# Appendix F: Ecology

F-9 Essential Fish Habitat Assessment

# Tappan Zee Hudson River Crossing Project

Rockland and Westchester Counties, New York
and
The Historic Area Remediation Site, New York Bight Apex

## Essential Fish Habitat Assessment

**Primary Agency and Contact:**

Jonathan McDade, New York Division Administrator

Federal Highway Administration

**In Coordination with:**

New York State Department of Transportation

New York State Thruway Authority

**Prepared by:**

AKRF, Inc.

AECOM

Arthur Popper, Ph.D.

Revised April 2012

# Essential Fish Habitat Assessment
# For the Tappan Zee Hudson River Crossing Project

Rockland and Westchester Counties, New York
and
The Historic Area Remediation Site, New York Bight Apex

**Revised April 2012**


**Primary Agency and Contact:**

Jonathan McDade, New York Division Administrator

Federal Highway Administration

**In Coordination with:**

New York State Department of Transportation

New York State Thruway Authority

**Prepared by:**

AKRF, Inc.

AECOM

Arthur Popper, Ph.D.

**Project Name:**

Tappan Zee Hudson River Crossing Project

**Date:**

Revised April 2012

**Primary Agency and Contact:**

Jonathan McDade, New York Division Administrator

Federal Highway Administration

**In Coordination with:**

New York State Department of Transportation

New York State Thruway Authority

# Table of Contents

# List of Tables

# List of Figures

# List of Attachments

**PAGE INTENTIONALLY LEFT BLANK**

# Chapter 1: Introduction and Federal Nexus

Essential fish habitat (EFH) is defined under the Magnuson-Stevens Fishery Conservation Management Act (16 USC §§ 1801 to 1883), as amended by the Sustainable Fisheries Act (SFA) of 1996, as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their physical, chemical and biological properties that are used by fish. "Substrate" includes sediment, hard bottom, structures, and associated biological communities that are under the water column. Waters and substrates necessary for fish spawning, breeding, feeding or growth to maturity—covering all stages within the life cycle of a particular species—refers to those habitats required to support a sustainable fishery and a particular species' contribution to a healthy ecosystem (50 Code of Federal Regulations (CFR) 600.10).

Section 303(a)(7) of the Magnuson-Stevens Act requires that the eight Regional Fishery Management Councils (RFMC) describe and identify EFH for each Federally managed species, and minimize adverse impacts from fishing activities on EFH. Section 305(b) (2)-(4) of the Magnuson-Stevens Act outlines the process for providing the National Marine Fisheries Service (NMFS) within the National Oceanic and Atmospheric Administration (NOAA), and the RFMC with the opportunity to comment on activities proposed by Federal agencies that have the potential to adversely impact EFH areas. Federal agencies are required to consult with NMFS (using existing consultation processes for the National Environmental Policy Act (NEPA), the Endangered Species Act, or the Fish and Wildlife Coordination Act) on any action that they authorize, fund or undertake that may adversely impact EFH.

Adverse effects to EFH, as defined in 50 CFR 600.910(A) include any impact that reduces the quality and/or quantity of EFH. Adverse effects may include:

- direct impacts such as physical disruption or the release of contaminants;
- indirect impacts such as the loss of prey, reduction in the fecundity (number of offspring produced) of a managed species; and
- site-specific or habitat wide impacts that may include individual, cumulative or synergetic consequences of a Federal action.

An EFH assessment of a Federal action that may adversely affect EFH must contain:

- a description of the proposed project;
- an analysis of the effects, including cumulative, on EFH, the managed species and associated species such as major prey species, and the life history stages that may be affected;
- the agency's conclusions regarding the effects of the action on EFH; and
- proposed mitigation if applicable (50 CFR 600.920(g)).

This EFH assessment has been prepared to demonstrate that the Tappan Zee Hudson River Crossing Project (the project) would be in compliance with the requirements of 50 CFR §660.920 implementing the Magnuson-Stevens Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267).

The following sections provide:

- An overview of the Tappan Zee Replacement Bridge Alternative, including discussion of the proposed landings, approach spans, main spans, and ancillary facilities.
- A description of the aquatic habitat and aquatic biota within the two study areas for the Replacement Bridge Alternative—the Hudson River Bridge Construction Site and the Historic Area Remediation Site (HARS) proposed as the dredged material disposal site for the Tappan Zee Replacement Bridge Alternative.
- An assessment of the potential for construction and operation of the Replacement Bridge Alternative and disposal of dredged material at the HARS to adversely affect aquatic habitat and aquatic biota.
- A separate assessment of potential adverse impacts to the fish species for which EFH has been identified within the study areas for the Hudson River Bridge Construction Site and the HARS.
- An assessment of potential adverse impacts to non-EFH species with the potential to occur in the Hudson River in the vicinity of the project as seasonal transients including; striped bass, a Fish and Wildlife Coordination Act (FWCA) species; and four species of federally-listed threatened or endangered marine turtles. Shortnose sturgeon, a federal and state-listed endangered species; and Atlantic sturgeon, a species recently listed for federal protection under the Endangered Species Act  and marine mammals are addressed separately in the Biological Assessment for the Tappan Zee Hudson River Crossing Project (see Appendix F-4 of the Tappan Zee Hudson River Crossing Project Draft Environmental Impact Statement (DEIS) (Federal Highway Administration in coordination with New York State Department of Transportation and New York State Thruway Authority 2012), and the more recent Revised Biological Assessment submitted to NMFS, dated April 2012. Consultations pursuant to Section 7 of the Endangered Species Act (ESA) have taken place for the area of the HARS during preparation of the Supplement to the Environmental Impact Statement for the HARS (USEPA 1997).
- A separate summary of potential direct, indirect and cumulative effects on EFH and the other species evaluated for the Hudson River Bridge Construction Site and the HARS study areas.

# Chapter 2: Project Description

## 2.1 OVERVIEW

The Replacement Bridge Alternative would replace the existing Tappan Zee Bridge (see Figures 1 and 2) with two new structures to the north of its existing location. The existing bridge would be demolished and removed. The purpose of the project is to maintain a vital link in the regional and national transportation network by providing a Hudson River crossing between Rockland and Westchester Counties, New York, that addresses the limitations and shortcomings of the existing Governor Malcolm Wilson Tappan Zee Bridge. Constructed in 1955, the 3.1-mile-long Tappan Zee Bridge (**Figures 1 and 2**) and its highway connections have been the subject of numerous studies and subsequent transportation improvements. Despite these improvements, congestion has grown steadily over the years and the aging bridge structure has reached the point where major reconstruction and extensive measures are needed to sustain this vital link in the transportation system.

## 2.2 DESCRIPTION OF THE REPLACEMENT BRIDGE ALTERNATIVE

The Replacement Bridge Alternative (see **Figure 3**) would be located to the north of the existing Tappan Zee Bridge where there is available NY State Thruway Administration (NYSTA) right-of-way available on both sides of the river to accommodate construction of the crossing and bridge landings for construction storage and staging areas and allow for a straight approach to the Westchester toll plaza. It would include two separate spans to provide service redundancy—a 96-foot-wide deck for the superstructure that includes a shared-use path and an 87-foot-wide deck for the superstructure that does not include a shared-use path. The two spans would be an average of 40 feet apart.

The following sections describe the proposed landings, approach spans, main spans, and ancillary facilities of the Replacement Bridge Alternative.

### 2.2.1 LANDINGS

In Rockland and Westchester Counties, Interstate 87/287 would be shifted northward to meet the new abutments of the Replacement Bridge Alternative (see **Figure 3**). The two approach span options (Short Span and Long Span described below) would result in a different configuration of the Rockland County landing. Where notable differences between the Short Span and Long Span Options would occur at the landings, they are described below. **Figure 3** reflects the Rockland County landing for the Short Span Option.

### 2.2.2 APPROACH SPANS

There are two options for the approach spans, the sections of the bridge that link the landings with the main spans over the navigable channel. These options—Short Span and Long Span—differ in terms of the type of structure as well as the number of and distance between bridge piers. Both approach span options would not preclude future transit service across the Tappan Zee Hudson River Crossing.

#### 2.2.2.1. Short Span Option

The Short Span Option would consist of two parallel bridge structures that would have a typical highway design with a road deck supported by girders and piers (see **Figures 4 and 5**). The decks of the parallel structures would be separated by a gap of about 70 feet for length of about 2,600 feet at the main span that would diminish closer to the shorelines. The following describes the general characteristics of the Rockland County and Westchester County approach spans for the Short Span Option:

- The Rockland County approach spans would extend 4,125 feet between the abutments and the main spans, and each would consist of 43 sections. The average distance between the piers of Rockland County approach spans would be 230 feet. There would be no gap between the parallel bridges at the abutments. The gap between the highway decks would widen to 70 feet at the main span.
- The Westchester County approach spans would extend 1,800 feet between the main spans and the abutments, and each would consist of 16 sections with an average distance between the piers of approximately 230 feet. The gap between the decks of the parallel bridges would range from 70 feet at the main span to about 40 feet at the abutments.

As the approach spans meet the main span, the road deck would be at an elevation of 175 feet above the Hudson River’s mean high tide elevation.

#### 2.2.2.2. Long Span Option

The Long Span Option would also consist of two parallel bridge structures. Each structure would have a truss supported by piers (see **Figures 4 and 6**). The road deck would be located on top of the trusses. As with the Short Span Option, the decks of the parallel structures would be separated by a gap of about 70 feet that would diminish closer to the shorelines. The following describes the general characteristics of the Rockland County and Westchester County approach spans for the Long Span Option:

- The Rockland County approach spans would extend 4,125 feet between the abutments and the main spans, and each would consist of 23 sections. The average distance between the piers of Rockland County approach spans would be about 430 feet. There would be no gap between the parallel bridges at the abutments. The gap between the highway decks would widen to 70 feet at the main spans.
- The Westchester County approach spans would extend 1,800 feet between the main spans and the abutments, and each would consist of 10 sections with an average distance between the piers of 430 feet. The gap between the parallel highway decks would range from 70 feet at the main spans to 40 feet at the abutments.

As the approach spans meet the main span, the road deck would be at an elevation of 195 feet above the Hudson River’s mean high water elevation.

### 2.2.3 MAIN SPANS

The main spans—the portions of the bridge that cross the navigable channel of the Hudson River—would provide adequate vertical and horizontal clearance for marine transport.

- The horizontal clearance affects the width of the Hudson River's navigable channel for water craft and must be clear of bridge piers and other bridge infrastructure. The U.S. Coast Guard requires a minimum horizontal clearance of 600 feet through the Tappan Zee crossing. However, a clearance of 1,042 feet is preferred to provide a safety buffer for maritime navigation through the channel.
- The vertical clearance affects the height of the bridge as well as the hull-to-mast height of marine vessels that navigate under the bridge. The Replacement Bridge Alternative would provide for a vertical clearance of 139 at mean high water to maintain the existing maximum hull-to-mast height of vessels that travel beneath the Tappan Zee crossing.

The two options considered for the bridge's main spans over the navigable channel—Cable-stayed and Arch—would result in a horizontal clearance of at least 1,000 feet and a vertical clearance of 139 feet over the navigable channel at mean high water. Neither main span options would preclude future transit service across the Tappan Zee Hudson River Crossing.

### 2.2.4 CONSTRUCTION DURATION

The Replacement Bridge Alternative would be constructed over an approximately 4½- to 5½-year period for the Long Span and Short Span Options respectively. The various stages of construction are described in more detail below.

## 2.3 PROJECT SETTING

This assessment of the potential effects of the Tappan Zee Hudson River Crossing Project on EFH evaluates impacts to EFH within two study areas: the Hudson River bridge construction site, and the HARS, proposed as the dredged material disposal site for the Tappan Zee Hudson River Crossing Project. The Hudson River bridge-construction study area comprises the area extending ½ mile north and south of the Interstate 87/287 right-of-way generally between Interchange 10 (US Route 9W) in Rockland County and Interchange 9 (US Route 9) in Westchester County (see **Figure 7**). This study area incorporates the portions of the bridge, the Rockland and Westchester Bridge Staging Areas on the river, and the bridge landings. The study area for the evaluation of hydroacoustic effects of pile driving extended beyond this area to the limit of the ensonified area defined by the 187 $SEL_{cum}$ re $1\mu Pa^2 \cdot s$ isopleths and is described in greater detail below. The HARS study area consists of the HARS (see **Figure 8**) which is located approximately 4 miles (3.4 nautical miles) east of Highlands, New Jersey and about 9 miles (7.7 nautical miles) south of Rockaway, Long Island.

### 2.3.1 HUDSON RIVER BRIDGE-CONSTRUCTION STUDY AREA

The approximately 3-mile-wide portion of the Hudson River within the study area is designated by the New York State Department of Environmental Conservation (NYSDEC) as a Class SB waterbody. Best usages of Class SB saline surface waters are primary and secondary contact recreation and fishing; these waters shall be suitable for fish propagation and survival. Within the study area, the Hudson River is included on the 2010 New York State 303(d) list due to the presence of contaminated sediment containing Polychlorinated Biphenyls (PCBs) (NYSDEC 2010a).

In the vicinity of the Tappan Zee Bridge, the river ranges in depth from less than 12 feet at mean lower low water (MLLW) along the western causeway to greater than 47 feet at MLLW in the shipping channel under the main span (see **Figure 9**). The Hudson River is tidally influenced from the Battery to the Federal Dam at Troy, New York. Tidal currents are generally greatest in the navigational channel. Results of field surveys conducted for the project in April 2007 and November 2008 indicate that peak vertically averaged tidal currents in the navigational channel are about 2.5 feet per second (ft/sec). Peak velocities during the spring freshet—a time of high freshwater inflows resulting from snow and ice melt in rivers—may be greater than 3 ft/sec. Velocities are generally lower in the western mud flats in the vicinity of the bridge, with peak velocities generally on the order of 1 to 2 ft/sec. The tidal excursion at the Tappan Zee Bridge is approximately 4.0 and 6.2 miles for the flood and ebb tide, respectively (DiLorenzo et al. 1999).

#### 2.3.1.1. Water Quality

##### *2.3.1.1.1. Salinity*

The salt front, as defined by the USGS for the Hudson River estuary, is where chloride concentration begins to exceed 100 milligrams per liter (mg/L) (Devries and Weiss, 2001). Seawater has a chloride concentration of about 19,400 mg/L. With the exception of very large freshwater discharge events, there is always a salt front present in the Hudson River estuary, the location of which varies at a given time with tidal forcing and the magnitude of freshwater discharge. In general, the salt front is located between 15 and 75 miles upstream of the Battery. It is located farther upriver during the summer when there are low freshwater inflows, and farther downriver during the spring when freshwater flows are greatest.

The term salt wedge is a more generic term that describes the tendency for saltwater to intrude beneath freshwater without substantial mixing. A salt wedge is marked by a steep salinity gradient, or halocline, in the vertical direction. The presence of a salt wedge does not indicate an immediate horizontal transition from fresh to salt water. In the Hudson River estuary, the transition is often 50 miles long.

**Figure 10** shows average salinities in Practical Salinity Units (PSU) over a 16-year period at the USGS gauge at Hastings-on-Hudson (#1376304), which is about 6 miles downstream of the Tappan Zee Bridge. Although salinity concentrations are somewhat lower at the Tappan Zee Bridge, the salinity at Hastings-on-Hudson is indicative of the magnitude and yearly variation of salinity at the bridge. At the Hastings-on-Hudson station, salinity ranged from about 2 to 6 PSU during high freshwater flow periods in the spring to a high of about 8 to 10 PSU during low freshwater flow periods in the summer. Salinities in the winter varied between 4 and 6 PSU. Salinities recorded during the 2006 and 2008 sampling program conducted for the project were similar to those recorded at Hastings-on-Hudson.

##### *2.3.1.1.2. Temperature*

Water temperatures are relatively uniform throughout the freshwater reach of the Hudson River estuary, and follow a similar cycle each year. At the mouth of the Hudson River estuary, near the Battery, temperatures are substantially affected by the inflow of water from the New York Bight and tend to exhibit a milder degree of variation throughout the year. **Figure 11** demonstrates the average yearly cycle in water temperature in the upper reach of the Hudson River estuary near Albany, and near its mouth, near the Battery over a period of 2002-2009. The NOAA Gauge at the Battery (#8518750) is 26.5 miles downstream of the bridge. The USGS gauge at Albany (#1359139) is 118 miles upstream of the bridge.

In the lower reaches of the Hudson River estuary and near the Tappan Zee Bridge, ocean water intrudes beneath fresh water to form a salt wedge, often resulting in a large degree of stratification in the water column. In these areas large vertical variations in temperature may be present. Average water temperatures at the Tappan Zee Bridge are generally close to the average of temperatures at the Battery and Albany, NY, ranging from below close to 0º Celsius (C) (32º Fahrenheit (F)) in the winter to about 25º C (77º F) in the summer, with temperatures in the spring ranging between 2º C and 10º C (36º F to 50º F).

*2.3.1.1.3. Suspended Solids*

Generally, suspended solids concentrations (SSC) show a strong correlation with water-column depth, with higher concentrations near the bottom of the river. Significant variation based on a variety of river conditions can also be expected, with the tidal cycle and magnitude of freshwater discharge being the most dominant factors. During the spring freshet sediment concentrations much higher than normal can be expected.

The USGS operates an Acoustic Doppler Current Profiler (ADCP) at the Hudson River estuary gauge station south of Poughkeepsie, approximately 27 miles north of the bridge. The station uses backscatter information from the ADCP to estimate suspended solids concentration (Wall et al. 2006). Using the SSC data combined with the current data measured by the device, an estimate of total sediment discharge is also calculated. This gauge has been monitoring SSC almost continuously since 2002, and represents the most complete data set of sediment concentration and sediment loading in the Hudson River estuary.

For the purposes of impact evaluation, an understanding of the typical sediment concentrations at the study area, and their variability, is useful. To aid in this understanding, the yearly variation of the depth-averaged SSC concentration at the USGS gauge south of Poughkeepsie is presented in **Figure 12** for the period 2002 through 2009. It is expected that the suspended sediment concentration at the Tappan Zee Bridge will be similarly inherently variable and seasonally dependent, as indicated by the USGS gauge upstream. Depth averaged SSC measurements made during field surveys of the Tappan Zee were similar in magnitude to those recorded at the Poughkeepsie station (see **Figure 12**).

SSC was recorded during water quality sampling conducted from late October through early December 2008 within the study area. Results showed that increases in SSC with depth were more dramatic at deep locations than at shallow water locations. Fluctuations in SSC occurred over each tidal cycle, with the highest SSC observed at max flood and max ebb tides. SSC recorded during this time frame generally ranged from about 10 to 75 mg/L, with maximum concentrations recorded of about 140 mg/L. Depth averaged water-column sediment samples in the vicinity of the Tappan Zee Bridge appear to range from 15 to 50 (mg/L) under normal conditions, and may exceed 100 mg/L during large freshwater events.

*2.3.1.1.4. Sediment Characteristics*

Bottom sediments in the Hudson River in the vicinity of the bridge comprise primarily clayey silt (see **Figure 13**). Accumulations of sand, silt and clay material are also observed along the causeway section of the existing bridge. Gravelly sediments are also found extensively near the eastern shore of the Hudson River and across a large swath of the mud flats north of the existing causeway section.

Due to releases from industrial activity, sediments deposited on the river bottom during the twentieth century are more likely to exhibit signs of contamination. Examples of industrial contamination include heavy metals, volatile or semivolatile organic compounds (VOCs or SVOCs), pesticides, and PCBs. Industrial-era sediments were identified through a combination of seismic-profiling data and the concentration of lead in sediment samples. The thickness of industrial era sediment deposits in the vicinity of the Tappan Zee Bridge is shown on **Figure 14**. While recently deposited sediments (i.e., from the 20th and 21st centuries) can be found throughout much of the study area. Deposition of recent sediments north of the existing bridge is limited, ranging from no deposition to a depth of about 2 feet, with most of the recent deposits occurring between 0 and about 8 inches. South of the bridge, deposition of recent sediments is limited on the western margin (ranging from 0 to 8 inches) with some areas of deeper deposition further east along the causeway (2 to 4 feet), deposition along the eastern margin appears to be greater (ranging from 0 to at least 6 feet). On the basis of the evaluation of recent sediment deposits, the net rate of deposition within the vicinity of the existing bridge is estimated to range from 0 inches per year to as high as 1 inch per year in the eastern margin south of the existing bridge.

Results from the 2006/2008 sediment sampling conducted for the project within the study area were compared to results found for historic Hudson River sampling conducted by Llanso et al (2003). These data are summarized in the Tappan Zee Hudson River Crossing Project Draft Environmental Impact Statement (DEIS) and in **Tables 1, 2, and 3**. In general, levels of contaminants such as metals, pesticides, and PCBs in the sediment samples collected within the study area are similar to average levels found elsewhere in the Hudson River as indicated by the Hudson River Benthic Mapping Project. On the basis of the results of the laboratory analysis of 2006 and 2008 sediment cores, the upper few feet of river sediment would be characterized as moderately contaminated following NYSDEC Technical and Operational Guidance Series (TOGS) 5.1.9, (NYSDEC 2004) with the exception of a few locations near the western and eastern Hudson River shorelines and south of the main span bridge piers where higher concentrations appear to have accumulated. The concentration of contaminants within the sediments is typically lower with increased depth.

## Table 1
## Sediment Chemistry Summary – Metals

| Parameter | Sediment Criteria | | Hudson River Average[2] | Number of Samples Analyzed | Detection Rate | Minimum (mg/kg) | Average (mg/kg) | Median (mg/kg) | 95th Percentile (mg/kg) | Maximum (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | ERL[1] (mg/kg) | ERM[1] (mg/kg) | | | | | | | | |
| Aluminum | NC | NC | 10256.9 | 313 | 100% | 483 | 11,714 | 11,700 | 17,300 | 21,700 |
| Antimony | NC | NC | -- | 156 | 0% | ND | ND | ND | ND | ND |
| Arsenic | 8.2 | 70 | 7.2 | 313 | 97% | ND | 8.06[A] | 7.4[A] | 14[B] | 26.4[B] |
| Barium | NC | NC | -- | 313 | 92% | ND | 43 | 32.9 | 91.04 | 190 |
| Beryllium | NC | NC | -- | 313 | 47% | ND | 0.79 | 0.76 | 1.1 | 2.61 |
| Cadmium | 1.2 | 9.6 | 1.0 | 313 | 46% | ND | 1.9[B] | 1.92[B] | 3.2[B] | 6[B] |
| Calcium | NC | NC | -- | 313 | 98% | ND | 4,919 | 2,620 | 16,550 | 64,600 |
| Chromium | 81 | 370 | 38.1 | 313 | 100% | 1.17 | 31 | 21.9 | 85.86 | 116 |
| Cobalt | NC | NC | -- | 313 | 96% | ND | 10 | 9.8 | 13.7 | 17.3 |
| Copper | 34 | 270 | 42.4 | 313 | 99% | ND | 32[A] | 12.4[A] | 102.55[B] | 1,550[C] |
| Iron | NC | NC | -- | 313 | 100% | 1380 | 24,227 | 24,200 | 32,600 | 40,900 |
| Lead | 46.7 | 218 | 44.6 | 313 | 100% | 1.42[A] | 36[A] | 10.9[A] | 137.4[B] | 604[C] |
| Magnesium | NC | NC | -- | 313 | 100% | 252 | 5,765 | 5,760 | 7,476 | 39,600 |
| Manganese | NC | NC | -- | 313 | 100% | 21.8 | 626 | 587 | 1,170 | 1,600 |
| Mercury | 0.15 | 0.71 | 0.38 | 313 | 37% | ND | 0.89[B] | 0.53[B] | 2.46[C] | 6.33[C] |
| Nickel | 20.9 | 51.9 | 21.5 | 313 | 99% | ND | 21 | 20.6 | 32.6 | 38.3 |
| Potassium | NC | NC | -- | 313 | 97% | ND | 2181 | 2,130 | 3,257 | 4,460 |
| Selenium | NC | NC | -- | 313 | 43% | ND | 4.01 | 3.945 | 6.2775 | 12.6 |
| Silver | 1 | 3.7 | 1.5 | 156 | 17% | ND | 2.02 | 1.9 | 3.04 | 3.3 |
| Sodium | NC | NC | -- | 313 | 94% | ND | 2,229 | 2,035 | 3,761.50 | 5,730 |
| Thallium | NC | NC | -- | 156 | 1% | ND | 12.4 | 12.4 | 12.4 | 12.4 |
| Vanadium | NC | NC | -- | 313 | 99% | ND | 24.7 | 23.7 | 36.3 | 54.1 |
| Zinc | 150 | 410 | 129.2 | 313 | 100% | 8.74 | 90 | 65 | 221 | 399 |

**Notes**: mg/kg = milligrams per kilogram; NC = no criteria; ND = not detected, -- = not available.

**Sources:**

[1] NYSDEC 1999

[2] Llanso et al. 2003

[A] Concentration falls within Class A - no appreciable contamination/no toxicity to aquatic life (NYSDEC 2004).

[B] Concentration falls within Class B - moderate contamination/chronic toxicity to aquatic life (NYSDEC 2004).

[C] Concentration falls within Class C - high contamination/acute toxicity to aquatic life (NYSDEC 2004).

**Table 2**
**Sediment Chemistry Summary – SVOCs**

| Parameter | Sediment Criteria | | Hudson River Average[3] | Number of Samples Analyzed | Detection Rate | Minimum (µg/kg) | Average (µg/kg) | Median (µg/kg) | 95th Percentile (µg/kg) | Maximum (µg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | ERL[1] (µg/kg) | ERM[1] (µg/kg) | | | | | | | | |
| Acenaphthene | 16 | 500 | 289.4 | 156 | 8% | ND | 36 | ND | 89 | 3,270 |
| Acenaphthylene | 44 | 640 | 139.2 | 156 | 16% | ND | 13 | ND | 111 | 206 |
| Anthracene | 85.3 | 1,100 | 283.2 | 156 | 27% | ND | 47 | ND | 155 | 2,030 |
| Benzo(a)anthracene | 261 | 1,600 | 176.4 | 156 | 43% | ND | 130 | ND | 418 | 3,760 |
| Benzo(a)pyrene | 430 | 1,600 | 174.1 | 156 | 51% | ND | 133 | 37 | 496 | 3,020 |
| Benzo(b)fluoranthene | NC | NC | 184.7 | 156 | 42% | ND | 110 | ND | 445 | 2,460 |
| Benzo(g,h,i)perylene | NC | NC | 123.5 | 156 | 42% | ND | 64 | ND | 260 | 1,530 |
| Benzo(k)fluoranthene | NC | NC | 163.4 | 156 | 42% | ND | 91 | ND | 328 | 2,370 |
| Chrysene | 384 | 2,800 | 178.7 | 156 | 44% | ND | 134 | ND | 487 | 3,490 |
| Dibenzo(a,h)anthracene | 63.4 | 260 | -- | 156 | 15% | ND | 14 | ND | 78 | 456 |
| Fluoranthene | 600 | 5,100 | 218.9 | 156 | 49% | ND | 333 | ND | 994 | 13,300 |
| Fluorene | 19 | 540 | 291.2 | 156 | 10% | ND | 28 | ND | 81 | 2,210 |
| Indeno(1,2,3-c,d)pyrene | NC | NC | 104.8 | 156 | 33% | ND | 53 | ND | 220 | 1,510 |
| 2-Methylnaphthalene | 70 | 670 | -- | 156 | 1% | ND | 0.96 | ND | ND | 113 |
| Naphthalene | 160 | 2,100 | 111.0 | 156 | 9% | ND | 11 | ND | 49 | 504 |
| Phenanthrene | 240 | 1,500 | 299.1 | 156 | 40% | ND | 163 | ND | 539 | 7,030 |
| Pyrene | 665 | 2,600 | 265.7 | 156 | 48% | ND | 288 | ND | 999 | 9,570 |
| Total PAHs (sum of above) | 4,020 | 44,792 | 3,003 | 156 | -- | 22.8[A] | 1,673[A] | 113[A] | 6,079[B] | 48,211[C] |
| bis(2-Ethylhexyl)phthalate | NC | NC | -- | 156 | 33% | ND | 82 | ND | 259 | 4,240 |
| Butyl benzyl phthalate | NC | NC | -- | 156 | 12% | ND | 101 | ND | 289 | 5,140 |
| Carbazole | NC | NC | -- | 156 | 3% | ND | 5.25 | ND | ND | 349 |
| Dibenzofuran | NC | NC | -- | 156 | 5% | ND | 20 | ND | 6.6 | 2,660 |
| Di-n-butyl phthalate | NC | NC | -- | 156 | 3% | ND | 30 | ND | ND | 4,360 |

**Notes:** µg/kg = micrograms per kilogram; NC = no criteria; ND = not detected; -- = not available.

**Sources:**

[1] NYSDEC 1999; [2] NYSDEC 1999; [3] Llanso et al. 2003

[A] Concentration falls within Class A - no appreciable contamination/no toxicity to aquatic life (NYSDEC 2004).

[B] Concentration falls within Class B - moderate contamination/chronic toxicity to aquatic life (NYSDEC 2004).

[C] Concentration falls within Class C - high contamination/acute toxicity to aquatic life (NYSDEC 2004).

## Table 3
## Sediment Chemistry Summary – Pesticides, PCBs, and Dioxins

| Parameter | Sediment Criteria ERL[1] (µg/kg) | ERM[1] (µg/kg) | BA- Chronic[1] (µg/gOC) | BA- Acute[1] (µg/gOC) | WA[1] (µg/gOC) | Hudson River Average[2] | Number of Samples Analyzed | Detection Rate | Minimum (µg/kg) | Average (µg/kg) | Median (µg/kg) | 95th Percentile (µg/kg) | Maximum (µg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| alpha-Chlordane | NC | NC | NC | NC | 0.006 | -- | 156 | 1% | ND | 0.1 | ND | ND | 16 |
| gamma-Chlordane | NC | NC | NC | NC | 0.006 | -- | 156 | 1% | ND | 0.09 | ND | ND | 15 |
| Chlordane (sum of above) | NC | NC | 0.002 | 0.05 | | -- | 156 | -- | -- | 0.19[A] | -- | -- | 31[B] |
| Dieldrin | NC | NC | 17.0 | NC | NC | -- | 156 | 1% | ND | 0.03[A] | ND | ND | 4.8[A] |
| 4,4'-DDD | NC | NC | - | - | NC | 5.7 | 156 | 14% | ND | 2.07 | ND | 12 | 54 |
| 4,4'-DDE | 2.2 | 27 | - | - | NC | -- | 156 | 7% | ND | 0.47 | ND | 3.85 | 17 |
| 4,4'-DDT | 1 | 7 | 1 | 130 | NC | 19.7 | 156 | 5% | ND | 2.47 | ND | 0.73 | 352 |
| Sum of DDT, DDD, and DDE | 1.58 | 46.1 | - | - | | 25.4 | 156 | -- | -- | 5.01[B] | -- | 16.58[B] | 423[C] |
| Aroclor 1242 | NC | NC | NC | NC | NC | -- | 156 | 13% | ND | 51 | ND | 280 | 1,520 |
| Aroclor 1248 | NC | NC | NC | NC | NC | -- | 156 | 8% | ND | 35 | ND | 239 | 1,200 |
| Aroclor 1254 | NC | NC | NC | NC | NC | -- | 156 | 4% | ND | 6.13 | ND | ND | 221 |
| Total PCBs | 22.7 | 180 | - | - | NC | 726.8 | 156 | -- | 40[A] | 169.95*[B] | 64[A] | 682.25[B] | 1,520*[C] |
| TCDD TEQ (pptr) | NC | NC | NC | NC | 0.0002 | -- | 17 | 100% | 0.069[A] | 11.84[C] | 0.89[A] | 54.2[C] | 94.67[C] |

**Notes**: µg/gOC = micrograms per gram of organic carbon; µg/kg = micrograms per kilogram; NC = no criteria; ND = not detected; BA = Benthic Aquatic; WA = Wildlife Accumulation; -- = not available; - ERM/ ERL applies.

**Sources:**

1 NYSDEC1999

2 Llanso et al. 2003

* The sum of PCBs is multiplied by two to determine the total PCB concentration (NYSDEC 2004).

A Concentration falls within Class A - no appreciable contamination/no toxicity to aquatic life (NYSDEC 2004).

B Concentration falls within Class B - moderate contamination/chronic toxicity to aquatic life (NYSDEC 2004).

C Concentration falls within Class C - high contamination/acute toxicity to aquatic life (NYSDEC 2004).

### 2.3.1.2. Aquatic Habitat

The Hudson River bridge construction study area encompasses intertidal and subtidal habitats of varying depths, ranging from shallow intertidal shorelines to shallow subtidal shoals and deeper channel habitats. There are no vegetated tidal wetlands present within the study area. The NYSDEC has mapped areas south of the existing bridge as littoral zone tidal wetlands (i.e., depths of no more than 6 feet at mean low water (MLW)). No NYSDEC tidal wetlands are mapped north of the bridge.

On the west side of the river, the shoreline typically consists of unvegetated intertidal beaches composed of coarse sand with scattered boulders. Immediately north of the bridge the shoreline is bulkheaded. Shallow water environments occur near the shorelines and along the western and eastern causeways, while deep water habitat occurs within and near the shipping channel and the main bridge span. Shallows attract aquatic organisms that prefer greater sunlight and less water depth for part or all of their life cycles, while deeper water areas attract organisms with deeper water column needs. The region under the existing bridge attracts certain organisms that use the pier structures as habitat, or that seek the organisms that adhere to the structures as food resources.

### 2.3.1.3. Aquatic Biota

The tidal action of the Hudson River, currents, and the seasonal variation in the amount of freshwater contributed to it by precipitation and runoff, make it a highly dynamic and unstable system. As a result, the ecosystem is typically dominated by a few well adapted species. The Tappan Zee section of the Hudson River is the major site of river water mixing with ocean water in the Lower Hudson River Estuary. This productive estuary area is a regionally significant nursery and wintering habitat for a number of anadromous, estuarine, and marine fish species, including the striped bass. It is also a migratory and feeding area for birds and fish that feed on the abundant fish and benthic invertebrate resources in this area. In 1992, the Habitat Work Group of the New York-New Jersey Harbor Estuary Program, administered by USEPA, requested that USFWS identify significant coastal habitats warranting special protection (USFWS 2011).

#### *2.3.1.3.1. Phytoplankton*

Diatoms are generally the most widely represented class of phytoplankton, accounting for 78 percent of the different taxa collected, with green algae (15 percent), blue-green algae (cyanobacteria) (3 percent), golden algae (Chrysophyceae) (2.5 percent), dinoflagellates (1 percent), and Cryptophyceae (a type of flagellate algae) (0.6 percent) comprising the remainder of the phytoplankton community. High turbidity and rapid mixing of the Hudson River (which lower light availability) limit primary production by phytoplankton (Smith et al. 1998).

#### *2.3.1.3.2. Submerged Aquatic Vegetation and Benthic Algae*

Submerged aquatic vegetation (SAV) are rooted aquatic plants that are often found in shallow areas of estuaries, at water depths of up to six feet at low water (New York's Sea Grant Extension Program undated). These communities exhibit high rates of primary productivity and are known to support abundant and diverse epifaunal and benthic communities. These organisms are important because they provide nursery and refuge habitat for fish. Light penetration, turbidity and nutrient concentrations are all important factors in determining SAV and benthic algae productivity and biomass.

NYSDEC has mapped the distribution of SAV in the Hudson River from Hastings-on-Hudson to Troy using 1997, 2002, and 2007 data. No SAV is mapped in the vicinity of the Replacement Bridge Alternative (see **Figure 15**), although SAV is mapped within the ½-mile study area on either side of the Replacement Bridge Alternative. SAV surveys were conducted as part of the project in 2009 to confirm the locations of SAV identified on the NYSDEC maps. The dominant species of SAV collected as part of the surveys is the native water celery (*Vallisneria americana*); two other species were collected in the vicinity of the project area, including Eurasian water-milfoil (*Myriophyllum spicatum*) and sago palmweed (*Potamogeton pectinatus*). SAV beds were found along the western bank of the river; on the east bank, SAV was only found north of the bridge.

#### *2.3.1.3.3. Zooplankton*

Zooplankton are an integral component of aquatic food webs—they are primary grazers on phytoplankton and detritus material, and are themselves used by organisms of higher trophic levels as food. Copepods, cladocerans, and rotifers are the primary representatives of zooplankton species in the Hudson River. Zooplankton also include life stages of other organisms such as fish eggs and larvae (i.e., ichthyoplankton) that spend only part of their life cycle as plankton. Analysis of long-term data from the Hudson River Utilities Long River Sampling Monitoring Program indicates larval Atlantic tomcod (*Microgadus tomcod*), bay anchovy (*Anchoa mitchilli*), striped bass, and white perch (*Morone americana*) as the dominant ichthyoplankton species. The higher-level consumers of zooplankton typically include forage fish, such as bay anchovy, as well as commercially and recreationally important species, such as striped bass and white perch during their early life stages.

#### *2.3.1.3.4. Benthic Invertebrates*

Versar (Llanso et al. 2003) collected benthic samples from the lower Hudson River estuary (river miles (RM11 to 40) in 2000 and 2001 which included the vicinity of the study area. In general, they found greatest numbers of species per sample in the lower portions of the study area (south of the Tappan Zee Bridge) and lowest numbers north of the bridge. Greatest benthic biomass occurred in shallow regions of Croton Bay and north of Piermont Pier on the western side of the river. Taxa which showed the greatest densities included the oligochaete worm *Tubificoides* spp., the clam *Rangia cuneata*, and the amphipod *Leptocheirus plumulosus*. They also found the barnacle *Balanus improvisus* and the pollution tolerant polychaete worms *Marenzelleria viridis* and *Heteromastus filiformis* to be present in relatively high abundances.

Bimonthly sampling of benthic resources in the study area for the project was conducted between March 2007 and January 2008. Samples were taken in the vicinity of the existing bridge and the footprint of the Replacement Bridge Alternative. A total of 48 species were collected during the benthic sampling program. Generally, the species richness and numbers of individuals were lower in late winter and early spring and higher in the summer and fall. Species diversity, while relatively constant throughout the year, was observed to be highest in July and lowest in January. The barnacle *Balanus* spp. and the amphipod *Leptocheirus plumulosus* were two of the dominant taxa collected in each of the six sampled months.

Benthic invertebrate sampling of the existing bridge piers conducted for the project in 2007 identified a total of 8 taxa and 2 taxa of benthic algae. The polychaete worm *Nereis* spp., amphipods, barnacles, grass shrimp, mud crabs, isopods, oysters, and ribbed mussels were collected from the piers, as well as red and green algae. These organisms were collected in similar densities on three types of pier structure, namely, steel, concrete and timber.

Surveys (side-scan sonar and seismic profiling combined with grab samples) identified seven potential oyster (*Crassostrea virginica*) beds south of the bridge and six potential beds to the north. All identified oyster beds except one were confirmed to contain at least some live organisms with beds exhibiting differences in terms of oyster density, amount of shell hash, gravel, or sandstone fragments, etc.

##### *2.3.1.3.5. Fishes*

The Hudson River estuary's fish community is species-rich. The estuary's species diversity is enhanced by its mid-latitude location on the Atlantic Coast. Southern tropical marine forms enter the Hudson River during the summer, and a number of northern fishes are near their southern limit. The Hudson River fish community, particularly in the estuarine reach, is a mixture of both temperate and tropical marine forms, freshwater forms, and intentional and accidental introductions (ASA 2006). Despite the large number of species that are occasionally found in the estuary, the majority of the fish represent only a limited number of species. More than 99 percent of the total fish community comprises only 10 to 15 percent of the species. In stable ecosystems, low species diversity may be an indicator of environmental stress. However, in highly dynamic and unstable ecosystems such as the Hudson River estuary, the biological community may be dominated by only a few species that are well adapted to such naturally dynamic conditions (ASA 2006).

Each of the fish species that occurs in the River can be classified by its salinity tolerance. Marine species live in the open Atlantic Ocean and nearshore waters and venture into the estuary during the warmer months of the year when salinity is relatively high. These species typically occupy the lower reaches of the estuary. Estuarine species occupy a large portion of the brackish estuary year-round and may be occasionally found in freshwater and marine reaches. Freshwater species live in the Hudson River and rarely, if ever, venture into low-salinity areas of the estuary such as the region in the vicinity of the Tappan Zee Bridge. Several fish species that occur in the Hudson River migrate from the Atlantic Ocean into freshwater habitats of the River, typically for spawning (anadromous), or leave the river to spawn in the open ocean (catadromous).

The dominant marine species in the Tappan Zee region is the bay anchovy. An analysis of the Fall Shoals data from 1998-2007 indicated that numerically, bay anchovy comprised about 82 percent of the total fish standing stock. Bay anchovy are found in salinities ranging from fresh to seawater and may be the most abundant species in the western north Atlantic (Newberger and Houde 1995). Other marine species which were at times abundant in the Utilities sampling program included weakfish (*Cynoscion regalis*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic croaker (*Micropogonias undulatus*), butterfish (*Peprillus triacanthus*) and bluefish (*Pomatomis saltatrix*).

Estuarine species are generally euryhaline (i.e. tolerant of wide salinity ranges), and are year-round residents of the saline portions of the Hudson River. Abundant estuarine species collected by the utilities' monitoring program included white perch, banded killifish (*Fundulus diaphanus*), Atlantic silverside (*Menidia menidia*), and hogchoker (*Trinectes maculatus*).

Anadromous species that use the estuary as spawning and nursery grounds include alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), shortnose sturgeon, Atlantic sturgeon, Atlantic tomcod, blueback herring (*Alosa aestivalis*), and striped bass. Adults typically enter the estuary in the spring and migrate upstream to low-salinity brackish and freshwater areas to spawn. The young fish then use the near-shore shoal areas for food and habitat as they make their way downstream, and generally leave the estuary in the fall. American eel (*Anguilla rostrata*) is the only catadromous species that occur in the Hudson. Although the Utilities data indicate that there are wide variations in the annual totals of collected eels, overall there has been a sharp decline in the number of individuals captured during these surveys since the mid 1980s.- The U.S. Fish and Wildlife Service and NMFS are currently reviewing the status of American eel to determine whether it should be proposed for listing as a protected species.

A number of changes in abundance trends within the Hudson River fish community have occurred in recent years. Heimbuch (2008) reported that average biomass of age 1 and older striped bass has increased over fivefold during the periods 1981–1990 and 1991–2005. This increase has been accompanied by declines in the populations of blueback herring, alewife, white perch, and Atlantic tomcod. Blueback herring and alewife have also been designated as candidate species under the ESA on November 2, 2011 due to population declines. It has been postulated that the increase in the predatory demand of striped bass could have been responsible for the decline of these other species (Heimbuch 2008). These five species comprised 85 percent of the catch of estuarine and diadromous species collected by beach seines from 1980 through 2000 (Hurst et al. 2004). Also, a stock assessment performed on American shad in 2007 indicated that the spawning stock, including the Hudson River population, has substantially declined (ASMFC 2007). Since March 2010 recreational and commercial fishing for American shad has been prohibited. This can be contrasted with the ASMFC's assessment of bluefish which considered the coastal stock to be rebuilt and not overfished (ASMFC 2009a).

A year-long fish survey was conducted for the project between April 2007 and May 2008 to further characterize the fish community within the study area and examine seasonal differences in abundance. These surveys combined hydroacoustics, gill nets, and trap nets to characterize the species composition, relative abundances, and distributions of fish populations within the project area.

Results of the hydroacoustic surveys indicate that the horizontal, vertical, and geographical distribution of fishes within the Tappan Zee region and in the project area, in particular, is substantially influenced by temperature and salinity. In the colder months of the year (December through April), the fish populations are concentrated in deeper waters with higher salinities. In the late winter and early spring, a distinct halocline (i.e., salinity gradient) was observed at a depth of approximately 19.7 feet (6 meters), below which fish densities increased. As the water temperature increased during late spring, the halocline dissipated and the salinity in the project area increased in the shallower depths. Also observed was a marked increase in the abundance of fishes at those depths, although the greatest abundances continued to occur in the deepest portion of the channel. In the warmer summer months of the year, early life stages of many species were present within the study area. Presumably these concentrations are salinity driven. A large percentage of the individuals that were captured were members of schooling species.

A total of 25 species (see **Table 4**) and just over 2,000 individual fishes and hundreds of blue crabs were collected during approximately 700 hours of gill-net sampling conducted for the project within the study area between April 2007 and May 2008. Fish were caught throughout the year at all of the sampling locations within the study area. However the total number of fish caught in the colder months was markedly lower than during the warmer months. Moreover, there were higher numbers of fish caught at the sampling locations with greater water depths. Anadromous and estuarine fishes were captured in every sampling event. Marine fishes were only captured in the warmer months of the year.

**Table 4**
**List of Fish Species Occurring within the Project Area**
**Based on Gill-net Sampling, 2007-2008**

| Common name | Scientific name | Assemblage |
|---|---|---|
| Alewife | *Alosa pseudoharengus* | Anadromous |
| American eel* | *Anguilla rostrata* | Catadromous |
| American shad | *Alosa sapidissima* | Anadromous |
| **Atlantic butterfish** | ***Peprilus triacanthus*** | **Marine** |
| Atlantic menhaden | *Brevoortia tyrannus* | Marine |
| Atlantic tomcod | *Microgadus tomcod* | Estuarine |
| **Bluefish** | ***Pomatomus saltatrix*** | **Marine** |
| Blueback herring | *Alosa aestivalis* | Anadromous |
| Blue runner | *Caranx crysos* | Marine |
| Common carp | *Cyprinus carpio* | Freshwater |
| Gizzard shad | *Dorosoma cepedianum* | Freshwater |
| Hickory shad | *Alosa mediocris* | Marine |
| Hogchoker | *Trinectes maculatus* | Estuarine |
| Naked goby* | *Gobiosoma bosci* | Estuarine/Marine |
| Northern kingfish | *Menticirrhus saxatilis* | Estuarine/Marine |
| Northern sea robin | *Prionotus carolinus* | Marine |
| Oyster toad fish* | *Opsanus tau* | Estuarine/Marine |
| Porgy | Family Sparidae | Marine |
| Shortnose sturgeon | *Acipenser brevirostrum* | Anadromous |
| Spot | *Leiostomus xanthurus* | Estuarine/Marine |
| Striped bass | *Morone saxatilis* | Anadromous |
| **Summer flounder** | ***Paralichthys dentatus*** | **Estuarine/Marine** |
| Weakfish | *Cynoscion regalis* | Estuarine |
| White catfish | *Ameiurus catus* | Freshwater |
| White perch | *Morone americana* | Estuarine |

**Note:**
* Species only captured in fish traps.
Species in Bold are Essential Fish Habitat Designated Species for Hudson River

### 2.3.2 THE HARS

The HARS (see **Figure 8**) is jointly managed by the U.S. Army Corps of Engineers (USACE) New York District and the U.S. Environmental Protection Agency (USEPA) Region 2 in accordance with the *Site Management and Monitoring Plan for the Historic Area Remediation Site* revised May 5, 2009 (SMMP)(USACE and USEPA 2009).

The SMMP:

- provides guidelines to document remediation of required areas within the HARS resulting from placement of an approximately 3-foot (1 meter) minimum required cap thickness of Remediation Material;
- specifies the collection of data to ensure that no significant adverse environmental impacts occur from the placement of Remediation Material at the HARS;
- enforces compliance with Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA) permit conditions;
- provides a baseline assessment of conditions at the HARS;
- provides a program for monitoring the HARS;
- describes special management conditions/practices to be implemented at the HARS;
- specifies the quantity of Remediation Material to be placed at the HARS and the presence, nature, and bioavailability of the contaminants in Remediation Material;
- specifies the anticipated use of the HARS, including the closure date; and
- provides a schedule for review and revision of the HARS SMMP.

Under MPRSA, the USACE and USEPA share responsibility for permitting and HARS designation and management. Placement of dredged material as Remediation Material at the HARS requires a permit from USACE under Section 103 of the MRPSA, subject to USEPA review and concurrence that the material meets applicable ocean disposal criteria. Placement of non-dredged material as Remediation Material at the HARS requires a permit from the USEPA under Section 102 of the MPRSA. To receive the permit, the materials must be suitable for remediation, in that they meet certain criteria related to contaminants based on sediment toxicity and bioaccumulation tests. In addition, in accordance with 40 CFR §227.16, the USEPA must evaluate alternative disposal options before permitting placement of dredged material at the HARS, and must find that there are no practicable alternative locations and methods of disposal or recycling available. In support of this required finding, and alternatives analysis can be found in Appendix H-5 to the Draft Environmental Impact Statement documenting that there are no practicable alternative locations for the placement of the dredged material at the HARS site.

The HARS comprises about 20 square miles (15.7 square nautical miles) within the apex of the New York Bight[1] that includes the approximately 3-square-mile (2.2-square nautical mile) Mud

[1] The New York Bight is a region defined as ranging from Cape Cod, MA, to Cape May, NJ, and includes Buzzard's Bay, Long Island Sound, New York Harbor and the New Jersey shore (http://web2.uconn.edu/seagrantnybight/).

Dump Site (MDS). The HARS is located on the shallow continental shelf within the New York Bight. Water depths at the HARS range from 46 to 138 feet. Over the past century, dredged material from the Port of New York and New Jersey was routinely disposed of at the MDS. The USEPA formally designated the MDS as an “interim” ocean dredged material disposal site in 1973, and gave it final designation in 1984. On September 29, 1997, the USEPA under 40 CFR §228, closed MDS and simultaneously re-designated the site and surrounding areas that were used historically as disposal sites for contaminated dredged material as the HARS, and proposed that the site be managed to reduce impacts to acceptable levels (in accordance with 40 CFR §228.1(c)) (62 FR 46142) through remediation with uncontaminated dredged material (Remediation Material)(i.e., dredged material that meets current Category I standards[1] and will not cause significant undesirable effects, including through bioaccumulation)(USACE and USEPA 2009). USEPA published final rule 67 FR 62659 on March 17, 2003, to modify the designation of the HARS to establish a HARS-specific worm tissue polychlorinated biphenyl (PCB) criterion of 113 parts per billion (ppb) for use in determining the suitability of proposed dredged material for use as Remediation Material. This amendment to the HARS designation established a pass/fail criterion for evaluating PCBs in worm tissue from bioaccumulation tests performed on dredged material proposed for use at the HARS as Remediation Material (USACE and USEPA 2009).

The HARS comprises three areas (see **Figure 16**): Priority Remediation Area (PRA), a 12 square-mile (9 square nautical miles) area to be remediated with at least about 3 feet (1 meter) of Remediation Material which is divided into 9 areas; a Buffer Zone, a 0.3-mile-wide (0.27 nautical miles) band around the PRA in which no placement of Remediation Material will be allowed, but may receive Remediation Material that incidentally spreads out of the PRA; and No Discharge Zone, an approximately 1.3-square-mile (1 square nautical mile) area in which no placement or incidental spread of Remediation material is allowed. From 1997 through December 2008, approximately 36 million cubic yards (MCY) of Remediation Material from 61 dredging projects have been placed at the HARS as part of the remediation. These remediation projects have included private and Federal maintenance dredging and deepening projects, with the majority of the Remediation Material (approximately 26 MCY) from Federal Deepening projects. Of the nine PRAs at the HARS, only the western PRAS (PRAS 1 through 4) have been remediated. As of 2008, about 13 percent, 17 percent, 64 percent, and 86 percent of the area in PRAs 1, 2, 3, and 4, respectively, and PRAs 5 through 9 are available for Remediation Material.

---

[1] USEPA Region 2 and USACE New York District classify dredged material into three categories on the basis of sediment toxicity and bioaccumulation tests:

- Category I: Sediments that meet ocean disposal criteria. Test results indicate no unacceptable toxicity or bioaccumulation. These sediments are acceptable for “unrestricted” ocean disposal. There are no potential short-term (acute) impacts or long-term (chronic) impacts; no special precautionary measures are required during disposal.

-Category II: Sediments that meet ocean disposal criteria. Test results indicate no significant toxicity but a potential for bioaccumulation. To protect from this potential, EPA and the USACE will require appropriate management practices such as capping. This is referred to as “restricted” ocean disposal.

-Category III: Sediments that do not meet ocean disposal criteria. These sediments are those that fail acute toxicity testing or pose a threat of significant bioaccumulation that cannot be addressed through available disposal management practices. These sediments cannot be disposed in the ocean.

Circulation in the New York Bight is complex with temporal and regional variability. Low frequency meteorological forcing, over 3 to 10 day periods, is responsible for much of the current fluctuations over the shelf. During spring and summer the wind energy is reduced and the water column is stratified. The magnitude of the currents increases with the distance offshore and decreases with depth (Beardsely and Boicourt 1981 in USACE 2002). Circulation in the Bight is dominated by a relatively slow flow to the southwest (0.1 feet per second (fps)) with an occasional clockwise bottom gyre. The southerly flow of the Hudson River plume along the New Jersey shoreline forces an opposing northward flow of more saline waters to the east (USEPA 1982 in USACE and USEPA 2009). Near bottom oscillatory tidal currents at the HARS are relatively weak, with maximum speeds of 0.3 fps. Mean currents are also less than 0.3 fps with directions that are dependent upon location, water depth and bottom topography (SAIC 1994b in USACE and USEPA 2009). Surface waves are generally less than about 7 feet in height except during major storms which are most common in the fall and winter (SAIC 1995c in USACE and USEPA 2009). Wave-induced near-bottom currents are greater than 0.7 fps only when surface wave heights are greater than 10 feet and storm centers are to the east or southeast. These wave conditions would occur less than 3 percent of the time in fall and winter, and less than 1 percent of the time in spring and summer (SAIC 1994a in USACE and USEPA 2009).

#### 2.3.2.1. Water Quality

##### *2.3.2.1.1. Salinity*

Salinities at the HARS are significantly greater than those at the bridge-construction site. Maximum salinities (33 to 34 parts per thousand [ppt]) occur inshore during the winter (February and March) when sub-freezing conditions reduce river runoff. Surface salinity, particularly near shore decreases with spring thaw and strong vertical gradients may develop. In summer, surface salinities are at the annual minimum (27 to 31 ppt) with bottom salinities of 27 to 29 ppt (USEPA 1982 in USACE and USEPA 2009).

