Appendix F: Ecology

F-4 Biological Assessment

Biological Assessment for the Tappan Zee Hudson River Crossing Project

January 2012

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For the Tappan Zee Hudson River Crossing Project

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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

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Project Name: *Tappan Zee Hudson River Crossing Project*

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Executive Summary

The Tappan Zee Bridge opened to traffic in 1955 as part of the New York State Thruway extension between Suffern, New York and Yonkers, New York. Over the years, the bridge and its highway connections have been the subject of numerous studies and transportation improvements. Improvements to the Tappan Zee Bridge included the installation of a movable barrier to allow for operation of a seven-lane cross section with four lanes in the peak direction, electronic toll collection, and variable pricing for commercial vehicles. Despite these improvements, congestion has grown steadily and the aging bridge structure has reached the point where major reconstruction is needed to sustain this vital link in the transportation system.

In April 2000, a Long Term Needs Assessment and Alternatives Analysis was completed by the New York State Governor's I-287 Task Force. The report concluded that while there was no single preferred solution for addressing the transportation needs in Tappan Zee Bridge/I-287 Corridor, both a short-term aggressive Transportation Demand Management (TDM) program and longer-term capital improvements were needed. All of the long-term alternatives evaluated by the Task Force called for replacement of the existing Tappan Zee Bridge. It was concluded that rehabilitation of the existing bridge would be highly disruptive, perhaps as costly, and not as beneficial in mobility enhancement or meaningful congestion relief, compared with a replacement bridge.

Over the next few years, project development continued with increasing involvement by the New York State Department of Transportation (NYSDOT). Alternatives for transit modes along the corridor were identified, as were a set of highway and bridge improvements. In 2011 it was determined that funding for the corridor project (bridge replacement, highway improvements, and new transit service) was not possible due to fiscal constraints. The financing of the crossing alone, however, was considered affordable. Therefore, it was determined that the scope of the project should be limited, and that efforts to replace the Hudson River crossing independent of the transit and highway elements should be advanced. On October 12, 2011, FHWA published an NOI to rescind the Tappan Zee Bridge/I-287 Corridor Project, thereby concluding the environmental review process for the combined study of bridge, highway, and transit elements. On that same date, FHWA published an NOI for the Tappan Zee Hudson River Crossing Project to examine alternatives for an improved Hudson River crossing between Rockland and Westchester Counties. As described in the NOI, FHWA, acting as the federal lead agency, and NYSDOT and NYSTA, acting as the co-sponsoring agencies, are preparing an EIS and other necessary documents to identify alternatives for an improved Hudson River crossing and to document the potential environmental consequences of these alternatives. Two Replacement Bridge Alternative options are being considered and are called the Long Span and Short Span Options. The two options would be constructed using the same general construction sequencing and methods over an approximately 4 ½ to 5 ½ year period, respectively.

Under Section 7 of the Endangered Species Act (ESA), the FHWA is required to consult with the United States Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries to determine whether any federally listed species or species proposed for listing as endangered or threatened, or their designated critical habitats, occur in the vicinity of a proposed project that is subject to United States Environmental Protection Agency

(USEPA) jurisdiction. In the event that a federally listed or proposed endangered or threatened species or its designated critical habitat occurs in the vicinity of a "major construction activity," a Biological Assessment (BA) must be prepared to determine whether the proposed federal action would affect that species. The regulations promulgated pursuant to the ESA require every federal agency to ". . .[e]nsure that any action it authorizes, funds, or carries out, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat" (50 CFR § 402.01) ."

In compliance with Section 7(c) of the ESA of 1973, as amended, this BA, prepared by FHWA, addresses the proposed action and its potential to impact one listed species – the shortnose sturgeon (*Acipenser brevirostrum*) and one species under consideration for listing – the Atlantic sturgeon (*Acipenser oxyrinchus)*. Section 7 of the ESA requires that, through consultation (or conferencing for proposed species) with the National Marine Fisheries Service (NMFS), federal actions do not jeopardize the continued existence of any threatened, endangered, or proposed species or result in the destruction or adverse modification of critical habitat. This BA evaluates the potential effects of the proposed transportation project on aquatic species that are federally listed or proposed for listing under the ESA. Specific project design elements are identified that avoid or minimize adverse effects of the proposed project on listed species and/or critical habitat.

The limits of the study area considered in this BA are different than from those typically considered in an EIS. The BA study area has been determined by the potential project effects for dredging and resuspension and redeposition of suspended sediment, acoustic impacts from pile driving, and loss of habitat. The potential geographic boundaries of these effects extend across the entire width of the Tappan Zee Reach of the Hudson River, and based on modeled sound isopleths with a 10 dB reduction associated with proposed BMPs, extend a maximum of 2210 meters (m) (7,250 feet) or less in both up and downriver directions. For sediment resuspension, which is a measure for assessing impacts to water quality, project increments 10 mg/L above ambient conditions may extend in a relatively thin band approximately 305-610 m (1,000 to 2,000 ft) from the dredges. Concentrations of 5 mg/L above ambient associated with the project may extend a greater distance in either an upstream or downstream direction, depending upon the tidal stage.

Using the results of a gill-net study conducted in the vicinity of the Replacement Bridge Alternative in 2007-2008, an analysis of the potential effects of pile driving on the shortnose and Atlantic sturgeon was undertaken. Results of this analysis indicated that 482 shortnose sturgeon could potentially be affected by sound at or greater than an SEL_{cum} of 187 dB re 1 μPa^2-s over the project duration for the Short Span Option. Similarly, 365 sturgeon have the potential to be affected by sound at or greater than SEL_{cum} of 187 dB over the project duration for the Long Span Option. The Short Span Option will have the potential to affect 0.80% of the shortnose sturgeon population and the Long Span Option will have the potential to affect 0.61% of the population assuming 60,000 fish as a current standing stock estimate for shortnose sturgeon in the Hudson River, and assuming that this number remains static for the duration of the project. These estimates are considered a conservative maximum number of fish potentially affected because they represent the encounter rate within the isopleths of SEL_{cum} of 187 dB re 1 μPa^2-s over several years of construction, and some fraction of that total number (i.e. the 482 or 365 fish) would likely be encountered more than once without having experienced the necessary sound for the onset of effects.

These findings are also likely to overestimate the number of shortnose sturgeon potentially affected for the following reasons:

- Since the calculations do not take into consideration the normal behaviors of the fish in response to a noxious stimulus, it is reasonable to assume that sturgeon, on hearing the pile driving sound, would either not approach the source or move around it. Since the pile driving sounds are very loud, it is also very likely that many of the fish will hear the sound, and respond behaviorally, well before they reached a point at which the sound levels exceeded even the interim SEL_{cum} criterion of 187 dB 1 μPa2·s. Thus, the likely behavioral response of the fish would be to alter the path through which they were traveling to avoid the sounds that were too loud and then resume their regular path once the highest sound levels were skirted.

- Based on the most recent scientific studies (e.g., Halvorsen et al. 2011), the 187 dB re 1μPa^2-s SEL_{cum} threshold is overly conservative, and far lower than cumulative sound levels that actually result in onset of physiological effects (e.g. greater than SEL_{cum} of 203 dB). If a higher threshold for onset, such as those proposed by Halvorsen et al. (2011), were to be used to evaluate the onset of injury to sturgeon, the size of the ensonified area that could potentially cause onset of physiological effects would be considerably reduced, as would the number of potentially affected fish.

- The analysis was conducted using a 10 dB reduction associated with implementation of BMPs, which may underestimate the level of noise attenuation that can be achieved by bubble curtains or other technologies (i.e., 20 dB; Caltrans 2009)

- Carlson et al. (2007) have provided evidence that as fish get larger there is less of a physiological impact from sounds, and that the threshold for onset to injury to larger fish, such as sturgeon, is substantially higher (i.e. 213 dB re 1 μPa^2-s) for fish above 200 grams, than the West Coast criterion for fish > 2 gm (i.e. 187 dB re 1 μPa^2-s).

Recently, the NMFS identified five Distinct Population Segments (DPS) of Atlantic sturgeon within the western North Atlantic. The Hudson River population is included in the New York Bight DPS. A review of the literature suggests that the likelihood of the project to affect the other four DPS of Atlantic sturgeon in any meaningful way is low. Because Atlantic sturgeon were not collected in the gill net sampling program, no estimate of fish within the ensonified zone was calculated.

A number of Environmental Performance Commitments (EPCs) which would also serve to minimize take will be implemented by the Project These include:

- Driving the largest [3 and 2.4 m (10 and 8 ft)] diameter piles within the first few months of the project thereby limiting the time period of greatest potential impact.

- 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 will be vibrated at least to 36.6 m (120ft) depth 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) which includes the testing of various sound attenuation devices 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 10 ft piles with an impact hammer within Zone C [water depths 5.5-13.7 m (18-45 feet)] to 5 hours per day during the period of spawning migration for shortnose and Atlantic sturgeon (April 1 to August 1).

- Maintaining a corridor where the sound level is below the West Coast threshold for onset of behavioral effects to fish totaling at least 5000-ft 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 ft.

- Pile tapping (i.e. a series of minimal energy strikes) for an initial period to frighten fish so that they move from the immediate area.

- Development of a comprehensive monitoring plan. Elements would include:

  - Monitoring locations to characterize the hydroacoustic field surrounding pile driving operations to evaluate the performance of underwater noise attenuation systems that are integral to the project.
  - Monitoring water quality parameters such as temperature, salinity, and suspended sediment concentrations in the vicinity of the pile driving.
  - Monitoring fish mortality and inspection of fish for types of injury.
  - Monitoring predation levels by gulls and other piscivorous birds, which would indicate that they are finding an increased number of dead or dying fish at the surface.
  - Developing criteria for re-initiating consultation with NMFS should specific numbers of shortnose or Atlantic sturgeon come to the surface injured or dead.
  - Preparing a Standard Operating Procedures Manual outlining the monitoring and reporting methods to be implemented during the program.

- In addition, dredging using an environmental bucket would only be conducted during a three-month period from August 1 to November 1 for the three years of the construction period in which dredging would occur, in order to minimize the potential for impacts to sturgeon migration, as well as migration by other fish species.

The results of this BA indicate that:

1. For individual shortnose and Atlantic sturgeon within the immediate vicinity of pile driving and other in-water construction activities, there is a potential for injury.

2. Pile driving and dredging would have minimal effects to sturgeon migratory activities as there will always be large portions of the river width that will not be ensonified, and dredging will be limited to a three-month window between August 1 and November 1 during 3 of the 4 ½ or 5 ½ construction years.

3. There is no designated critical habitat for shortnose sturgeon and none is proposed for Atlantic sturgeon.

4. Dredging of 0.67-0.71 square kilometers (km) (165-175 acres) for access channels will create an area of reduced foraging opportunities for both shortnose and Atlantic sturgeon 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 condition. 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.

5. Incidental vessel strikes will be insignificant because sturgeon are generally found within one meter of the bottom in the deepest available water. Based on the types of vessels to be employed and their drafts, there should always be sufficient clearance between vessels and the river bottom.

6. Indirect effects from resuspended sediments are expected to be insignificant.

7. A review of the literature suggests that the likelihood of the project to affect the four other DPS of Atlantic sturgeon in any meaningful way is low.

The BA concludes that while the Replacement Bridge Alternative may injure some individual shortnose and/or Atlantic sturgeon in the immediate vicinity of the pile driving resulting in an incidental take, and while dredging and armoring of the bottom will result in a temporary reduction in foraging opportunities, the project will not jeopardize the continued existence of the shortnose or Atlantic sturgeon populations of the Hudson River.

Based on the fact that marine mammals are rare and transient to the study area, the proposed project will not jeopardize the continued existence of the marine mammal species that have been reported in the Tappan Zee Reach of the Hudson River.

Effect Determination for Critical Habitat

There is no designated critical habitat for the shortnose sturgeon and no critical habitat has been proposed for Atlantic sturgeon at this time.

Overall Effect Determination

Overall project effects are summarized in the table below that lists affected species and major project elements, and the effect determinations associated with each.

Overall Project Effects

Jurisdiction	Federal Status	Common Name	Effect Determination for Pile Driving	Effect Determination for Permanent Loss of Habitat Due to Dredging	Effect Determination for Vessel Traffic	Effect Determination for Sediment Resuspension	Overall Effect Determination for Project
NMFS	Endangered	Shortnose Sturgeon	Likely to adversely affect	No effect	No effect	No effect	Likely to adversely affect
NMFS	Proposed for Listing	Atlantic Sturgeon	Likely to adversely affect	No effect	No effect	No effect	Likely to adversely affect
NMFS	Various	Marine Mammals	No effect	No effect	No effect	No effect	No effect

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Chapter 1 Project Overview

The Tappan Zee Bridge opened to traffic in 1955 as part of the New York State Thruway extension between Suffern, New York and Yonkers, New York. Over the years, the bridge and its highway connections have been the subject of numerous studies and transportation improvements. Improvements to the Tappan Zee Bridge included the installation of a movable barrier to allow for operation of a seven-lane cross section with four lanes in the peak direction, electronic toll collection, and variable pricing for commercial vehicles. Despite these improvements, congestion has grown steadily and the aging bridge structure has reached the point where major reconstruction is needed to sustain this vital link in the transportation system.

In April 2000, a Long Term Needs Assessment and Alternatives Analysis was completed by the New York State Governor's I-287 Task Force. The report concluded that while there was no single preferred solution for addressing the transportation needs in Tappan Zee Bridge/I-287 Corridor, both a short-term aggressive Transportation Demand Management (TDM) program and longer-term capital improvements were needed. All of the long-term alternatives evaluated by the Task Force called for replacement of the existing Tappan Zee Bridge. It was concluded that rehabilitation of the existing bridge would be highly disruptive, perhaps as costly, and not as beneficial in mobility enhancement or meaningful congestion relief as compared with a replacement bridge.

