Total volume released (yd3)	Time For TSS to return to ambient (hrs)	Max Distance of TSS Plume exceeding ambient (ft)		Max Distance of deposition exceeding (ft)			Area of deposition exceeding (acres)		
									50 mg/L	100 mg/L	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]
Scenario B-1	Pre-lay trenching between Morgan HDD pit and the Midline tie-in (2.5% loss)	Clamshell	MP 12.50 - MP 16.60	11,250	422.3	2.5	4,392	1.7	2,428	591	89	26	0	11.1	0.5	0.0
Scenario B-2	Pre-lay trenching between Morgan HDD pit and the Midline tie-in (0.5% loss; no scow overflow)	Clamshell	MP 12.50 - MP 16.60	11,250	422.3	0.5	878	0.4	262	0	0	0	0	0.0	0.0	0.0
Scenario B-3	Post-lay trenching between Morgan HDD pit and the Midline tie-in (2 passes; 5% loss)	Jet Trencher	MP 12.50 - MP 16.60	29,135	66.0	5	3,559	0.2	2,018	1,476	97	0	0	13.0	0.0	0.0
Scenario B-4	Excavation activities at Morgan Shore (0.5% loss)	Clamshell	(i) MP 12.50 (ii)~1,200 ft north of MP 12.30	11,250	24.9	0.5	52	0.4	328	148	102	0	0	0.5	0.0	0.0
Scenario B-5	Pre-lay trenching across the Raritan Channel (0.5% loss)	Clamshell	MP 17.31 - MP 17.89	11,250	321.6	0.5	668	0.5	0	0	0	0	0	0.0	0.0	0.0
Scenario B-6	Pre-lay trenching between the anchorage area and the Chapel Hill Channel (0.5% loss)	Clamshell	MP 24.00 - MP 25.20	11,250	270.0	0.5	562	0.0	0	0	15	0	0	0.6	0.0	0.0
Scenario B-7	Excavation of Ambrose Channel HDD pit (West) (2.5% loss)	Clamshell	MP 29.52	11,250	33.7	2.5	351	1.1	443	0	371	253	0	3.6	1.2	0.0
Scenario B-8	Excavation of Ambrose Channel HDD pit (West) (0.5% loss)	Clamshell	MP 29.52	11,250	33.7	0.5	70	0.0	0	0	148	0	0	0.6	0.0	0.0
Scenario B-9	Excavation at the Ambrose HDD pit (East) and Ambrose Channel tie-in (2.5% loss)	Clamshell	MP 30.40	11,250	83.5	2.5	869	0.0	0	0	295	243	187	3.8	2.7	1.4
Scenario B-10	Pre-lay trenching between the Neptune crossing and end of pipeline (2.5% loss)	Clamshell	MP 35.19 to MP 35.49	11,250	31.0	2.5	329	0.6	656	0	138	0	0	2.0	0.0	0.0
Scenario B-11	Dredging of backfill source material from Ambrose Channel (2.5% loss)	Clamshell	Ambrose Channel (W to E)	11,250	533.0	2.5	5,555	1.0	2,280	1,033	171	0	0	59.7	0.0	0.0

Table 2 (cont.)

Scenario	Construction Activity	Equipment Type	Location	Production rate (ft3/hr)	Duration of modeled activity (hr)	Equipment Loss (%)	Total volume released (yd3)	Time For TSS to return to ambient (hrs)	Max Distance of TSS Plume exceeding ambient (ft)		Max Distance of deposition exceeding (ft)			Area of deposition exceeding (acres)		
									50 mg/L	100 mg/L	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]
Scenario B-12	Dredging of backfill source material from Rockaway Inlet (2.5% loss)	Clamshell	Rockaway Inlet (S to N)	11,250	533.0	2.5	5,555	0.2	3,757	2,116	299	131	0	46.5	15.6	0.0
Scenario B-13	Dredging of backfill source material from Earle Channel (2.5% loss)	Clamshell	Earle Channel (W to E)	11,250	533.0	2.5	5,555	0.8	5,331	1,099	128	0	0	25.5	0.0	0.0
Scenario B-14	Dredging of backfill source material from Ambrose Channel (0.5% loss)	Clamshell	Ambrose Channel (W to E)	11,250	533.0	0.5	1,111	0.0	0	0	0	0	0	0.0	0.0	0.0
Scenario B-15	Dredging of backfill source material from Rockaway Inlet (0.5% loss)	Clamshell	Rockaway Inlet (S to N)	11,250	533.0	0.5	1,111	0.2	197	0	79	0	0	7.5	0.0	0.0
Scenario B-16	Dredging of backfill source material from Earle Channel (0.5% loss)	Clamshell	Earle Channel (W to E)	11,250	533.0	0.5	1,111	0.5	0	0	0	0	0	0.0	0.0	0.0
Scenario B-17	Side-cast across the Anchorage area (100% loss)	Clamshell	MP 24.00 to MP 24.78	11,250	154.0	100	64,311	0.9	6,283	3,084	390	259	161	53.8	36.0	22.8
Scenario B-18	Side-cast at the Ambrose HDD pit (West) (100% loss)	Clamshell	MP 29.52	11,250	33.7	100	14,050	7.3	19,587	17,684	1,198	787	397	18.5	6.4	4.3
Scenario B-19	Side-cast at the Ambrose HDD pit (East) and Ambrose Channel tie-in (100% loss)	Clamshell	MP 30.40	11,250	83.5	100	34,777	1.6	3,822	2,789	407	305	269	6.5	4.4	3.8
Scenario B-20	Side-cast between the Neptune crossing and RDL	Clamshell	MP 35.19 to MP 35.49	11,250	31.6	100	13,152	1.9	1,690	1,296	436	348	249	22.7	14.9	9.9
Scenario B-21	Backfill of trench between Morgan HDD exit and the Midline tie-in	Clamshell	MP 12.50 - MP 16.60	7,500	794.1	100.0	219,591	1.2	2,641	1,329	453	364	282	280.5	222.6	161.5
Scenario B-22	Backfilling of Ambrose Channel HDD Pit (West)	Clamshell	MP 29.52	7,500	63.2	100.0	17,563	1.3	1,788	1,526	948	755	499	15.1	8.9	5.1

4 References

RPS, 2017. Northeast Supply Enhancement Project: Hydrodynamic and Sediment Transport Modeling Results – Base Case Simulations. Prepared for Ecology & Environment, Inc. on behalf of Transcontinental Gas Pipe Line Company, LLC. August 28, 2017.

TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F-4 – HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING RESULTS – ADDENDUM 3

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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RPS

Northeast Supply Enhancement Project:
Hydrodynamic and Sediment Transport Modeling Results: Addendum 3

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1 Introduction

1.1 Project Background

As part of its Northeast Supply Enhancement Project (Project), Transcontinental Gas Pipe Line Company, LLC (Transco) is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey, as well as its existing offshore natural gas pipeline system in New Jersey and New York. A major portion of the Project includes the installation of a 26-inch outer diameter pipeline, referred to as the “Raritan Bay Loop” that will extend from the Sayreville, New Jersey shoreline (MP12.16) approximately 23.33 miles across the Raritan Bay and Lower New York Bay to the Rockaway Transfer Point in the Atlantic Ocean. The pipeline installation will require a range of dredging and burial techniques (e.g. clamshell dredging, jet trenching, submersible pumping, and backfilling) each of which has the potential to produce seabed disturbances, suspended sediment plume formation, and smothering due to sedimentation. RPS has been contracted to develop and apply customized hydrodynamic, and sediment transport and dispersion models to help assess the potential environmental impacts of these Project-related activities.

1.2 Objectives and Tasks

Results from an initial set of “base case” construction activities were completed by RPS in August 2017. The base case modeling report described the development and calibration of a three-dimensional hydrodynamic model for the New York/New Jersey Harbor Estuary (NY/NJ Harbor Estuary), using the Water Quality Model and Analysis Package / Boundary-Fitted Hydrodynamics (WQMAP/BFHYDRO) modeling system and application of the Suspended Sediment Fate (SSFATE) sediment model to simulate offshore construction activities including mechanical (clamshell) dredging, post-pipelay burial by jet trencher, hand-jetting, and suction dredging (submersible pumping). Subsequent report addenda in September 2017 (Addendum 1) and May 2018 (Addendum 2) described modeling of additional Project-related activities, including dredging of navigation channels, the use of environmental buckets to limit sediment losses, backfilling along portions of the pipeline route, and side-casting of dredged sediments to the seabed during certain phases of the installation

This report (Addendum 3) describes new applications of the modeling systems to simulate sediment losses from: (i) deeper dredging and burial (15 ft of sediment cover) of the pipeline at the Raritan and Chapel Hill channel crossings and adjacent anchorage area, and (ii) backfilling sections of the pipeline trench at varying advance rates. An overview of the additional SSFATE scenarios and model results are provided in Sections 2 and 3. The base case modeling report provides a complete description of the modeling systems, model theory, validation of the hydrodynamic predictions, and references for each model (RPS 2017).

2 SSFATE Model Setup

2.1 Description of SSFATE Scenarios

The additional sediment modeling scenarios that RPS has developed in consultation with Transco and E&E are summarized in Table 1 and presented graphically in Figure 1. The new SSFATE scenarios (13 total) were developed to simulate sediment releases for three types of construction activities associated with different stages of the offshore installation between MP 12.50 and the Rockaway tie-in point at MP 35.49. Specifically, these include:

1. Clamshell dredging with an "environmental" bucket where sediment is lost as the bucket ascends through the water column (0.5% sediment loss). No overflow of the scow barge is permitted.
2. Clamshell dredging with an "environmental" bucket where sediment is lost as the bucket ascends through the water column, and from overflow of the scow barge at the sea surface (2.5% sediment loss).
3. Simulations of placement of backfill materials for segments of the pipeline route excavated using clamshell dredges.

Both dredging activities (1 and 2) were simulated using a constant dredge production rate of 11,250 ft^3/hr. Backfilling was simulated using production rates ranging from 4,800 ft^3/hr to 7,500 ft^3/hr.

Table 1. Description of activities being simulated for each modeling scenario included in Addendum 3.

Scenario	Construction Activity	Equipment Type	Point/Line Source	Location	Excavation Volume (yd^3)	Duration (day)
Scenario C-1	Clamshell dredge Raritan Channel deep prism (15-ft burial) with no scow overflow	Clamshell	Line	MP 17.23 - MP 17.97	357,503	35.8
Scenario C-2	Clamshell dredge anchorage deep prism (15-ft burial) with no scow overflow	Clamshell	Line	MP 24.00 - MP 24.70	162,836	16.3
Scenario C-3	Clamshell dredge extended Chapel Hill Channel deep prism (15-ft burial) with no scow overflow	Clamshell	Line	MP 24.70 - MP 25.61	204,607	20.5
Scenario C-4	Clamshell dredge anchorage deep prism (15-ft burial) with scow overflow	Clamshell	Line	MP 24.00 - MP 24.70	162,836	16.3
Scenario C-5	Backfill Raritan Channel base-case prism (up to 8-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 17.31 - MP 17.89	167,025	25.1
Scenario C-6	Backfill Raritan Channel deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 17.23 - MP 17.97	446,879	67.0
Scenario C-7	Backfill anchorage area base-case prism (7-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 24.00 - MP 24.78	80,388	12.1
Scenario C-8	Backfill anchorage area deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 24.00 - MP 24.70	203,545	30.5
Scenario C-9	Backfill extended Chapel Hill Channel prism (up to 8-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 24.78 - MP 25.61	83,439	12.5
Scenario C-10	Backfill extended Chapel Hill Channel deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	Line	MP 24.70 - MP 25.61	255,759	38.4
Scenario C-11	Backfill of trench between Morgan HDD exit and the Midline tie-in @ 4,800 cf/hr	Clamshell	Line	MP 12.50 - MP 16.60	219,591	51.5
Scenario C-12	Backfill Raritan Channel deep prism (15-ft burial) @ 4,800 cf/hr	Clamshell	Line	MP 17.23 - MP 17.97	446,879	104.7
Scenario C-13	Backfill of Ambrose HDD Pit (East) and tie-in @ 4,800 cf/hr	Clamshell	Point	MP 30.40	40,563	9.5

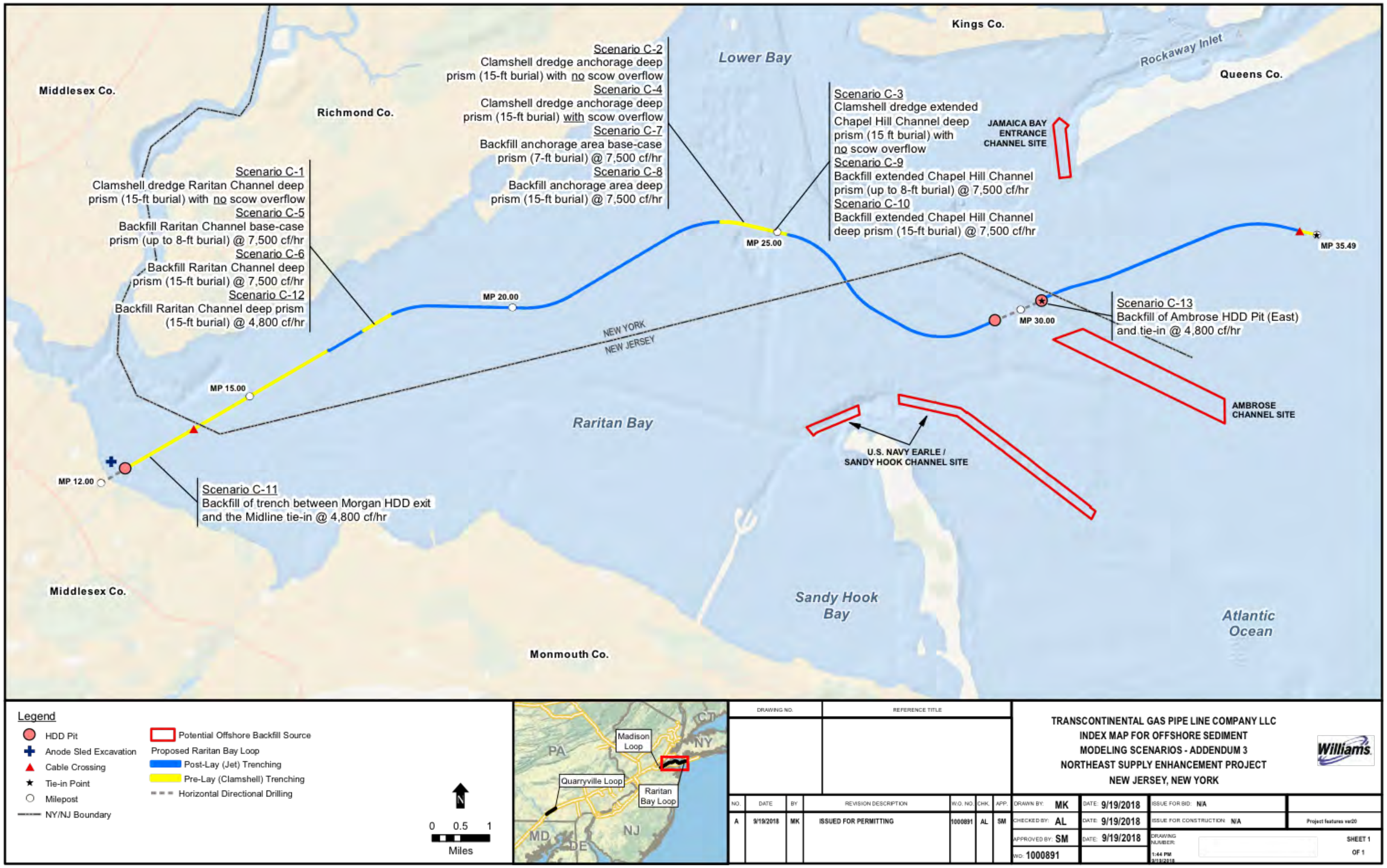

Figure 1. Map view showing sediment modeling scenario locations (from E&E).

3 SSFATE Results

3.1 Scenario C-1 – Clamshell Trenching Across the Raritan Channel (Deep Prism, 0.5% loss)

Scenario C-1 simulated releases associated with pre-lay trenching across the Raritan Channel (between MP 17.23 and MP 17.97) under the revised assumption that the pipeline would require a minimum of 15 ft of cover along this reach and that sediment losses would be limited to 0.5% of the excavation volume through use of an environmental bucket (with no scow overflow). Trench volumes were estimated using a trapezoidal prism with a 1:3 slope and a 7 ft wide trench base. In total, this scenario assumed 357,503 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of November 6 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 2 (May 2018) modeling, which included comparable simulations of dredging across the Raritan Channel. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 1,788 yd^3 of sediment over 35.8 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 17.23 and MP 17.97 are presented in Figure 2 and Figure 3, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. Overall, the plume that arises from trenching across the Raritan Channel is predicted to remain in close proximity to the dredge during most of the simulation, and as a result the cumulative plume footprint closely matches the trenching route. Although the simulation extends over one month, the cumulative plume does not exhibit notable variation along the route (i.e. oscillation with tides). Instead, elevated TSS concentrations (above 10 mg/L) remain adjacent to the dredge and appear well mixed (vertically) in the water column with lowest values predicted near the deepest sections of the channel. TSS concentrations rise toward either bank of the channel. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations are expected to return to ambient levels almost instantaneously (less than 1 minute) after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

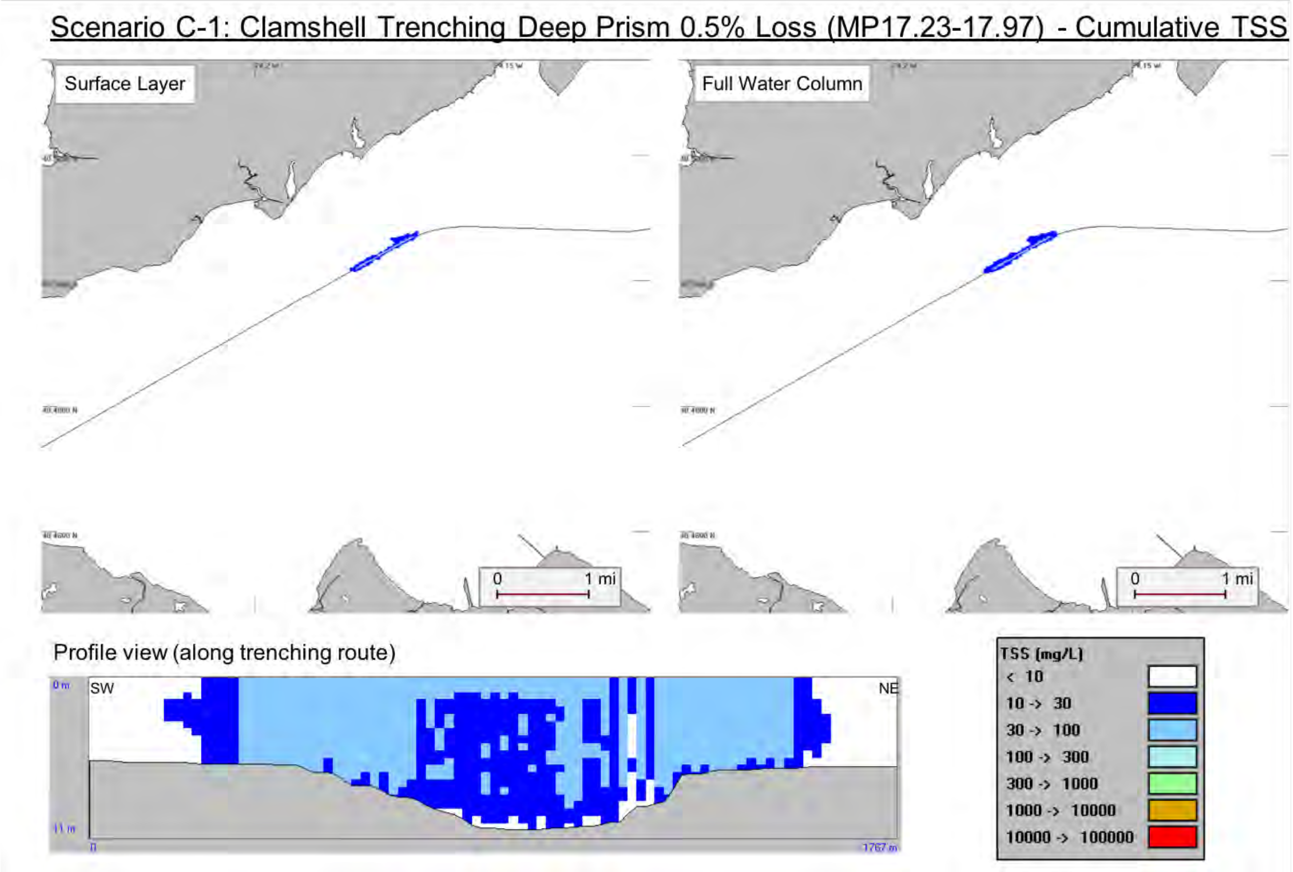

Figure 2. Cumulative TSS concentrations for Scenario C-1 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

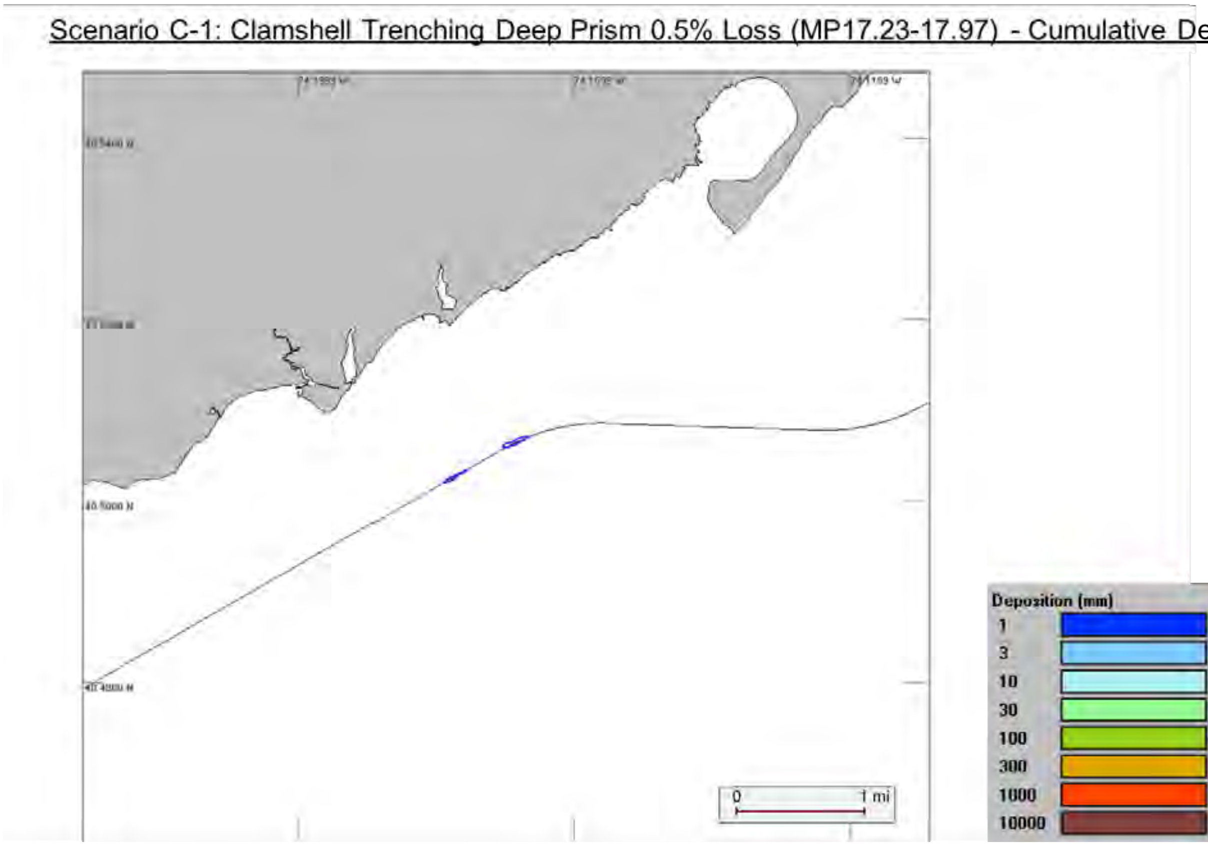

Figure 3. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) between MP 17.23 and MP 17.97. Maximum predicted thickness = 0.1 in (1.7 mm).