##### *2.3.2.1.2. Temperature*

During the winter months, water temperatures are relatively uniform within the HARS (USACE 2002). During spring and summer months, waters at the HARS become thermally stratified with warmer waters at the surface and cooler waters at the bottom. The thermocline dissipates in the fall as bottom waters begin to warm. Thermal stratification acts to contain bottom sediments and prevent re-suspension.

##### *2.3.2.1.3. Suspended Solids*

Turbidity at the HARS is low through the water column with a small mid-depth maximum in the central portion of the HARS. The effects of dredged material placement on water quality of the New York Bight have been observed to be minimal, with contaminant concentrations in disposal plumes at the MDS dissipating quickly (less than one hour) to background levels. While plume behavior varies with the grain size of the dredged material, total suspended solids near the center of the dredged material placement plume body have been observed to reach near background levels in 35 to 45 minutes (Battele 1994 in USACE and USEPA 2009). Dissolved oxygen concentrations are consistently above 2.0 milligrams per liter (USACE 2002).

*2.3.2.1.4. Sediment Characteristics*

Use of the New York Bight Apex as a disposal area over the past 100 years has influenced sediment characteristics within the HARS (USACE 2009). The HARS is dominated by mounded dredged material that rises up to 40 feet from the historic sea floor in some areas (USEPA 1997 in USACE 2002). Surface sediments are heterogeneous, ranging from areas dominated by muddy (fine-grained) sediments to areas covered with coarse sediments (primarily sand) at the former cellar dirt site (USACE 2002). Toxicity testing of the sediments at HARS using amphipods found a wide range of survival percentage (Battele 1996 in USACE 2002). Sediments exhibiting significant toxicity were generally located across the middle of the HARS (USACE 2002).

#### 2.3.2.2. Aquatic Habitat

The study area encompasses offshore habitats at depths ranging from 46 to 138 feet. The bathymetry of the HARS site is characterized by large mounds of deposited dredge material composed of a range of sediment grain sizes from fine silt and clay to coarse sand and gravel as high as 40 feet.

#### 2.3.2.3. Aquatic Biota

Within the HARS, sampling of benthic invertebrates indicated the majority of the species to be annelids (61 percent, including *Prionospio steenstrupi*, a surface deposit feeder, *Polygordius*, and *Pherusa*, a surface-deposit feeder) followed by crustaceans (17 percent) and mollusks (11 percent) (USACE and USEPA 2009).

The New York Bight Apex of the Atlantic Ocean is a transitional region for many species of fish and shellfish. Finfish known to occur in the region include:

- Demersal species—silver hake, red hake, yellowtail flounder, scup, summer flounder, winter flounder, tautog, cod, black sea bass, little skate, windowpane flounder, four spot flounder, ocean pout, cunner, spiny dogfish, spotted hake, northern sea robin, gulf stream flounder, sea raven and longhorn sculpin.
- Pelagic species—butterfish, Atlantic herring, bluefish, and weakfish.
- Pelagic/Anadromous—American shad, alewife and striped bass (USACE and USEPA 2009).

Shellfish include surf clam, sea scallop, American lobster, long-finned squid, rock crab, horseshoe crab, short-finned squid, and Jonah crab (USACE and USEPA 2009).

## 2.4 DESCRIPTION OF CONSTRUCTION ACTIVITIES

### 2.4.1 SCHEDULE

Construction of the Short Span Option would take approximately 5½ years. Throughout the construction period roadway work would be required at various times. During that time, the approach roadways would be shifted and remain in the new location for an extended period before being shifted again. The dredging (see **Figure 17**) would occur in three 3-month phases from August 1 through November 1 over a 4-year period, and construction of the main span would consist of approximately 3½ years of construction. Completion of the short span approaches would involve approximately 3½ to 4 years of construction. Demolition of the existing Tappan Zee Bridge would be expected to span approximately 1 year.

Construction of the Long Span Option would last approximately 4½ years. The construction sequence and schedule would be similar to that of the Short-Span Option with the exception of the construction of the approaches, which would be expected to take approximately 2½ to 3 years.

### 2.4.2 BRIDGE ELEMENTS

#### 2.4.2.1. Landings

Landings would employ typical highway construction techniques and would be completed on both the Westchester and Rockland sides of the Hudson River upland from the bridge abutment to the tie in with the existing roadway. Construction of the landings would occur throughout the duration of the construction. The alterations to the landings would consist of changes in roadway grade, elevation, direction, and general configuration.

#### 2.4.2.2. Approaches

Beginning at the abutments, the approaches carry traffic from the land to the main span of the bridge. Construction of the approaches would last for approximately three and a half to four years for the short-span alternative, and two and a half to three years for the long-span alternative. The piles, pile caps, piers, and deck that compose this segment of the bridge would be built sequentially so that as a new pile is being constructed, a completed pile would be undergoing further transformation with, for example, the addition of a pile cap.

#### 2.4.2.3. Main Span

The main span would stretch between the Westchester and Rockland approaches. It is the segment of the bridge that would be defined largely by its superstructure design as an arch or cable stayed bridge. Within its substructure, the piers would be more substantial than those of the approaches. All main span work would be done sequentially and in a similar manner as that of the approaches. The piles, pile caps, pylons, and deck construction would last approximately three and a half years.

### 2.4.3 CONSTRUCTION OF KEY ELEMENTS

Construction of either option of the Replacement Bridge Alternative would require a wide range of activities on both sides of the river as well as from within the waterway itself. In addition, due to the lack of available land along the waterfront in the vicinity of the bridge, staging areas at some distance from the construction site would be required. Furthermore, it is likely that some bridge components would be pre-fabricated well outside the study area and transported to the site via barge.

To support construction of the main span and bridge approaches, materials, equipment, and crews would be transported from upland staging areas in Westchester and Rockland counties (see **Figure 18**) to temporary platforms that would be constructed on the shoreline of the river within the Bridge Landing Areas (see **Figures 19 and 20**). Dredged channels (see **Figure 17**) would provide access to the two work areas in the shallow portion of the river crossing: the Rockland and Westchester approaches. Substructure construction would establish the foundation of the bridge through the processes of pile driving, construction of pile caps, and construction of columns. Superstructure construction would then take place either with a gantry that would move from pier to pier lifting segments from barges below (as in the case of the short-span design option) or a short pier-head truss segment would be lifted atop the next open pier column and secured (as in the case of the long-span option). The following sections describe the construction activities with the potential to affect EFH within the study area.

#### 2.4.3.1. Waterfront Construction Staging

The shoreline areas near the proposed bridge site are limited by adjacent development. In order to provide space for the docking of vessels, the transfer of materials and personnel, and the preparation of construction elements, temporary platforms (approximately 9 acres) would be extended out from the shoreline over the Hudson River (see **Figures 19 and 20**). The —1.35 acre permanent portion of the Rockland platform would also enable the continued maintenance of the original Tappan Zee Bridge while the Replacement Bridge Alternative is being constructed, as well as provide continued support for the New York State Thruway Authority (NYSTA) Dockside Maintenance facility operation. Steel piles would be driven to support the platforms. These platforms would provide access to the Replacement Bridge site via temporary trestles. Their main purposes would be to facilitate delivery of heavy duty bridge elements from an offsite fabrication facility, receive deliveries from the concrete batch plant, receive deliveries (i.e., construction equipment and light duty bridge elements) from the staging areas, and allow for barge-mounted cranes to erect heavy duty bridge elements. Upon completion of construction, the temporary platforms and the piles that support them would be removed. The permanent platform which would also be constructed on piles within the Rockland Bridge Staging Area would remain.

As the construction of the temporary platforms and access trestles would begin at the shoreline, an access road and work area near the shore would also be constructed. A channel would be dredged specifically to provide barge access to the temporary platforms from in-river work sites.

#### 2.4.3.2. Dredged Access Channel

Since the proposed bridge alignment spans extensive shallows, it would be necessary to dredge an access channel for tugboats and barges to use during construction of the approach spans. These vessels would be used for the installation of cofferdams, pile driving, the construction of pile caps and bridge piers, and the erection of bridge decks and other superstructure components. As noted earlier, temporary, trestle-type access platforms would be constructed near the shoreline to provide access for construction vehicles that would operate on the trestles. With the installation of the temporary platforms, dredging of the near-shoreline area would be avoided.

Two alternate construction methods were evaluated in an effort to avoid the need to dredge an access channel. One method involved the use of overhead gantries for the construction of foundations and the other consisted of the implementation of a full-length temporary trestle for access. Both of these alternatives were found to be impractical: the former because it is not practicable for the heavy-duty pile-driving requirements of the replacement bridge and the latter because the deep soft soils in the shallow waters of the construction zone would require foundations that would be expensive and time-consuming to construct.

As shown in **Figure 17**, dredging would be conducted in three stages over a 4-year period for a duration of three months each year from August 1 to November 1, a dredging period selected to minimize impacts to aquatic resources. The purpose of the first two dredging stages (Years 1 and 2) would be to provide access for bridge construction, while the final dredging stage (Year 4) would provide access for demolition of portions of the existing bridge allowing completion of the remaining portions of the new structure. Each of these three-month spans would occur during the August 1 to November 1 window. All dredging would be done using environmental bucket with no barge overflow, and no double handling of dredged material.

Based on an analysis of the types, number, size and operation of vessels that would operate in the access channel during construction, it was determined that a clear draft of 14 feet at MLLW would be required within the access channel. To avoid the potential for grounding of vessels, an additional two feet would be added to provide a working channel depth of 16 feet at MLLW.

The likelihood of resuspending fine sediment material due to movement of vessels, particularly tugboats, within the dredged channel will be further minimized by placing a layer of sand and gravel (referred to as “armor”) at the bottom of the channel following dredging. The sediments in the vicinity of the area to be dredged are highly susceptible to resuspension into the water column. Without “armoring,” prop scour from working tugboats in the channel would result in the generation of suspended sediment at rates several orders of magnitude greater than what would occur from the dredging operation itself. Therefore, it was concluded that this level of sediment resuspension and ultimate transport into the river would pose an unnecessary and potentially substantial adverse effect to the marine environment.

The installation of the sand and gravel would take place as soon as the dredging for that section of the channel was completed, forming a protective layer to keep sediment from further disturbance. Without this protective layer, additional dredging would be required to create a deeper work zone. The stone or gravel materials used for the armoring would be delivered by barges or scows, and would be placed within the channel in a manner that minimizes resuspension of bottom material during placement. The materials would not be removed after the project completion, since they would become fully buried by the gradual deposition of river sediments over time. The dredging depth required assumes that two feet of stone or gravel armor is placed on the bottom. In total, the channel would be dredged to a depth corresponding to 16 feet below MLLW.

**Table 5** shows the amount of material to be dredged during each stage for the two bridge design options. For either design option, the channel width would measure approximately 475 to 530 feet, and it would extend approximately 7,000 feet from the Rockland County side into deeper waters and 2,000 feet from the Tarrytown temporary platform into deeper waters. Because the long span alternative would occupy a wider footprint, a slightly larger area must be dredged for that alternative. It is estimated that approximately 1.68 and 1.74 million cubic yards of sediment would be dredged for the short and long span options, respectively.

Environmental Performance Commitments (EPCs) to be implemented during dredging operations include:

- adherence to a 3-month fall window of August 1 to November 1 when dredging would be allowed;

- use of an environmental bucket with no barge overflow and no double handling of dredged material
- armoring of the channel to prevent re-suspension of sediment during the movement of construction vessels, installation and removal of cofferdams, and pile driving.
- in-water suspended sediment/turbidity monitoring in accordance with NYSDEC-determined requirements.

**Table 5**
**Dredging Quantities for the Replacement Bridge Alternatives**

| Construction Stage | Short Span | | Long Span | |
|---|---|---|---|---|
| | Quantity (million CY) | Percent of Total | Quantity (million CY) | Percent of Total |
| Stage 1 | 1.08 | 64% | 1.12 | 64% |
| Stage 2 | 0.42 | 25% | 0.43 | 25% |
| Stage 3 | 0.18 | 11% | 0.19 | 11% |
| Total | 1.68 | 100% | 1.74 | 100% |

**Notes:**
CY = cubic yards
Dredging for bridge demolition (Stage 3) includes that portion of the bridge which must be removed to complete the Replacement Bridge Alternative tie-in.

### 2.4.3.3. Transport and Disposal of Dredged Material

During each three-month period when dredging is occurring, dredged materials would be collected from the bottom of the river by barge-mounted cranes with an environmental bucket and placed into hopper scows, which are boats with a capacity of approximately 2,500 cubic yards. To ensure that the scows do not exceed the maximum allowable draft of the river work zone, they would be limited to 80 percent of their maximum load, or 2,000 cubic yards per load.

Each dredging stage would occur during a 90-day period. During that period, it is estimated that dredging would occur up to 75 of the 90 days, with two dredge operations occurring at a time. During the most extensive dredging stage, Stage 1, up to approximately 15,000 cubic yards of materials would be dredged each day. **Table 6** presents the estimated daily volumes of materials removed for each dredging stage for the two replacement bridge alternatives.

Certain activities related to project construction are left to the discretion of the contractor. One of these specific activities would be the ultimate transport and disposal of dredged materials from construction of the access channel. Transport by ocean scow and placement in the HARS in the New York Bight would offer a number of benefits to the project including cost, schedule, logistics and the avoidance of impacts to the surrounding residential communities on the Rockland and/or Westchester shorelines.

**Table 6**
**Daily Materials Removal by Construction Stage**

| Construction Stage | Short Span Daily Volume (cubic yards/day) | Long Span Daily Volume (cubic yards/day) |
|---|---|---|
| Stage 1 | 14,600 | 15,000 |
| Stage 2 | 5,700 | 5,800 |
| Stage 3 | 2,400 | 2,600 |

In this option, the dredged materials would be placed in shallow draft dredge scows and transferred to the ocean scows in the deeper water adjacent to the navigation channel with a large barge-mounted excavator positioned between the two scows. Silt curtains would be set up around the three barges to minimize dispersion of suspended sediment. In order to increase the economic loading[1] the contractor may elect to allow the dredged material to settle in the shallow scows before transferring the material to the ocean scow. The water from the dredge scow would be decanted to a second tank or scow to settle out the suspended sediments before being discharged back to the Hudson River. Monitoring of decant water would be conducted in accordance with the requirements established by the NYSDEC on the basis of the toxicity and bioaccumulation test results submitted to demonstrate suitability of the dredged material for placement at the HARS.

Following decanting, the dredged material would be transferred from the dredge scow to the ocean scow. Measures would be implemented during this transfer process to minimize loss of dredged material to the Hudson River and associated increases in suspended sediment (e.g., turbidity curtains).

The deeper draft ocean scows (vessels with a larger draft, typically up to 18 feet, and a larger capacity [up to 4,500 cubic yards] that are too deep for the construction channel) would then transport the material to the HARS, located about 4 miles east of Sandy Hook, NJ., where materials would be placed at the site in accordance with the permit conditions for that placement. An assessment of potential effects from the placement of dredged material from the project at the HARS is presented in Chapter 7 of this EFH. The HARS is overseen by the U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (USEPA). This site was historically used for ocean disposal of dredged material and a variety of waste products, including some contaminated materials. Today, the site is being remediated through a

[1] "Economic load is the load in a dredge hopper or scow that corresponds to the minimum unit dredging cost. Economic load is dependent on the material dredged, equipment used, distance to disposal site, and other site-specific factors. Economic load does not necessarily correspond to the maximum load or highest density load that can be obtained." (Palermo, M.R., and R.E. Randall. 1990. *Practices and Problems Associated with Economic Loading and Overflow of Dredge Hoppers and Scows*. Dredging Research Program, Technical Report DRP-90-1. Department of the Army, Environmental Laboratory, Waterways Experiment Station, Vicksburg, Mississippi)

program to cap those historic sediments with cleaner sediments dredged from New York Harbor that meet certain criteria established by the Ocean Dumping Act.

A permit is required for dredged material to be placed at the HARS from the USACE for that placement. To receive the permit, the materials must be suitable for remediation, in that they meet certain criteria related to contaminants based on sediment toxicity and bioaccumulation tests. In addition, in accordance with 40 CFR §227.16, the USEPA must evaluate alternative disposal options before permitting placement of dredged material at the HARS, and must find that there are no practicable alternative locations and methods of disposal or recycling available. In support of this required finding, an alternatives analysis can be found in Appendix F-4 to the Draft Environmental Impact Statement documenting that there are no practicable alternative locations for the placement of the dredged material at the HARS site.

In recognition of the many benefits offered by the HARS site, the project is proceeding with sampling and analysis of the dredged material in support of a permit under Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 from the USACE.

If the permit application for the use of the HARS is denied in whole or part, the contractor would be required to dispose of the dredged material at an approved upland facility in accordance with all applicable laws and regulations. However, due to the estimated number of truck trips that would be required (nearly 800 round trips daily) and the potential for adverse traffic, air quality and noise impacts on the local community the contractor would not be allowed to transport the dredged material by truck from the waterfront staging areas in Rockland or Westchester Counties. The contract documents would specify that alternate means of transport of the dredged material such as barge or barge to rail would be required for disposal.

#### 2.4.3.4. Substructure Construction

Substructure construction would vary as a function of water depth and sediment conditions at each location. Work on the foundations can be categorized into three segments referred to as Zone A, Zone B, and Zone C (see **Figures 5 and 6**). Pile installation would typically be performed one row of piles at a time. The actual pile driving is done one pile at a time. As shown in **Table 7**, a total of 1,326 piles for Piers 1 to 57 would be required for the Short Span Option. **Table 8** includes similar information for the Long Span Option at Piers 1 thru 32. The Long Span Option would require 836 piles. In terms of the largest piles, the number of the 10-foot piles would be the same (50) for either option. The greatest difference between the two options would be the number of smaller 4-foot piles with the Sport Span Option requiring approximately 346 more piles than the Long Span Option. The Long Span Option would also require 104 less 6-foot piles and 40 less 8-foot piles for a total difference of 490 piles. Under either option, the driving of the largest piles (8- and 10-foot) would only occur for a few months in the first year of construction. During April 1 to August 1, driving of 8- or 10-foot diameter piles with an impact hammer would be limited to 5 hours per day within in-water construction Zone C (deeper than 18 feet at MLLW).

**Table 7**
**Pile Driving, Short Span Option**

| Pier No. | Substructure Zone | Pile Size (diameter ft) | No. of Piles Within each Pier | Total No. of Piles |
|---|---|---|---|---|
| 1-3 | A1 | 6 | 4 | 24 |
| 4-8 | B1 | 6 | 6 | 60 |
| 9 - 14 | B1 | 4 | 20 | 240 |
| 15-32 | B1 | 4 | 20 | 720 |
| 33-35 | B1 | 8 | 4 | 24 |
| 36-43 | C | 8 | 4 | 64 |
| 44-45 | C | 10 | 25 | 50 |
| 46-50 | C | 6 | 6 | 60 |
| 51-57 | B2 | 6 | 6 | 84 |
| | | | **Total** | **1,326** |

**Table 8**
**Pile Driving, Long Span Option**

| Pier No. | Substructure Zone | Pile Size (diameter ft) | No. of Piles Within each Pier | Total No. of Piles |
|---|---|---|---|---|
| 1-2 | A1 | 6 | 4 | 16 |
| 3 | A1 | 6 | 6 | 12 |
| 4 | B1 | 6 | 6 | 12 |
| 5-17 | B1 | 4 | 25 | 614 |
| 18-21 | B1 | 8 | 4 | 32 |
| 22-23 | C | 8 | 4 | 16 |
| 24-25 | C | 10 | 25 | 50 |
| 26-28 | C | 6 | 6 | 36 |
| 29-30 | B2 | 6 | 6 | 24 |
| 31-32 | A2 | 6 | 6 | 24 |
| | | | **Total** | **836** |

EPCs to be employed during construction of the substructure include:

- Driving the largest (10 and 8 ft) diameter piles within the first few months of the project thereby limiting the duration of time that piles with the greatest potential impact are utilized.
- Using cofferdams and silt curtains, where feasible, to minimize discharge of sediment into the river.
- Using a vibratory pile driver to the extent feasible (i.e., all piles would be vibrated at least to depth of 120 feet or to vibration refusal) particularly for the initial pile segment.
- Using bubble curtain, cofferdams, isolation casings, Gunderboom, or other technologies to achieve a reduction of at least 10 dB of noise attenuation.

- Using the results of the Hudson River site specific Pile Installation Demonstration Project (PIDP) to inform the project on the effectiveness of BMP technologies for reducing sound levels, and implementing BMPs to achieve maximum sound reduction.
- Limiting the periods of pile driving to no more than 12-hours/day.
- Limiting driving of 8- and 1-foot diameter piles with an impact hammer within Zone C (water depths greater than 18 feet at MLLW) to 5 hours per day during the period of spawning migration for shortnose, Atlantic sturgeon, and other anadromous fish species (April 1 to August 1).
- Maintaining a corridor where the sound level is below the West Coast threshold for onset of physiological effects to fish totaling at least 5000 feet at all times during impact hammer pile driving. This corridor shall be continuous to the maximum extent possible but at no point shall any contributing section be smaller than 1500 feet.
- Pile tapping (i.e., a series of minimal energy strikes) for an initial period to frighten fish from the region of the pile being driven.
- Development of a comprehensive monitoring plan. Elements would include:
  1. Monitoring water quality parameters such as temperature, salinity, and suspended sediment concentrations in the vicinity of the pile driving.
  2. Monitoring fish mortality and inspection of fish for types of injury, as well as a program for determining contaminant levels in dead sturgeon through tissue analysis methods.
  3. Monitoring the rate of recovery of the benthic community within the dredged area and armored bottom and also providing site specific information on sedimentation processes and time of recovery of soft bottom habitat following construction and temporary modification of bottom habitat.
  4. Supporting the Atlantic and shortnose sturgeon sonic tagging program through coordination with NMFS and NYSDEC. This may include placement of telemetry receivers in the project area.
  5. Monitoring predation levels by gulls and other piscivorous birds, which would indicate an increased number of dead or dying fish at the surface.
  6. Preparing a Standard Operating Procedures Manual outlining the monitoring and reporting methods to be implemented during the program.

##### *2.4.3.4.1. Foundation Zone A*

The two areas of shallowest water depth extend from the shorelines on the Rockland and Westchester sides of the Hudson. These areas, where the water depth is less than 7 feet, are labeled as Zone A. The area adjacent to the Rockland shoreline is labeled Zone A1; the area adjacent to the Westchester shoreline is Zone A2. Zone A substructure elements would be constructed within cofferdams from adjacent temporary trestle platforms. These cofferdams would be constructed prior to pile driving the bridge foundation piles. The cofferdam would remain flooded during pile installation.

<u>Cofferdams</u>

A cofferdam is a watertight chamber designed to facilitate construction in an area that would otherwise be underwater. In this case, the cofferdams would be composed of interlocking sheet piles extending into the riverbed a distance of up to 20 feet. Upon completion of the cofferdam, foundation piles would be driven into the riverbed prior to dewatering. The remaining work of pile cap and pier construction would follow the dewatering process.

<u>Pile installation</u>

Prior to pile driving, a template to guide piles would be placed within the cofferdam to ensure that the piles are in position and to hold them when pile driving is not taking place. Once all piles are driven, the template and its supports would be removed and transitioned to the next cofferdam. A quick, low-noise, moderate-energy vibratory hammer would be used to install much of the length of the pile, after which a high efficiency hydraulic impact hammer suspended from cranes operating on the two temporary shoreline access trestles would be used to apply force to the tops of the piles so as to deliver the piles more deeply into the riverbed. It should be noted that the use of vibratory hammers for the entire driving operation is not possible due to the excessive depth to bedrock. Feasibility of using vibratory hammers to drive piles deeper than originally proposed in order to reduce the duration of impact hammering will be tested in the PIDP. It is anticipated that the initial set for these deep piles cannot be overcome after pile sections are spliced. Using the vibratory hammer rather than the impact hammer to accomplish the majority of the pile driving would require the addition of substantially more pilings than originally proposed in order to achieve the desired weight-bearing capacity and settlement of pilings into the substrate. The extent of vibratory piling will be reconsidered after the results from the PIDP are available.

A 300-ton crawler crane would suspend the 150-foot pile sections and support the pile driving hammer during operation. Upon completion of pile installation, the soil within each pile would be excavated and transported to an off-site disposal facility. Finally, a tremie concrete plug, which braces the bottom of the sheet pile cofferdam and provides a seal at the base of the cofferdam to allow for dewatering of the cofferdam, would be poured inside the pile and a steel reinforcing cage would be inserted into the pile. Since the water within the cofferdam would be of the same quality as the water outside the cofferdam, treatment during the dewatering process is not proposed but would be done if required by the NYSDEC.

<u>Pile caps</u>

As previously mentioned, a tremie concrete plug would be poured into the hollowed pile. The pile itself would be dewatered down to the plug. Prior to the installation of the pile cap, pier reinforcement, post tensioning ducts, and pile reinforcement would be secured. A pile cap, which is a reinforced concrete slab constructed atop a cluster of foundations piles, would then be constructed to form a single structural element that would allow for even distribution of the weight that the piles bear, avoiding over stressing any individual component. These slabs would also provide a larger area for the construction of the columns that they will support.

#### *2.4.3.4.2. Foundation Zone B*

The water depths in Zone B range from 5 to 18 feet, and the zone is characterized by a relatively deep soft-soil profile. Zones B1 (close to the Rockland shoreline) and B2 (close to the Westchester shoreline) are located adjacent to Zones A1 and A2 and are closer to the centerline of the river. The functions performed in Zone B substructure construction would take place in cofferdams, as in Zone A, but the tasks would be completed from barges and support vessels rather than the temporary platforms.

Pile Installation

Piles, which would be transported in two pieces to Zone B by barge, would measure between 250 and 300 feet due to the relatively deep soft-soil profile within the zone. Pile driving would begin immediately upon completion of the cofferdam construction. As in Zone A, a 300 ton crawler crane would lift the pile sections. A pile-driving rig would supply a hammer suspended from the barge mounted crane. The template would be positioned to guide the lower pile section into proper position before the pile would be allowed to delve into the soft stratum under its own weight. The depth achieved in this manner would be considerable, and should the application of further pressure be called for, a vibratory hammer would be used to drive the remainder of the pile into place. Upon the placement of the lower segment of the pile, preparations to begin welding the two segments together will commence. In order for the two segments to be joined, the upper segment would be hovered over the lower until the automated welding process was complete. Upon the completion and inspection of the welding, the remaining length of the conjoined pile would be driven to required depth or specified penetration resistance with a hydraulic hammer. As in Zone A, the soil within the pile would be excavated and transported to an off-site disposal facility in order to create space for the tremie plug and steel reinforcing cage.

Pile caps

The construction process of pile caps in Zone B would be similar to that of Zone A. One difference would be that a granular fill material would be distributed inside of the cofferdam to enable the tremie seal to be poured to its planned elevation. This granular material would remain after the removal of the cofferdam.

*2.4.3.4.3. Foundation Zone C*

Foundation Zone C lies between Zones B1 and B2, connecting the two sides of the river. This zone is defined by the greatest water depths, which range from 18 to 45 feet. Construction in this zone would encompass the construction of the main span as well as that of both approaches.

The first substructure construction activity in Zone C would be the installation of the foundation piles. In this zone, due to the greater depths than Zones A or B, cofferdam construction would follow the pile installation, thus requiring that the cofferdam be constructed around the installed pile to create a dry environment in which to construct the tremie seal. The cofferdam in Zone C would be constructed using a different method than that utilized in Zones A and B. This alternative method, the “hanging cofferdam method,” would begin with the installation of a temporary support structure above the foundation piles on which the cofferdam would be assembled. The cofferdam components would then be pieced together from pulleys secured to the top beams of the support structure. After the placement of the cofferdam, the tremie slab would be poured onto a steel deck acting as the cofferdam floor. Divers would seal the gaps between the piles and the cofferdam deck before the dewatering process. The tremie slab would then be poured, and the unreinforced slab would bond the piles to the cofferdam pending the construction of the reinforced pile cap.

### 2.4.3.5. Construction of Bridge Superstructure

Completion of the bridge superstructure would include piers, columns, pylons (for a cable-stayed option), bridge deck, roadway finishes, lighting, and the shared use path. Much of the material would be pre-fabricated at various locations and delivered to the project site via barge. At the construction site, these elements would be lifted into place by gantries and cranes operating on barges, the temporary work platforms, or completed portions of the structure.

### 2.4.3.6. Existing Bridge Demolition

The existing Tappan Zee Bridge contains five segments: causeway, east trestle, east deck truss, west deck truss, and main spans. The demolition of the existing bridge will be performed in two stages. The first stage will include partial demolition to allow for construction of the new bridge, and the second stage will occur after the completion of the new bridge. No blasting of the existing structure would occur.

#### *2.4.3.6.1. Causeway and East Trestle Spans*

The causeway is a simple span construction composed of 166 spans measuring 50 feet, with the exception of one 100-foot span. The east trestle consists of 6 spans. Within its simple span construction, the causeway contains a stringer and deck superstructure and a substructure of concrete columns and footings on timber piles. Initially, the deck and stringers would be lifted out and placed onto awaiting barges. Then, the protective dolphins would be cut so as to offer unrestricted access for pier removal. Columns and footings would either be cut with diamond wire or broken by pneumatic hammers. Finally, the timber piles forming the causeway foundation would be cut to just below the mud line. All materials would be transported to an appropriate permitted off-site disposal facility, and a turbidity curtain would be utilized to ensure that demolition debris would not be dispersed. Side-scan sonar surveys would be performed in order to verify that all generated debris would be removed from the river.

#### *2.4.3.6.2. Deck Truss Spans*

The deck truss spans, including 13 east deck, 7 west deck, and all approach truss spans, each contain a deck slab, steel trusses, and concrete piers supported on buoyant foundations or caissons. The deck slabs would be removed and transported off-site by an awaiting barge. A channel would then be dredged in Stage 3 to provide access to the trusses near the Westchester shoreline, and steelwork would either be removed by barge-mounted crane or a crane mounted on an adjacent in-tact span. Caisson-supported piers would be demolished using the same process as in the causeway and east trestle spans, and would then be removed to the mud line using diamond cutting wire devices or pneumatic hammers. Steel H piles would remain below the mud line. Turbidity curtains and netting would also be used in this stage.

#### *2.4.3.6.3. Main Span*

The main span stretches 2,412 feet and is structurally formed by a through truss above a deck supported by four latticework piers on buoyant foundations, ice deflectors around the two central piers, and pre-stressed concrete beams on 30-inch diameter steel piles. Initially, the main span deck slab would be lifted and removed off-site by barge. Then, the entire suspended span would be lowered onto a barge via a strand jack or winch system. Conventional barge-mounted cranes would then deconstruct the anchor span steelwork piece by piece and the ice-breaker and fender structures protecting the main span piers would be demolished by divers and barge-mounted cranes. The pier steelwork would also be removed piece by piece, and the buoyant caissons would be cut and flooded. Following main span demolition, a barge-mounted crane operated clam shell bucket would clear the river bottom of debris. Side-scan sonar surveys would verify that all debris and concrete were removed from the river.

# Chapter 3: EFH Designations—Hudson River Bridge Construction Study Area

To delineate EFH, coastal littoral and continental shelf waters were first mapped by the regional Fisheries Management Councils (FMCs) and then superimposed within ten minute-by-ten minute (10’ by 10’) square coordinate grids. Finally, survey data, gray literature, peer-review literature, and reviews by academic and government fisheries experts were used by the FMCs to determine whether these 10’ X 10’ grids support EFH for federally managed species. The Mie-Atlantic Fisheries Management Council (MAFMC) has designated EFH in the lower portion of the Hudson River. The study area is within a portion of the Hudson River/Raritan/Sandy Hook Bays, New York/New Jersey Estuary. **Table 9** lists the species and life stages of fishes identified as having EFH within the Hudson River Bridge Construction Study Area. Chapter 8, “EFH Assessment for Placement of Project Dredged Material at HARS,” identifies the EFH designated species for the HARS and assesses the potential impacts to EFH from the proposed placement of dredged material from the Tappan Zee Hudson River Crossing Project.

**Table 9**
**Essential Fish Habitat Designated Species for the Hudson River**

| Species | Eggs | Larvae | Juveniles | Adults/ Spawning Adults |
|---|---|---|---|---|
| Red hake (*Urophycis chuss*) | | M, S | M, S | M, S / |
| Winter flounder (*Pseudopleuronectes americanus*) | M, S | M, S | M, S | M, S / M, S |
| Windowpane flounder (*Scophthalmus aquosus*) | M, S | M, S | M, S | M, S / M, S |
| Atlantic herring (*Clupea harengus*) | | M, S | M, S | M, S / |
| Bluefish (*Pomatomus saltatrix*) | | | M, S | M, S / |
| Atlantic butterfish (*Peprilus triacanthus*) | | M | M, S | M, S / |
| Atlantic mackerel (*Scomber scombrus*) | | | S | S / |
| Summer flounder (*Paralichthys dentatus*) | | F, M, S | M, S | M, S / |
| Scup (*Stenotomus chrysops*) | S | S | S | S / |
| Black sea bass (*Centropristis striata*) | n/a | | M, S | M, S / |
| King mackerel (*Scomberomorus cavalla*) | x | x | x | x |
| Spanish mackerel (*Scomberomorus maculatus*) | x | x | x | x |
| Cobia (*Rachycentron canadum*) | x | x | x | x |
| Clearnose skate (*Raja eglanteria*) | | | x | x / |
| Little skate (*Leucoraja erinacea*) | | | x | x / |
| Winter skate (*Leucoraja ocellata*) | | | x | x / |

**Source:** National Marine Fisheries Service. “Summary of Essential Fish Habitat (EFH) Designation” posted on the Internet at http://www.nero.noaa.gov/hcd/ny3.html
M=The EFH designation for this species includes the mixing water/brackish salinity zone of the Hudson River estuary (0.5ppt<salinity<25.0 ppt)
F=The EFH designation for this species includes the tidal freshwater salinity zone of the Hudson River estuary (0.0 ppt<or=salinity<or=0.5 ppt)
S=The EFH designation for this species includes the seawater salinity zone of the Hudson River estuary (salinity> or=25.0 ppt)
Blank cells indicate that no EFH designation occurs for the particular life stage.
x= EFH has been designated for this species and lifestage.

Detailed descriptions of the life histories, habitat requirements, and potential project impacts to these species, as well as to marine turtles and mammals and striped bass within the Hudson River bridge construction study area are provided below following the general discussion of potential aquatic impacts from the proposed project.

# Chapter 4: Potential Impacts to EFH—Hudson River Bridge Construction Study Area

## 4.1 GENERAL DISCUSSION OF POTENTIAL AQUATIC IMPACTS FROM THE CONSTRUCTION OF THE PROPOSED PROJECT

### 4.1.1 WATER QUALITY

For the Hudson River, the principal water quality resources issues for the construction of the Replacement Bridge Alternative is the resuspension of river sediments during construction and removal of the existing bridge foundations, and the transport and eventual deposition of this resuspended sediment elsewhere in the Hudson River. While the sand fraction of river sediment settles out relatively quickly after being resuspended, the finer sediment fractions will remain suspended and will be transported away from the construction area and will be deposited elsewhere in the estuary or leave the estuary altogether. Hydrodynamic modeling was used to project the plume of resuspended sediment that would result from sediment disturbing construction activities and the fate and transport of this plume within the Hudson River estuary. Two public domain models were employed in the modeling; the Environmental Fluid Dynamics Code (EFDC) model and Research Management Associates (RMA) model. The EFDC is a state-of-the-art hydrodynamic model that can be used to simulate aquatic systems in one, two, and three dimensions. It is one of the most widely used and technically defensible hydrodynamic models in the world (www. Epa.gov/Athens/wwqtsc/html/efdc.html). The EFDC model and technical support is available from the USEPA and is the most widely used hydrodynamic model. The RMA model is a dynamic two-dimensional depth-averaged finite element hydrodynamic model that was developed for the USACE and is used extensively for bridge scour evaluations in estuaries. It is one component of the US Army Corps of Engineers TABS-MD System (US Geological Service (USGS) Surface Water and Water Quality Models Information Clearinghouse (http://smig.usgs.gov/cgi-bin/SMIC/model_home_pages/model_home?selection=rma2).

As indicated in the construction timeline presented in **Figure 17**, there are periods when sediment disturbing activities evaluated in the hydrodynamic modeling would occur concurrently, with the majority of the potential for sediment resuspension occurring during the first two dredging periods. The hydrodynamic modeling results evaluated in this EFH comprise conservative scenarios that would be expected to result in the greatest sediment resuspension:

- stage 1 dredging with pile driving for the main span (Zone C) and trestles;
- pile driving and cofferdam installation and dewatering for Zones C and B, movement of construction vessels, and trestle construction after Stage 1 dredging is complete; and
- stage 2 dredging combined with pile driving and cofferdam installation and dewatering for Zones C and B, and movement of construction vessels.

#### 4.1.1.1. Sediment Resuspension and Transport

The Long Span Option would have fewer total number of piers (35) than the Short Span Option (62), resulting in a shorter construction duration (4½ years) than the short span option (5½ years). While the number of main span piers is the same between the two options, the long span option has far fewer piers in the approaches.

Sediment disturbing construction activities include dredging, cofferdam construction, and pile driving within Substructure Zones A and B, pile driving within Substructure Zone C (see **Figures 5 and 6** for the location of these zones) and the movement of construction vessels within the construction access channel for the Long and Short Span options. Within Construction Zones A and B (see **Figures 5 and 6**) pile driving would occur within the cofferdams and would not have the potential to re-suspend sediment within the river. Within Zone C, piles would be driven first and then the pile caps installed within hanging cofferdams. Therefore, only the Zone C piles would have the potential to result in additional sediment re-suspension. Hydrodynamic modeling was used to project the plume of resuspended sediment that would result from these concurrent sediment disturbing construction activities and the fate and transport of this plume within the river estuary.

The results of the modeling of the scenarios expected to result in the greatest resuspension of sediment indicated in **Figures 21 through 24** are similar for the Long Span and Short Span Options and indicate that total suspended sediment concentrations in the range of 50 to 100 mg/L above ambient conditions would only occur in the immediate vicinity of the dredges. This level of increase would be expected to occur within the allowable mixing zone for dredging. Other sediment disturbing construction activities would result in a much smaller contribution of suspended sediment (i.e., driving of piles for the cofferdams, pile driving, vessel movement and cofferdam dewatering). On flood and ebb tides, concentrations of 10 mg/L above ambient conditions may extend in a relatively thin band approximately 1,000 to 2,000 feet from the dredges, while concentrations of 5 mg/L may extend a greater distance. Total suspended sediment concentrations recorded during sampling conducted for the project ranged from 13 to 111 mg/L. Additionally, the approximately 8-year record of suspended sediment concentration (SSC) recorded by the USGS at Poughkeepsie (see **Figure 12)** indicates there is considerable variation in the suspended sediment concentration within the Hudson River, as would be expected with an estuarine environment. During periods of higher freshwater flow the differences between low and high SSCs range between approximately 20 to 40 mg/L, during periods of low freshwater inflow the differences between low and high SSCs range from about 5 to 20 mg/L.

Therefore, the projected increases in suspended sediment due to dredging concurrent with other sediment-disturbing construction activities would be well within the natural variation in suspended sediment concentration and would not result in adverse impacts to water quality and would be expected to meet the turbidity standard for Class SB waters at the edge of the mixing zone. Concentrations of total suspended sediment from cofferdam construction (which include the discharge of river water recovered during dewatering) and pile driving would be approximately 5 to 10 mg/L in the immediate vicinity of the activity (within a few hundred feet) which would be much less than that projected to result from dredging and would not result in adverse water quality impacts. Concentrations of total suspended sediment resulting from construction vessel movement are projected to be less than 5 mg/L. Increases of total suspended sediment concentration above ambient would be greatest during slack tide, without tidal action to disperse it (see **Figures 21 and 23**).

Placement of the sand/gravel armoring material within the dredged area, similar to the placement of granular capping material over contaminated sediment, has the potential to result in sediment resuspension when the capping material is deposited upon the sediment, but would not be expected to affect the magnitude of sediment resuspension projected through the hydrodynamic modeling. Results of monitoring conducted during placement of granular capping material on soft sediment indicated that resuspended sediment plumes were due to fines washed of the sand cap material and not due to resuspension of bottom sediment as the capping material was put in place (USACE 2005). Measures would be implemented during placement of the sand layer of the armoring to minimize resuspension of the newly exposed sediment. These measures are the same type of measures that have been demonstrated to successfully cap contaminated sediment with minimal mixing of the cap with contaminated sediment (Palermo et al. 2011), and for the capping of subaqueous dredged material (Palermo et al. 1998). They include both mechanical (dry sand capping material with bottom-dump barge, side-casting, bucket/clamshell, tremie (gravity-fed downpipe)) and hydraulical (wet/slurry of sand placed from a pipe or tremie, or from a spreader barge) placement of the capping material (USACE 2005 and 2006, USEPA 1994, Palermo et al. 2011). Mechanical methods rely on the gravity settling of the granular capping materials in the water column (Palermo et al. 2011) which can result in less water column dispersion than discharge of hydraulically-handled cap material because it settles faster in the water column (USACE 1991). Hydraulic methods can allow for a more precise placement of the material at the surface or depth but may require use of a dissipation devise to reduce sediment resuspension (Palermo et al. 2011, USACE 1991).

Placing sand capping material in layers has been found to allow gentle spreading, resulting in a more stable sand cap (Ling and Leshchinsky undated), and avoiding displacement of or mixing with the underlying sediment (USEPA 2005). This results in a decrease in the turbidity plume with each successive cap layer. The reduction in sediment resuspension observed by placing granular capping material in lifts or layers may afford the ability to place subsequent layers using an alternative methodology that may allow faster placement (USEPA 2008). Therefore, once the sand layer of the proposed armoring is in place, the placement of the gravel would have limited potential to result in sediment resuspension. With the implementation of these methods of placement of granular capping material that have been proven to reduce sediment resuspension during placement, additional sediment resuspension that would occur during the placement of the armoring material would be minimized and would not be expected to result in adverse water quality impacts.

In summary, the results of the hydrodynamic modeling of changes in suspended sediment resulting from construction activities—dredging, pile driving, cofferdam construction, and vessel movement—indicate that with the exception of the portion of the mixing zone within the immediate vicinity of the dredge, increases in suspended sediment would be minimal for the Long and Short Span Options and within the natural range of variation of suspended sediment concentration within this portion of the river. Sediment resuspension resulting from dredging and other sediment disturbing activities would be expected to meet the Class SB turbidity standard at the edge of the mixing zone. Resuspended sediment would dissipate shortly after the completion of the dredging activities, and would not result in adverse impacts to water quality. During the periods of in-water construction when no dredging is occurring, the limited sediment resuspension during pile driving, cofferdam installation and removal, and vessel movement would be localized, would be expected to dissipate shortly after the completion of in-water construction activity and would not result in adverse water quality impacts. Similarly, with the implementation of measures demonstrated to minimize sediment resuspension during placement of capping or armoring material, the placement of the armoring material within the dredged area would not result in adverse water quality impacts. For all of the reasons presented above the increase in suspended sediment projected to result from dredging and other in-water sediment-disturbing construction activities, even under the worst case scenarios, and the placement of armoring within the dredged channel, would not result in adverse impacts to water quality of the Hudson River.

#### 4.1.1.2. Sediment Quality and Water Quality Impacts Due to Resuspension

As described under *Project Setting*, the moderate levels of contaminants indicated through laboratory analysis of sediment samples collected within the study area in 2006 and 2008 typically apply to only the upper few feet and the concentrations of these contaminants decline to those that would be considered to have no appreciable contamination according to NYSDEC TOGS 5.1.9. within a few feet of the mudline. Resuspension of sediments during dredging can also affect water quality through the release of contaminants dissolved in the sediment pore water (i.e., the water occupying the spaces between sediment particles). Considering the limited plume of increased suspended sediment above ambient concentrations projected to occur during the three-month dredging periods, and the limited area of sediments with low to moderate levels of contamination within the area to be dredged, the release of any contaminants would not result in adverse impacts to water quality.

These findings are supported in an evaluation conducted by Hayes (2012) for the Tappan Zee Hudson River Crossing. Using the DREDGE model, Dr. Hayes evaluated projected dissolved concentrations of certain contaminants present within sediments of the Hudson River bridge construction study area, as described in Section 2.3.1 of this EFH Assessment. The dissolved contaminant concentrations were evaluated at the edge of a 500-foot mixing zone and compared to acute water quality criteria for Class SB waters. The results of this analysis indicate that dissolved water column concentrations of the sediment contaminants (arsenic, cadmium, copper, lead, mercury, total PCBs and Total PAHs) predicted by the DREDGE model are all substantially less than their acute water quality criterion for aquatic exposure.

The other in-water construction activities with the potential to result in sediment resuspension (pile driving, installation of the cofferdam and vessel movement) for the Long and Short Span Options are projected to result in a minimal increase in SSC above ambient concentrations. These projected increases would actually be much lower, because within Zones A and B, the sand/gravel armoring layer installed throughout these two zones to minimize scouring would also minimize any resuspension of sediment resulting from the installation of the cofferdams. River water recovered during dewatering of the cofferdams would be treated (e.g., tanks to settle out any suspended sediments and water filtration system as necessary) and discharged back to the Hudson River in accordance with conditions issued by the NYSDEC under the Section 401 water quality certification for the project and would not result in adverse impacts to water quality of the Hudson River.

#### 4.1.1.3. Existing Bridge Demolition

Bridge demolition would occur in two stages. The first stage includes partial demolition to allow for construction of the replacement bridge in the vicinity of the Westchester shoreline. The second stage includes the remaining demolition after completion of the replacement bridge. Use of turbidity curtains during removal of the columns and footings and cutting of the timber piles would minimize the potential for sediment resuspended during the bridge removal activities to adversely affect water quality. Following removal of the existing bridge, sediment that has been deposited within mounds in the vicinity of the existing bridge piers may erode over time until reaching a new equilibrium elevation. Because the Tappan Zee portion of the Hudson River is considered to be neither a depositional or erosional environment (i.e., in equilibrium) (Nitsche et al. 2007) as indicated by the results of the 20th century sediment mapping presented in **Figure 14**, the erosion of these sediments in the vicinity of the existing bridge would be limited under normal river conditions and would most likely occur during high flow events. While some of these sediment deposits have elevated concentrations of certain contaminants (NYSDEC TOGS 5.1.9 Class B or Class C categories), these elevated concentrations do not extend more than a few feet below the mudline. Therefore, the gradual erosion of some areas of contaminated sediment following the removal of the bridge would not be expected to result in adverse impacts to water quality or result in water quality conditions that fail to meet the Class SB standards. These findings are also supported by the previously discussed results of the DREDGE modeling that indicated that dredging of the sediments within the Hudson River bridge construction study area would result in dissolved concentrations of contaminants at the edge of a 500-foot mixing zone that are far below the acute water quality criteria for Class SB waters (Hayes 2012). Gradual erosion of some areas of contaminated sediment would be expected to result in less resuspension of bottom sediment than dredging, and even lower concentrations of dissolved contaminants than dredging.

### 4.1.2 AQUATIC BIOTA

Construction of the project has the potential to affect benthic macroinvertebrates, fish, and EFH due to loss of habitat from dredging, pier installation (e.g., pile driving, installation of cofferdams and fendering), the temporary change in bottom habitat resulting from dredging and subsequent placement of armoring, temporary increases in suspended sediment due to dredging and other sediment disturbing construction activities, and hydroacoustic effects on fish and benthic macroinvertebrates, as discussed in detail below.

#### 4.1.2.1. Benthic Macroinvertebrates

**Tables 10 and 11** indicate permanent and temporary impacts to benthic macroinvertebrates due to platform coverage, dredging and armoring. Temporary increases in suspended sediment and changes to the hydroacoustic environment have the potential to affect benthic macroinvertebrate resources.

##### *4.1.2.1.1. Dredging*

The primary impact to benthic macroinvertebrates from dredging is the loss of the habitat and animals associated with the dredged material (Hirsch et al. 1978). Dredging can also cause the conversion of shallow subtidal habitat to deeper subtidal habitat and can result in temporary increases of suspended sediment due to resuspension of bottom sediment. This section addresses the potential impacts to benthic macroinvertebrates from the loss of habitat and individuals. Potential impacts associated with increased suspended sediment are evaluated under *In-water Construction Activities*. The frequency of dredging or disturbance of an area affects the invertebrate community and its ability to recover following each dredging event. Benthic communities found in environments with a great deal of variability such as estuaries have higher rates of recovery from disturbance. Recovery rates of benthic macroinvertebrate communities following dredging range from only a few weeks or months to a few years, depending upon the type of project, the type of bottom material, the physical characteristics of the environment and the timing of disturbance (Hirsch et al. 1978, LaSalle et al. 1991). In a two year study in the lower Hudson River, Bain et al. (2006) reported that within a few months following dredging, the fish and benthic communities at a dredged location were no different from seven nearby sites that had not been dredged. The results of monitoring did not indicate a lasting effect at the dredged site.

Dredging activities for the project have the potential to remove benthic macroinvertebrates, including oyster beds, and the food resources they provide to other aquatic resources. Approximately 165 to 175 acres of bottom habitat—including about 5.3 acres of NYSDEC regulated littoral zone tidal wetland and 160-170 acres of open water benthic habitat—would be dredged during three 3-month phases, from August 1 through November 1, over a four year period (see **Figure 17**). The dredging period of August 1 to November 1 would avoid periods of anadromous fish spawning migrations and peak biological activity. In addition, the trench would be armored following dredging and the benthic habitat within the dredge zone which was primarily soft sediment would be changed to a substrate of sand overlain with gravel. Since armoring would occur up to 20 feet of the side slope, approximately 155 to 165 acres of sand/gravel bottom would result from the project.

**Table 10**
**Overwater Coverage from Platforms**

| | Habitat | Acres |
|---|---|---|
| **Temporary Overwater Coverage** | | |
| West Platform-Storage Platform Area | Open Water | 4.26 |
| East Platform-Storage Platform Area | Open Water | 2.30 |
| East Platform-Docking Platform Area | Open Water | 1.84 |
| East Platform-Access Road | Littoral Zone | 0.50 |
| | **TOTAL** | **8.9** |
| **Permanent Overwater Coverage** | | |
| Permanent Platform | Littoral Zone | 0.00 |
| Permanent Platform | Open Water | 2.44 |
| | **TOTAL** | **2.44** |

**Table 11**
**Potential Loss of River Bottom, Wetlands, and Adjacent Area Habitats due to Project Activities**

| | Possible Freshwater Wetland Areas (acres) | NYSDEC Littoral Zone Tidal Wetlands (acres) | NYSDEC Tidal Wetland Adjacent Area (acres) | Open Water Benthic Habitat (acres) | Total Short Span (acres) | Total Long Span (acres) |
|---|---|---|---|---|---|---|
| *Temporary* | | | | | | |
| West Platform-Storage Platform Area | - | - | - | 0.21 | 0.21 | 0.21 |
| East Platform-Storage Platform Area | - | - | - | 0.12 | 0.12 | 0.12 |
| East Platform-Docking Platform Area | - | - | - | 0.09 | 0.09 | 0.09 |
| East Platform-Access Road | 0.15 | 0.03 | 0.4 | - | 0.58 | 0.58 |
| Dredging/Armoring | - | 5.3 | - | 160-170/ 155-165 | 175/165 | 165/160 |
| West Nyack Staging Area | 2.0 | - | - | - | 2.0 | 2.0 |
| Tilcon Quarry Staging Area | - | - | - | - | - | 0 |
| **TOTAL TEMPORARY** | **3.5** | **5.3** | **0.4** | **160.4-170.4** | **178** | **168** |
| *Permanent* | | | | | | |
| Permanent Platform-Pile-Supported | - | - | - | 0.12 | 0.12 | 0.12 |
| Permanent Maintenance Area Fill to be Removed | - | - | - | (0.10) | (0.10) | (0.10) |
| New Bridge | - | - | - | 6.5-8.0 | 8 | 6.5 |
| Removal of Existing Structure | - | - | - | (7.1) | (7.1) | (7.1) |
| **TOTAL PERMANENT** | **0** | **0** | **0** | **(0.58)-0.92** | **0.92** | **(0.58)** |

While the dredging would result in the loss of individual macroinvertebrates, it is not expected to result in any permanent adverse impacts on these species at the population level within the Hudson River Estuary. The majority of the bottom habitat and associated benthic macroinvertebrates within the area impacted is the soft sediment community which dominates the Upper New York Harbor and Hudson River. Calculations indicate that deposition within the dredged channel following completion of construction will occur at a rate of about one foot per year. Other studies in the Hudson River region have reported somewhat lower desposition rates on the order of approximately 1 to 5 inches per year (Nitsche et al 2010; Bokuniewicz, H. J. 1988; Wilber and Icco 2003). In any case, recolonization by benthic organisms adapted to softer sediments could be expected to begin within a few months after completion of construction in any given area. Prior to the deposition of sufficient sediment to support a soft substrate benthic invertebrate community, some recolonization of the gravel armor material would be expected occur. Organisms within the nearby gravel substrate located within the main channel (NYSDEC benthic mapper http://www.dec.ny.gov/lands/33596.html, and Nitsche et al. 2007) would serve as a source of organisms to colonize the gravel capping material until the soft sediment is of a sufficient depth to be colonized by soft substrate organisms. Although the area affected by dredging is substantial, the effects to the soft sediment habitat, which is the dominant sediment type in the lower estuary, should be viewed as temporary and not indicative of a permanent adverse impact.

##### *4.1.2.1.2. In-Water Construction Activities*

In-water construction activities have the potential to result in temporary and permanent habitat loss, habitat modification, and temporary increases in suspended sediment due to resuspension of bottom sediment as described below.

<u>Pier Construction</u>

During construction, a total of approximately 8 acres and 7 acres of open water benthic habitat would be lost within the footprint pilecaps and fendering for the Short Span and Long Span Options, respectively.