1.1. Federal Nexus

On November 28, 2000, the New York State Thruway Authority (NYSTA) and the Metropolitan Transportation Authority Metro-North Commuter Railroad (MNR) announced that an Environmental Impact Statement (EIS) would be undertaken to identify and evaluate alternatives to address the mobility needs of the I-287 Corridor, as well as the structural and safety needs of the Tappan Zee Bridge. The alternatives contained in the I-287 Task Force report, as well as those suggested by elected officials, transportation and environmental groups, community groups, and the public, were considered and an approach to evaluating and advancing alternatives was established. On December 23, 2002, the Federal Highway Administration (FHWA) published a Notice of Intent (NOI) to prepare an Alternatives Analysis (AA) and EIS for the Tappan Zee Bridge/I-287 Corridor in the Federal Register.

Over the next few years, project development continued with increasing involvement by the New York State Department of Transportation (NYSDOT). Alternatives for transit modes along the corridor were identified, as were a set of highway and bridge improvements. Also, in 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was enacted, which incorporated changes in the metropolitan planning and environmental review processes for transportation projects. FHWA determined that a revised NOI should be published to update the public and interested agencies on the alternatives development, to identify NYSDOT as the Project Director, and to incorporate the provisions of SAFETEA-LU. The revised NOI was published on February 14, 2008.

In 2011, while advancing financial analysis, it was determined that funding for the corridor project (bridge replacement, highway improvements, and new transit service) was not possible at that time. The financing of the crossing alone, however, was considered affordable. Therefore, it was determined that the scope of the project should be limited, and efforts to replace the Hudson River crossing independent of the transit and highway elements should be advanced. On October 12, 2011, FHWA published an NOI to rescind the Tappan Zee Bridge/I-287 Corridor Project, thereby concluding the environmental review process for the combined study of bridge, highway, and transit elements.

On that same date, FHWA published an NOI for the Tappan Zee Hudson River Crossing Project to examine alternatives for an improved Hudson River crossing between Rockland and Westchester Counties. As described in the NOI, FHWA, acting as the federal lead agency, and NYSDOT and NYSTA, acting as the co-sponsoring agencies, are preparing an EIS and other necessary documents to identify alternatives for an improved Hudson River crossing and to document the potential environmental consequences of these alternatives.

Under Section 7 of the Endangered Species Act (ESA), the FHWA as the Federal Sponsor is required to consult with the United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) to determine whether any federally listed species or species proposed for listing as endangered or threatened species, or their designated critical habitats, occur in the vicinity of a proposed project. While there are no federally listed species under the jurisdiction of the USFWS in the vicinity of the proposed project, the shortnose sturgeon, an endangered aquatic species, occurs throughout the estuarine portion of the Hudson River. In the event that a federally listed or proposed endangered or threatened species or its designated critical habitat occurs in the vicinity of a "major construction activity," a Biological Assessment (BA) must be prepared to determine whether the proposed federal action would affect that species. The regulations promulgated pursuant to the ESA require every federal agency to ". . .[e]nsure that any action it authorizes, funds, or carries out, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat" (50 CFR § 402.01).

This BA, prepared by FHWA, addresses the proposed action in compliance with Section 7(c) of the ESA of 1973, as amended. Section 7 of the ESA requires that, through consultation (or conferencing for proposed species) with the National Marine Fisheries Service (NMFS), federal actions do not jeopardize the continued existence of any threatened, endangered, or proposed species or result in the destruction or adverse modification of critical habitat. A second BA has been prepared for a Pile Installation Demonstration Project (PIDP), scheduled for spring 2012, which has among its objectives the testing of various sound attenuation technologies.

This BA evaluates the potential effects of the proposed transportation project on species that are federally listed or proposed for listing under the ESA. Specific project design elements are identified that avoid or minimize adverse effects of the proposed project on listed species and/or critical habitat.

The findings of the BA will be discussed in the Record of Decision (ROD), which will include an effects determination that presents conclusions, supported by information presented in the BA, regarding potential effects on the local population of the species discussed. This BA will be submitted to NOAA Fisheries for review and a final determination of effect. The BA will be completed prior to construction, and the bridge design will reflect appropriate measures to protect these species that result from the consultation process. The BA addresses only the currently proposed construction activities. If NOAA Fisheries determine that the construction activities would adversely affect a federally listed species or a species proposed for listing, then the FHWA must enter into formal consultation and obtain a Biological Opinion concerning the potential for incidental "taking" of such species before conducting the project. "Take" is defined in the ESA as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Incidental take is understood to occur should the activities associated with implementing the ROD adversely affect the shortnose sturgeon or Atlantic sturgeon habitat and/or mating behavior. If it is determined that the construction activities are not likely to adversely affect the species, NOAA Fisheries will issue written concurrence that the remedial project is not likely to adversely affect the species.

In addition to FHWA's involvement with the project, several other federal agencies will be involved. The USACE and U.S. Environmental Protection Agency (EPA) will require an application for transport and ocean disposal of dredge material under Section 103 of the Marine Protection, Research and Sanctuaries Act, and the United States Coast Guard will be consulted to acquire a bridge permit required under the General Bridge Act of 1946 for construction of bridges over navigable waters of the United States. There is also a possible need for Section 404 and Section 10 permits from the USACE.

1.2. Project Description

The proposed Replacement Bridge Alternative (Project) would result in a new bridge crossing of the Hudson River between Rockland and Westchester Counties. A number of design parameters have been considered to develop the location and general configuration of the Replacement Bridge. However, to provide for flexibility in the final design of the Replacement Bridge, this assessment considers options for certain structural characteristics of the bridge.

The Project would be constructed north of the existing Tappan Zee Bridge. The planning for the Replacement Bridge considered a footprint that would maximize the use of existing NYSTA right-of-way while minimizing effects on existing highway infrastructure in Rockland and Westchester Counties. Replacement bridge alignments both north and south of the existing Tappan Zee Bridge were considered, and it has been determined that an alignment north of the existing bridge is more prudent for the following reasons:

- There is available NYSTA right-of-way to the north of the existing highway on both sides of the Hudson River to accommodate construction of a new crossing. Sufficient right-of-way is not available on the south side of the existing highway at the Rockland landing.

- A north alignment allows for a straight approach to the Westchester toll plaza. A south alignment would result in a conflict between the new crossing's horizontal curvature and the approach to the toll plaza, which would not meet design and safety standards.

- Construction storage and staging areas are available north of the existing bridge on both sides of the Hudson River. Staging for a southern alignment could require temporary or permanent acquisition of property.

Therefore, the Replacement Bridge would be located to the north of the existing Tappan Zee Bridge.

The following sections describe the features of the Project. To conform to highway design standards, including widths and grades, the Replacement Bridge Alternative would result in new bridge and modifications to Interstate 87/287 between approximately Interchange 10 (Route 9W) in Nyack and Interchange 9 (Route 9) in Tarrytown. The following sections describe the proposed salient features relative to this BA, including approach spans, main spans, and ancillary facilities of the Replacement Bridge (see **Figure 1**).

1.2.1. Landings and Approach Spans

In Rockland and Westchester Counties, Interstate 87/287 would be shifted northward to meet the new abutments of the Replacement Bridge. There are two options for the Replacement Bridge's approach spans (Short Span and Long Span Options), which would result in somewhat different configurations of the Rockland County landing.

1.2.1.1. Short Span Option

The Short Span Option would consist of two parallel bridges that would have a typical highway design with a road deck supported by girders and piers (see Figure 2). The parallel bridges would be separated by a gap that would vary in dimension across the approach spans. 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 1,257 m (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 70.1 m (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 spans.

- The Westchester County approach spans would extend 548.6 m (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 70.1 m (230 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 53.3 m (175 feet) above the Hudson River's mean high-tide elevation.

1.2.1.2. Long Span Option

The Long Span Option would also consist of two parallel bridges. Each bridge would have a truss structure supported by piers (see **Figure 2**). The road deck would be located on top of the trusses. The parallel bridges would be separated by a gap that would vary in dimension across the approach spans. 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 1,257 m (4,125 feet) between the abutments and the main spans, and each would consist of 23 sections. The average distance between the piers of the Rockland County approach spans would be about 131 m (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 548.6 m (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 131 m (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 59.4 m (195 feet) above the Hudson River's mean high-tide level.

1.2.2. Main Span

The main spans, which are the portions of the bridge that cross the navigable channel of the Hudson River, must 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 183 m (600 feet) through the Tappan Zee crossing. However, a clearance of 305 m (1,000 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 at least 42.4 m (139 feet) of vertical clearance at mean high tide to maintain the existing hull-to-mast height requirements of vessels that travel beneath the Tappan Zee crossing.

This BA considers two options for the bridge's main spans over the navigable channel—Cable-stayed and Arch (see **Figure 3**). Both options would result in a horizontal clearance of at least 305 m (1,000 feet) and a vertical clearance at least 42.4 m (139 feet) over the navigable channel.

1.2.2.1. Cable-stayed Option

The Cable-stayed Span Option would result in two spans supported by cables connected to towers. The four towers (two towers per span) would rise about 122 m (400 feet) above the road deck and would be set approximately 91.4 m (300 feet) outward from the limits of the navigable channel. Cables would extend from each of the towers to various points on the road deck, in effect holding it up from above. The cables would support the entirety of the main spans between the approach structures. The cables would extend both eastward and westward from each tower tying into the road deck as much as 91.4 m (300 feet) away from the towers. The cables would be anchored to the ground through the tower foundations. Each section of the road deck would be connected to the towers by multiple cables, resulting in a highly redundant structure.

1.2.2.2. Arch Option

This option would consist of a steel arch that would extend eastward and westward from the main spans' piers. The main spans' piers would be located about 152.4 m (500 feet) outward from the limits of the navigable channel. The supports would curve upward and support the road deck from below. On either side of the navigable channel, the curved supports would extend above the road deck and meet in the middle forming the arch. The top of the arch would be about 61 m (200 feet) above the road deck. Suspender cables would extend vertically from the arch structure to support the road deck.

1.3. Study Area and Setting

The Hudson River is one of the major rivers on the Atlantic coast, extending from its source at Lake Tear of the Clouds on Mount Marcy in the Adirondacks to the Battery in New York Harbor, a distance of approximately 507 km (315 miles) (Geyer and Chant, 2006). In the study area, the Hudson River is tidally influenced and is commonly referred to as the Hudson River estuary. The estuarine portion of the river begins at the Troy Dam about 247.8 km (154 miles) north of the Battery in southern Manhattan. Tides in the Hudson River estuary are semidiurnal, having two high waters and two low waters each day with an average range of 0.98 m (3.2 feet) (NOAA Tide Tables, 2009). At approximately 4.8 km (3 miles) in width in the study area, the river is designated by New York State Department of Conservation (NYSDEC) as a Class SB (saline) waterbody, intended to be suitable for recreation, and fish survival and propagation. Water quality surveys by the Project Sponsors identified considerably variable concentrations of suspended sediments in the water column near the bridge depending on water depth, season, and weather conditions.

In the vicinity of the bridge, the river ranges in depth from less than 3.7 m (12 feet) along the western causeway to greater than 14.3 m (47 ft) in the shipping channel under the main span. The causeway and bridge piers cause river currents to locally scour the bottom sediments, resulting in depressions in the bottom of the river alongside the bridge.

The Hudson River and its tributaries are tidally influenced. The Hudson River in the vicinity of the TZB is referred to as an estuary due to the blending of freshwater and marine (saline) inputs. Bottom sediments are comprised of clayey silt. The river provides shallow as well as deep water habitat for a wide range of plants and animals, as described in subsequent sections of this chapter. The tidal action of the river, currents, and the seasonal variation in the amount of freshwater contributed by precipitation and runoff, make it a highly dynamic and unstable system. As a result, the ecosystem is generally dominated by a few well adapted species.

Bottom sediments throughout most of the estuary are generally soft and comprised of mud or sandy mud, but other bottom types such as sand or gravelly sand occur as well, and are more common in the upper portions of the estuary (AKRF 2010). The river provides shallow and deep water habitats for a wide range of aquatic and terrestrial plants and animals, as described in subsequent sections of this BA. The tidal action of the 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.

In 1992, the Habitat Work Group of the New York-New Jersey Harbor Estuary Program, administered by the United States Environmental Protection Agency (USEPA), requested that USFWS identify significant coastal habitats warranting special protection. The Tappan Zee section of the Hudson River was included in an area described as follows (USFWS 2011):

"The significant habitat complex boundary for the lower Hudson River estuary follows the shores of the Hudson River from the tip of Battery Park, Manhattan, generally referred to as river kilometer 0 (river mile 0), north to the Stony Point area river kilometer 66 (river mile 41). The boundary of the complex includes all riverine and estuarine habitats, including open water and tidal wetlands in this stretch of the river. This section of the river is the major site of river water mixing with ocean water in the Hudson Estuary, and includes the moderate and high salinity zones (mesohaline and polyhaline salinity zones) of the river. 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 (*Morone saxatilis*), and is a migratory and feeding area for birds and fish that feed on the abundant fish and benthic invertebrate resources in this area" (http://library.fws.gov/pubs5/web_link/text/low_hud.htm).

In 1990, the New York State Department of State (NYSDOS) designated several Significant Coastal Fish and Wildlife Habitats (SCFWH) within the stretch of the Hudson River between River Miles 11 and 40. These SCFWWs include Haverstraw Bay and Croton River and Bay (9.7 m, or 6 miles, north of the bridge), the Lower Hudson Reach (6.4 m, or 4 miles, south of the bridge), and Piermont Marsh (3.2 m, or 2 miles, south of the bridge). The NOAA and NYSDEC have designated Piermont Marsh part of the Hudson River National Estuarine Research Reserve. No SCFWHs occur within the study area.

The study area in the immediate vicinity of the replacement bridge 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 in this area. Areas south of the existing bridge less than 1.8 m (6 feet) deep at mean low water (MLW) are mapped as littoral zone wetlands by the NYSDEC. 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. The eastern shoreline adjacent to the railroad tracks consists of riprap armoring in the vicinity of the replacement bridge.