3.2 Scenario C-2 – Clamshell Trenching Across the Anchorage Area (Deep Prism, 0.5% loss)

Scenario C-2 simulated releases associated with pre-lay trenching between MP 24.00 and MP 24.70 (across the Anchorage Area to the start of the Chapel Hill Channel transition), under the revised assumption that the pipeline would require a minimum of 15 ft of cover along this reach and that sediment losses would be limited to 0.5% of the excavation volume through use of an environmental bucket (with no scow overflow). The trench volume was estimated using a trapezoidal prism with a 1:3 slope, an 18.5 ft trench depth, and a 7 ft wide trench base. In total, this scenario assumed 162,836 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 2 (May 2018) modeling scenarios, which included comparable simulations of dredging across the Anchorage Area. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 814 yd^3 of sediment over 16.3 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 24.00 and MP 24.70 are presented in Figure 4 and Figure 5, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. As with Scenario C-1, the cumulative TSS plume is well mixed throughout the water column and remains very close to the source for the duration of the simulation. TSS concentrations are lowest directly above the seabed. The use of an environmental bucket for dredging and prevention of scow overflow has the effect of limiting excess TSS concentrations to relatively low levels throughout the simulation. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations are expected to return to ambient levels within 10 minutes from the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

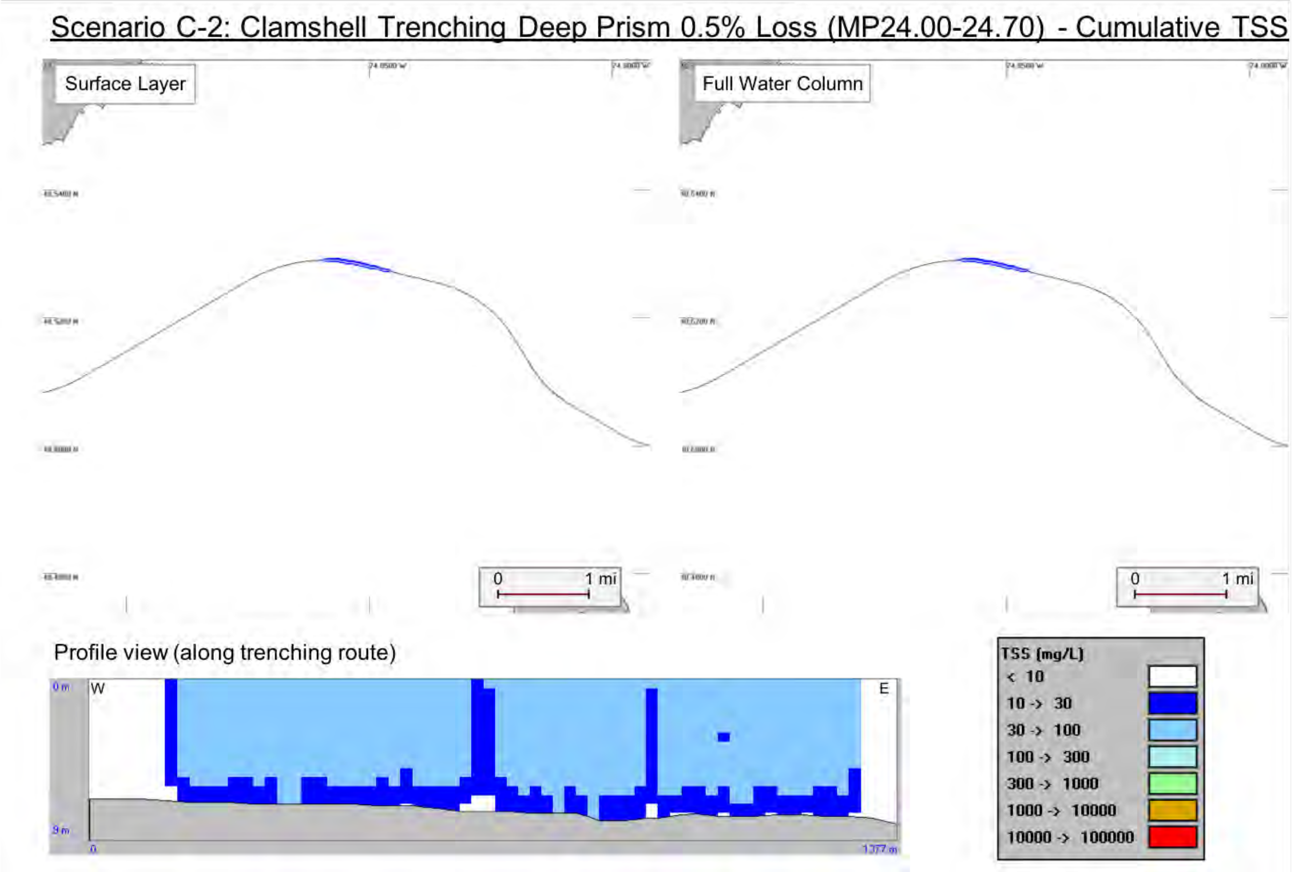

Figure 4. Cumulative TSS concentrations for Scenario C-2 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

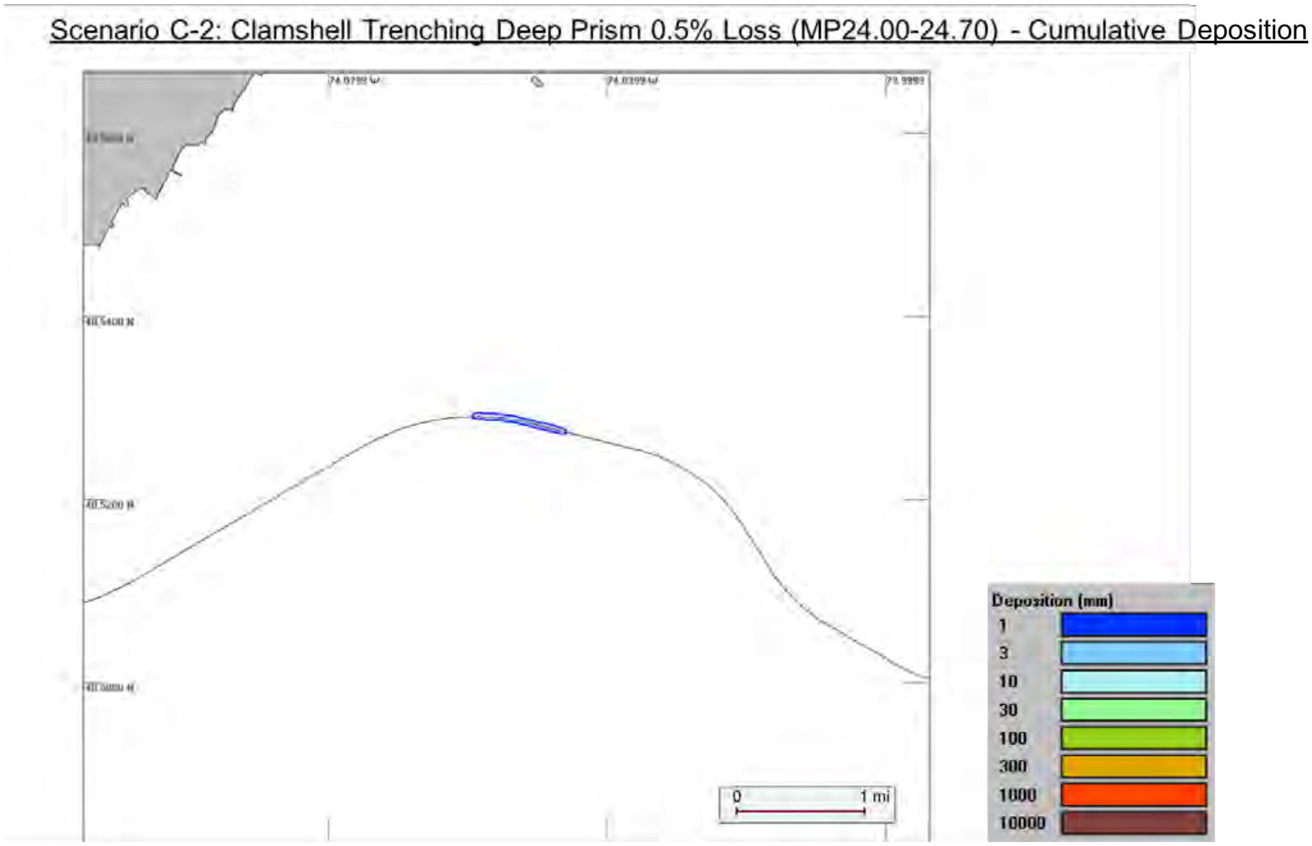

Figure 5. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) between MP 24.00 and MP 24.70. Maximum predicted thickness = 0.2 in (6.3 mm).

3.3 Scenario C-3 – Clamshell Trenching Across the Chapel Hill Channel (Deep Prism, 0.5% loss)

Scenario C-3 simulated releases associated with pre-lay trenching between MP 24.70 and MP 25.61 (extended Chapel Hill Channel crossing), under the revised assumption that the pipeline would require a minimum of 15 ft of cover along this reach and that sediment losses would be limited to 0.5% of the excavation volume through use of an environmental bucket (with no scow overflow). The extension of clamshell dredging with environmental bucket to MP 25.61 was in response to feedback Transco received from the New York State Department of Environmental Conservation (NYSDEC) related to the presence of contaminants exceeding the NYSDEC "Class C" threshold. Trench volumes were estimated using a trapezoidal prism with a 1:3 slope and a 7 ft wide trench base. In total, this scenario assumed 204,607 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 2 (May 2018) modeling scenarios, which included comparable simulations of dredging across the Chapel Hill Channel. Losses from the clamshell bucket were assumed to be 0.5% of the total excavation volume, distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 1,023 yd^3 of sediment over 20.5 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 24.70 and MP 25.61 are presented in Figure 6 and Figure 7, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. Overall, the expression of the water column plume is similar to the previous scenario (C-2) due to the assumption of reduced loading from the sediment source (i.e. limitation of sediment losses to 0.5% of excavation volume). The highest TSS concentrations are predicted to occur in the surface waters although, like Scenario C-2, the cumulative plume (above 10 mg/L) is generally well mixed throughout the water column and remains close to the source for the duration of the simulation. The pattern of seabed deposition also appears compact around trenching route, indicating limited sediment transport. At no point during the simulation are water column concentrations predicted to exceed 100 mg/L and TSS concentrations are expected to return to ambient levels within 0.3 hours (16 minutes) after the conclusion of trenching. Sediment deposition does not reach the level of 0.4 in (1.0 cm) during the simulation.

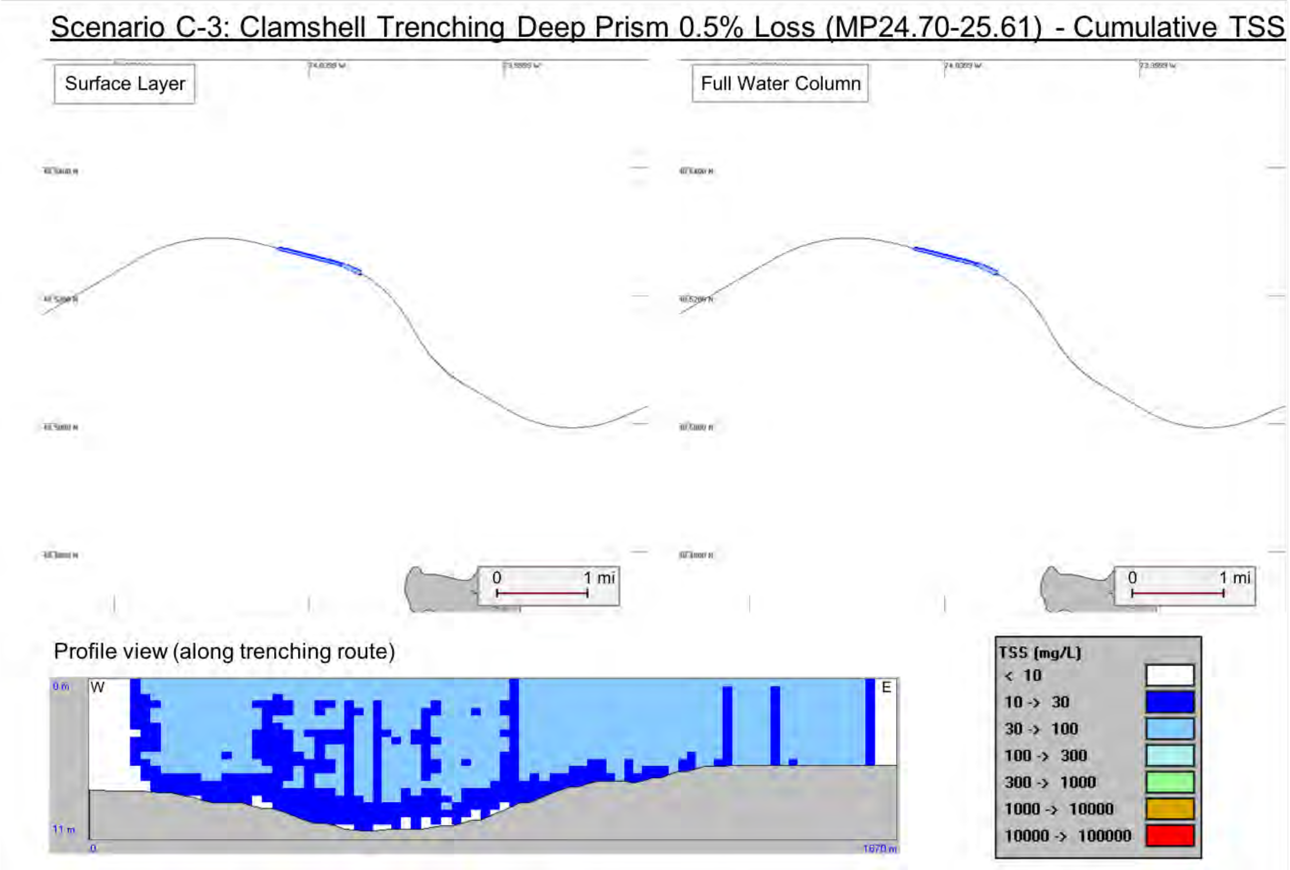

Figure 6. Cumulative TSS concentrations for Scenario C-3 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

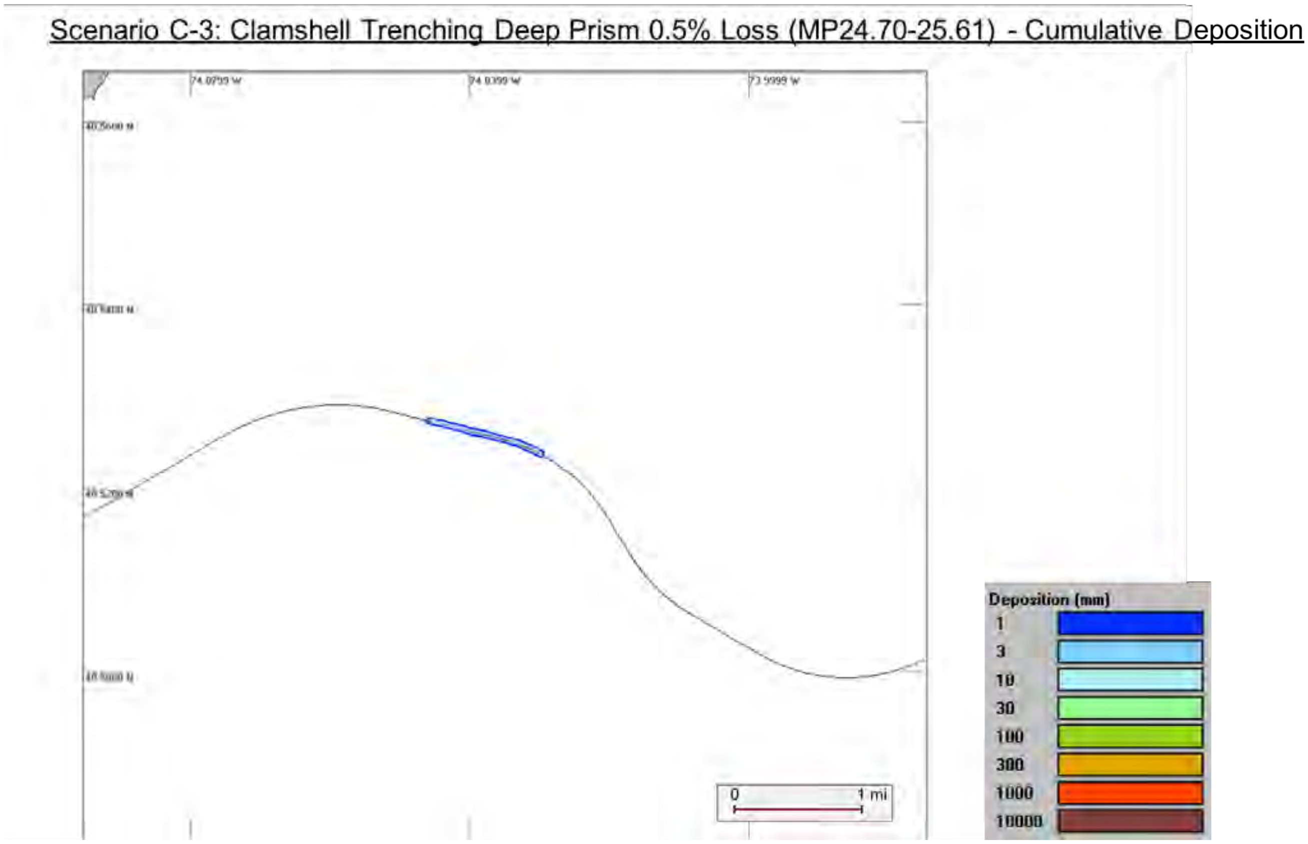

Figure 7. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) MP 24.70 and MP 25.61. Maximum predicted thickness = 0.2 in (6.0 mm).

3.4 Scenario C-4 – Clamshell Trenching Across the Anchorage Area (Deep Prism, 2.5% loss)

Scenario C-4 simulated releases associated with pre-lay trenching between MP 24.00 and MP 24.70 (Anchorage Area to the start of the Chapel Hill Channel transition), under the revised assumption that the pipeline would require a minimum of 15 ft of cover along this reach and that sediment losses would be limited to 2.5% of the excavation volume through use of an environmental bucket. The simulation replicates Scenario C-2, with the distinction that scow overflow would be permitted at a rate of 2% of the dredge production. Trench volumes were estimated using a trapezoidal prism with a 1:3 slope, an 18.5 ft trench depth, and a 7 ft wide trench base. In total, this scenario assumed 162,836 yd^3 of sediment will be removed from the trench by the clamshell dredge, which is assumed to operate at a constant production rate of 11,250 ft^3/hr.

The activity was modeled as a line source, assuming a single pass of the clamshell dredge in one direction (West to East) and a start date of October 27 to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 2 (May 2018) modeling scenarios, which included comparable simulations of dredging across the Anchorage Area. Losses from the clamshell bucket were assumed to be 2.5% of the total excavation volume, with 2% released at the sea surface (representing barge overflow) and the remaining 0.5% distributed equally through the water column (representing loss from the bucket as it is raised and lowered during the dredging cycle). The simulation included the release of 4,071 yd^3 of sediment over 16.3 days.

Water column and sediment bed results from simulations of clamshell trenching between MP 24.00 and MP 24.70 are presented in Figure 8 and Figure 9, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. In this case the cumulative TSS plume is slightly larger than Scenario C-2 and more concentrated within the upper water column. Maximum TSS concentrations (860 mg/L) occur at the surface as a direct result of scow overflow, however, the plume dissipates rapidly with distance and TSS concentrations exceeding 100 mg/L are limited to areas within 197 ft from active dredging. TSS concentrations are expected to return to ambient levels within 0.5 hours (28 minutes) after the conclusion of trenching. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 112 ft from the source and covers a total of 14.7 acres of the seabed.

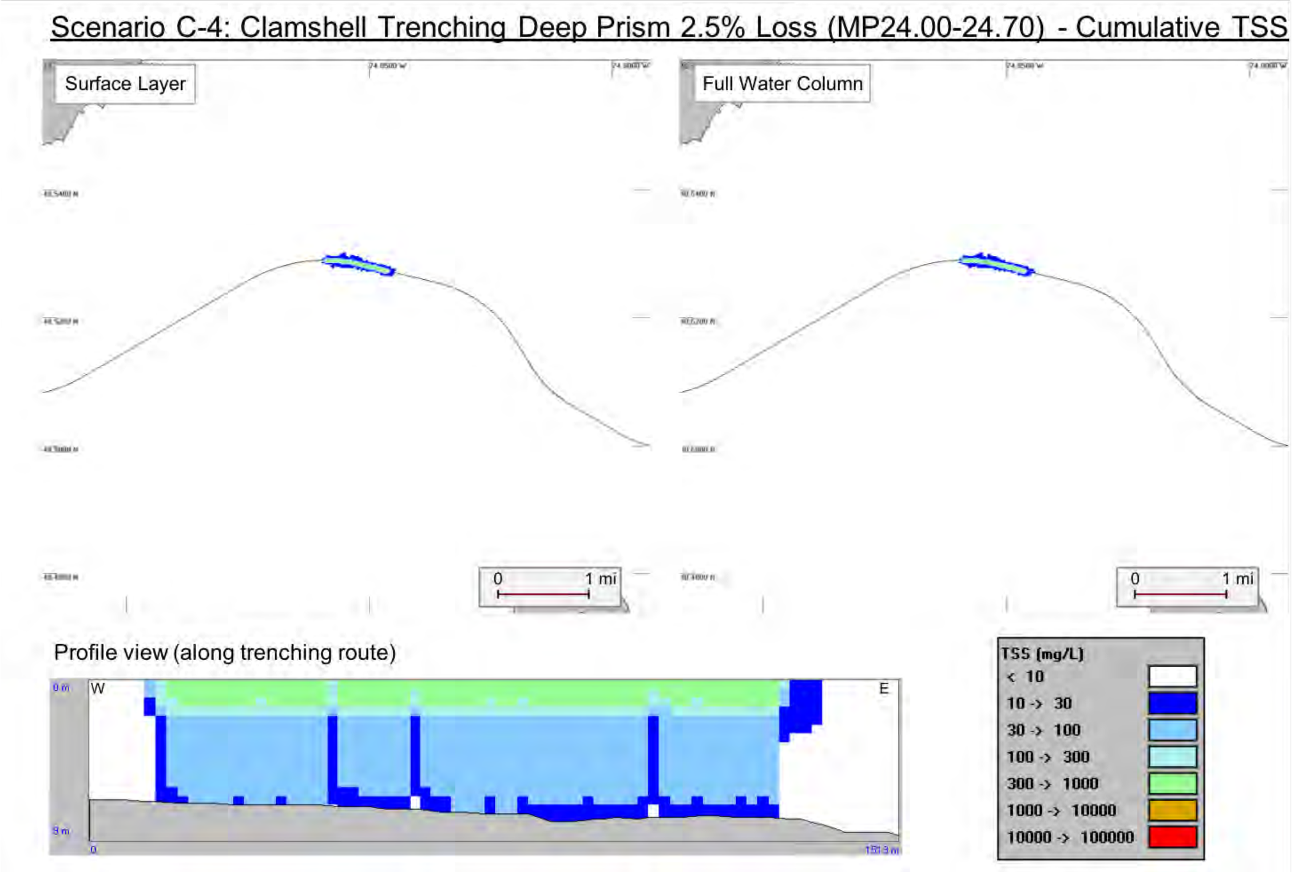

Figure 8. Cumulative TSS concentrations for Scenario C-4 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

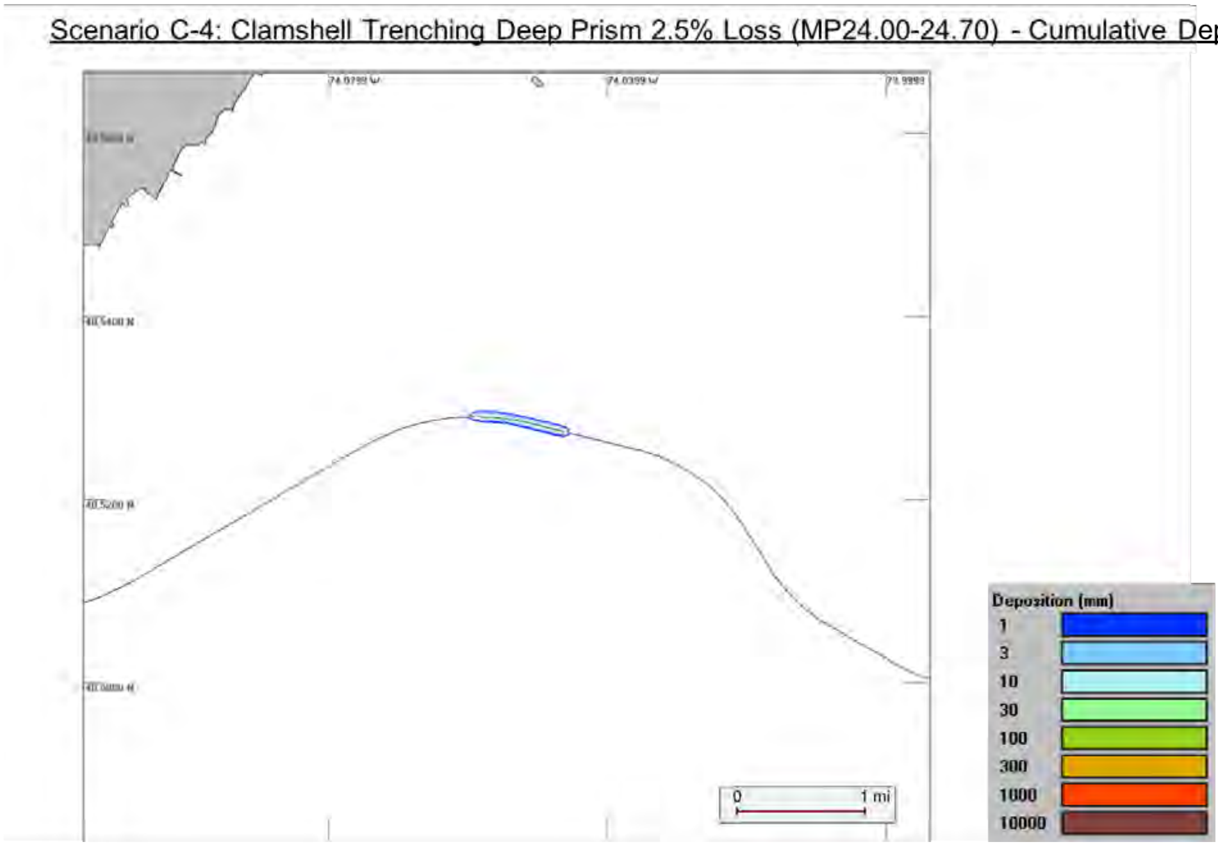

Figure 9. Extent of seabed deposition resulting from pre-lay clamshell trenching (0.5% loss) between MP 24.00 and MP 24.70. Maximum predicted thickness = 1.2 in (31.5 mm).