<u>Temporary Platforms within Bridge Staging Areas</u>

Impacts to benthic habitat would also occur due to the construction of two temporary work platforms north of the existing bridge within the Bridge Staging Areas. Temporary platforms would be constructed on the east and west sides of the river. Since the work platforms for the two bridge replacement options would be the same, approximately 9 acres of open water benthic habitat would be temporarily affected due to overwater coverage, and about 0.3 acres of open water benthic habitat would be temporarily lost within the footprint of the piles supporting the temporary platforms. After construction, these temporary platforms would be removed and the supporting piles cut at the mudline.

<u>Permanent Platform Within the Rockland Bridge Staging Area</u>

As discussed above, a permanent work platform would also be constructed on piles within the Rockland Landing Staging Area. The permanent work platform would result in about 2.44 acres of overwater habitat that would be shaded by the platform. The footprint of the piles associated with the docking and maintenance areas of the permanent platform would result in a loss of 0.12 acres of bottom habitat. However, this loss would be mostly offset by the removal of existing fill within the current maintenance area, creating 0.10 acres of new benthic and associated open water habitat.

##### *4.1.2.1.3. Temporary Increases in Suspended Sediment from Construction Activities*

Construction activities that are expected to contribute to sediment resuspension include dredging, vessel movements, cofferdam construction, pile driving and demolition of the existing bridge. A wide array of benthic macroinvertebrates occurs near the bridge; they vary from motile to sessile benthic organisms and include mollusks (e.g., oysters and clams), annelids (i.e., worms), and arthropod crustaceans such as mysid shrimp, amphipods, isopods, crabs, and other species. Although estuarine benthos have developed behavioral and physiological mechanisms for dealing with variable concentrations of suspended sediment and are well adapted to changes in sedimentation and resuspension processes, certain organisms could be impacted by high levels of water column TSS interfering with their methods of feeding (e.g., filter feeders) and/or causing possible habitat impairment. With respect to shellfish, negative impacts to oyster egg development have been observed at TSS concentrations of 188 mg/L and impacts to clam egg development at 1,000 mg/L (Clarke and Wilber 2000). NOAA, NMFS has identified 390 mg/L (NMFS 2011a) as a concentration below which adverse impacts to benthos are not anticipated.

In studies of the tolerance of crustaceans to suspended sediments that lasted up to two weeks, nearly all mortality was caused by extremely high suspended sediment concentrations (greater than 10,000 mg/L) (Clarke and Wilber 2000), levels which would not occur from the in-water work associated with the proposed project.

Background concentrations of TSS in the bridge vicinity generally vary between 15 mg/L and 50 mg/L throughout the year. The increase in TSS levels predicted to occur as a result sediment-disturbing activities would range from 50-100 mg/L in the immediate vicinity of the dredging to 5 mg/L to 10 mg/L over a relatively limited river area near the replacement bridge construction site. Such increases in water column solids loads would be within the normal variation occurring in the Hudson River and well below levels that would be expected to affect normal life functions of benthic invertebrates. Thus, impacts to benthic invertebrates due to increased water column suspended sediments from construction activities are expected to be minimal and would not result in adverse impacts to benthic communities.

Adverse impacts would occur due to the permanent loss of up to 13 acres of oyster beds caused by dredging and in-water construction activities for the new bridge piers. As discussed in Chapter 18 of the DEIS, “Construction Impacts,” mitigation for loss of oyster reefs and impacts to benthic habitat would be finalized after consultation with NYSDEC, USACE, and NMFS.

#### *4.1.2.1.4. Bridge Demolition*

As discussed above, demolition of the bridge could cause turbidity and the potential resuspension of contaminated sediments. Turbidity curtains would be used during removal of the columns and footings and cutting of the timber piles would minimize the potential for sediment that may be resuspended during bridge removal activities to affect benthic macroinvertebrates and other aquatic biota. Since the benthic sampling program for the project indicated similar benthic community structure in bottom sediments at both existing and proposed bridge location, and because the demolition is not expected to substantially alter sediment characteristics, the benthic community recolonizing the restored bottom habitat following bridge demolition would be expected to be similar to that lost as a result of dredging. Demolition of the existing bridge would also remove the benthic invertebrates and algae that are attached to the bridge, which provide forage and structural habitat for fish. However, the new bridge would offset much of these losses by providing similar structural habitat for these species. Impacts to benthic invertebrates due to increased water column suspended sediments from bridge demolition activities are expected to be minimal and would not result in adverse impacts to benthic communities.

#### *4.1.2.1.5. Hydroacoustic Effects*

Limited information is available on how benthic invertebrates may use sound (e.g., Popper et al. 2003) and there is little information indicating whether sounds from construction would have any impact on invertebrate behavior. The one available study on effects of seismic exploration on shrimp suggests no behavioral effects at sound levels, with a source level of about 196 dB re 1 µPa rms at 1 meter (Andriguetto-Filho et al. 2005).

There is also no substantive evidence on whether the high sound levels from pile driving or any anthropogenic sound would have physiological effects on benthic invertebrates. The only potentially relevant data are from a study on the effects of seismic exploration on snow crabs on the east coast of Canada (Boudreau et al. 2009). The preponderance of evidence from this study showed no short- or long-term effects of seismic exposure in adult or juvenile animals, or on eggs.

The lack of any internal air bubbles (equivalent to the fish swim bladder) that would be set in motion by high intensity sounds would suggest that there would be little impact on benthic invertebrates. However, like fish, if the benthic invertebrates are very close to the source, the shock wave from the source might have an impact on survival.

Impacts to benthic invertebrates due to increased water column suspended sediments from hydroacoustic effects associated with pile driving activities are expected to be minimal and would not result in adverse impacts to benthic communities.

##### *4.1.2.1.6. Summary*

In summary, the temporary and permanent losses of benthic habitat articulated above and in Table 11 would not result in a permanent adverse impact to populations of benthic macroinvertebrates within the lower Hudson River estuary.

#### 4.1.2.2. Submerged Aquatic Vegetation (SAV)

The nearest SAV beds to the replacement bridge construction site are small and located north of the project area (see **Figure 15**). Therefore, dredging and temporary platform construction for the project would not directly impact SAV, but would have the potential to result in indirect impacts due to potential temporary increases in suspended sediment levels and sedimentation rates within these beds. However, dredging operations would occur during the later portion of the SAV growing season, minimizing potential adverse impacts to this resource. Additionally, as discussed above under *Water Quality,* cumulative increases in suspended sediment due to dredging and other in-water construction activities are projected to be within the range of normal variation in SSC within this portion of the Hudson River. Therefore, construction of the project would not result in adverse environmental impacts to SAV within the Hudson River.

#### 4.1.2.3. Fishes

##### *4.1.2.3.1. Dredging*

Where access channels are dredged, there would be a temporary loss of habitat that could impact fish that use the dredged area. These impacts would occur, in part, as a result of a localized reduction in benthic fauna. However, the dredging footprint represents a small percentage (1.2%) of the soft bottom habitat within the Tappan Zee Region (RM 24-33) as defined by the Hudson River Utilities, and a much smaller amount of the soft bottom habitat of the Hudson River Estuary. Additionally, dredging would occur from August 1 to November 1, a period that would minimize the potential for impacts to anadromous fish spawning migration and outside the peak period of biological activity within this portion of the Hudson River when there is the greatest potential for EFH species to occur. Thus, the temporary reduction of benthic fauna within the dredged area would not substantially reduce foraging opportunities for the river’s fish populations. Once construction is completed, the dredged channels would be restored over time to their original elevations by action of natural sedimentation, and the river’s benthic community would recolonize those areas as well.

*4.1.2.3.2. Temporary and Permanent Platforms Within the Bridge Staging Areas*

Approximately 8 acres of temporary platforms would be erected within the Bridge Staging Areas in the Hudson River to facilitate bridge construction. These platforms would be supported by an array of small piles driven into the river substrate. The piles would occupy approximately 0.4 acres of benthic habitat representing a minor reduction of foraging opportunities for fish near the construction site. An approximately 2.44-acre permanent platform would be built on piles and also result in potential shading effects. However, the supporting piles for the platforms would provide a substrate for encrusting organisms which would provide some additional foraging opportunities for fish. Moreover, fish are widely known to seek structures for shelter and the temporary and permanent platforms could represent a favorable diversity in habitat that currently is a large flat, silty bottom. Therefore, the minimal modification of foraging habitat, and the temporary and permanent coverage of aquatic habitat by overwater structures would not result in adverse impacts to fish within the Lower Hudson River estuary.

*4.1.2.3.3. Temporary Increases in Suspended Sediment from Construction Activities*

As described above under Benthic Macroinvertebrates, construction activities expected to contribute to sediment resuspension include dredging, vessel movements, cofferdam construction, pile driving and demolition of the existing bridge.

Resuspension of sediments can have a range of impacts to fish depending on the species and life stages being considered. Lethal levels of TSS vary widely among species; one study found that the tolerance of adult fish for suspended solids ranged from 580 mg/L to 24,500 mg/L (Sherk et al. 1975 as cited in NMFS 2003). Common impacts to fish are the abrasion of gill membranes resulting in an inability to collect oxygen, impairment of feeding, reduction in dissolved oxygen, and fatal impacts to early life stages. Increased TSS can inhibit migratory movements as well. A study conducted by NOAA concluded that TSS concentrations as low as 350 mg/L could block upstream migrations of various species (NOAA 2001). Fish, however, are mobile and generally avoid unsuitable conditions in the field, such as large increases in suspended sediment and noise (Clarke and Wilber 2000). Fish also have the ability to expel materials that may clog their gills when they return to cleaner, less sediment-laden waters.

Burton (1993) indicated that concentrations of suspended solids can reach thousands of milligrams per liter before an acute toxic reaction is reached. Lethal effects were demonstrated between concentrations of 580 to 700,000 mg/L depending on species, (580 mg/L for sensitive species and 1,000 as more typical). Striped bass did not avoid concentrations of 954 to 1,920 mg/L to reach spawning sites (Summerfelt and Mosier 1976; Burton 1993) which are well above the levels likely to be encountered during dredging operations.

Larval stage fish also have a wide suspended sediment tolerance range. Kiorboe et al. 1981 (as cited in Clarke and Wilber 2000), indicate that hatching of striped bass and white perch can be delayed if daily sediment concentrations reach 100 mg/L. Wilbur and Clarke 2001 (as cited in NMFS 2003), indicate that hatching is delayed for striped bass and white perch at concentrations of 800 mg/L and 100 mg/L, respectively. In a 2003 Biological Opinion, the NMFS indicated that TSS concentrations below 100 mg/L are not likely to affect eggs and larvae—at least over short durations (NMFS 2003).

The TSS projected to occur as a result of the project’s construction would be below the physiological impact thresholds of adult and larval fish and also below concentrations that would be expected to impact migration. Furthermore, anadromous fish such as striped bass, American shad, blueback herring, and alewife spawn well upriver and their most vulnerable early life stages such as eggs and yolk-sac larvae would not be expected to occur in the Tappan Zee vicinity. Impacts due to increased water column suspended sediments are expected to be minimal and would not result in adverse impacts to fish within the Lower Hudson River estuary.

Given the tolerance of the EFH species with the potential to occur in the study area to high concentrations of suspended sediments, the turbid nature of the Hudson River under ambient conditions, the limited area over which turbidity would be increased, and the lack of impacts from the release of contaminants due to the resuspension of sediments, the resuspension of bottom sediment that would result from construction of the project would not result in adverse impacts to EFH species.

##### *4.1.2.3.4. Hydroacoustic Effects*

Sound in water follows the same physical principles as sound in air, however, due to higher density of water, sound in water travels about 4.5 times faster than in air (approximately 4,900 feet per second versus 1,100 feet per second in air), and attenuates much less rapidly over distance from the source than in air. As a result of the greater speed, the wavelength of a particular sound frequency is about 4.5 times longer in water than in air (Rogers and Cox 1988; Bass and Clarke 2003).

The most commonly considered aspects of sound are frequency (i.e., number of cycles per unit of time, with hertz (Hz) as the unit of measurement) and amplitude (loudness, measured in decibels, or dB). The frequencies of primary relevance to humans are those in their hearing range, which is from about 20 Hz to 20,000 Hz in a child and perhaps 20 Hz to 10,000 Hz in an older adult. When considering fish, the hearing range to be considered may extend from as low as 20 Hz to, in most species, perhaps 800 to 1,000 Hz. Most fish in the Hudson River fit into this hearing range, although catfish may hear to about 3 or 4 kHz and some of the herring-like fishes (and specifically the American shad) can hear to over 100 kHz (Popper et al. 2003; Bass and Ladich 2008; Popper and Schilt 2008).

In addition, an acoustic field from any source consists of a propagating pressure wave, generated from particle motions in the medium that causes compression and rarefaction. This sound wave consists of both pressure and particle motion components that propagate from the source. All fishes have sensory systems to detect the particle motion component of a sound field, while fishes with a swim bladder (a chamber of air in the abdominal cavity) may also be able to detect the pressure component. Pressure detection is primarily found in fishes where the swim bladder (or other air chamber) lies very close to the ear, whereas fishes in which there is no air chamber near the ear primarily detect particle motion (Popper et al. 2003; Popper and Schilt 2009; Popper and Fay 2010).

The level of a sound in water can be expressed in several different ways, but always in terms of dB relative to 1 micro-Pascal (μPa). Decibels, a log scale, is used to “compress” very large differences of sound level (e.g., from a whisper to cracking of thunder) into more manageable numbers. As a consequence, a doubling of sound pressure level (whether in air or water) is seen as a change of just a few dB. Thus, each 10 dB increase is a ten-fold increase in sound pressure. Accordingly, a 10 dB increase is a 10x increase in sound pressure, and a 20 dB increase is a 100x increase in sound pressure.

For the purposes of this EFH, the following measures are defined:

- Peak sound pressure level (SPL) is the maximum sound pressure level in a signal measured in dB re 1 µPa.
- Sound exposure level (SEL) is the integral of the squared sound pressure over the duration of the pulse – in this case a full pile driving strike. Measured in dB re $1 \mu Pa^2 \cdot s$.
- $SEL_{cum}$ is the energy accumulated over multiple strikes. The rapidity with which the $SEL_{cum}$ accumulates depends on the level of the single strike SEL ($SEL_{SS}$). The actual level of accumulated energy ($SEL_{cum}$) is the logarithmic sum of the total number of single strike SELs. Thus, $SEL_{cum}$ (dB) = Single-strike SEL + 10log10(N); where N is the number of strikes.

Sound levels are analyzed in several different ways. The most common approach is "root mean square" (rms) pressure level which is the average level of a sound signal over a specific period of time, such as the average level 90 percent of the time of the whole signal. Alternatively, one may measure "Peak" sound level, which is the highest level of sound within a signal. Peak is most often used to give an indication of the maximum level of a sound, but it does not give a good picture of the overall sound energy in a signal.

The frequencies in the impulsive signal that is typical of a single strike from a pile driving operation are primarily below about 500 Hz. In order to attempt to better characterize the full extent of energy in the signal, acousticians developed the concept of Sound Exposure Level (SEL), which is simply the integration over time of the square of the acoustic pressure in the signal. Thus the SEL is an indication of the total acoustic energy received by an organism from a particular source (such as pile strikes).

SEL is generally expressed as the total energy in a signal over one second. There are two ways of looking at SEL that are relevant to the issue of pile driving. First is what is referred to as "single strike" SEL – the amount of energy in one strike of a pile ($SEL_{ss}$). The second is "cumulative SEL" (or $SEL_{cum}$), which represents the summed energy in all strikes over some period of time or, perhaps, during the driving of a single pile. $SEL_{cum}$ is particularly useful since it indicates the full energy to which an animal is exposed during any kind of signal (assuming the animal remains in the same place for the duration of the signal – such as for all strikes to embed a single pile), and thus it is possible to use this measure to compare total sound exposure between two signals with waveforms that are very different than one another, such as between a pile driving strike and a burst of sonar.

<u>Physiological Effects</u>

The current interim criteria for onset of physiological effects on fish were agreed to in a Memorandum of Agreement (MOA) by FHWA, USFWS, NMFS, CalTrans and the Washington Department of Transportation on June 12, 2008. As a result of the MOA a set of interim criteria was established for the acoustic levels at which there could be a potential onset of physiological effects to fish. The criteria are referred to as the interim West Coast criteria (reviewed in Woodbury and Stadler 2008; Stadler and Woodbury 2009). These criteria are intended to reflect the onset of physiological effects (Stadler and Woodbury 2009), and not levels at which fish are mortally damaged. Indeed, the onset of physiological effects may be minimal changes in fish tissues that have no biological consequence (Halvorsen et al. 2011). The interim criteria are:

Peak SPL: 206 decibels relative to 1 micro-Pascal (dB re 1 µPa).

$SEL_{cum}$: 187 decibels relative to 1 micro-Pascal-squared second (dB re 1µPa$^2$·s) for fishes above 2 grams (0.07 ounces).

$SEL_{cum}$: 183 dB re 1µPa$^2$·s for fishes below 2 grams (0.07 ounces).

Behavioral Effects

For purposes of assessing behavioral effects of pile driving at several West Coast projects, NMFS employs a 150 dB re 1µPa rms SPL criterion, although it is pointed out in Caltrans (2009) that, at least on the West Coast, "…NOAA Fisheries staff informally indicated … that they do not expect exceedance of the 150 dB RMS behavior threshold to trigger any mitigation."

*Recent Results Relevant to the Interim Criteria for Onset of Physiological Effects*

A recent peer-reviewed study from the Transportation Research Board (TRB) of the National Research Council of the National Academies of Science describes the first carefully controlled experimental study of the effects of pile driving sounds on fish (Halvorsen et al. 2011). This investigation was funded by National Cooperative Highway Research Program (NCHRP) of the TRB, Caltrans, and the Bureau of Ocean Energy Management (BOEM), as well as by the Canadian Department of Fisheries and Oceans (DFO), and was developed and overseen by individuals from highway programs throughout the United States as well as leading experts in underwater acoustics and hearing from the U.S. and abroad. The study was the first to document effects of pile driving sounds (recorded by actual pile driving operations) under simulated free-field acoustic conditions where fish could be exposed to signals that were precisely controlled in terms of number of strikes, strike intensity, and other parameters. The acoustic field simulated one that would take place beyond about 33 ft from a source. Sufficient number of animals exposed to the source, as well as controls (treated identically to experimental other than for their being exposed to sound), were used to provide a strong statistical base. Subsequent to treatment, animals were subject to extensive necropsy (autopsy) to determine the types of physiological effects and the sound exposure levels at which these would show up.

The study was conducted on Chinook salmon (*Oncorhynchus tshawytscha*), an endangered species on the US West Coast. The study considered the onset of a wide variety of potential physiological effects that ranged from small amounts of hemorrhage at the base of fins to severe hemorrhage or rupture of the swim bladder and surrounding body tissues (kidney, liver, spleen, etc.). It was determined that very small effects, such as small hemorrhages at the base of fins are not life threatening nor would they have any short or long-term effect on fish, unlike damage such as swim bladder rupture which would result in mortality. Based on a thorough statistical analysis of results, with extensive controls, it was determined that onset of physiological effects that have the potential of reduced fitness, and thus a potential effect on survival, started at above 210 dB re 1 µPa$^2$·s $SEL_{cum}$, a level that is about 23 dB above the current West Coast interim onset criteria. The peak level for effects is about the same as the current West Coast level.

Subsequent work, using the identical methodology has demonstrated that there is complete recovery from effects on Chinook salmon exposed to sounds as high as 216 dB re 1µPa$^2$·s $SEL_{cum}$ when fish were kept in the laboratory (higher levels could not be used in that particular study. In addition, other studies have shown that similar results to those reported for Chinook salmon were also found in several other species, including lake sturgeon (*Acipenser fulvescens*). There was small variation in the onset level for physiological effects, but all were well above 200 203 dB re 1µPa$^2$·s $SEL_{cum}$ or levels well above the West Coast interim criteria.

*Sound and Effects on Fish*

Sound is a critical source of environmental information for most vertebrates (e.g., Fay and Popper 2000). While we most often think in terms of sound for communication (e.g., speech), perhaps the most important use of sound is to learn about one's environment. Indeed, humans and all other vertebrates have auditory systems that listen to the "auditory scene" and can, from this, learn a great deal about the environment, and the things in it (Fay and Popper 2000; Bass and Ladich 2008). Although the "visual scene" is restricted by the field of view of the eyes and light level, the auditory scene provides a three-dimensional, long distance sense that works under most all environmental conditions. It is, therefore, likely that hearing evolved for detection of the auditory scene (Fay and Popper 2000), and that fishes use sound to learn about their general environment, the presence of predators and prey, and, in many species, for acoustic communication. As a consequence, sound is important for fish survival, and anything that impedes the ability of fish to detect a biologically relevant sound could affect individual fish rather than survival of the species.

Richardson et al. (1995) defined different zones around a sound source that could result in different types of effects on fishes. There are a variety of different potential effects from any sound, with a decreasing range of effects at greater distances from the source. Thus, very close to the source, effects may range from mortality to behavioral changes. Somewhat further from the source, mortality is no longer an issue, and the effects range from physiological to behavioral. As one gets even further, the potential effects decline even further. The actual nature of effects, and the distance from the source will vary and depend on a large number of factors, such as fish hearing sensitivity, source level, how the sounds propagate away from the source and the resultant sound level at the fish, whether the fish stays in the vicinity of the source, the motivation level of the fish, etc.

*Sound Sources from Which Different Effects Might Occur*

There are limited data from other projects to demonstrate the circumstances under which immediate mortality occurs: mortality appears to occur when fish are close [(within a meter to 9 m (a few ft to 30 ft)] to driving of relatively large diameter piles. Studies conducted by California Department of Transportation (Caltrans, 2001) showed some mortality for several different species of wild fish exposed to driving of steel pipe piles 2.4 m (8 ft) in diameter, whereas Ruggerone et al. (2008) found no mortality to caged yearling coho salmon (*Oncorhynchus kisutch*) placed as close as 0.6 m (2 ft) from a 0.45 m (1.5 ft) diameter pile and exposed to over 1,600 strikes. Thus, in the overall range of effects on fish in ecosystems such as the Tappan Zee, only a very small fraction of a fish population likely will be close enough to a pile to be subject to immediate mortality.

Of greater relevance than immediate mortality to aquatic organisms caused by pile driving and other intense sound sources is the potential for physiological effects that could potentially result in delayed mortality. At the same time, many of the physiological effects of exposure to pile driving sound are highly unlikely to have any effect on fish survival. Indeed, the potential physiological effects are highly diverse, and range from very small ruptures of capillaries in fins (which are not likely to have any effect on fitness or survival) to severe hemorrhaging of major organ systems such as the liver, kidney, or brain (Stephenson et al. 2010). Other potential effects include rupture of the swim bladder (the bubble of air in the abdominal cavity of most fish species that is involved in maintenance of buoyancy). (See Halvorsen et al. 2011 for a review of potential injuries from pile driving.)

Effects on body tissues may result from barotrauma or result from rapid oscillations of air bubbles. Barotrauma occurs when there is a rapid change in pressure that directly affects the body gasses. Gas in the swim bladder, blood, and tissue of fish can experience a change in state, expand and contract during rapid pressure changes, which can lead to tissue damage and organ failure (Stephenson et al. 2010).

Related to this are changes that result from very rapid and substantial excursions (oscillations) of the walls of air-filled chambers, such as the swim bladder, striking near-by structures. By way of example, under normal circumstances the walls of the swim bladder do not move very far during changes in depth or when impinged upon by normal sounds. However, very intense sounds, and particularly those with very sharp onsets (also called "rise time"), will cause the swim bladder walls to move greater distances and thereby strike near-by tissues such as the kidney or liver. Rapid and frequent striking (as during one or more sound exposures) can result in bruising, and ultimately in damage, to the nearby tissues.

At the same time, there are data showing that very intense signals may not necessarily have substantial physiological effects and that the extent of effect will vary depending on a number of factors including sound level, rise time of the signal, duration of the signal, signal intensity, etc. For example, investigations on the effects of very high intensity sonar showed no damage whatsoever to ears and other tissues of several different fish species (Kane et al. 2010).

Moreover, studies involving exposure of fish to sounds from seismic air guns, signal sources that have very sharp onset times, as found in pile driving, also did not result in any tissue damage (Popper et al. 2007; Song et al. 2008; although see McCauley et al. 2000, 2003 for an instance of inner ear hair cell damage to seismic air guns). Finally, recent studies of the effects of pile driving sounds on fish showed that there is a clear relationship between onset of physiological effects and single strike and cumulative sound exposure level, and that the initial effects are very small and would not harm an animal (and from which there is rapid and complete recovery), whereas the most intense signals (e.g., >210 dB $SEL_{cum}$) may result in tissue damage that could have long-term mortal effects (Halvorsen et al. 2011).

<u>Approach to Estimating Hydroacoustic Effects on Fish</u>

The current NMFS West Coast criteria stipulates that the onset of physiological effects occurs at an $SEL_{cum}$ of 187 dB re 1μPa$^2$•s. Furthermore, in the recent PIDP BO, NMFS (2012) viewed this level as one at which there are no impacts on sturgeon fitness. Moreover, recent studies on Chinook salmon (Halvorsen et al. 2011) show that there are no effects at all on fish at an $SEL_{cum}$ of well over 203 dB re 1μPa$^2$•s.[1] These data also show that onset of physiological effects in Chinook salmon occurs at about 210 dB re 1μPa$^2$•s, but the effects at this level are not likely to affect fitness. It is only until $SEL_{cum}$ gets close to 216 dB re 1μPa$^2$•s that potentially harmful effects start to be encountered.

Based on the recent pile driving studies and discussions with NMFS, and as is incorporated in the Revised Biological Assessment prepared for the Tappan Zee Hudson River Crossing Project (FHWA 2012), it is proposed that there are three hierarchical $SEL_{cums}$ in determining numbers of

[1] The value for Chinook salmon is actually an $SEL_{cum}$ of 210 dB, but the level for other species varies by a few dB and so the 203 dB value is used here to be very conservative and consider the potential "worst case" for onset of physiological effects until even more data are available.

animals potentially taken as a result of pile driving. While these levels of injury were used in determining take for sturgeon species, they would presumably apply to EFH species and other species of fish as well. These three levels are highly conservative, even in light of the Halvorsen et al. (2011) data. Each level is associated with an increasing effect level. (1) Level for potential onset of physiological effects without any impact on fitness - 187 dB re 1μPa$^2$•s, (2) potential onset of recoverable physical injury such as external tissue effects, e.g., minor hemorrhage - 197 dB re 1μPa$^2$•s, and (3) potential onset of mortal injuries - 207 dB re 1μPa$^2$•s.

The rationale for these levels is as follows. The selection of an $SEL_{cum}$ of 187 dB re 1μPa$^2$•s is based on current West Coast criteria. This value is, as discussed above, used in determination of the areas around pile driving at which fish have the potential to have the start of physiological effects, but without any changes in fitness. The $SEL_{cum}$ of 197 dB re 1μPa$^2$•s, is 10 times the lower level of 187 dB re 1μPa$^2$•s and still 13 dB lower than the level that Halvorsen et al. (2011) showed to be the onset of minor physiological effects that are likely not to result in changes in fitness. Finally, the $SEL_{cum}$ of 207 dB re 1μPa$^2$•s, is 100 times greater energy than the current criteria and yet still well below the actual results from Halvorsen et al. (2011) and others for the onset of mortality.

*Hydroacoustic Modeling*

In order to analyze the potential impacts of the project's pile driving on Hudson River aquatic resources, the likely hydroacoustic scale of pile driving was modeled (JASCO 2011) (see **Figures 25 through 29**). The extent of the sound pattern generated by pile driving for the project was determined by application of three different sound propagation modeling approaches (i.e., MONM, VSTACK, and FWRAM). The models account for the frequency composition of the source signal and the physics of acoustic propagation in the Hudson River and underlying geological substrates. This type of modeling differs from generalized and empirical acoustic models, such as "practical spreading loss" models (Caltrans, 2009), that do not take into full account the source characteristics or the many site-specific factors that could influence the rate of noise transmission such as water depth and substrate transmission characteristics.

Various pile driving scenarios were used to generate the cumulative sound exposure level ($SEL_{cum}$) for each day over the construction period. Maximum and typical pile driving scenarios were analyzed (see **Figures 25 through 29**). In addition, the application of Best Management Practices (BMPs) that provided a 10 dB reduction in sound was incorporated into the acoustic modeling effort. These practices represent various methods to reduce the extent to which a waterbody would be ensonified by pile driving operations. Various BMPs have been employed on pile driving operations around the country, including air bubble curtains of various forms, isolation casings, Gunderbooms, and dewatered cofferdams. The Project Sponsors have committed to the use of BMPs to attenuate the potential impacts of sound associated with pile driving, and rely on the results of the PIDP to inform the project for making decisions regarding BMP implementation. The results of the hydroacoustic modeling are depicted in **Figures 22 through 29**, as described below.

**Figure 25** presents the peak SPL, with BMPs, for 4-, 6-, 8-, and 10-ft piles being driven at representative locations along the alignment of the replacement bridge. The figure illustrates the transmission loss that would occur as distance from the pile driving site increases. Transmission loss is not uniform across the different size piles since the piles would be driven at locations where water depth and other environmental factors vary. For the 4-ft piles, sound above the interim 206 dB peak threshold encompasses a distance of about 30 ft; for the 10-ft piles the 206 dB peak SPL the distance increases to approximately 300 ft.

The following figures present accumulated energy ($SEL_{cum}$) for driving a pile over the time for driving the pile and should be understood that way. Thus, the information in these figures does *not* represent the energy from a single strike or the instantaneous level of sound at any one moment in time (as represented for rms levels in **Figure 25**). Moreover, the accumulated energy in the following figures represents the received energy for an animal *only* if the animal stays in the same location for the duration of the pile driving activity.

**Figure 26** presents the $SEL_{cum}$ metric for installing two 10-ft piles at the replacement bridge main span over the number of strikes that are predicted to be needed to fully seat the piles. The proposed schedule for concurrent placement of two 10-ft piles would be the same for both the Short and Long Span Options. The concentric "circles" (or isopleths) of different colors represent distances from the pile driving activity at which various $SEL_{cum}$ levels would be attained during the driving of the two piles. For example, the 187 dB isopleths extends over a mile in each direction north and south of the point of pile driving and 49 percent of the cross sectional width of the river. This can be contrasted with the 187 dB re 1 $\mu Pa^2 \cdot s$ isopleth profile for installing four 4-ft piles at the replacement bridge main span in one day, which does not extend substantial distances in any direction (see **Figure 27**).

**Figure 28** indicates the cross sectional area of the river that would be ensonified by the 187 dB re $1\mu Pa^2 \cdot s$ isopleths over the duration of the construction period for the Short Span Option, and assumes a BMP reduction of 10 dB. During the period of driving the 10 foot piles, 49 percent of the river cross sectional width would be occupied within the 187dB re $1\mu Pa^2 \cdot s$ isopleth. This ensonified area would be between 43 and 61 percent during the four-month period when 4, 6, and 8 ft piles are all being driven, sometimes simultaneously. The figure indicates that driving of the 10 and 8 ft piles would take place in the first few months of the first year of construction, limiting the period of time of greatest potential impact, During the remaining years of the construction period, the affected cross section of the river is considerably less, on the order of 14 to 38 percent. Given that the river is approximately 3 miles wide, there would always be a considerable portion of the river that remains below the threshold noise criteria, thereby insuring adequate corridors for migration and movement of fish through the region. **Figure 29** indicates the cross sectional area of the river that would be ensonified by the 187 dB re $1\mu Pa^2 \cdot s$ isopleths over the duration of the construction period for the Long Span Option.

*Results of Hydroacoustic Modeling*

The results of the hydroacoustic modeling performed in the DEIS and the BA indicate that there is potential for physiological effects (at 187 dB re $1\mu Pa^2 \cdot s$), recoverable injury (197 dB re $1\mu Pa^2 \cdot s$) and onset of mortality (207 dB re $1\mu Pa^2 \cdot s$) to individual fish in the immediate vicinity of the pile driving, Since potential effects to a variety of species were assessed (shortnose sturgeon, Atlantic sturgeon, striped bass, bay anchovy, weakfish, etc.) these potential effects would presumably extend to EFH species as well. For all species examined, the assessment indicated that only a very small portion of the standing stock or population size would be subject to sound exposures resulting in the onset of physiological effects (187 dB re $1\mu Pa^2 \cdot s$). A far smaller amount of fish would be exposed to levels causing injury or mortality.

For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the

Hudson River's width never reaches the $SEL_{cum}$ criterion established for onset of physiological injury. Furthermore, even within a single day of operations (assuming up to a 12 hour day), there is likely to be no pile driving activity for a substantial amount of time, such as when piles are put in place, being welded, or when the pile driving machinery is relocated. Thus, fish in much of the river will not be exposed to pile driving sounds for significant periods, and the likelihood of accumulating sufficient energy ($SEL_{cum}$) to result in onset of physiological effects is low. Finally, fish are not likely to remain in an area at which noise (from pile driving or other source) would cause discomfort.

The expression $SEL_{cum}$ represents the total energy at a particular location in the river for a discrete duration (typically the number of strikes) of a particular pile driving operation. Often, this represents the duration for the full driving of a single pile, or even for multiple piles if driven in a single day (if a pile is driven over two days, there is a "resetting" of the $SEL_{cum}$ after 12 hours and accumulation starts again (Carlson et al., 2007; Stadler and Woodbury, 2009). It is important to note that it is highly unlikely that a fish would be exposed to the full $SEL_{cum}$ of a pile driving operation since that could only occur if the fish stays in place and exhibits no swimming behaviors (including behavioral response to the pile driving sounds) for the duration of the pile driving operation. Thus, the scenario with fish receiving a full accumulated exposure to any pile driving is highly unlikely and conservative for most Hudson River species of concern including EFH species.

Thus, caution must be used when interpreting the model's results that present $SEL_{cum}$ at different locations relative to the pile driving because the model does not take into consideration any behavioral responses of fish that would result in the fish not being exposed to $SEL_{cum}$ levels that would result in onset of physiological effects. Furthermore, data from Halvorsen et al. (2011) document that $SEL_{cum}$ has to be substantially above the minimum level that would result in onset of low levels of physiological effects to be potentially fatal. Thus, for example, Chinook salmon exhibit some minor effects at a $SEL_{cum}$ at about 210 dB re $1\mu Pa^2 \cdot s$, but it is not until the levels reach 216 – 219 dB re $1\mu Pa^2 \cdot s$ that injuries become potentially fatal (Halvorsen et al. 2011). The study indicated there was recovery from injuries sustained at 210 dB re $1\mu Pa^2 \cdot s$ within several days of exposure, and that none of the injuries observed were of a kind that would lead to a loss of fitness.

*Effects of Sound on Fish Behavior*

Results of empirical studies of hearing of fishes, amphibians, birds, and mammals (including humans), in general, show that behavioral responses vary substantially, even with a single species, depending on a wide range of factors such as the motivation of an animal at a particular time, the nature of other activities that the animal is engaged in when it detects a new stimulus, the hearing capabilities of an animal or species, and numerous other factors (Brumm and Slabbekoorn 2005). Thus, it is difficult to assign a single criterion above which behavioral responses to noise would occur.

It is also critical to note that animals (and humans) generally do not respond to sounds that are minimally perceivable (whether there is background sound or not). Sounds generally have to be well above the minimal detectable level in order to elicit behavioral changes (Dooling et al. 2009). At the lowest sound levels the animal may just ignore the sound since it is deemed to be unimportant or too distant to be of immediate relevance. It is only at higher amplitudes where the animal becomes "aware" of the sound and may make a decision whether or not to behaviorally respond to the sound. In some cases, sounds may be "masked" by background noise of the same or similar frequencies (Bee and Swanson 2007). In this case, the masked sound could either be undetectable or less detectable than it would otherwise be under quieter conditions. In a natural setting, it is possible that the sound has to be sufficiently above the masked threshold of detection for the animal to be able to resolve the signal within the surrounding ambient noise and recognize the signal as being of biological relevance.

By way of example, in an experiment on responses of American shad to sounds produced by their predators (dolphins), it was found that if the predator sound is detectable, but not very loud, the shad will not respond (Plachta and Popper 2003). But, if the sound level is raised an additional 8 or 10 dB, the fish will turn and move away from the sound source. Finally, if the sound is made even louder, as if a predator were nearby, the American shad go into a frenzied series of motions that probably helps them avoid being caught. It was speculated by the researchers that the lowest sound levels were those recognized by the American shad as being from very distant predators, and thus, not worth a response. At somewhat higher levels the shad recognized that the predator was closer and then started to swim away. Finally, the loudest sound was thought to resemble a very near-by predator, eliciting maximum response to avoid predation.

At the same time, there is evidence from a recent study in Norway (Doksaeter et al. 2009) that fishes will only respond to sounds that are of biological relevance to them. Doksaeter et al. (2009) showed no responses by free-swimming herring (*Clupea* spp.) when exposed to sonars produced by naval vessels. Similarly, sounds at the same received level that had been produced by major predators of the herring (killer whales) elicited strong flight responses. Significantly, the sound levels at the fishes from the sonar in this experiment was from 197 dB to 209 dB re 1 µPa (rms) at 1,000 to 2,000Hz. The hearing threshold for herring that are most closely related to those used in the Doksaeter et al. (2009) study in this frequency range is about 125 to 135 dB re 1 µPa (also see Mann et al., 2005). This means that the fish showed no reactions to a sound that was up to 84 dB above the fish's hearing threshold (209 dB re 1 µPa sonar vs. 120 dB re 1 µPa threshold) but not biologically relevant to this species.

There is not an extensive body of literature on effects of anthropogenic sounds on fish behavior, and even fewer studies on effects of pile driving, and many of these were conducted under conditions that make the interpretation of the results for this project uncertain. Of the studies available, the most useful in assessing the potential effects on behavior of pile driving on fish are those that use seismic air guns since the air gun sound spectrum is reasonably similar to that of pile driving. The results of the studies summarized below suggest that there is a potential for underwater sound of certain levels and frequencies to affect behavior of fish but that it varies with fish species, the existing hydroacoustic environment, and the behavioral response may change over time as fish individuals habituate. The project will maintain a corridor where ensonification due to pile driving is below the 150 dB µPa rms SPL behavioral guidance level suggested by NMFS (see **Figures 30 through 33**). Therefore, the project would minimize the potential for the driving of piles with an impact hammer project to impede movement of fish in the Hudson River. Behavioral responses to other noise sources, such as noise associated with vessel traffic, and the results of noise deterrent studies are also summarized below.

*Behavioral Studies Using Pile Driving (or Pile Driving-Like) Sounds*

There have been very few studies that have examined behavioral effects of pile driving on fish. Most of these studies, as reviewed by Popper and Hastings (2009) were in small cages where behavior is severely constrained and so would not be considered a normal setting. In order for the results of an empirical study to be relevant to an assessment of the potential for pile driving, or other anthropogenic stimuli, to affect fish and other aquatic biota, it be done in free-swimming wild animals. While not done on free-swimming animals, Mueller-Blenke et al. (2010) evaluated response of Atlantic cod (*Gadus morhua*) and Dover sole (*Solea solea*) in large pens to playbacks of sounds recorded during pile driving during construction of wind farms. The investigators reported that a few representatives of both species exhibited some movement response, which they claim to have represented increased swimming speed or freezing to the pile-driving stimulus at peak sound pressure levels ranging from 144 to 156 dB re 1 µPa for sole and 140 to 161 dB re 1 µPa for cod. However, with the methodology used it was impossible to determine fish position more frequently than once every 80 seconds, and so, despite the suggestions of behavioral responses by the investigators, it was scientifically impossible to know if, and how, fish were moving or otherwise responding to the sound. Moreover, even in the few times that the investigators could glean information that suggested that fish moved from one place in the pen to another during sound presentation, this was only for very few fish, and it is not even clear that the authors interpretation of these results were correct since several alternative interpretations are possible from the very limited data. Finally, the statistical analysis of the results was very limited, and could not be used to document any behavioral responses by any animals.

Feist (1991) examined the responses of juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior during pile driving operations. Feist had observers watching fish schools in less than 1.5 m water depth and within 2 m of the shore over the course of a pile driving operation. The report (Feist's MS thesis) did not give pile size, other than to say that one was hollow steel and the other solid. While sound measurements were attempted, data were not available for this publication according to the author, thus none of the limited results can be correlated with sound levels from the pile driving operation. Feist did report that there were changes in distribution of schools at up to 300 m from the pile driving operation, but that of the 973 schools observed, only one showed any overt startle or escape reaction to the onset of a pile strike. Moreover, there was no statistical difference in the number of schools in the area on days with and without pile driving, although other behaviors changed somewhat. However, without data on sound levels, it is impossible to use the Feist data to help understand how fish would respond to pile driving and whether such sounds could result in avoidance or other behaviors. Indeed, one interesting observation, though in need of quantification and correlation with sound levels, is that the size of the stocks of salmon never changed, but appeared to be transient, suggesting that normal fish behavior of moving through the study area used was taking place no differently during pile driving operations and in quiet periods. These results, albeit very weak, suggest that at least these species of salmon are not avoiding pile driving operations.

*Field Studies of Effects of Seismic Air Guns on Behavior*

Aside from the few studies that have examined the effects of pile-driving noise on fishes, a number of additional studies have examined the effects of other anthropogenic impulsive sounds on fish with sound spectrums and rise time similar to those generated by pile driving, such as seismic air guns. The sound produced by seismic air guns is similar to that produced by a pile-driving strike in terms of the length of time to reach peak amplitude and the component of the sound most likely to elicit a startle response. Because the rise time of the signal for seismic air guns is even sharper for seismic air guns than for pile driving, noise generated by seismic air guns has the potential to be more behaviorally and physiologically disturbing to fish than pile driving.

In an evaluation of the behavior of free-swimming fishes to noise from seismic air guns, fish movement (e.g., swimming direction or speed) was observed in the Mackenzie River (Northwest Territories, Canada) using sonar. Fishes did not exhibit a noticeable response even when sound exposure levels (single discharge) were on the order of 175 dB re 1 µPa2–s and peak levels of over 200 dB re 1 µPa (Jorgenson and Gyselman, 2009).

Wardle et al. (2001) observed very minor behavioral responses to the air gun emissions (most often very brief startle responses) and no permanent changes in the behavior throughout the course of the study in response to peak sound levels of 210 dB re 1 µPa at 16 meters (52.5 feet) and 195 dB re 1 µPa at 109 meters (358 feet) from the source. Moreover, no animals appeared to leave the reef during noise production. Temporary changes in behavior in response to exposure to seismic air guns were reported in Engås et al. (1996), Engås and Løkkeborg (2002), Slotte et al. (2004), and Løkkeborg et al. (2012) although the level of sound received by fish was not reported. In other studies that looked at catch rate, Skalski et al. (1992) showed a 52 percent decrease in rockfish (*Sebastes* sp.) catch when the area of catch was exposed to a emissions of a seismic air gun at 186-191 dB re 1 µPa (mean peak level). The results also suggested that rockfish would show a startle response to sounds as low as 160 dB (re 1 µPa), but this sound level did not appear to elicit a decline in catch.

McCauley et al. (2000) examined the effects of seismic air guns on caged pink snapper (*Pagrus auratus* Forster). Fish were caged and exposed to hundreds of emissions from an air gun as it approached and moved over and beyond the cage for approximately 1.5 hours. Received SEL exceeded 180 dB re 1 $\mu Pa^2$-s for several of the shots. Startle responses, when they occurred, were elicited by sound levels greater than 156-161 dB re 1 µPa. In addition to the startle response, some individuals moved from the bottom of the cage, possibly to areas of lower sound levels. Behavior of individuals that did respond to the seismic sounds returned to normal within 14 to 30 minutes of cessation of seismic exposure and those individuals exhibited no long-term physiological or behavioral effects. (McCauley et al. 2003). Fish were also reported to habituate to the seismic air gun (McCauley et al. 2000), which means that after some amount of exposure, fish will no longer pay attention to the sound and the sound will have no further effect on behavior.

In an evaluation of the effects of a seismic survey on wild and caged fish of various species inside of Scotts Reef Lagoon in Western Australia, McCauley et al. (2008) observed some startle responses and small levels of movement in fishes exposed to sound exposure levels (single sound) of about 145-155 dB re 1uPa2-s.

*Behavioral Responses to Other Sound Sources*

Noise from construction vessels used to conduct the project also have the potential to affect fish behavior. Using divers to observe behavioral responses of bluefin tuna (*Thunnus thynnus*) in large in-ocean cages (approximately 70 meters square opening and 30 meters deep) to passing boats, Sarà et al. (2007) documented changes in the depth, location and swimming patterns of the tuna school in the presence of sounds from approaching ferries and hydrofoils. However, the authors did not provide sound levels received by the fish.

Two recent studies suggest that fish will show behavioral responses to sounds far below 150 dB re 1 µPa (rms). However, both studies were conducted on fish within small tanks with the underwater sound source located close by, an experimental setup which would have exposed the test subjects to both sound pressure and particle motion components of the sound field, although only the sound pressure was measured. Since all of the fish in both studies are very likely to be most responsive to particle motion and not pressure, and since particle motion was not measured, it is impossible to know to which aspect of the signal the fish were responding. Indeed, due to tank acoustics it is very highly likely that there the fish were exposed to very large particle motion signals (Parvulescu, 1967), and any behavioral responses were associated with that component of the sound.

In one study, signals recorded from the operation of wind farms were found to temporarily alter the behavior of roach (*Rutilus rutilus*) and three-spined sticklebacks (*Gasterosteus aculeatus*) (Andersson et al. 2007). The reported sound pressure levels eliciting responses were from 80 to 120 dB re 1 µPa (rms), although, as indicated above, particle motion, the actual stimulus that the fish could detect, was not measured. Similarly, Purser and Radford (2011) also examined the behavioral response (e.g., startle response and foraging behavior) of three-spined sticklebacks to short (10-sec) and long (300-sec) sounds. Fish showed an increased level of startle response and poorer foraging behavior at sound levels of about 150 dB re 1 µPa. Again, however, particle motion, the likely stimulus for both species in this small tank, was not measured or reported.

A nine-month long study by Wysocki et al. (2007) demonstrated that continuous exposure to sounds at 150 dB re 1 µPa produced no behavioral responses in rainbow trout, and no indications whatsoever of effects on stress levels, growth, or feeding. Turnpenny et al. (1994), in an unpublished report, examined the behavior of three species of fish in a pool in response to different sounds and reported avoidance behavior at certain levels of pure-tone test frequencies. However, due to poor experimental design and substantial errors in acoustics, the results of this study are impossible to interpret because of lack of calibration of the sound field at different frequencies and depths of the tanks, and due to other problems with experimental design (see comments on this study by Popper and Hastings 2009).

Studies that examined the effectiveness of underwater sound to deter fish from entering an area (e.g., dam spillways, or irrigation ditches, power plant intakes) suggest that fish will not change movement or show avoidance when sound is used as a potential fish deterrence (reviewed in Van Der Walker 1967; Popper and Carlson 1998). The exception was a study by Maes et al. (2004), who used a sound deterrent system from 20 to 600 Hz to control the movement of some clupeid fishes (*Alosa* spp.) in an attempt to deter fish from the water intake of a nuclear power plant. Fishes without swim bladders, and others that are thought to have poor hearing (e.g., sticklebacks) were not deterred by the sound. In contrast, fish with presumably better hearing capabilities (clupeids) were deterred to some degree by the sound, although there are no data on received sound levels. Moreover, this work has not been replicated. In contrast, Ploskey et al. (2000), in a very well designed study, investigated the responses of a number of schools of different juvenile salmonid species near the Bonneville Dam on the Columbia River to sounds that ramped up and down in intensity from silent to 160 dB re 1 µPa every two seconds. Only one of over 100 schools of fish exhibited a short startle response, but no individuals were deterred from the vicinity of the dam or altered their behaviors in a way that differed from the control fish, thereby indicating no avoidance of the sound.

*Hydroacoustic Modeling Results and Fish Behavior*

**Figures 30 through 33** present the modeled isopleths of areas in which 150 dB re 1 µPa would result from pile driving. These figures indicate that portions of the river would also be below the 150 dB RMS guidance for fish behavioral effect and the likelihood of a behavioral response, such as avoidance or startle, at 150 dB re 1 µPa is very low when one takes into consideration the data presented above regarding known behavioral responses of fish. In all cases, other than in the acoustically flawed studies by Peuser and Radford (2011) and Andersson et al. (2007), fish show no responses to sounds at 150 dB re 1 µPa rms. Other studies show small responses at substantially higher sound levels to which fish either habituate or from which they recover shortly after the end of exposure (e.g., McCauley et al. 2000, 2008; Wardle et al. 2001). In some cases, no response has been observed even at sound levels substantially higher than 150 dB re 1 µPa (e.g., Jorgensen and Gyselman (2009). Additionally, these sounds may not be detectable to fish if there is any masking from other ambient noises, such as those produced by the river, boats, and other non-project related sources (e.g., traffic on the current bridge, the railway along the shore of the Hudson River). As a consequence, even though the 150 dB re 1 µPa isopleth from driving a 10-ft pile (assuming a 10 dB reduction from noise attenuation measures) is considerable in the east-west direction, masking would mean that the sound is not perceived by the fish as being 150 dB re 1 µPa until the actual sound level (without the presence of a masker) is approximately 5-10 dB higher.

While the results of the behavioral studies to date suggest that there is not likely to be any adverse behavioral response from any fish species, at sound levels as low as 150 dB re 1 µPa, implementation of the EPC measures described previously for pile driving would minimize the potential for behavioral effects. Therefore, the project would minimize the potential for the project to impede movement of fish in the Hudson River. Moreover, and perhaps of even greater significance in ensuring a minimal or no behavioral impacts on fish is the fact that the duration of pile driving during bridge construction would be a very small percent of the total project duration. There is no pile-driving produced by impact hammering over approximately 93 percent of the project's construction. Combining this with the efforts to ensure a corridor where sounds will be below 150 dB re 1 µPa (rms) during pile driving, construction of the project would not result in adverse impacts to fish due to behavioral effects.

#### *4.1.2.3.5. Impacts Associated with Increased Vessel Traffic*

Several EFH species are known or documented to occur within the stretches of the river that included the project area; therefore, these species also may be directly impacted by increased vessel traffic in these areas.

Between 2000 and 2008, annual vessel traffic under the Tappan Zee Bridge ranged from 8,000 to 16,000 vessels per year (excluding small recreational boats, for which no data are available). **Table 12** provides a description of some of the larger vessels that travel along the Hudson River shipping channel, as reported by Hudson River Pilots, who operate many of these vessels. These data are based on vessel movements recorded between January 2005 and October 2006.

Materials shipped via the Hudson River vary from construction materials to oil. The majority of imports passing through the Port of Albany (approximately 95 percent) comprise oil. Cargo typically exported from Albany include grain, scrap metal, project cargo (e.g., industrial cargo from General Electric in Schenectady), heavy lift cargo, and cement. Several other marine terminals are located in the Hudson River Valley, including Newburgh, which supports marine terminals that accommodate oil barges; and Yonkers, in which Refined Sugars operates a marine terminal.

**Table 12**
**Ship and Barge Movements on the Hudson River**

| Displacement (tons) | # of Ships | # of Barges* | Length Min/Max (feet) | Beam Min/Max (feet) | Draft Min/Max (feet) | Air Draft Min/Max (feet) |
|---|---|---|---|---|---|---|
| 0-10,000 | 46 | | 300/400 | 40/70 | 15/20 | 60/150 |
| 10,001-20,000 | 132 | 20 | 120/565 | 64/75 | 15/27 | 100/120 |
| 20,001-40,000 | 248 | 57 | 500/600 | 75/90 | 16/31 | 111/140 |
| 40,001-60,000 | 233 | | 600/730 | 76/106 | 21/33 | 117/140 |
| 60,001-80,000 | 9 | | 623/811 | 100/106 | 21/33 | 129/140 |
| 80,000+ | 8 | | 735/805 | 106/137 | 27/33 | 129/140 |

**Notes:** *This table only reflects the number of vessels operated by Hudson River Pilots. Total barge movements are estimated to be approximately 2,800-3,000 per year.
**Sources:** Hudson River Pilots, Jan. 2005 – Oct. 2006

Construction of the new bridge and demolition of the existing bridge could affect marine traffic in the Hudson River due to increased use of the navigation channel and restrictions on navigation during construction of the main spans' substructure and superstructure, and demolition of the existing bridge. Delivery and installation of the segments would be coordinated with the U.S. Coast Guard to minimize the effect on shipping. It is anticipated that two hours would be required for the delivery of each section, with time included for the segment to reach the required clearance and be stabilized. For the Arch Option, bridge segments may also be delivered by barge, with a similar number of segments required. However, instead of construction in segments, there is the potential that the contractor may construct the Arch in one large full span lift—a method that would require closing of the main shipping channel for one or two days. To minimize any adverse effects on marine navigation, the NYSDOT and NYSTA would coordinate with the U.S. Coast Guard in conjunction with the Bridge Permit process to develop acceptable navigation windows and limit any channel closures to the minimum time necessary to provide a safe construction process.

Therefore, while the project would have a potential for increased vessel traffic for the delivery of materials, as well as dredge vessel traffic, the construction vessels would not occur within the navigation channel and at times, use of the navigation channel for the project would result in decreased vessel traffic due to restrictions that may be required for delivery and installation of certain bridge elements.