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.

1.4. Consultation History

Informal consultations have been occurring with NMFS throughout the course of the project. Consultations have occurred with both the Habitat Conservation Division (HCD) in Milford, CT and the Protected Resources Division (PRD) in Gloucester, MA. The objective of the initial informal consultations was to develop and review the Hudson River ecological, hydrodynamic and sediment sampling program (Proposed Ecological Investigations within the Hudson River and along the I-287 Corridor, March 10, 2006), the results of which would support the DEIS and EIS impact analyses. Data were collected from April 2007 through May 2008 with additional sampling of oyster beds and submerged aquatic vegetation (SAV) during 2009. These data were reviewed with NMFS. Furthermore, design option concepts for the replacement bridge were presented to the agency at several meetings beginning in February 2008.

Detailed methodologies have been presented to NMFS related to the approaches that will be employed to assess ecological impacts of resuspended sediment and underwater noise, two of the more complex issues associated with bridge construction. A detailed, explanatory "read-ahead" document was submitted to the agency followed by a presentation in their offices for each of the two methodologies. The presentations were generally organized as follows:

- Discussion of ecological issues
- Relevant construction activities
- Proposed "on set of effects" criteria
- Use of sampling data
- Analytical procedures (i.e., mathematical models).

At each of the methodology meetings, comments were requested from NMFS with regard to the proposed "onset of effects" criteria and the analytical methods that would be employed in the DEIS analysis. General comments on the proposed acoustic "physiological effects" criteria have been received from NMFS-PRD (August 24, 2010; Julie Crocker to Melissa Toni).

A subsequent meeting was held with NMFS in Gloucester, MA on October 14, 2011 with members of the HCD and the PRD. The objective of the initial meeting was to develop and review the planned Pile Installation Demonstration Project (PIDP) for the proposed bridge replacement project. This meeting detailed the PIDP and the methodologies that will be employed to assess direct and indirect ecological effects associated with the PIDP.

Recently, NMFS provided commentary on the Project's scoping document, and provided an extensive list of items to consider during the preparation of the EIS, the BA and Essential Fish Habitat (EFH) evaluation (NOAA 2011a). A second meeting was held in Gloucester, MA on December 14, 2011 to continue the coordination of the PIDP and the Project's Biological

Assessment and Essential Fish Habitat analyses. At this meeting NMFS provided comments on the Draft PIDP BA (NMFS 2011a), but raised issues that are relevant to the Biological Assessment for the Replacement Bridge Alternative as well. Portions of the commentary not addressed herein will be addressed completely though future interactions / meetings with NMFS and subsequent document revisions as the consultation process advances.

Chapter 2 Federally Proposed and Listed Species and Designated Critical Habitat

The USFWS lists of federally threatened, endangered, candidate, and proposed species for Westchester and Rockland Counties include only one endangered fish species, the shortnose sturgeon (*Acipenser brevirostrum*; endangered) occurring within the study area. Shortnose sturgeon are also currently listed for protection by the State of New York as an endangered species. Atlantic sturgeon (*Acipenser oxyrinchus*) are also known to occur in the study area, and although they are not currently federally listed as threatened or endangered, Atlantic sturgeon have been proposed for listing for federal protection under the ESA.

Alewife and blueback herring were designated as candidate species on November 2, 2011. These species are being considered for listing as endangered or threatened under the ESA. Candidate status does not carry any procedural or substantive protections under the ESA.

According to sources cited in the most recent NMFS commentary, a November 15, 2011 letter from Patricia Kurkul to Michael Anderson (NMFS 2011b), seals and dolphins are present occasionally in the Hudson River and may migrate through the study area (DiGiovanni 2011 as cited in NMFS 2011b). Harbor porpoises (*Phocoena phocoena*) occasionally may also be present in the study area (Jackson et al. 2005 as cited in NMFS 2011b). However, the study area does not contain any marine mammal concentration areas or seal haul-out areas (NMFS 2011b). The NMFS letter also indicated that large whales and sea turtles, including those listed under the ESA, are similarly unlikely to occur in the study area.

2.1. Shortnose Sturgeon

The shortnose sturgeon is a member of the family Acipenseridae. The shortnose sturgeon is a long-lived, slow-maturing species. It is the smallest sturgeon species native to North America, achieving maximum lengths of up to 1,070 millimeters ("mm") (42 inches) in the Hudson River (Bain 1997), and maximum lifespans of approximately 50 to 60 years (Kynard 1997).

Within North America, the shortnose sturgeon inhabits large coastal rivers along the Atlantic coast, ranging from New Brunswick, Canada, to the Saint Johns River in Florida. Nineteen distinct sub-stocks, ranging in size from less than 100 adults in the Merrimack River (Massachusetts) to greater than 60,000 adults in the Hudson River, have been recognized (NMFS 1998a). Shortnose sturgeon adults generally remain in their natal rivers or estuaries; there is little evidence of interbreeding or interchange of fish among stocks (Kynard 1997). McCleave et al. (1977) studied daily movements of shortnose sturgeon in a Maine estuary and did not find any conclusive evidence of a distinct or abrupt change in swimming pattern at the time of tidal change.

Hudson River shortnose sturgeon typically inhabit the deepest water available (Hastings et al. 1987; O'Herron et al. 1995) but often move into shallow areas to forage. In tidal reaches of the Hudson River, the deepest water typically is found within or adjacent to the navigation channel, away from river shores. Shortnose sturgeon prefer lower salinity waters, and although they rarely can be found in pure seawater (approximately 34 parts per thousand (“ppt”), they generally have a maximum salinity tolerance in the range of 30 to 31 ppt (Holland and Yelverton 1973; Dadswell et al. 1984). Their distribution and life history pattern in the Hudson River is summarized in **Figure 4**.

2.1.1. Adults (including spawning adults)

The shortnose sturgeon’s age at sexual maturity varies by latitude. In mid-Atlantic estuaries, including the Hudson River, male shortnose sturgeon can reach sexual maturity at three to five years of age, and females at six to ten years (Dadswell et al. 1984). First spawning may follow sexual maturation in males by up to one to two years, whereas in females spawning may be delayed for up to five years (Dadswell 1979). Based on the percentage of sexually developing fish from August through March collections in New Brunswick, Canada, it appears that females spawn once every third year, and males every other year (Dadswell 1979). Other data (e.g., annuli formation in the pectoral rays) suggest a 5 to 11 year interval between individual spawning events (Dadswell 1979). NMFS (2011b) has indicated that, based on limited data, females spawn every three to five years, while males spawn approximately every two years.

Shortnose sturgeon fecundity can be quite variable. Estimates of number of eggs per gravid female range from 27,000 to over 200,000, with a mean of 11,568 eggs/kg body weight (see Dadswell et al. 1984 for review of reported fecundity values). This high fecundity likely evolved in the presence of highly variable environmental conditions of primary spawning grounds, as well as high natural early life stage mortality rates.

Shortnose sturgeons spawn well north of the Tappan Zee Bridge between the Troy dam and RM 131 (Dovel et al 1992). Shortnose sturgeon undertaking the spawning migration in the Hudson River travel upriver in deeper channel areas as far as accessible spawning habitat permits (**Figure 4**, adapted from Bain et al. 1998). Spawning usually occurs when River temperatures increase to about 8.8°C (47°F), and concludes when temperatures reach 12.2°C–15.0°C (54°F–59°F) (Kynard 1997). River channels with rock or gravel substrate and moderate bottom current velocities are the preferred spawning habitat of the shortnose sturgeon (NMFS 1998a).

2.1.2. Eggs

Shortnose sturgeon are broadcast spawners, with fertilization occurring externally (Gilbert 1989). Ripe and fertilized eggs have diameters of 3.0 to 3.2 mm and can be as large as 3.5 mm (0.12 to 0.13 inches and 0.14 inches), respectively (Dadswell et al. 1984; Buckley and Kynard 1981). Shortnose sturgeon eggs are demersal and adhere to objects on the river bottom within 20 minutes of fertilization. Eggs hatch approximately 13 days after fertilization at temperatures between 7.7°C and 12.2°C (46°F and 54°F) (Bain 1997).

Eggs are confined to freshwater reaches above the saline area and would not be expected to occur in Tappan Zee region.

2.1.3. Larvae

Upon hatching, larvae are 7.3 to 11.3 mm (0.29 to 0.44 inches) long (Taubert 1980; Buckley and Kynard 1981). Research on larval behavior indicates that hatchlings exhibit negative phototaxis (i.e. response to light), and seek cover under any available structure immediately after hatching (Richmond and Kynard 1995). Within the first one to two days of hatching, larvae denied access to, or physically dislocated from, cover will exhibit a temporary and short-lived “swim-up and drift" behavior. In the wild, this behavior allows the larvae to move short distances (with the assistance of currents) to locate available cover downstream. Yolk-sac larvae (“YSL”) will continue to seek benthic cover for about a week, but after one to two days post-hatch their movements are predominantly parallel to the bottom (Richmond and Kynard 1995). At 9 to 12 days post-hatch, the yolk sac is absorbed and larvae have well-developed, functioning eyes, a mouth with teeth, and fins that enable them to swim normally (Kynard 1997).

In laboratory tests, larvae were nocturnally active, and preferred the deepest water available to them (Richmond and Kynard 1995). Even shortnose sturgeon embryos released near the surface of a test enclosure sought bottom cover. In other hatchery experiments, ten-day-old larvae attempted to remain on the bottom or placed themselves under available cover (Pottle and Dadswell 1979; Washburn and Gillis Associates 1980). After the yolk sac is completely absorbed, post yolk-sac larvae actively feed on zooplankton (Buckley and Kynard 1981; Washburn and Gillis Associates 1980). Snyder (1988) and Parker (2007) considered individuals to become juveniles at around 57 mm TL with the transformation occurring on about day 40 after hatching for fish from the Connecticut River (Parker 2007).

Larvae are predominately confined to freshwater reaches above the saline area and would not be expected to occur in Tappan Zee region.

2.1.4. Juveniles

The juvenile phase can be subdivided into young of the year (YOY) and immature sub-adults. YOY and sub-adult habitat use differs and is believed to be a function of salinity tolerance (NMFS 2011c). Little is known about YOY behavior and habitat use although it is believed that they are found in freshwater habitats above the saltwedge for about one year. Hence, YOY would not be expected to occur in the Tappan Zee study area. Sub-adults would be expected to occupy similar spatio-temporal patterns as adults and occupy a much wider portion of the estuary, including the Tappan Zee study area.

The early growth of shortnose sturgeon is relatively rapid compared to many species, and occurs during the first few months following hatching as YOY gradually migrate to downstream deep, brackish, waters from the spawning grounds. Upon reaching about 14 to 17 mm total length (0.5 to 0.7 inches TL), shortnose sturgeon generally resemble adults and may leave bottom cover briefly to swim in the water column (although they remain strongly bottom-oriented). In the wild, fish of this size probably disperse downstream using currents as conveyance (Richmond and Kynard 1995).

The juveniles (fish ranging from 2 to 8 years old) can be found in brackish areas of the Hudson River. The primary summer habitat for shortnose sturgeon in the middle section of the Hudson River above Newburgh is the deep river channel (13 to 42 m deep, or 43 to 138 feet). The river channel downstream of this middle estuary area is 18 to 48 m deep (59 to 157 feet [Peterson and Bain 2002]).

2.1.5. Hudson River Population

In its 1979 NMFS Biological Opinion for the Indian Point Generating Station, NMFS used an assumption of a shortnose sturgeon population of 6,000 individuals, although other contemporary estimates placed the Hudson River shortnose sturgeon population at approximately 13,000 individual adults (Bain 1997). By the 1990s, the Hudson River adult population was estimated to be as high as approximately 60,000, which represents the largest shortnose sturgeon population in the United States (Bain et al. 1998; 2007). Other researchers have suggested that some populations segments (including the Hudson River) have recovered to historic abundance levels (Wirgin et al. 2005; Woodland and Secor 2007). The increase in the shortnose sturgeon population in the Hudson River has been attributed to both managed population recovery and regional conservation measures, specifically the enactment and enforcement of fishing regulations (Bain et al. 2007).

According to Woodland and Secor (2007), twenty years of sustained annual recruitment has contributed to strong recovery of shortnose sturgeon in the Hudson River. During this period there were several particularly strong year classes that translated into substantial population growth. Size and body condition of the fish caught in these studies indicate the population is primarily healthy, long-lived adults. Hoff et al. (1988, in Bain 1997) reported most captures of adult shortnose sturgeon during river monitoring of fish distributions by the Hudson River electric utilities from 1969 to 1980 occurred between river miles (RM) 24 to 76 (from near the New York/New Jersey border up to near Poughkeepsie).

Dovel et al. (1992) concluded that most of all adults form an overwintering concentration near Kingston. Bain (1997), however, described a second late fall and overwintering area near Haverstraw Bay between km 54 and 61 (RM 33-37).

From 2000-2009, the Fall Shoals Monitoring Program sponsored by a coalition of Hudson River Utilities collected 289 juvenile and adult shortnose sturgeon using a beam trawl. The majority of these fish were collected north of West Point (RM 47) and were adults. Only eight shortnose sturgeon were collected in the Utilities designated Tappan Zee region (RM 24-33). Greater than 90% of all shortnose sturgeon were collected from bottom habitats in waters greater than 6.1 m (20 ft) in depth. A review of commercial catch data provided by NYSDEC (NYSDEC 2011 unpublished data) indicated that from the years 1980-2002 shortnose sturgeon were collected in the Tappan Zee vicinity (RM 25-27) in 14 of 23 years. The Utilities also report the number and size of shortnose sturgeon collected as part of their Striped Bass and Atlantic tomcod sampling program.