3.5 Scenario C-5 – Backfilling Across the Raritan Channel

Scenario C-5 simulated the placement of backfill material to fill the excavated trench extending across the Raritan Channel between MP 17.31 and MP 17.89. The simulation replicates Scenario A-7 presented in Addendum 1 (backfilling of the Raritan Channel using "base case" volumes), with the distinction that backfilling would be slowed to a rate of 7,500 ft^3/hr for this portion of the pipeline route. Along this reach, the pipeline will be buried to variable depths (between 4 and 8 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-5, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 601 hours (25.1 days) while placing backfill sediments over approximately 0.58 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 167,025 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 133,620 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 17.31 and MP 17.89 are presented in Figure 10 and Figure 11, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. During most of the burial activity, the plume remains confined to the mid- and lower portions of the water column. At lower concentrations (below 100 mg/L) the plume migrates West/East with the tidal current as the simulation advances. Higher concentrations (above 10,000 mg/L) occur at or near the seabed across the channel (reflecting the release of all material at this height within the water column) although transport away from the source is limited. Plumes above 10 mg/L reach the surface layer only intermittently during the simulation. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,066 ft from the source, although that distance drops to 722 ft for 99.9% of occurrences in the model (Table 3). TSS concentrations remain elevated above ambient levels for 1.8 hours after the conclusion of backfilling.

Sediment deposition at or above 0.4 in (1.0 cm) extends up to 492 ft from the source and covers a total of 41.4 acres of the seabed.

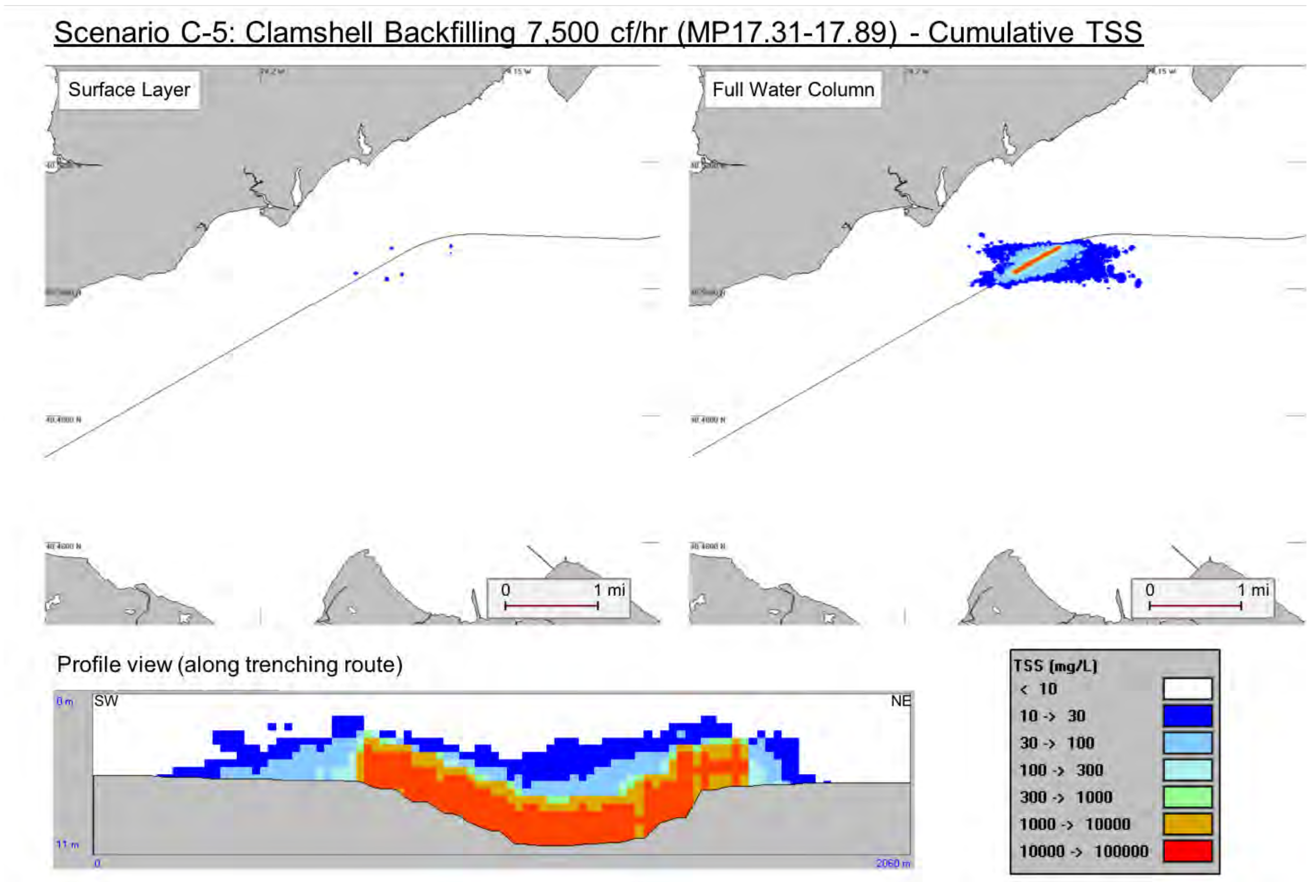

Figure 10. Cumulative TSS concentrations for Scenario C-5 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

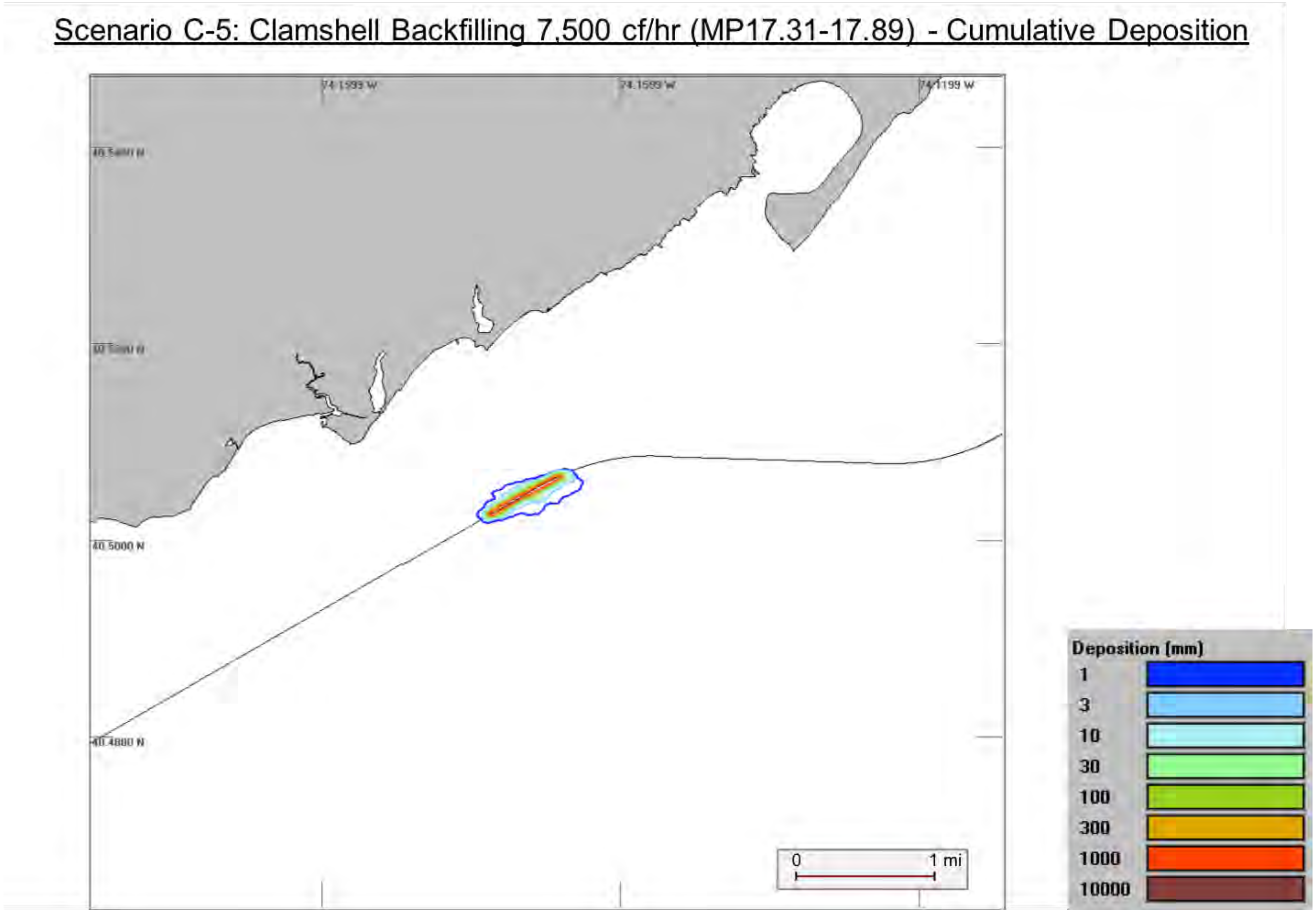

Figure 11. Extent of seabed deposition resulting from backfilling between MP 17.31 and MP 17.89. Maximum predicted thickness = 94.5 in (2,400 mm).

3.6 Scenario C-6 – Backfilling Across the Raritan Channel (Deep Prism)

Scenario C-6 simulated the placement of backfill material to fill the excavated trench extending across the Raritan Channel between MP 17.23 and MP 17.97, corresponding to the filling of the "deep prism" trench excavated in Scenario C-1. The simulation is comparable to C-5, with modifications to start/end points and backfilling volumes to account for changes in the trench configuration that may be required to achieve deeper burial beneath the Raritan Channel. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-6, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. During this run the clamshell dredge was assumed to operate continuously for 1,609 hours (67.0 days) while placing backfill sediments over approximately 0.74 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 446,879 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location (Scenario C-1) is 357,503 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 17.23 and MP 17.97 are presented in Figure 12 and Figure 13, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. As with Scenario C-5, high TSS concentrations (above 10,000 mg/L) remain confined to the mid- and lower portions of the water column (reflecting the release of all material at this height within the water column) with isolated portions of the water surface exceeding 10 mg/L intermittently during the simulation. The cumulative plume appears similar to C-5, although the footprint is slightly expanded due to the larger volumes and longer duration backfilling. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,165 ft from the source and TSS concentrations remain elevated above ambient levels for 1.6 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 801 ft from the source and covers a total of 77.2 acres of the seabed.

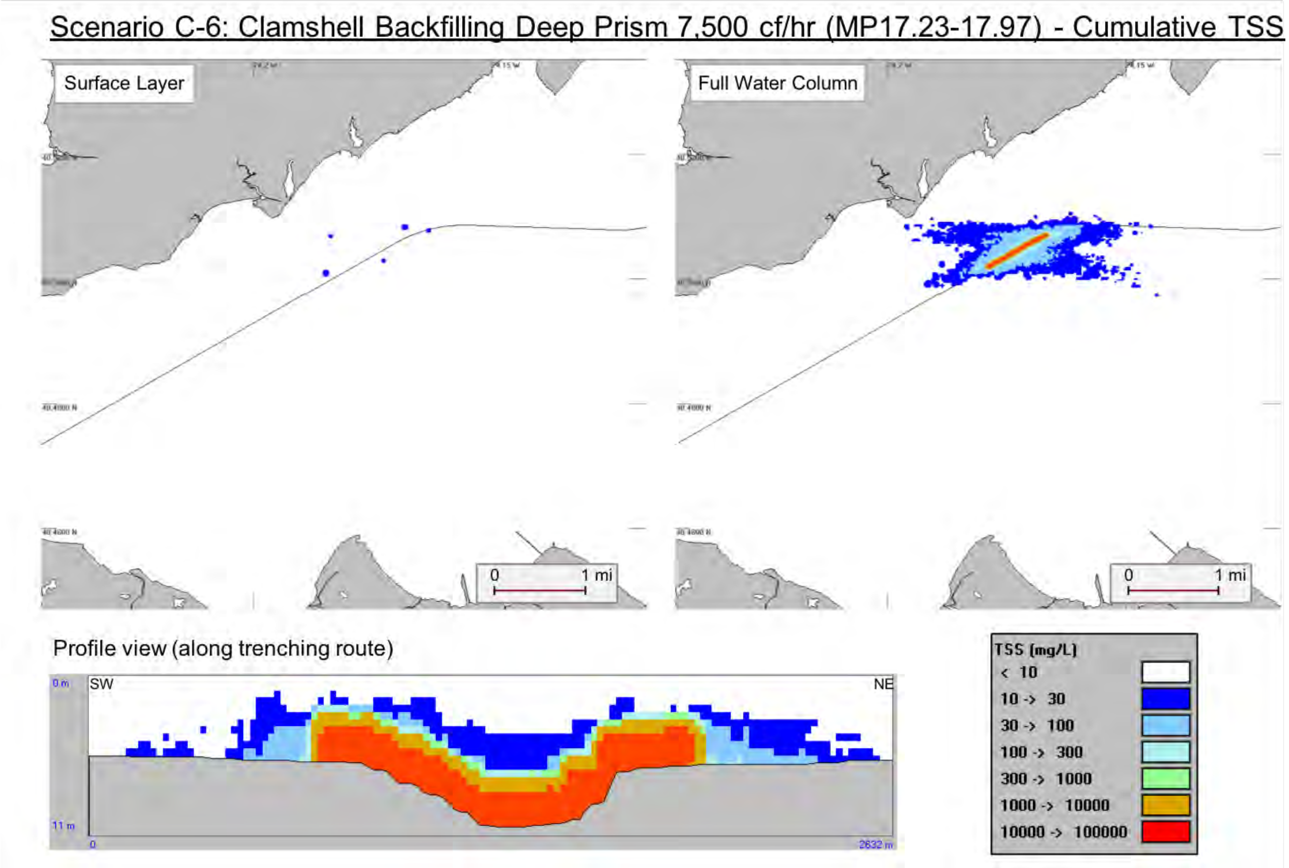

Figure 12. Cumulative TSS concentrations for Scenario C-6 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the maximum plume extent.

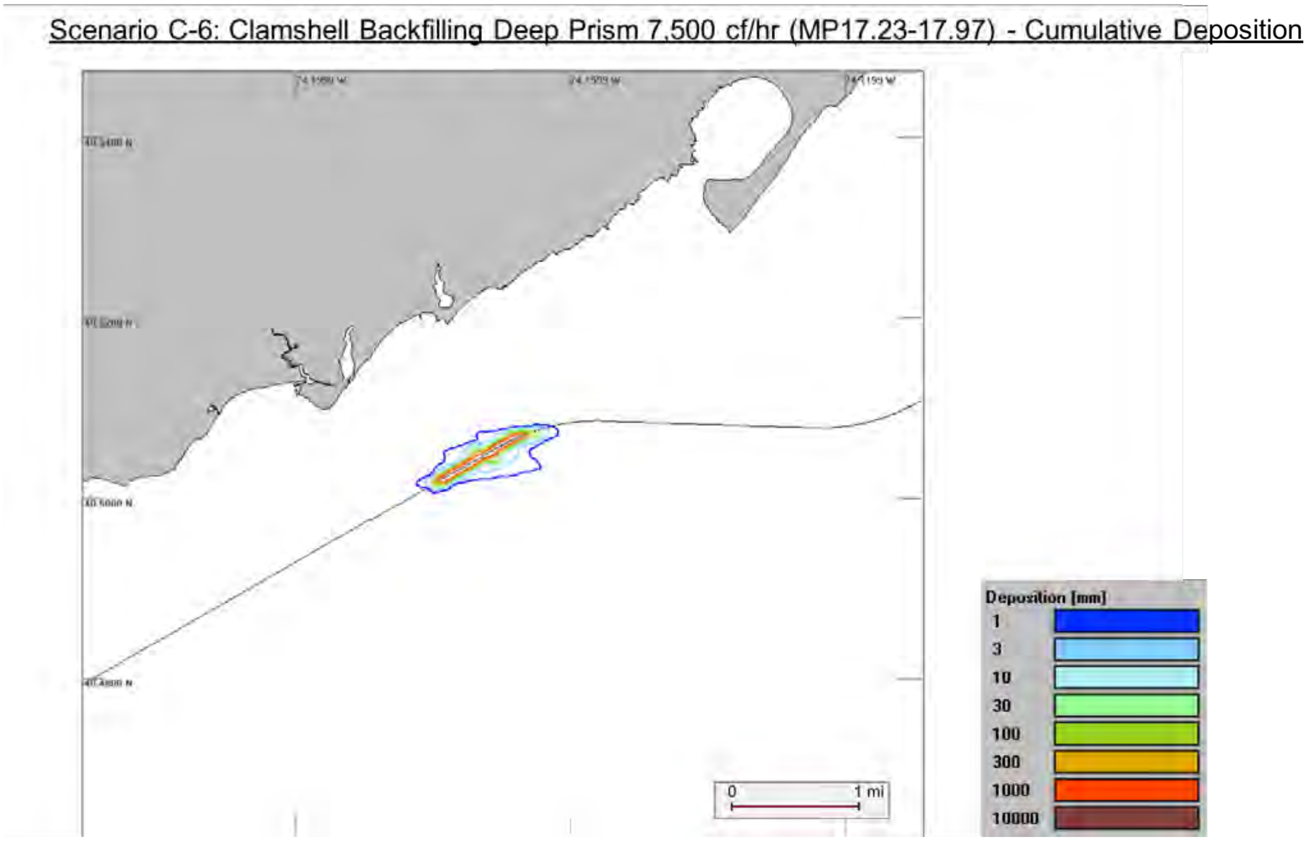

Figure 13. Extent of seabed deposition resulting from backfilling between MP 17.23 and MP 17.97. Maximum predicted thickness = 130.7 in (3,320 mm).

3.7 Scenario C-7 – Backfilling Across the Anchorage Area

Scenario C-7 simulated the placement of backfill material to fill the excavated trench extending across the Anchorage Area between MP 24.00 and MP 24.78. The simulation replicates the first part of Scenario A-8 presented in Addendum 1 (backfilling between the Anchorage Area and Chapel Hill Channel using "base case" volumes), with the distinction that backfilling would be slowed to a rate of 7,500 ft^3/hr for this portion of the pipeline route. Along this reach, the pipeline will be buried to variable depths (between 4 and 8 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-7, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. During this run the clamshell dredge was assumed to operate continuously for 289 hours (12.1 days) while placing backfill sediments over approximately 0.78 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 80,388 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 64,311 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 24.00 and MP 24.78 are presented in Figure 14 and Figure 15, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. During backfilling, the sediment plume oscillates West/East with the tidal currents, which are aligned with the general orientation of the pipeline route in this part of Raritan Bay. As with other backfilling simulations, elevated TSS plumes (above 10 mg/L) are confined to the mid- and lower portions of the water column. Maximum concentrations are predicted directly adjacent to the placement source (5 ft above the seabed), reflecting the release of all material at this height within the water column. At the surface, TSS concentrations briefly exceed 10 mg/L in only a few locations (maximum of 11.8 mg/L) and generally remain below this threshold. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,247 ft from the source, although that distance drops to 935 ft for 99.9% of occurrences in the model (Table 3). TSS concentrations remain elevated above ambient levels for 1.0 hours after the conclusion of backfilling.

Sediment deposition at or above 0.4 in (1.0 cm) extends up to 318 ft from the source and covers a total of 43.4 acres of the seabed.

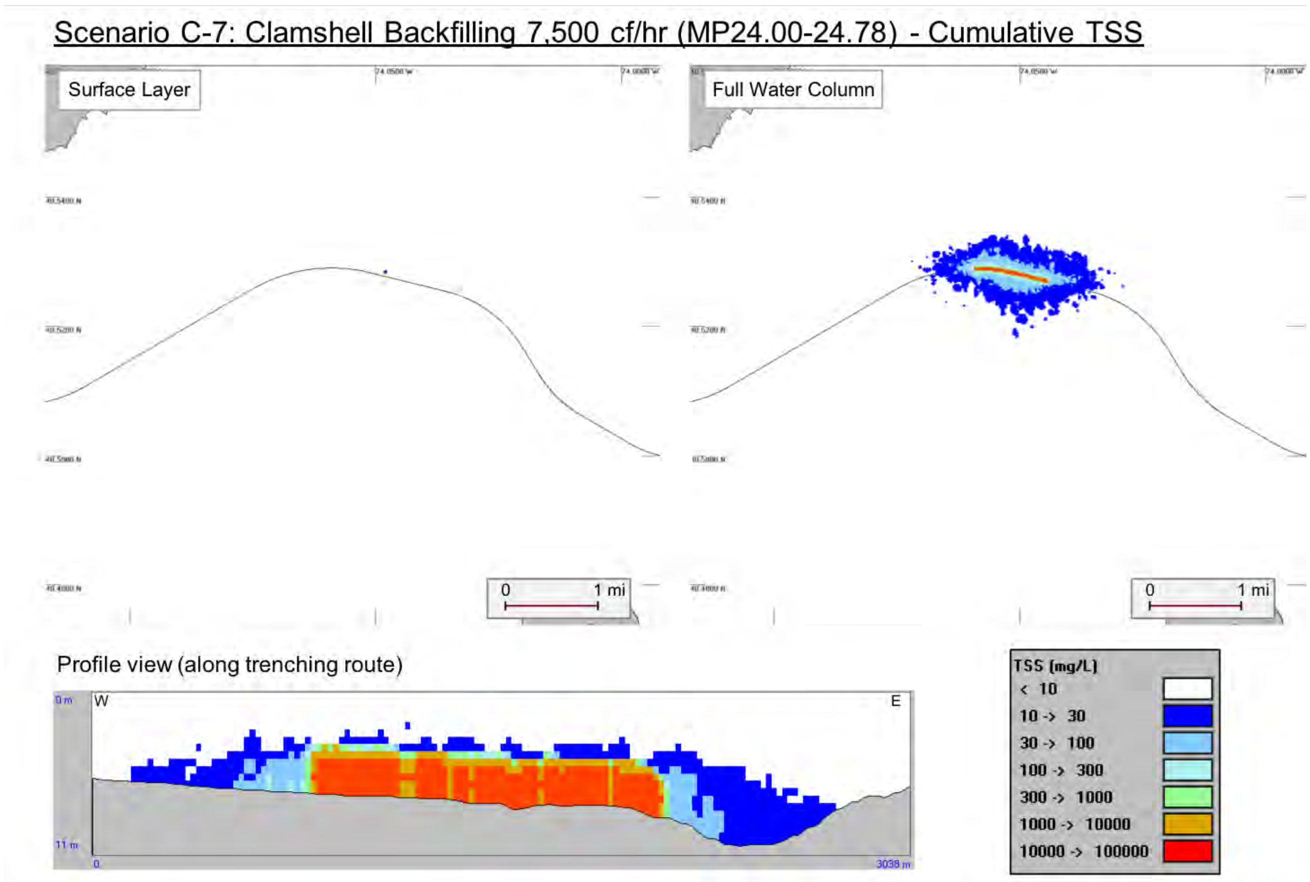

Figure 14. Cumulative TSS concentrations for Scenario C-7 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

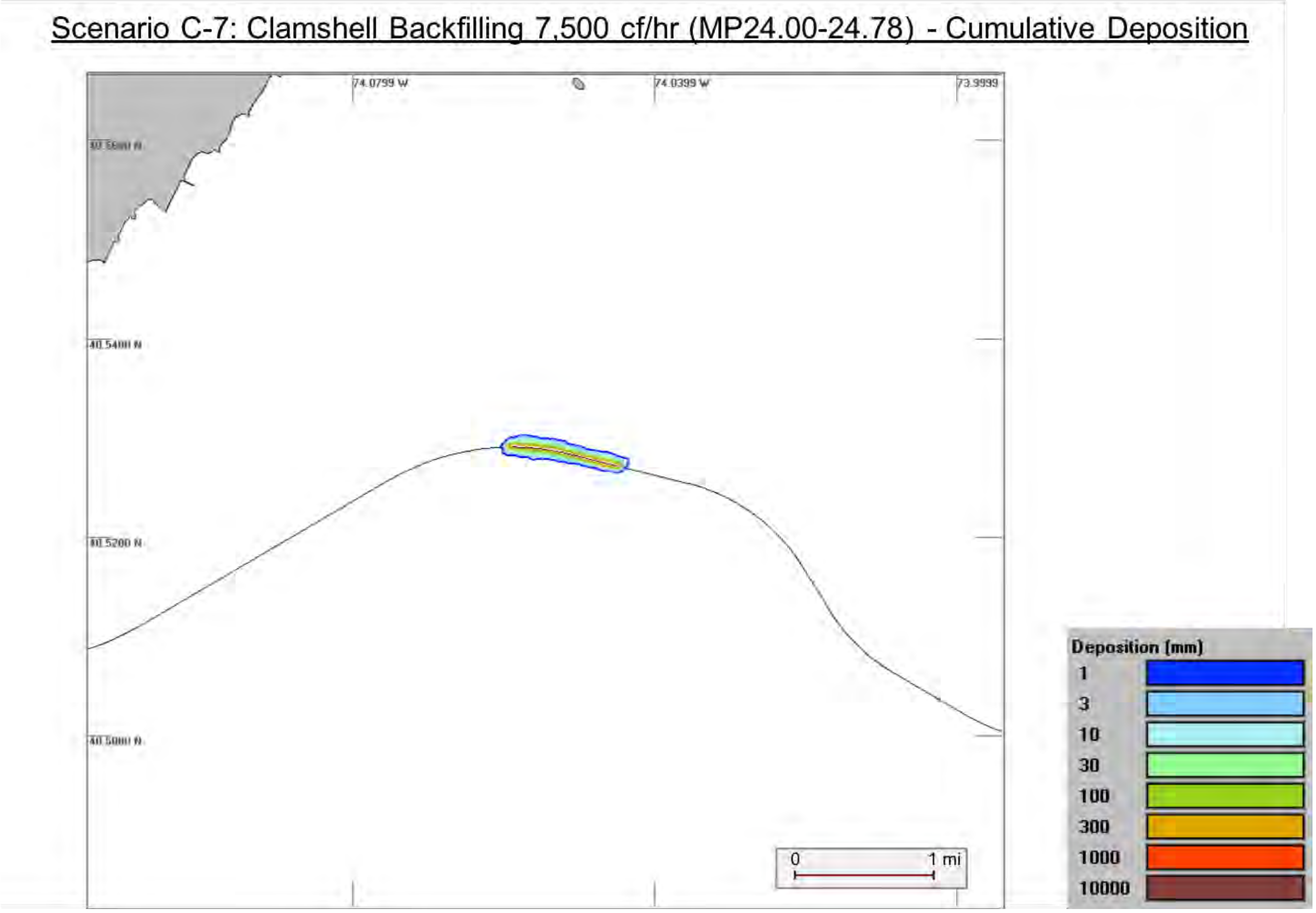

Figure 15. Extent of seabed deposition resulting from backfilling between MP 24.00 and MP 24.78. Maximum predicted thickness = 37.3 in (947 mm).