The potential direct effects associated with increases in vessel traffic within the dredged construction channel include potential collision with vessels and disturbance of foraging and migratory adults and juveniles associated with an increase in surface activity and noise. For the fish species for which EFH has been designated in the Hudson River, the effects of vessel strikes is likely a function of fish size and location within the water column; however, impacts to these (smaller) species from increased vessel traffic is more likely to occur in the form of propeller entrainment. While propeller entrainment has not been widely studied, Gutreuter et al. (2003) estimated the mortality rates of adult fish caused by entrainment through the propellers of commercial towboats operating in Mississippi and Illinois River channels. The method combined trawling behind towboats (to recover a fraction of the kills) and the use of a hydrodynamic model of diffusion (to estimate the fraction of the total kills). Estimates of entrainment mortality rates ranged from 0.13 fish/km of towboat travel (80 percent confidence interval, 0.00-0.41 fish/km) for skipjack herring (*Alosa chrysochloris*), 0.53 fish/km (0.00-1.33) for both shovelnose sturgeon (*Scaphirhynchus platorynchus*) and smallmouth buffalo (*Ictiobus bubalus*), up to 2.52 fish/km (1.00-6.09) for gizzard shad (*Dorosoma cepedianum*). In a related study of the same river reaches, Killgore et al. (2011) detected no effects of towboat operation variables (speed and engine revolutions per minute [RPM]) on entrainment rate (i.e., fish/km); however, the entrainment rate exhibited was closely related to hydraulic and geomorphic characteristics of the channel. Entrainment rate was low (<1 fish/km) in wide sections of the river, deep water, and swift current while entrainment in narrow sections with shallow, slow water was highly variable and reached relatively high levels (>30 fish/km). Although total entrainment rate was not related to engine RPM in this study, the authors reported that the probability of being struck by a propeller increased with fish length and engine RPM, with a presumed increase in mortality.

The increased surface activity and associated noise would have the potential to displace/disrupt adult and juvenile fish within the study area during foraging and migratory activities within the vicinity of in-water activities on a given day, which would minimize the potential for losses due to contact with vessels.

Another potential impact associated with increased vessel traffic is radiated noise. It is of considerable importance that fish transiting the navigable Hudson River will encounter an acoustic environment that is generally highly energetic under “normal” conditions. The sound levels lower in the estuary result from the high volume of commercial shipping traffic within the tidal Hudson and New York Harbor. While noise levels from shipping in the estuary are not known, it is possible to get a first approximation based upon sound levels from other locations. For example, a recent study in Hong Kong Harbor, one of the busiest ports in the world, demonstrated that there was a generally high noise level in the area (Würsig et al. 2002). The highest sound levels recorded in that study were associated with ship propellers (probably due to cavitation effects). Sound levels ranged from a high of about 148 dB re 1 µPa to a low of 110 dB re 1 µPa·m). While these recordings were made from within the frequency range of 10 – 20,000 Hz, the bulk of the acoustic energy was below 1,600 Hz. Even from these limited data, it is apparent that the sound from even a single vessel is above hearing thresholds of many fishes found in the Estuary. In other words, the sound level from a single ship could potentially be detectable to a fish within 50 or 100 meters of the propeller.

Other data also demonstrates that ships produce a great deal of noise. For example, a merchant ship traveling at 10-15 knots may produce 163 dB re 1 µPa·m at 50 Hz and 137 dB re 1 µPa·m at 300 Hz, while a large tanker (153 - 214 m long) at 15-18 knots may produce 176 dB re 1 µPa·m at 50 Hz and 149 dB re 1 µPa·m at 300 Hz (Mazzuca 2001). Although one overall ambient noise level due to marine traffic has been estimated to be around 75 dB re 1 µPa·m per Hz at 100 Hz, the source level associated with a large tanker can be as high as 186 dB re 1 µPa·m per Hz at a distance of 1 meter (Gisiner 1998). Richardson et al. (1995) suggest source levels and dominant frequencies ranging from 152 dB re 1 µPa·m at 6300 Hz for a five-meter boat with an outboard motor through 162 dB re 1 µPa·m for a tug and barge traveling at 18 km/hr, to a large tanker with a source level of 177 dB re 1 µPa·m in the 100 Hz band. Other authors cite shipping traffic at frequencies from 20 to 300 Hz, with smaller vessels producing the higher frequency sound peaking at around 300 Hz and larger cargo vessels producing lower frequency sounds (MMS 2001).

Because these representative values of radiated vessel noise are well below the peak SPL of 206 dB re 1 μPa established for pile driving, and because the Hudson River is subject to substantial commercial and recreational vessel noise under "normal" conditions, any incremental increase sound associated with vessel traffic related to bridge construction is not expected to affect fish, including EFH species.

*4.1.2.3.6. Summary*

The studies and analyses presented above indicate that pile driving and dredging would have minimal effects to anadromous fish migratory activities, as there would always be large portions of the river width that will not be ensonified due to driving piles with an impact hammer. There would be an acoustic corridor of at least 5000 feet at all times below the West Coast threshold for onset of physiological effects to fish, would presumably also include EFH species. The acoustic corridor shall be continuous to the maximum extent possible but at no point shall any contributing section be smaller than 1500 feet. Driving of 8- or 10-foot diameter piles with an impact hammer in the vicinity of the navigation channel (i.e. Zone C) would be restricted to 5 hours per day from April 1 to August 1, and dredging to be conducted in 3 of the 5 construction years would be limited to three month windows (August 1 to November 1). Dredging of 165 to 175 acres for access channels would create an area of reduced foraging opportunities for fish due to loss of benthic habitat. However, upon completion of in-water activities in a given area, estuarine depositional processes would, over time, allow the benthic habitat to return to its pre-construction state. Additionally, benthic organisms that prefer gravel substrates that would be introduced as a result of armoring would be expected to colonize the dredged construction channel. Gravel substrate is available nearby within and near the navigation channel that would serve as a source of these organisms. The temporary loss of the access channel area would represent a minor fraction of similar habitat in the Tappan Zee portion of the Hudson River. Incidental vessel strikes would be insignificant. Therefore, construction of the Replacement Bridge Alternative would not result in adverse impacts to populations of fish species in the Hudson River, including those designated as having EFH within the study area.

## 4.2 GENERAL DISCUSSION OF POTENTIAL AQUATIC IMPACTS FROM THE OPERATION OF THE PROPOSED PROJECT

### 4.2.1 WATER QUALITY

The principal potential impact to water quality of the Hudson River from the operation of the Replacement Bridge Alternative is the discharge of stormwater runoff from the decks of the replacement bridge. NYSDEC General Permit GP-0-010-01 regulates the discharge of stormwater runoff from construction activities associated with soil disturbance, including both water quality and quantity controls. NYSDEC requires treatment of stormwater runoff from areas of soil disturbance to improve water quality, as well as a reduction of peak flows of stormwater runoff providing channel protection, overbank flood protection and flood control. The technical standards and design criteria for stormwater management facilities are presented in NYSDEC's New York State SWMDM (NYSDEC 2010b).

The stormwater quality management goals stated in the SWMDM are to achieve an 80 percent reduction in total suspended solids (TSS) and a 40 percent reduction in total phosphorus (TP).

Most water quality treatment practices accomplish this goal by collecting the stormwater runoff and detaining it for some length of time, infiltrating it into the ground or filtering it. These practices, commonly referred to as "standard practices," are assumed to meet the required removal efficiencies if designed according to the requirements presented in the SWMDM. Other treatment systems, or proprietary practices, such as hydrodynamic separators and grit chambers, can also be employed for water quality treatment. Typically proprietary practices are used when there are certain site specific conditions that prohibit the implementation of "standard practices."

Stormwater runoff discharges from the Replacement Bridge Alternative would be ultimately discharged into the Hudson River, a tidal water body. The Hudson River is not on the State's Section 303(d) list of waterbodies impaired by stormwater runoff or within a watershed improvement strategy area. Therefore, stormwater quantity or the channel protection volume, overbank flood protection or flood control sizing criteria would not be required. However, post-construction stormwater quality treatment practices would be required for runoff discharging to the Hudson River from the bridge landing portions of Interstate 87/287 in both Rockland and Westchester Counties. Stormwater runoff from the approaches and main span of the Replacement Bridge Alternative would be discharged directly to the Hudson River without treatment, as occurs for the existing bridge. With the implementation of post-stormwater quality treatment controls at the bridge landings, the net concentration of pollutants to the Hudson River from the Replacement Bridge Alternative (landings, approach spans, and main spans) would be expected to decrease for TSS and increase by only 3.4 pounds per year for TP. This increase in TP loadings from the Replacement Bridge Alternative would not result in adverse impacts to water quality of the Hudson River, or result in a failure to meet the Class SB water quality standards. When comparing just pollutant loadings within the landings under the existing and Replacement Bridge Alternative, pollutant loadings would decrease for TP and TSS. Given the overall decrease between the existing bridge and the proposed bridge in terms of both TSS and the minimal projected increase in TP, the water quality resulting from the operation of the project would not adversely affect EFH, or striped bass or marine turtles and mammals.

### 4.2.2 AQUATIC BIOTA

With respect to effects on EFH species potentially present in the project area, or other species of concern, the operation of the replacement bridge is not expected to result in any incremental increase in the effects of the existing bridge (to be removed). As discussed under *Water Quality*, the operation of the project would not result in adverse impacts to water quality of the Hudson River. Given that the Tappan Zee region of the Hudson River is not a migratory pathway for any species for which the Hudson has been designated as EFH, the effects of under-bridge lighting is not expected to result in any impediment to fish migration. Coupled with the generally highly turbid waters of the river, the fact that many species that regularly occur in the project area inhabit the deepest water available, and the presence of other anthropogenic lights along both shorelines of the River and associated with other river crossings, the operation of the project would not result in adverse effects to fish or EFH due to under-bridge lighting.

It has been maintained that shading of estuarine habitats can result in decreased light levels and reduced benthic and water-column primary production, both of which may adversely affect invertebrates and fishes that use these areas, particularly with respect to use as refuge and foraging habitat (Able et al. 1998, and Struck et al. 2004). The amount of area shaded by overwater structures will be affected by the height and width of the structure, construction materials and orientation of the structure relative to the arc of the sun (Burdick and Short 1995, Fresh et al. 1995 and 2000, Olson 1996, 1997 in Nightingale and Simenstad 2001) and piling density. Shading due to bridges has been found to affect plant communities such as tidal marshes and SAV, as well as benthic invertebrate communities within tidal marshes (Struck et al. 2004, and Broome et al., 2005 in CZR 2009). However, adverse effects on marsh vegetation and benthic macroinvertebrates have been found to be minimal when the bridge height-to-width ratio is greater than 0.7 (Struck et al, 2004, Broome et al. 2005 in CZR 2009). Significantly fewer oligochaete worms, which are common in the Hudson River, were found under bridges with a height-to-width ratio less than 0.7 when compared to marshes not affected by shading (Struck et al. 2004). Struck et al. (2004) found that bridges with height-to-width ratios greater than 1.5 had the lowest light attenuation beneath the bridge.

Because the elevations of the existing Tappan Zee Bridge and the Replacement Bridge Alternative are not consistent over the length of the structure (see **Figure 4**), the height-to-width ratio of the bridge varies along its length. **Table 13** compares the ratio of the existing bridge and the Short and Long Span Options for the Replacement Bridge Alternative at the stations indicated in **Figure 2**. The two spans of the Replacement Bridge Alternative would be separated by a gap of up to 70 feet. While impacts to vegetated wetlands or SAV would not be expected to be affected by the construction of the Replacement Bridge Alternative, the height-to-width ratios presented below provide an indication of the potential for the existing and Replacement Bridge Alternative to result in shading impacts. As indicated below, the height-to-width ratio for the portion of the existing bridge within the causeway (the western approach to the main span comprising Stations 845+00 to approximately 905+00) is low, ranging from 0.2198 to 0.2857). The ratio for these same stations for the Replacement Bridge Alternative, Short and Long Span Options, are much higher, ranging from 0.35 near the shoreline to 1.20, with the ratios for the Long Span Option being slightly greater because the height for this approach option is higher. The portion of the western approach just prior to the main span (Stations 920+00 to 935+00) has a ratio that ranges from 0.54 to 1.05 for the existing bridge. Again, the ratios of these stations for the Replacement Bridge Alternative are much greater, ranging from 1.23 to 1.82. The ratios for the main span of the existing bridge range from 1.51 to 1.52 and for the Replacement Bridge Alternative 1.49 to 1.82, while the ratios for the eastern approach are fairly similar for the existing and Replacement Bridge Alternative, ranging from 0.89 to 1.31 with the Long Span Option for the Replacement Bridge Alternative having the higher ratios.

The ratios in **Table 13** consider the height-to-width ratio separately for the two spans of the Replacement Bridge Alternative, assuming that the separation between the decks of the two spans (i.e., 70 feet at the main span and then decreasing toward the shorelines) allows light to penetrate between the two structures. This represents the best case analysis. Under this case, the Replacement Bridge Alternative would clearly result in a lower potential for shading of aquatic habitat compared to the existing bridge, particularly along the causeway (western approach to the main span). Even under the worst case, which assumes no separation between the spans of the Replacement Bridge Alternative and which would conservatively result in a halving of the height-to-width ratios presented in **Table 13**, the Replacement Bridge Alternative would still result in greater ratios (i.e., less shading) than the existing bridge for the western approach, but may result in more shading than the existing bridge for the eastern approach. Overall, the height-to-width ratios imply that even if the Replacement Bridge Alternative were treated as a single structure, with no separation between the spans, there would be a decrease in the potential for shading impacts to aquatic resources.

**Table 13**
**Height-to-Width Ratios for the Existing Bridge and Short and Long Span Options for the Replacement Bridge Alternative at Various Stations Across the Length of the Bridge**

| Location | Existing | Short Span | | Long Span | |
|---|---|---|---|---|---|
| | 91 ft-wide deck | 96ft-wide | 87ft-wide | 96ft-wide | 87ft-wide |
| 845+00 | 0.29 | 0.34 | 0.38 | 0.44 | 0.48 |
| 860+00 | 0.22 | 0.52 | 0.57 | 0.60 | 0.67 |
| 875+00 | 0.22 | 0.70 | 0.78 | 0.78 | 0.86 |
| 890+00 | 0.22 | 0.91 | 1.00 | 0.96 | 1.06 |
| 905+00 | 0.22 | 1.08 | 1.20 | 1.13 | 1.24 |
| 920+00 | 0.54 | 1.23 | 1.36 | 1.24 | 1.37 |
| 935+00 | 1.05 | 1.46 | 1.61 | 1.46 | 1.61 |
| 950+00 | 1.52 | 1.65 | 1.82 | 1.65 | 1.82 |
| 965+00 | 1.51 | 1.49 | 1.64 | 1.49 | 1.64 |
| 980+00 | 1.01 | 1.19 | 1.31 | 1.19 | 1.31 |
| 995+00 | 1.07 | 0.99 | 1.09 | 0.89 | 0.98 |

## 4.3 ASSESSMENT OF EFH SPECIES WITHIN THE HUDSON RIVER BRIDGE CONSTRUCTION STUDY AREA

An analysis of EFH for each fish species and life stage listed in **Table 9**—including the likelihood that the species would occupy the project area on the basis of physical site characteristics including salinity regime, water depth, and/or sediment type—is summarized below for each species. Table 14 summarizes the EFH species that were evaluated but determined not likely to occur within the Hudson River bridge construction study area on the basis of physical site characteristics (e.g., salinity, water depth, sediment). Of the 13 EFH species identified for the Hudson River estuary, the majority were found in highest abundance in the lower reaches of the estuary from the Battery to Yonkers (river miles 0-23). Only three of these species—Atlantic butterfish, bluefish and summer flounder—were captured during the 2007-2008 sampling program for the project. These marine species were captured in the warmer months of the year when higher water temperatures and salinities are present within the Hudson River bridge construction study area. Six EFH species were collected in the Utilities Long River Monitoring Program between 1998 and 2007, albeit relatively infrequently in the Tappan Zee region (RM 24-33) compared to collections in the lower reaches of the estuary. Among these species were winter flounder (egg, larvae, young of year and yearling or older), bluefish (young of year, yearling and older), Atlantic herring (larvae, young of year, yearling and older), windowpane flounder (eggs, larvae, young of year, yearling and older), summer flounder (larvae, young of year), and Atlantic butterfish (larvae, young of year, yearling and older). The Utilities Fall Shoals Program also collected winter and summer flounder, bluefish and Atlantic butterfish, but in relatively few of the samples taken between 1998 and 2007. Atlantic mackerel, Spanish mackerel and scup were each collected in fewer than 3 of over 1,800 samples taken in the Tappan Zee region (RM 24-33) over the ten year period.

**Table 14**
**Essential Fish Habitat Species Not Likely to Occur Within the Hudson River Bridge Construction Study Area On the Basis of Physical Site Characteristics**

| Species | Reason |
|---|---|
| **Atlantic Mackerel** | Juveniles and adults are most common at salinities ≥25 ppt[1] |
| **Black Sea Bass** | Juveniles and adults can be found at salinities from 8 - 38 ppt but are most common at salinities >20 ppt[1] |
| **Cobia** | Juveniles and adults are most common at salinities ≥25 ppt[1] |
| **King Mackerel** | Juveniles and adults are most common at salinities >32 ppt[1] and depths >59 ft[3]. Eggs and larvae are common at salinities >30 ppt[1]. |
| **Red Hake** | Larvae are found at depths >33 ft[3]. Juveniles and adults are most common at salinities > 20 ppt[1]. Adults are most common at depths >82 ft[3]. |
| **Scup** | All life stages are most common at salinities >15 ppt[1] and are designated as using habitats with salinities ≥25 ppt[2] |
| **Spanish Mackerel** | Eggs and larvae are most common at depths >39 ft[3]. Juveniles are most common at salinities >12 ppt[1]. Adults are most common at salinities >32 ppt[1]. |
| **Clearnose Skate** | Juveniles and adults are most common at salinities >20 ppt[1]. |
| **Little Skate** | Juveniles and adults are most common at salinities >20 ppt[1]. |
| **Winter Skate** | Juveniles and adults are most common at salinities >20 ppt[1]. |

[1]Salinities in the Tappan Zee region range from 0 - 12 ppt over the course of the year (AECOM Hudson River Ecology chapter).

[2]NMFS Essential Fish Habitat designation of "S" Seawater salinity zone.

[3]Depths greater than 30 ft are limited to the navigation channel, which is approximately 15% of the river width in the Tappan Zee region. Maximum depths do not exceed 60 ft.

### 4.3.1 ATLANTIC BUTTERFISH (*PEPRILUS TRIACANTHUS*)

Butterfish occur from Newfoundland to Florida and are most abundant between southern New England and Cape Hatteras. It has been suggested that two populations of butterfish exist. One population appears largely restricted to shoals (less than 20 m [66 ft]) south of Cape Hatteras, and another mainly north of Hatteras that occurs in shoals and possibly some deeper waters along of the shelf. Throughout its range, butterfish are found over the entire shelf, inshore and offshore. According to Able and Fahay (1998), butterfish move inshore as water temperatures increase during the spring and migrate back offshore as inshore water temperatures decrease in the fall. Butterfish require 10°C (50ºF) for survival. This species spawns from June to August in inshore waters generally less than 30 m (98 ft) deep.

Peak egg production is in late June and early July off Long Island Sound. Very few butterfish eggs have been collected in the Hudson River estuary during utilities-sponsored fish surveys conducted between 1998 and 2007. Those that were collected were found in late June and July in the lower estuary from the Battery to near Yonkers at river mile 23. No butterfish eggs have been reported from the Tappan Zee region during these surveys. However, the Hudson River is within an area designated as EFH for larval, juvenile, and adult butterfish. Studies performed in the Hudson-Raritan Estuary noted that butterfish comprised less than 1 percent of total catches of fish (USACE 2000).

Newly hatched larvae are between 2 and 16 mm (0.1-0.6 in) in length. Larvae are found at the surface and often in the shelter of the tentacles of large jellyfish. The latter tend to be more nektonic (freely swimming) than planktonic (passively drifting with currents) when between 10 and 15 mm (0.4-0.6 in) long. Larvae are found at temperatures ranging from 7-26°C (45-79°F), although most abundant at 9-19°C (48-66°F), and at depths less than 120 m (394 ft) (Cross et al. 1999).

At 6 mm (0.24 in), larval body depth has increased substantially in proportion to length. At 15 mm (0.6 in), the fins are differentiated and the young fish takes on the general appearance of the adult. Adult butterfish can range from 120 to 305 mm (4.7-12 in) long. Both juveniles and adults have similar habitat characteristics. Both are eurythermal and euryhaline and are common often near the surface in sheltered bays and estuaries during the spring to autumn months. In the Hudson-Raritan trawl survey, juveniles and adults were found at depths from 3-23 m (10-75 ft), salinities from 19-32 parts per thousand (ppt), and dissolved oxygen from 3-10 mg/L. Juvenile and adult butterfish also often prefer sandy and muddy substrates, and temperatures from 3-28°C (37-82°F) (Cross et al. 1999).

Occasional adult and juvenile butterfish have the potential to occur within the study area. Spawning would not occur within the study area. Woodhead (1990) reports butterfish to be a common transient in the New York Harbor in the summer. Atlantic butterfish prefer sandy bottoms, but are not closely associated with the bottom when inshore during the summer. They may stay close to the bottom during the day and move into the water column at night (Smith 1985). They are found in the Hudson-Raritan estuary in greatest abundance during summer and based on the last available decade of Utilities data (1998-2007), butterfish are present in the lower Hudson River from the Battery to West Point (upriver from the study area) from July through October (sampling starts in July). They have not been caught upstream of West Point and are far more abundant in the first 23 river miles (Battery and Yonkers) compared to areas farther upstream. The highest densities of butterfish are in the channel and to some extent, the deep bottom habitats in waters greater than 20 feet deep. They are infrequently collected in the shallow shoal habitat (i.e., less than 20 feet deep).

Because the Tappan Zee region of the Hudson River is marginal habitat for butterfish in terms of normal salinity ranges and the Hudson River is not a migratory corridor for the species, individuals this species are not likely to occur in the project area in large numbers but would occur during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee region of the Hudson River does not represent a significant portion of the EFH for this species. Atlantic butterfish were collected within the study area during the sampling conducted for the project and were collected during the Utilities Fall Shoals Program from 1998 to 2007, although in relatively few of the samples. The Mid-Atlantic butterfish stock is considered overfished (NOAA 2011).

Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB RMS guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.2 ATLANTIC MACKEREL (*SCOMBER SCOMBRUS*)

Atlantic mackerel is a pelagic marine species that occurs on both sides of the North Atlantic, and in the western North Atlantic from Labrador to North Carolina. It sustains fisheries from the Gulf of St. Lawrence and Nova Scotia to the Cape Hatteras area. There may be two populations: one occurring in the northern Atlantic and associated with the New England and Maritime Canadian coast, and another more southerly population that inhabits the mid-Atlantic coast. Both populations overwinter in the deep waters at the edge of the continental shelf, generally moving inshore (in a northeastern direction) during the spring, and reversing this migration in autumn. The southern population begins its spawning migration by moving inshore between the Delaware Bay and Cape Hatteras and then in a northeastern direction along the coast. The timing of the migration and spawn is driven by warming water temperatures. The peak spawn for the southern population occurs off New Jersey and Long Island Sound in April and May. Most spawning occurs in the shoreward half of the continental shelf and in waters from 7 to 14°C (45-57°F), with the peak being 10 to 12°C (50-54°F) (Studholme et al. 1999). Eggs of the Atlantic mackerel have been collected in low abundance from mid-April to June and primarily in the lower portion of the Hudson River estuary from the Battery up to river mile 23 near Yonkers, based on utilities-sponsored fish survey data. Larval Atlantic mackerel are also collected in low abundances during May and June in the same region. Very few eggs or larvae are collected in the project area near Tappan Zee. Only 1 juvenile Atlantic mackerel was collected during these surveys in the Yonkers region. By June, schools of juveniles can be found off Massachusetts, and they move into the Gulf of Maine by June and July. In the New York Harbor Estuary, juveniles may be present from April to December, but are most common from April through June and October through November. Adults are present from April through June and from September through December, most commonly from April to May and from October to November (USACE 2000). The Hudson River is within an area designated as EFH for juvenile and adult Atlantic mackerel.

Juvenile metamorphosis includes swimming and schooling behaviors starting at approximately 30-50 mm (1.2-2.0 in), and they closely resemble adults by about 1 year of age. In the New York Harbor Estuary, juveniles are present in the spring and summer months, preferring depths from 4.9-9.8 m (16-32 ft), salinity ranges from 26-28.9 ppt, dissolved oxygen from 7.3-8.0 mg/L and temperatures from 17.6-21.7°C (64-71°F) (Studholme et al. 1999).

Adult Atlantic mackerel can range from 26 cm (10 in) in their second year to about 40 cm (15.8 in) in their sixth year. NEFSC trawl survey data indicate that adults are found in the spring at temperature ranges from 5-13°C (41-55°F) dispersed from 0-380 m (1,250 ft) (most abundant at 160-170 m [525-558 ft]), and in the summer at temperatures ranging from 4-14°C (39-57°F) at depths of 10-180 m (33-591 ft) (abundant at 50-70 m [164-230 ft]). Adults also prefer salinities of 25 ppt or greater (Studholme et al. 1999).

Due to salinity requirements, adults are not likely to be present within the Hudson River, in the study area (**Table 14**), where salinity is less than 10 PSU over much of the year except for during periods of low freshwater flows when the salt front is pushed upriver Atlantic mackerel were rarely collected during trawls in the New York Harbor by USACE from October 1998 through November 1999 (USACE 1999). Most individuals were found in the Lower Harbor (Raritan Bay and Sandy Hook Bay) (Woodhead and McEnroe 1991 in USACE 1999).

The habitat found within the Tappan Zee region of the Hudson River does not represent a significant portion of the EFH for juvenile and adult Atlantic mackerel. This species would not be expected to occur within the study area except as rare transient individuals. Therefore, adverse impacts would not occur to the EFH for this species.

### 4.3.3 ATLANTIC HERRING (*CLUPEA HARENGUS*)

Atlantic herring is a planktivorous marine species that occurs in coastal waters throughout the Northwestern Atlantic waters from Greenland to North Carolina. They are most abundant north of Cape Cod and relatively scarce in waters south of New Jersey (USACE 2000). Adult Atlantic herring routinely move into estuaries, but are largely restricted to well-mixed waters at salinities greater than 24 ppt. Adults rarely move into fresh water (Smith 1985) and appear to limit their distribution based on the transition zone between well-mixed and stratified waters. Juvenile and adult herring undergo complex north-south migrations and inshore-offshore migration for feeding, spawning, and overwintering. They spawn once a year in late August through November in the coastal ocean waters of the Gulf of Maine and Georges Banks. This species never spawns in brackish water and eggs of this species have not been collected in the Hudson River during utilities-sponsored fish surveys between 1998 and 2007. Post-spawn, the adults migrate to the New York Bight to overwinter from December to April and are followed several weeks later by larval herring that are transported to estuaries and tidal rivers where they also overwinter. The autumn migration by adults to overwintering areas is done in tight schools while the spring migration to spawning areas is much more dispersed. The Hudson River is within an area designated as EFH for larval, juvenile, and adult Atlantic herring.

Larval herring are free-floating, and for autumn-spawned fish this stage can last 4 to 8 months until the spring metamorphosis into juveniles. A fraction of those hatched remain at the spawning site, while others may drift in ocean currents, reaching eastern Long Island Sound and entering the Hudson River estuary on flood tides. In the Gulf of Maine, larvae occur at temperatures ranging from 9 to 16°C (48-61°F), and a salinity of 32 ppt. During post-metamorphosis, which occurs through April and May, juveniles form large schools and move into shallow waters. In the Hudson River, larval Atlantic herring are typically collected during spring and early summer and primarily in the lower reaches of the River from the Battery to river mile 23 near Yonkers. Larval herring are also collected further upstream in the Tappan Zee and Croton-Haverstraw regions, but are sparse upstream of Indian Point and river mile 46. Large schools of juveniles have been collected during spring and early summer (late April through late

June) between the Battery and Indian Point and are at peak abundances during May in the Tappan Zee region, based on utilities-sponsored fish survey data collected from 1998-2007. As early juveniles, Atlantic herring are found in brackish waters, but as older juveniles, this species emigrates from the estuary during summer and fall to overwinter in higher salinity bays or near the bottom in offshore areas. Within Long Island Sound, springtime abundances have been reported as being highest at temperatures ranging from 9 to 10°C (48- 50°F), depths ranging from 10 to 30 m (33-98 ft), and salinity ranging from 25 to 28 ppt. Within the New York Harbor Estuary, catches of herring were highest at temperatures ranging from 3 to 6°C (37-43°F) and in the deeper portions of the estuary (USACE 2000). Juveniles in the NOAA Northeast Fisheries Science Center (NEFSC, http://www.nefsc.noaa.gov) bottom trawl surveys of the New York Harbor Estuary were found to prefer temperatures at 2-16°C (36-61°F) and 12-22°C (54-72°F), and were most abundant at 4-6°C (40-43°F) and 15-18°C (59-64°F). Juveniles are commonly found at depths ranging from 30-135 m (98-443 ft) which varied seasonally (depths increasing with the summer months) (Reid et al. 1999).

On average, males and females mature at about 25-27 cm (10-11 in). In the NEFSC bottom trawl surveys, adults collected were most abundant at 3-6°C (37-43°F) at depths ranging from 4.5 to 13.5 m (14 to 44 ft). Preferred salinities for the Atlantic herring are greater than 28 ppt (Reid et al. 1999). Juveniles and adults perform diel and semi-diel vertical migrations in response to daily photoperiods and variations in turbidity. Being sensitive to light intensity, activity is highest after sunrise and just before sunset, when the herring will avoid the surface during daylight to avoid predators (Reid et al. 1999).

In 1999 the NOAA Technical Memo for the species indicated that the U.S. stock complex has fully recovered from the effects of over-exploitation during the 1960s and 1970s (Reid et al. 1999). The Atlantic herring fishery is not overfished and is not approaching an overfished condition (NFMS 2011b). The NMFS has designated the Hudson River mixing and salinity zone as EFH for Atlantic sea herring larvae, juveniles, and adults.

Larvae, young of year, yearling and older Atlantic herring were observed in the Utilities Long River Monitoring Program collections between 1998 and 2007. However, abundances are highest in the lower portion of the estuary downstream of the project area. In the context of this species' habitat requirements, the Tappan Zee region of the Hudson River is marginal habitat for Atlantic herring based on low relative abundances of this species in the vicinity of the project area compared to abundances further downstream. Furthermore, salinities in the project area are near the low end of the species' normal salinity ranges, particularly for older juveniles and adults. Finally, the Hudson River is not a migratory corridor for the species. Because the habitat found within the Tappan Zee region of the Hudson River does not represent a significant portion of the EFH for this species and individuals of this species are not likely to occur in the project area in large numbers. The project is not likely to result in adverse impacts to EFH for this species.

### 4.3.4 BLACK SEA BASS (*CENTROPRISTIS STRIATA*)

Black sea bass is a marine species that occurs from Cape Cod, Massachusetts to Cape Canaveral, Florida. The fishery is divided into two populations: one major population north of Cape Hatteras, North Carolina, and one in southern waters. The northern population migrates seasonally: shoreward and north in the spring and offshore and south in the autumn. In the autumn, older fish move offshore sooner and overwinter in deeper waters (73 to 163 m [240-535 ft]) than young-of-the-year fish (56 to 110 m [184-361 ft]). Black sea bass can tolerate temperatures as low as 6°C (43°F) but are most abundant in off-shore waters warmer than 9°C (48°F) between 20 to 60 m (66-197 ft) deep (USACE 2000). During the spring migration, adults move to spawning grounds on the nearshore continental shelf and juveniles move inshore and into estuaries. For the northern population, spawning generally takes place in the summer, in water 18 to 45 m deep from the Chesapeake Bay to Montauk Point, New York. The Hudson River is within an area designated as EFH for juvenile and adult black sea bass.

Larvae develop for the most part in continental shelf waters and are most abundant in the southern portion of the Middle Atlantic Bight. Larvae quickly become bottom dwellers and may move into estuaries as late-stage larvae or early juveniles, although eggs and larvae are not typically found in estuaries (Able et al. 1995). While inhabiting the estuary, juvenile black sea bass are strongly structure-oriented and occupy bottom habitats consisting of shells, amphipod tubes and rubble, and have been observed on inshore jetties in late May to early June.

In the Hudson River, young-of-the-year have been captured in both open water and inter-pier areas. Juvenile sea bass occur in the saline portions of estuaries from Massachusetts to Florida starting with the initial spring migration until late autumn and are commonly found around jetties, piers, wrecks, and bottom areas with shells (USACE 2000). They appear to prefer hard bottom (Bigelow and Schroeder 1953).

Juveniles settle in estuaries and the inner continental shelf growing up to 19 cm (7.5 in). Young-of-the-year black sea bass inhabit estuarine areas in the Mid-Atlantic Bight at depths from 1-38 m (3-125 ft) from July to September. They prefer structured bottoms, shell patch substrates and often find shelter around manmade structures. Juveniles can be found in water temperatures ranging from 6-30°C (43-86°F) and salinities ranging from 8-38 ppt (but most preferring >20 ppt). The young-of-the-year are migratory during some portions of the first year. They migrate out of the estuaries and away from inner continental shelf nursery areas during the autumn as water temperatures drop (Steimle et al. 1999b). Adult black sea bass prefer similar habitat conditions as that of the juvenile and perform similar migratory patterns. Adults also tend to seek shelter around manmade structures (Steimle et al. 1999b) and are more common in nearshore coastal and offshore habitats than within estuaries

Black sea bass are bottom feeders, consuming crabs, shrimp, mollusks, small fish, and squid. Woodhead (1990) describes black sea bass as a common summer transient in the New York Harbor. Individuals have been collected in the New York Harbor and the Hackensack River (Smith 1985). Young-of-the-year black sea bass (i.e., juveniles) have been collected in the lower Hudson River off Manhattan from mid-July to September (Able et al. 1995) and are collected during utilities-sponsored fish surveys primarily in August downstream of the project area between the Battery and Yonkers in channel and bottom habitats at depths exceeding 20 feet. Eggs and larvae of this species have not been collected during utilities surveys in the Hudson River. Based on these observations, eggs and larvae are not expected to occur in the study area and there is a low probability that juvenile black sea bass will occur within the study area. For each of these life stages, it is unlikely that project activities would have an impact on this species.

The black sea bass fishery is not currently overfished or approaching an overfished condition (NOAA 2011). The NMFS has designated the Hudson River mixing and salinity zones as EFH for black sea bass juveniles and adults.

Due to salinity requirements (**Table 14**), adults and juveniles are not likely to be present in the study area except in the lower portion of the estuary downstream of the project area near Tappan Zee or during periods of low freshwater flows when the salt front is pushed upriver. The Hudson River is not a migratory corridor for this species and individuals are not likely to occur within the study area in large numbers as suggested by fish-survey data. The habitat found within the Tappan Zee region of the Hudson River does not represent a significant portion of the EFH for this species (i.e., poly- to euhaline nearshore and offshore structured habitat) and individuals would not be expected to occur within the study area except as rare transient individuals. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.5 BLUEFISH (*POMATOMUS SALTATRIX*)

Bluefish is a carnivorous marine species that occurs in temperate and tropical waters on the continental shelf and in estuarine habitats around the world. In North America, bluefish live along most of the Atlantic coastal waters from Nova Scotia south, around the tip of Florida, and along the Gulf Coast to Mexico. Bluefish migrate between summering and wintering grounds, generally traveling in groups of fish of similar sizes and loosely aggregated with other groups. They generally migrate north in the spring and summer and south in the autumn and winter.

Along the North Atlantic, summering waters are centered in the New York Bight, southern New England and northern sections of the North Carolina coastline. Wintering grounds are found in the southeastern parts of the Florida coast. Juvenile and adult bluefish travel far up estuarine waters (where salinity may be less than 10 ppt), but are more often found at higher salinities in poly- and euhaline waters (>20ppt), while eggs and larvae are largely restricted to marine habitats as a result of the adults preferred spawning locations in nearshore and offshore waters (USACE 2000). The Hudson River is within an area designated as EFH for juvenile and adult bluefish.

There are two spawning stocks along the U.S. Atlantic coast—a south Atlantic spring spawn, and mid-Atlantic summer spawn. The fish spawning in the spring migrate to the Gulf Stream/coastal shelf interface between northern Florida and Cape Hatteras in April and May.

Post-spring spawn, smaller bluefish drift westward while the larger fish slowly migrate north along the shelf and west into mid-Atlantic bays and estuaries including the New York Harbor Estuary where they remain until autumn. Summer-spawning fish migrate to the mid-Atlantic from Cape Cod to Cape Hatteras in June through August. Summer post-spawn fish head towards the mid-Atlantic shores and are particularly abundant in Long Island Sound (USACE 2000, Fahay et al. 1999). Juveniles from the spring spawn drift north in the early summer and enter the important nursery habitats in estuaries and bays along the mid-Atlantic coast in June. Summer-spawned fish enter the estuaries in mid- to late-summer (Buckel et al. 1999). All spent fish and juveniles migrate to the wintering grounds in the autumn (USACE 2000).

Juveniles in the Mid-Atlantic Bight inhabit inshore estuaries from May to October, preferring temperatures between 15 and 30°C (59-86°F), and salinities between 23 and 33 ppt. Although juvenile and adult bluefish are moderately euryhaline, they occasionally will ascend well into estuaries where salinities may be less than 3 ppt. Juveniles use estuaries as nursery areas, and can be found over sand, mud, silt, or clay substrates.. Bluefish juveniles are sensitive to changes in temperature; thermal boundaries apparently serve as important cues to juvenile migration off shore in the winter season (Fahay et al. 1999) and may impede early migration into the estuary during the spring.

Adult bluefish are pelagic and highly migratory with a seasonal occurrence in Mid-Atlantic estuaries from April to October. They prefer temperatures from 14-16°C (57-61°F) but can tolerate temperatures from 11.8-30.4°C (35-87°F) and salinities greater than 25 ppt. Adult bluefish are not uncommon in bays and larger estuaries, as well as in coastal waters (Bigelow and Schroeder 1953, Olla and Studholme 1971 in Fahay et al. 1999).

Within the Hudson River Estuary, juvenile and adult bluefish may occur in the late spring through autumn. No spawning would occur within the study area and no bluefish eggs or larvae have been collected during utilities-sponsored fish surveys conducted from 1998 through 2007. Juvenile or older bluefish were captured during the 2007-2008 sampling program for the project during the warmer months of the year when higher salinities are present within the study area. Additionally, juvenile bluefish were observed in the Utilities Long River Monitoring and Fall Shoals Program collections (which are targeted to early life stages). Equally high abundances were recorded from the Battery to West Point near river mile 55, including within the project area. Very low abundances were found in the Hyde Park region and no juvenile bluefish were collected upstream of river mile 85. Peak juvenile abundances typically occur in late August and September and dwindle into late October as juveniles migrate offshore for the winter.

Historically, bluefish was categorized as overfished—the stock size was below the minimum threshold set for this species—and a rebuilding program has been implemented. However, recent estimates of fishing mortality suggest that the rebuilding program, state-by-state quota system, and recreational harvest limit have been successful (MAFMC 2002, NMFS 2003, 2004, 2005). The bluefish fishery is not currently overfished, nor considered to be approaching overfishing status (NOAA 2011).

Juvenile and adult bluefish occupy the saline portions of Hudson River estuary during summer and fall, but emigrate from the River in late fall to overwintering grounds on the continental shelf during the rest of the year. The habitat found within the Tappan Zee region of the Hudson River does not represent a significant portion of the EFH for this species. The Hudson River is not a migratory corridor for this species and individuals are not likely to occur within the study area in large numbers as suggested by fish-survey data.

Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep-water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB re 1 µPa rms guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.6 COBIA (*RACHYCENTRON CANADUM*)

Cobia are large, migratory, coastal pelagic fish of the monotypic family Rachycentridae. In the western Atlantic Ocean, cobia occur from Massachusetts to Argentina, but are most common along the south Atlantic coast of the United States and in the northern Gulf of Mexico. In the eastern Gulf, cobia migrate from wintering grounds off south Florida into northeastern Gulf waters during early spring. They occur off their northwest Florida, Alabama, Mississippi, and southeast Louisiana wintering grounds in the fall. Some cobia overwinter in the northern Gulf at depths of 100 to 125 m (328 to 410 feet). The Hudson River is within an area designated as EFH for eggs, larval, juvenile and adult cobia. However, only one collection of cobia was made during utilities-sponsored fish surveys between 1998 and 2007, which was a juvenile collected in open-water channel habitat in the Yonkers region during late August. Eggs and larval cobia have not been reported from these surveys in the Hudson River.

Information on the life history of cobia from the Gulf and the Atlantic Coast of the United States is limited. Essential fish habitat for coastal migratory pelagic species such as cobia includes sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters, from the surf to the shelf break zone, but from the Gulf Stream shoreward, including areas inhabited by the brown alga, *Sargassum* spp. For cobia, essential fish habitat also includes high salinity bays, estuaries, and seagrass habitat. The Gulf Stream is an essential fish habitat because it provides a mechanism to disperse coastal migratory pelagic larvae. Preferred temperatures are greater than 20°C and salinities are greater than 25 ppt.

Cobia are likely to occur only as rare transient individuals within the study area due to its coastal migrations, pelagic nature, and salinity requirements (**Table 14**). Individuals would have the potential to occur during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species and individuals would not be expected to occur within the study area except as rare transient individuals. Therefore, the project would not result in adverse impacts to the EFH for this species. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species. This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.7 KING MACKEREL (*SCOMBEROMORUS CAVALLA*)

King mackerel is a marine species that inhabits Atlantic coastal waters from the Gulf of Maine to Rio de Janeiro, Brazil, including the Gulf of Mexico. There may be two distinct populations of king mackerel. One group migrates from waters near Cape Canaveral, Florida south to the Gulf of Mexico, making it there by spring and continuing along the western Florida continental shelf throughout the summer. A second group migrates to waters off the coast of the Carolinas in the summer, after spending the spring in the waters of southern Florida, and continues on in the autumn to the northern extent of the range. The Hudson River is within an area designated as EFH for eggs, larval, juvenile, and adult king mackerel.

Overall, temperature appears to be the major factor governing the distribution of the species. The northern extent of its common range is near Block Island, Rhode Island, near the 20°C (68°F) isotherm and the 18-meter (59 ft) contour. King mackerel spawn in the northern Gulf of Mexico and southern Atlantic coast. Larvae have been collected from May to October, with a peak in September. In the south Atlantic, larvae have been collected at the surface with salinities ranging from 30 to 37 ppt and temperatures from 22 to 28°C (70-81°F). Adults are normally found in water with salinity ranging from 32 to 36 ppt (USACE 2000).

Due to salinity and water depth requirements (**Table 14**), king mackerel are not likely to be present within the Hudson River in the study area except during periods of low freshwater flows when the salt front is pushed upriver. This species has not been collected during utilities-sponsored fish monitoring in the Hudson River. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species. This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.8 RED HAKE (*UROPHYCIS CHUSS*)

Red Hake is a bottom-dwelling fish that lives on sand and mud bottoms along the continental shelf from southern Nova Scotia to North Carolina (concentrated from the southwestern part of the Georges Banks to New Jersey). Spawning adults and eggs are common in marine portions of most coastal bays between Rhode Island and Massachusetts. Spawning occurs from May to June in the New York Bight (Steimle et al 1999a). The Hudson River is within an area designated as EFH for larval, juvenile, and adult red hake.

Larval red hake are free floating and occur in the middle and outer continental shelf. They are most common in water temperatures from 11 to 19°C (52-66°F) and depths from 10 to 200 m (33-660 ft). Recently metamorphosed juveniles remain pelagic (i.e. in the water column) for approximately two months, during which time they achieve growth up to 25-30 mm (1.0-1.2 in) in total length. Shelter/structure is a critical habitat requirement for juvenile red hake. In the autumn, juveniles descend from the water column to the bottom and seek sheltering habitat in depressions in the sea floor. Juvenile settlement usually occurs in October and November. Older juveniles use scallop shells, mussel beds, moon snail egg collars, and other available structure until their second autumn when they move inshore to waters less than 55 m (180 ft) in depth. They typically remain inshore until the temperature reaches 4°C (39°F), at which point they migrate offshore to overwinter (USACE 2000, Steimle et al. 1999a).

Woodhead (1990) describes red hake as a common resident of the New York Harbor system. In the Harbor Estuary, the distribution of red hake is influenced by salinity, water temperature, and dissolved oxygen. Juvenile red hake were collected when salinity was greater than 22 ppt and at depths from 5 to 50 m (16-164 ft) deep. Collections tapered off when salinity reached greater than 28 ppt. Adult red hake prefer temperatures from 2 to 22°C (36-72°F), salinity ranging from 20 to 33 ppt and depths greater than 25 m (82 ft) deep. In Middle Atlantic Bight, red hake occur most often in coastal waters in the spring and autumn, moving offshore to avoid warm summer temperatures. Additionally, red hake have been reported to be sensitive to dissolved oxygen levels and within the Hudson River Estuary they preferred dissolved concentrations of 6 mg/L or more (Steimle et al. 1999a).

Within the study area, juvenile and adult red hake have the potential to occur in the deeper waters of the Hudson River, but may be limited by occasional low DO concentrations and low salinity. The study area represents a small portion of the EFH for this species. Eggs of this species have been reported at very low densities in early spring (March-April), but were limited primarily to the lower estuary from the Battery to Yonkers at river mile 23 based on utilities-sponsored fish surveys conducted between 1998 and 2007. Several collections of red hake eggs have also been reported from the Cornwall region (river miles 56-61) upstream of the project area, but no red hake eggs have been collected in the Tappan Zee region during these surveys. Larvae of this species have not been reported to occur in the River, however, juvenile red hake have been collected from the Battery in the lower Hudson River estuary in bottom habitat deeper than 20 feet. Juveniles typically occur in this region of the River during spring (April-May) and late fall (November-December), but have not been documented from the project area during these surveys.

In 1999, the NOAA Technical Memo for the species indicated that the red hake are managed as two U.S. stocks: a northern stock, from the Gulf of Maine to northern Georges Bank and a southern stock, from southern Georges Bank into the Middle Atlantic Bight (Steimle 1999a). The southern stock index was relatively stable from the mid-1960s until the 1980s when it declined with a short period of increase about 1990-1991. The southern stock (or overall stock) is not currently considered overfished and no management action is considered required (NMFS 2011b).

Because the Tappan Zee region of the Hudson River is marginal habitat for red hake in terms of normal salinity ranges and the Hudson River is not a migratory corridor for the species, this species is not likely to occur in the project area in large numbers. Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB re 1 µPa rms guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.9 SCUP (*STENOTOMUS CHRYSOPS*)

Scup is a marine fish that occurs primarily on the continental shelf from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. It migrates extensively from inshore summer grounds to offshore winter grounds. Scup arrive in the waters off New Jersey and New York by early May. During the summer months, older fish (four years old or older) tend to stay in the inshore waters of the bays while the younger fish are found the more saline waters of estuaries such as the New York Harbor Estuary. Spawning occurs in May through August with a peak in June and occurs principally in the estuaries of New York and New Jersey. Juveniles grow quickly and migrate with the rest of the population to offshore wintering grounds starting in late October. They usually are absent from inshore waters by the end of November (USACE 2000). The Hudson River is within an area designated as EFH for eggs, larval, juvenile, and adult scup.

Scup eggs are buoyant and are rather small (0.8 to 1.0 mm [0.03-0.04 in]), hatching in about 2-3 days depending on temperature. Most were collected from May-August at depths less than 50 m (164 ft) and at temperatures ranging from 11-23°C (52-73°F) (Steimle et al. 1999c). Newly hatched larvae are pelagic and approximately 2 mm (0.08 in) long. In approximately three days following hatching, diagnostic characteristics of the species are evident. Shortly thereafter, the larvae abandon the pelagic phase and become bottom dwelling. They occur in water with temperatures ranging from 14-22°C (57-72°F) and occupy more saline (23-33 ppt) portions of estuaries. They are often found within the water column at depths less than 50 m (164 ft) (Steimle et al. 1999c).

Juveniles from 15-30 mm (0.6-1.2 in) and up to 10 cm (4 in) are common during November. By the end of their first year they can reach up to 16 cm (6.3 in). Juveniles inhabit estuarine areas at depths of 5-12 m (16-39 ft), particularly areas with sand and mud substrates or mussel and eelgrass beds. Juveniles prefer temperatures from about 9-27°C (48-81°F) and salinities greater than 15 ppt (Steimle et al. 1999c). Scup males and females reach sexual maturity at age two and reach about 15.5 cm (6 in).

In the New York Harbor Estuary, spawning occurs primarily in the Lower New York Bay and the Eastern Long Island Bay (USACE 2000) and would be unlikely to occur within the vicinity of the study area. However, eggs and larval scup were not collected in the project area or within the Hudson River estuary during utilities-sponsored fish surveys conducted between 1998 and 2007. Juveniles were observed in low abundance, primarily in the lower reaches of the River from the Battery to Yonkers near river mile 23, but were also collected as far upstream as Indian Point above the project area. Juvenile scup were present in the vicinity of the project area in bottom habitats in waters deeper than 20 feet from late July into August. Woodhead (1990) reports that scup is a common summer transient in the New York Harbor. Although overfishing of the scup stock is occurring (NMFS 2004), the rebuilding schedule and management measures implemented in 1996 have resulted in a dramatic increase in scup abundance. The scup fishery is not currently overfished or approaching an overfished condition (NOAA 2011).

Because the Tappan Zee region of the Hudson River is marginal habitat for scup in terms of normal salinity ranges (**Table 14**) and the Hudson River is not a migratory corridor for the species, this species is not likely to occur in the study area in large numbers. Adults and juveniles would have the potential to occur from July through November with freshwater flows are lower and the salinity is higher. Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB RMS guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.10 SPANISH MACKEREL (*SCOMBEROMORUS MACULATUS*)

Spanish mackerel is a marine species that can occur in the Atlantic Ocean from the Gulf of Maine to the Yucatan Peninsula. The Hudson River is within an area designated as EFH for eggs, larval, juvenile, and adult Spanish mackerel. This species occurs most commonly between the Chesapeake Bay and the northern Gulf of Mexico from spring through autumn, and then over-winters in the waters of south Florida. Spanish mackerel spawn in the northern extent of their range (along the northern Gulf Coast and along the Atlantic Coast). Spawning begins in mid-June in the Chesapeake Bay and in late September off Long Island, New York. Temperature is an important factor in the timing of spawning and few spawn in temperatures below 26°C (79°F). Spanish mackerel apparently spawn at night. Studies indicate that Spanish mackerel spawn over the Inner Continental Shelf in water 12-34 m (39-112 ft) deep.

Spanish mackerel eggs are pelagic and about 1 mm in diameter. Hatching takes place after about 25 hours at a temperature of 26°C. Most larvae have been collected in coastal waters of the Gulf of Mexico and the east coast of the United States and no eggs or larvae of this species have been collected in the Hudson River during utilities-sponsored fish surveys conducted between 1998 and 2007. Juvenile Spanish mackerel can use low salinity estuaries (~12.8 to 19.7 ppt) as nurseries and also tend to stay close inshore in open beach waters (USACE 2000). Only one juvenile Spanish mackerel was collected in the Hudson River within the Tappan Zee region. This individual was observed in the deep channel habitat during late September.

Overall, temperature and salinity are indicated as the major factors governing the distribution of this species. The northern extent of their common range is near Block Island, Rhode Island, near the 20°C (68°F) isotherm and the 18-meter (59-ft) contour. During warm years, they can be found as far north as Massachusetts. They prefer water from 21 to 27°C (70-81°F) and are rarely found in waters cooler than 18°C (64°F). Adult Spanish mackerel generally avoid freshwater or low salinity (less than 32 ppt) areas such as the mouths of rivers (USACE 2000).

Because this is a marine species that prefers higher salinity waters, Spanish mackerel are not likely to be present within the study area except during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species (**Table 14**). This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to EFH for this species.

### 4.3.11 SUMMER FLOUNDER (*PARALICHTHYS DENTATUS*)

Summer flounder prefer the estuarine and shelf waters of the Atlantic Ocean and are found between Nova Scotia and southeastern Florida. They are most abundant from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina. Summer flounder usually appear in the inshore waters of the New York Bight in April, continuing inshore in May and June, and reach their peak abundance in July and August. Spawning takes place in the New York Bight in nearshore waters outside estuarine systems in September to October. Spawning occurs in surface water temperatures of 7-14°C (45-57°F), with peak activity occurring around 10-12°C (50-54°F) (Packer et al. 1999). The Hudson River is within an area designated as EFH for larval, juvenile, and adult summer flounder.

Larvae occur in water from 0 to 22°C (32-72°F) and are transported to estuarine nurseries by currents. Juvenile summer flounder are well adapted to the temperature and salinity ranges present in estuarine habitats. They are distributed throughout the estuary prior to late summer and are more concentrated in sea grass beds (as opposed to tidal marshes) in the late summer and early autumn (USACE 2000). Planktonic larvae (2-13 mm [0.08-0.5 in]) have been found in temperatures ranging from 0-23°C (32-73°F), but are most abundant between 9°C and 17°C (48-63°F). Salinity preference within the New York area for this species was found between 20-30 ppt. In the Mid -Atlantic Bight, larvae were found at depths from 10-70 m (33-230 ft). Greater densities of young fish were found in or near inlets (Packer et al. 1999).

Young summer flounder move into shallow estuaries (i.e. 0.5-5.0 m [1.6-16 ft] in depth) using these areas as nursery habitat in the autumn, summer, and spring months. Juvenile summer flounder are able to withstand a wider range of temperatures (greater than 11°C [52°F]) and salinities from 10-30 ppt than many species, and have evolved this tolerance to exploit estuarine nursery areas. Juveniles can be found on mud and sand substrates in flats, channels, salt marsh creeks, and eelgrass beds (Packer et al. 1999).

Adult summer flounder feed both in the shelf waters and estuaries and are more active in the daylight hours; they generally feed by sight (USACE 2000). Adults are found to grow to lengths ranging from 25-71 cm (10-28 in). They inhabit sand substrates at depths up to 25 m (82 ft), at temperatures ranging from 9-26°C (48-79°F) in the autumn, 4-13°C (39-55°F) in the winter, 2-20°C (36-72°F) in the spring, and 9-27°C (48-81°F) in the summer. Salinity is known to have a minor effect on distribution as compared to substrate preference (Packer et al. 1999).

In 2002, the stock was considered overfished and was in the 8th year of a 10-year rebuilding program (NMFS 2003, MAFMC 2002). The latest stock assessment for summer flounder indicates that management measures have been successful. The resource is no longer overfished although overfishing is currently occurring (NMFS 2005). The summer flounder fishery is not overfished and is currently rebuilding (NOAA 2011).