A year-long, project-specific fish survey was conducted between April 2007 and May 2008 to further characterize the fish community and examine seasonal differences in abundance near the

Tappan Zee Bridge. These surveys combined hydroacoustics, gill nets, and trap nets to characterize the species composition, relative abundances, and distributions of fish populations within the study area. A total of 25 species and just over 2,000 individual fishes and hundreds of blue crabs were collected during approximately 680 hours of gill-net sampling within the study area between April 2007 and May 2008. A total of 12 shortnose sturgeon were captured in gill nets during the bi-monthly fish-sampling effort within the Tappan Zee study area. The sturgeon were captured in the warmer months of the year—between May and October—at both the bridge and reference locations in water depths between 1.8 and 9.1 m (6 and 30 feet). Although no individuals were captured during the December, February, and April sampling events, it is possible that the species is present within the study area but that the cold waters slowed its movements enough so fish would not be captured by the gill net, a stationary and passive gear type.

The shortnose sturgeon that were collected in the 2007-2008 sampling program ranged in size from an estimated 450 mm (1.5 ft) to 990 mm (3.2 ft) in total length. Eleven of the 12 fish collected were 650 cm (2.1 ft) or larger, and based on their sizes, are presumed to have been adult sturgeon.

2.2. Atlantic Sturgeon

Atlantic sturgeon, proposed for listing as endangered for the New York Bight population by NMFS, is also known to occur in the Hudson River. By contrast with shortnose sturgeon, which spend a great deal of their lives in the Hudson River, Atlantic sturgeon spend most of their lives in marine waters along the Atlantic coast. It is a large anadromous, bottom-feeding species that spawns in the Hudson River and matures in marine waters; females return to spawn at age 15 or older and males return earlier at 12 years o older (Bain 1997, citing other authors). Young et al. (1988) reported that in the Hudson River, maturity of females Atlantic sturgeon begins at age 11 and increases gradually for the next ten years until all females are mature. In the Hudson River, Atlantic sturgeon are found in the deeper portions and do not occur farther upstream than Hudson, New York.

Like shortnose sturgeon, the Atlantic sturgeon is a member of the family Acipenseridae, and ranges from the Hamilton River, Labrador to northeastern Florida (Gruchy and Parker 1980). Atlantic sturgeon is one of the largest fish species in North America with a maximum recorded length of about 4.2 meters (14 feet) (Bain 1997). The oldest recorded Atlantic sturgeon was a 60-year-old individual from the St. Lawrence River (Gilbert 1989). Male Atlantic sturgeon generally do not reach maturity until at least 12 years and females as late as 19 years (Dovel and Berggren 1983). Their interannual spawning period can range from three to five years, and adults usually inhabit marine waters either all year during non-spawning years or seasonally during spawning years (Bain 1997). Atlantic sturgeons are anadromous; they spawn in freshwater, but spend most of their lives in ocean waters often undertaking long distance migrations along the Atlantic Coast (Bain 1997).

Wrege et al. (2011) studied activity patterns of Gulf of Mexico sturgeon, a subspecies of Atlantic sturgeon, in Pensacola Bay. These authors found that Gulf sturgeon were more active at night in all seasons except summer. Gulf sturgeon migrate out of the estuary to the Gulf of Mexico in fall and up through the bay system to summering habitats in rivers in spring.

Several genetic studies have attempted to characterize the population structure and the homing fidelity of Atlantic sturgeon. DNA studies among different Atlantic sturgeon populations suggest that they are reproductively separate and exhibit high fidelity to natal spawning grounds (Wirgin et al. 2002; Waldman et al. 2002). In 2007, NMFS proposed five distinct population segments (DPS) for the U.S. Atlantic sturgeon based largely on DNA results, while another study estimated at least nine population segments (ASSRT 2007; Grunwald et al. 2008).

2.2.1. Adults (including spawning adults)

In the Hudson River population, spawning and early development occurs in the freshwater portion of the River from late May through mid-July, while adult and large juvenile Atlantic sturgeon occupy marine waters. In recent studies, the primary spawning site for Atlantic sturgeon was identified in Hyde Park, New York at RM 83 (Bain et al. 2000). The spawning habitat is along the west side of the River, and spawning appears to be associated with rock islands, irregular bedrock, and substrate of silt and clay (Bain et al. 2000). The area is freshwater throughout the year, with water depths ranging from 12 to 24 meters (39 to 79 feet). Water temperatures in habitats used for spawning have been documented between 19 to 28°C (66 to 82°F) (Bain et al. 2000).

2.2.2. Eggs and Larvae

Like the eggs of shortnose sturgeon, the eggs of Atlantic sturgeon are adhesive, and after fertilization and hydration are approximately 2.2 mm (0.09 inches) (Hardy and Litvak 2004). After hatching, the larvae remain closely associated with the bottom in deep channel habitats (Bain et al. 2000). Atlantic sturgeon larvae are about 7 mm (0.28 inches) TL upon hatching. The transition from the larval to the juvenile stage is estimated to occur at about 30 mm (1.18 inches) TL, based on Hudson River specimens (Bath et al. 1981). In the Hudson River, the larvae have been recorded from around RM 37 to RM 92 (Dovel and Berggren 1983). This range includes some brackish waters; however, larval Atlantic sturgeon have limited tolerance to salt and the most favorable larval habitat must occur well upstream of the salt front (Van Eenennaam et al. 1996). It is believed that the preferred habitat for larval Atlantic sturgeon is close to the spawning habitat between RM 37 to RM 92, with larvae gradually moving downstream as they grow and develop the salt tolerance that is characteristic of juveniles and adults (Bain et al. 2000). Neither eggs nor larvae would be expected to occur in the vicinity of the project.

2.2.3. Juveniles and Winter Habitat

Juvenile Atlantic sturgeon smaller than about 70 cm TL and 6 years old tend to occupy summer rearing and over-wintering habitats in the freshwater reaches of the Hudson River (Bain et al. 2000). From April through October, early Hudson River juvenile Atlantic sturgeon are primarily found between RM 42 and 66 and at water temperatures between 24 and 28°C (75 and 82°F) (Bain et al. 2000). This region comprises the highland gorge and wide estuarine portion of the Hudson River, where the transition from freshwater to brackish water typically occurs. Juvenile

Atlantic sturgeon are most often found in salinities ranging from 0 to 5 ppt (Bain et al. 2000). Water depths associated with most juvenile captures ranged from 10 to 25 meters (33 to 82 feet), and the substrates were primarily silt and sand (Bain et al. 2000). Later studies have pointed to Haverstraw Bay as the primary habitat for juvenile Atlantic sturgeon (Sweka et al. 2007). These studies suggest that while soft bottoms in deep habitat comprised only 25% of the available habitat in Haverstraw Bay, these habitats yielded the greatest frequency of catches, the highest catch per unit effort ("CPUE"), and lowest variance of CPUE (Sweka et al. 2007).

Hudson River winter habitat of Atlantic sturgeon has been described using data from trawl and gill-net sampling that was conducted between 1975 through 1978 (Dovel and Berggren 1983). When water temperature in the river reaches approximately 9°C (48°F), most juvenile Atlantic sturgeon that have not migrated to the ocean appear to congregate in a deep-water habitat between RM 12 and 46 (Bain et al. 2000). Water temperatures during winter can reach 0°C (32°F) in this segment of the Hudson River, salinity typically ranges from 3 to 18 ppt, and water depths in the channel commonly range from 20 to 40 meters (66 to 131 feet) (Bain et al. 2000). It appears that most juvenile sturgeon habitats prefer clay, sand, and/or silt substrates.

Juvenile Atlantic sturgeon that complete the migration to the ocean generally are older than 6 years and are longer than roughly 70 cm. These fish occupy marine habitats during the winter, and rivers, estuaries, and coastal marine habitats during the summer (Bain et al. 2000). It is thought that adult Atlantic sturgeon undertake the same migrations as the marine migrant juveniles (Bain et al. 2000).

Late juvenile and adult Atlantic sturgeon in the Hudson River also are known to occupy similar habitats in other rivers. Tagged Hudson River Atlantic sturgeon have been recaptured in tributaries of the Chesapeake Bay and in the Delaware River (Dovel and Berggren 1983). There also are accounts of concentrations of late juvenile and adults in coastal marine waters during the summer, including the deep waters of Long Island Sound off the Connecticut coast, with at least one fish collected that was originally tagged in the Hudson River (Bain et al. 2000; Eyler 2006). The Long Island Sound habitat was approximately 30 to 40 meters (98 to 131 feet) deep with mud substrate.

Adult Atlantic sturgeons do not appear to occupy the freshwater reaches of the Hudson River during the winter. Autumn collections of fish leaving the coastal waters and estuaries have been reported by fishermen in Chesapeake Bay, New York, and New Jersey, and some scientific researchers also have documented this out-migration (Bain et al. 2000; Kieffer and Kynard 1993). A study by NYSDEC has indicated that tagged Atlantic sturgeon left the Hudson River by late July (NYSDEC unpublished data).

2.2.4. Hudson River Population and Other Distinct Population Segments (DPS)

No data on abundance of juvenile Atlantic sturgeon in the Hudson River are available prior to the 1970s; however, catch depletion analyses conservatively estimated that 6,000 to 6,800 females comprised the spawning stock during the late 1800s (Secor 2002; Kahnle et al. 2005). Two population estimates of age-1 Atlantic sturgeon have been developed for the Hudson River. In 1977, the 1976 cohort was estimated at 25,647 individuals (95% confidence interval of 13,206–

53,039) (Dovel and Berggren 1983). In 1994, the cohort size was estimated at 4,314 (95% confidence interval of 1,916–10,473) individuals (Peterson et al. 2000). The large confidence intervals from the latter study point to the difficulty in obtaining a precise population estimate for Atlantic sturgeon for a small population in a large river system such as the Hudson River (Sweka et al. 2007). Kahnle et al, (1998) estimated the age-zero Hudson River population in 1994 to be 9,529 based on the capture of 15 captive-hatched and 14 wild origin age-1 Atlantic sturgeon in 1995. Of the total, 4,929 would have been captive-hatched and 4,600 of wild origin. An estimate of 870 spawning adult fish per year, consisting of approximately 600 males and 270 females, was calculated based on fishery dependent data collected from 1985-1995 (Kahnle et al. 1997).

Current abundance trends for Atlantic sturgeon in the Hudson River are also available from a number of ancillary surveys. From July to November during 1982-1990 and 1993, NYSDEC sampled the abundance of juvenile fish in Haverstraw Bay and the Tappan Zee Bay. The CPUE of immature Atlantic sturgeon was 0.269 in 1982 and declined to zero by 1990 (ASSRT 2007). The American shad (*Alosa sapidissima*) gill net fishery in the Hudson River estuary, conducted annually from early April to late May, incidentally captures young Atlantic sturgeon (< 100 cm) and has been monitored by fisheries observers since 1980. The CPUE of Atlantic sturgeon as shad bycatch was greatest in the early 1980s and decreased until the mid 1990s, but has gradually begun to increase slightly since then (ASSRT 2007).

The Utilities' Long River Sampling Program samples ichthyoplankton river-wide from the George Washington Bridge (RM 12) to Troy (RM 153) using a stratified random design (Con Edison 1997; ASSRT 2007). These data, which are collected from May to July, have provided an annual abundance index of juvenile Atlantic sturgeon in the Hudson River estuary since 1974. In addition, data from the Utilities' Fall Shoals Sampling Program, conducted from July through October/November, is used to calculate an annual index of the number of fish captured per haul. Indices from utility surveys conducted from 1974 through 2007 (LRS and FSS) indicate that the annual abundance of juvenile Atlantic sturgeon has been in decline over the monitoring period, with the CPUE peaking at 12.29 in 1986 (the highest of the survey period) and then declining to 0.47 in 1990 (Con Edison 1997; ASSRT 2007). Since 1990, the CPUE has ranged from 0.47-3.17, and has increased somewhat in recent years to 3.85 (in 2003). Taken together, these population estimates and annual abundance indices suggest a generally decreasing population trend for the Hudson River.

Between 2000-2009, the Hudson River Utilities Fall Shoals Sampling Program has collected 241 juvenile and sub-adult Atlantic sturgeon using a beam trawl. The majority of these fish were collected north of West Point (RM 47). Only five Atlantic sturgeon were collected in the Utilities defined Tappan Zee region (RM 24-33). Greater than 95% of all Atlantic sturgeon were collected from bottom habitats in waters greater than 6.1 m (20 ft) in depth. Between 2000-2009, the Utilities' Long River Program also collected 16 yolk and post yolk-sac larvae, all upstream of Cornwall (RM 58). The Utilities also report the number and size of Atlantic sturgeon collected as part of their Striped Bass and Atlantic tomcod sampling program.

No Atlantic sturgeon were captured in project-specific gill nets during the bi-monthly fish-sampling effort within the study area between 2007-2008. However, the carcass of an Atlantic sturgeon was observed floating approximately 152.4 m (500 feet) north of the bridge in May of 2008.

Commercial catch data provided by NYSDEC from observed fishing trips for the American shad gill net fishery (NYSDEC 2011 unpublished data) indicated that from the years 1980-2002 Atlantic sturgeon were collected in the study area between RM 25 and 27 in 14 of 23 years. However, Atlantic sturgeon were collected in only one year after 1992, which coincided with a marked reduction in commercial fishing effort. A separate adult Atlantic sturgeon tracking program was developed by NYSDEC which began tagging fish in 2007 with digital sonic tags. The study results confirm that the study area serves as a migration corridor for adult Atlantic sturgeon. Most of the fish that were tagged arrived in the Hudson from early April to late June and left the river by late July.

Although not currently listed as either threatened or endangered by the United States Fish and Wildlife Service (“USFWS”), NMFS, or NYSDEC, Atlantic sturgeon (*Acipenser oxyrinchus*) is likely to be listed in the very near future. In 2007, a Status Review Team (“SRT”) consisting of biologists from NMFS, the U.S. Geological Survey (“USGS”), and USFWS completed a status review report on Atlantic sturgeon in the United States. The SRT recommended that Atlantic sturgeon in the United States be divided into the following five distinct population segments (“DPS”): Gulf of Maine; New York Bight; Chesapeake Bay; Carolina; and South Atlantic.