3.8 Scenario C-8 – Backfilling Across the Anchorage Area (Deep Prism)

Scenario C-8 simulated the placement of backfill material to fill the excavated trench extending across the Anchorage Area between MP 24.00 and MP 24.70, corresponding to the filling of the “deep prism” trench from Scenario C-2. The activity is similar to the backfilling in Scenario C-7, with modified start/end points and backfilling volumes to account for changes in the trench configuration that may be required to achieve a minimum 15 ft of cover across the Anchorage Area. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-8, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 733 hours (30.5 days) while placing backfill sediments over approximately 0.70 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 203,545 yd^3 of sediment was placed along this section of the trench, which includes an “overfill” factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location (Scenario C-2) is 162,836 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 24.00 and MP 24.70 are presented in Figure 16 and Figure 17, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. The overall dimensions of the sediment plume are comparable to those predicted in Scenario C-7 although notably, the maximum extent of TSS concentrations above 100 mg/L concentration is slightly smaller, despite the larger volumes and longer duration of backfilling. As with other backfilling simulations, elevated TSS plumes (above 10 mg/L) are confined to mid- and lower portions of the water column. Maximum concentrations are predicted directly adjacent to the placement source (5 ft above the seabed), reflecting the release of all material at this height within the water column. At the surface, TSS concentrations briefly exceed 10 mg/L in a few locations (maximum of 13.7 mg/L) but generally remain below this threshold. Water column concentrations of 100 mg/L are predicted to extend a maximum of 919 ft from the source and TSS concentrations remain elevated above ambient levels for 1.3 hours after the conclusion of backfilling.

Sediment deposition at or above 0.4 in (1.0 cm) extends up to 371 ft from the source and covers a total of 49.6 acres of the seabed.

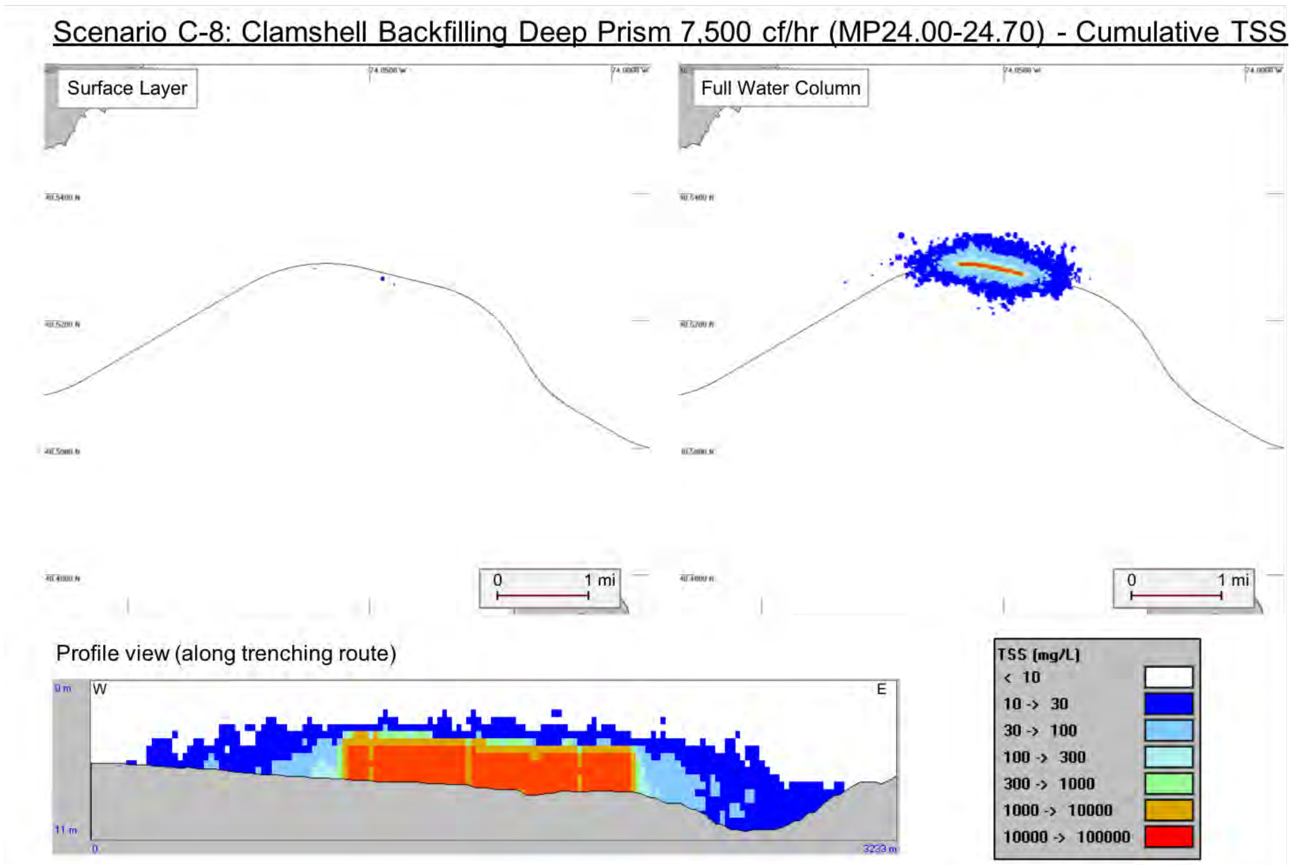

Figure 16. Cumulative TSS concentrations for Scenario C-8 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

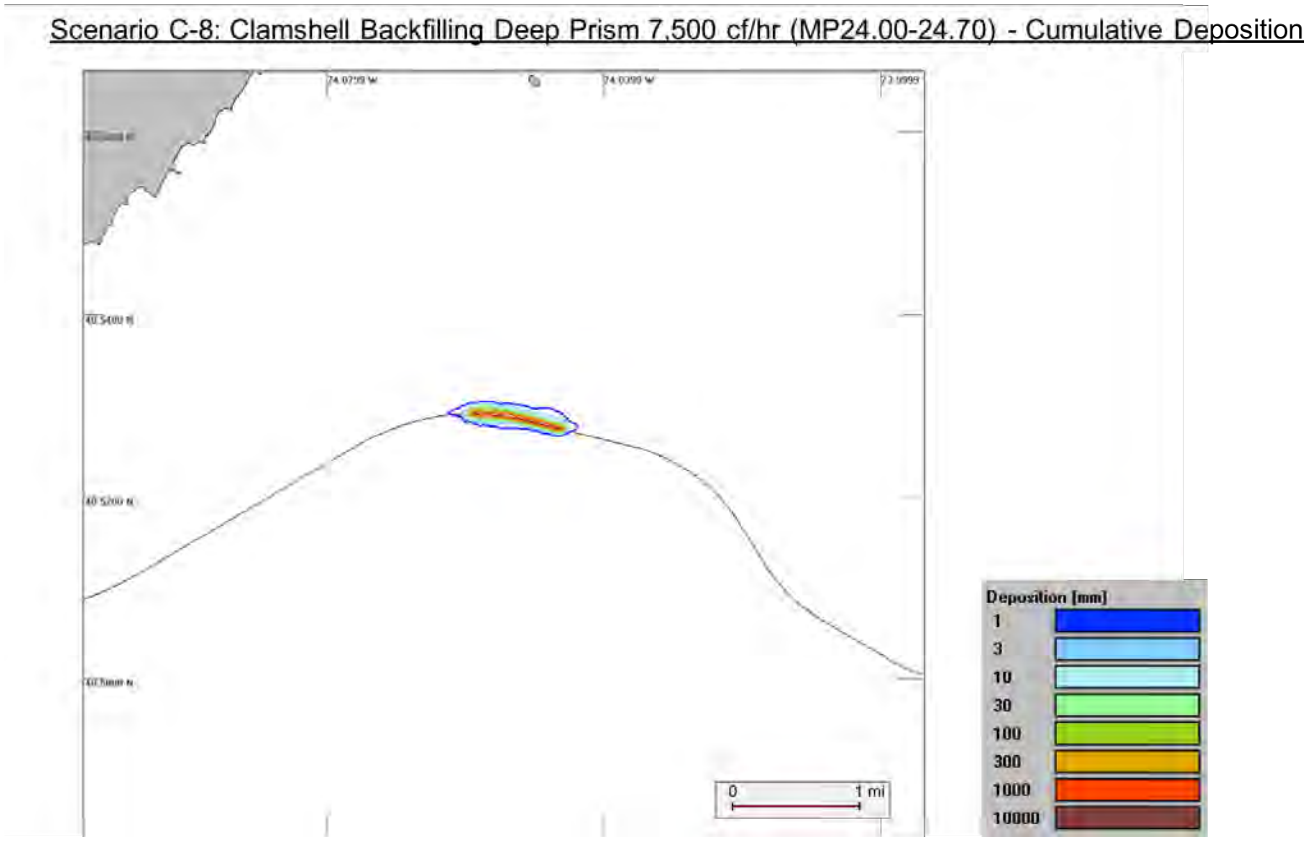

Figure 17. Extent of seabed deposition resulting from backfilling between MP 24.00 and MP 24.70. Maximum predicted thickness = 104.3 in (2,650 mm).

3.9 Scenario C-9 – Backfilling Across the Chapel Hill Channel

Scenario C-9 simulated the placement of backfill material to fill the excavated trench extending across the Chapel Hill Channel between MP 24.78 and MP 25.61. The simulation replicates the latter portion of Scenario A-8 presented in Addendum 1 (backfilling between the Anchorage Area and Chapel Hill Channel using "base case" prism assumptions), with the distinction that backfilling would be slowed to a rate of 7,500 ft^3/hr for this portion of the pipeline route. The route is also extended by 0.41 miles to MP 25.61 (as compared to MP 25.20 in A-8). Along this reach, the pipeline will be buried to variable depths (between 4 and 8 ft of sediment cover), requiring trench excavation between 7.5 ft and 10.5 ft below the seabed. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-9, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 300 hours (12.5 days) while placing backfill sediments over approximately 0.83 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 83,439 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 66,751 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 24.78 and MP 25.61 are presented in Figure 18 and Figure 19, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. During the model run the sediment plume is generally oriented in a West/East configuration, oscillating back and forth with the tide along the primary axis of Raritan Bay. Peak TSS concentrations are predicted to occur within 10 ft from the seabed, reflecting the release of all material at this height within the water column. As with other backfilling simulations, TSS concentrations at the surface briefly exceed 10mg/L in a few locations (maximum of 13.7 mg/L) but generally remain below this threshold. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,247 ft from the source and TSS concentrations remain elevated above ambient levels for 1.8 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 545 ft from the source and covers a total of 52.3 acres of the seabed.

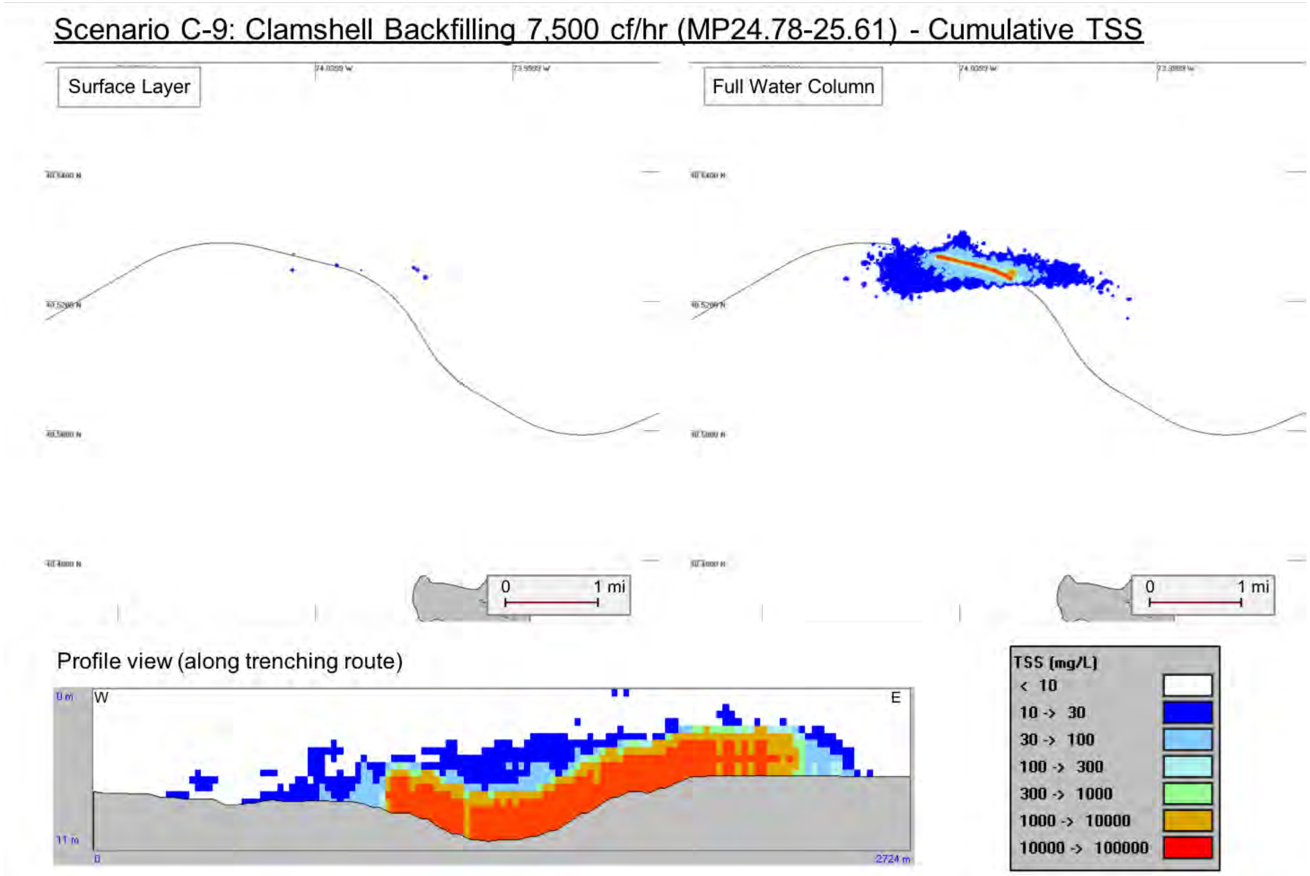

Figure 18. Cumulative TSS concentrations for Scenario C-9 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

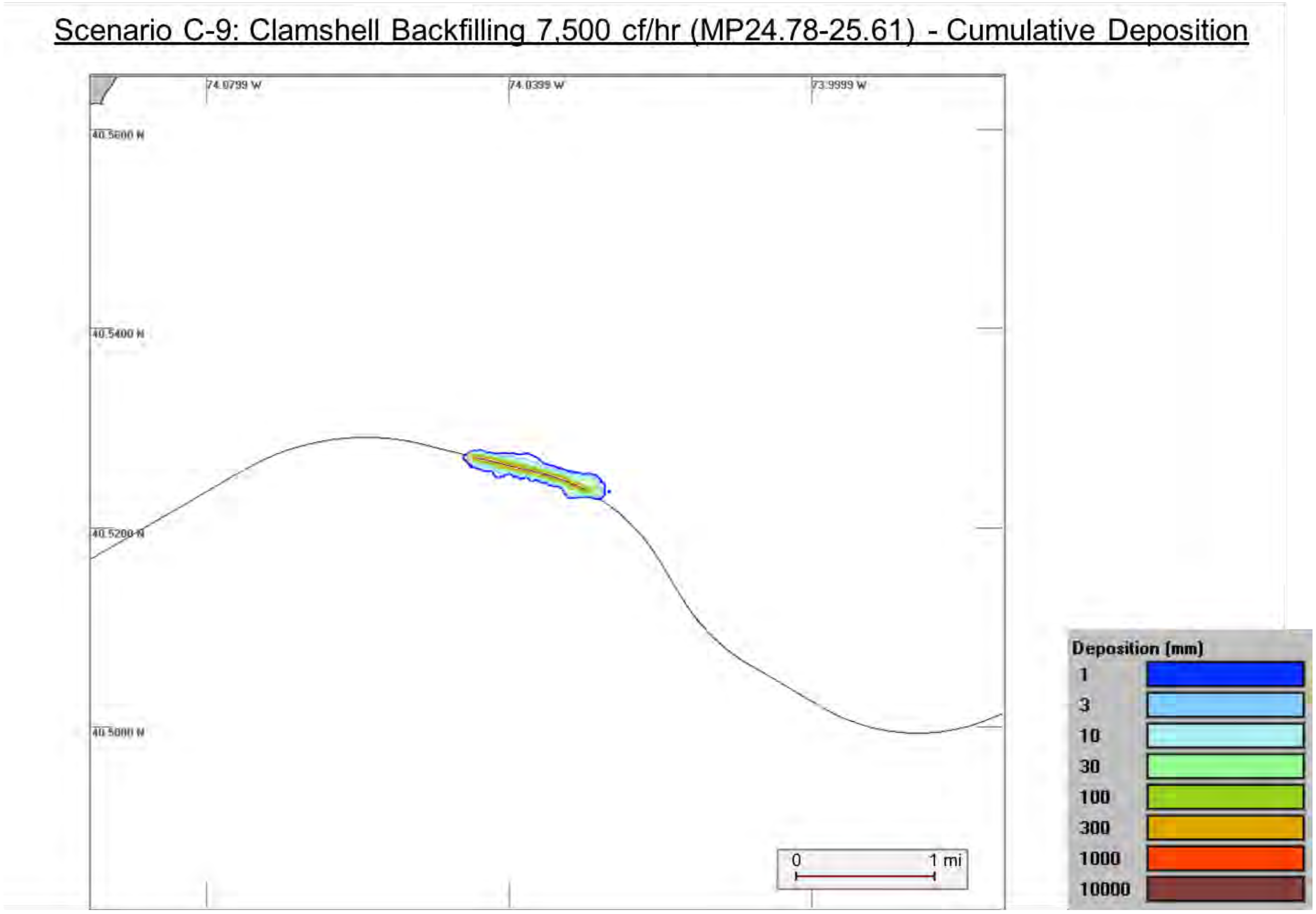

Figure 19. Extent of seabed deposition resulting from backfilling between MP 24.78 and MP 25.61. Maximum predicted thickness = 34.9 in (886 mm).

3.10 Scenario C-10 – Backfilling Across the Chapel Hill Channel (Deep Prism)

Scenario C-10 simulated the placement of backfill material across the Chapel Hill Channel between MP 24.70 and MP 25.61, corresponding to the filling of the "deep prism" trench from Scenario C-3. The activity is comparable to the backfilling in Scenario A-8 presented in Addendum 1 (backfilling between the Anchorage Area and Chapel Hill Channel using "base case" prism assumptions), with two important distinctions: (i) backfilling would be slowed to a rate of 7,500 ft^3/hr for this portion of the pipeline route, and (ii) start/end points and backfilling volumes are modified to account for changes in the trench configuration to achieve deeper burial across the channel as well as the extension of clamshell dredging in response to NYSDEC feedback. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (7,500 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-10, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 922 hours (38.4 days) while placing sediments over approximately 0.91 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 255,759 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location (Scenario C-3) is 204,607 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 24.70 and MP 25.61 are presented in Figure 20 and Figure 21, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. Overall, the model results are similar to Scenario C-9, with larger areas of deposition due to the slightly expanded trench length. TSS concentrations up to and exceeding 10,000 mg/L are predicted near the channel bed but are confined to mid- and lower portions of the water column (reflecting the release of all material at this height within the water column). At the surface, TSS concentrations briefly exceed 10 mg/L in a few locations (maximum of 14.6 mg/L) but generally remain below this threshold. Water column concentrations of 100 mg/L are predicted to extend a maximum of 1,247 ft from the source and TSS concentrations remain elevated above ambient levels for 1.8 hours after the conclusion of backfilling.

Sediment deposition at or above 0.4 in (1.0 cm) extends up to 577 ft from the source and covers a total of 70.7 acres of the seabed.