Summer flounder eggs have not been reported from utilities-sponsored fish surveys conducted in the Hudson River from 1998 to 2007. Larval summer flounder, however, are frequently collected during the spring (March-April) in the lower estuary near the Battery (river miles 0-11). Juvenile and adult summer flounder have the potential to occur in the Hudson River within the study area during the warmer months. Juveniles, in particular are often collected in bottom habitats at depths exceeding 20 feet from the Battery to Tappan Zee during the spring (March-April) and again in October. Additionally, summer flounder were captured during the 2007-

2008 sampling program for the project during the warmer months of the year when higher salinities are present within the study area.

Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB re 1 µPa rms guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Furthermore, because summer flounder do not have a swim bladder, the likelihood of physical damage is far lower than for fish species with a swim bladder. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Loss of bottom habitat due to the placement of the piles and other structures (including armoring of the dredged channel) would be minimal and would not be expected to result in significant reductions in fish habitat or prey availability. Furthermore, the loss of these habitats will be fully or nearly fully offset by the removal of the existing bridge and associated piles to below the mud line. The small incremental increase in overwater shading resulting from the proposed project would also be offset by the removal of the existing bridge. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.12 WINTER FLOUNDER (*PSEUDOPLEURONECTES AMERICANUS*)

Winter flounder typically are found from Labrador to North Carolina, but are most common in estuaries from the Gulf of St. Lawrence to the Chesapeake Bay (Bigelow and Schroeder 1953, Heimbuch et al. 1994, USACE 2000). This fairly small, thick flatfish is abundant in the Hudson River Estuary, where it is a resident, but may move upriver into fresh water (Heimbuch et al. 1994). It spawns during the winter and early spring, typically at night in shallow, inshore estuarine waters with sandy bottoms. Woodhead (1990) reports spawning to occur mostly in the Lower New York Bay and the New York Bight. The Hudson River is within an area designated as EFH for eggs, larval, juvenile, adult, and spawning adult winter flounder.

Winter flounder have negatively buoyant eggs that clump together and sink following fertilization (Heimbuch et al. 1994, USACE 2000). Optimal egg hatching occurs at 3°C (37°F) and in salinity ranging from 15 to 25 ppt. Winter flounder larvae develop to juveniles within the estuarine systems. In March, April and May, winter flounder larvae can be found in the Upper New York Bay near the bottom (Heimbuch et al. 1994).

For the first summer, young-of-year winter flounder remain in the shallow waters (0.1-10 m [0.2-33 ft] in depth) of bays and estuaries where temperatures are generally less than 28°C

(82°F) and salinities range from 5-33 ppt. Juveniles often occupy areas with sand and/or mud substrates where they feed on a variety of worms and small crustaceans, switching to mostly mollusks as they grow. Juveniles beyond their first year have also been found to overwinter in estuaries at temperatures less than 25°C (77°F), salinities from 10-30 ppt, and depths from 1-5 m (3-16 ft) (Pereira et al. 1999). However, in some studies, wintertime juvenile catches generally increased outside of the estuary while at the same time decreasing within the estuary, suggesting that juveniles migrate out of the estuary in the winter (Pearcy 1962, Warfel and Merriman 1944, and Richards 1963 in Pereira et al. 1999).

Adult winter flounder prefer depths of 20 to 48 m (66-158 ft) and are commonly associated with mud, sand, pebble, or gravel bottoms (USACE 2000), feeding on small invertebrates and fishes. Because they are sight feeders, increased turbidity can interfere with feeding success (USACE 2000).. Adults generally leave the Hudson River Estuary in the summer as water temperatures increase, returning in the autumn (Woodhead 1990). Winter flounder will live close to shore, swimming in shallow water to feed. Adults tend to move to deeper water when water temperatures increase in the summer or decrease in the autumn and winter (Heimbuch et al. 1994). NMFS Northeast Fisheries Science Center (NEFSC) trawls within the New York Harbor Estuary found adult winter flounder at temperatures between 4°C and 12°C (39-54°F) and salinities as low as 15 ppt, although most were found at salinities greater than 22 ppt. The bulk of the adult catch occurred in water depths of 25 m (82 ft) or less in the spring (during and just after spawning) and 25 m or deeper in the autumn (prior to spawning) (Pereira et al. 1999).

All stages of this demersal fish have the potential to occur within the Hudson River in the study area. Winter flounder eggs have been reported in the lower estuary from the Battery to Yonkers near river mile 23 during spring (March and April) , but have not been collected in the Tappan Zee region based on utilities-sponsored fish monitoring data. However, larvae are distributed throughout the River and are commonly observed in most habitats between March and June with peak abundances in the project area during mid-April.

Within the Hudson River, young-of-the-year are most abundant from the mouth of the River at the Battery upriver to Indian Point (river mile 46). Juvenile winter flounder may occur from early April through December, although they are most abundant in the River between April and July, with peak densities in the Tappan Zee region during May and June, based on utilities-sponsored fish surveys conducted from 1998 to 2007. While in the estuary, juvenile winter flounder are most commonly collected in the deeper channel habitats at depths exceeding 20 feet. Catches of winter flounder in the Hudson River Estuary off Manhattan have been reported to be highest from May through June (Woodhead 1990). Older winter flounder have been found in the Harbor Estuary from late May to September (Heimbuch et al. 1994).

While winter flounder are found throughout the Hudson River Estuary, this species is currently experiencing high fishing rates that are in excess of natural production (annual exploitation rates from 55 to 70 percent). The Southern New England/Mid-Atlantic stock unit (which includes the New York population), is subject to overfishing and is considered overfished with reduced harvest currently needed for the fishery to rebuild (NOAA 2011).

Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB re 1 µPa rms guidance for behavioral effect. Furthermore, because winter flounder do not have a swim bladder, the likelihood of physical damage is far lower than for fish species with a swim bladder. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Loss of bottom habitat due to the placement of the piles and other structures (including armoring of the dredged channel) would be minimal and would not be expected to result in significant reductions in fish habitat or prey availability. Furthermore, the loss of these habitats will be fully or nearly fully offset by the removal of the existing bridge and associated piles to below the mud line. The small incremental increase in overwater shading resulting from the proposed project would also be offset by the removal of the existing bridge. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

#### 4.3.13 WINDOWPANE (*SCOPHTHALMUS AQUOSUS*)

Windowpane, also called sand flounder, is found from the Gulf of St. Lawrence to South Carolina and maximally abundant in the New York Bight. Windowpanes are generally found offshore on sandy bottoms in water between 80 m deep (262 ft) and close inshore in estuaries just below the mean low water mark. They migrate inshore into shallow shoal waters in the summer and early autumn as water temperatures increase, and migrate offshore during the winter and early spring months when temperatures decrease. Windowpanes spawn within the mid-Atlantic Bight from April to December in bottom waters, with temperatures ranging from 8.5 to 13.5°C (47-56°F). Spawning peaks occur in May and then again in the autumn in the southern portion of the Bight (USACE 2000). The Hudson River is within an area designated as EFH for eggs, larval, juvenile, adult, and spawning adult windowpane.

The eggs and larvae are found predominately in the estuaries and coastal shelf water for the spring spawning period and in the coastal shelf waters alone for those eggs spawned in the autumn. Windowpane eggs are buoyant, and can be found in the water column at temperatures of 5-20°C (41-68°F), specifically at 4-16°C (39-61°F) in spring (March through May), 10-16°C (50-61°F) in summer (June through August), and 14-20°C (57-68ºF) in autumn (September through November), and within depths less than 70 m (230 ft) (Chang et al. 1999). Larvae are free swimming, and typically are found in the areas of the estuaries where salinity ranges from 18 to 30 ppt in the spring and on the continental shelf in the autumn. Juvenile windowpanes were found year-round in both the shelf waters and inshore during a recent study of the New York Harbor Estuary (Chang et al. 1999). In this study, juvenile fish were fairly evenly distributed but seemed to prefer the deeper channels in the winter and summer. They were most abundant where bottom water temperatures ranged from 5 to 23°C (41-73°F), depths ranged from 7 to 17 m (23-56 ft), salinities ranged from 22 to 30 ppt, and dissolved oxygen concentrations ranged from 7 to 11 mg/L. Similarly, adults were fairly evenly distributed year-round, preferring deeper channels in the summer months. Adults were collected in bottom waters where temperatures ranged from 0 to 23°C (32-73°F), depths were less than 25 m (82 ft), salinity ranged from 15 to 33 ppt, and dissolved oxygen ranged from 2 to 13 mg/L (USACE 2000).

All life stages of windowpane have the potential to occur within the vicinity of the study area in the Hudson River. Eggs have been reported from the lower estuary from the Battery to Yonkers near river mile 23 during much of the year (March to October), Some windowpane eggs have been collected in the vicinity of the project area near Tappan Zee, primarily in May and June, but abundances there are lower than those observed near the mouth of the River. Larval and juvenile windowpane have been frequently collected during utilities-sponsored fish surveys in the River, where highest abundances were typically reported in the lower estuary near the Battery (river mile 0-11). Relatively high abundances were also observed in the Yonkers and Tappan Zee regions, with less abundances further upstream to West Point near river mile 55. Larval windowpanes recruit to channel and bottom habitats in the deeper portion of the River (>20 feet deep) during May and June. Juveniles are most abundant in the project area in the Tappan Zee region during June. The southern New England/Middle Atlantic windowpane stock is currently considered to be subject to overfishing but no longer overfished and the Southern New England/Mid-Atlantic stock is rebuilding (NOAA 2011). As with winter flounder, this species is widely distributed throughout the Harbor Estuary.

Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities. Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB RMS guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Furthermore, because windowpane do not have a swim bladder, the likelihood of physical damage is far lower than for fish species with a swim bladder. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH for this species and would not be expected to affect movement of this species within the river. Water quality changes, including the resuspension of bottom sediments, during construction of the proposed project would be minimal and temporary, limited to the immediate area of the activity. Loss of bottom habitat due to the placement of the piles and other structures (including armoring of the dredged channel) would be minimal and would not be expected to result in significant reductions in fish habitat or prey availability. Furthermore, the loss of these habitats will be fully or nearly fully offset by the removal of the existing bridge and associated piles to below the mud line. The small incremental increase in overwater shading resulting from the proposed project would also be offset by the removal of the existing bridge. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH for this species.

### 4.3.14 CLEARNOSE SKATE (*RAJA EGLANTERIA*)

Clearnose skates are a marine species that occur in the Atlantic Ocean from the Gulf of Maine to northern Florida and in the northern Gulf of Mexico. The Hudson River is within an area designated as EFH for all life stages of the clearnose skate. In the Hudson/Raritan estuary, this species occurs most commonly in the summer, but moves offshore during the cooler months.

Spawning takes place in spring and summer north of Cape Hatteras. Clearnose skates produce a pair of eggs during each of the multiple reproductive events each season and may produce up to 35 pairs of eggs in a year. Eggs are deposited and attached to submerged vegetation or structure and incubate for approximately 90 days, at which time a fully formed juvenile clearnose skate hatches from the egg case.

The center of distribution for juvenile and adult clearnose skates is in coastal waters from Delaware Bay south to Cape Hatteras, with fewer individuals collected in the Hudson/Raritan estuary and Long Island Sound. Those individuals that have been collected near the Hudson River were found near deeper channel habitats. Juveniles and adults are most common at depths ranging from 16 – 26 ft and over soft sediments at salinities > 20 ppt.

Because this is a marine species that prefers higher salinity waters, clearnose skates are not likely to be present within the study area (**Table 14**) except during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species (**Table 14**). This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to EFH for this species.

### 4.3.15 LITTLE SKATE (*LEUCORAJA ERINACEA*)

Little skates are a marine species that occur in the Atlantic Ocean from Nova Scotia to Cape Hatteras. The Hudson River is within an area designated as EFH for all life stages of the little skate. In the Hudson/Raritan estuary, juveniles of this species occur most commonly during winter and spring, but makes short migrations to deeper waters during the summer months. Adults were uncommon in the estuary.

Spawning takes place year-round but is most frequent during winter and summer. Little skates produce a pair of eggs during each of the multiple reproductive events each season and may produce up to 30 pairs of eggs in a year. Eggs are deposited and attached to submerged vegetation or structure and incubate for approximately 180 days, at which time a fully formed juvenile little skate hatches from the egg case.

Juveniles in the Hudson/Raritan estuary are most common at depths ranging from 20 – 26 ft and over coarse, sandy and gravel sediments at salinities between 15 and 33 ppt, with the majority found at salinities > 25 ppt. Fewer adults are found in the estuary, but those that do occur are most common at depths > 23 ft and salinities > 20 ppt.

Because this is a marine species that prefers higher salinity waters, little skates are not likely to be present within the study area (**Table 14**) except during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species (**Table 14**). This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to EFH for this species.

### 4.3.16 WINTER SKATE (*LEUCORAJA OCELLATA*)

Winter skates are a marine species that occur in the Atlantic Ocean from Newfoundland to Cape Hatteras. The center of their distribution is on Georges Bank and the northern portion of the Mid-Atlantic Bight. The Hudson River is within an area designated as EFH for all life stages of the winter skate. In the Hudson/Raritan estuary, this species occurs most commonly from fall through spring, but moves offshore or into deep channel habitats during the summer months.

Spawning takes place from summer to early winter. Like other skates, winter skates produce pairs of egg cases which are deposited and attached to submerged vegetation or structure and incubate until hatching, at which time a fully formed juvenile winter skate emerges from the egg case.

In the Hudson/Raritan estuary, juvenile winter skates are most common at depths ranging from 16 – 26 ft and over sandy and gravel sediments at salinities > 20 ppt. Very few adults are found in this estuary.

Because this is a marine species that prefers higher salinity waters, winter skates are not likely to be present within the study area (**Table 14**) except during periods of low freshwater flows when the salt front is pushed upriver. The habitat found within the Tappan Zee Region of the Hudson River does not represent a significant portion of the EFH for this species (**Table 14**). This species would not be expected to occur near the project site except as rare transient individuals. Therefore, the project would not result in adverse impacts to EFH for this species.

# Chapter 5: Potential Impacts to Marine Turtles Within the Hudson River Bridge Construction Study Area

Four species of marine turtles, all state and federally listed, occur in coastal areas around the mouth of the Hudson River. Juvenile Kemp's ridley (*Lepidochelys kempii*) and large loggerhead (*Caretta caretta*) turtles are most common and regularly enter the New York Harbor and bays in the summer and fall. The other two species, green sea turtle (*Chelonia mydas*) and leatherback sea turtle (*Dermochelys coriacea*), are usually restricted to the high salinity areas of New York Harbor (USFWS 1997) and do not routinely move into the Hudson River as far upstream as the Tappan Zee region. These turtle species primarily inhabit Long Island Sound and Peconic and Southern Bays. They neither nest in the Hudson River Estuary, nor do they reside there year-round (Morreale and Standora 1995). It is unlikely that individuals of these four turtle species would occur in the study area (NMFS 2011b). Therefore, the project would not result in adverse impacts to marine turtles within the Hudson River bridge construction study area.

# Chapter 6: Potential Impacts on Striped Bass Within the Hudson River Bridge Construction Study Area

Striped bass (*Morone saxatilis*) are anadromous, spending most of their life cycle in the marine environment but returning to fresh water to reproduce. They are native to North America and range along the Atlantic coast from the St. Lawrence River in Canada to the St. Johns River in northern Florida and from western Florida to Louisiana along the coast of the Gulf of Mexico. The Hudson River supports one of several principal spawning populations, which also include Delaware Bay, Chesapeake Bay, the Roanoke and Chowan rivers and Albemarle Sound, North Carolina, the Santee River in South Carolina and the St. Johns River in northern Florida.

Adult striped bass on the Atlantic coast feed in nearshore waters from summer through late winter. Northward migration of Hudson River fish extends as far north as the Bay of Fundy, Nova Scotia, with older fish tending to travel further north (Waldman et al. 1990). Over the winter, adult striped bass (ages 4 and older) aggregate near the mouths of their natal rivers and begin moving upstream to spawn as water temperatures increase in the spring. Spawning begins in the spring when water temperatures reach about 57°F. Peak spawning typically occurs at about 60 to 65°F in freshwater areas of estuaries where currents are moderate to swift (CHGE et al. 1999). In the Hudson River, spawning occurs primarily between mid-May and mid-June in the middle portion of the Hudson River Estuary from Indian Point (RM 42) upstream to Saugerties (RM 106) (CHGE et al. 1999; ASA 2010). Depending on their age and size, females produce up to several million pelagic eggs. Based on utilities fish surveys from 1998 to 2007, striped bass eggs are collected in May and June and primarily upstream of Indian Point at river mile 46, with peak densities near Cornwall (river mile 56-61) and very low densities in the Tappan Zee region. Yolk-sac larvae (YSL) hatch from the eggs in 25 to 109 hrs, depending on temperature. Typically 0.125-inches long at hatching, the YSL initially drift with the current. Older YSL are mobile and exhibit positive phototaxis, or movement toward light (CHGE et al. 1999).

Larval striped bass recruit to the River during summer (May-July) and are abundant throughout the Hudson River but occur in higher numbers from Tappan Zee to Hyde Park than in the lower estuary. The higher numbers of striped bass larvae in the upstream reaches of the Hudson River are a result of spawning in the Croton-Haverstraw reach and further north.

As juveniles, striped bass begin move out of the middle estuary into the broader, shallower nursery habitat of the lower estuary (Tappan Zee through Croton-Haverstraw Bays, RM 24 through RM 38) to feed on copepods and amphipods. Larger juveniles feed on insect larvae, worms, opossum shrimps, crabs and small fish (Gardinier and Hoff 1982). Juvenile abundances are typically highest during late summer (July and August) and upstream Hyde Park in deeper (>20-ft) bottom habitats. In the Tappan Zee region, juvenile striped bass are frequently collected in shallow shoal and deeper bottom habitat, as well.

By the end of their first summer, many juvenile striped bass have moved downstream to the lower estuary and into New York Harbor, western Long Island Sound and along the south shore of Long Island (CHGE et al. 1999; Dunning et al. 2009). Juvenile striped bass overwinter in the lower Hudson River estuary, where they feed primarily on benthic invertebrates, such as gammarid amphipods (Dunning et al. 2009). During their second year, striped bass become largely piscivorous (Walter et al 2003; Dunning et al. 2009) consuming American shad, alewife, blueback herring, white perch, Atlantic tomcod and bay anchovy (Walter et al 2003; Dunning et al 1997; Heimbuch 2008). Juvenile striped bass are also prey for some marine and estuarine predator species.

At Age 2 or 3, striped bass leave Atlantic coast estuaries and begin the typical seasonal coastal migration, northward during the spring and summer and southward during the fall. Dispersal of Age 2+ striped bass out of the Hudson River is density-dependent and possibly to reduce intra-specific competition for food (Dunning et al. 2006). Striped bass in the Hudson River exhibit multiple life history strategies. Some individuals are thought to mature and remain year round in the upper freshwater portion of the estuary, while others adopt an anadromous life style and, once sexually mature, spend most of their time in coastal saltwater habitats but enter freshwater and brackish habitats in the spring to spawn (Zlokovitz et al. 2003).

Adult striped bass are top predators and are prey to few other animals. Adult striped bass in the Lower Hudson-Raritan Estuary prey upon at least 20 different taxa, dominated by a variety of small-bodied and juvenile fishes and crustaceans (Steimle et al. 2000; Dunning et al. 2009). Striped bass predation can impact juvenile abundances of prey species, including alewife and blueback herring, Atlantic tomcod, white perch, and bay anchovy (Heimbuch 2008; Schultz et al. 2006). Intraspecific predation (i.e., cannibalism) may also reduce the survival of striped bass from PYSL to juveniles (Heimbuch 2008). Since striped bass rarely move more than 10 miles offshore, they are available to sport and commercial fishermen throughout their migration route, often resulting in significant sport and commercial harvest (ASMFC 2009c). The most recent stock assessment for striped bass found that the coastal stock is healthy, with spawning stock biomass well above the target level specified in the Interstate Fisheries Management Plan (ASMFC 2009c) and stocks at historically high levels (NYSDEC 2010c).

The project would not result in adverse impacts to striped bass. Adult striped bass enter the Hudson River to spawn during spring and summer but spend most of their time in coastal waters, not within the study area for the project. Spawning occurs in freshwaters far upstream of the study area and would not be adversely affected by the construction or operation of the Replacement Bridge Alternative. Because striped bass spawning occurs far upriver, the majority of the larval striped bass are also located upstream of the study area. Some larvae would also drift with the prevailing current downstream and into the study area where they are very abundant during the summer. Juvenile striped bass are found in the Tappan Zee region within the study area as well. However, the highest abundances of juvenile striped bass are upstream of the study area, in the Hyde Park region. Because striped bass larvae and juveniles are widely distributed throughout the Hudson River, losses of individuals resulting from the construction of the project would not result in adverse impacts to striped bass populations of the Hudson River.

The analysis performed in the DEIS indicated that for the Short Span Option, the number of striped bass encounters within the boundaries of a $SEL_{cum}$ level of 187 dB re $1\mu Pa^2$-s (onset of physiological effects would range from 0.08% (lower bound) to 0.7% (upper bound) of their standing stock. For the Long Span Option the number of fish encounters within the 187 dB re $1\mu Pa^2$-s ispoleth would range from approximately 0.06 percent to 0.7 percent of the striped bass standing stock. There would be far fewer striped bass that would be exposed to sound levels that would bring on the onset of injury (197 dB re $1\mu Pa^2$-s) or mortality (207 dB re $1\mu Pa^2$-s).

# Chapter 7: Summary of Effects on EFH and Designated Species Within the Hudson River Bridge Construction StudyArea

## 7.1 POTENTIAL DIRECT IMPACTS

Direct effects are considered to be any adverse effects arising from project activities that could result in immediate impacts on individual fish. The primary potential direct impact to EFH species from the project is the physical disturbance to adults and juveniles as a result of pile driving, increased vessel traffic, and dredging. In the winter, few, if any, of the EFH species are likely to be in the project area because the salinity of the Hudson River within the study area would be far below the preferred salinity range. However, in the warmer months of the year several EFH species do frequent the Tappan Zee Region. Sounds from pile driving and other in-water construction activities will be temporary, and would not be expected to represent a barrier to movement of individuals within the Hudson River. Potential hydroacoustic impacts to fish using the deep water portions of the Hudson River due to pile driving with an impact hammer would only occur during the initial few months of in-water construction activities, and from April 1 to August 1 would be restricted to 5 hours per day for the 8- or 10-foot diameter piles in the vicinity of the navigation channel (i.e., Zone C— waters18 feet or deeper at MLLW). Pile driving would not occur at night and would not be continuous during the day (i.e., when piles are being put in place or being welded, or when the pile driver is being relocated). For most of the pile driving scenarios modeled, including those in which the maximum number of simultaneous piles are being driven and/or for the largest piles, a substantial portion of the Hudson River's width would never reach the $SEL_{cum}$ criterion established for onset of physiological injury, and portions of the river would also be below the 150 dB re 1 µPa rms guidance for behavioral effect. Fish would not be expected to remain in an area at which noise would cause discomfort. Therefore, the hydroacoustic environment resulting from pile driving with an impact hammer would result in a temporary loss of a small area of EFH and would not be expected to affect movement of EFH species within the river. The species identified as having EFH within the study area are common throughout the waters of the Lower Hudson Estuary and it is anticipated that only a small percentage of the fish stock in the region would be exposed to potential impact. None of the EFH species utilize the project area or the Tappan Zee Region as their sole spawning grounds and/or critical habitat. Therefore, pile driving with an impact hammer would not be expected to result in adverse impacts to EFH or the species identified as having EFH within the study area.

The potential direct effects associated with increases in vessel traffic within the dredged construction channel include potential collision with vessels and disturbance of foraging and migratory adults and juveniles associated with an increase in surface activity and noise. For the fish species for which EFH has been designated in the Hudson River, the effects of vessel strikes is likely a function of fish size and location within the water column; however, impacts to these (smaller) species from increased vessel traffic is more likely to occur in the form of propeller damage. However, the increased surface activity and associated noise would have the potential to displace/disrupt adults and juveniles during foraging and migratory activities within the vicinity of the in-water activities on a given day, which would minimize the potential for losses due to contact with vessels.

The frequency of dredging or disturbance of an area affects the invertebrate community and its ability to recover following each dredging event. For EFH species that feed on benthos dredging would result in a sizable loss of bottom habitat and temporary alteration of this habitat that could affect foraging opportunities. However, benthic communities found in environments with a great deal of variability such as estuaries generally have high rates of recovery from disturbance, because they are adapted to disturbance. Recovery of the benthic macroinvertebrate community within the dredged and armored areas is expected to start upon cessation of bottom disturbing construction activities in a particular portion of the dredged construction channel. Therefore, while the dredging would result in the loss of individual macroinvertebrates, it is not expected to result in adverse impacts of these species at the population level within the Hudson River Estuary. The majority of the bottom habitat and associated benthic macroinvertebrates within the area impacted is the soft sediment community which dominates the Upper New York Harbor and Hudson River. Deposition of sediment into the dredged channel is projected to occur at a rate of one foot per year. Recolonization by benthic organisms adapted to softer sediments could be expected to begin within a few months after completion of in-water activities in any given area. Prior to the deposition of sufficient sediment to support a soft substrate benthic invertebrate community, some recolonization of the gravel armor material would be expected occur.

## 7.2 POTENTIAL INDIRECT IMPACTS

Indirect effects are defined as any effects that are caused by or will result from the proposed action later in time that do not directly affect individuals but may affect them by changes in habitat. The primary potential indirect impact to EFH species at the bridge-construction site is the physical disturbance as a result of loss of habitat, changes in interpier water velocities, total suspended solids (TSS), re-deposition of sediments from dredging activities, and operational impacts on water quality. Loss of bottom habitat due to the placement of the piles and other structures (including armoring of the dredged channel) would be minimal and would not be expected to result in significant reductions in fish habitat or prey availability. Furthermore, the loss of these habitats will be fully or nearly fully offset by the removal of the existing bridge and associated piles to below the mud line. Therefore, habitat changes resulting from the project would not adversely affect EFH.

Water quality changes resulting from resuspension of bottom sediment during dredging and other sediment disturbing construction activities would be minimal and temporary, limited to the immediate area of the activity, and within the range of suspended sediment concentration reported for this portion of the Hudson River. Therefore increases in suspended sediment resulting from dredging and other sediment disturbing construction activities would not adversely affect EFH.

Upon completion of construction, the operational impacts of either option would be largely positive. The wider spacing of piers for both options would reduce benthic scour and allow for more sunlight to enter the water column; thereby, reducing the conditions currently experienced along the western cause way of the existing bridge. The Long Span Option would have wider spaced piers which would thereby further reduce interpier velocity and scour than the Short Span Option configuration. The Replacement Bridge Alternative would result in a decrease in the potential for shading impacts to aquatic resources and the overwater shading resulting from the proposed project would also be offset by the removal of the existing bridge. Operation of the project would not result in adverse impacts to water quality of the Hudson River, or adversely affect aquatic habitat due to under-bridge lighting. Therefore, the project would not result in adverse impacts to the EFH.

## 7.3 POTENTIAL CUMULATIVE IMPACTS

The assessment of cumulative effects addresses the potential impacts from the project and other projects proposed within, or in the vicinity of, the Hudson River bridge construction study area that may affect EFH, striped bass, and marine turtles. Within the Hudson River, the proposed Champlain Hudson Power Express Inc. cable project and the American Sugar Refining, Inc. maintenance dredging project are the projects identified for evaluation of cumulative effects with the Tappan Zee Replacement Bridge Alternative because they are reasonably foreseeable during construction and may use the same project area. At the present time, US Gypsum, located upriver within Haverstraw Bay, is not expected to dredge its Stony Point facility and is not, therefore, evaluated with respect to cumulative impacts for the Replacement Bridge Alternative.

Champlain Hudson Power Express Inc. filed an application for a Certificate of Environmental Compatibility and Public Need Pursuant to Article VII of the Public Service Law of New York State. The Applicant is proposing to construct and operate a 1,000 MW submarine, underground, high-voltage, direct current, cable transmission system which will transport power from Canada and upstate New York to load centers in the New York City metropolitan area. The proposal calls for burying cables within two separate trenches 6 feet apart along a 118-mile stretch of the Hudson River that includes the study area for the Tappan Zee Replacement Bridge Alternative. Within the study area, the cables would be buried through the use of water jetting, where possible, and by hydroplow or dredging where water jetting is not feasible (i.e., within Haverstraw Bay).

Depending upon the proposed timing of the submarine cable installation, there is a potential for conflict between the competing activities of the cable and Replacement Bridge Alternative that would need to be resolved for the portion of the cable that would be traversing the study area. Water jet embedment as a technique for underwater cable installation, is considered to have temporary and minimal impacts to aquatic resources compared to dredging. This is because the trench (four feet deep and two feet wide) created by the jetting device for each cable and its installation would only result in a temporary disturbance of the river bottom (ESS 2011). The associated increase in suspended sediments would also be expected to be short-term and localized because much of the resuspended sediments would be contained within the limits of the trench wall, with only a minor percentage of the re-suspended sediments leaving the trench. Any re-suspended sediments leaving the trench would be expected to settle out within proximity of the trench depending on sediment grain size, composition, water currents and the hydraulic jetting forces imposed on the sediment column (HDR/DTA, April 2010, *Champlain Hudson Power Express HVDC Transmission Project, Least Environmentally Damaging Practical Alternative Evaluation*, Prepared for Champlain Hudson Power Express, Inc., Toronto, Ontario, http://www.chpexpress.com/docs/regulatory/USACE/CHPE_USACE_Application_Apendices.pdf). Water jetting would potentially result in the loss of some benthic organisms unable to move from within the footprint of the trench, due to direct contact with the water jet or an inability to tolerate burial. The benthic community within the disturbed area would be expected to recover following completion of the trenching process (Ocean Surveys, Inc. 2005 in HDR/DTA 2010). Finfish would be expected to avoid areas of temporarily increased suspended sediment (HDR/DTA 2010).

American Sugar Refining, Inc. received authorization from the NYSDEC and the USACE to conduct maintenance dredging (approximately 80,000 cubic yards) within an approximately 5-acre berth area (approximately 650- to 850-feet long and extending into the river from the shoreline for about 300 feet) located about 14 miles downriver from the study area. The NYSDEC permit expires on October 31, 2016. It restricts dredging to the period of July 1 to October 31 and requires that anti-sedimentation curtains (floating boom with attached silt curtain with a minimum 3-ft depth) be deployed around the spoil-receiving barge and the mechanical dredge during dredging to minimize dispersal of dredged material. Dredge material was determined to meet the requirements for disposal at the HARS and would be transported to the HARS in bottom-opening barges.

Maintenance dredging by American Sugar Refining, should it occur concurrently with dredging for the project, would be at least 14 miles down-river. This distance is far beyond the 1,000 to 2,000 feet over which the incremental increase in suspended sediment of 10 mg/L due to the Replacement Bridge Alternative has been projected by the hydrodynamic modeling and beyond the 5 mg/L incremental increase in projected suspended sediment. Furthermore, compliance with the permit conditions would minimize the potential for the maintenance dredging to adversely affect water quality due to increased suspended sediment.

Cumulative adverse impacts to EFH, striped bass, and marine turtles would not be expected to occur as a result of the cable project and maintenance dredging activities with the Replacement Bridge Alternative. Collectively, these projects would not have the potential to affect spawning habitat within the study area for the species evaluated because the majority of the EFH spawn in the coastal and offshore waters of the Atlantic Ocean. No eggs were collected in the Tappan Zee region (RM 24-33) for 11 of the 13 EFH species. Striped bass spawn in the freshwater reaches of the Hudson River well upstream of the Tappan Zee region (RM 24-33) based on peak egg densities in the Cornwall region (RM 56-61). Eggs of Atlantic mackerel have also been reported in the Tappan Zee region, but only rarely and in very low densities, based on utilities fish surveys. The primary spawning habitat for this species is located over the continental shelf within the Mid-Atlantic Bight, with very little evidence for spawning in tidal rivers or estuaries. The primary spawning habitat for windowpane flounder is located in the nearshore coastal waters of the Mid-Atlantic Bight; however, spawning is also known to occur in the saline portions of the lower Hudson River at salinities greater than 25 ppt. Windowpane flounder eggs have been collected in low relative abundance during utilities fish surveys in the Tappan Zee region. The majority of windowpane flounder eggs are reported from the lower 23 miles between the Battery and Yonkers. On the basis of the range of preferred spawning salinities for windowpane flounder and the relatively low abundance of eggs in the Tappan Zee region, it is likely that eggs spawned downstream of the Tappan Zee study area are transported upstream on flood tides, rather than being spawned in the study area. Low densities of striped bass eggs have been reported by the utilities fish surveys from the Tappan Zee region suggesting that some spawning may occur just upstream of, or within, the study area. Based on considerably higher egg densities upstream of the project area, the low densities of striped bass eggs collected in the Tappan Zee region do not represent a significant proportion of the population's reproductive output.

The limited duration and area of disturbance resulting from cable installation within the study area would not be expected to result in changes in water quality (i.e., increases in suspended sediment) or result in long-term changes to aquatic habitat. Furthermore, the cumulative activities of these projects are not expected to adversely affect foraging or migration through the study area for EFH or striped bass. Should dredging be required for the installation of the cable in Haverstraw Bay, the distance between the study area and Haverstraw Bay is greater than 5 miles and outside the projected area of incremental increase in suspended sediment due to the project and would not result in cumulative adverse impacts to water quality within the study area. Therefore, cumulative adverse effects to water quality would not be expected to occur from these three projects.

The area of maintenance dredging for American Sugar Refining extends only 300 feet into the river from the east bank and does not extend into the navigation channel. Therefore, the three projects would not be expected to result in cumulative adverse impacts to migration of EFH or other anadromous fish species.

In summary, no cumulative adverse impacts to EFH, striped bass, and marine turtles would be expected to occur from the Replacement Bridge Alternative at the bridge-construction site near Tappan Zee in the Hudson River.

# Chapter 8: EFH Assessment for Placement of Project Dredged Material at the HARS

## 8.1 INTRODUCTION

As discussed in Section 2.4.3.3, "Transport and Disposal of Dredged Material," the disposition of the dredged material would be left to the discretion of the contractor. However, transport by ocean scow and placement in the HARS in the New York Bight would offer a number of benefits to the project including cost, schedule, logistics and the avoidance of impacts to the surrounding residential communities on the Rockland and/or Westchester shorelines. Should this option be pursued by the contractor, the dredged materials would be transported to the HARS. This chapter:

- identifies the environmental reviews and consultations that have been undertaken for remediation of HARS, including the programmatic EFH for Placement of Category I Dredged Material at the Historic Area Remediation Site in the New York Bight Apex;
- summarizes the findings from the "*Programmatic Essential Fish Habitat Assessment for Placement of Category I Dredged Material at the Historic Area Remediation Site in the New York Bight Apex* (USACE 2002), the measures incorporated in the Site Management and Monitoring Plan for the Historic Area Remediation Site (USACE and USEPA 2009) to manage the operational aspects of dredging, HARS remediation activities and HARS monitoring;
- identifies the volume and characteristics of dredged material from the project that would be placed at the HARS as Remediation Material;
- evaluates potential adverse impacts to aquatic biota and EFH from offshore dredged material disposal at the HARS;
- provides profiles for the EFH species currently identified as having EFH in the vicinity of the HARS that were not evaluated in the programmatic EFH for HARS (i.e., clearnose skate, little skate, smooth dogfish, thresher shark and winter skate) and describes the applicability of the Programmatic EFH assessment for HARS to the project; and
- evaluates potential direct, indirect and cumulative impacts to EFH due to placement of dredged material from the project at the HARS.

## 8.2 AGENCY CONSULTATIONS

### 8.2.1 NEPA AND SECTION 7 CONSULTATION

Pursuant to the National Environmental Policy Act (NEPA) the USEPA Region 2 prepared a Supplement to the Environmental Impact for the HARS (USEPA 1997). Consultations pursuant to Section 7 of the Endangered Species Act (ESA) have taken place for the area of the HARS during preparation of the SEIS. The USEPA prepared a biological assessment that concluded that the closure of the Mud Dump Site and designation of the HARS would not be likely to adversely affect loggerhead and kemps ridley sea turtles, and humpback and fin whales (USEPA

1997). Special conditions are included in USACE Section 103 permits for placement of Remediation Material at HARS that requires the presence of NMFS approved Endangered Species Observer(s) on disposal scows during their trips to the HARS. The role of these observers is to prevent adverse impacts to endangered or threatened species transiting the area between the proposed dredge site and the HARS. With the implementation of these conditions placement of Remediation Material at the HARS would not result in adverse impacts to listed endangered or threatened species.

### 8.2.2 PROGRAMMATIC EFH FOR PLACEMENT OF CATEGORY I DREDGED MATERIAL AT THE HARS

Disposal of dredged material offshore such as the placement of Remediation Material at the HARS has the potential to result in the following impacts:

- burial/disturbance of benthic habitat;
- conversion of substrate/habitat and changes in sediment composition;
- increased in suspended sediment and turbidity;
- release of contaminants in the water column;
- changes in bottom topography, altered hydrological regimes and altered current patterns; and
- release of nutrients/eutrophication (NMFS 2008).

The USACE prepared a programmatic EFH for placement of Category 1 Dredged material at the HARS (SACE 2002), which was reviewed by NMFS. On the basis of the programmatic EFH and information provided by the USACE and USEPA during the site designation process the NMFS determined that the agency had no conservation recommendations to offer provided that the HARS is operated in accordance with the SMMP and that no further consultation pursuant to Section 305(b) of the Magnuson Stevens Act would be necessary. The Programmatic EFH for the HARS, attached to this EFH as Attachment 1, assessed the potential effects of the placement of Category I dredged material on the managed fish species identified as having EFH within the HARS. Table 15 presented below indicates the managed species currently identified as having EFH in the vicinity of the HARS and identifies those species and or life stages that were not evaluated in the programmatic EFH for the HARS. These species include clearnose skate, little skate, smooth dogfish, thresher shark and winter skate.

Direct impacts evaluated in the programmatic EFH included the burial of the benthic community with Remediation Material and temporary increases in suspended sediment. This loss of prey species for EFH dependent on benthic invertebrates would be minimized spatially and temporally through use of a grid system for the placement of Remediation Material. The USACE determined that direct burial of EFH species is possible yet improbably and, therefore, would have minimal impact on target species of their EFH. Although the placement of Remediation Material would have the potential to result in increased turbidity and contaminant concentrations, these effects are typically short-lived (less than one hour) and would cause no more than minimal impact on EFH. Furthermore, recolonization of a healthier benthic community would occur by those benthic invertebrate individuals able to unbury themselves and recolonization by individuals from nearby similar habitats. The placement of Remediation Material would result indirect impacts through minor changes in bathymetry that would not be expected to create noticeable changes in the physical oceanography and would not be sufficient to alter the relationship of the benthic community with the photic zone. The cumulative impacts resulting from placement of Remediation Material at the HARS would be beneficial because the "remediation of the HARS will result in an improved benthic community, and ultimately, improvement of the fishing and shellfishing resources of the New York Bight" (USACE 2002).

The programmatic EFH for the HARS states that "The remediation of the HARS with Category I sediments is the most expeditious means of eliminating the potential risk associated with contaminated sediments of the Priority Remediation Area. Decreased contaminant toxicity and bioavailability to fish and shellfish resources will greatly reduce the risk to biota of the New York Bight. The planned remediation will also prevent dispersion of degraded sediments from the seafloor as a result of resuspension due to high-energy events." Placement of Category I dredged material at the HARS was determined to result in "no more than minimal impact to Essential Fish Habitats" for the species evaluated and that "remediation efforts at the HARS should be conducted without the need for seasonal restrictions or mitigation measures to protect habitat or individual species" (USACE 2002).

## 8.3 POTENTIAL IMPACTS FROM THE PLACEMENT OF DREDGED MATERIAL FROM THE PROPOSED PROJECT AT THE HARS

Remediation Material has been placed at the HARS since at least 1998. Permit and contract specifications require placement at pre-determined locations within the HARS. Since development and installation of the Automated Disposal Surveillance System (ADISS) monitoring/positioning systems aboard scows and tugs, discrete placement grids have been used for organized placement at the HARS. ADISS allows placement at designated latitude-longitude coordinates. Specific grid coordinates and instructions/requirements are contained in the Department of the Army permits issued by the USACE. Placement of Remediation Material within the nine PRAs (approximately 1 square nautical mile) is managed in priority order, beginning with PRA-1 and ending with Area 9. Use of a particular PRA may be discontinued upon completion of remedial activities and demonstration that at least a 1 meter cap of Remediation Material has been placed over the entire area. Placement is occurring in several phases within each area to allow consolidation of sediments and assessment of coverage. The USACE, using the STFate numerical model, determine the distance from the HARS border where material can be placed such that water quality standards are not exceeded. Most maintenance dredging projects, which are predominantly composed of silt and clay, have been used to remediate the central and eastern portions of HARS PRAs 1, 2, and 3 and the northern portion of PRA 4. Remediation Material that is mostly sand and dredged rock has been used to remediate areas closer to the outer edges of PRAs 1 through 3 (USACE and USEPA 2009).

The grid area designated for placement is proportional to the estimated volume of material for remediation associated with each project with higher volume projects using larger area grids. Grid cells are typically 250 feet by 500 feet, with cells of 100 to 150 feet by 100 to 200 feet used for coarse material. The goal is to provide 0.5 to 3 feet of coverage within a grid during each dredging project. If an area has been used for placement of maintenance mud, usually the area is not used for additional placement for a year to allow compaction and dewatering of the mud. Grids for concurrent projects are spaced far enough apart, at least 3280 feet if one grid is due north of the other, to avoid vessel interference during placement (USACE and USEPA 2009).

As presented in Table 5 of this EFH, dredging would be conducted in three stages, each stage conducted during a separate dredging season occurring within a three-month period from August 1 to November 1. For the Long Span Option, the option with the higher dredging quantities, approximately 1.12 MCY would be dredged during Stage 1, 0.43 MCY during Stage 2, and 0.19 MCY during Stage 3, for a total of 1.74 MCY. This volume is about 5 percent of the volume of Remediation Material placed at the HARS in PRAs 1 through 4 as of December 2008.

Section 2.3.4, “Sediment Characteristics,” provides a detailed discussion of the sediments within the study area that would be dredged as a result of the project. As discussed in that section, Hudson River bottom sediments in the study area comprise primarily clayey silt, similar to much of the sediment within the HARS and already evaluated by the USEPA and the USACE with respect to water quality effects during placement. Additionally, the dredged material from the project would only be placed at HARS as Remediation Material if it is determined to meet the Category I sediment criteria, and therefore, would not cause significant undesirable effects to aquatic biota, including through bioaccumulation. The dredged material would be placed at the location and in accordance with the placement protocols that would be specified in conditions issued by the USACE in the permit for the project. Therefore, increases in suspended sediment and concentrations of contaminants that may be released due to placement of the dredged material from the project within the HARS would be expected to dissipate rapidly and would not result in adverse impacts to water quality or result in adverse effects to fish and other aquatic biota due to changes in water quality. Similarly, the location for placement selected by the USACE, would be determined on the basis of the sediment characteristics developed on the basis of sediment sampling that would be conducted as part of the Section 103 permit application, and would not be expected to adversely affect water quality outside the mixing zone established for the HARS.

As evaluated in the programmatic EFH, direct impacts to fish during placement of the dredged material at the HARS would be expected to be minimal due to the small contact footprint of the fluidized sediments as they leave the barge (typically 50 foot by 100 foot), Remediation Material is placed sequentially in a predetermined grid, resulting in continuous remediation in one zone rather than random placement increasing the chance of escape by fish using the area, and noise from vessels repetitively working in one area would further increase the likelihoods that fish would leave the area receiving placement of material.

Fish species that feed on benthic or pelagic fishes or squid (e.g., bluefish, summer flounder, scup) are present at the HARS. Individuals of these species would be expected to leave the area receiving dredged material during a placement event. Because there would be sufficient similar habitat available nearby with similar benthic invertebrates, adverse impacts due to loss of prey species would not be expected to occur to these species. Fish that feed on pelagic and planktonic invertebrates and larvae (e.g., Atlantic sea herring, red hake, and Atlantic butterfish) would have minimum disruption to their feeding. It is anticipated that these species would avoid the Remediation Material and plume, and simply relocate to neighboring waters.

Because the characteristics of the sediment from the project would be similar to those in and around the HARS, benthic invertebrates would be expected to quickly recolonize the cells used for the placement of this material.

## 8.4 EFH SPECIES

**Table 15** presents the fish species and life stages identified as having EFH within the HARS. The five species not evaluated in the programmatic EFH, clearnose skate, little skate, smooth dogfish, thresher shark and winter skate, are profiled below.

### 8.4.1 CLEARNOSE SKATE (*RAJA EGLANTERIA*)

The clearnose skate occurs along the Atlantic coast from the Nova Scotian Shelf to northeastern Florida and in the northern Gulf of Mexico from Texas to Florida. It is considered a southern species that is rare in the northern part of its range (Packer et al. 2003a). The New York Bight is within an area designated as EFH for juvenile and adult clearnose skates. North of Cape Hatteras, clearnose skates move inshore and northward along the continental shelf during the spring and early summer and offshore and southward during autumn and early winter. This species occurs off of New Jersey and New York from late April through May and October through November (Packer et al. 2003a).

In winter, juveniles are concentrated from the Delmarva Peninsula south to Cape Hatteras out to the 200 m contour. In spring they concentrate inshore from the Delmarva south to Cape Hatteras. In summer they occur inshore from the New Jersey coast to around Cape Hatteras with a limited presence off Cape Cod. In Hudson-Raritan Estuary bottom trawls, the largest numbers were found in the summer, particularly in and near channels and south of Coney Island. Small numbers were collected in the spring and autumn, with very few collected in the winter. The distribution of adults in Hudson-Raritan Estuary trawls was similar to that of the juveniles (Packer et al. 2003a).

This skate is found on soft bottoms along the continental shelf but also occur on rocky or gravelly bottoms. It is most abundant at depths less than 364 feet. The Hudson-Raritan trawls found juveniles most abundant at depths of 16 to 23 feet and temperatures 55 to 75°F. Adults were most abundant at depths of 16 to 26 feet and temperatures 48 to 75°F. In this survey, clearnose skates were found at salinities ranging from 22 to 32 ppt (Packer et al. 2003a).

Clearnose skates juveniles and adults would have the potential to occur at the HARS during the period that dredged material from the project would be placed at the HARS, late summer through late fall, although the larger population of this southern species is concentrated around the Delmarva Peninsula and further south. The northeastern stocks of clearnose skate are not overfished and nor is overfishing occurring (NMFS 2011). Because the placement of the Remediation Material from the project would not result in adverse impacts to water quality, sufficient bottom habitat would still be available for foraging for benthic invertebrates within the vicinity of the area receiving placement, and a small percentage of the population for this species would be expected to occur within the HARS, the placement of dredged material from the project at HARS would not result in adverse impacts to EFH for this species.

**Table 15**
**Essential Fish Habitat Designations by Life Stage Within the Historical Area Remediation Site**

| Species | | Life Stage | | | |
|---|---|---|---|---|---|
| **Common name** | **Scientific name** | **Eggs** | **Larvae/YOY** | **Juvenile** | **Adult** |
| Atlantic bluefin tuna | *Thunnus thynnus* | | | X | (1) |
| Atlantic cod | *Gadus morhua* | | | | X |
| Atlantic herring | *Clupea harengus* | | X | X | X |
| Atlantic skipjack tuna | *Katsuwonus pelamis* | | | | X |
| Blue shark | *Prionace glauca* | n/a* | (1) | X (2) | X |
| Clearnose skate | *Raja eglanteria* | | n/a* | | X (2) |
| Dusky shark | *Carcharhinus obscurus* | n/a* | X | X | X (2) |
| Little skate | *Leucoraja erinacea* | | n/a* | X (2) | |
| Monkfish | *Lophius americanus* | X | X | X | X |
| Ocean pout | *Macrozoarces americanus* | X | X | X | X |
| Red hake | *Urophycis chuss* | X | X | X | X |
| Sand tiger shark | *Carcharias taurus* | n/a* | X | | |
| Sandbar shark | *Carcharhinus plumbeus* | n/a* | (1) | X | X |
| Shortfin mako shark | *Isurus oxyrinchus* | n/a* | X | X | X (2) |
| Silver hake (whiting) | *Merluccius bilinearis* | X | X | X | X |
| Smooth dogfish | *Mustelus canis* | n/a* | X (2) | X (2) | X (2) |
| Thresher shark | *Alopias vulpinus* | n/a* | X (2) | X (2) | X (2) |
| Tiger shark | *Galeocerdo cuvier* | n/a* | (1) | X (2) | X (2) |
| White shark | *Carcharodon carcharias* | n/a* | X (2) | X | X (2) |
| Windowpane flounder | *Scophthalmus aquosus* | X | X | X | X |
| Winter flounder | *Pseudopleuronectes americanus* | X | X | X | X |
| Winter skate | *Leucoraja ocellata* | | n/a* | X (2) | |
| Witch flounder | *Glyptocephalus cynoglossus* | X | X | | |
| Yellowtail flounder | *Limanda ferruginea* | X | X | X | X |

**Notes:**
(1) Species was present in Programmatic EFH for the HARS
(2) Species was not present in Programmatic EFH for the HARS
* Life stage does not exist for this species

**Sources:**
NOAA's EFH Mapper (http://sharpfin.nmfs.noaa.gov/website/EFH_Mapper/map.aspx)
USACE. Undated. Programmatic Essential Fish Habitat Assessment for Placement of Category I Dredged Material at the Historic Area Remediation Site in the New York Bight Apex.

### 8.4.2 LITTLE SKATE (*LEUCORAJA ERINACEA*)

Little skates occur from Nova Scotia to Cape Hatteras and are one of the most dominant demersal (bottom-dwelling) species in the northwest Atlantic. The center of abundance is in the northern portion of the Mid-Atlantic Bight and on George's Bank, where it is found year-round. Little skates do not make extensive migrations but do move onshore and offshore with the seasons, generally to shallow waters in the spring and deeper waters in winter (Packer et al. 2003b). The New York Bight is within an area designated as EFH for juvenile and adult little skates.

Little skates are generally found on sandy or gravelly bottoms but can also be found on muddy bottoms. This species are generally found in the Hudson-Raritan Estuary when temperatures are less than about 61 to 64°F. Juvenile little skates are generally absent from the Hudson-Raritan Estuary and the New York Bight apex during summer months and well distributed throughout in the spring, autumn, and winter. Those that were collected in the estuary in the summer during trawl surveys were generally found in the deeper, warmer waters of channels. Juveniles were generally found at depths between 13 to 79 feet and salinities between 17 and 35 ppt (but most at ≥ 25 ppt).

Few adults were collected during the Hudson-Raritan Estuary surveys (conducted 1992-1997), and only two adults were collected during summer surveys. Temperatures where this species was collected ranged from 34 to 63°F, depths from 5 to 16 m (16 to 52 feet), and salinities from 18 to 32 ppt (but most at ≥ 25 ppt). Based on NEFSC trawls, juvenile little skates have the potential to occur in the Hudson-Raritan Estuary and in the New York Bight apex in the autumn through the spring, although the adults would be less common, and would therefore, have the potential to be present during the period when dredged material from the project would be placed at HARS. The northeastern stocks of little skate are not currently overfished nor is overfishing occurring (NMFS 2011). Because the placement of the Remediation Material from the project would not result in adverse impacts to water quality, sufficient bottom habitat would still be available for foraging for benthic invertebrates within the vicinity of the area receiving placement, and a small percentage of the population for this species would be expected to occur within the HARS, the placement of dredged material from the project at HARS would not result in adverse impacts to EFH for this species.

### 8.4.3 WINTER SKATE (*LEUCORAJA OCELLATA*)

The winter skate occurs from the south coast of Newfoundland and the southern Gulf of St. Lawrence to Cape Hatteras. Its center of abundance is on Georges Bank and in the northern portion of the Mid-Atlantic Bight. It is often second in abundance to the little skate (Leucoraja erinacea) and immature winter skates are often confused with immature little skates (Packer et al. 2003c). The New York Bight is within an area designated as EFH for juvenile and adult winter skates.

This skate is found most often on sandy or gravelly bottoms but can also be found on muddy bottoms. It is most abundant at depths less than 364 feet. During surveys of the Hudson-Raritan Estuary, juvenile winter skates were generally absent during the summer and well distributed in winter, spring, and autumn. This species was most abundant in winter. Those individuals present in the summer were generally found in deeper channel waters. Juveniles are found in warmer waters during the spring and autumn (most at 6 to 9°C and 5 to 17°C, respectively) than winter (mostly in 0 to 7°C), and remain mostly around depths of 16 to 26 feet during those seasons.

Salinities ranged from 15 to 34 ppt, but most were found between 23 and 32 ppt. Very few adults were collected in these surveys (conducted 1992-1997). Too few were found to determine their habitat preferences.

Juvenile and adult winter skates have the potential to occur within the vicinity of the New York Bight and the HARS. The center of distribution for winter skate stocks in the Northeast region is over Georges Bank, north of the HARS, although this species does occur in lesser abundance in the northern Mid-Atlantic Bight and within the New York Bight (Packer et al. 2003c). Seasonally, winter skate juveniles and adults are more common in the vicinity of the HARS during winter and spring and less abundant during the summer and fall months. Therefore, individuals would have the potential to occur at HARS during the late summer to late fall period when dredged material from the project would be placed at the HARS, but in low numbers. In the 2008 Report to Congress, the Southern New England and Georges Bank stocks were declared overfished (NMFS 2009). However, as of the most recent 2010 Report to Congress, the northeastern stocks of winter skate are not currently overfished, and overfishing is not occurring (NMFS 2011). Because the placement of the Remediation Material from the project would not result in adverse impacts to water quality, sufficient bottom habitat would still be available for foraging for benthic invertebrates within the vicinity of the area receiving placement, and a small percentage of the population for this species would be expected to occur within the HARS, the placement of dredged material from the project at HARS would not result in adverse impacts to EFH for this species.