The Atlantic Sturgeon Status Review Team identified 15 stressors that appear to be impacting the United States populations of Atlantic sturgeon (ASSRT 2007). Of the stressors evaluated, fishing bycatch mortality, degraded water quality, lack of adequate state and/or Federal regulatory mechanisms, and dredging activities were identified as the most significant threats to the viability of Atlantic sturgeon populations. In addition, some populations were impacted by unique stressors, including habitat impediments (e.g., Cape Fear and Santee-Cooper rivers) and apparent ship/propeller strikes (e.g., Delaware and James Rivers) (ASSRT 2007). NMFS cites locks and dams, overfishing and the more recent impact of bycatch and habitat degradation as causes for the Atlantic sturgeon decline in the Northeast (NMFS, Species of Concern Atlantic sturgeon www.nmfs.noaa.gov/_)

In October 2010, NMFS published two proposed rules to list five distinct population segments (DPS) of Atlantic sturgeon (75 FR 61872; 75 FR 61904). The Hudson River is contained within the New York Bight, which is one of the DPS identified in the proposed rule. Within the northeast region NMFS has determined that for the New York Bight and Chesapeake Bay DPS, an endangered listing is warranted, while a listing of threatened is warranted for the Gulf of Maine DPS.

As part of the ongoing Endangered Species Act listing for Atlantic sturgeon, the National Marine Fisheries Service (NMFS) is considering each of the five Distinct Population Segments (DPS) as an individual species. Because Atlantic sturgeon are thought to range widely along the Atlantic coast and have been shown to move among DPS (Erickson et al. 2011), there is a possibility that individuals from all five DPS could occur in the New York Bight DPS and may potentially pass through the Tappan Zee study area. As a result, Atlantic sturgeon from any of the five DPS could be affected by project activities associated with construction of the new Tappan Zee Bridge. For this reason, it is necessary to evaluate the potential for project effects on each of the five DPS.

Despite the fact that some individuals may migrate over large distances, their movement, in general, appears to be more localized to the coastal waters of the DPS of their origin (Erickson et al. 2011). For example, movement of Hudson River sturgeon has been shown to be largely limited to coastal waters from Long Island to the Chesapeake Bay, suggesting that the potential impact of bridge construction on Atlantic sturgeon may be greatest for individuals from the New York Bight DPS and possibly individuals from the adjacent Chesapeake DPS and much less for sturgeon from non-contiguous DPS.

The study area is located centrally within the New York Bight DPS, which is bounded to the north by the Gulf of Maine DPS and to the south by the Chesapeake DPS. Further south are the Carolina and South Atlantic DPS. Atlantic sturgeon from each of the DPS are unique in terms of their biological and genetic attributes, which provides the basis for their consideration as separate "species" (ASSRT 2007, Grunwald et al. 2008). While some mixing of individuals between the New York Bight and more southern DPS has been shown to occur in the southern portion of the New York Bight DPS (i.e., Delaware Bay; Waldman et al. 1996), nearly all Atlantic sturgeon (up to 99%) from further north in the New York Bight DPS are considered to be endemic to this DPS based on genetic analyses (Waldman et al. 1996). Fewer than 4% of Atlantic sturgeon in the coastal waters of the New York Bight likely originate from more southern DPS, while very few sturgeon (0% based on genetic analysis by Waldman et al. 1996) from the Gulf of Maine DPS move south into the New York Bight DPS. Earlier tag-recapture studies from the Carolina DPS suggests that Atlantic sturgeon from the two southern DPS have more restricted geographic distributions and move shorter distances than sturgeon from northern DPS, with all the recaptures in those areas coming from the Carolina or South Atlantic DPS (NMFS 1998b). These studies suggest that the majority of Atlantic sturgeon remain in coastal waters within their DPS or in adjacent DPS.

Although Atlantic sturgeon are capable of ranging widely along the Atlantic coast and of movement throughout DPS (Erickson et al. 2011), tagging and genetic studies indicate high site fidelity in natal rivers and very low gene flow among populations (Dovel and Berggren 1983, Savoy and Pacileo 2003, Grunwald et al. 2008). The fact that adult sturgeon return to their natal river to spawn (Collins et al. 2000, Grunwald et al. 2008), reduces the likelihood of impacting individuals from the four other DPS. Furthermore, the infrequency with which Atlantic sturgeon spawn (1-5 years for males and 2-5 years for females) further reduces the potential effects of bridge construction on Atlantic sturgeon from the New York Bight DPS. That is, since only a subset of adult sturgeon migrate to spawning grounds in the Hudson River during a given year, the remainder of the adult sturgeon should be unaffected. Use of the Hudson River by sturgeon from DPS outside of the New York is a possibility (ASSRT 2007), however, the abundance of these individuals in the Hudson River relative to sturgeon from the New York Bight DPS is unknown, but likely to be low.

Based on the best available information, the potential impacts of bridge construction on Atlantic sturgeon are greatest for individuals from the New York Bight DPS and much less likely for individuals from the four other DPS, despite the potential for Atlantic sturgeon to disperse widely among Atlantic coastal habitats and throughout DPS. Support for this conclusion comes primarily from recent tagging studies demonstrating that the majority of Atlantic sturgeon from the Hudson River remain within the New York Bight and coastal Chesapeake DPS, and from genetic studies that have shown distinct populations among DPS, low gene flow among populations and high site fidelity for natal rivers.

At this time, no critical habitat has been proposed for Atlantic sturgeon.

2.3. Marine Mammals

NMFS indicated that dolphins, harbor porpoises, and seals make occasional use of the Tappan Zee region of the Hudson River (NMFS 2011b). These species are marine, and only occur in the tidal Hudson River as transients. Rigorous scientific surveys of these species within the Hudson River are not known; however, anecdotal sightings of dolphins and other species have been published by the NYSDEC in the Hudson River Almanac. Both alleged and confirmed sightings of bottlenose dolphin (*Tursiops truncatus*) have been mentioned for Tappan Zee, Kingston Point, Tivoli Bay, Rhinecliff, and Peekskill in 1997 and 2008 (NYSDEC 2008). In addition, at least one confirmed death of an observed bottlenose dolphin occurred during the same reporting period. A follow-up necropsy was conducted by the Aquarium of Wildlife Conservation at Coney Island, Brooklyn, New York. The reported cause of death was stress related to an entanglement with monofilament fishing line resulting in septicemia (NYSDEC 2008). The Hudson River Almanac has also reported observation of harbor seals (*Phoca vitulina*), harp seal (*Phoca groenlandica*) in 1996, hooded seal (*Cystophora cristata*) in 1996, gray seal (*Halichoerus grypus*) in 2004, and harbor porpoise (*Phocoena phocoena*) in 1995, 1997, 1999, and 2005. Due to the anecdotal (and often unconfirmed) nature of these reports, it is difficult to determine the frequency of occurrence for any of these species in the Tappan Zee Reach, except to note that the NYSDEC considers the harbor seal “relatively common” in the Hudson River Estuary, although not necessarily in the Tappan Zee Reach.

There is a possibility that the Historic Area Remediation Site (HARS) will be used for the disposal of the project’s dredged material. 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 effects to threatened or endangered species, also including marine mammals.

Chapter 3 Environmental Baseline

The focus of this BA is confined to the habitats and biota that are directly relevant to shortnose and Atlantic sturgeon and marine mammals – namely the aquatic habitats that occur below the mean high tide line. The following narratives describe the physical aquatic habitat and biota within the study area.

3.1. Physical Habitat

The study area encompasses intertidal and subtidal habitats of varying depths, ranging from shallow intertidal shorelines to shallow subtidal shoals and deeper channel habitats. Along the shorelines, coarse woody and rocky debris provide structural refuge and foraging substrates for fishes. Benthic habitat includes submerged aquatic vegetation and oyster beds, as well as unvegetated areas of coarse sandy to fine silty sediments. The navigation channel provides deeper open-water and deep-water benthic habitats.

3.1.1. Water Quality

The water quality classification in the vicinity of the TZB is a driving factor in assessing the effects of the Tappan Zee Replacement Bridge. The Hudson River near the TZB is classified by NYSDEC as a Class SB water. There are no numeric water quality standards for the parameters typically associated with suspended sediments, such as turbidity or total suspended sediment (TSS), colloidal, and settleable solids (6 NYCRR § 703.2). However, the narrative standards state that an action should not increase turbidity sufficiently to result in a substantial visible contrast to natural conditions, or any suspended, colloidal or settleable solids from sewage, industrial or other wastes that would cause deposition or impair the waters for their best use.

The Hudson River is tidally influenced from the Battery to the Federal Dam at Troy, NY. Tides at the Battery have an average range of 1.37 m (4.5 ft), with the mean range decreasing to 0.98 m (3.2 ft) at the TZB and gradually increasing again to 1.43 m (4.7 ft) at the Federal Dam (NOAA Tide Tables, 2009). The majority of freshwater flow enters the Hudson River north of the Federal Dam, with the remaining freshwater flow entering from various tributaries downstream of the dam. The variation between freshwater flows at the mouth of the river and in the vicinity of the TZB is a few percent (DiLorenzo et al. 1999).

The Hudson River estuary is well studied and a large number of other data sources exist. These include permanent monitoring stations, such as the USGS gauge at Hastings on Hudson (8 km, or 5 miles, downstream from the TZB), the Hudson River Environmental Conditions Observing System gauge at Piermont Pier (3.2 km, or 2 miles, downstream), and the US Geological Survey (USGS) gauge at West Point (38.6 km, or 24 miles, upstream). Other monitoring stations include the NOAA gauge at The Battery and the USGS gauge south of Poughkeepsie which continuously monitors SSC.

The USGS gauge south of Poughkeepsie uses backscatter information from an Acoustic Doppler Current Profiler (ADCP) to estimate suspended solids concentration (SSC) (Wall et al. 2006). Using the SSC estimates combined with the current data measured by the device, an estimate of total sediment discharge is also calculated. This gauge has been operating almost continuously since 2002.

Available guidance and precedent suggest that the suspended solids concentrations (SSC) in the vicinity of the TZB do not need to be rigorously defined, as (1) water quality standards for suspended solids are typically defined in relative rather than absolute terms, and (2) existing background conditions do not materially alter the behavior of sediments resuspended by construction activities.

3.1.2. Sediment Characteristics

The physical properties of river sediments (particularly grain-size distribution, which is an input to dispersion and settling models) and the presence or absence of contamination in the sediment are key parameters in determining potential effects from suspended sediments. The predominant sediment texture in the vicinity of the TZB is clayey silt. As shown in **Figure 5**, accumulations of sand, silt and clay material are observed along the causeway section of the existing bridge. Gravelly sediments are also found extensively in the navigation channel south of the TZB near the eastern shore of the Hudson River and across a large swath roughly 1,000 ft north of the existing causeway section of the TZB.

3.1.3. Sediment Chemistry

Because of anthropogenic influences, sediments deposited during the industrial era are considered more likely to be “contaminated.” Mapping of suspected industrial-era sediment deposits in the vicinity of the TZB was developed by Lamont-Doherty Earth Observatory (LDEO) through the integration of acoustic mapping and lead concentration data, as shown in **Figure 6**. This mapping indicates industrial-era sediments in the project study area are generally less than 1 ft in depth. Some thicker deposits are likely to be found south of the existing bridge and near the eastern shore, with depths approaching 1.8 m (6 ft) in certain areas.

In order to identify the sediment chemistry of the study area, sediment samples were collected in 2006 and 2008 using vibracore methods. Up to 1.5 m (5 ft) of sediment was collected at 38 locations; sediment chemistry analyses was conducted for SVOCs-base/neutral (BN) fractions, pesticides, PCBs, and metals. A subset consisting of 17 samples from 10 cores was analyzed for dioxins analysis.

As compared to the 48.3-km (30-mile) segment of the Hudson River centered around the TZB, the results of the 2006 and 2008 sediment sampling programs indicate that sediments in the immediate vicinity of the bridge are not markedly different from the river as a whole in terms of bulk chemistry, as shown by comparison to local river average data in Tables 7 through 9. In the case of metals, for the 10 analytes for which Hudson River average results are available, average concentrations are generally of the same order of magnitude as that found in project-specific samples. While organic contaminants were generally found to be of higher concentrations in the project-specific samples than in the previous samples, this relationship was also generally true when comparing only to the subset of previous Hudson River samples within one mile of the TZB. Comparing only previous samples from within one mile of the bridge to the larger 48.3-km

(30-mile) area, sediment characteristics near the TZB were generally comparable to those further away. Furthermore, in all cases, the data indicated very few exceedances of the benthic aquatic chronic or acute criteria. In that respect, the project-specific and historic Hudson River data are consistent in that they indicate that Hudson River sediments are effected by low-level organic contaminants on a widespread basis.

3.2. Aquatic Biota

3.2.1. Phytoplankton

Phytoplankton are microscopic plants whose movements within the system are largely governed by prevailing tides and currents. Several species can obtain larger sizes as chains or in colonial forms. Light penetration, turbidity and nutrient concentrations are important factors in determining phytoplankton productivity and biomass.

In one 1998 study focusing on the Hudson River, investigators collected 161 phytoplankton species. 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).

3.2.2. 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 study area, although SAV is mapped within the ½ mile study area. 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 study 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.

3.2.3. 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.

3.2.4. Benthic Invertebrates

Invertebrate organisms that inhabit river bottom sediments as well as surfaces of submerged objects (such as bridge piers, riprap, and debris) are commonly referred to as benthic invertebrates. These organisms are important to an ecosystem's energy flow because they convert detrital and suspended organic material into carbon (or living material); moreover, they are also integral components of the diets of ecologically and commercially important fish and waterfowl species.

Some of these animals live on top of the substratum (epifauna) and some within the substratum (infauna). Substrate type (rocks, pilings, sediment grain size, etc.), salinity, and DO levels are the primary factors influencing benthic invertebrate communities; secondary factors include currents, wave action, predation, succession, and disturbance.