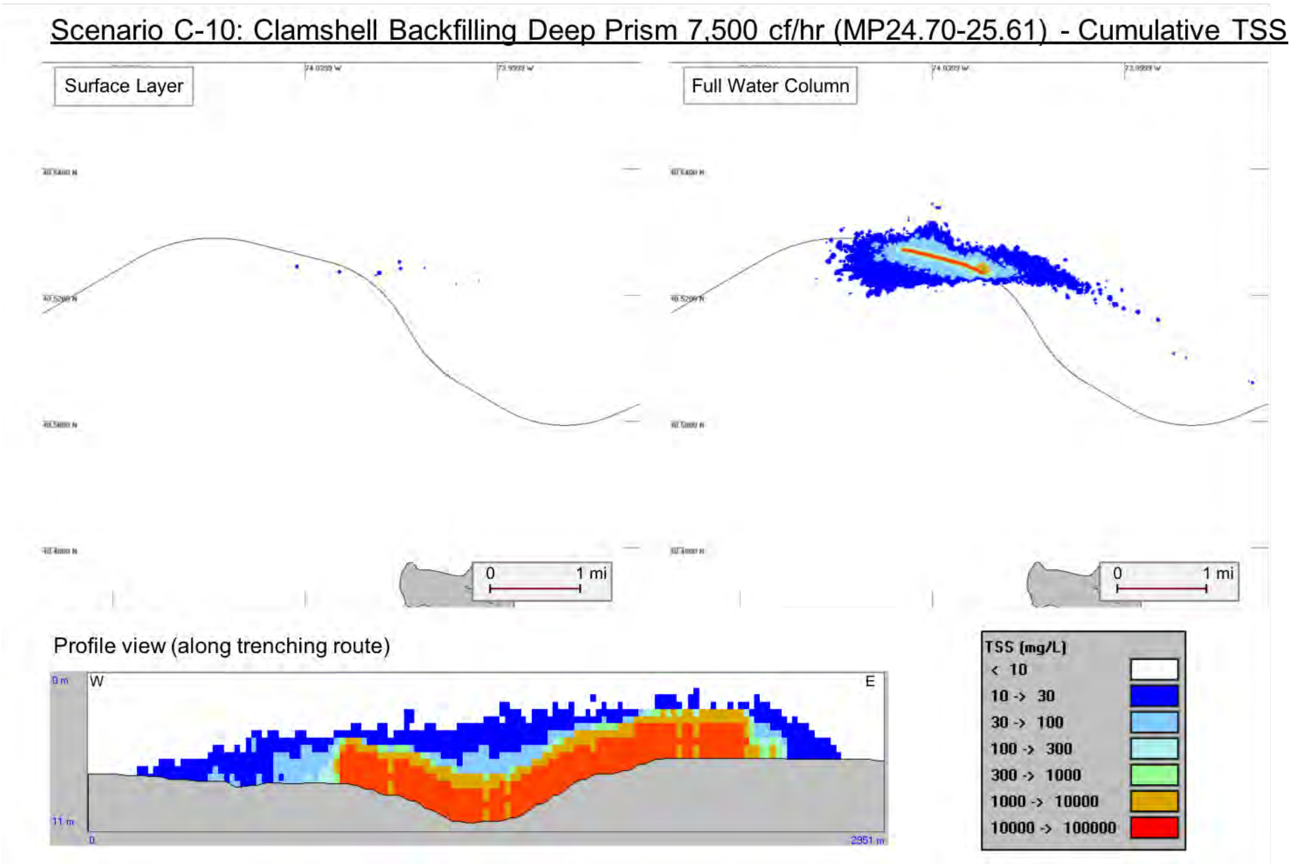

Figure 20. Cumulative TSS concentrations for Scenario C-10 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

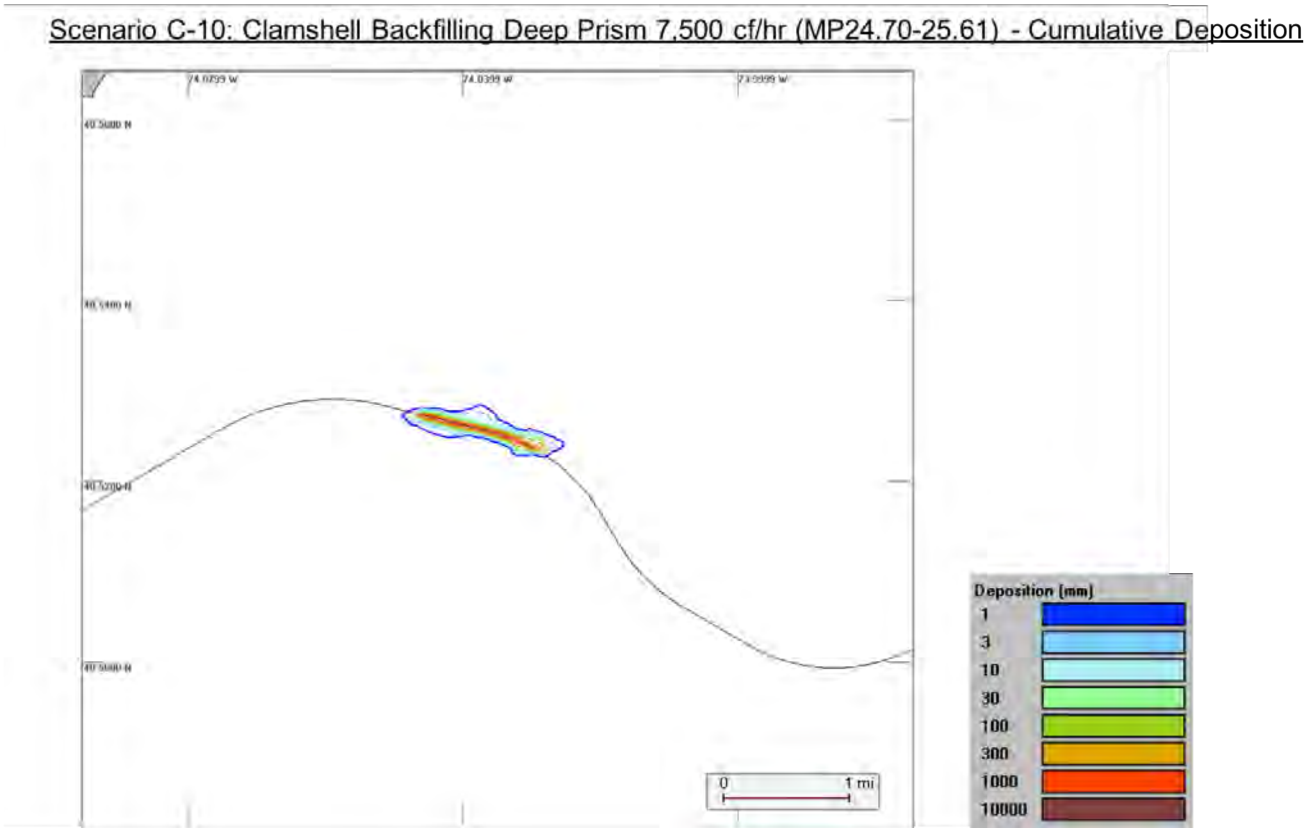

Figure 21. Extent of seabed deposition resulting from backfilling between MP 24.70 and MP 25.61. Maximum predicted thickness = 92.5 in (2,350 mm).

3.11 Scenario C-11 – Backfilling Between Morgan HDD and Midline Tie-in

Scenario C-11 simulated the placement of backfill material within the excavated trench extending between MP 12.50 and MP 16.60. The simulation replicates Scenario A-5 (Addendum 1) and Scenario B-21 (Addendum 2), with the distinction that backfilling would be slowed to a rate of 4,800 ft^3/hr for this portion of the pipeline route. Along this reach, the pipeline will be buried to a minimum 4 ft of cover, requiring trench excavation of 7.5 ft below the seabed. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate of 4,800 ft^3/hr.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-11, the simulation was performed using a start date of May 2 (immediately following backfill activities at the Morgan Shore) to be consistent with the schedule applied for previous modeling scenarios. The clamshell dredge was assumed to operate continuously for 1,235 hours (51.5 days) while placing backfill sediments over approximately 4.10 miles. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 219,591 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 175,673 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 12.50 and MP 16.60 are presented in Figure 22 and Figure 23, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. During most of the simulation, the plume oscillates with the tide along the primary axis of Raritan Bay (East/West). Near the Morgan Shore HDD pit, elevated TSS concentrations (above 1,000 mg/L) extend through most of the water column but as the backfilling route advances into deeper water the extent and duration of plumes in the upper 5 to 10 ft becomes more intermittent. Overall, the peak concentrations occur within the lower 10 ft, reflecting the release of all material at this height within the water column. Water column concentrations of 100 mg/L are predicted to extend a maximum of 591 ft from the source and TSS concentrations remain elevated above ambient levels for 1.1 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 420 ft from the source and covers a total of 250.3 acres of the seabed.

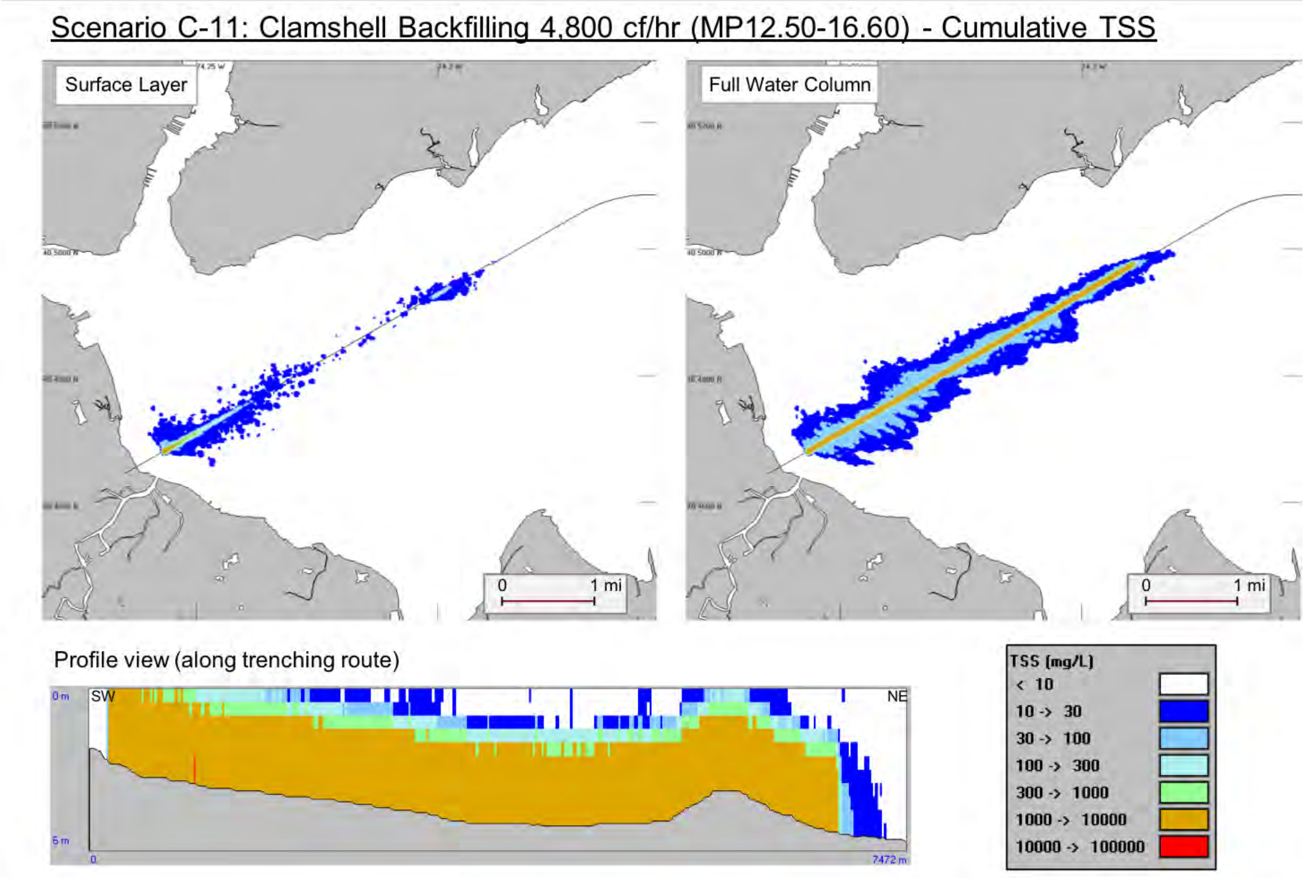

Figure 22. Cumulative TSS concentrations for Scenario C-11 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the main plume axis.

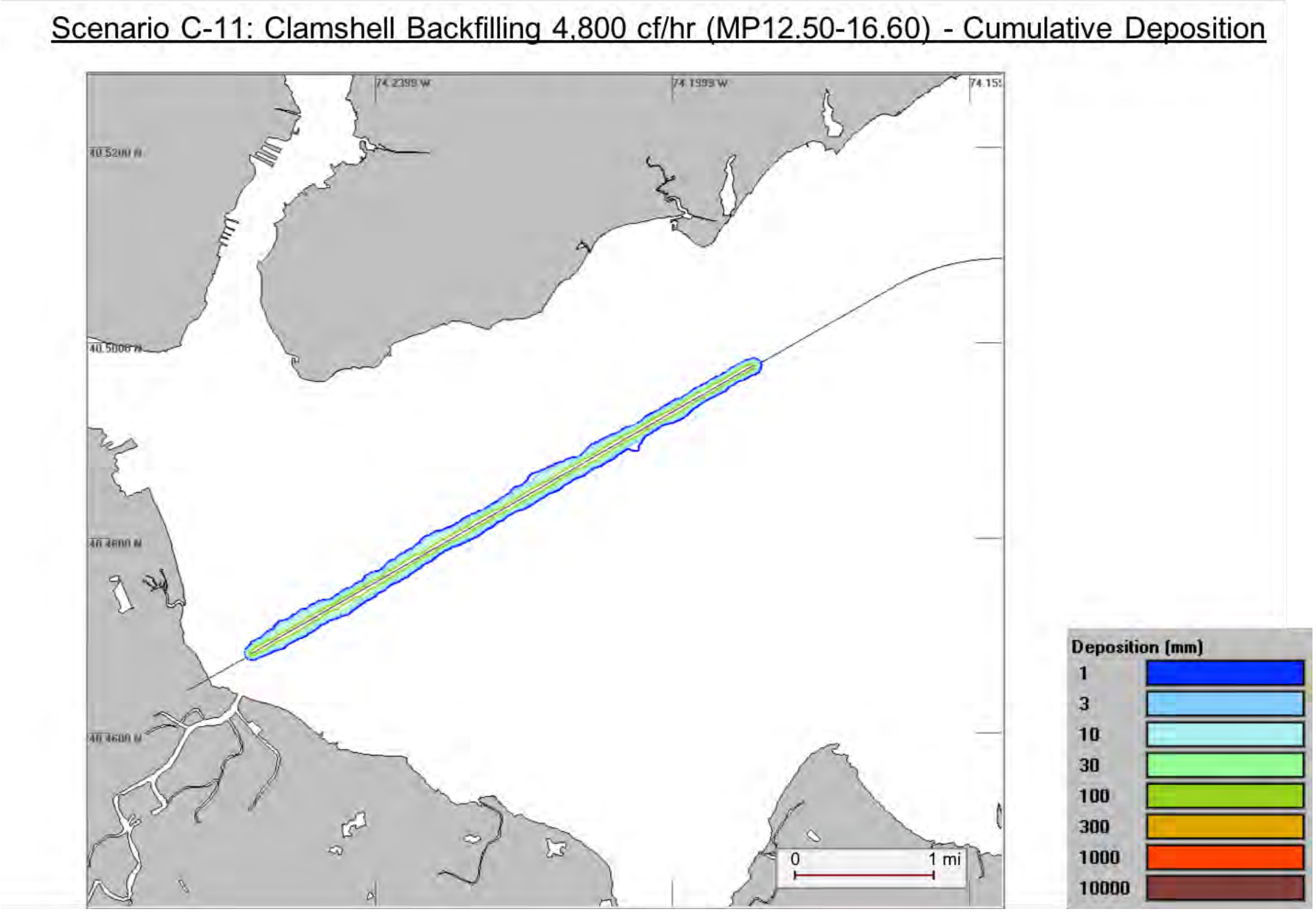

Figure 23. Extent of seabed deposition resulting from backfilling between MP 12.50 and MP 16.60. Maximum predicted thickness = 13.0 in (331 mm).

3.12 Scenario C-12 – Backfilling Across the Raritan Channel (Deep Prism)

Scenario C-12 simulated the placement of backfill material across the Raritan Channel between MP 17.23 and MP 17.97, corresponding to the filling of the "deep prism" trench excavated in Scenario C-1. The simulation replicates Scenario C-6, with the distinction that backfilling would be slowed to a rate of 4,800 ft^3/hr for this portion of the pipeline route. Backfilling of the trench was simulated as a line source and assumed that the construction area would be returned to grade with a single pass of the clamshell dredger advancing in the same direction (West to East) as the original excavation activity. The clamshell dredge was assumed to operate at a constant production rate (4,800 ft^3/hr) for the full duration of the activity.

Backfilling operations were modeled to take place in Q2 2019, concurrent with the dredging of source material simulated in Scenarios A-1 through A-3 (Addendum 1). For Scenario C-12, the simulation was performed using a start date of May 1 to be consistent with the schedule applied for the Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 2,514 hours (104.7 days) while placing backfill sediments over approximately 0.74 mile. During backfilling the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 446,879 yd^3 of sediment was placed along this section of the trench, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location (Scenario C-1) is 357,503 yd^3.

Water column and sediment bed results from simulations of backfilling between MP 17.23 and MP 17.97 are presented in Figure 24 and Figure 25, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. As with Scenario C-6, the sediment plume remains confined to the mid- and lower portions of the water column with isolated portions of the water surface exceeding 10 mg/L intermittently during the simulation. Near the source, concentrations typically exceed 10,000 mg/L near the seabed across the channel, reflecting the release of all material at this height within the water column. TSS concentrations dissipate rapidly with distance from the clamshell bucket. The cumulative plume and deposition areas are similar to C-6 although the peak TSS concentrations and distance to critical thresholds (e.g. 50 and 100 mg/L) are notably lower as a result of the slower backfill rate. Water column concentrations of 100 mg/L are predicted to extend a maximum of 853 ft from the source, and that distance drops to 591 for 99.9% of occurrences in the model (Table 3). TSS concentrations remain elevated above ambient levels for 1.1 hours after the conclusion of backfilling. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 653 ft from the source and covers a total of 76.8 acres of the seabed.

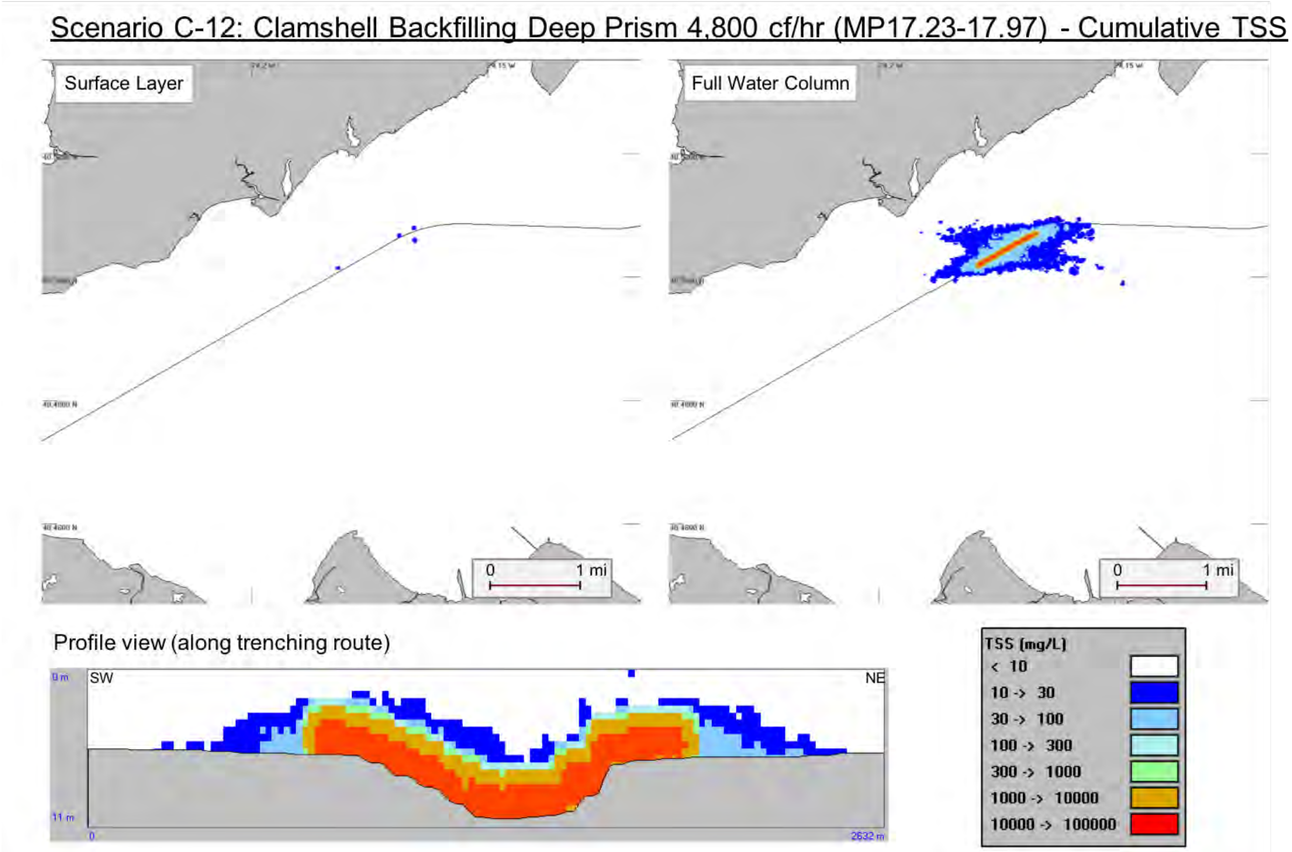

Figure 24. Cumulative TSS concentrations for Scenario C-12 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the trenching route.

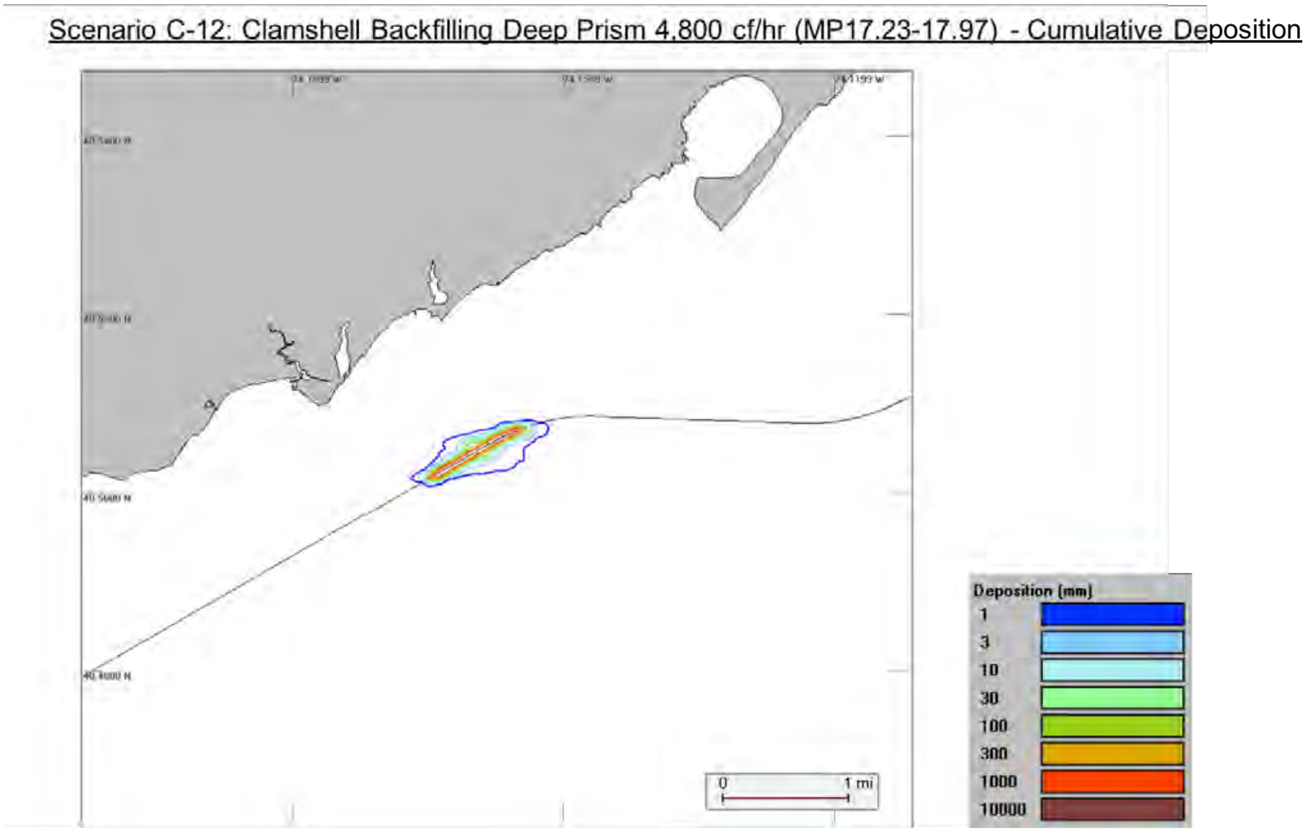

Figure 25. Extent of seabed deposition resulting from backfilling between MP 17.23 and MP 17.97. Maximum predicted thickness = 128.0 in (3,250 mm).

3.13 Scenario C-13 – Backfilling of the Ambrose Channel HDD Pit (East) and Tie-in

Scenario C-13 simulated the placement of backfill material at MP 30.40, directly east of the Ambrose Channel. At this location backfill will be required for two excavation areas associated with the Ambrose HDD campaign: (i) the Ambrose Channel HDD pit (East), which will extend to a depth of 24 ft, and (ii) the tie-in point on the east side of the HDD, which will be excavated to 7.5 ft. The simulation replicates Scenario A-10 (Addendum 1), with the distinction that backfilling would be slowed to a rate of 4,800 ft^3/hr for both activities. Both activities were simulated, in sequence as a stationary (point) source from the HDD (East) point (MP 30.40). Both involve backfill by clamshell dredge, which is assumed to operate at a constant production rate of 4,800 ft^3/hr.

Backfilling operations were modeled to occur concurrent with the dredging of source material (see Addendum 1, Scenarios A-1 through A-3). The simulation was performed using a start date of May 16 (immediately following backfilling of the Ambrose HDD pit [West]) to be consistent with the schedule applied for the "Base Case" (August 2017) and Addendum 1 (September 2017) modeling scenarios. The clamshell dredge was assumed to operate continuously for 228 hours (9.5 days), during which time the clamshell bucket releases 100% of the source sediment directly into the water column at a fixed height of approximately 5 ft above the seabed. This scenario assumed a total of 40,563 yd^3 of sediment was placed at the HDD pit, which includes an "overfill" factor of 20% to account for material that may be dispersed or off-target during backfill placement. The original excavation volume for this location is 32,450 yd^3 .