### 8.4.4 SMOOTH DOGFISH (*MUSTELUS CANIS*)

This species is not managed in federal waters, but is included in the Atlantic States Marine Fisheries Commission’s Interstate Fishery Management Plan. As of 2009, there was no assessment of smooth dogfish stocks on the Atlantic coast (ASMFC 2009).

Smooth dogfish are demersal sharks found along the Atlantic coast as far north as Massachusetts. They occupy continental shelves and inshore waters as deep as 200 meters and primarily feed on large crustaceans (particularly crabs and American lobsters). They also feed on small bony fish, gastropods, bivalves, and marine annelid worms (Compagno 1984). During winter, smooth dogfish are primarily found between southern North Carolina and the Chesapeake Bay. In spring, they migrate along the coast when bottom waters reach 43°F. When temperatures drop again, they migrate offshore to their overwintering areas (Compagno 1984). Smooth dogfish have been collected during sampling programs in the Hudson-Raritan Estuary (USACE 2004; NOAA 2000).

Smooth dogfish would have the potential to occur within the HARS during the period that dredged material from the project would be placed there as Remediation Material. However, because the placement of the Remediation Material from the project would not result in adverse impacts to water quality, sufficient bottom habitat would still be available for foraging for benthic invertebrates within the vicinity of the area receiving placement, and a small percentage of the population for this species would be expected to occur within the HARS, the placement of dredged material from the project at HARS would not result in adverse impacts to EFH for this species.

#### 8.4.5 THRESHER SHARK (*ALOPIAS VULPINUS*)

EFH for the thresher shark has been designated in waters offshore from Long Island, New York in pelagic waters deeper than 164 feet (NMFS 2012). Thresher sharks are large, active, and strong-swimming sharks widely distributed in warm and temperate waters in the Atlantic Ocean. They are found in both coastal and oceanic waters, but usually occur within 40 to 75 miles of land over continental and insular shelves and slopes (Strasburg 1958, Holts 1988, Litvinov 1990 as cited in Smith et al. 2008). Juveniles tend to remain over the continental shelf in shallow water, while adults are most common in deeper water. Both juveniles and adults are often associated with highly productive water in regions of upwelling or intense mixing.

In the warm season (April to August), the thresher shark undertakes inshore and northerly coastal migrations. They are known to travel in schools segregated by sex and size, and catches of adults are skewed at certain times and locations in the Atlantic. Female-dominated schools move shoreward in spring, presumably towards inshore nursery areas. Near the end of spring, inshore schools are made up of predominantly neonates and pregnant females, to the exclusion of adult males (Moreno et al. 1989; Smith et al. 2008).

The HARS site is located outside the longitude given for thresher shark EFH and is shallower (approximately 46 to 138 feet) than the thresher shark EFH (USACE 2002); therefore, thresher shark EFH is not located within the HARS site and placement of dredged material from the project at HARS would not result in adverse impacts to EFH for this species.

## 8.5 SUMMARY OF EFFECTS ON EFH FROM PLACEMENT OF DREDGED MATERIAL FROM THE PROJECT AT THE HARS

#### 8.5.1 POTENTIAL DIRECT IMPACTS

As described in the programmatic EFH for the HARS, direct impacts to EFH resulting from the placement of dredged material from the project at the HARS as Remediation Material would be the burial of benthic invertebrates within the cells receiving the material. While the loss of benthic invertebrates within the placement cells would be immediate, there would be sufficient foraging area available outside each approximately 250 foot by 500 foot cell such that fish species that forage on benthic invertebrates would not be adversely affected. Individual EFH would be expected to leave the area of the cells receiving dredged material from the project and would not be directly impacted due to the placement of the material due to burial or contact with the barge. Water quality impacts resulting from placement of the dredged material such as increased turbidity and contaminant concentrations would be expected to be temporary (less than an hour) and would not result in adverse impacts to EFH. Because the dredged material placed at the HARS from the project would be similar to the existing sediment at the HARS recolonization of the cell(s) receiving this material would be expected to occur rapidly.

#### 8.5.2 POTENTIAL INDIRECT IMPACTS

Benthic invertebrates contained in the dredged material from the project would have the potential to provide additional prey for EFH species using the habitats in the vicinity of the cells receiving placement of the Remediation Material. While minor changes to bathymetry may occur as a result in the placement, it would never be more than approximately 3 feet, which would not be expected to adversely affect the suitability of the sediment for benthic invertebrates on the basis of depth or light penetration.

### 8.5.3 POTENTIAL CUMULATIVE IMPACTS

The primary cumulative impact from the placement of the dredged material from the project at the HARS would be the eventual remediation of the HARS which would result in an improved benthic community and improved habitat for fish and shellfish. The placement of the dredged material from the project at the HARS in three stages would minimize the area of disturbance within the cells designated for the project by the USACE during each dredging season for the project. Because changes to water quality during placement of Remediation Material would be expected to be limited temporally and spatially, placement of the dredged material with material from other projects would not be expected to result in adverse impacts to water quality or EFH. Given the large area of the HARS yet to be remediated in RPAs 5 through 9, and much of PRA 1 and 2 has been remediated, placement of the dredged material from the project concurrent with placement of material from other projects, sufficient EFH would still be available within the HARS that placement of the dredged material concurrent with placement of Remediation Material from other projects would not be expected to result in adverse impacts to EFH.

# Chapter 9: References

Able, K.W., A.L. Studholme, and J.P. Manderson. 1995. Habitat quality in the New York/New Jersey Harbor Estuary: An evaluation of pier effects on fishes. Final Report. Hudson River Foundation, New York, NY.

Able, K.W., J.P. Manderson, and A.L. Studholme. 1998. The distribution of shallow water juvenile fishes in an urban estuary: the effects of manmade structures in the Lower Hudson River. Estuaries 21: 731-744.

Applied Science Associates, Inc. (ASA). 2010. Hydrothermal Modeling of the Cooling Water Discharge from the Indian Point Energy Center to the Hudson River. ASA Project 09-167. March 22, 2010.Atlantic States Marine Fisheries Commission (ASMFC). 2007. American Shad Stock Assessment Report for Peer Review, Volume I. Stock Assessment Report No. 07-01(Supplement) of the Atlantic States Marine Fisheries Commission. August 2007.

Atlantic States Marine Fisheries Commission (ASMFC). 2008. Interstate Fishery Management Plan for Atlantic Coastal Sharks. Fishery Management Report No. 46 of the Atlantic States Marine Fisheries Commission. August 2008.

Atlantic States Marine Fisheries Commission (ASMFC). 2009a. 2009 Review of the Atlantic States Marine Fisheries Commission: Fishery Management Plan for Bluefish (*Pomatomus saltatrix*).

Atlantic States Marine Fisheries Commission (ASMFC). 2009b. Addendum I to the Interstate Fishery Management Plan for Atlantic Coastal Sharks. September 2009.

Atlantic States Marine Fisheries Commission (ASMFC). 2009c. 2009 Stock Assessment Report for Atlantic Striped Bass. Atlantic States Marine Fisheries Commission, Washington, D.C.

Bain, M.B., M.S. Meixler, and G.E. Eckerlin. 2006. Biological Status of Sanctuary Waters of the Hudson River Park in New York. Final Project Report for the Hudson River Park Trust. Cornell University.

Bass, A.H. and C.W. Clarke. 2003. The physical acoustics of underwater sound. In: A.M. Simmons, A.N. Popper, and R.R. Fay (eds.) Acoustic Communication, pp. 15-64. New York: Springer Science and Business Media, LLC.

Bass, A. H., and F. Ladich. 2008. Vocal-acoustic communication: From neurons to brain. In: J.F. Webb, R.R. Fay, and A.N. Popper (eds.) Fish Bioacoustics, pp. 253-278. New York: Springer Science+Business Media, LLC.

Bee, M. A., and E.N. Swanson. 2007. Auditory masking of anuran advertisement calls by road traffic noise. Animal Behaviour 74: 1765-1776.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service Volume 53.

Bokuniewicz, H.J. 1988. *A brief summary of the geology of Raritan Bay* in Hudson/Raritan estuary: Issues, resources, status, and management, pp. 45-57. NOAA Estuary-of-the-

Month seminar series, No.9 (dredged "borrow pits" in New York Harbor had sedimentation rates of 4-9 cm/yr (1.5 to 3.5 in/yr).

Boudreau, M., S. C. Courtenay, and K. Lee (eds). 2009. Potential Impacts of Seismic Energy on Snow Crab: An Update to the September 2004 Review. Proceedings of a workshop held January 3, 2007 at the Gulf Fisheries Center. Canadian Technical Report of Fisheries and Aquatic Sciences 2836. 31pp.

Broome, S.W., C.B. Craft, S.D. Struck, and M. SanClements. 2005. Final Report: Effects of Shading from Bridges on Estuarine Wetlands. N.C. State University Center for Transportation and the Environment/NCDOT Joint Research Program.

Brumm, H, and H. Slabbekoorn. 2005. Acoustic communication in noise. Advances in Behavior 35: 151-209

Buckel, J.A., D.O. Conover, N.D. Steinberg, and K.A. Mckown. 1999. Impact of age-0 bluefish (Pomatomus saltatrix) predation on age-0 fishes in the Hudson River estuary: evidence for density-dependent loss of juvenile striped bass (Morone saxatilis). Canadian Journal of Fisheries and Aquatic Sciences 56: 275-287.

Burdick, D.M. and F.T. Short. 1995. The effects of boat docks on eelgrass beds in Massachusetts coastal waters, Waquoit Bay National Research Reserve, Boston, MA.

Burton, W.H. 1993. Effects of bucket dredging on water quality in the Delaware River and the potential for effects on fisheries resources. Versar, Inc. 9200 Rumsey Road, Columbia, MD 21045

California Department of Transportation (Caltrans). 2001. Pile Installation Demonstration Project, Fisheries Effect Assessment. PIDP EA 012081, Caltrans Contract 04A0148. San Francisco - Oakland Bay Bridge East Span Seismic Safety Project.

California Department of Transportation (Caltrans), 2009. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on Fish. Technical report prepared by ICF Jones & Stokes and Illingworth and Rodkin, Inc, for California Department of Transportation, Sacramento CA.

Carlson, T. J., M.C. Hastings, and A.N. Popper. 2007. Update on Recommendations for Revised Interim Sound Exposure Criteria for Fish During Pile Driving Activities. http://www.dot.ca.gov/hq/env/bio/files/ct-arlington_memo_12-21-07.pdf

Casper, B. M., F.M. Matthews, M.B. Halvorsen, T.J. Carlson, and A.N. Popper. 2011. Recovery from exposure to pile driving signals by Chinook salmon. Journal of the Acoustical Society of America 129: 2436.

Central Hudson Gas & Electric Corp., Consolidated Edison Company of New York Inc., New York Power Authority, and Southern Energy New York (CHGE). 1999. Draft Environmental Impact Statement: For State Pollutant Discharge Elimination System Permits for Bowline 1 & 2, Indian Point 2 & 3, and Roseton 1 & 2 Steam Electric Generating Stations, Orange, Rockland, and Westchester Counties. December 1, 1999.

Chang, S., P.L. Berrien, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Windowpane, Scophthalmus aquosus, Life History and Habitat

Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 137, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Clarke, D.G. and D.H. Wilber. 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. DOER Technical Notes Collection (ERDC TN-DOER-E9), US Army Engineer Research and Development Center, Vicksburg, MS.

Compagno, L.J.V. 1984. FAO Species Catalog Vol.4, Part 1 and 2: Sharks of the world: An annotated and illustrated catalogue of shark species known to date. FAO Fish. Synop. 125. FAO, Rome, Italy.

Cross, J.N., C.A. Zetlin, P.L. Berrien, D.L. Johnson, and C. McBride. 1999. Essential Fish Habitat Source Document: Butterfish, Peprilus triacanthus Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 145, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list.

CZR, Inc. 2009. Mid-Currituck Bridge Study, Essential Fish Habitat Technical Report, WBS Element: 34470.1TA1, STIP No. R-2576, Currituck County and Dare County. Prepared by CZR, Inc., Wilmington, NC. Prepared for Parsons Brinkerhoff and for the North Carolina Turnpike Authority. November 2009.

DeVries, M. and L. Weiss. 2001. Salt-Front Movement in the Hudson River Estuary, New York: Simulations by One-Dimensional Flow and Solute-Transport Models. United States Geological Survey, Troy, New York. Water Resources Division. Water Resources Investigations Report 99-4024.

DiGiovanni, R. 2011. A Review of marine mammal and Se Turtle Sightings and Strandings in the Hudson River and New York Harbor 1980 through September 2011. Unpublished report prepared by the Riverhead Foundation for Marine research and Preservation for NMFS. 8 pp.

DiLorenzo, J., P. Huang, D. Ulman, and T. Najarian. 1999. Hydrologic and Anthropogenic Controls on the Salinity Distribution of the Middle Hudson River Estuary. Technical Report. Najarian Associate, Inc.

Doksaeter, L, O.R. Godø, N.O. Handegard, P.H. Kvadsheim, F-P.A. Lam, C. Donovan, and P.J. Miller. 2009. Behavioral responses of herring (Clupea harengus) to 1–2 and 6–7 kHz sonar signals and killer whale feeding sounds. Journal of the Acoustical Society of America 125: 554-564.

Dooling, R. J., E.W. West, and M.R. Leek. 2009. Conceptual and computation models of the effects of anthropogenic sound on birds. Proceedings of the Institute of Acoustics, 31 (pt 1).

Dunning, D. J., Q. E. Ross, K. A. McKown, and J. B. Socrates. 2009. Effect of striped bass larvae transported from the Hudson River on juvenile abundance in Western Long Island Sound. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1: 343-353.

Dunning, D. J., J. R. Waldman, Q. E. Ross, and M. T. Mattson. 2006. Dispersal of age-2+ striped bass out of the Hudson River. American Fisheries Society Symposium 51: 287-294.

Engås, A. and S. Løkkeborg. 2002. Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates. Bioacoustics 12: 313-315.

Engås, A., S. Løkkeborg, E. Ona, and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Science 53: 2238-2249.

ESS Group, Inc. 2011. Technical Review Report of the Application of Champlain Hudson Power Express, Inc. for a Certificate of Environmental Compatibility and Public Need. Prepared for Riverkeeper and Scenic Hudson, Inc. Revised January 21, 2011.

Fahay, M.P., P.L. Berrien, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Bluefish, Pomatomus saltatrix Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 144, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Federal Highway Administration (FHWA). 2003. Woodrow Wilson Bridge Project: Shortnose Sturgeon Biological Assessment Supplement. January 2003.

Feist, B.E. 1991. Potential Impacts of Pile Driving on Juvenile Pink (Oncorhynchus gorbuscha) and Chum (*O. keta*) Salmon Behavior and Distribution. Master of Science Thesis. University of Washington. Seattle, Washington.

Fredette, T.J. and G.T. French. 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Marine Pollution Bulletin 49:93-102.

Fresh, K.L., B. Williams, and D. Penttila. 1995. Overwater structures and impacts on eelgrass in Puget Sound, WA. Puget Sound Research 1995 Proceedings. Seattle, WA: Puget Sound Water Quality Authority.

Fresh, K.L., B.W. Williams, S. Wyllie-Echeverria, and T. Wyllie-Echeverria. 2000. Mitigating impacts of overwater floats on eelgrass *Zostera marina* in Puget Sound, Washington, using light permeable deck grating. Draft.

Gardinier, M. and T. B. Hoff. 1982. Diet of striped bass in the Hudson River estuary. New York Fish and Game Journal 29: 152-165.

Germano, J.D., D.C. Rhoads, and J.D. Lunz. 1994. An integrated, tiered approach to monitoring and management of dredged material sites in the New England region. Waltham (MA): US Army Corps of Engineers, New England Division. DAMOS Contribution No. 87, Report No. SAIC-90/7575&234.

Gisiner, R. C. 1998. Proceedings of the workshop on the effects of anthropogenic noise in the marine environment, February 10-12, 1998. Marine Mammal Science Program. Office of Naval Research, Arlington, VA.

Gutreuter, S., J.M. Dettmers, and D.H. Wahl. 2003. Estimating Mortality Rates of Adult Fish from Entrainment Through the Propellers of River Towboats. Transactions of the American Fisheries Society 132: 646-661.

Halvorsen, M.B., B.M. Casper, C.M. Woodley T.J. Carlson, and A.N. Popper. 2011. Predicting and mitigating hydroacoustic effects on fish from pile installations. NCHRP Research Results Digest 363, Project 25-28, National Cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences, Washington, D.C. http://www.trb.org/Publications/Blurbs/166159.aspx

Hastings, M. C., C.A. Reid, C.C. Grebe, R.L. Hearn, and J.G. Colman. 2008. The effects of seismic airgun noise on the hearing sensitivity of tropical reef fishes at Scott Reef, Western Australia. Underwater Noise Measurement, Effect and Mitigation, Proceedings.

HDR/DTA, April 2010, Champlain Hudson Power Express HVDC Transmission Project, Least Environmentally Damaging Practical Alternative Evaluation, Prepared for Champlain Hudson Power Express, Inc., Toronto, Ontario. Accessed at: http://www.chpexpress.com/docs/regulatory/USACE/CHPE_USACE_Application_Apendices.pdf

Heimbuch, D. G. 2008. Potential effects of striped bass predation on juvenile fish in the Hudson River. Transactions of the American Fisheries Society 137: 1591-1605.

Heimbuch, D., S. Cairns, D. Logan, S. Janicki, J. Seibel, D. Wade, M. Langan, and N. Mehrotra. 1994. Distribution Patterns of Eight Key Species of Hudson River Fish. Coastal Environmental Services, Inc. Linthicum, MD. Prepared for the Hudson River Foundation, New York, NY.

Hirsch, N.D., L.H. DiSalvo, and R. Peddicord. 1978. Effects of dredging and disposal on aquatic organisms. Technical Report DS-78-5. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A058 989.

Holts, D.B. 1988. Review of US West Coast commercial shark fisheries. Marine Fisheries Review 50: 1-8.

Hurst, T.P., K.A. McKown, and D.O. Conover. 2004. Interannual and Long-Term Variation in the Nearshore Fish Community of the Mesohaline Hudson River Estuary. Estuaries 27: 659-669.

JASCO Applied Sciences (JASCO). 2011. Final Report: Tappan Zee Bridge Construction Hydroacoustic Noise Modeling. March 2011.

Jorgensen, J.K. and E.C. Gyselman, E.C. 2009. Hydroacoustic measurements of the behavioral response of arctic riverine fishes to seismic airguns. Journal of the Acoustical Society of America 126: 1598-1606.

Killgore, K.J., L.E. Miranda, C.E. Murphy, D.M. Wolff, J.J. Hoover, T.M. Keevin, S.T. Maynord, and M.A. Cornish. 2011. Fish entrainment rates through towboat propellers in the Upper Mississippi and Illinois rivers. Transactions of the American Fisheries Society 140: 570-581.

Kiorboe, T., E. Frantsen, C. Jensen, and O. Nohr. 1981. Effects of suspended-sediment on development and hatching of herring (Clupea harengus) eggs. Estuarine, Coastal, and Shelf Science 13: 107-111.

LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Department of the Army, Environmental laboratory, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi.

Ling, H.P. and D. Leshchinsky. Undated. Guidance for In-Situ Subaqueous Capping of Contaminated Sediments. Appendix C: Case Studies on Geotechnical Aspects of In-Situ Sand Capping. Prepared for United States Environmental Protection Agency.

Litvinov, F.F. 1990. Structure of epipelagic elasmobranch communities in the Atlantic and Pacific Oceans and their change in recent geologic time. Journal of Ichthyology 29: 75-87.

Llanso, R., M. Southerland, J. Volstad, D. Strebel, G. Mercurio, M. Barbour, and J. Gerritsen. 2003. Hudson River Estuary Biocriteria Final Report. Submitted to A. Newell, New York State Department of Environmental Conservation. May 2003.

Maes, J., A.W.H. Turnpenn, D.R. Lambert, J.R. Nedell, A. Permentier, and F. Ollevier. 2004. Field evaluation of a sound system to reduce estuarine fish intake rates at a power plant cooling water inlet. Journal of Fish Biology 64: 938-946.

Mann, D. A, A.N. Popper, and B. Wilson. 2005. Pacific herring hearing does not include ultrasound. Biology Letters 1: 158-161 doi:10.1098/rsbl.2004.0241

Mazzuca, L.L. 2001. Potential effects of low-frequency sound (LFS) from commercial vehicles on large whales. Masters thesis, University of Washington, Seattle, WA. 70 pp.

McCauley, R. D., J. Fewtrell, A.J. Duncan, C. Jenner, M.N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhiyta, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys – A study of environmental implications. APPEA Journal 40: 692-706.

McCauley, R. D., J. Fewtrell, and A. N. Popper. 2003. High intensity anthropogenic sound damages fish ears. Journal of the Acoustical Society of America 11: 638-642.

McCauley, R.D., C.S. Kent, and M. Archer. 2008. Impacts of seismic survey pass-bys on fish and zooplankton, Sott Reef Lagoon Western Australia, full report of Curtin University findings. CMST Project 696_2, Report R2008-32 for ERM/Woodside Energy

Mid-Atlantic Fishery Management Council (MAFMC). 2002. Council Management, A Quiet Success Story. Council Newsletter, Summer 2002.

Minerals Management Service (MMS). 2001. Environmental Survey of Potential Sand Resource Sites: Offshore New Jersey. OCS Study. MMS 2000-052. Prepared by Applied Coastal Research and Engineering, Inc., Continental Shelf Associates, Inc., Barry A. Vittor & Associates, Inc., and Aubrey Consulting, Inc.

Moreno, J.A., J.I. Parajua, and J. Moron. 1989. Biologia reproductive y fenologia de Alopias vulpinus (Bonnaterre, 1788) (Squaliformes: Alopiidae) en el Atlantico nor-oriental y Mediterraneo occidental. Scientia Marina 53: 37-46.

Morreale, S.J. and E.A. Standora. 1995. Cumulative evidence of southward migration of juvenile sea turtles from temperate northeastern waters. Proceedings of the Twelfth Annual Workshop on Sea Turtle Biology and Conservation. Pp. 85-86. NOAA Technical Memorandum NMFS-SEFSC-361.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society 124: 225-234.

Mueller-Blenkle, C., P.K. McGregor, A.B. Gill, M. H. Andersson, J. Metcalfe, V. Bendall, P. Sigray, D.T. Wood, and F. Thomsen. 2010. Effects of Pile-driving Noise on the Behaviour of Marine Fish. COWRIE Ref: Fish 06-08, Technical Report 31st March 2010.

National Marine Fisheries Service (NMFS). 2009. National Marine Fisheries Service 2008 Report to Congress The Status of U.S. Fisheries. Accessed on November 3, 2009. Available: http://www.nmfs.noaa.gov/sfa/statusoffisheries/booklet_status_of_us_fisheries08.pdf. May 2009.

National Marine Fisheries Service (NMFS). 2011. National Marine Fisheries Service 2010 Report to Congress The Status of U.S. Fisheries. Accessed on January 17, 2012. Available:http://www.nmfs.noaa.gov/sfa/statusoffisheries/2010/2010_Report_to_Congress.pdf. July 2011.

National Marine Fisheries Service (NMFS). 2012. Thresher shark (Alopias vulpinus), Essential Fish Habitat for Thresher Shark. Accessed on January 17, 2012. http://www.nero.noaa.gov/hcd/threshershark.htm.

National Marine Fisheries Service (NMFS). 2003. Annual Report to Congress on the Status of U.S. Fisheries—2002, U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service (NMFS). 2004. Annual Report to Congress on the Status of U.S. Fisheries—2003, U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service (NMFS). 2005. Annual Report to Congress on the Status of U.S. Fisheries—2004, U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service (NMFS). 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States, NOAA Technical Memorandum NMFS-NE-209, US Department of Commerce, National Oceanic and Atmospheric Administration, NMFS, Northeast Regional Office, Gloucester, Massachusetts, February 2008, http://www.nefsc.noaa.gov/publications/tm/tm209/tm209.pdf.

National Marine Fisheries Service (NMFS). 2011a. Correspondence from Patricia A Kurkul, Regional Administrator, US Department of Commerce, National Oceanic and Atmospheric Administration, NMFS, Northeast Region dated November 15, 2011 to Mr. Michael P. Anderson, PE, New York State Department of Transportation, Tappan Zee Hudson River Crossing Project.

National Marine Fisheries Service (NMFS). 2011b. National Marine Fisheries Service 2010 Report to Congress on the Status of US Fisheries. US Department of Commerce, NOAA, NMFS, Office of Sustainable Fisheries, 32pp. http://www.nmfs.noaa.gov/sfa/statusoffisheries/2010/2010_Report_to_Congress.pdf

National Oceanic and Atmospheric Administration (NOAA). 2001. Letter regarding NMFS's biological opinion regarding FERC's issuance of a permit for Millennium pipeline.

United States Department of Commerce. National Marine Fisheries Service, Northeast Region. September 4, 2001.Newberger, T.A. and E.D. Houde. 1995. Population biology of bay anchovy Anchoa mitchilli in the mid Chesapeake Bay. Mar. Ecol. Prog. Ser. 116: 25-37.

New York State Department of Environmental Conservation (NYSDEC). 2004. In-water and Riparian Management of Sediment and Dredged Material. NYSDEC Division of Water Technical and Operational Guidance Series 5.1.9. Albany, NY.

New York State Department of Environmental Conservation (NYSDEC). 2010a. 2010 Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy. June 2010. Available http://www.dec.ny.gov/docs/water_pdf/303dlistfinal10.pdf.

New York State Department of Environmental Conservation (NYSDEC). 2010b. New York State Stormwater Management Design Manual. August 2010.

Nightingale, B. and C. Simenstad. 2001. Overwater Structures: Marine Issues. Prepared by Washington State Transportation Center (TRAC) and Washington State Department of Transportation. Research Project T1803, Task 35, Overwater Whitepaper. Prepared for Washington State Transportation Commission, Department of Transportation and in cooperation with the United States Department of Transportation, Federal Highway Administration.

Nitsche, F.O., T.C. Kenna, M. Haberman. 2010. *Quantifying 20$^{th}$ century deposition in complex estuarine environment: An example from the Hudson River. Estuarine,* Coastal and Shelf Science 89 (2012) 163-174 (measured average sedimentation rates of 2.8 cm/yr (1.1 in/yr) in a previously dedged area of the Haverstraw Bay channel, just north of the Tappan Zee reach with local extremes ranging to between 5 to 10 cm/yr (2-4 in/yr)).

Nitsche, F.O., W.B.F. Ryan, S.M. Carbotte, R.E. Bell, A. Slagle, C. Bertinado, R. Flood, T. Kenna, and C. McHugh. 2007. Regional patterns and local variations of sediment distribution in the Hudson River Estuary. Estuarine Coastal and Shelf Science 71: 259-277.

Olla, B.L., and A.L. Studholme. 1971. The effect of temperature on the activity of bluefish Pomatomus saltatrix L. Biological Bulletin (Woods Hole) 141(2): 337-349.

Olson, A.M., E.G. Doyle, and S.D. Visconty. 1996. Light requirements of eelgrass: A literature survey. Report to Washington State Department of Transportation (WSDOT) and Washington State Transportation Center (TRAC).

Olson, A.M., S.D. Visconty, and C.M. Sweeney. 1997. Modeling the shade cast by overwater structures. University of Washington, School of Marine Affairs. SMA Working Paper-97-1.

Packer, D.B., S.J. Griesbach, P.L. Berrien, C.A. Zetlin, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Summer Flounder, Paralichthys dentatus, Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 151, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ -list

Packer, D.B., C.A. Zetlin, and J.J. Vitaliano. 2003a. Essential Fish Habitat Source Document: Clearnose Skate, *Raja eglanteria*, Life History and Habitat Characteristics. National

Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE-174.Packer, D.B., C.A. Zetlin, and J.J. Vitaliano. 2003b. Essential Fish Habitat Source Document: Little Skate, Leucoraja erinacea, Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE-175.Packer, D.B., C.A. Zetlin, and J.J. Vitaliano. 2003c. Essential Fish Habitat Source Document: Winter Skate, Leucoraja ocellata, Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE-179.

Palermo, M.R., J.E. Clausner, M.P. Rollings, G.L. Williams, T.E. Myers, T.J. Fredette, and R.E. Randall. 1998. Guidance for Subaqueous Dredged material Capping. US Army Corps of Engineers, Waterways Experiment Station, Dredging Operations and Environmental Research Program. Technical Report DOER-1.

Palermo, M.R., S. Maynord, J. Miller, and D.D. Reible. 2011. Guidance for In-Situ Subaqueous Capping of Contaminated Sediments. Great Lakes Contaminated Sediments Program, Sediment Assessment and Remediation Report, http://www.epa.gov/greatlakes/sediment/iscmain/four.html, lat updated on Friday, may 13, 2011.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder, *Pseudopleuronectes americanus* (Walbaum). Parts I-IV. Bull. Bingham Oceanogr. Collect. 18(1):5-78.

Pereira, J.J., R. Goldberg, J.J. Ziskowski, P.L. Berrien, W.W. Morse, and D.L. Johnson. 1999. Essential Fish Habitat Source Document: Winter Flounder, Pseudopleuronectes americanus, Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 138, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Plachta, D.T.T. and A.N. Popper. 2003. Evasive responses of American shad (Alosa sapidissima) to ultrasonic stimuli. Acoustical Research Letters Online 4: 25-30. doi:10.1121/1.1558376.

Ploskey, G.R., P.N. Johnson, and T.J. Carlson. 2000. Evaluation of a low-frequency sound-pressure system for guiding juvenile salmon away from turbines at Bonneville Dam, Columbia River. North American Journal of Fisheries Management 20: 951-967.

Popper, A.N. and T.J. Carlson. 1998. Application of the use of sound to control fish behavior. Transactions of the American Fisheries Society 127: 673-707.

Popper, A.N., R.R. Fay, C. Platt, and O. Sand. 2003. Sound detection mechanisms and capabilities of teleost fishes. In: S.P. Collin and N.J. Marshall (eds.) Sensory Processing in Aquatic Environments, pp. 3-38. Springer-Verlag, New York.

Popper, A. N., M.B. Halvorsen, E. Kane, D.D. Miller, M.E. Smith, P. Stein, and L.E. Wysocki. 2007. The effects of high-intensity, low-frequency active sonar on rainbow trout. Journal of the Acoustical Society of America 122: 623-635.

Popper, A. N. and M.C. Hastings. 2009. Effects of anthropogenic sources of sound on fishes. Journal of Fish Biology 75: 455-498.

Popper, A.N. and C.R. Schilt. 2008. Hearing and acoustic behavior (basic and applied). In: J.F. Webb, R.R. Fay, and A.N. Popper (eds.) Fish Bioacoustics, pp. 17-48. New York: Springer Science+Business Media, LLC.

Reid, R.N., L.M. Cargnelli, S.J. Griesbach, D.B. Packer, D.L. Johnson, C.A. Zetlin, W.W. Morse, P.L. Berrien. 1999. Essential Fish Habitat Source Document: Atlantic Herring, Clupea harengus Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 126, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Richards, S.W. 1963. The demersal fish population of Long Island Sound. Bull. Bingham Oceanogr. Collect. 18(2):101 p.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. New York: Academic Press.

Rogers, P.H. and M. Cox. 1988. Underwater Sound as a Biological Stimulus. In: J. Atema, R.R. Fay, A.N. Popper, and W.N. Tavolga (eds.) Sensory Biology of Aquatic Animals, pp. 131-149. Springer-Verlag: New York.

Ruggerone, G.T., S.E. Goodman, and R. Miner. 2008. Behavioral response and survival of juvenile coho salmon to pile driving sounds. Natural Resources Consultants, Inc. for Port of Washington.

Sarà, G., J.M. Dean, D. D'Amato, G. Buscaino, A. Oliveri1, S. Genovese, S. Ferro, G. Buffa, M. Lo Martire and S. Mazzola. 2007. Effect of boat noise on the behaviour of bluefin tuna Thunnus thynnus in the Mediterranean Sea. Marine Ecology Progress Series 331: 243–253.

Schultz, E.T., K.M.M. Lwiza, J.R. Young, K.J. Hartman, and R.C. Tipton. 2006. The dynamics of bay anchovy in the Hudson River Estuary: process-oriented studies and long term changes. American Fisheries Society Symposium 51: 197-213.

Sherk, J.A., J.M. O'Conner, and D.A. Neumann. 1975. Effects of suspended and deposited sediments on estuarine environments. In: L.E. Cronin (ed.) Estuarine Research 2, pp. 541-558.

Skalski, J. R., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (Sebastes spp.). Canadian Journal of Fisheries and Aquatic Sciences 49: 1357-1365.

Slotte, A., K. Kansen, J. Dalen,and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. Fisheries Research 67: 143-150.

Smith, S.E., R.C. Rassmussen, D.A. Ramon, and G.M. Cailliet. 2008. Biology and ecology of thresher sharks (family: Alopiidae). In: E. Pikitch and M. Camhi (eds.) Sharks of the Open Ocean, pp. 60-68. Blackwell Publishing Ltd., Oxford.

Smith, C.L. 1985. The Inland Fishes of New York State. The New York State Department of Environmental Conservation.

Smith, T.E., R.J. Stevenson, N.F. Caraco, and J.J. Cole. 1998. Changes in phytoplankton community structure during the zebra mussel (*Dreissena polymorpha*) invasion of the Hudson River (New York). Journal of Plankton Research 20: 1567-1579.

Stadler, J. H., and D. P. Woodbury. 2009. Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. Inter-Noise 2009, Ottawa, Ontario, Canada.

ftp://167.131.109.8/techserv/Geo-Environmental/Biology/Hydroacoustic/References/Literature%20references/Stadler%20and%20Woodbury%202009.%20%20Assessing%20the%20effects%20to%20fishes%20from%20pile%20driving.pdf (February 2011).

Steimle, F.W., W.W. Morse, P.L. Berrien, and D.L. Johnson. 1999a. Essential Fish Habitat Source Document: Red Hake, Urophycis chuss Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 133, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Steimle, F.W., C.A. Zetlin, P.L. Berrien, and S. Chang. 1999b. Essential Fish Habitat Source Document: Black Sea Bass, Centropristis striata Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 143, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Steimle, F.W., C.A. Zetlin, P.L. Berrien, D.L. Johnson, and S. Chang. 1999c. Essential Fish Habitat Source Document: Scup, Stenotomus chrysops Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 149, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Strasburg, D.W. 1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. Fishery Bulletin 138: 335-361.

Struck, S.D., C.B. Craft, S.W. Broome, M.D. SanClements, and J.N. Sacco. 2004. Effects of bridge shading on estuarine marsh benthic invertebrate community structure and function. Environmental Management 34: 99-111.

Studholme, A.L., D.B. Packer, P.L. Berrien, D.L. Johnson, C.A. Zetlin, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Atlantic Mackerel, Scomber scombrus Life History and Habitat Characteristics. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NE 141, http://www.nefsc.nmfs.gov/nefsc/habitat/efh/ - list

Summerfelt, R.C. and D. Mosier. 1976 Evaluation of ultrasonic telemetry to track striped bass to their spawning grounds. Final Report., Dingell-Johnson Proj. F-29-R, Segments 5, 6, and 7. Okla. Dept. Wildl. Conserv. 101pp.

Turnpenny, A.W.H., K.P. Thatcher, and J.R. Nedwell. 1994. The Effects on Fish and Other Marine Animals of High-Level Underwater Sound. Report FRR 127/94, Fawley Aquatic Research Laboratories, Ltd., Southampton, UK.

United States Army Corps of Engineers (USACE). 1991. Equipment and Placement Techniques for Capping. Technical Note DRP-5-05. November 1991.

U.S. Army Corps of Engineers (USACE). 2000. Memorandum for the Record: Statement of Findings and Environmental Assessment for Application Number 1998-00290-Y3 by the Hudson River Park Trust. CENAN-OP-RE.

United States Army Corps of Engineers (USACE). 2001. Monitoring at the New London Disposal Site 1992-1998 Vol. I. Concord (MA): USACE, New England District. DAMOS Contribution No. 128, SAIC No. 515.

United States Army Corps of Engineers (USACE). 2002. Programmatic Essential Fish Habitat Assessment for Placement of Category I Dredged material at the Historic Area

Remediation Site in the New York Bight Apex, Prepared by USACE Operations Division, New York District, 26 Federal Plaza, New York, NY 1027-0090.

United States Army Corps of Engineers (USACE). 2004. New York and New Jersey Harbor Deepening Project, Essential Fish Habitat Assessment. January 2004.

United States Army Corps of Engineers (USACE). 2005. Equipment and Placement Techniques for Subaqueous Capping. ERDC TN-DOER-R9. September 2005.

United States Army Corps of Engineers (USACE). 2006. Engineering and Design. Foundation Engineering: In-the-Wet Design and Construction of Civil Works Projects. Engineer Technical Letter No. 1110-2-565. September 30, 2006.

United States Army Corps of Engineers (USACE) and US Environmental Protection Agency (USEPA). 2009. Site Management and Monitoring Plan for the Historic Area Remediation Site, Revised May 5, 2009, USACE, New York District, 26 Federal Plaza New York, NY 10278-0090 and USEPA, Region 2, 290 Broadway, New York, NY 10007-1866 http://www.nan.usace.army.mil/harbor/hars/pdf/sitemmp.pdf.

United States Environmental Protection Agency (USEPA). 1994. ARCS Remediation Guidance Document, Chapter 4. EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.

United States Environmental Protection Agency (USEPA). 1997. Supplemental to the Environmental Impact Statement on the New York Dredged Material Disposal Site Designation for the Designation of the Historic Area Remediation Site (HARS) in the New York Bight Apex. Report by Battelle Ocean Sciences to US Environmental Protection Agency, Region 2, New York City, NY. EPA Contract Nos. 68-C2-0134 and 68-C7-00045, May 1997. 450 pp,

United States Environmental Protection Agency (USEPA). 1997. Biological Assessment for the Closure of the Mud Dump Site and Designation of the Historic Area Remediation Site in the New York Bight Apex. USEPA, Region 2, 290 Broadway, New York, NY 100007-1866.

United States Environmental Protection Agency (USEPA). 2005. Contaminated Sediment Remediation Guidance for hazardous Waste Sites. USEPA Office of Solid Waste and Emergency Response, EPA-540-R-05-012, OSWER 9355.0-85.

United States Environmental Protection Agency (USEPA). 2008. Measuring Contaminant Resuspension Resulting from Sediment Capping. EPA/600/S-08/013. August 2008.

United States Fish and Wildlife Service (USFWS). 2011. Significant Habitats and Habitat Complexes of the New York Bight Watershed. Available http://library.fws.gov/pubs5/begin.htm. Accessed March 25, 2011.

Urquhart, G. A., A.D. Hawkins, and C. Hall. 2006. Monitoring of pile driving at Aberdeen Harbour. Report prepared for the Rive Dee Trust and Aberdeen Harbour Board.

Van Derwalker, J. G. 1967. Response of salmonids to low frequency sound. Pages 45–54 in W. N. Tavolga, editor. Marine bio-acoustics, Volume 2. Pergamon Press, New York.

Waldman, J. R., D. J. Dunning, Q. E. Ross, and M. T. Matson. 1990. Range dynamics of Hudson River striped bass along the Atlantic Coast. Transactions of the American Fisheries Society 119: 910-919.

Wall, G., E. Nystrom, and L. Simon. 2006. Use of an ADCP to Compute Suspended-Sediment Discharge in the Tidal Hudson River, New York. United States Geological Survey. Technical Report 2006-5055.

Walter III, J. F., A. S. Overton, K. H. Ferry, and M. E. Mather. 2003. Atlantic coast feeding habits of striped bass: a synthesis supporting a coast-wide understanding of trophic biology. Fisheries Management and Ecology 10: 349-360.

Wardle, C. S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie. 2001. Effects of seismic air guns on marine fish. Continental Shelf Research 21: 1005-1027.

Warfel, H.E. and D. Merriman. 1944. Studies on the marine resources of southern New England. Bull Bingham Oceanogr. Collect. 9: 1-91.

Wilber, D.H. and D.G. Clarke. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21: 855-75.

Wilber, P. and L.E. Iocco. 2003. *Using a GIS to examine changes in the bathymetry of borrow pits in Lower Bay, New York Harbor*, USA. Marine Geodesy, 26:49-61 (dredged sites in New York Harbor exhibit sedimentation rates between 6.25 to 12.5 cm/yr (2.4 to 4.8 in/yr)).

Woodbury, D. and J. Stadler. 2008. A proposed method to assess physical injury to fishes from underwater sound produced during pile driving. Bioacoustics 17: 289-291.

Woodhead, P.M. 1990. The Fish Community of New York Harbor: Spatial and temporal Distribution of major Species. Report to the New York - New Jersey Harbor Estuary Program, New York, NY.

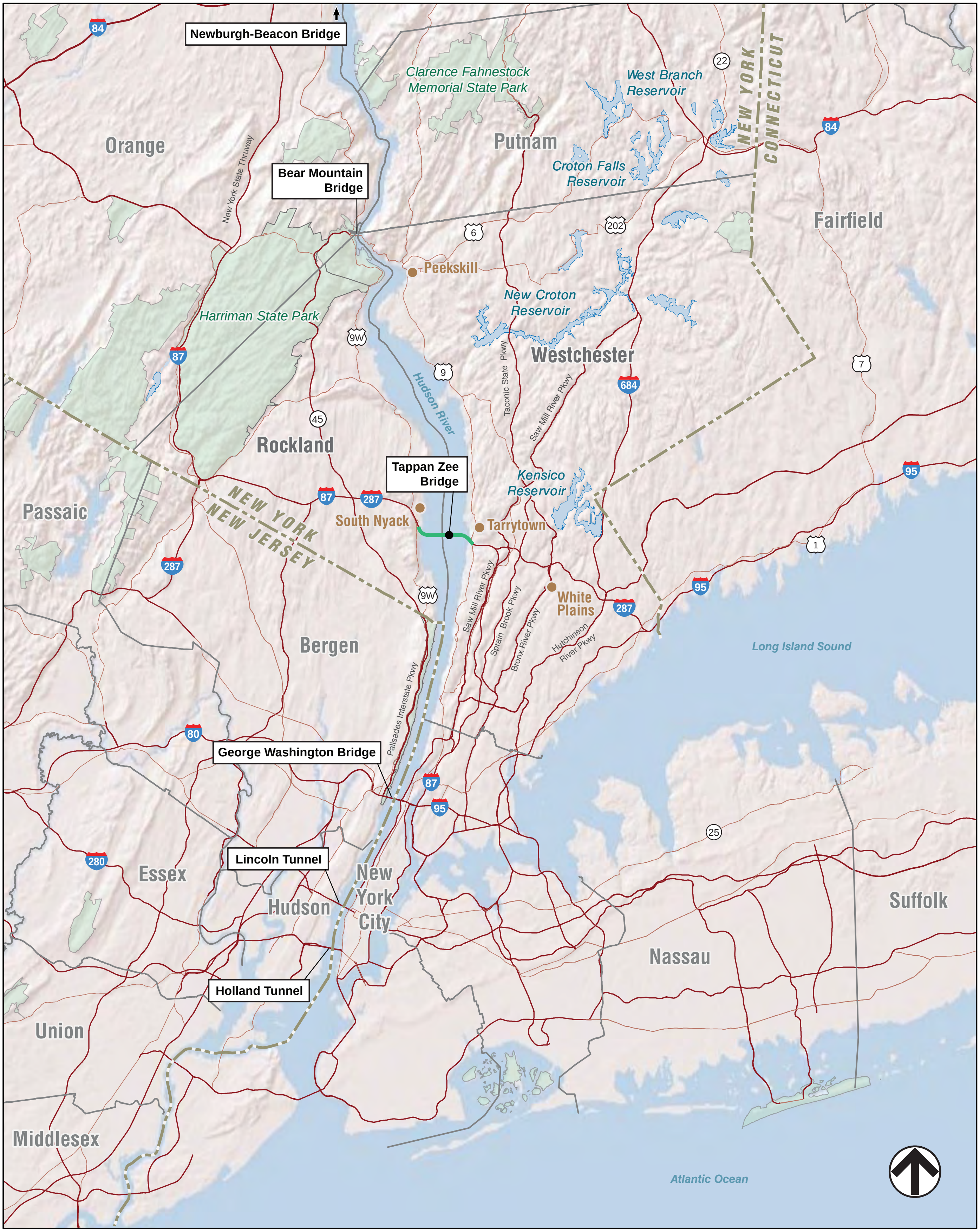
Woodhead, P.M. and M. McEnroe. 1991. Habitat use by the fish community. A report on Task 5.1 of the New York/New Jersey Harbor Estuary Program. Marine Services Research Center, State University of New York, Stony Brook, NY.

Wysocki, L. E., J.W. Davidson, III,, M.E. Smith, A.S. Frankel, W.T. Ellison, P.M. Mazik, A.N. Popper, and J. Bebak. 2007. Effects of aquaculture production noise on hearing, growth, and disease resistance of rainbow trout *Oncorhynchus mykiss*. Aquaculture 272: 687-697.

Wysocki, L.E., K. Montey, and A.N. Popper. 2009. The influence of ambient temperature and thermal acclimation on hearing in a eurythermal and a stenothermal otophysan fish. Journal of Experimental Biology 212: 3091-3099.

Würsig, B., R.R. Reeves, and J.G. Ortega-Ortiz. 2002. Global climate change and marine mammals. In: P.G.H. Evans and J.A. Raga (eds.), Marine Mammals – Biology and Conservation. Kluwer Academic/Plenum Publishers, New York.Zlokovitz, E.R., D.H. Secor, and P.M. Piccoli. 2003. Patterns of migration in Hudson River: striped bass as determined by otolith microchemistry. Fisheries Research 63: 245-259.

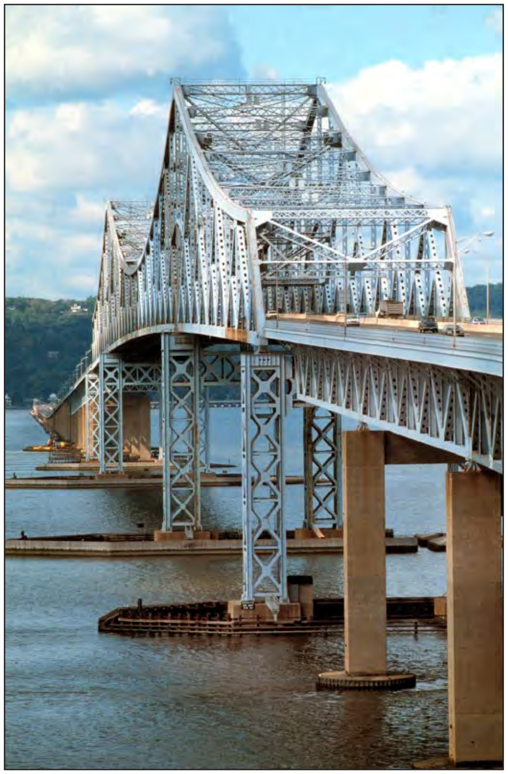
# FIGURES

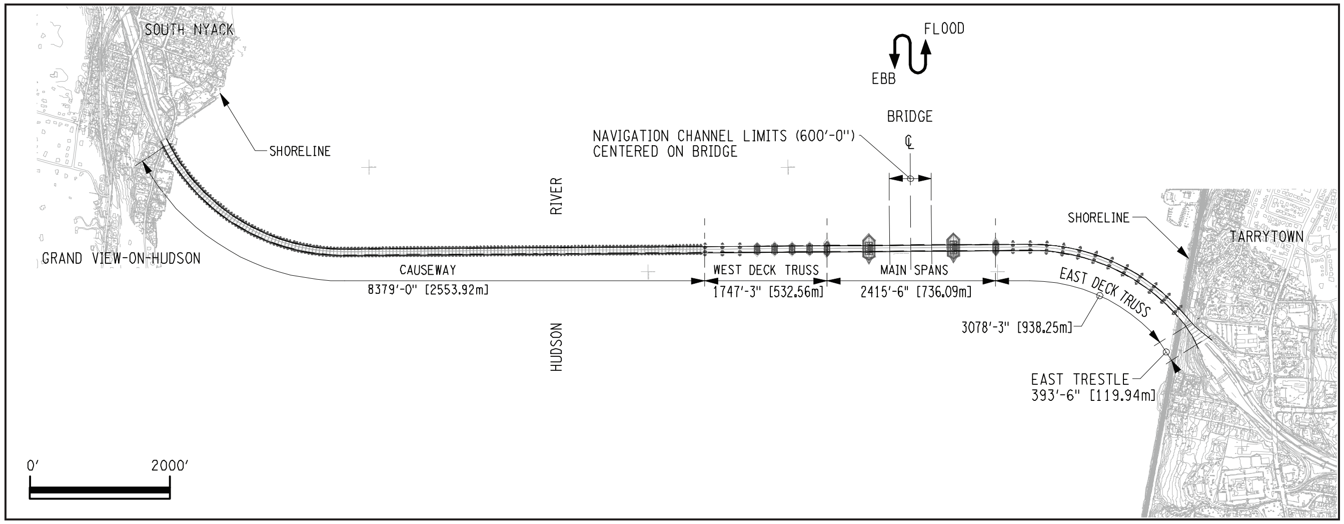



0 10 MILES
SCALE

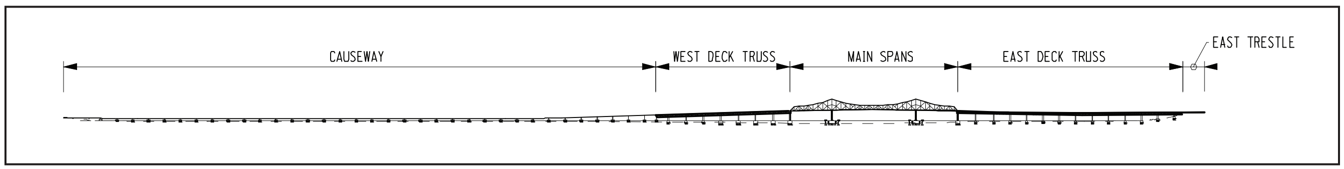


Figure 1
**Project Location and Regional Roadway Network**

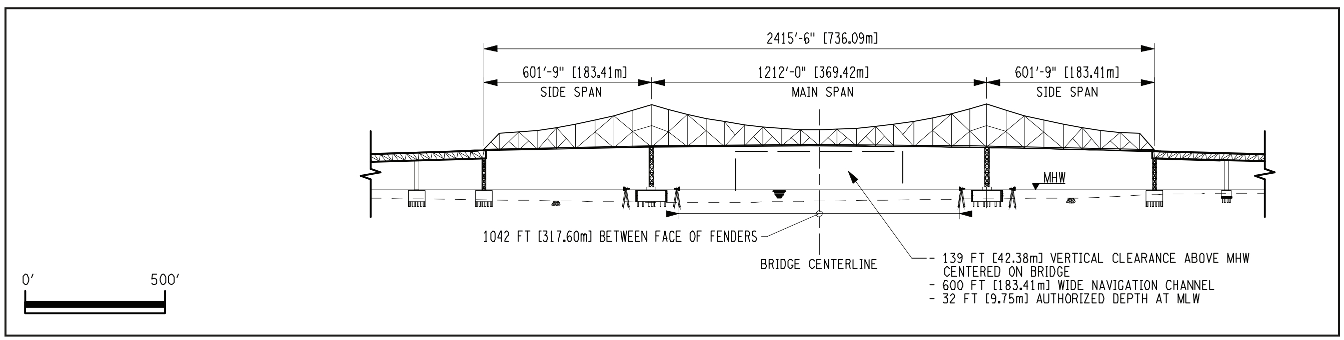





PLAN




PROFILE




MAIN SPANS

**TAPPAN ZEE HUDSON RIVER CROSSING**
Essential Fish Habitat

Figure 2
# Existing Bridge Plan, Profile, and Photographs

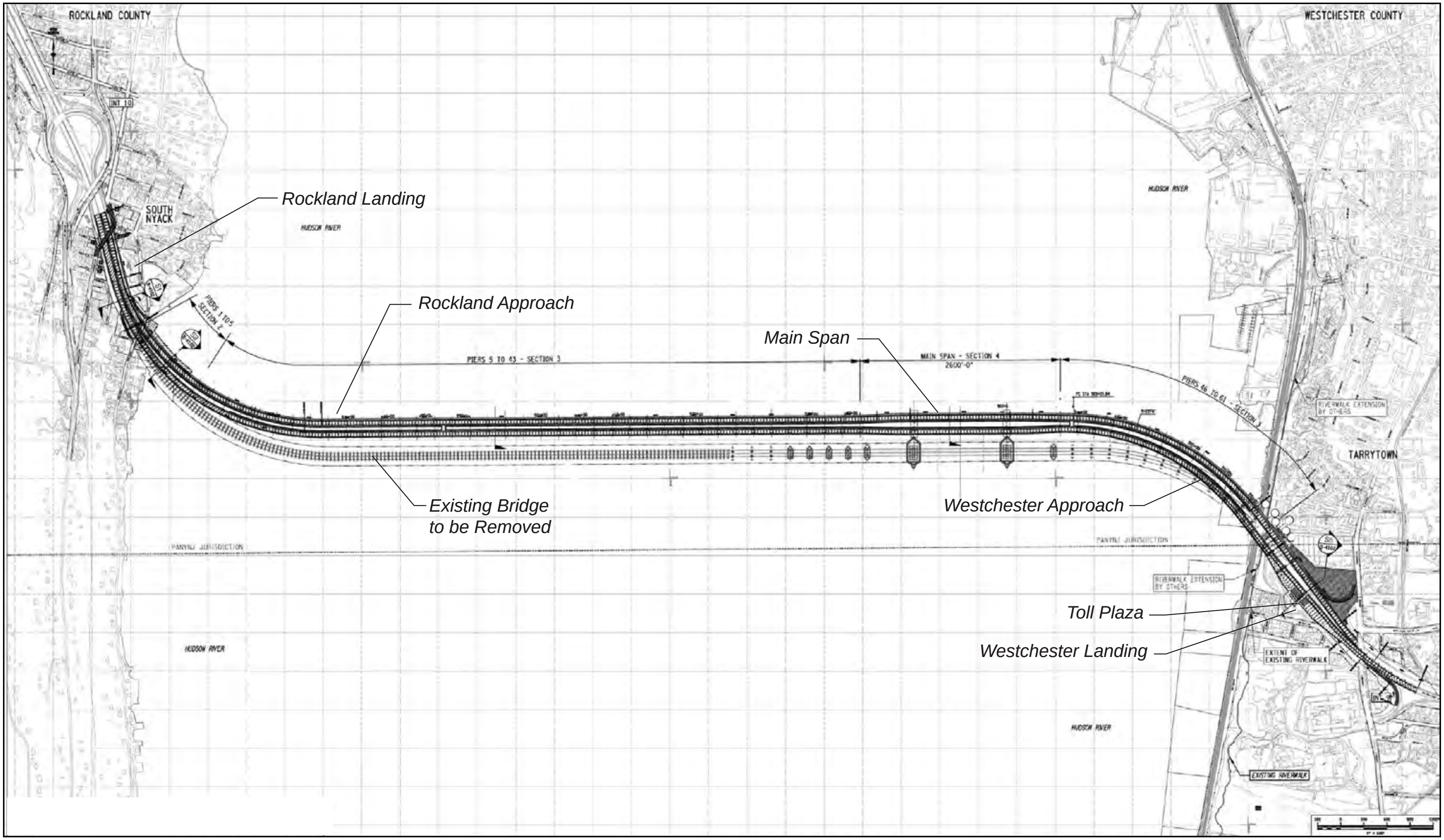
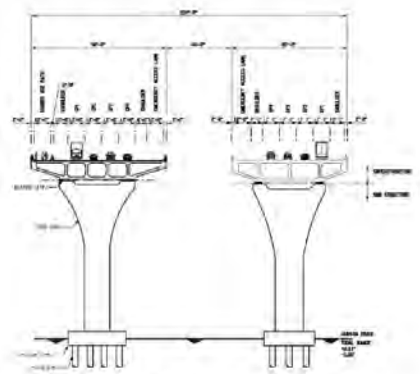