Versar (Llanso et al. 2003) collected benthic samples from the lower Hudson River estuary (RM 11 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 bridge vicinity was conducted between March 2007 and January 2008 on behalf of the Project Sponsors in order to better characterize the fauna in the immediate vicinity of the existing bridge and the Bridge Replacement Alternative. Samples were taken in the vicinity of the footprint of the existing and proposed bridges as well as the locations of the proposed temporary causeways along the southeast and southwest portions of the existing bridge. Forty one bottom benthic locations and six bridge pier locations were sampled for this phase of the project.

A total of 48 species were collected during the bottom sediment sampling program. Total numbers, species richness, and species diversity which consider both number of species and the evenness of distribution were calculated. Greatest diversity was observed 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. A one way analysis of variance (ANOVA) indicated that, for the most part, there was no statistically significant difference in benthic diversity, total numbers of individuals, or species richness between the current and proposed bridge alignment. There was often a statistical difference for the benthic metrics between the approach areas for the causeways and the other locations. These locations, south of the bridge, are thought to accumulate thick sediment deposits which may account for the different benthic community characteristics.

Benthic invertebrate sampling of the existing bridge piers conducted for the project in 2007 identified a total of 8 taxa and two 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.

3.2.5. Fish

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 species can enter the Hudson River during the summer, and a number of northern fishes are near their southern limit in the New York Harbor Estuary. A report by Smith and Lake (1990) noted that 201 species have been documented in the Hudson River. These species were classified by their probable origin, which demonstrated that 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). Over the period from 1974 to 2006, the total number of species collected annually in the utilities' monitoring program has varied from 64 to 104. 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% of the total fish community is comprised of only 10-15% of the species documented to be present in the river. 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 (*Anchoa mitchilli*). An analysis of the Fall Shoals data from 1998-2007 indicated that numerically, bay anchovy comprised about 82% 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. 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 (*Peprilus 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*), 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, blueback herring, and alewife to determine whether any or all of these three species should be proposed for listing as a protected species.

Chapter 4 Project Details

4.1. Construction

As shown in **Figure 7**, construction of the Short Span Option would take approximately 5½ years. The schedule shows both preliminary activities used to support the construction of the project (i.e., dredging and temporary platforms) as well as individual elements of bridge construction (i.e., main span and approaches). 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 would occur in three stages over the 5 ½ year period during a three-month window between August 1 and November 1 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 (see **Figure 7**). 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.

4.1.1. 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 construction activity for the landings, however, would be gradual, as the roadways on both sides would be altered and then maintained for lengthy spans of time before being altered again. The alterations to the landings would consist of changes in roadway grade, elevation, direction, and general configuration.

4.1.2. 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.

4.1.3. 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.

4.2. 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 to temporary platforms that would be constructed on the shoreline of the river, as shown in **Figure 8**. Dredged channels 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).

4.2.1. 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 would be extended out from the shoreline over the Hudson River (see **Figures 9** and **10**). The Rockland platforms would protect the shoreline and also enable the continued maintenance of the original Tappan Zee Bridge as well as providing continued support for the New York State Thruway Authority (NYSTA) Dockside Maintenance facility operation. 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.

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.

4.2.2. 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 utilize during construction of the approach spans. These vessels would be instrumental in 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. This would avoid the need to dredge the near-shoreline area.

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 11**, dredging would be conducted in three stages over a 4-year period for a duration of 3 months in the fall of the year. 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 for completion of the remaining portions of the new structure. Each of these three-month spans would occur during the limited fall window (between August 1 and November 1) when dredging is typically allowed in the New York Harbor/Hudson River Estuary area; this is the period when dredging activities would have the minimum effect on aquatic resources.

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 at least 3.6 m (12 feet) 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 4.3 m (14 feet) at the lowest observed water level, which occurs during the Spring Neap Tide. The lowest observed water level is referred to as Mean Low Low Water (MLLW).

In addition, to minimize any adverse effects from the re-suspension of the fine sediment material due to movement of vessels, particularly tugboats, within the dredged channel, a layer of sand and gravel (referred to as “armor”) would be placed at the bottom of the channel following dredging. As discussed below in Section 18-4-12 (Water Resources) 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 substantive adverse effect to the environment.

The installation of the sand and gravel would take place as soon as the dredging for that section of the channel was successfully 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 sand and gravel materials would be delivered by barges or scows, and would be placed within the channel by barge-mounted cranes. 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 once construction was completed. The dredging depth required assumes that two feet of sand and gravel armor is placed on the bottom. In total, the channel would be dredged to a depth corresponding to 4.9 m (16 feet) below MLLW.

Table 1 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 145 to 161 m (475 to 530 feet), and it would extend approximately 2,133 m (7,000 feet) from the Rockland County side into deeper waters and 610 m (2,000) feet from the Tarrytown access trestle 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 1.28 and 1.33 million cubic meters (1.68 and 1.74 million cubic yards) of sediment would be dredged for the short and long span options, respectively.

Table 1
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.

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

- Adherence to a 3-month fall window when dredging between August 1 and November 1 would be allowed;
- Use of an environmental bucket with no barge overflow; and
- Armoring of the channel to prevent re-suspension of sediment during the movement of construction vessels, installation and removal of cofferdams, and pile driving.

4.2.3. 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 placed into hopper scows, which are boats with a capacity of approximately 1,911 cubic meters (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 1,529 cubic meters (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 busiest dredging stage, Stage 1, up to 11,468 cubic meters (15,000 cubic yards) of materials would be dredged each day. **Table 2** presents the estimated daily volumes of materials removed for each dredging stage for the two replacement bridge alternatives.

Table 2
Daily Materials Removal by Construction Stage

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

After placement in the hopper scows, the next step in the dredge materials handling would depend on the dredge placement option selected.

As discussed above in the introduction of this chapter, 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 dredge spoils from construction of the access channel. Transport by ocean scow and placement in the Historic Area Remediation Site (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.

In this option, the dredged materials would be transported to HARS, 5.6 km (3.5 miles) east of Sandy Hook, NJ. 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 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 H to Draft Environmental Impact Statement documenting that there are no practicable alternatives 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 approved, the dredged materials from the Tappan Zee Hudson River Crossing Project placed at the HARS would be transferred from the hopper scows to larger capacity [up to 3,440 cubic meters (4,500 cubic yards)] ocean scows. These vessels have large drafts, typically up to 5.5 m (18 feet), that would be too large to be accommodated in the dredged construction channel. Therefore, materials would be transferred from the hopper scows to the ocean scows in deeper water areas of the Hudson River. The ocean scows would then travel to the HARS, where materials would be placed at the site in accordance with the permit conditions for that placement.

If the permit application for the use of HARS is denied in whole or part, the contractor would be required to dispose of the dredged material at an approved 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.

4.2.4. 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 12** and **13**). 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 3**, a total of 1,326 piles for Piers 1 to 57 would be required for the Short Span Option. **Table 4** 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 3-m (10-foot) piles would be the same (50) for either option. The greatest difference between the two options would be the number of smaller 1.2-m (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 1.8-m (6-foot) piles and 40 less 2.4-m (8-foot) piles for a total difference of 490 piles. Under either option, the driving of the largest piles [2.4- and 3-m) (8- and 10-foot)] would only occur for a few months in the first year of construction.

Table 3
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 4
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**

Environmental Performance Commitments (EPCs) to be employed during construction of the substructure include:

- Driving the largest [3 and 2.4 m (10 and 8 ft)] diameter piles within the first few months of the project thereby limiting the time period of greatest potential impact.

- 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 will be vibrated at least to 36.6 m (120ft) depth 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) which includes the testing of various sound attenuation devices 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 10 ft piles with an impact hammer within Zone C [water depths 5.5-13.7 m (18-45 feet)] to 5 hours per day during the period of spawning migration for shortnose and Atlantic sturgeon (April 1 to August 1).

- Maintaining a corridor where the sound level is below the West Coast threshold for onset of behavioral effects to fish totaling at least 5000-ft 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 ft.

- Pile tapping (i.e. a series of minimal energy strikes) for an initial period to frighten fish so that they move from the immediate area.

- Development of a comprehensive monitoring plan. Elements would include:

  - Monitoring locations to characterize the hydroacoustic field surrounding pile driving operations to evaluate the performance of underwater noise attenuation systems that are integral to the project.
  - Monitoring water quality parameters such as temperature, salinity, and suspended sediment concentrations in the vicinity of the pile driving.
  - Monitoring fish mortality and inspection of fish for types of injury.
  - Monitoring predation levels by gulls and other piscivorous birds, which would indicate that they are finding an increased number of dead or dying fish at the surface.
  - Developing criteria for re-initiating consultation with NMFS should specific numbers of shortnose or Atlantic sturgeon come to the surface injured or dead.
  - Preparing a Standard Operating Procedures Manual outlining the monitoring and reporting methods to be implemented during the program.

- In addition, dredging using an environmental bucket would only be conducted during a three-month period from August 1 to November 1 for the three years of the construction period in which dredging would occur, in order to minimize the potential for impacts to sturgeon migration, as well as migration by other fish species.

4.2.4.1. 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 measures less than 2.1 m (7 feet) in depth, are labeled as Zone A. The area adjacent to the Rockland shoreline is labeled Zone A1, while 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.

Cofferdams

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 6.1 m (20 feet). Upon completion of the cofferdam, foundation piles would be driven into the riverbed.

Pile installation

Prior to pile driving, a template to guide piles would be placed within the cofferdam to ensure that they are in position and to hold them when pile driving is not taking place. 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 depths 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. From these tests, 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. Once all piles are driven, the template and its supports would be transitioned to the next cofferdam.

Pile caps

A 300-ton crawler crane would suspend the 45.7-m (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. 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.

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.

4.2.4.2. Foundation Zone B

The water depths in Zone B range from 1.5 to 5.5 m (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.

Pile Installation

Piles, which would be transported in two pieces to Zone B by barge, would measure between 76.2 and 91.4 m (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.

4.2.4.3. 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 5.5 to 13.7 m (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.

4.2.5. 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.

4.2.6. 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.

4.2.6.1. Causeway and East Trestle Spans

The causeway is a simple span construction composed of 166 spans measuring 15.2 m (50 feet), with the exception of one 30.5-m (100-foot) span. The east trestle is comprised 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.

4.2.6.2. 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.

4.2.6.3. Main Span

The main span stretches 735.2 m (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 76 cm (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 5 Project Action Area

5.1. Limits of Action Area

The Hudson River is one of the major rivers on the Atlantic Coast, extending from its source at Lake Tear of the Clouds on Mount Marcy in the Adirondacks to the Battery in New York Harbor, a distance of approximately 507 km (315 miles) (Geyer and Chant, 2006). In the study area, the Hudson River is tidally influenced and commonly referred to as the Hudson River estuary. The estuarine portion of the river begins at the Troy Dam about 248 km (154 miles) north of the Battery in southern Manhattan. Tides in the Hudson River estuary are semidiurnal, having two high waters and two low waters each day with an average range of 0.98 m (3.2 feet) (NOAA Tide Tables, 2009). At approximately 4.8 km (3 miles) in width in the study area, the river is designated by NYSDEC as a Class SB (saline) waterbody, intended to be suitable for recreation, and fish survival and propagation. Water quality surveys by the Project Sponsors identified considerably variable concentrations of suspended sediments in the water column near the bridge depending on water depth, season and weather conditions.

In the vicinity of the bridge, the river ranges in depth from less than 3.6 m (12 feet) along the western causeway to greater than 14.3 m (47 feet) in the shipping channel under the main span. The causeway and bridge piers cause river currents to locally scour the bottom sediments, resulting in depressions in the bottom of the river alongside the bridge.

The study area in the immediate vicinity of the replacement bridge encompasses intertidal and subtidal habitats of varying depths, ranging from shallow intertidal shorelines to shallow subtidal shoals and deeper channel habitats. Areas south of the existing bridge less than 1.8 m (6 feet) deep at mean low water (MLW) are mapped as littoral zone wetlands by the NYSDEC. 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. The eastern shoreline adjacent to the railroad tracks consists of riprap armoring in the vicinity of the replacement bridge.

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. The habitat of the Tappan Zee Reach is dominated by a large shallow western shoal with soft sediments, deep channel in the middle of the river with coarse-grained sediments, and narrow shallow shoal on the east side of the river denominated by soft sediments. Within the Tappan Zee Reach, the benthic habitat also has a patchy distribution of oyster beds. All of the benthic habitats in the reach (e.g., soft and coarse-grained sediments, oyster beds, and bridge piers), provide foraging opportunities for species in the Tappan Zee Reach.

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 organisms that use the pier structures as habitat, or that seek the organisms that adhere to the structures as food resources.

The entire east bank of the Hudson River within the study area has been developed as rail beds (rip rap), piers, or bulkheads. Several vegetated tidal wetland areas or tidally-influenced areas were observed along tributaries to the Hudson River, as well as between the rail beds. The rip rap and beach areas may provide food and shelter values for fish, shellfish, and other wildlife.

The limits of the study area considered in this BA have been determined by the potential project effects for dredging and re-deposition of suspended sediment, acoustic impacts from pile driving, and loss of habitat. The potential geographic boundaries extend across the entire width of the Tappan Zee Reach, and based on modeled sound isopleths extend a maximum of 2,210 m (7,250 feet) or less in both up and downriver directions. For sediment resuspension, which is a measure for assessing impacts to water quality, project incremental concentrations above 10 mg/L above ambient conditions may extend in a relatively thin band approximately 305 to 610 m (1,000 to 2,000 ft) from the dredges. Concentrations of 5 mg/L above ambient may extend a greater distance in either an upstream or downstream direction, depending upon the tidal stage.

Chapter 6 Effects Analysis

The assessment of impacts focuses on potential direct and indirect effects on the shortnose and Atlantic sturgeon populations in the study area. The following were determined to be indicators of direct and indirect effects:

- Direct effects. Direct effects are considered to be any adverse effects arising from project activities that could result in immediate impacts on shortnose and Atlantic sturgeon individuals or changes to their habitat. These effects are defined as physical injury or death, disruption of migration or spawning behaviors, and direct alteration of existing habitat. For this BA direct effects were evaluated for pile driving increased vessel traffic, dredging activities, and shading from the new structures.