Water column and sediment bed results from simulations of backfilling at the Ambrose Channel (East) pit and tie-in are presented in Figure 26 and Figure 27, and summarized in Table 2. Table 3 provides further information on the extent of plumes above 50 and 100 mg/L at different statistical thresholds. The predicted sediment plume from backfilling at this location shows a distinct alignment with the tidal currents that flow in and out of the entrance to Raritan Bay. Although elevated TSS concentrations (above 10 mg/L) are confined to the lower half of the water column, strong current velocities at this location result in greater transport of suspended sediments into and out of the Bay at relatively high concentrations. Water column concentrations of 100 mg/L are predicted to extend up to 5,151 ft from the source, although that distance drops to 2,247 ft for 99.9% of occurrences in the model (Table 3). TSS concentrations return to ambient levels approximately 0.4 hour (26 minutes) after the conclusion of dredging. Sediment deposition at or above 0.4 in (1.0 cm) extends up to 774 ft from the source and covers a total of 13.4 acres of the seabed.

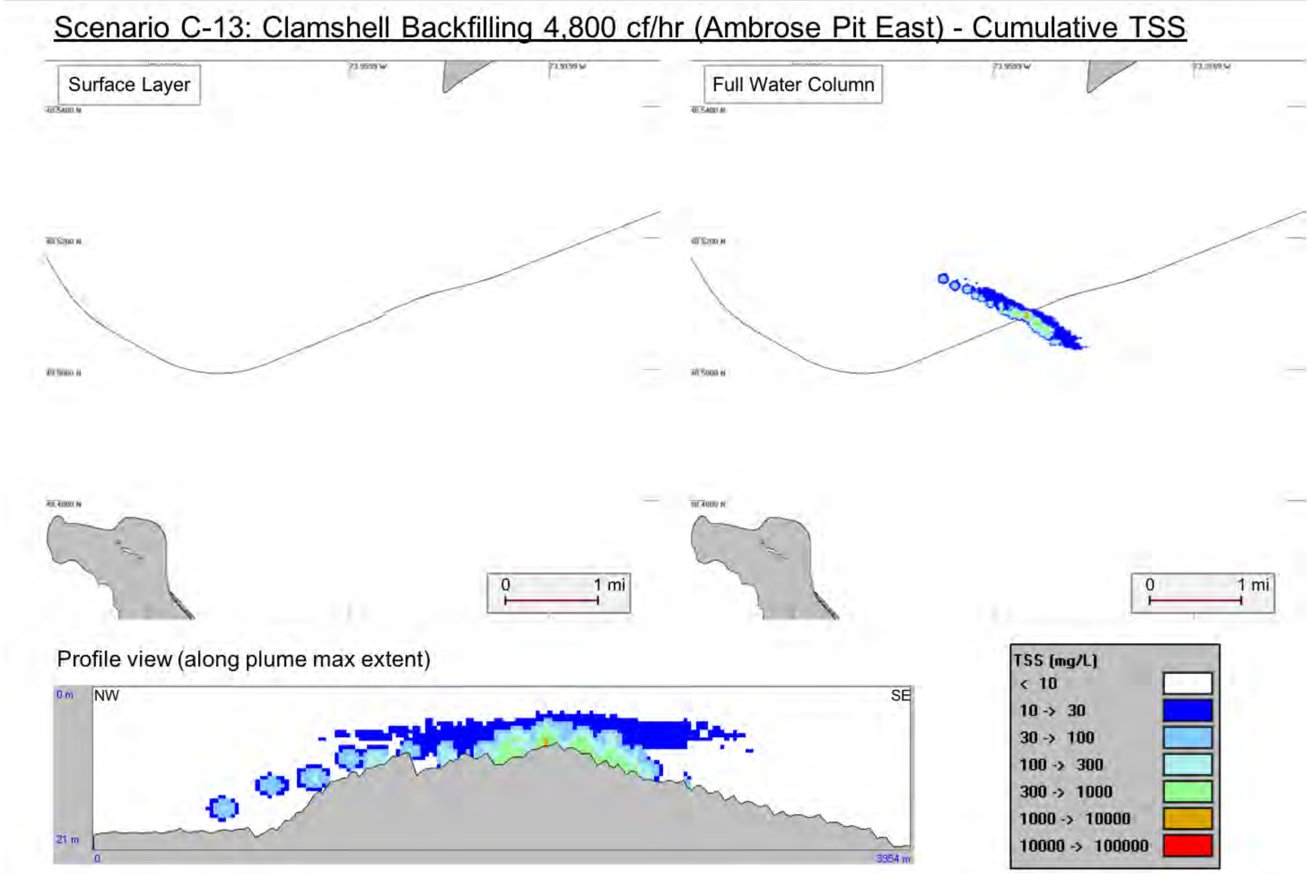

Figure 26. Cumulative TSS concentrations for Scenario C-13 over the full simulation period for the surface layer (left; 0-1.6 ft below the sea surface) and the full water column (right). The profile view shows a cross-section of TSS concentrations along the dredging route.

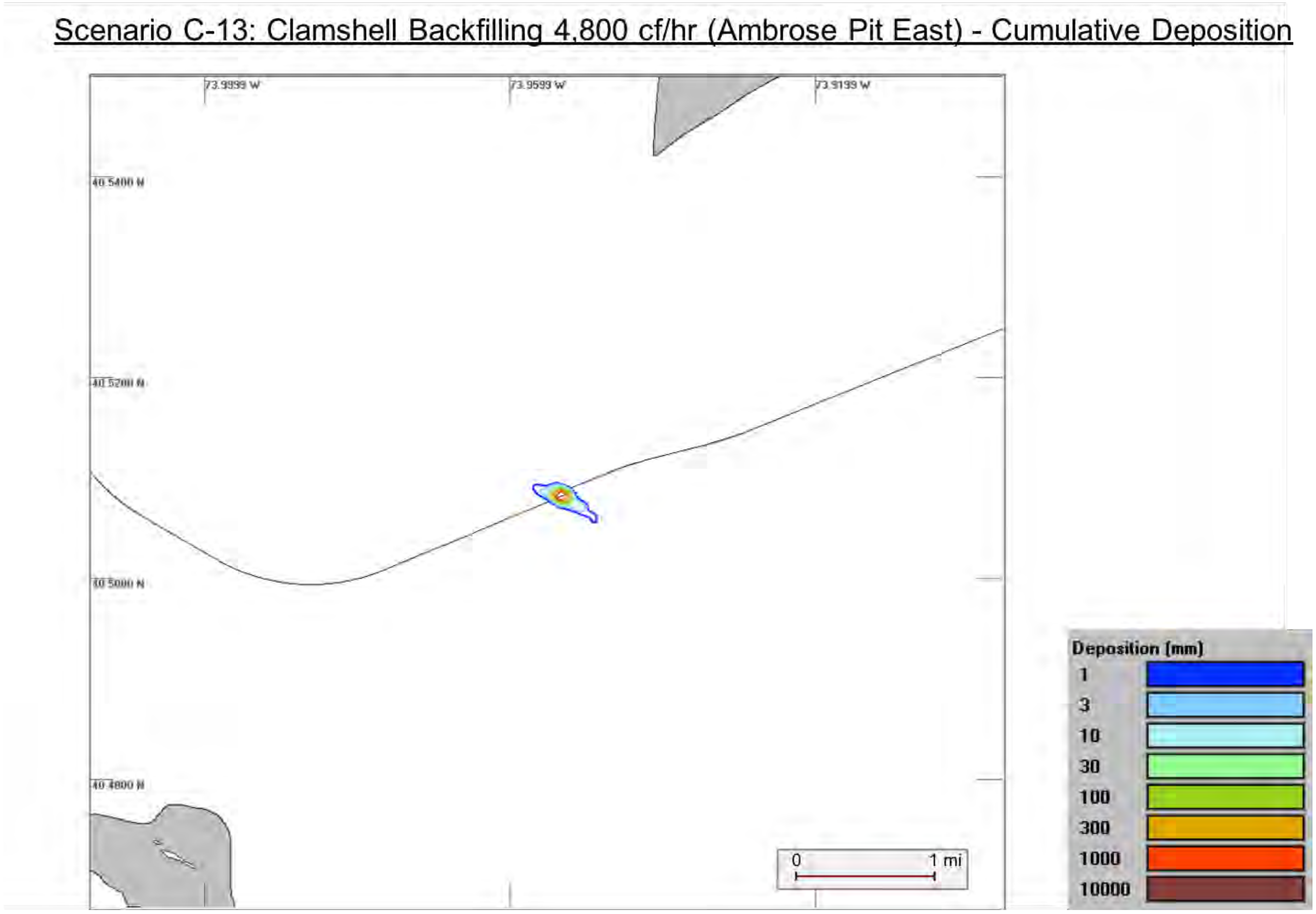

Figure 27. Extent of seabed deposition resulting from backfilling at the Ambrose (East) HDD pit. Maximum predicted thickness = 107.9 in (2,740 mm).

Table 2. Summary of Addendum 3 simulation results.

Scenario	Construction Activity	Equipment Type	Location	Production rate (ft3/hr)	Duration of modeled activity (hr)	Equipment Loss (%)	Total volume released (yd3)	Time For TSS to return to ambient (hrs)	Max Distance of TSS Plume exceeding ambient (ft)		Max Distance of deposition exceeding (ft)			Area of deposition exceeding (acres)		
									50 mg/L	100 mg/L	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]	0.3 cm [0.12 in]	1.0 cm [0.4 in]	3.0 cm [1.2 in]
Scenario C-1	Clamshell dredge Raritan Channel deep prism (15-ft burial) with no scow overflow	Clamshell	MP 17.23 - MP 17.97	11,250	858.0	0.5	1,788	0.0	131	--	0	0	0	0.0	0.0	0.0
Scenario C-2	Clamshell dredge anchorage deep prism (15-ft burial) with no scow overflow	Clamshell	MP 24.00 - MP 24.70	11,250	390.8	0.5	814	0.1	131	--	85	0	0	9.9	0.0	0.0
Scenario C-3	Clamshell dredge extended Chapel Hill Channel deep prism (15-ft burial) with no scow overflow	Clamshell	MP 24.70 - MP 25.61	11,250	491.1	0.5	1,023	0.3	131	--	82	0	0	11.9	0.0	0.0
Scenario C-4	Clamshell dredge anchorage deep prism (15-ft burial) with scow overflow	Clamshell	MP 24.00 - MP 24.70	11,250	390.8	2.5	4,071	0.5	262	197	174	112	13	24.1	14.7	0.2
Scenario C-5	Backfill Raritan Channel base-case prism (up to 8-ft burial) @ 7,500 cf/hr	Clamshell	MP 17.31 - MP 17.89	7,500	601.3	100	167,025	1.8	1,509	1,066	574	492	384	55.7	41.4	32.5
Scenario C-6	Backfill Raritan Channel deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	MP 17.23 - MP 17.97	7,500	1,608.8	100	446,879	1.6	2,444	1,165	981	801	643	109.6	77.2	60.8
Scenario C-7	Backfill anchorage area base-case prism (7-ft burial) @ 7,500 cf/hr	Clamshell	MP 24.00 - MP 24.78	7,500	289.4	100	80,388	1.0	1,755	1,247	371	318	253	55.3	43.4	33.5
Scenario C-8	Backfill anchorage area deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	MP 24.00 - MP 24.70	7,500	732.8	100	203,545	1.3	1,772	919	453	371	325	63.4	49.6	39.7
Scenario C-9	Backfill extended Chapel Hill Channel prism (up to 8-ft burial) @ 7,500 cf/hr	Clamshell	MP 24.78 - MP 25.61	7,500	300.4	100	83,439	1.8	1,985	1,247	614	545	443	68.8	52.3	39.0
Scenario C-10	Backfill extended Chapel Hill Channel deep prism (15-ft burial) @ 7,500 cf/hr	Clamshell	MP 24.70 - MP 25.61	7,500	920.7	100	255,759	1.8	2,493	1,247	787	577	522	96.8	70.7	56.1
Scenario C-11	Backfill of trench between Morgan HDD exit and the Midline tie-in @ 4,800 cf/hr	Clamshell	MP 12.50 - MP 16.60	4,800	1,235	100	219,591	1.1	1,460	591	525	420	266	314.6	250.3	183.2
Scenario C-12	Backfill Raritan Channel deep prism (15-ft burial) @ 4,800 cf/hr	Clamshell	MP 17.23 - MP 17.97	4,800	2,513.7	100	446,879	1.1	1,575	853	817	653	574	105.6	76.8	61.5
Scenario C-13	Backfill of Ambrose HDD Pit (East) and tie-in @ 4,800 cf/hr	Clamshell	MP 30.40	4,800	228.2	100	40,563	0.4	5,299	5,151	945	774	456	19.7	13.4	9.5

Table 3. Maximum extent of TSS plumes exceeding 50 and 100 mg/L for all model time steps (100% of occurrences) and 99.9%, 99%, and 95% of occurrences.

Scenario	Construction Activity	Max Distance of TSS Plume exceeding ambient (ft) - all occurrences		Max Distance of TSS Plume exceeding ambient (ft) - 99.9% of occurrences		Max Distance of TSS Plume exceeding ambient (ft) - 99% of occurrences		Max Distance of TSS Plume exceeding ambient (ft) - 95% of occurrences	
		50 mg/L	100 mg/L	50 mg/L	100 mg/L	50 mg/L	100 mg/L	50 mg/L	100 mg/L
Scenario C-1	Clamshell dredge Raritan Channel deep prism (15-ft burial) with no scow overflow	131	--	66	--	66	--	66	--
Scenario C-2	Clamshell dredge anchorage deep prism (15-ft burial) with no scow overflow	131	--	66	--	66	--	66	--
Scenario C-3	Clamshell dredge extended Chapel Hill Channel deep prism (15-ft burial) with no scow overflow	131	--	131	--	131	--	66	--
Scenario C-4	Clamshell dredge anchorage deep prism (15-ft burial) with scow overflow	262	197	262	197	262	197	197	148
Scenario C-5	Backfill Raritan Channel base-case prism (up to 8-ft burial) @ 7,500 cf/hr	1,509	1,066	1,444	722	1,132	591	853	476
Scenario C-6	Backfill Raritan Channel deep prism (15-ft burial) @ 7,500 cf/hr	2,444	1,165	2,231	1,066	1,296	853	1,033	476
Scenario C-7	Backfill anchorage area base-case prism (7-ft burial) @ 7,500 cf/hr	1,755	1,247	1,575	935	1,378	771	1,017	656
Scenario C-8	Backfill anchorage area deep prism (15-ft burial) @ 7,500 cf/hr	1,772	919	1,509	853	1,198	722	968	591
Scenario C-9	Backfill extended Chapel Hill Channel prism (up to 8-ft burial) @ 7,500 cf/hr	1,985	1,247	1,952	1,198	1,706	1,001	1,115	738
Scenario C-10	Backfill extended Chapel Hill Channel deep prism (15-ft burial) @ 7,500 cf/hr	2,493	1,247	2,034	1,181	1,444	1,050	1,165	722
Scenario C-11	Backfill of trench between Morgan HDD exit and the Midline tie-in @ 4,800 cf/hr	1,460	591	1,312	525	1,050	394	722	328
Scenario C-12	Backfill Raritan Channel deep prism (15-ft burial) @ 4,800 cf/hr	1,575	853	1,263	591	984	328	722	262
Scenario C-13	Backfill of Ambrose HDD Pit (East) and tie-in @ 4,800 cf/hr	5,299	5,151	2,280	2,247	1,280	1,247	804	771

4 References

RPS, 2017. Northeast Supply Enhancement Project: Hydrodynamic and Sediment Transport Modeling Results – Base Case Simulations. Prepared for Ecology & Environment, Inc. on behalf of Transcontinental Gas Pipe Line Company, LLC. August 28, 2017.

TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX F-5 – CONTAMINANT TRANSPORT MODELING RESULTS FOR NEW JERSEY WATERS

NORTHEAST SUPPLY ENHANCEMENT PROJECT

December 2019

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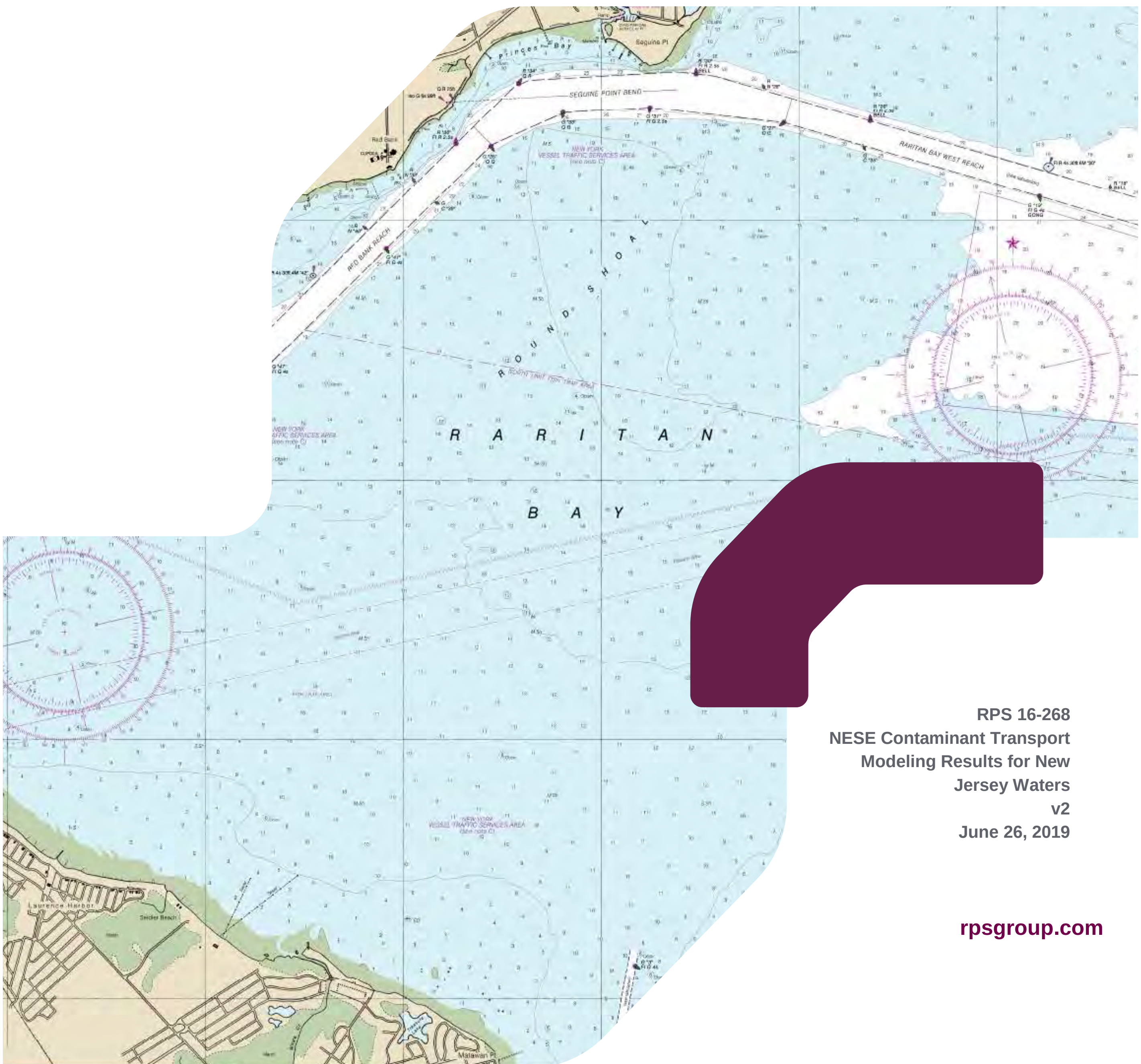
MAKING COMPLEX EASY

NESE CONTAMINANT TRANSPORT MODELING RESULTS FOR NEW JERSEY WATERS

Final Report



RPS 16-268
NESE Contaminant Transport Modeling Results for New Jersey Waters
v2
June 26, 2019

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1 INTRODUCTION

1.1 Project Background

As part of its Northeast Supply Enhancement Project (Project), Transcontinental Gas Pipe Line Company, LLC (Transco) is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey, as well as its existing offshore natural gas pipeline system in New Jersey and New York. Transco plans to expand discrete segments of its system from the existing Station 195 in Lancaster, Pennsylvania, to the Rockaway Transfer Point. The Rockaway Transfer Point is the interconnection between the Project and Transco's existing Rockaway Delivery Lateral (RDL) subsea manifold in New York waters, approximately 3 miles seaward of Rockaway, New York. A major portion of the Project includes the installation of a 26-inch outer diameter pipeline, referred to as the "Raritan Bay Loop" that will connect the Project's proposed "Madison Loop" (Middlesex County, NJ) to the Rockaway Transfer Point (Figure 1). The offshore portion of the Raritan Bay Loop will extend from the Sayreville, New Jersey shoreline (MP12.16) approximately 23.33 miles across Raritan Bay and Lower New York Bay to the Rockaway Transfer Point in the Atlantic Ocean. Approximately the first two miles of the Raritan Bay Loop route (MP12.16 to MP14.01) are in New Jersey (NJ) waters and are the focus of this study.

The pipeline installation will require a range of dredging and burial techniques (e.g. clamshell dredging, jet trenching, and backfilling) each of which has the potential to produce seabed disturbances, suspended sediment plume formation, and sedimentation. In addition, the dredging activities are expected to cause the re-suspension of contaminants that have deposited in the sediments over time. The first two miles of the Raritan Bay Loop route in NJ are proposed to be dredged using a clamshell dredge with an environmental bucket. The sediments along this portion of the pipeline route have measured amounts of several metals and contaminants including mercury, arsenic, manganese, phenanthrene, BIS(2-Ethylhexyl)Phlalate (BIS), 4,4'-DDE, and polychlorinated biphenyls (PCBs) as Total Aroclors.

In a previous study, a hydrodynamic and sediment transport and dispersion model application was developed to help assess potential environmental impacts of Project-related activities (RPS, 2017) as they pertained to seabed sediment disturbance and sediment resuspension. The 2017 report described the computer modeling systems and approach being used to evaluate the Project and provided predictions of suspended sediment concentrations and deposition from a set of initial "base case" construction scenarios. The present report describes the application of a contaminant transport model, and simulations, using the same calibrated hydrodynamic model output, to assess the potential maximum water column concentration of re-suspended contaminants, at the edge of a 500-ft dredging mixing zone at key locations along the route at several locations in NJ waters.

1.2 Study Area Description

The offshore portion of the Raritan Bay Loop will cross parts of three major water bodies that converge at the New York Bight Apex: Raritan Bay, Lower New York Bay, and the Atlantic Ocean. Collectively, these water bodies form a generally triangular-shaped embayment situated at the southern extent of the New York – New Jersey (NY/NJ) Harbor Estuary, a complex system of bays and tidal rivers where the Hudson, Hackensack, Passaic, and Raritan rivers meet the Atlantic Ocean. The embayment is bound to the south and west by New Jersey (Monmouth and Middlesex Counties), and to the north and northwest by New York (Richmond, Kings, and Queens Counties). The Sandy Hook peninsula extends approximately 5 miles into the embayment from the southeast, forming a partial barrier to waves and currents approaching from the Atlantic Ocean. Several major navigational channels cross the study area, connecting the New York Bight with Upper New York Bay – one of the largest and busiest harbors in the world.

Hydrodynamic circulation in the area is complex and is influenced by both the circulation of the NY/NJ Harbor Estuary and the large-scale shelf circulations of the New York Bight. Circulation in the NY/NJ Harbor Estuary is tidal with predominant semi-diurnal variability but is also influenced by fresh water outflow from the Hudson River and Raritan River, and surface winds including sea-breeze and land-breeze effects (Gopalakrishnan and Blumberg 2011). The mean tide range at the Sandy Hook, New Jersey NOAA station (Station ID: 8531680), near the center of the study area, is 4.7 feet (NOAA Tides and Currents 2017). Surface currents in this area have been shown to exhibit daily variation in flow direction, with flow mainly moving southwesterly during incoming tides and mixed flow direction occurring during outgoing tides (Bruno and Blumberg 2009). In Raritan Bay and Lower New York Bay, current patterns can be complex, but there is a general tendency for the outflowing Hudson River and Raritan River to veer south, creating an overall counter-clockwise gyre within the basin (Jeffries 1962; Gopalakrishnan and Blumberg 2011).

Water depths across the study area are relatively shallow, and deepen gradually from the Bay shoreline to the offshore extent. Depths in the central basin of Raritan and Lower New York Bay range from approximately 10 to 30 ft below MLLW, although greater water depths (up to 75 ft below MLLW) are present within the navigational channels. Depths offshore of the Rockaway Peninsula generally range from 20 to 30 ft below MLLW.