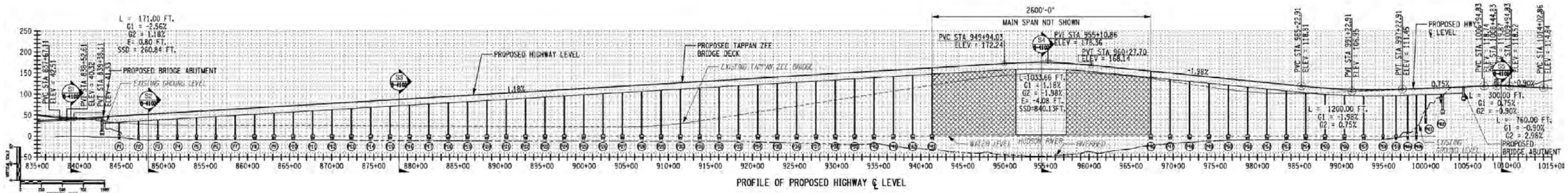



Figure 3
**Replacement Bridge Alternative**

## Short Span Option

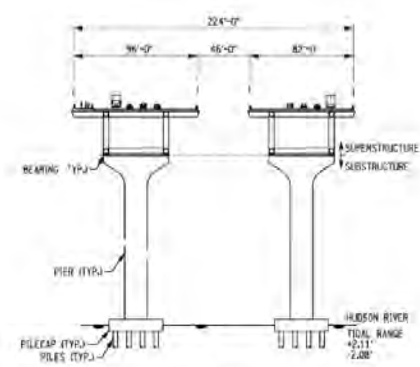


Short Span Cross-Section

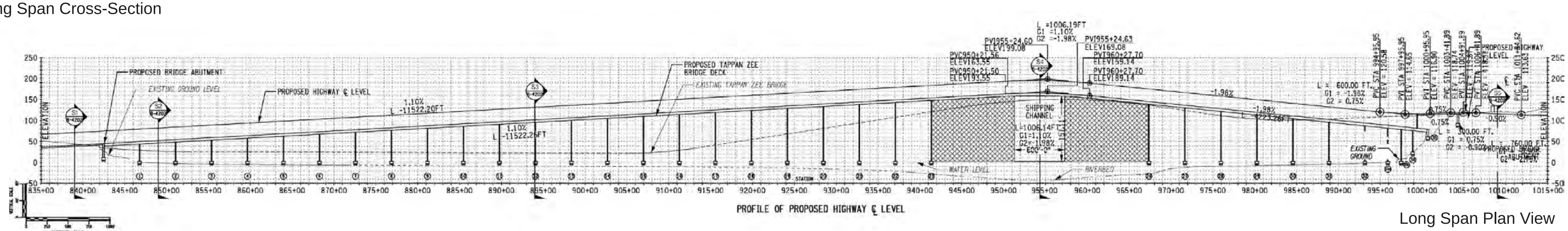



Short Span Plan View

## Long Span Option




Long Span Cross-Section




Long Span Plan View



Figure 4
**Approach Spans Options**

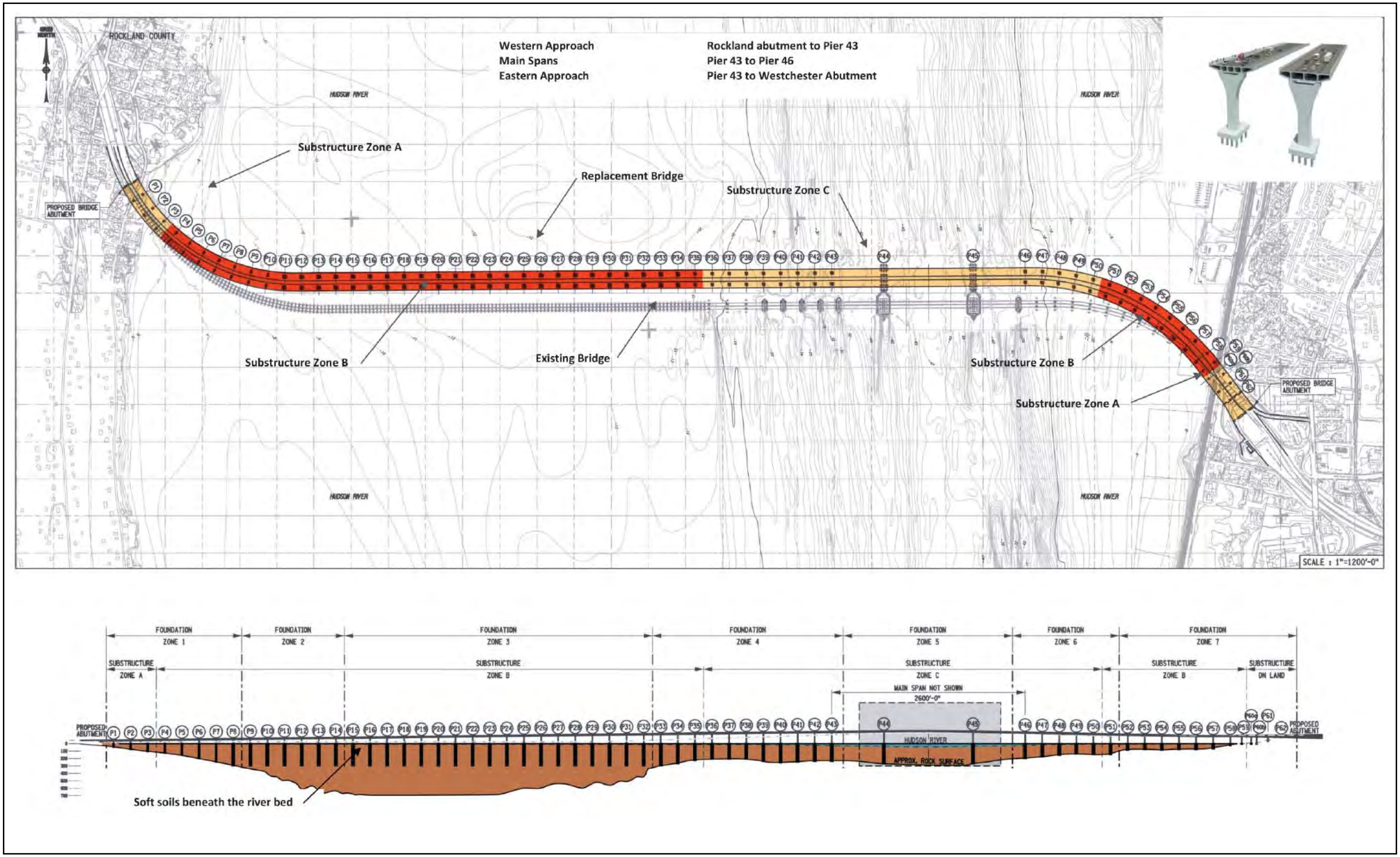





Figure 5
## Construction Zones for Short Span Bridge Option

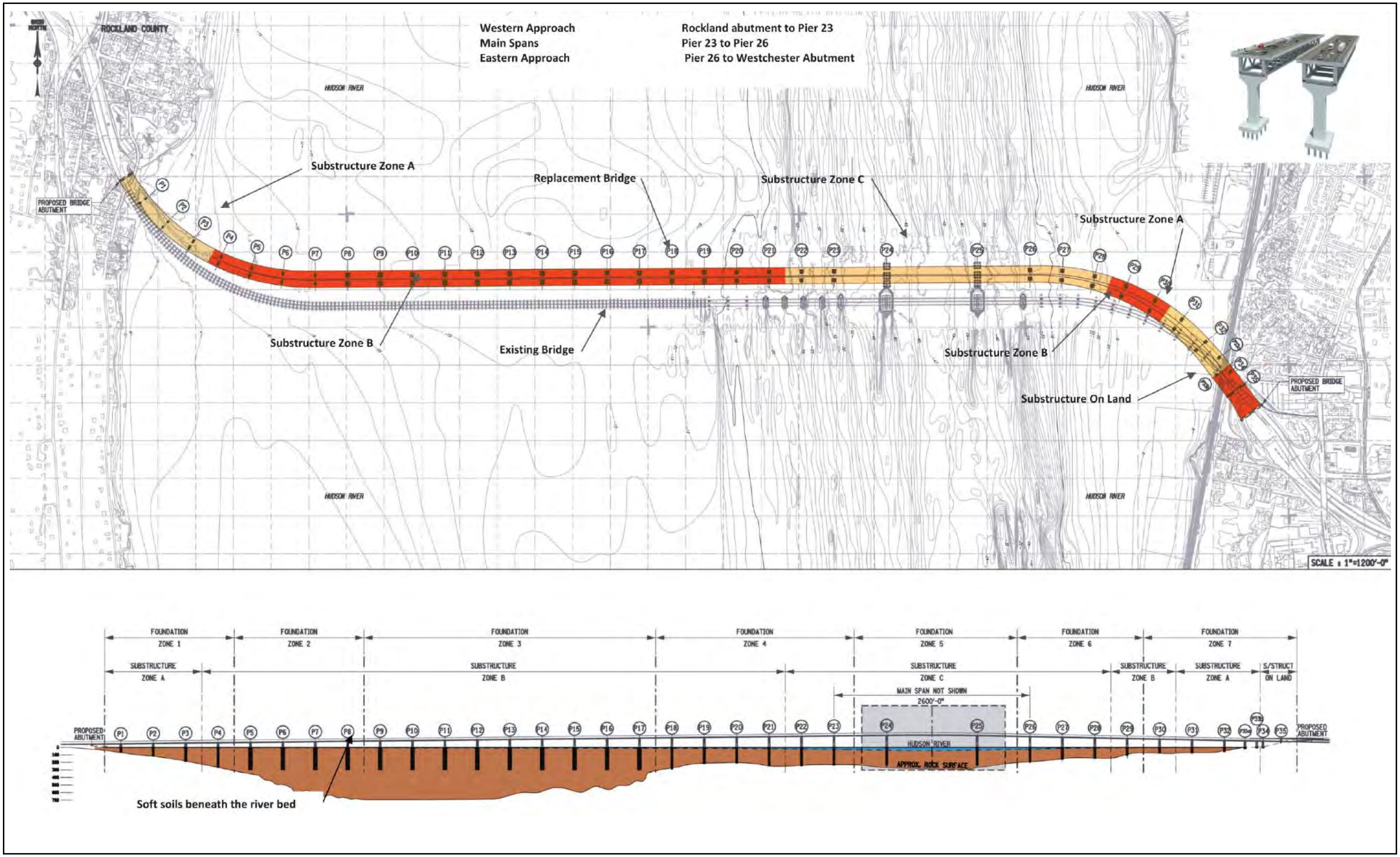





Figure 6
**Construction Zones for Long Span Option**

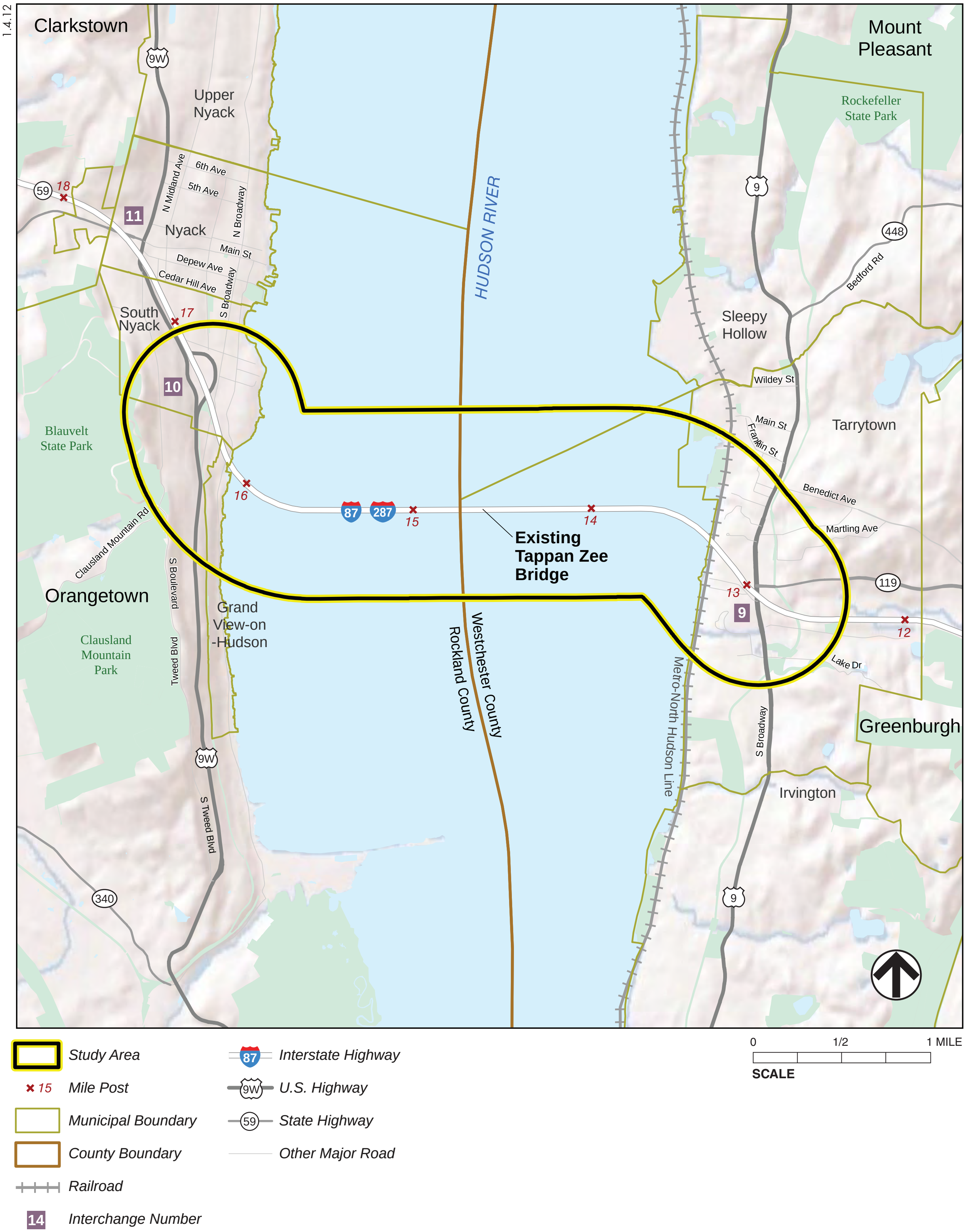
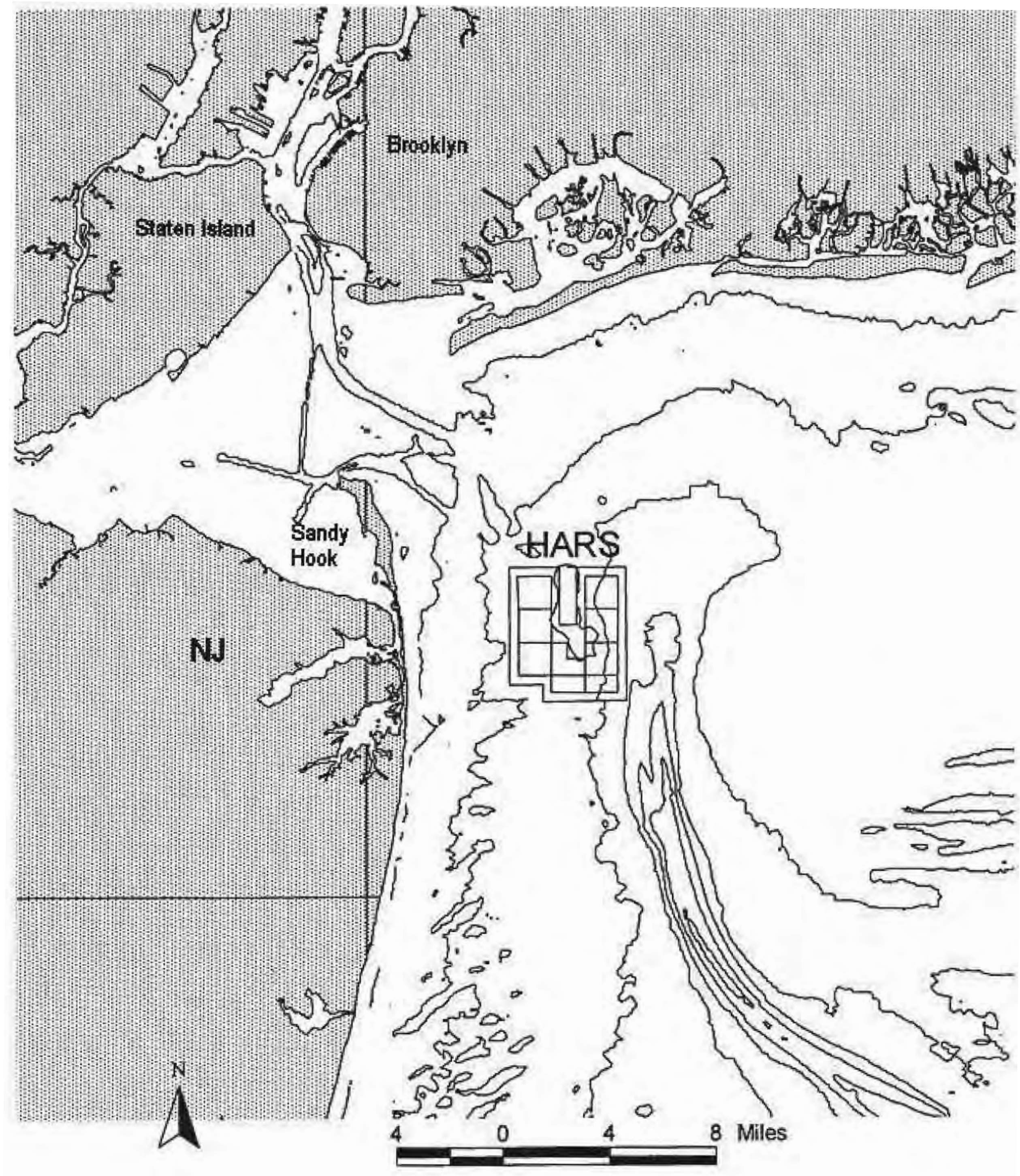






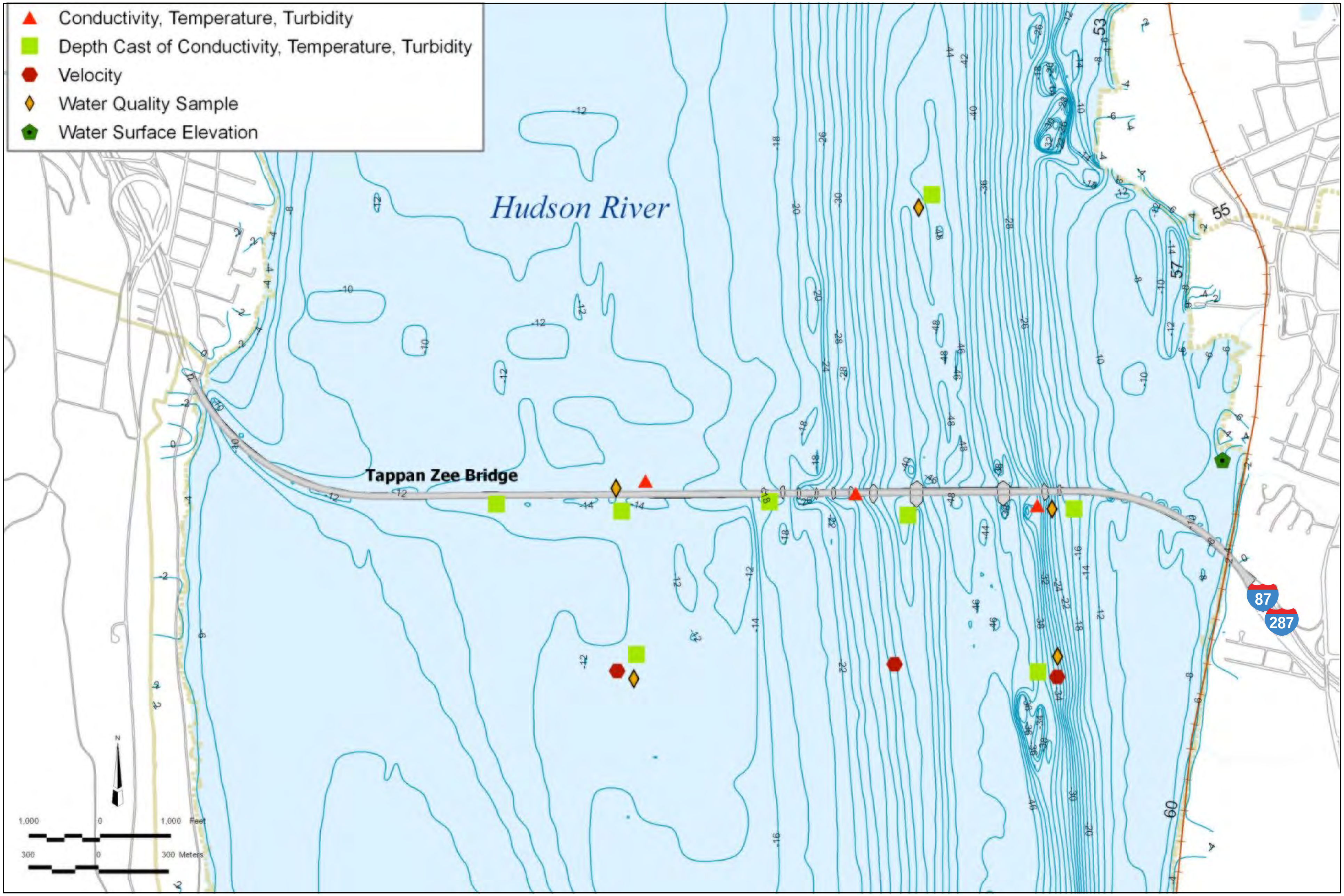

Figure 7
**Hudson River Bridge Construction Study Area**




SOURCE: USACE and USEPA 2009



Figure 8
**Location of HARS**




**TAPPAN ZEE HUDSON RIVER CROSSING**
Essential Fish Habitat

Figure 9
**Bathymetry**




Figure 10
**Average Salinity Concentration at Hastings-on-Hudson**

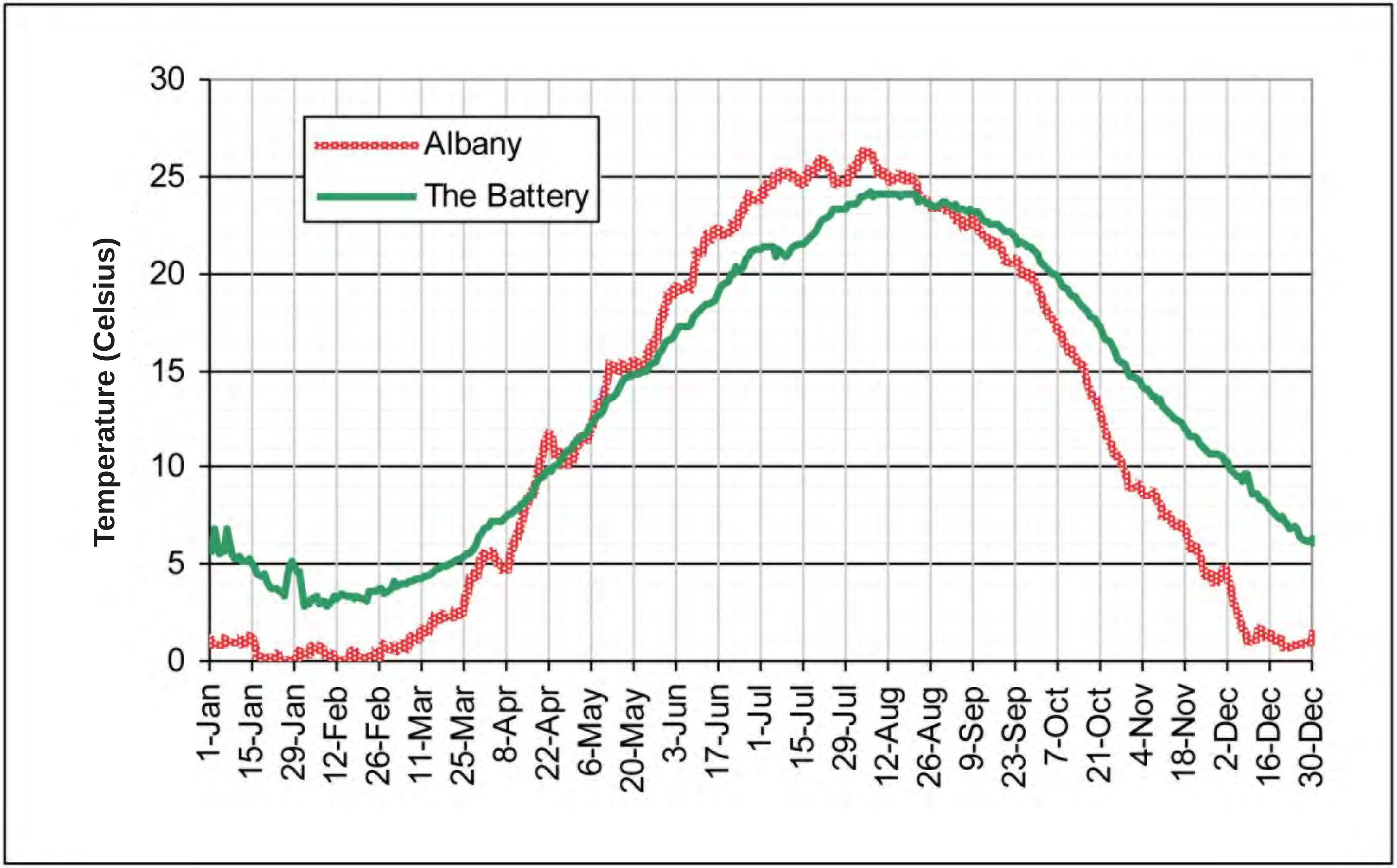





Figure 11
**Average Water Temperature at Albany and the Battery**

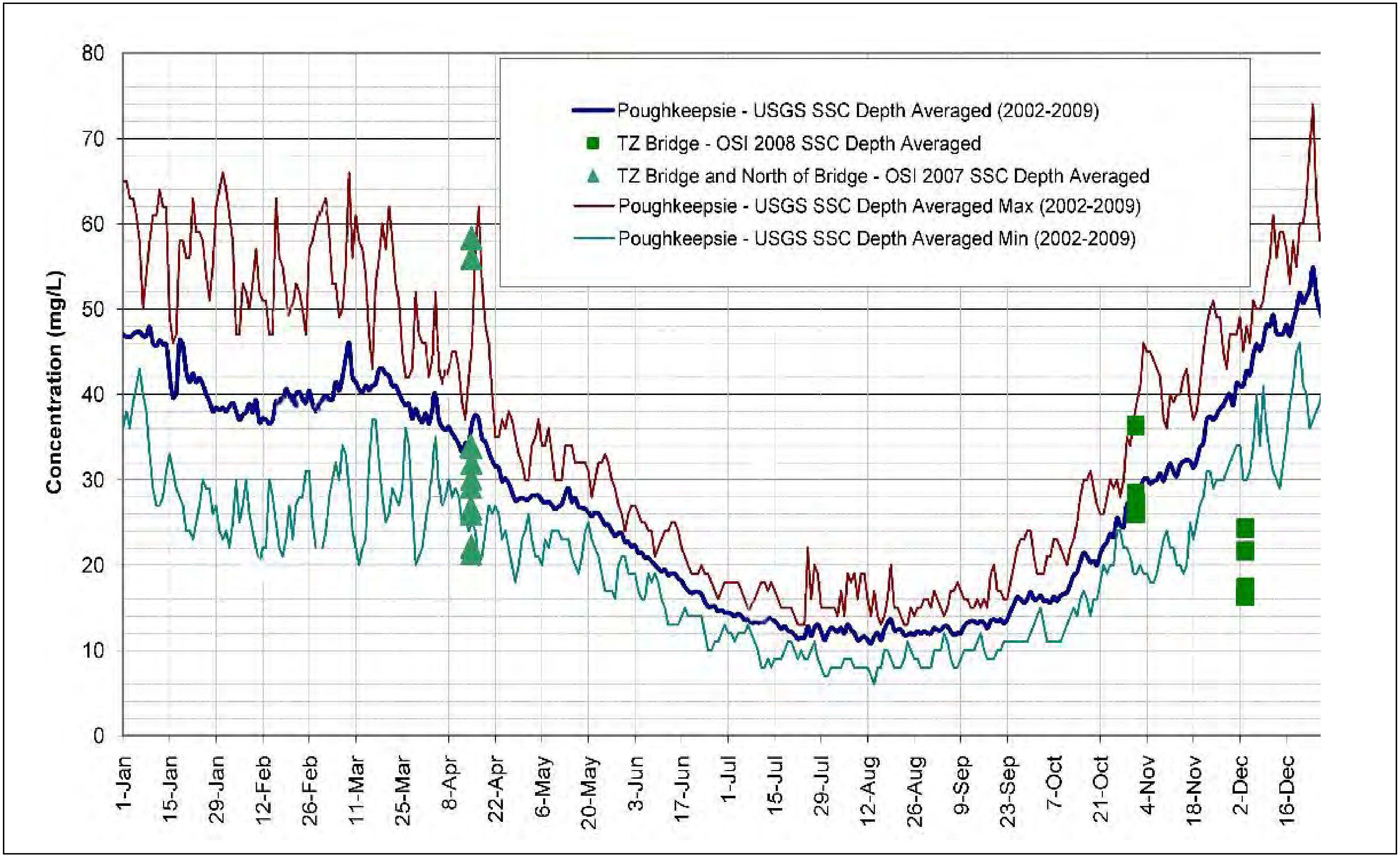
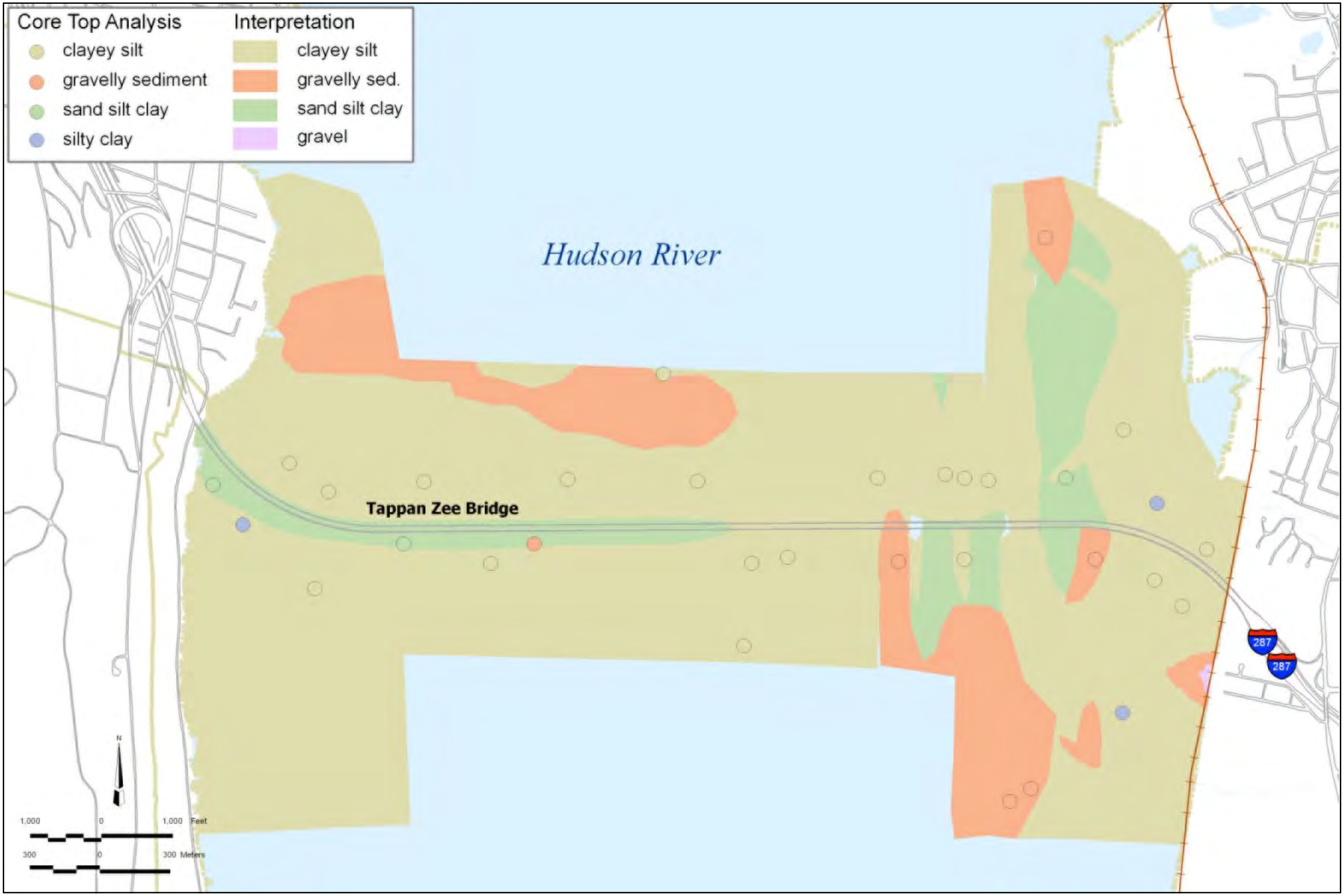





Figure 12
**SSC Data**




**TAPPAN ZEE HUDSON RIVER CROSSING**
Essential Fish Habitat

Figure 13
**Sediment Texture**

1.4.12

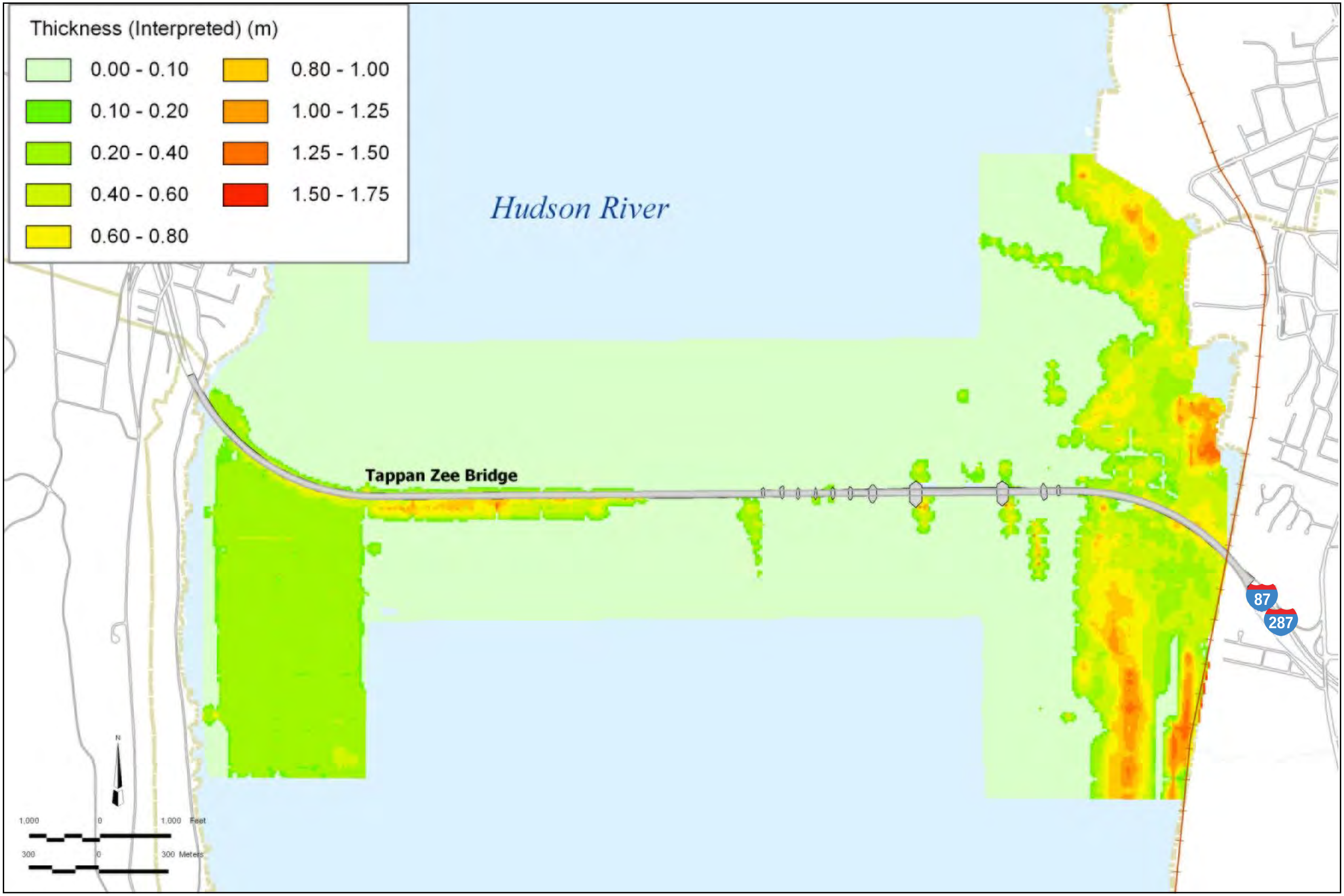
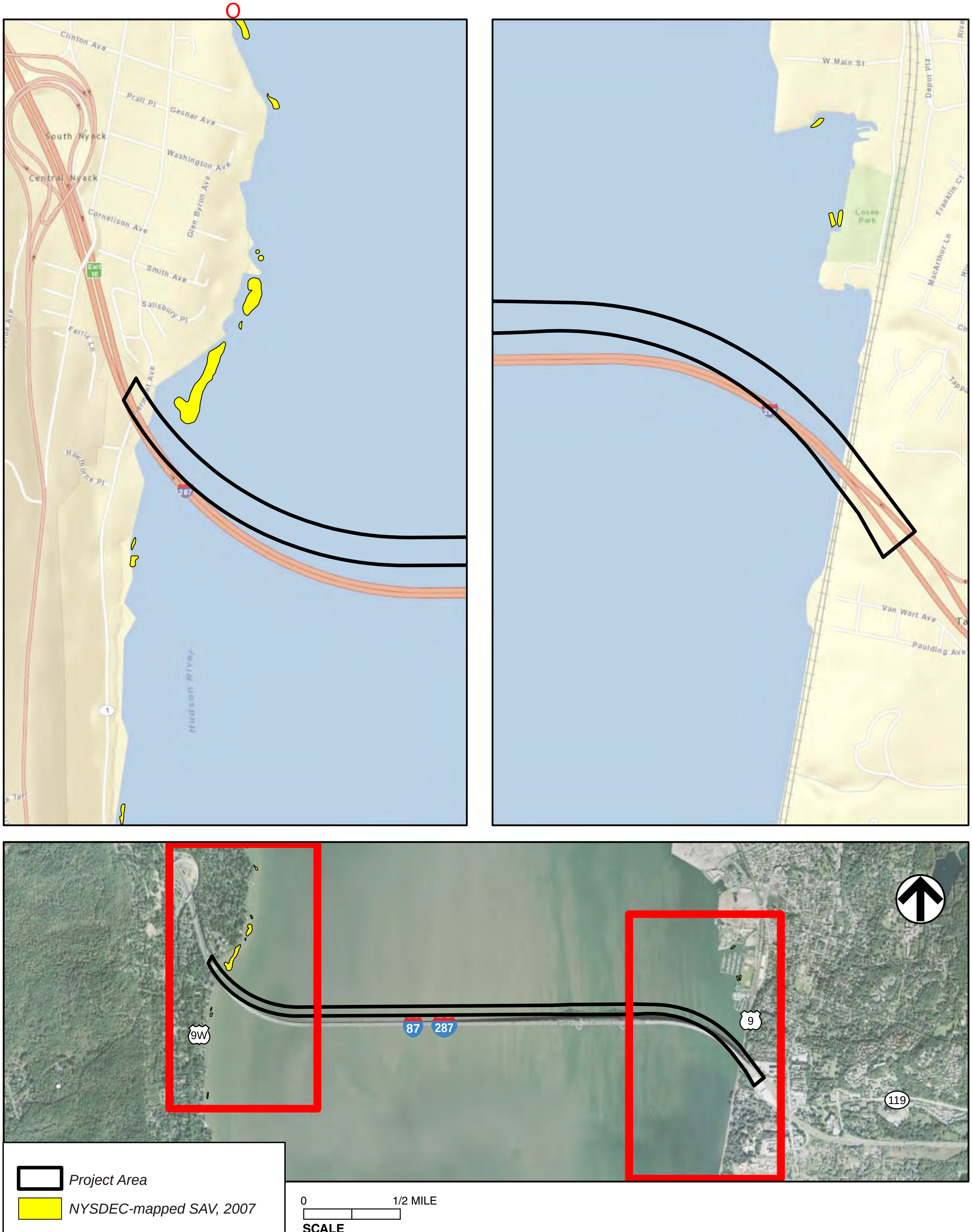





Figure 14
**Recent Sediment Deposit Thickness**

1.4.12




**TAPPAN ZEE HUDSON RIVER CROSSING**
Essential Fish Habitat

Figure 15
## Submerged Aquatic Vegetation (SAV)

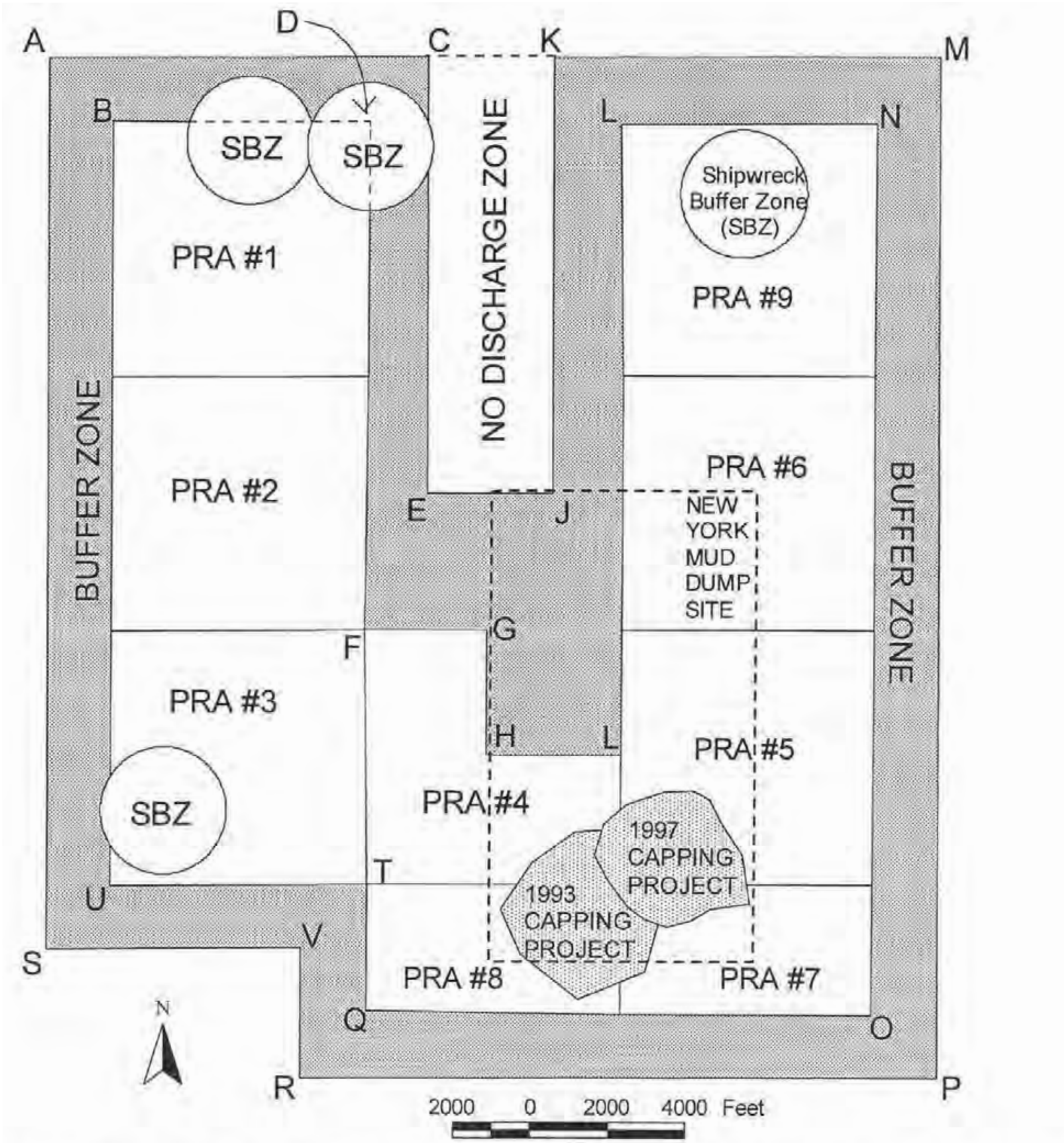
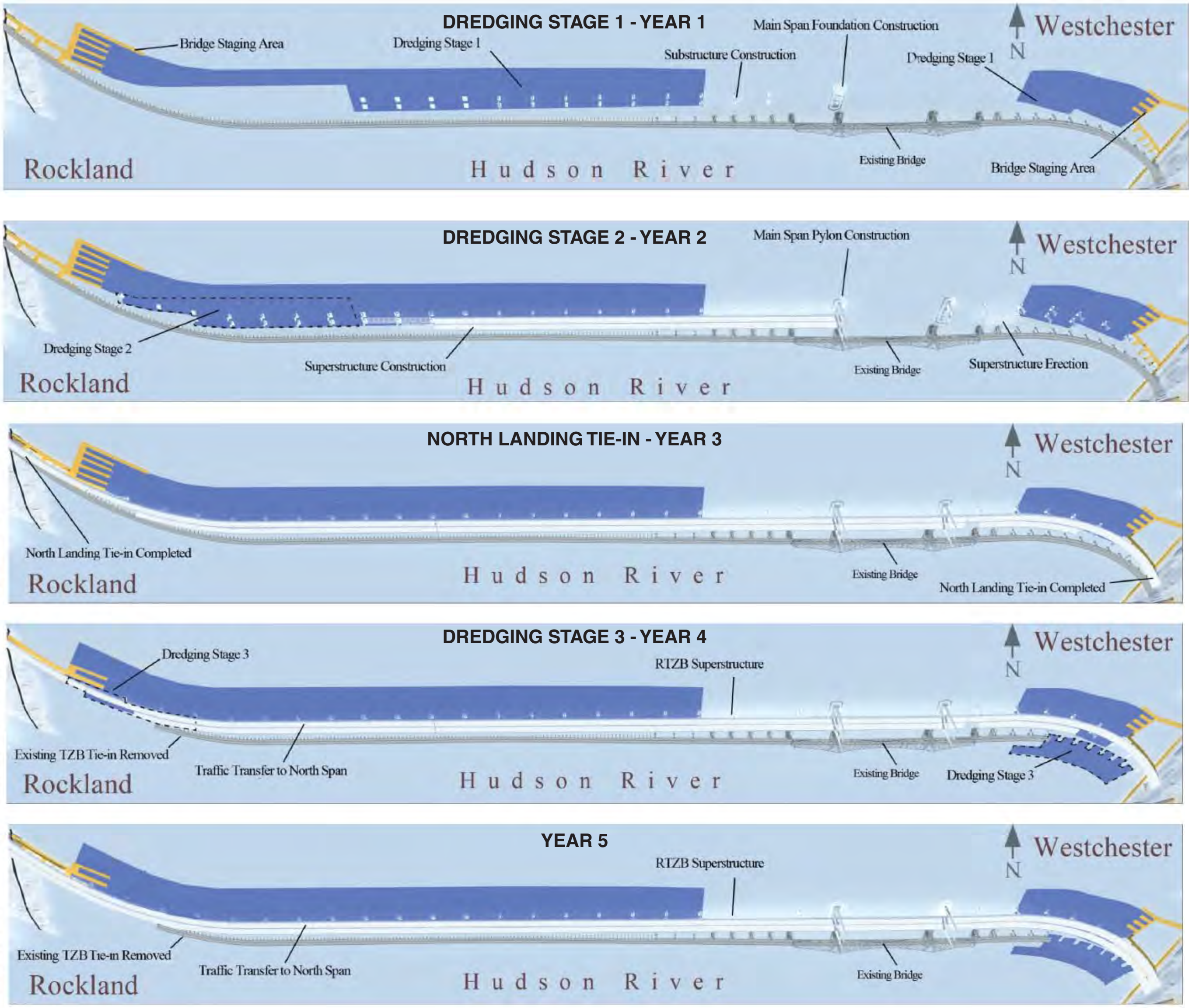