- Indirect effects. Indirect effects are defined as any effects that are caused by or will result from the proposed action later in time, but which are still reasonably certain to occur (50 CFR § 402.02). These effects are defined as water/sediment quality impairment and indirect alteration of habitat, inclusive of burial of spawning substrates by resuspension of material during vessel movements, dredging or backfill/capping, and associated effects.

6.1. Direct Effects

The primary potential direct effects of the project resulting in an incidental take of shortnose and Atlantic sturgeon from the project are associated with the physical disturbance to adults and juveniles as a result of pile driving and increased vessel traffic. In addition, the dredging required to facilitate construction barge access could also affect the foraging ability of these sturgeon species. Finally, the BA considers the potential for direct effects from shading.

6.1.1. Acoustic Effects from Pile Driving

In order to understand the potential impacts of the sounds produced by pile driving, as well as other anthropogenic sources, on the listed shortnose and candidate Atlantic sturgeon, it is necessary to have a basic understanding of sound, and, in particular, underwater sound. In this BA the potential effects from pile driving are evaluated based on the interim West Coast criteria for onset of physiological effects agreed to in a Memorandum of Agreement (MOA) by FHWA, USFWS, NMFS, CalTrans, and the Washington Department of Transportation on June 12, 2008.

6.1.1.1. Current Interim Criteria for the Onset of Physiological and Behavioral Effects

Physiological effects

As a result of the aforementioned 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 were established in June 12, 2008 and 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." This BA evaluates the potential for the project to result in onset of temporary behavioral changes to sturgeon.

6.1.1.2. 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 the 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 and federal agencies 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 at 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 10 m (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 recovery from effects on Chinook salmon exposed to sounds as high as 216 dB 1 μPa^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 203 dB 1 μPa^2·s SEL_{cum} or levels well above the West Coast interim criteria.

Basic Background on Acoustics and Fish Bioacoustics

Sound in water follows the same physical principles as sound in air. The major difference is that due to the density of water, sound in water travels about 4.5 times faster than in air [(approx. 1,493.5 m/s vs. 335.3 m/s (4,900 ft/s vs. 1,100 ft/s)], 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. In 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 3,000 or 4,000 Hz and some of the herring-like fishes (and specifically the American shad) can hear to over 100,000 Hz. (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; Fay and Popper 2000).

Measuring the Energy in a Signal

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 report, 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 1μPa^2-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 + $10\log_{10}(N)$; 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% of the time of the whole signal as shown in **Figure 14**. Alternatively, one may measure "Peak" sound level, which is the highest level of sound within a signal (e.g., the highest point in Figure 14). 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.

Figure 14 shows an impulsive signal that is typical of a single strike from a pile driving operation. The frequencies in this sound 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.

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 comparable "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 as well as survival of the population or species.

Potential Effects of Anthropogenic Sound on Fish

Richardson et al. (1995) defined different zones around a sound source that could result in different types of effects on fishes. As shown in **Figure 15**, 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. 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 as a result of pile driving: 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 onset of 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).

6.1.1.3. Effects of Sound on Fish Behavior

Currently, NMFS Northwest Regional Office uses a guidance value of 150 dB re 1 µPa rms for the onset of behavioral responses (NMFS 2011). As of this writing, neither NOAA Fisheries nor USFWS has provided any research data or related citations to support this threshold. The following sections provide an analysis based on recent literature.

6.1.1.4. Results of Empirical Studies on Effects of Sound on Behavior

Results of empirical studies of hearing of fishes, amphibians, birds, and mammals (including humans), in general, show that behavioral responses vary substantially, even within 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 larger sound levels 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 indicate 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 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 were 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 (see Section 6.1.3.2 below), 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 (Section 6.1.3.3). 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 and the existing hydroacoustic environment. In addition, behavioral response may change over time as fish individuals habituate. Behavioral responses to other noise sources, such as noise associated with vessel traffic, and the results of noise deterrent studies, are also summarized below.

The vast majority of the (albeit limited) behavioral studies to date, discussed below, suggest that there is not likely to be any adverse behavioral response from sturgeons, or any fish species, at sound levels as low as 150 dB re 1 μPa. However, in order to ensure that there is limited effect at this level, or even at higher sound levels, the project will maintain a corridor where ensonification due to pile driving is below the 150dB rms SPL behavioral guidance level suggested by NMFS. 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 sturgeon is the fact that the duration of pile driving during bridge construction will be a very small percent of the total project duration equating to approximately 93% of the total duration of bridge construction during which there will be no impact hammering sounds in the Hudson River. Combining this with the efforts to ensure a corridor where sounds will be below 150 dB re 1 μPa (rms) during pile driving should minimize any chance of behavioral impacts on sturgeons.

6.1.1.5. Behavioral Studies Using Pile Driving (or Pile Driving-Like) Sounds

There have been very few studies that have examined behavioral effects, including avoidance behavior, 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 representative of a natural 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, such study must examine free-swimming wild animals.

While not done on free-swimming animals, Mueller-Blenke et al. (2010), in an unpublished report that has not been peer reviewed, attempted to evaluate response of Atlantic cod (*Gadus morhua*) and Dover sole (*Solea solea*) in large pens to playbacks of pile driving sounds recorded during construction of Danish 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 (*Oncorhyncus 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.

6.1.1.6. 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 and have generally shown that there is no onset of behavioral responses, including startle responses until the sounds are well above 150 dB re 1 µPa (rms).

The seismic studies are of some use in helping understand potential effects on fish since 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 μPa^2–s and peak levels 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 ft) and 195 dB re 1 μPa at 109 meters (358 ft) from the source. Moreover, no animals appeared to leave the reef during noise production. Temporary changes in fish catch, and thus presumably 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 μPa^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 affect 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 $1uPa^2$-s.

6.1.1.7. Behavioral Responses to Other Sound Sources

Noise from construction vessels also has 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.

6.1.1.8. Behavioral Responses of Sturgeon to Pile Driving

The question remains as to how sturgeon will respond behaviorally to pile driving sounds generated during bridge construction. It has been demonstrated that sturgeons have small swim bladders (Beregi et al. 2001). This finding, along with studies of hearing in sturgeon, suggests the idea that these fish are likely to primarily detect particle motion (see Lovell et al. 2005; Meyer et al. 2010, 2012, discussed below). Accordingly, the low particle motion component of signals likely to arise from pile driving suggest that these species, like flatfish and other fishes with swim bladders far removed from the ear, are less likely to hear such sounds unless they are very close to the sound source.

While there are no data for hearing by either species of sturgeon in the Hudson River, there are data for the closely related lake sturgeon (*Acipenser fulvescens*), both in terms of hearing sensitivity and structure of the auditory system (Lovell et al. 2005; Meyer et al. 2010, 2012). The data suggest that lake sturgeon can hear sounds from below 100 Hz to about 500 Hz (Lovell et al. 2005); while Meyer et al. (2010) reported evidence to suggest that the same species may hear up to 800 Hz. These data also demonstrate that sturgeon are not sensitive to sound pressure, but, instead, that they primarily detect the particle motion component of a sound field (Lovell et al. 2005; Meyer et al. 2010).

Based on the known hearing capabilities of sturgeon and the findings that they are primarily detectors of particle motion and little or no pressure, it is difficult to use pressure as a measure for potential behavioral impacts on sturgeon (e.g., 150 dB re 1 μPa rms). Indeed, as pointed out by Lovell et al. (2005), since sturgeon are primarily (and perhaps only) sensitive to particle motion, it will take a much higher level of signal (with much higher sound pressures) to elicit behavioral responses from sturgeon than from fish that are primarily pressure sensitive.

Sturgeon Behavior at 150 dB re 1 μPa rms

There are no data to indicate how sturgeon will behave in response to sound pressure at the NMFS criterion level. However, even if one makes the assumption that sturgeon do detect pressure signals, 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 Purser and Radford (2011) and Andersson et al. (2007) (discussed above), 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)).

It is also worth noting that, in using the modeled isopleths of areas in which 150 dB re 1 μPa would result from pile driving (see **Figures 16-19**), 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 3-m (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.

The conclusion from the available data is that if/when sturgeon encounter sound levels of 150 dB re 1 μPa, and even sounds of higher levels, they are either not likely to detect the sound nor are they likely show any behavioral responses, such as startle or avoidance, to the sound since it is just at the level of detection. Moreover, even if sounds at higher levels elicit a behavioral response, the most likely reaction will be an initial startle response, similar to that even humans show when they encounter a loud and unexpected signal, but then the fish (as humans) will continue doing what they had been doing. (Indeed, this has been documented many times during attempts to use sound to cause avoidance reactions by fish at hydropower dams and irrigation channels, as discussed above.) In addition the, albeit limited, data suggest that even if fish show an initial behavioral response to the sound, they are likely to quickly habituate to its presence and then “ignore” the sound and continue with their normal behaviors.

It is likely that sturgeon will not show any adverse behavioral response to sounds at 150 dB re 1 μPa, which enlarges the potential migration corridors available to them during the construction. It is conceivable that higher sound levels well above the 150 dB re 1 μPa could potentially cause sturgeons to change behaviors, ranging from just halting movement to their turning away from the source. In many cases the changes in movement are likely to result in sturgeon quickly moving to a region of lower sound levels in the river, at which time they will continue with their original migratory movement through the corridor. In other cases, it is possible that the sturgeon will stop migratory movements, as if the sounds were a physical barrier and then resume movement once the sound stops.

While it is possible that any acoustic barrier could delay migratory and other important behaviors of sturgeon, there is no pile-driving from impact hammering for approximately 93% of the project duration. Thus, few fish would ever encounter an acoustic “barrier” and, even then, they would only be “delayed” for the very small amount of time that the sound is present. Once the sound is ceases, the fish will continue in their normal pathway since the “drive” to reach spawning or feeding grounds is generally very high in animals. (e.g., salmon and American shad are very well known to overcome massive barriers to get to spawning sites, and it is likely that the same applies for other species that have natal homes).

Affected Area and Potential Physiological Effects based on Modeled Pile Driving

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 2011a). 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 substrate. 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. 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.

Figure 20 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 20). 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 21 presents the SEL_{cum} metric for installing two pairs of 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 concurrent placement of two pairs of 10-ft piles is considered a representative worst case for driving of

10 ft piles, and 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 accumulated sound energy levels (SEL_{cum}) would be reached over the duration of 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% of the cross sectional width of the river. This can be contrasted with the 187 dB 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 22**).

Figure 23 indicates the cross sectional area of the river that would be reach an accumulated sound level of 187 dB re 1μPa^2-s 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% of the river cross sectional width would be within the 187dB re 1μPa^2-s isopleth. Similarly, the ensonified area would be between 43 and 61% 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 effects, 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%. 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 sturgeon and other fish species through the region. **Figure 24** indicates the cross sectional area of the river that would be ensonified to the 187 dB re 1μPa^2-s isopleths over the duration of the construction period for the Long Span Option.

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. Moreover, even though fish would accumulate energy over the course of a pile driving operation (assuming the fish does not leave the area), the actual number of strikes to which the fish would be exposed, and the time intervals between the strikes, would be of importance. If the fish is exposed to fewer strikes, the total energy to the fish is lower (assuming that all strikes are generally similar in SEL_{ss}).

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 1μPA^2-s, but it is not until the levels reach 216 – 219 dB re 1μPA^2-s that injuries become potentially fatal (Halvorsen et al. 2011). The study indicated there was recovery from injuries sustained at 210 dB re 1μPA^2-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 (Casper et al. 2011, in press).

Measures for Minimizing Potential Effects of Pile Driving and Estimating Numbers of Shortnose Sturgeon Potentially Affected

Adult shortnose sturgeon are likely to be present in the Tappan Zee Reach throughout the construction period. If an individual fish remains within an area(s) ensonified over Peak 206 dB re 1 μPa^2-s for a single strike or 187 dB re 1 μPa^2-s for accumulated energy ($SEL_{cum,}$) there is the potential for the onset of physiological effects. While the areas to be ensonified by the pile driving do not represent spawning grounds for any either sturgeon species, they are used for foraging and transit during migrations up and down the river.

Fish that may be close to the piles during a pile driving operation are going to be exposed to single strike sound levels that are above the interim criteria defined above (e.g., 206 dB re 1 μPa peak), and there is the likelihood of mortality to these individual animals. However, methods have been tested that suggest, albeit with minimal data, that it is possible to get fish to move from the vicinity of pile driving prior to the onset of maximum strikes. For example, during the construction of the Woodrow Wilson Bridge over the Potomac River, there is evidence that tapping the pile with lower energy for the first few strikes may “frighten” fish away from the piles before full operations begin (FHWA 2003). Reports from the Woodrow Wilson Bridge construction suggest that this kind of ramp-up procedure substantially decreased mortality; however, it is appropriate to acknowledge that these findings were anecdotal and were not part of scientifically controlled studies.

Pile driving in the warmer months of the year could expose a considerable number of sturgeon to potential effects as they use the project vicinity as a foraging area, but sturgeon would likely leave an area ensonified above the above Peak 206 dB or 187 dB SEL_{cum} from pile driving operations if such sounds caused discomfort. On days when pile driving occurs during migration periods, a substantial portion of the cross section of the Hudson River would not be ensonified with sound energy of greater than 187 dB (**Figures 23** and **24**). Importantly, for a period of 12 hours or more each day there would be no pile driving activities and pile driving is anticipated to occur for no more than five days a week. Thus, the majority of time each week the river would experience no sound energy above normal ambient, and pile driving activities would not represent a barrier to upriver or downriver movement of sturgeon, or to foraging.