1.3 Objectives and Tasks

To address potential impacts from contaminant resuspension during Project-related activities, RPS has been contracted to develop and apply a customized contaminant transport and dispersion model to the study area. Specifically, the analysis includes simulations of the fate and transport of suspended metals, chemicals and PCBs using RPS' CHEMMAP modeling system. CHEMMAP is being applied to simulate the potential contaminant transport from offshore construction activities of a mechanical (clamshell) dredging system. Current fields developed for the base case modeling (RPS, 2017) are used as the primary transport mechanism for the contaminant dispersion model.

A brief description of the hydrodynamic model and its application to the Project area are presented in Section 2. Section 3 provides an overview of the CHEMMAP contaminant transport and fates model system, and Section 4 presents the application and results from the CHEMMAP model application for the metals, chemicals and PCB scenarios. References for the model systems are provided in Section 5.

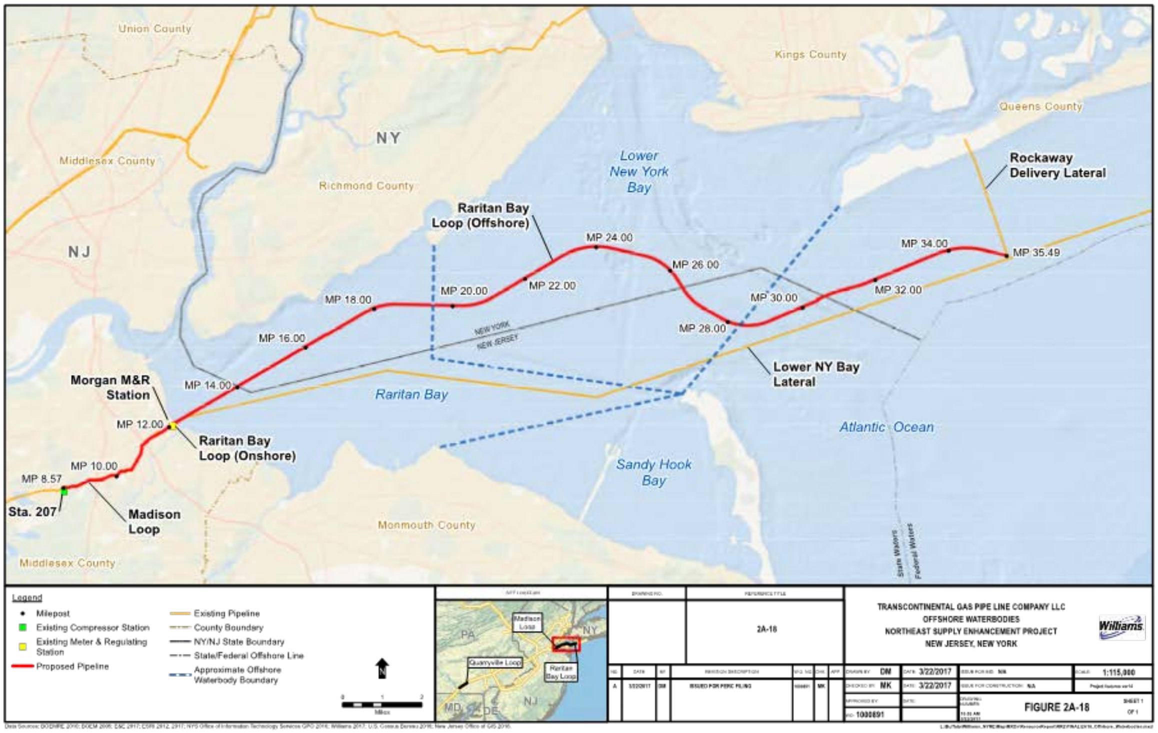

Figure 1. Offshore study area for the proposed Raritan Bay Loop (from Williams/Transco).

2 HYDRODYNAMIC MODEL

The development, validation, and application of a three-dimensional hydrodynamic model application for the NY/NJ Harbor Estuary, including waters of Raritan Bay, Lower New York Bay and nearby waters of the Atlantic Ocean, was completed for the earlier sediment transport study (RPS, 2017). RPS' WQMAP model system (Mendelsohn et.al., 1995), containing the BFHYDRO hydrodynamic model (Muin and Spaulding, 1997) was used to model the circulation patterns 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 same hydrodynamic model output used in the previous study, was also used for the contaminant dispersion model scenarios in this study.

The WQMAP system contains multiple models and a graphical user interface for handling input and output. The computational engine is a family of general curvilinear coordinate system computer models including a boundary conforming gridding model (BFGRID), a hydrodynamic model (BFHYDRO), a single constituent mass transport model (BFMASS) and an eight-state variable water quality, eutrophication model (BFWASP). The output from BFHYDRO is seamlessly integrated into RPS' transport models including CHEMMAP (contaminant transport and fates model). The previous application of BFHYDRO to simulate hydrodynamics within the NY/NJ Harbor Estuary is briefly discussed below. Further description of the BFHYDRO model system can be found in RPS (2017).

2.1 BFHYDRO Application

2.1.1 Model Grid (Resolution/Bathymetry)

To appropriately capture the tides, currents and circulation patterns of the Raritan Bay system, an existing grid and model domain was extended and refined to cover the study areas of Raritan Bay, Sandy Hook Bay, and Lower New York Bay. The larger domain of the grid extends several miles south and east into New York Bight, into Long Island Sound, and to the head of the tide in the Hudson, Raritan, and Passaic and Hackensack Rivers.

The grid was refined to a high resolution in the areas through which the pipeline route passes, and in other areas of specific interest (e.g. bathymetric features and channels, which affect circulation). The grid cells range in size from approximately 140 x 140 m (460 x 460 ft) in Raritan Bay to 2.4 x 3.2 km (1.5 x 2.0 mi.) offshore in the NY Bight. Note that the water column contaminant concentrations do not depend on the hydrodynamic model grid for calculations; there is a separate gridding and calculation method employed in the CHEMMAP model which will be discussed in a later section.

The bathymetry used in the hydrodynamic model grid was taken from three sources:

- Electronic NOAA NOS charts, CMAP database
- NOAA's "maintained channels" ENC layer database
- Swath bathymetry along the Project offshore route collected by Rogers Surveying in 2016

The bathymetry sources were combined to create a detailed database in the NY/NJ Harbor Estuary, and the final grid and bathymetry is presented in Figure 2. The Hudson, Raritan, Passaic and Hackensack rivers all extend upstream to the head of the tide (not shown in Figure 2).

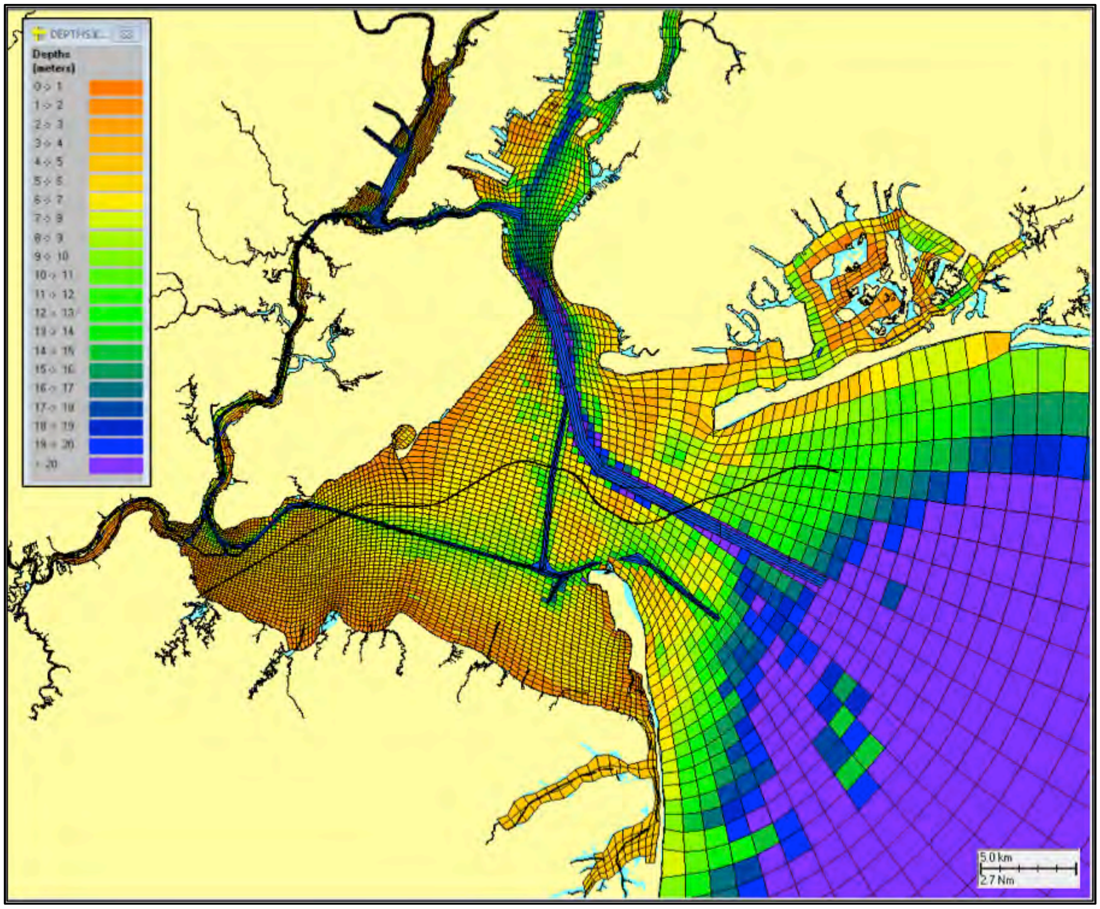

Figure 2. BFHYDRO, boundary conforming grid and bathymetry for NY/NJ Harbor Estuary and the New York Bight.

2.1.2 Boundary Conditions

Tidal Boundary Conditions

The open tidal boundaries were forced with a detailed time series of tidal elevation from a NOAA station close to the open boundary for the 2011–2012 time period. These dates were selected to overlap with the deployment of a series of current meters in Raritan Bay so the data could be used for comparison with model predictions. The tidal elevation time series from NOAA Stations 8531680 (Sandy Hook) and 8516945 (Kings Point) available at a 6-minute time step and were used to drive the open boundaries in the New York Bight and Long Island Sound, respectively.

River Boundary Conditions

The river flow rate for the 2011 – 2012 period was specified for the major inputs to the NY/NJ Harbor Estuary, based on USGS Station Gauge data. The major rivers included were the Raritan, Hudson, Passaic and Hackensack, where tributaries to each were also included as the watershed drainage areas for many of the rivers are large (particularly the Hudson). A total of 11 USGS gauged river flows were included for the 2011-2012 period.

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 NOAA NWS Station 8531680, also located at Sandy Hook, which is representative of the Raritan Bay area, just to the west.

2.1.3 Model Calibration

The model was set up and run in three-dimensional mode, using the boundary conditions described in the previous section. The simulation period was chosen to match the period of available in-situ current data identified during the preliminary phases of the modeling task. The Rutgers Marine & Coastal Sciences department had deployed a series of Acoustic Doppler Current Profiler (ADCP) moorings at five sites in Raritan Bay, spanning the period of September 2011 through October 2012. The model was run for that period, and tidal elevation and current predictions from the model were compared to observations recorded at various NOAA station locations and at each of the five ADCP mooring locations. The calibration is summarized here, but the interested reader is referred to the calibration report (RPS, 2017).

The model-predicted tidal elevation signal was analyzed at 11 NOAA subordinate tide station locations in the model domain, generating the major tidal harmonic constituents, to assess the time propagation through the system. A comparison was made at each station, of the model-predicted to observed (NOAA calculated) major semi-diurnal and diurnal harmonic tidal constituents in the domain, showing excellent correspondence.

The model's ability to predict the currents in the study domain is of primary interest in the model application. Model predicted currents were compared to observations at the surface and bottom at each of the Rutgers moorings. Two important features were noted in the currents; the first is that the currents ebb and flood are primarily tidal, and fairly rectilinear. The second is that the bottom currents are not much smaller than the surface currents, as might be expected in a well-mixed estuary. The model predictions picked up the variability, and follow the trends and magnitudes of the observed currents well, clearly exhibiting the semi-diurnal tidal response as well as the wind induced offsets around mid-January at the surface and bottom.

Examples of the model-predicted maximum flood and ebb tide current fields, on January 9th, 2012 are presented in Figure 3 and Figure 4, respectively. The currents are represented by vectors at each grid cell in the model domain, where the size of the vector represents the current speed, and the arrow head points in the direction of current flow. Strong flood tide currents (Figure 3) can be seen on the right side of the map, to enter the bay through the reach just north of Sandy Hook, and head into Raritan Bay and curl southward into Sandy Hook bay as well. The flood tide currents diminish as they enter Raritan Bay proper but accelerate around the two points on the south shore and again at the entrance to the Raritan River, at the left side of the map.

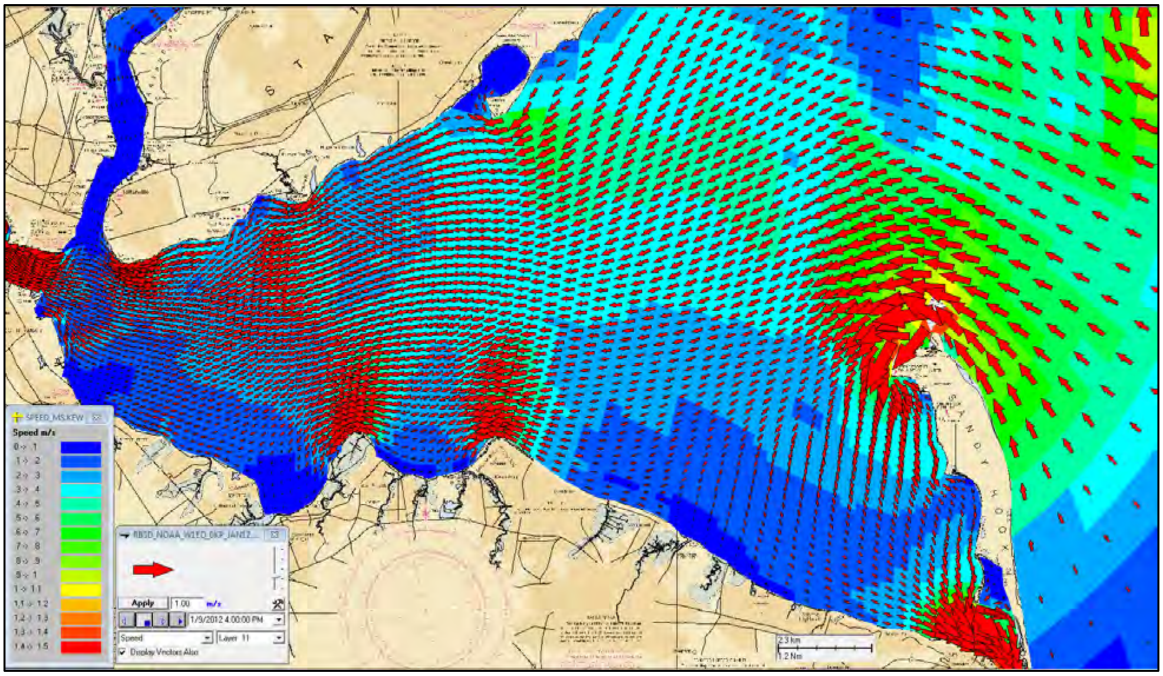

Figure 3. Example model-predicted maximum flood tide currents in the Raritan Bay study area, January 9th, 2012. The current vectors (red arrows) are plotted over color-coded current speed contours.

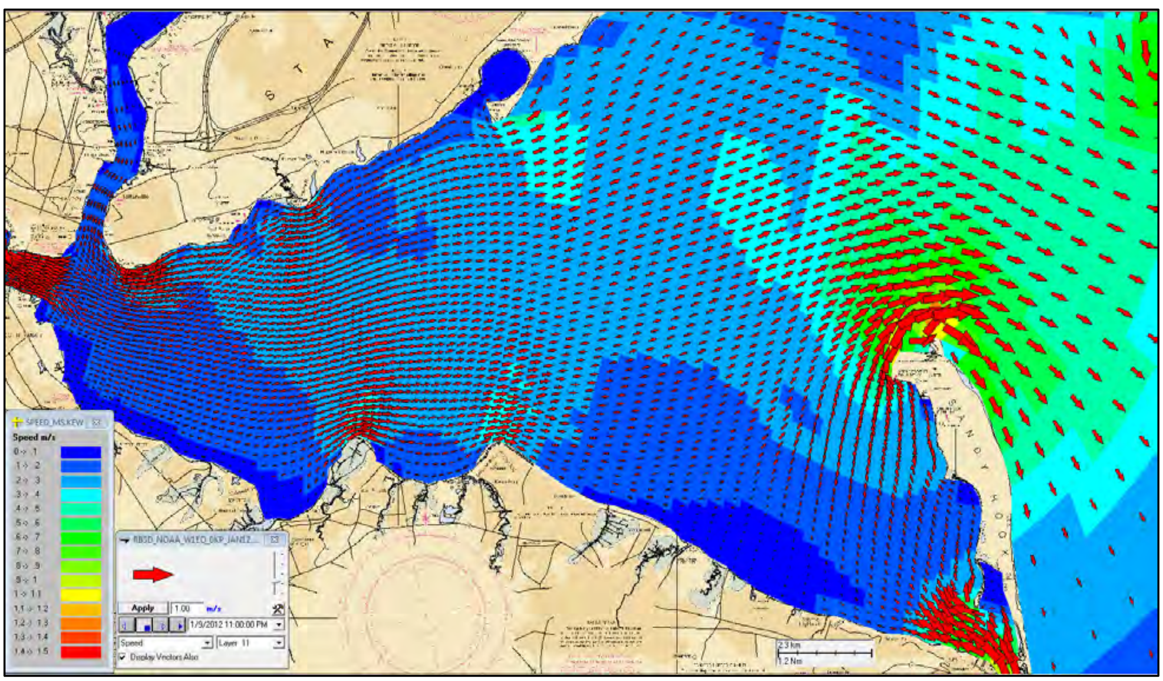

Figure 4. Example model-predicted maximum ebb tide currents in the Raritan Bay study area, January 9th, 2012. The current vectors (red arrows) are plotted over color coded current speed contours.

2.1.4 BFHYDRO Results

With the model application and calibration complete and acceptable, a series of long-term simulations were set up and executed. The simulations used the 2011 and 2012 forcing data set described in the previous sections. Each simulation covered a 6-month time period, to correspond with the dredging and pipe burial schedule planned for the Project. A list of the scenarios with start and end dates is presented in Table 1.

Table 1. Hydrodynamic model simulations for the sediment and contaminant transport and dispersion studies

Run #	Run Name	Start Date	End Date
1	RB3D_NOAA_W1EQ_LIS_2011B.BPC	7/1/2011	12/31/2011
2	RB3D_NOAA_W1EQ_LIS_2011W.BPC	10/1/2011	3/31/2012
3	RB3D_NOAA_W1EQ_LIS_2012A.BPC	1/1/2012	6/30/2012
4	RB3D_NOAA_W1EQ_LIS_2012S.BPC	4/1/2012	9/30/2012

The simulations were confined to the 6-month span to reduce the overall size of the hydrodynamics model output and facilitate ease of use and general manageability. The 4 scenarios were stored in a hydrodynamic ‘library’ for use in the sediment transport model application. The 6-month run time spans overlap, to allow long dredging scenarios to continue, start to finish without changing inputs, by selecting the appropriate input file. The overlapping periods are identical.

3 CONTAMINANT TRANSPORT MODELING

3.1 CHEMMAP Model Description

The chemical fate and transport model (CHEMMAP) predicts the trajectory and fate of a wide variety of chemical products, including floating, sinking, soluble and insoluble chemicals and product mixtures. Processes simulated include: transport, surface slick spreading, and entrainment of floating materials; transport of dissolved and droplet/particulate-phase chemicals in three dimensions; evaporation and volatilization; dissolution and adsorption onto suspended particulate material (SPM); sedimentation and resuspension; and degradation.

The chemical fates model estimates the distribution of chemical (as mass and concentrations) on the water surface, on shorelines, in the water column, and in the sediments. The model incorporates a Lagrangian three-dimensional transport model, separately tracking surface slicks, entrained droplets or particles of pure chemical, chemical adsorbed to suspended particulates, and dissolved chemical.

The model uses physical-chemical properties to predict the fate of chemicals released into the environment. These include density, vapor pressure, water solubility, environmental degradation rates, adsorbed/dissolved partitioning coefficients (KOW, KOC), viscosity, and surface tension. The model can incorporate a variety of one- to four-dimensional hydrodynamic data files as inputs. The fates model may be run as a forecast/hindcast of a single event (deterministic simulation) or in stochastic mode to estimate probable contaminant distributions given a long-term record of historical environmental conditions. Outputs of the fates model include mass balance information and animated time-varying plots of trajectories and concentrations. The model is described in French McCay (2001). Example applications are discussed in French McCay and Isaji (2004) and French McCay et al. (2008).

3.1.1 Chemical Property Data

The physical-chemical properties required by the model to simulate the transport and fate of the released material were compiled for a suite of chemicals from published literature sources; this compilation is referred to as the chemical database. The model can simulate releases of pure chemicals, chemicals in aqueous or hydrophobic solutions, or chemicals in emulsions (i.e., mixtures of particulate material suspended in an aqueous carrier or solvent). Thus, the chemical database includes these mixtures and solutions in addition to pure chemicals. The various chemical states that can be defined are summarized below

- Pure chemical
  - Solid, powder
  - Solid, pellets or granular crystals
  - Solid, block
  - Liquid
  - Gas
- Suspended and/or dissolved in a bulk liquid
  - Dissolved in an aqueous solution
  - Particulate (solid) suspended in aqueous solution (an emulsion)
  - Dissolved in a hydrophobic solvent
  - Dissolved in or adsorbed to hydrophobic material that is suspended as an emulsion in an aqueous solution
  - Both dissolved in an aqueous solution and adsorbed to hydrophobic particulate material that is suspended as an emulsion in the aqueous solution

Several properties vary with temperature. Thus, the model input values are for a standardized temperature of 77o F (25^{o}C) and the model corrects the chemical properties to the ambient temperature. The algorithms for temperature correction of viscosity and vapor pressure are taken from French et al. (1996), who developed a regression using the data in Gambill (1959).

3.1.2 Chemical Fates Model

The chemical fates model estimates the distribution of the released chemical. The model is initialized with a definition of the released chemical mass at the location and depth of the release, in a state dependent upon the physical-chemical properties of the material. The state (i.e., the categories described above) and solubility are the primary properties influencing the initialization. If the chemical is highly soluble in water and is either a pure chemical or dissolved in water (before it is released), the chemical mass is initialized in the water column in the dissolved state and in a user-defined initial volume. If chemical is an insoluble or semi-soluble liquid, and/or its density is less than or equal to that of water, and the release is defined as at the water surface, the model initializes the material as floating on the water surface. For insoluble or semi-soluble solids, liquids and gases released underwater, the released mass is initialized in the water column at the release depth in a user-defined plume volume, as particles, droplets or bubbles, respectively. The median particle size is characterized by a user-defined diameter.

If the released chemical is a particulate in an aqueous emulsion or dissolved in a hydrophobic solvent, the released mass is initialized as particles (droplets) in the water column at the release depth. The particle size is user defined, typically based on product specification data. The initial plume volume is assumed that of the bulk liquid volume released. Insoluble solids in large pelletized or block state when released are also initialized in this manner. For the state where the chemical of interest is both adsorbed to particles and dissolved (to a limited extent) in the water phase of the bulk liquid, dissolved mass is also initialized in the initial plume volume. The mass of chemical released is corrected from the bulk release volume using appropriate density and concentration data input to the model.

Chemical mass is transported in three-dimensional space and time, by surface wind drift, eddy mixing, currents, and vertical movement in accordance with buoyancy and dispersion. The model simulates adsorption onto suspended sediment, resulting in sedimentation of material. Stokes' Law is used to compute the vertical velocity of pure chemical particles or suspended sediment with adsorbed chemical. If rise or settling velocity overcomes turbulent mixing, the particles are assumed to float or settle to the bottom respectively. Settled particles may later resuspend (assumed to occur above 20 cm/sec current speed). However, if the chemical is specified as "sticky in water," which is a property flag defined in the chemical database, resuspension will not occur. (Thus, the "stickiness" is a parameterization of poorly understood processes at the sediment and shoreline interface, where chemical may be specified to remain permanently after contact.)

Wind-driven current (drift) in the surface water layer is calculated within the fates model, based on hourly wind speed and direction data. Surface wind drift of oil has been observed in the field to be 1-6% of wind speed in a direction 0-30 degrees to the right (in the northern hemisphere) of the down-wind direction (Youssef and Spaulding, 1993, 1994). The algorithm developed by Youssef and Spaulding is used for wind transport in the surface wave-mixed layer.

The horizontal turbulent diffusion (randomized mixing) coefficient normally ranges from 0.1-10 m2/sec for modeling turbulent dispersion in coastal and marine waters (Okubo and Ozmidov, 1970; Okubo (1971). The vertical turbulent diffusion (randomized mixing) coefficient is computed as a function of wind speed in the wave-mixed layer, based on Thorpe (1984). In deeper water below the wave-mixed layer, the vertical turbulent diffusion coefficient is typically 0.0001-0.001 m2/sec. The diffusion coefficients (other than the vertical in the wave-mixed layer) are model inputs.