Figure 16
**Priority Remediation Areas, Buffer Zone and No Discharge Zone**




Note: Long Span Option is depicted, Short Span Option will be similar



Figure 17
**Dredging Sequence, Years 1 to 5**




Figure 18
**Potential Upland Staging Areas**

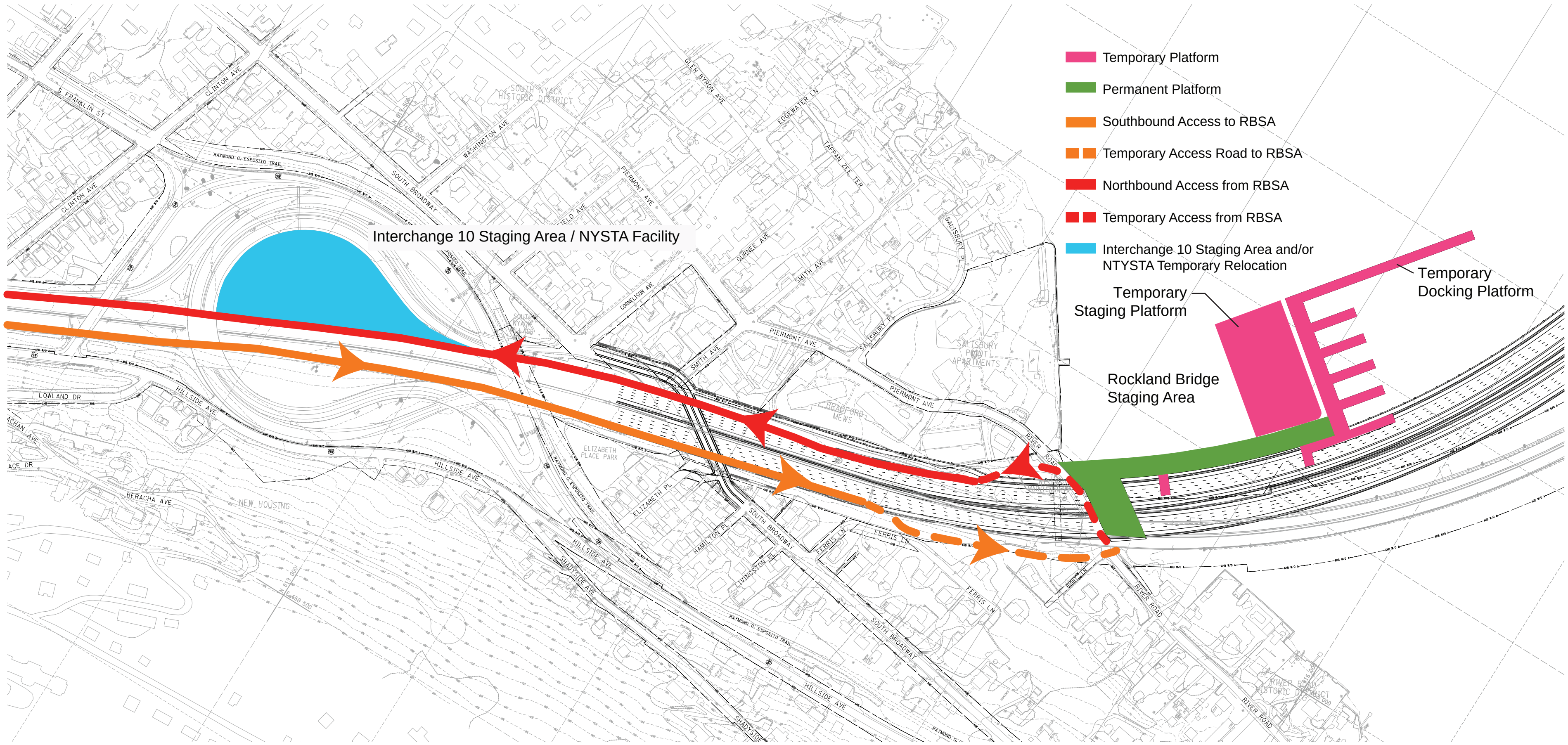



Figure 19
## Rockland Landing Construction Access

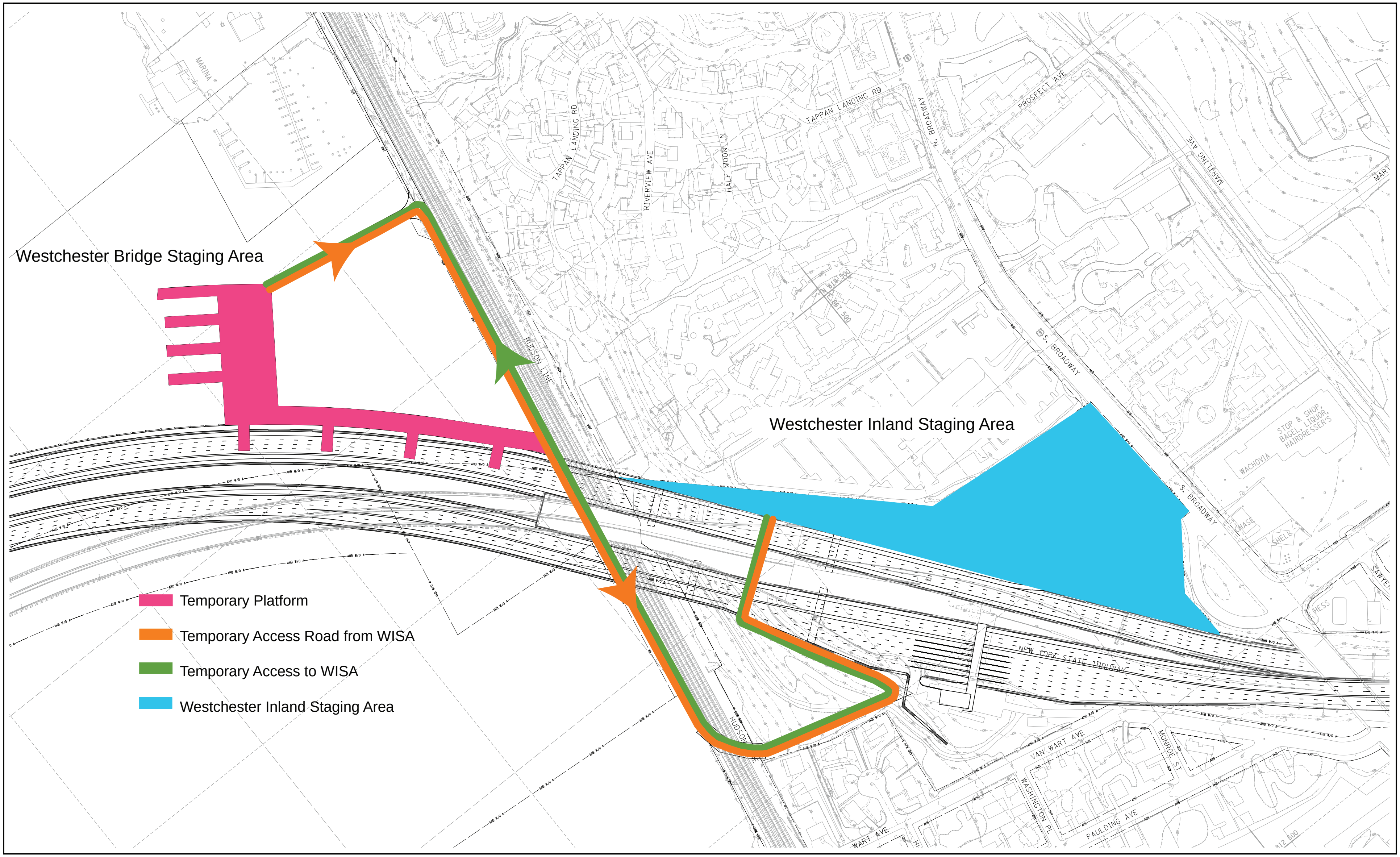
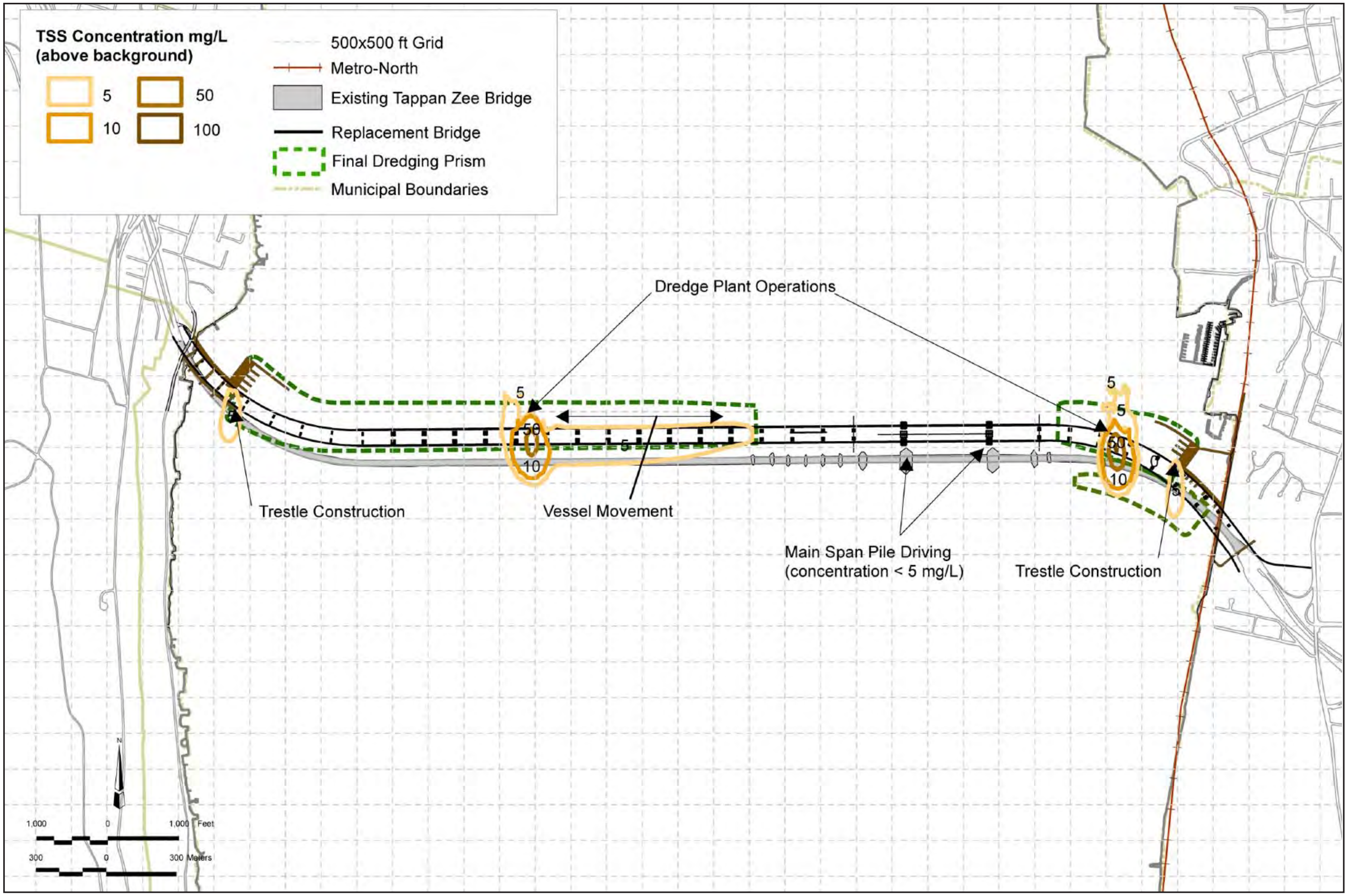





Figure 20
## Westchester Landing Construction Access

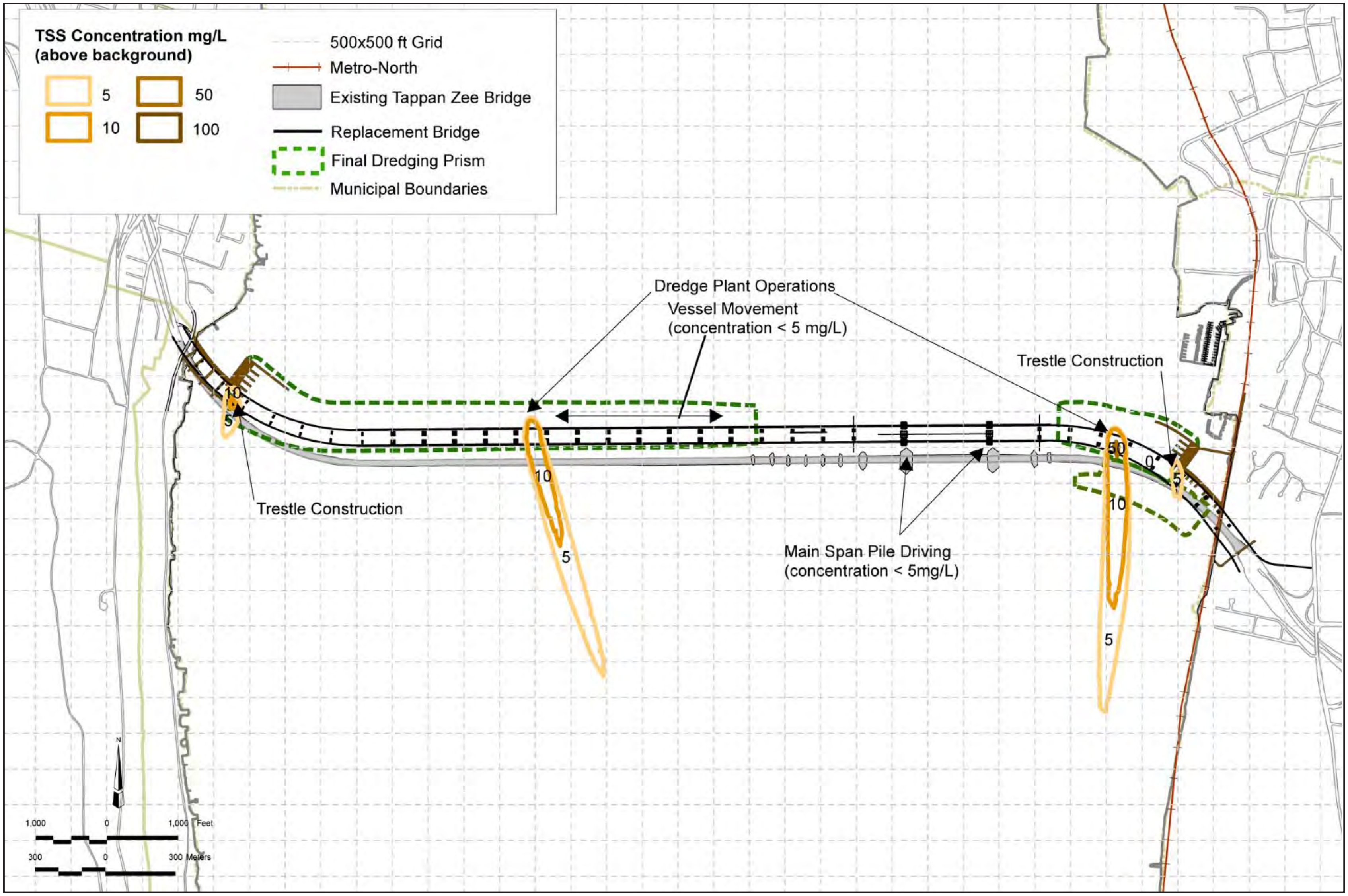



Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* During Stage 1 Dredging-Near Slack Tide

*Note: Short Span Option would be similar

Figure 21

## Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option During Stage 1 Dredging – Near Slack Tide

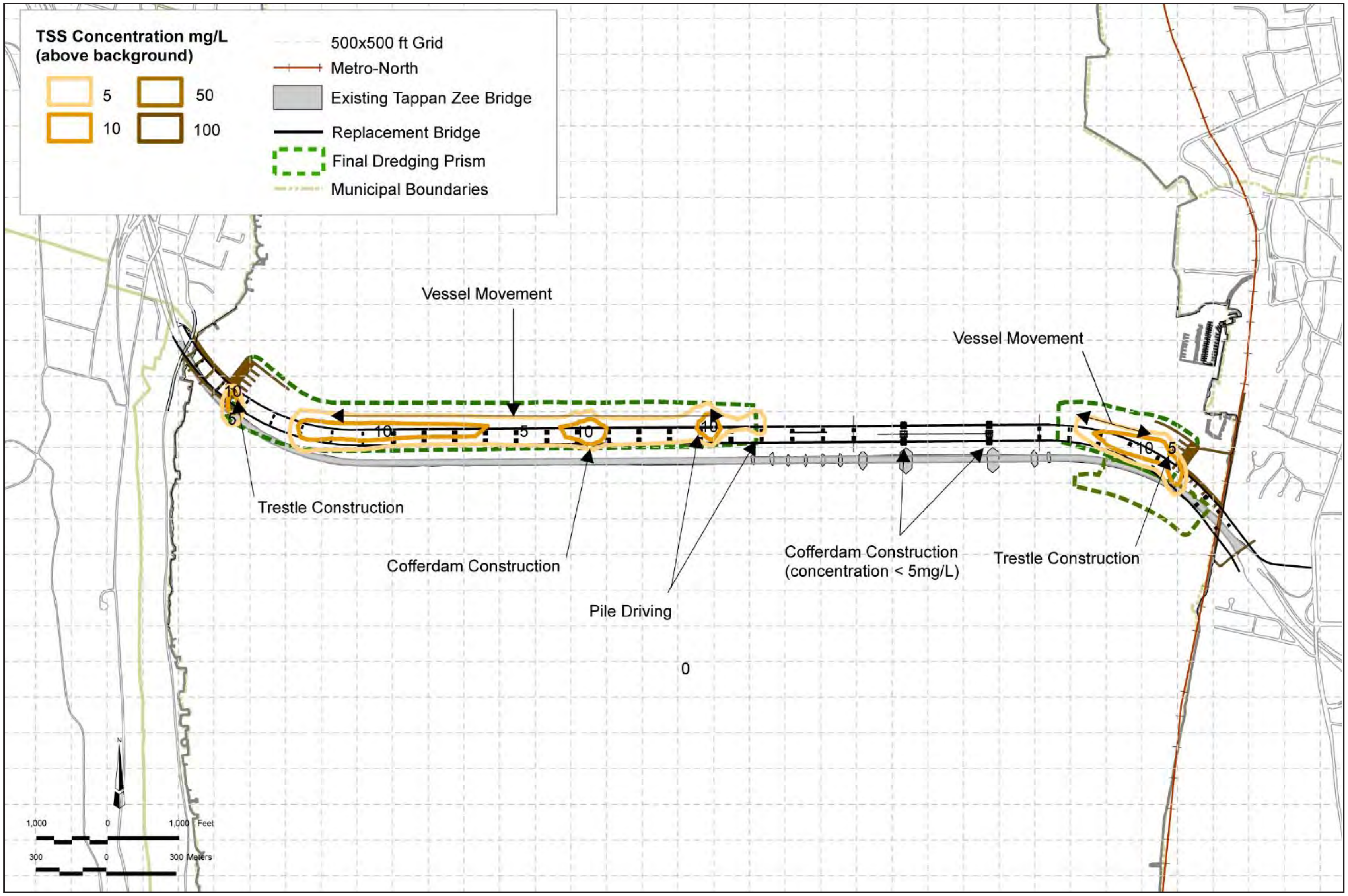



Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* During Stage 1 Dredging-Ebb Tide

*Note: Short Span Option would be similar

Figure 22

# Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option During Stage 1 Dredging – Ebb Tide

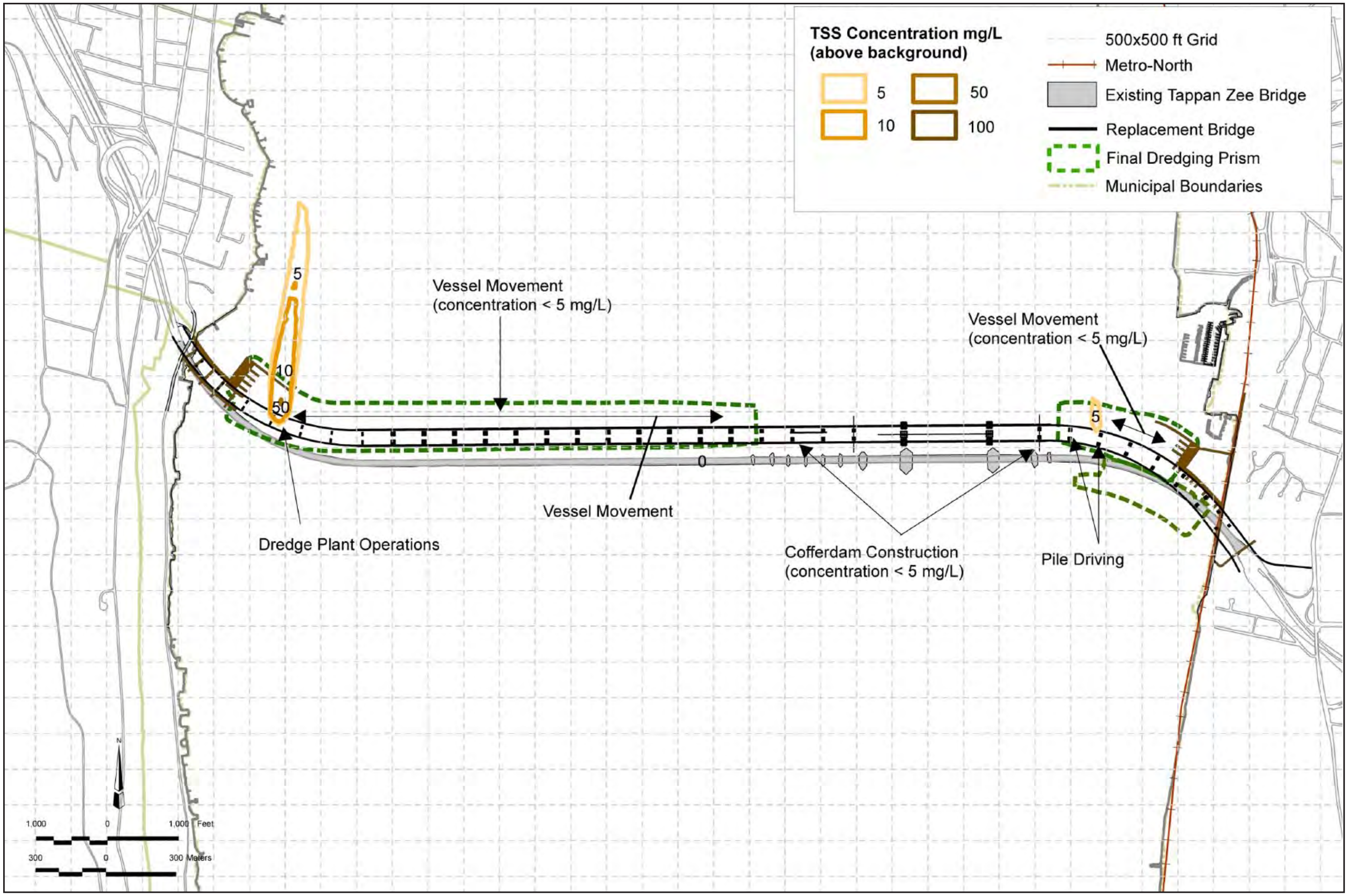



Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* Zones C and B Construction After Dredging and Armoring – Near Slack Tide

*Note: Short Span Option would be similar

Figure 23

**Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option Zones C and B Construction After Dredging and Armoring – Near Slack Tide**




Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* During Stage 2 Dredging and Zones C and B Construction– Flood Tide

*Note: Short Span Option would be similar

Figure 24

## Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option During Stage 2 Dredging and Zones C and B Construction – Flood Tide

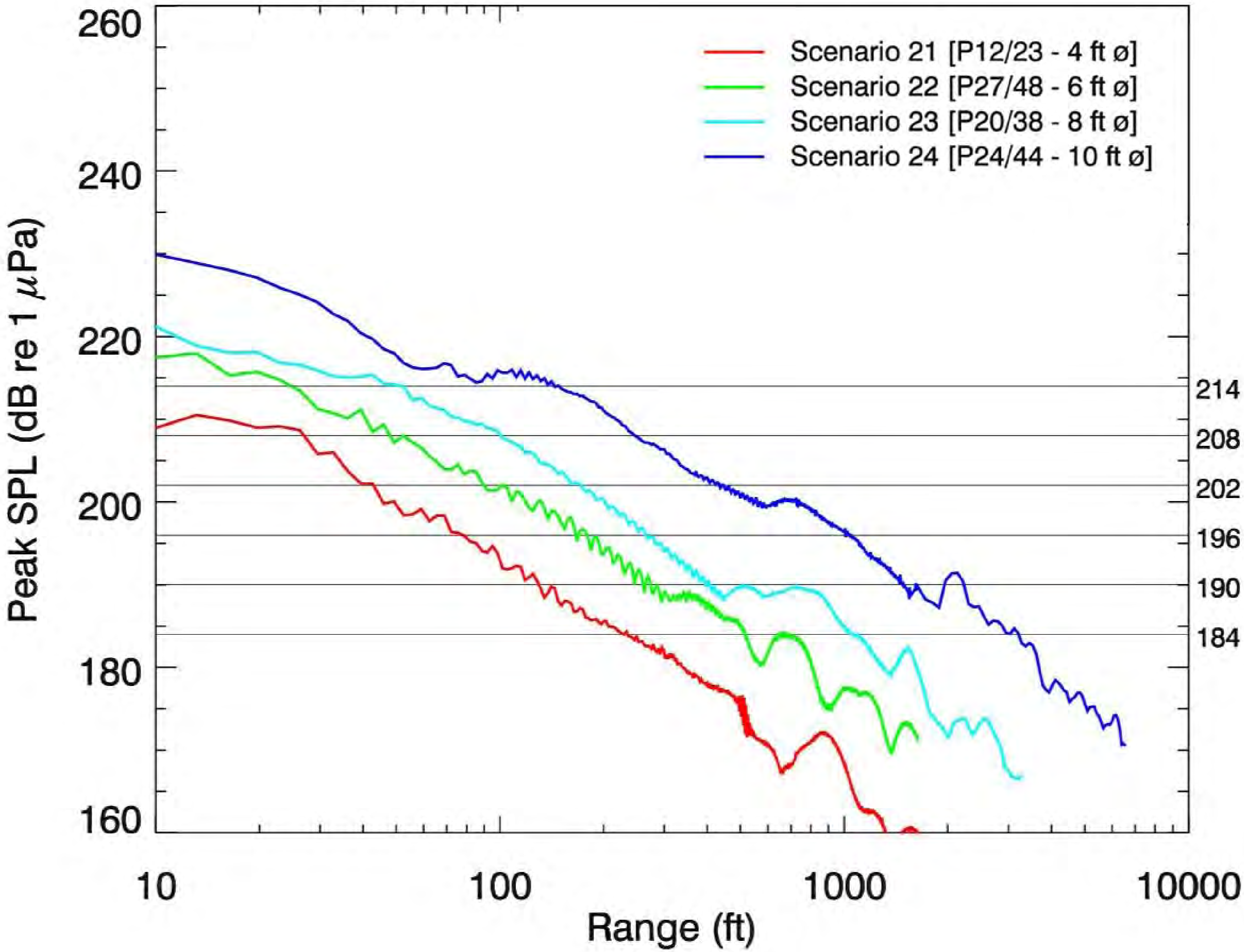





Figure 25
**Impact Hammering of 4, 6, 8 and 10 Feet Diameter Piles with BMPs**

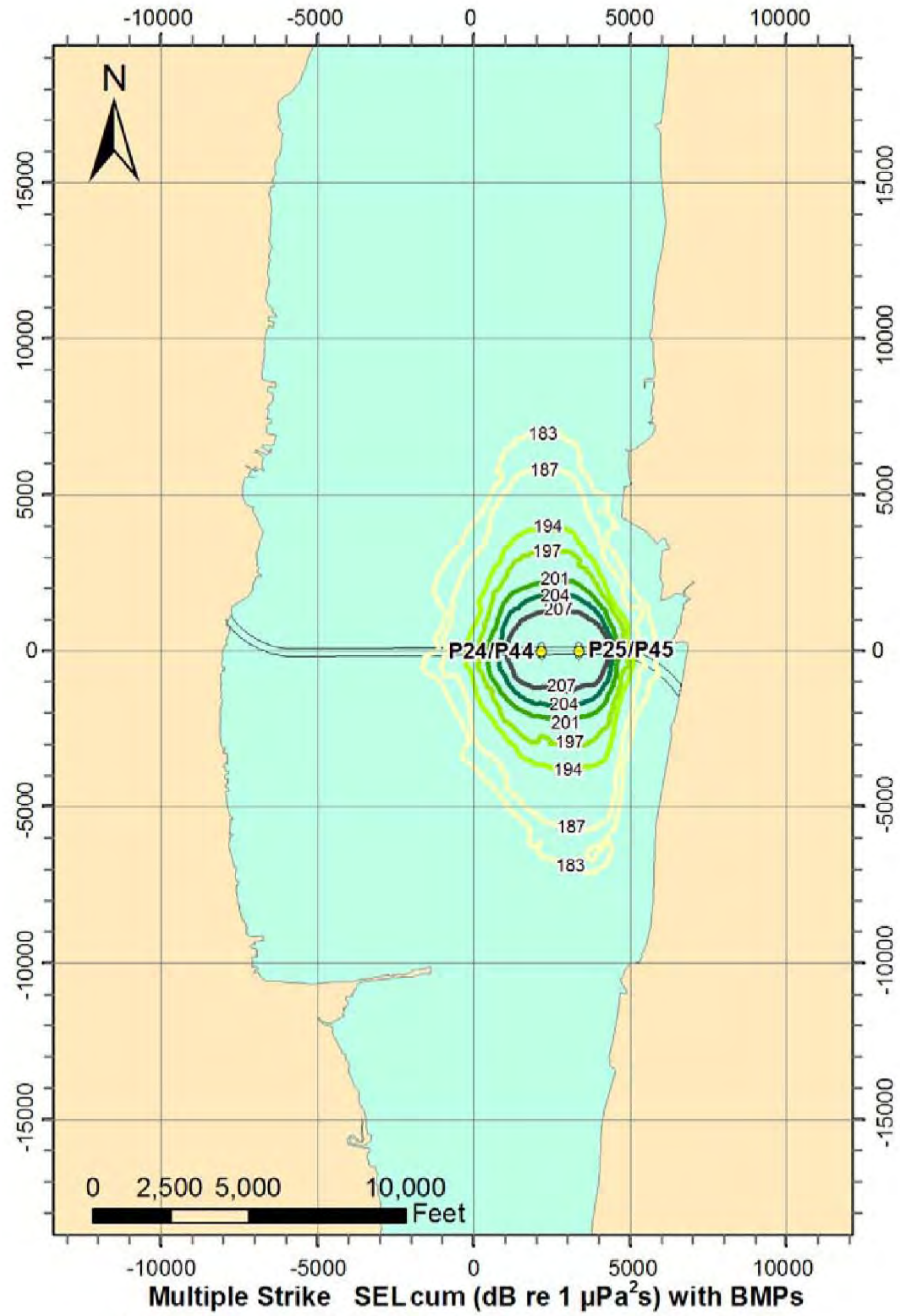



Figure 26

**Isopleths for Short and Long Span Options - Driving of Two 10 Foot Piles at Piers 24, 25, 44 & 45**

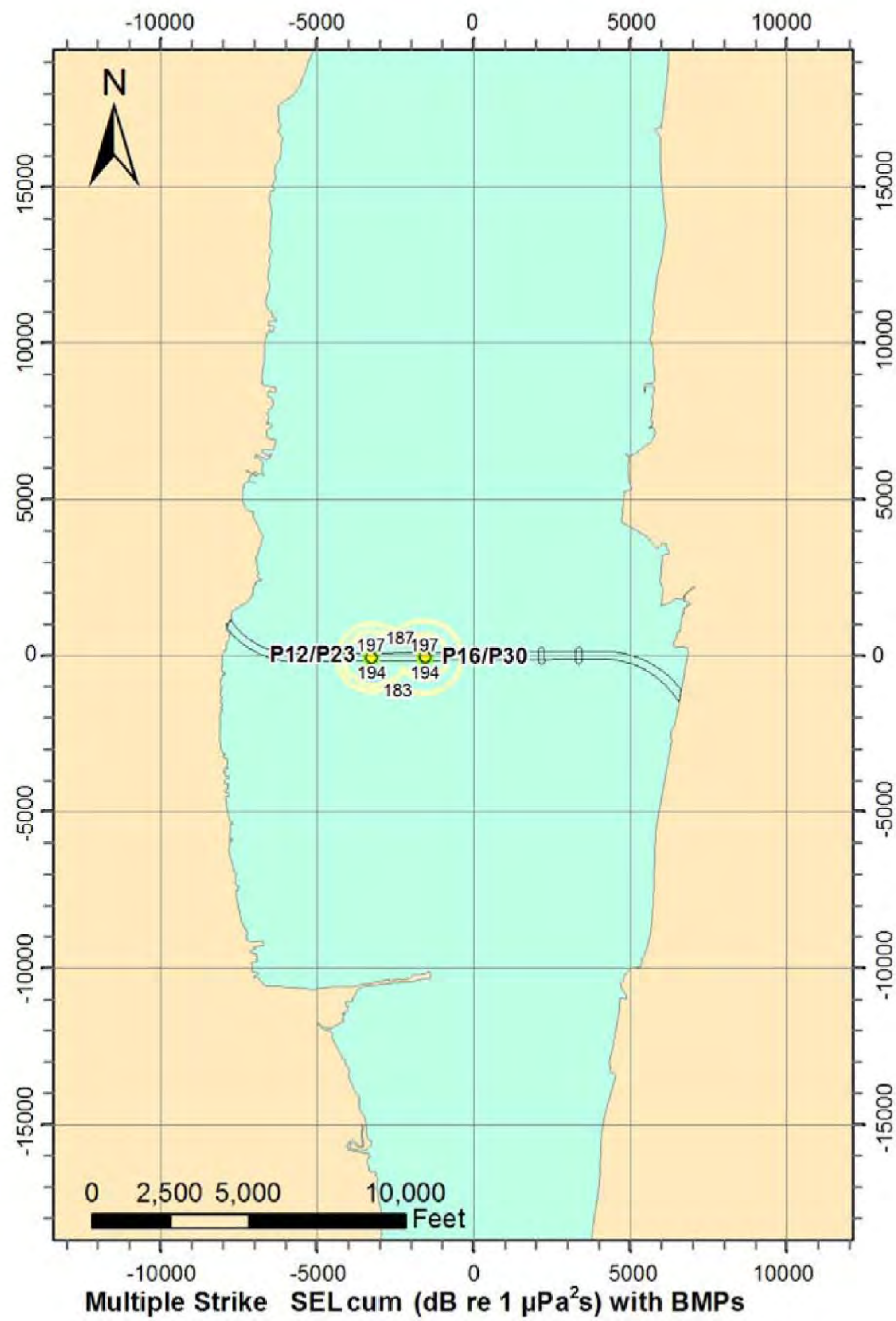



Figure 27

**Isopleths for Short and Long Span Options - Driving of Four 4 Foot Piles at Piers 12, 16, 23 & 30**

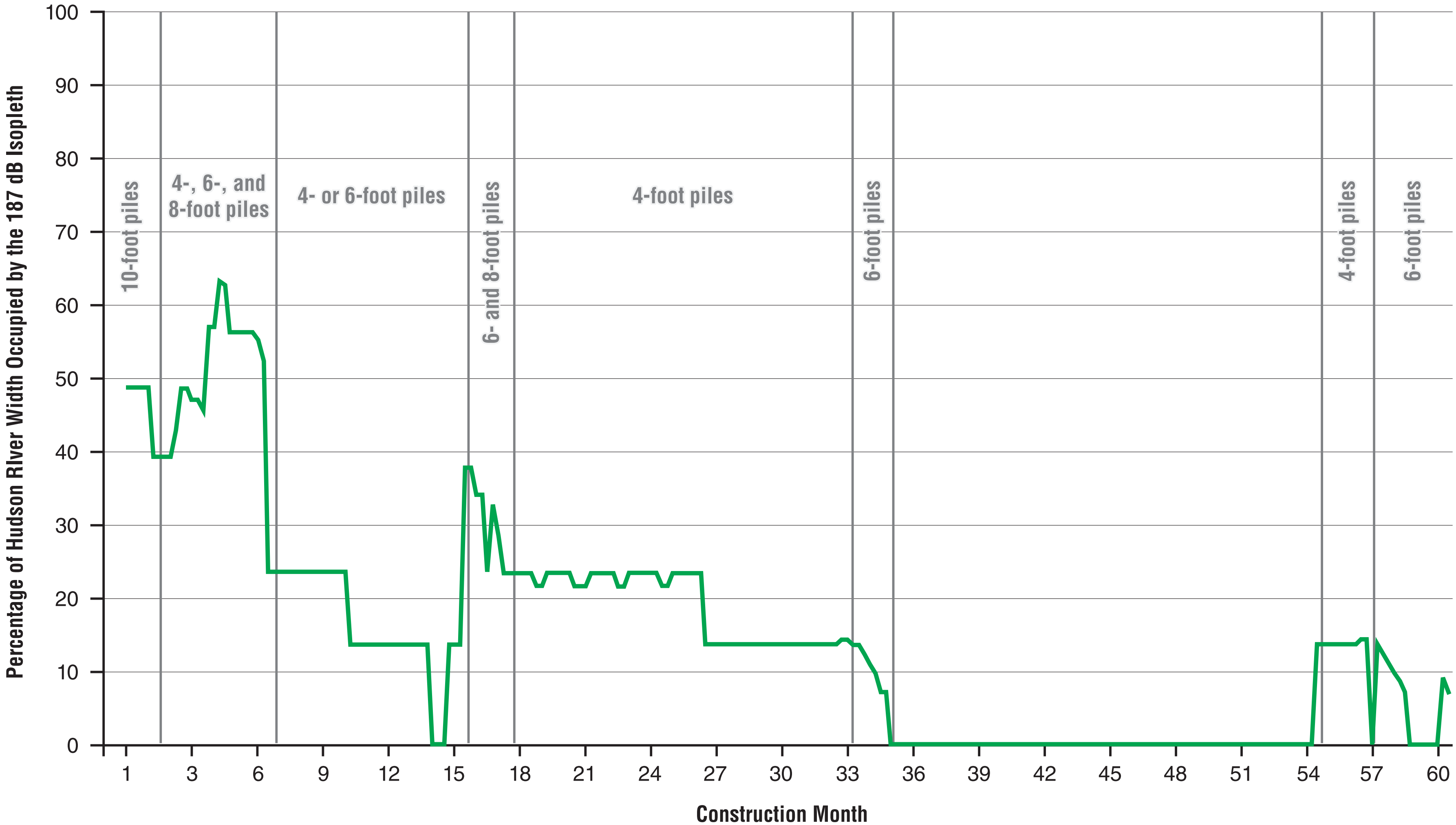



Figure 28

**Percent of the Hudson River Width Occupied by the $SEL_{cum}$ 187 dB re 1 µPa²·s Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Short Span Option**

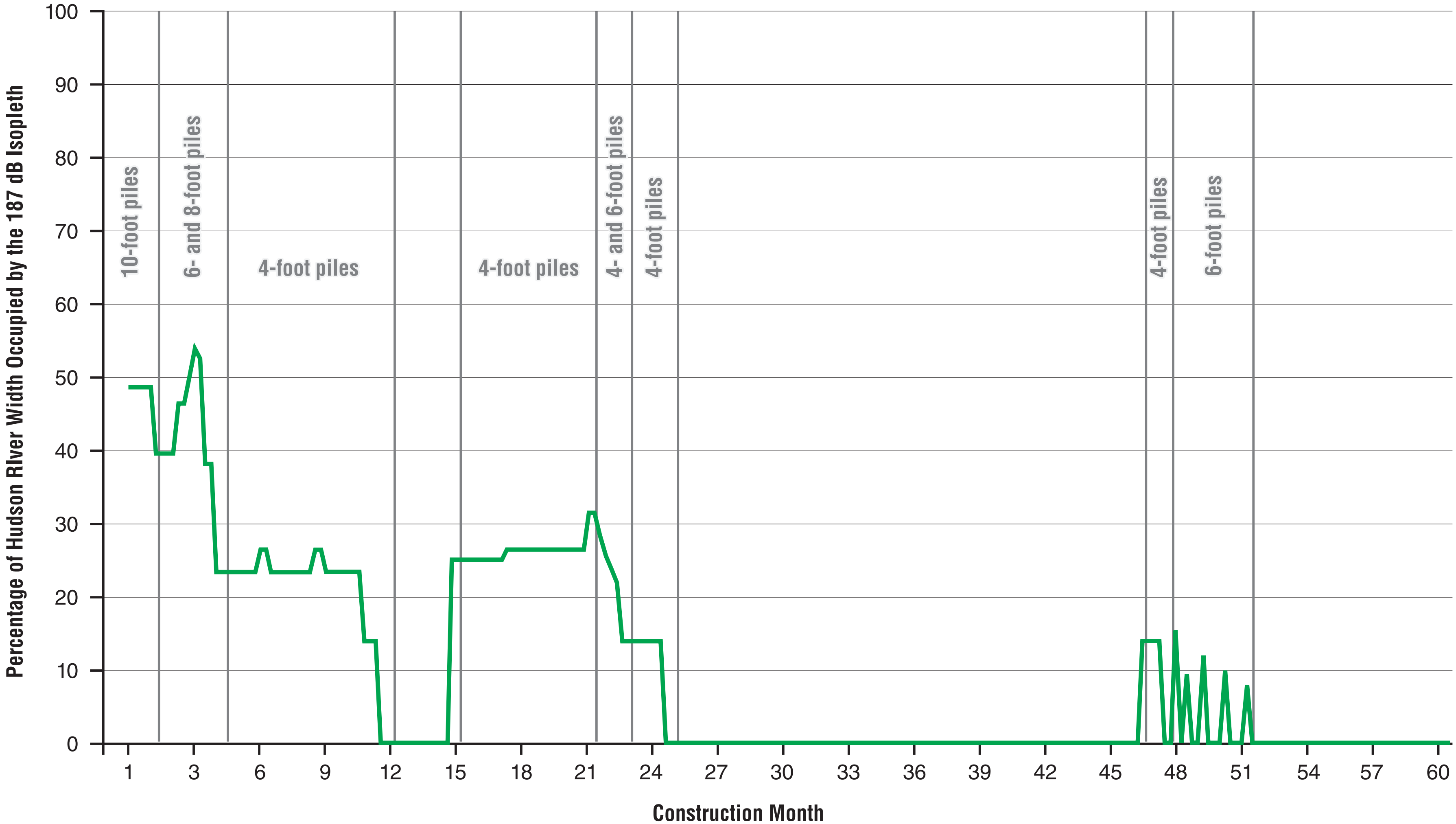



Figure 29

**Percent of the Hudson River Width Occupied by the $SEL_{cum}$ 187 dB re 1 $\mu Pa^2 \cdot s$ Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Long Span Option**

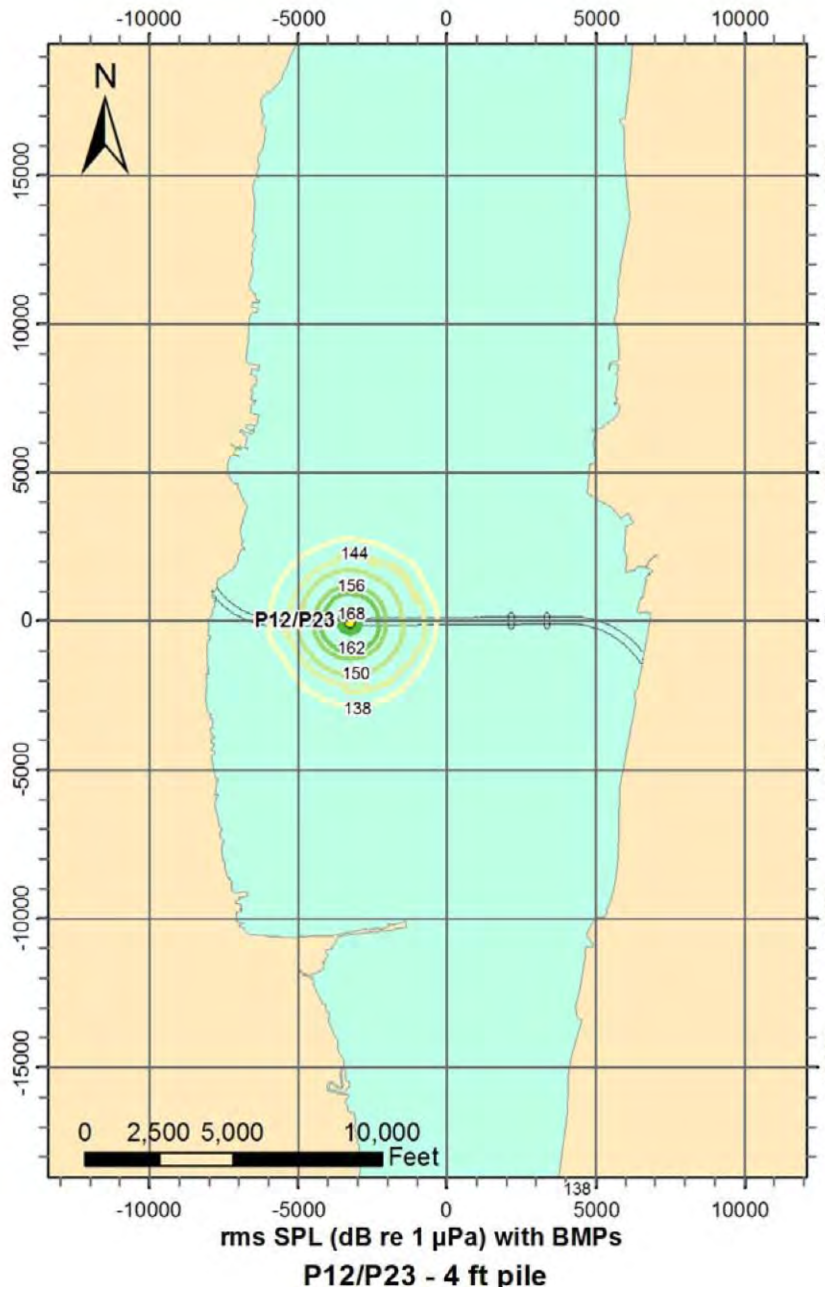



Figure 30

**Peak Sound Pressure Levels for Short and Long Span Options, Single 4-foot Diameter Pile BMPs Applied**

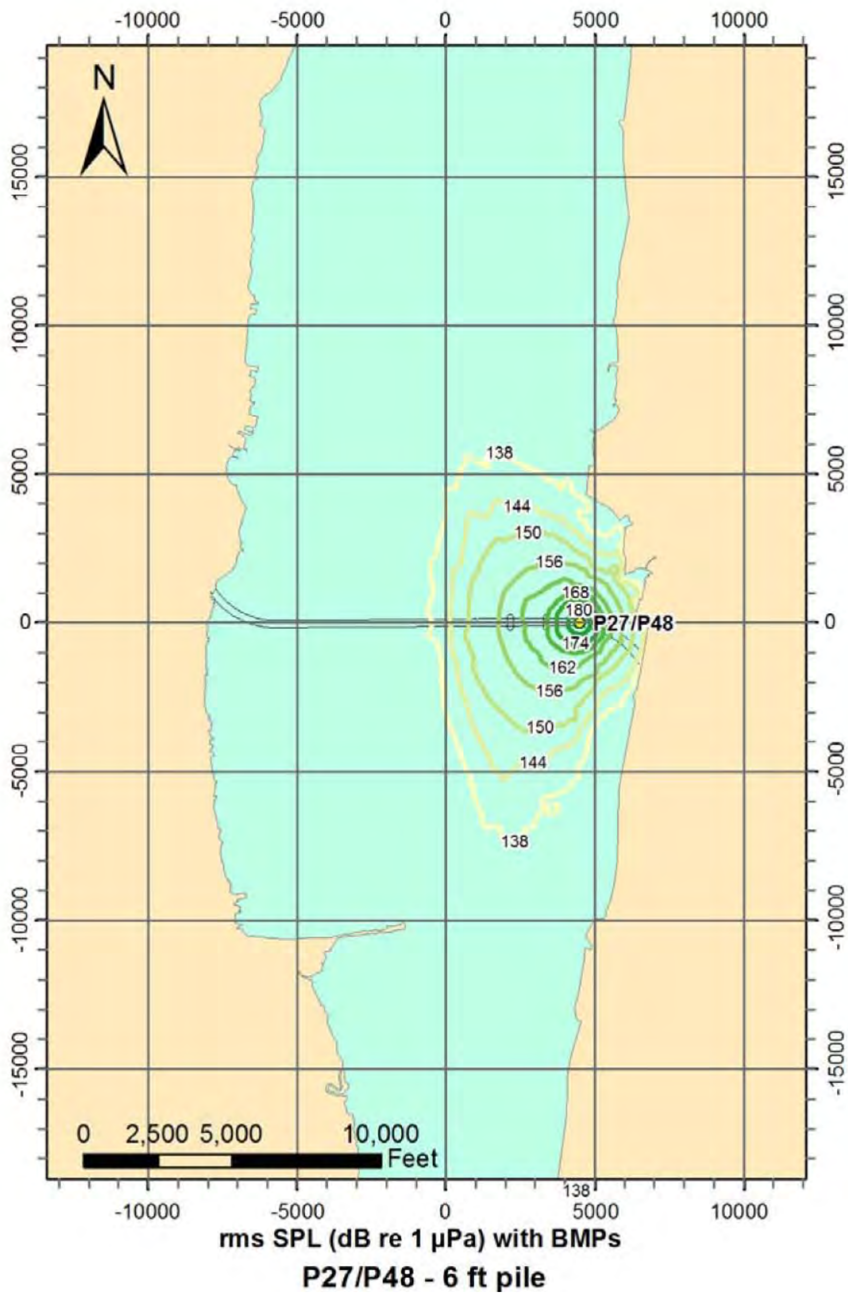



Figure 31
**Peak Sound Pressure Levels for Short and Long Span Options, Single 6-foot Diameter Pile BMPs Applied**

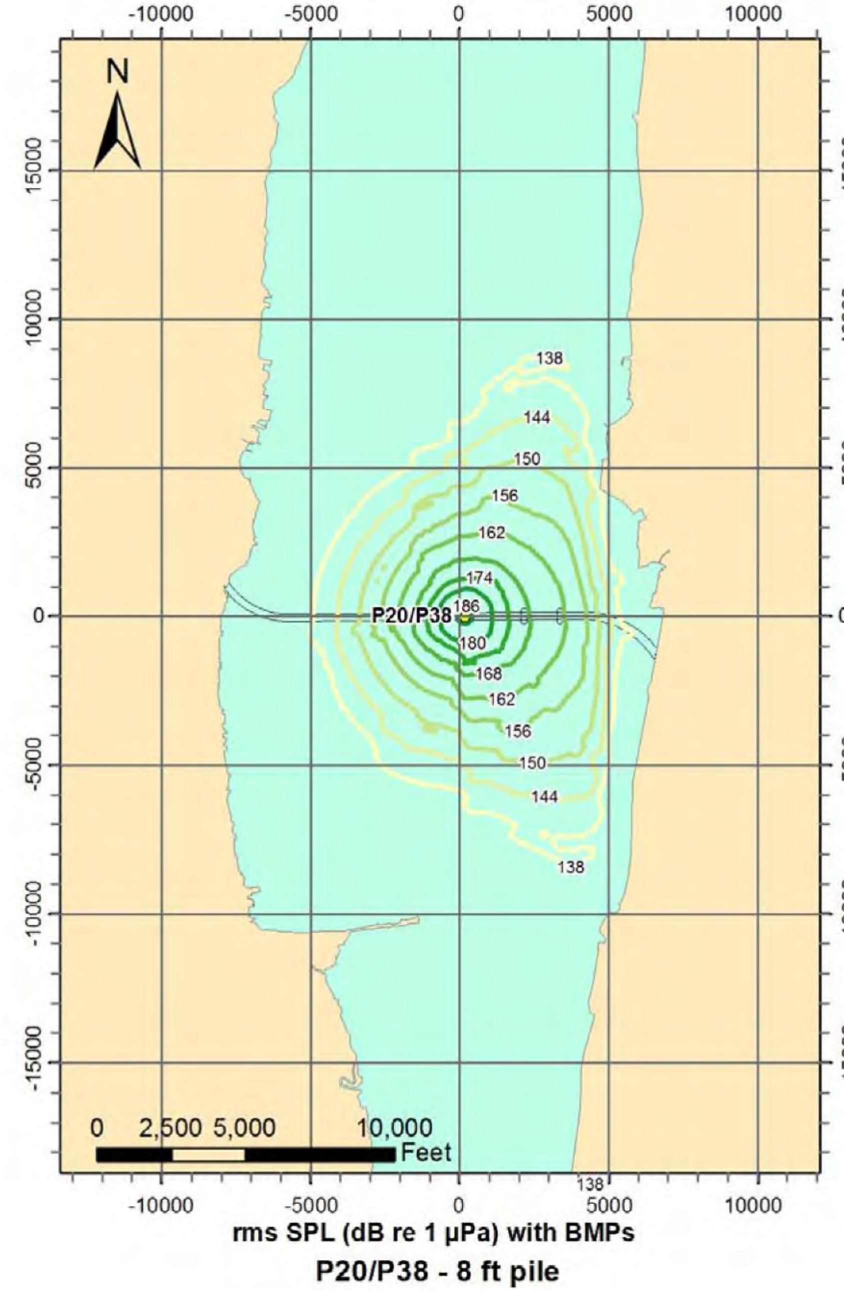



Figure 32

**Peak Sound Pressure Levels for Short and Long Span Options, Single 8-foot Diameter Pile BMPs Applied**

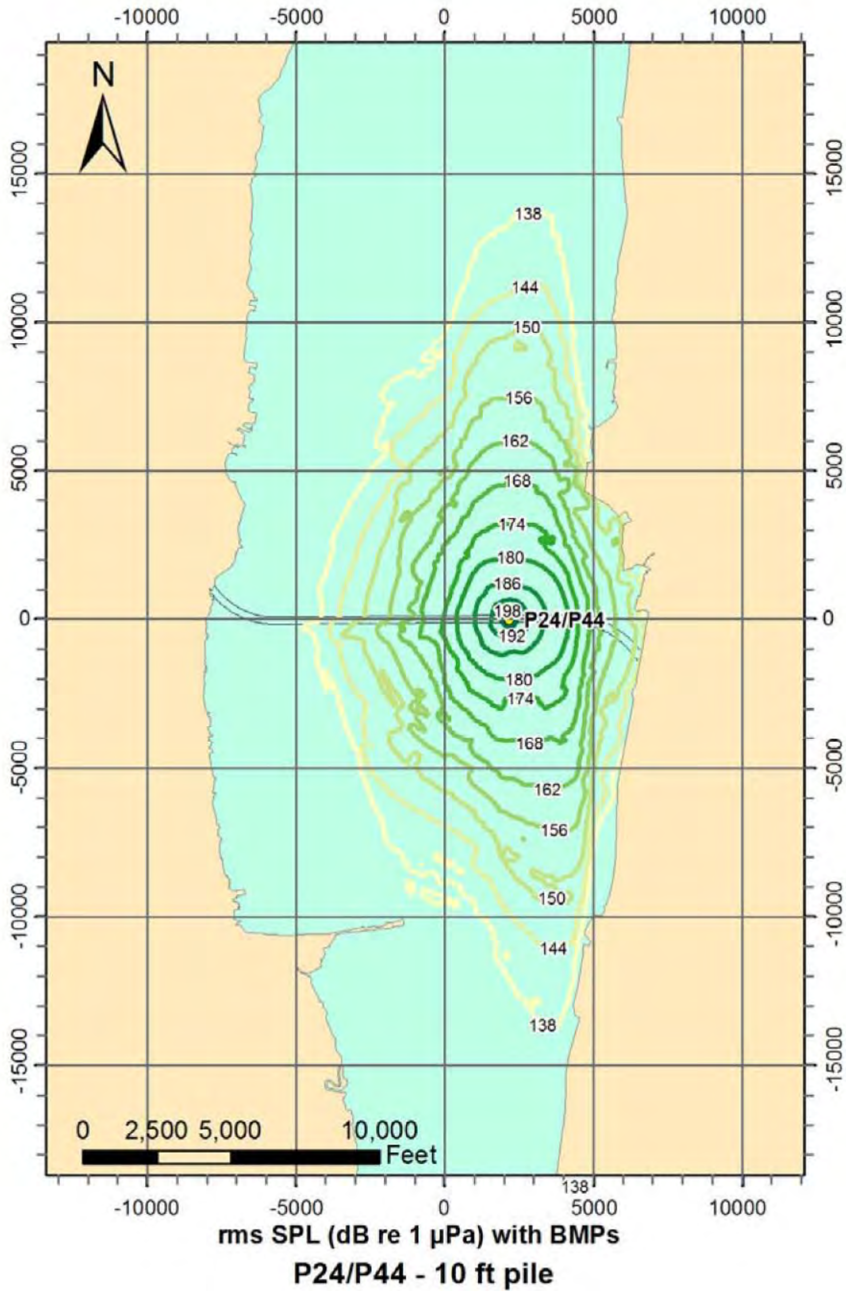



Figure 33

**Peak Sound Pressure Levels for Short and Long Span Options, Single 10-foot Diameter Pile BMPs Applied**