For surface floating liquids, the model estimates surface spreading, transport, and entrainment into the water column, to determine trajectory and fate at the surface. Spreading is simulated using the algorithm of Fay (1971). Entrainment is modeled as for oil, using data in Delvigne and Sweeney (1988). Surface floating chemicals interact with shorelines, depositing and releasing material according to shoreline type and whether the material is assumed “sticky.” The algorithms used are those developed for oil spills, as described in French McCay (2004).

Dissolution of the chemical of interest from an insoluble solvent (such as naphtha) is modeled using algorithms previously developed for oil (French et al., 1996). The model developed by Mackay and Leinonen (1977) is used for dissolution from a surface slick. The slick (spillet) is treated as a flat plate, with a mass flux (Hines and Maddox, 1985) related to solubility and temperature. A well-mixed layer is assumed, with most of the resistance to mass transfer lying in a hypothetical stagnant region close to the slick.

For subsurface solvent droplets, dissolution of the chemical of interest is treated as a mass flux across the surface area of a droplet (treated as a sphere) in a calculation analogous to the Mackay and Leinonen (1977) algorithm. Dissolution rate of pure chemicals is a function of solubility using a first-order constant rate equation. Dissolved chemical in the water column is assumed to adsorb to particulate matter according to equilibrium partitioning theory, where partitioning between dissolved and adsorbed is in constant proportions (using a partition coefficient related to the octanol-water partition coefficient, DiToro et al, 1991).

Evaporation from floating chemicals is modeled following the approach in Mackay and Matsugu (1973) where the rate of mass flux to the atmosphere increases with vapor pressure, temperature, wind speed, and surface area. Conceptually, this model assumes that the transfer of mass from liquid to the air is limited by molecular diffusion across a stagnant boundary layer in the air just above the chemical’s surface.

Volatilization from the water column is calculated from the chemical’s vapor pressure (a strong function of temperature) and solubility. The procedure outlined by Lyman et al. (1982), based on Henry’s Law and mass flux (Hines and Maddox, 1985), is followed in the model. The volatilization depth for dissolved substances in the water column is limited to the maximum of one half the wave height. Wave height is computed from the wind speed (CERC, 1984).

Degradation is estimated assuming a constant rate of "decay" specific to the environment where the mass exists (i.e., atmosphere, water column, or sediment). This degradation rate accounts for biological and chemical changes to another chemical form, assumed not to be toxic and/or to be no longer tracked in the simulation.

The released chemical is modeled using the Lagrangian approach, where multiple sublots (called spillets) of the entire mass (or volume) released are tracked as they move in three-dimensional space over time (by addition of the transport vectors due to wind, currents, and buoyancy). At each time step, phase transfer rates (evaporation, dissolution, volatilization, and entrainment) are calculated and a proportionate percentage of the spillets are transferred to a new phase as appropriate. The fates model tracks the chemical in space and time within the following compartments of the model domain:

- Water surface:
    - area covered by surface floating chemical
    - radius and thickness of surface floating chemical
- Water column:

  - total chemical concentration
  - pure chemical droplet or particulate concentration
  - dissolved chemical concentration
  - chemical concentration adsorbed to suspended sediments
- Sediments:
  - total mass in sediments
  - pure chemical droplet or particulate concentration in the bioturbated layer (assumed 10 cm)
  - dissolved concentration in interstitial water (bioturbated layer)
  - chemical concentration adsorbed to sediments (bioturbated layer)
- Shorelines:
  - area and length contaminated
  - mass of chemical per unit area

CHEMMAP has a Graphical User Interface (GUI), so the user can visualize individual time steps of the model integration and export complete animations of the scenario. The model also calculates and outputs area, plume thickness, and volume of exposure above a range of thresholds.

4 CHEMMAP APPLICATION FOR THE NESE PROJECT

The objective of the model application was to predict the spatial and temporal characteristics of contaminant plumes that may arise during dredging activities involved in burial along segments of the pipeline route in New Jersey state waters where contaminants exceeding NJDEP Ecological Effects Range – Medium (ER-M) thresholds were detected in the sediments.

4.1 Sediment Contaminant Releases

As part of a 2018 project-specific geochemical site investigation, vibracore samples were collected from 69 sites along the Raritan Bay Loop route. At six of these sites in NJ waters, contaminants were detected in the sediments at concentrations exceeding ER-M Screening Criteria. Contaminant transport modeling was performed along those segments using CHEMMAP. The potentially affected reaches encompass sampling sites VC208, VC214, VC304, DEP3, DEP4R and DEP5R. Figure 5 and Figure 6 show the location of each site with respect to the proposed pipeline route, and Table 2 presents the contaminants of concern at each site as well as the corresponding sediment transport modeling scenario, which was used to characterize the rate and distribution of resuspended sediments (see RPS, 2017; 2018). The previous studies (RPS, 2017; 2018) documented a series of sediment transport simulations which were run to predict suspended sediment concentration and seabed deposition resulting from the proposed offshore pipeline installation and associated construction activities.

Table 2. Vibracore sampling site, associated Class C contaminants and corresponding deep-burial or re-evaluated method sediment transport scenario.

Vibracore Sampling Site	Sediment Transport Modeling Scenario	Installation Method	Contaminants exceeding threshold
VC208	B-2	Clamshell Dredge (with environmental bucket)	Mercury, PCB Aroclors, 4,4'-DDE, Arsenic
VC214	B-2	Clamshell Dredge (with environmental bucket)	Mercury, PCB Aroclors, 4,4'-DDE, Arsenic, BIS, Phenanthrene
VC304	B-2	Clamshell Dredge (with environmental bucket)	Manganese
DEP3	B-2	Clamshell Dredge (with environmental bucket)	Manganese
DEP4R	B-2	Clamshell Dredge (with environmental bucket)	Manganese
DEP5R	B-2	Clamshell Dredge (with environmental bucket)	Manganese

Table 3 presents the sediment concentration of the contaminants that exceeded the ER-M Screening Criteria, as well as the concentration for arsenic at VC208 that NJDEP identified as a concern though it did not exceed the ER-M criterion. The sediment concentrations listed are developed from a composite of samples at each respective site.

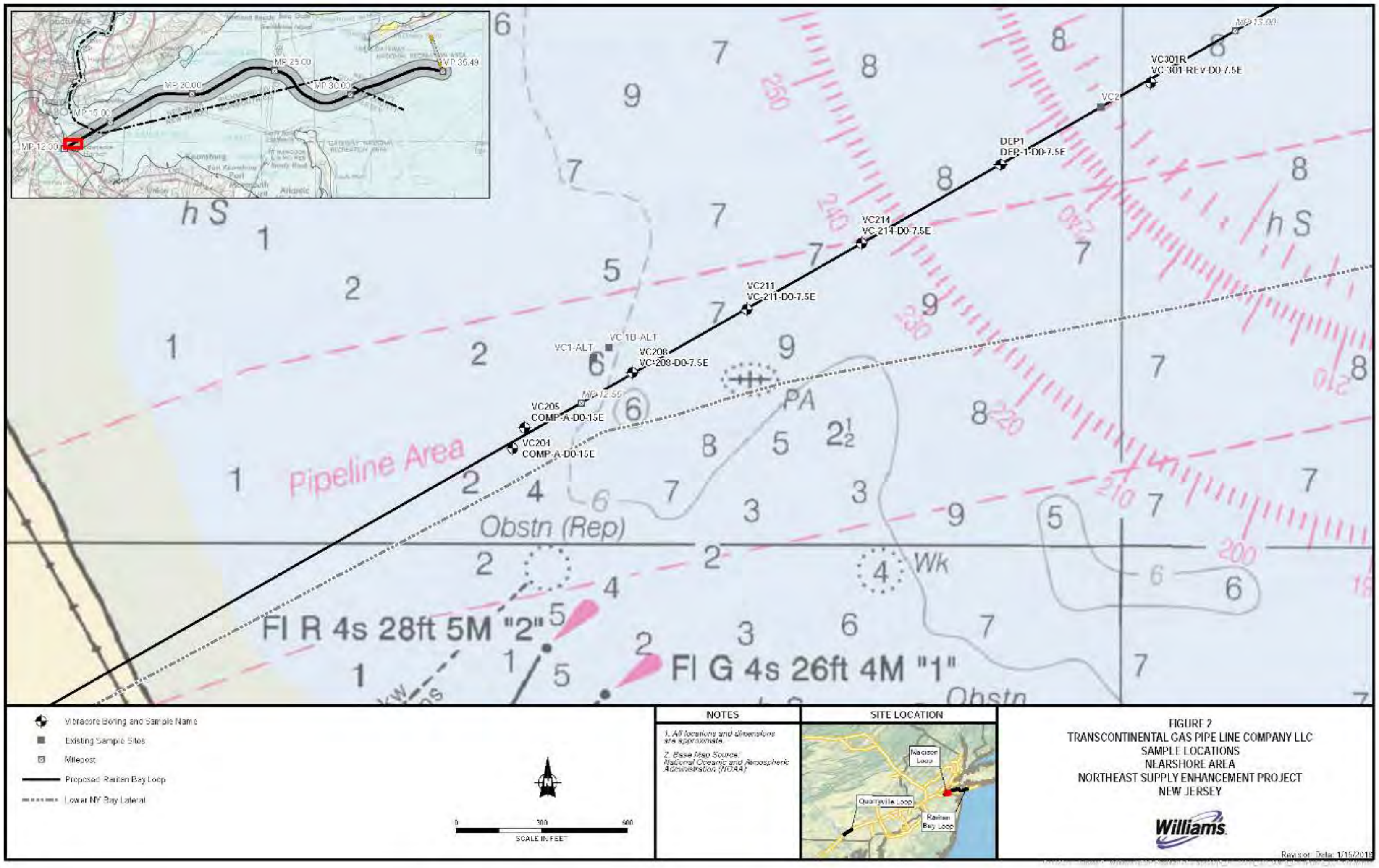

Figure 5. Vibracore sampling site locations in NJ waters, near shore.

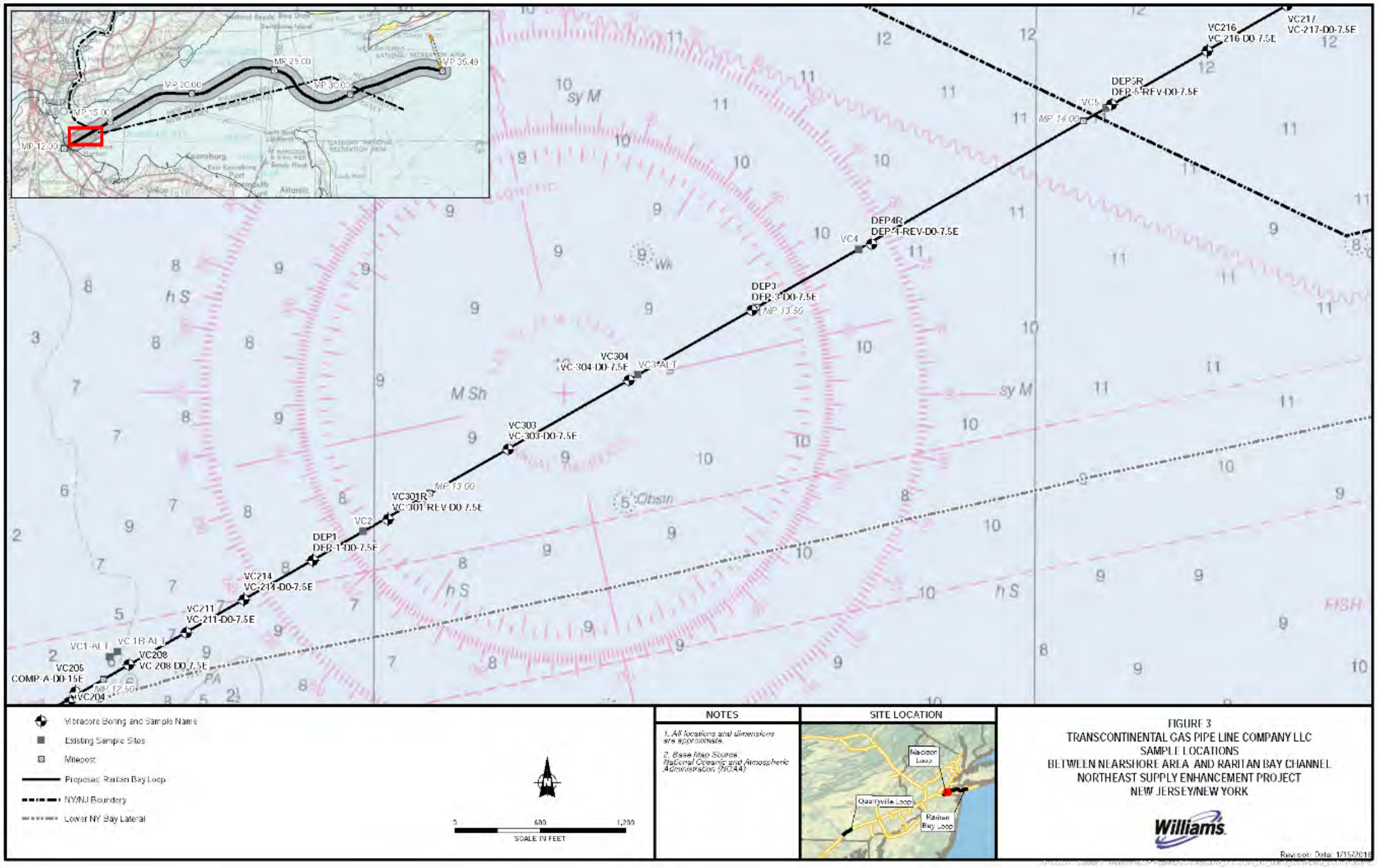

Figure 6. Vibracore sampling site locations in NJ waters, farther offshore.

Table 3. Vibracore sampling sites, associated contaminant concentrations and the NJDEP ER-M for each contaminant (mg/kg).

	BIS	Phenanthrene	Arsenic	Manganese	Mercury	PCBs	4,4-DDE
ER-M	**2.64651**	**1.5**	**70**	**260**	**0.71**	**0.18**	**0.027**
VC208	-	-	63.8	-	1.56	0.821	0.0289
VC214	4.98	2.2	70.1	-	2.17	0.869	0.0366
VC304	-	-	-	366	-	-	-
DEP3	-	-	-	379	-	-	-
DEP4	-	-	-	353	-	-	-
DEP5	-	-	-	371	-	-	-

4.1.1 Sediment Contaminant Source Terms

The resuspension of contaminants during all modeling scenarios discussed herein was evaluated assuming the use of a clamshell dredge with an environmental bucket and no barge scow overflow. Sediment and contaminant losses from this activity was represented in CHEMMAP by characterizing the source strength, vertical distribution, and contaminant concentration in the sediments.

For all clamshell dredging activities, the dredge advance rate was initially calculated based on an estimated production rate of 7,500 ft3/hr. Sediment losses from the clamshell dredge are assumed to be 0.5% of the total dredge volume for excavation activities, distributed evenly throughout the water column in five vertical layers.

4.2 CHEMMAP Scenarios

The fate and transport of each contaminant was evaluated at each reach individually, generating a matrix of 14 scenarios, as indicated in Table 2 and Table 3. Each segment was centered on the vibracore site under consideration, with end-points located half the distance to the two adjacent vibracore sites.

For each scenario the sediment loading was based on the activity volume, production rate, sediment percent solids, and sediment loss factor. The contaminant load was based on the sediment load and the contaminant concentration. The assumptions and details of the sediment loads are detailed in the sediment transport modeling report (RPS, 2017; 2018), though key metrics of the contaminated segments are presented in Table 4 below. The contaminant loadings were developed using the contaminant concentration from the specific vibracore site listed in Table 3.

The total volume excavated for a segment was estimated using the shape of the cross-sectional area excavated for the equipment type, and the required excavation depth for the segment being modeled, multiplied by the length of the segment.

Table 4. Total sediment mass loss calculation input parameters for each segment of the given scenarios.

Vibracore Site	Equipment Type	Base Length (ft)	Angle of Repose	Trench Depth (ft)	Segment Length (ft)	XS Area (ft^2)	Volume Excavated (ft^3)	% Solid	Sediment Loss Factor (%)
VC208[1]	Clamshell	7	3	7.5	475	221	104,975	44.2%	0.5
VC214[1]	Clamshell	7	5	7.5	528	221	116,688	44.2%	0.5
VC304[1]	Clamshell	7	5	7.5	1003	221	221,663	28.1%	0.5
DEP3[1]	Clamshell	7	3	7.5	950	221	209,950	28.1%	0.5
DEP4R[1]	Clamshell	7	3	7.5	1478	221	326,638	29.2%	0.5
DEP5R[1]	Clamshell	7	3	7.5	1373	221	303,433	24.5%	0.5

[1] A uniform trench cross-section was used for portions of the route where the actual trench geometry may be variable (e.g. around channels). The total volume of these sections was conserved in the model.

The solid fraction of sediment at each vibracore site and the equipment loss factor were used to determine the total amount of sediments resuspended along a segment. The total contaminant mass was estimated as the contaminant concentrations (mg/kg) multiplied by the sediment mass lost (resuspended) from each segment.

Table 5 summarizes the contaminant modeling scenarios that RPS has developed in coordination with E & E. The scenario name reflects the vibracore sampling site and the contaminant simulated. A clamshell dredge with environmental bucket is the only equipment type evaluated for scenarios in this report and the input factors are based on the corresponding sediment transport study. The duration of each activity is estimated from the production rates for each of the dredging methods (RPS, 2017; 2018) and the segment length.

Table 5. Description of activities being simulated for each contaminant modeling scenario.

Scenario Name	Vibracore Site	Contaminant	Equipment Type	Trenching Activity Duration (hrs)	Contaminant Mass Loss (mg)
VC208_Hg_NJ	VC208	Mercury	Clamshell	13.89	2.72E+04
VC208_As_NJ	VC208	Arsenic	Clamshell	13.89	1.11E+06
VC208_PCB_NJ	VC208	PCB Aroclors	Clamshell	13.89	1.43E+04
VC208_44DDE_NJ	VC208	4,4'-DDE	Clamshell	13.89	5.04E+02
VC214_Hg_NJ	VC214	Mercury	Clamshell	15.43	4.21E+04
VC214_As_NJ	VC214	Arsenic	Clamshell	15.43	1.36E+06
VC214_PCB_NJ	VC214	PCB Aroclors	Clamshell	15.43	1.68E+04
VC214_PHEN_NJ	VC214	Phenanthrene	Clamshell	15.43	4.26E+04
VC214_BIS_NJ	VC214	BIS(2-Ethylhexyl)Phlalate	Clamshell	15.43	9.65E+04
VC214_44DDE_NJ	VC214	4,4'-DDE	Clamshell	15.43	7.10E+02
VC304_Mn_NJ	VC304	Manganese	Clamshell	29.32	8.58E+06
DEP3_Mn_NJ	DEP3	Manganese	Clamshell	27.77	8.41E+06
DEP4R_Mn_NJ	DEP4R	Manganese	Clamshell	43.20	1.26E+07
DEP5R_Mn_NJ	DEP5R	Manganese	Clamshell	40.12	1.04E+07

4.3 CHEMMAP Transport Scenario Results

CHEMMAP simulations were performed for each of the installation activities listed in Table 5. All modeling assumed continuous operation for each phase of the construction. The calculated loads for each contaminant along each segment were considered to be released in a uniform manner, and evenly distributed along the segment. The sediments and contaminants released into the water column, timed to match the sediment transport modeling, experienced the same tidal flood and ebb current conditions from the associated hydrodynamic model predictions. The currents transported and dispersed the released contaminant particles back and forth around the moving dredging activity, while they settled slowly back to the seafloor.

For segments with multiple contaminant analyses, the scenarios were set up identically, except for the contaminant being simulated. For each segment, the start time, path and advance rate of the dredging activity was identical, but the loading, and the contaminant specific parameters varied.

4.3.1 Water Quality Criteria

The water quality criteria for the modeled contaminants can be found in the New Jersey Administrative Code 7:9B Surface Water Quality Standards (NJAC 7:9B). The NJAC 7:9B acute and chronic criteria for saline waters are presented in Table 6 along with the USEPA National Recommended Water Quality Criteria for Aquatic Life (EPA n.d.) for comparison. As listed in Table 6, no acute or chronic criteria is provided for BIS, Phenanthrene, Manganese or 4,4'-DDE with which to compare the model predicted concentrations. There is a chronic threshold for PCBs and both chronic and acute values for arsenic and mercury. For arsenic and mercury, the acute threshold is higher than the chronic value.

Table 6. Select Water Quality Standards/Criteria for saline waters.

Analyte	NJAC 7:9B Acute (µg/L)	NJAC 7:9B Chronic (µg/L)	EPA Acute (µg/L)	EPA Chronic (µg/L)
Bis(2-Ethylhexyl)phthalate	None	None	None	None
Phenanthrene	None	None	None	None
Arsenic	69 (Dissolved)	36 (Dissolved)	69 (Dissolved)	36 (Dissolved)
Mercury	1.8 (Dissolved)	0.94 (Dissolved)	1.8 (Dissolved)	0.94 (Dissolved)
PCBs	None	0.03	None	0.03
4,4' DDE	None	None	None	None
Manganese	None	None	None	None

4.3.2 Scenario Results

Gridded concentrations of each contaminant were stored and post-processed to determine the maximum concentration at 500' from the moving source, at each time step. The maximum of all the time steps over a simulation was determined and stored as the maximum 500' concentration for that simulation. The final results from this analysis are presented in Table 7 below as maximum contaminant concentration (throughout the water column) predicted over the duration of the model run, at a 500-ft radius from the dredging activity at any given time. These model predicted concentrations at 500' were then compared to the corresponding NJDEP acute and chronic water quality criteria (if available) and flagged if the predicted value was greater than the criteria threshold, and the total duration that the predicted concentrations exceeded the criteria was then determined.

Table 7. Model predicted maximum concentration at 500' for 7,500 cf/hr (PCBs at 4,800 cf/hr) (ug/L).

	BIS	Phenanthrene	Arsenic	Manganese	Mercury	PCBs*	4,4-DDE
VC208	-	-	2	-	0.06	0.018	0.001
VC214	0.331	0.16	5	-	0.17	0.026**	0.003
VC304	-	-	-	20	-	-	-
DEP3	-	-	-	13	-	-	-
DEP4	-	-	-	11	-	-	-
DEP5	-	-	-	14	-	-	-

* The PCB contaminant transport scenarios reported used a dredge excavation rate of 4,800 cf/hr.

** The PCB transport scenario for the VC214 segment also employed a slack tide pause operations.

Considering the model-predicted concentrations at the 500’ mixing zone edge for arsenic and mercury at the VC208 and VC214 segments, none exceeded the NJDEP acute or chronic criteria and therefore the exceedance duration was zero for these scenarios at 7,500 cf/hr.

At the 7,500 cf/hr the PCB concentrations were found to exceed the chronic threshold for brief durations at both the VC208 and VC214 segments. Therefore, the model was rerun at a slower 4,800 cf/hr dredging rate for PCBs along both segments. Resulting concentrations along segment VC208 were 100% compliant, while those at VC214 still showed short non-compliance periods around slack tide. A new scenario for the VC214 segment was run at 4,800 cf/hr that included a 1-hour slack tide pause, during which operations were halted and no dredging was performed. Implementing that control strategy resulted in concentrations along segment VC214 that were 100% compliant.

A summary of the exceedance results for each constituent along each reach is presented in Table 8 (a) and (b) for the Acute and Chronic Criteria, respectively.

For contaminants that do not have criteria for comparison, model predictions indicate that maximum contaminant concentrations are also reduced when the average dredging rate is slowed.

The modeling results above, coupled with the best management practices Transco has committed to implement, support a conclusion that contaminants introduced into the water column during construction will not have an adverse impact on water quality. In addition, any contaminant concentrations that are introduced into the water column will be localized, temporary and of short duration. Further, Transco will implement a water quality monitoring program during construction to help ensure compliance with state water quality standards.

Table 8. Summary table of results for the contaminant concentration criteria exceedance (hrs) at the 500-ft mixing zone boundary for (a) Acute Criteria, and (b) Chronic Criteria.

(a) NJAC 7:9B Acute Criteria Exceedance Results at 7,500 cf/hr (hrs)

	BIS	Phenanthrene	Arsenic	Manganese	Mercury	PCBs	4,4-DDE
VC208			0		0	-	-
VC214	-	-	0		0	-	-
VC304				-			
DEP3				-			
DEP4				-			
DEP5				-			

(b) NJAC 7:9B Chronic Criteria Exceedance Results at 7,500 cf/hr (PCBs at 4,800 cf/hr) (hrs)

	BIS	Phenanthrene	Arsenic	Manganese	Mercury	PCBs *	4,4-DDE
VC208			0		0	0	-
VC214	-	-	0		0	0 **	-
VC304				-			
DEP3				-			
DEP4				-			
DEP5				-			

* The PCB contaminant transport scenarios reported used a dredge excavation rate of 4,800 cf/hr.

** The PCB transport scenario for the VC214 segment also employed a slack tide pause operations.

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