Moreover, a number of Environmental Protection commitments (EPCs) are being implemented by the Project to reduce the potential for pile driving associated injury to sturgeon and other aquatic species. These measures were enumerated in Section 4.2.5 Substructure Construction:

Methods for Estimating the Potential Number of Shortnose Sturgeon Affected by the Pile Driving

Using fish abundance estimates from a 1-year comprehensive gill-net sampling study, the encounter rate of shortnose sturgeon in the study area was estimated as the number of shortnose sturgeon collected per gill net per hour. From June 2007 – May 2008, 476 gill nets were deployed just upstream of the existing Tappan Zee Bridge (and within the study area) for a total sampling time of 679 hours. During this time, 12 shortnose sturgeon were collected: 7 in September and October, 4 in May and June and 1 in August. Based on the observed number of sturgeon collected over 679 gill-net hours, the encounter rate for shortnose sturgeon in the proposed bridge replacement area is 0.02 sturgeon encountered per hour of sampling.

To estimate the potential number of shortnose sturgeon affected by pile driving activities, it was necessary to scale gill-net encounter rates from a single gill-net sample (the gill net is 125 ft in length) to the area encompassed by the isopleth bounding the SEL_{cum} of 187 dB re 1µPa^2-s (**Figures 21** to **22**; JASCO 2011a). The SEL_{cum} of 187 dB re 1µPa^2-s, which is the NMFS interim threshold measure for onset of physical injury to fish was used to determine the number of shortnose sturgeon that would have been collected if multiple gill nets were deployed side-by-side across the width of the 187 dB re 1µPa^2-s isopleth. For the Short Span Option the width of the 187 dB isopleth for the pile sizes ranges from 310.9 m to 2,841.9 m (1,020 ft to 9,324 ft), depending on the size of the pile, or combination of pile sizes being driven (see **Table 5**). However, for about 80% of the weeks that construction will be ongoing, the width of the isopleths will be 1,066.8 m (3,500 ft) or less. For the Long Span Option the width of the 187 dB isopleth for the pile sizes ranges from 359 m to 2,427.7 m (1,178 ft to 7,965 ft), depending on the size of the pile, or combination of pile sizes being driven (see **Table 6**). For 80% of the weeks that construction will be ongoing for the Long Span Option, the width of the isopleths will be 1,191.8 m (3,910 ft) or less.

Movement by shortnose sturgeon has been shown to be strongly oriented into or with river currents (McCleave et al. 1977; Richmond and Kynard 1995). This is supported by data collected during the 2007-2008 gill net study, in which shortnose sturgeon were collected with greater frequency in gill nets deployed across the river current vs. with the current. Based on these results, it can be assumed that sturgeon move in an upstream or downstream direction through the study area and at a constant rate and would thus be intercepted by gill nets spanning the width of the noise isopleth. It was also assumed that catch rates are proportional to shortnose sturgeon abundance, which is a central assumption of most fish-sampling gears, and that sturgeon were uniformly distributed throughout the Tappan Zee region. Under these assumptions, each gill net would encounter shortnose sturgeon at the same rate allowing the estimates of sturgeon number to be scaled to the width of the isopleth.

Estimated Number of Shortnose Sturgeon Potentially Affected by the Replacement Bridge Alternative

Tables 5 and 6 provide a summary of the number of shortnose sturgeon potentially exposed to the pile driving at various locations with BMPs providing a reduction of 10 dB. Based on this approach, 482 shortnose sturgeon have the potential to be exposed to an SEL_{cum} of 187 dB re 1 µPa^2-s over the project duration for the Short Span Option (see **Table 5**). Similarly, 365 sturgeon have the potential to be exposed to an SEL_{cum} of187 dB over the project duration for the Long Span Option (Table 6). Assuming 60,000 as a valid, current standing stock estimate for shortnose sturgeon in the Hudson River and assuming that this number remains static for the duration of the pile-driving activities, the Short Span Option has the potential to expose 0.80% of the population and the Long Span Option has the potential to expose 0.61% of the shortnose surgeon population. These estimates can be viewed as a conservative maximum because they represent the encounter rate within the isopleths over several years, and one should assume that some fraction of that total number would be encountered more than once without having experienced the necessary sound for the onset of injury.

Table 5
Number of Shortnose Sturgeon Potentially Affected by Pile Driving – Short Span Bridge Option

								With 10 dB BMPs			
Year	Week	Pile Diameter (feet)	Number of piles	Number of piles driven/day	Pile driving time (hours/pile)	Number of concurrently driven piles	Estimated pile driving time (hours)	Width of isopleth for 187-db SEL_{cum} (ft)	Number of gill nets (125-ft) to span width of isopleth	Sturgeon encounter rate per gill net (fish/hr)	Number of shortnose sturgeon potentially exposed to pile driving
1	40-44	10	50	4	1.55	2	38.75	7186	57	0.02	44.55
	45-48	6,8	20	7	1.11	2	11.1	5807	46	0.02	10.32
	49	6,8	8	7	1.11	2	4.44	6336	51	0.02	4.50
	50-51	4,8	20	6	1.14	2	11.4	7170	57	0.02	13.08
	52	4,8	10	6	1.14	2	5.7	6952	56	0.02	6.34
2	1	4,8	10	6	1.14	2	5.7	6952	56	0.02	6.34
	2	4,8	10	6	1.14	2	5.7	6735	54	0.02	6.14
	3-4	4,6,8	30	10	1.14	3	11.4	8418	67	0.02	15.36
	5	4,6,8	15	10	1.14	3	5.7	9324	75	0.02	8.50
	6	4,6,8	15	10	1.14	3	5.7	9253	74	0.02	8.44
	7	4,6,8	15	10	1.14	3	5.7	8312	66	0.02	7.58
	8-12	4,6,8	75	10	1.14	3	28.5	7732	62	0.02	35.25
	13	6,8	12	7	1.14	2	6.84	7732	62	0.02	8.46
	14-28	4,4	160	6	1.14	2	91.2	3490	28	0.02	50.9
	29-49	4	95	3	1.14	1	108.3	2024	16	0.02	35.15
	50-51	4,4,6	30	10	1.14	3	11.4	5581	45	0.02	10.18
	52	4,4,6	15	10	1.14	3	5.7	5036	40	0.02	4.59
3	1	4,4,6	15	10	1.14	3	5.7	5036	40	0.02	4.59
	2	4,4	10	6	1.14	2	5.7	3490	28	0.02	3.18
	3	4,4,6	15	10	1.14	3	5.7	4836	39	0.02	4.41
	4	4,4,6	16	10	1.14	3	6.08	4217	34	0.02	4.10
	5-10	4,4	65	6	1.14	2	37.05	3461	28	0.02	20.51
	11-12	4,4	22	6	1.14	2	12.54	3197	26	0.02	6.42
	13-17	4,4	53	6	1.14	2	30.21	3461	28	0.02	16.73
	18-20	4,4	30	6	1.14	2	17.1	3197	26	0.02	8.76
	21-25	4,4	55	6	1.14	2	31.35	3461	28	0.02	17.35
	26-27	4,4	20	6	1.14	2	11.4	3197	26	0.02	5.84
	28-33	4,4	60	6	1.14	2	34.2	3461	28	0.02	18.96
	34-35	4,4	20	6	1.14	2	11.4	3197	26	0.02	5.84
	36-41	4,4	60	6	1.14	2	34.2	3461	28	0.02	18.96
	42-52	4	60	3	1.14	1	68.4	2024	16	0.02	22.2
4	1-14	4	70	3	1.14	1	79.8	2024	16	0.02	25.9
	15-16	6	12	4	0.33	1	3.96	2120	17	0.02	1.34

Table 5
Number of Shortnose Sturgeon Potentially Affected by Pile Driving – Short Span Bridge Option

Year	Week	Pile Diameter (feet)	Number of piles	Number of piles driven/day	Pile driving time (hours/pile)	Number of concurrently driven piles	Estimated pile driving time (hours)	With 10 dB BMPs: Width of isopleth for 187-db SEL_{cum} (ft)	With 10 dB BMPs: Number of gill nets (125-ft) to span width of isopleth	With 10 dB BMPs: Sturgeon encounter rate per gill net (fish/hr)	With 10 dB BMPs: Number of shortnose sturgeon potentially exposed to pile driving
	17-18	6	6	4	0.33	1	1.98	2019	16	0.02	0.64
	19	6	6	4	0.33	1	1.98	1821	15	0.02	0.58
	20	6	6	4	0.33	1	1.98	1624	13	0.02	0.51
	21	6	4	4	0.33	1	1.32	1440	12	0.02	0.30
	22-23	6	8	4	0.33	1	1.64	1060	8	0.02	0.44
5	50-52	4	15	3	1.14	1	17.1	2024	16	0.02	5.55
	1-5	4	25	3	1.14	1	28.5	2024	16	0.02	1.85
	6-7	6	12	4	0.33	1	3.96	2120	17	0.02	1.34
	9	6	6	4	0.33	1	1.98	2019	16	0.02	0.64
	10	6	6	4	0.33	1	1.98	1821	15	0.02	0.58
	11	6	6	4	0.33	1	1.98	1624	13	0.02	0.51
	12	6	4	4	0.33	1	1.32	1440	12	0.02	0.30
	13	6	4	4	0.33	1	1.32	1280	10	0.02	0.27
	14	6	4	4	0.33	1	1.32	1060	8	0.02	0.22
	21	6	6	4	0.33	1	1.98	1346	11	0.02	0.43
6	22	6	6	4	0.33	1	1.98	1020	8	0.02	0.32
Potential number of sturgeon affected											
Shortnose sturgeon affected											**482**
Percentage of shortnose sturgeon standing crop (60,000 fish)											**0.80**

Table 6
Number of Shortnose Sturgeon Potentially Affected by Pile Driving – Long Span Bridge Option

Year	Week	Diameter (feet)	Number of piles	Number of piles driven/day	Pile driving time (hours/pile)	Number of concurrently driven piles	Estimated pile driving time (hours)	With 10 dB BMPs: Width of isopleth for 187-db SEL_{cum} (ft)	With 10 dB BMPs: Number of gill nets to span width of isopleth	With 10 dB BMPs: Sturgeon encounter rate (fish/hr)	With 10 dB BMPs: Number of shortnose sturgeon potentially affected by pile driving
1	40-44	10	50	4	1.55	2	38.75	7186	57	0.02	44.55
	45-48	6,8	20	7	1.11	2	11.1	5866	47	0.02	10.42
	49-50	6,8	16	7	1.11	2	8.88	6862	55	0.02	9.75
	51	6,8	12	7	1.11	2	6.66	7387	59	0.02	7.87
	52	6,8	14	7	1.11	2	7.77	7965	64	0.02	9.90
2	1	6,8	10	7	1.11	2	5.55	7767	62	0.02	6.90
	2-3	8	12	3	1.11	1	13.32	5648	45	0.02	12.04
	4-11	4,4	88	6	1.14	2	50.16	3458	28	0.02	27.76
	12-13	4,4	20	6	1.14	2	11.4	3910	31	0.02	7.14
	14-21	4,4	80	6	1.14	2	45.6	3458	28	0.02	25.2
	22-23	4,4	22	6	1.14	2	12.54	3910	31	0.02	7.84
	24-30	4,4	73	6	1.14	2	41.61	3458	28	0.02	23.01
	31-33	4	45	3	1.14	1	51.3	2064	17	0.02	16.95
	47-52	4,4	60	6	1.14	2	34.2	3712	30	0.02	20.34
3	1-4	4,4	40	6	1.14	2	22.8	3712	30	0.02	13.56
	5-18	4,4	160	6	1.14	2	91.2	3910	31	0.02	57.1
	19	4,4,6	21	10	1.14	3	7.98	3910	31	0.02	4.99
	20-21	4,6	34	7	1.14	2	19.38	4653	37	0.02	14.43
	22	4,6	22	7	1.14	2	12.54	4200	34	0.02	8.43
	23	4,6	16	7	1.14	2	9.12	3784	30	0.02	5.52
	24	4,6	11	7	1.14	2	6.27	3512	28	0.02	3.52
	25	4,6	11	7	1.14	2	6.27	3240	26	0.02	3.25
	26-33	4	40	3	1.14	1	45.6	2064	17	0.02	15.04
5	17-20	4	20	3	1.14	1	22.8	2064	17	0.02	7.52
	23	6	6	4	0.33	1	1.98	2282	18	0.02	0.72
	25	6	4	4	0.33	1	1.32	1395	11	0.02	0.29
	28	6	6	4	0.33	1	1.98	1759	14	0.02	0.56
	32	6	6	4	0.33	1	1.98	1469	12	0.02	0.47
	36	6	6	4	0.33	1	1.98	1178	9	0.02	0.37
Potential number of sturgeon affected											
Shortnose sturgeon affected											**365**
Percentage of shortnose sturgeon standing crop (60,000 fish)											**0.61**

These findings are also likely to overestimate the number of shortnose sturgeon potentially affected for the following reasons:

- Since the calculations do not take into consideration the normal behaviors of the fish in response to a noxious stimulus, it is reasonable to assume that sturgeon, on hearing the pile driving sound, would either not approach the source or move around it. Since the pile driving sounds are very loud, it is also very likely that many of the fish will hear the sound, and respond behaviorally, well before they reached a point at which the sound levels exceeded the behavioral criterion of 150 dB re 1 μPa or the interim SEL_{cum} criterion of 187 dB 1 $\mu Pa^2 \cdot s$. The likely behavioral response would be to alter the path through which the fish were traveling to avoid the sounds that were too loud and then resume their regular path once the highest sound levels were skirted.

- Based on the most recent scientific studies (e.g., Halvorsen et al. 2011), the 187 dB re 1μPa^2-s SEL_{cum} threshold is overly conservative, and far lower than cumulative sound levels that actually result in onset of physiological effects in rigorous experimental studies. If a higher threshold for onset, such as those proposed by Halvorsen et al. (2011) (e.g. SEL_{cum} of 203 dB or greater) were to be used to evaluate the onset of injury to sturgeon, the size of the ensonified area that could potentially cause onset of physiological effects would be considerably reduced, as would the number of potentially affected fish.

- The analysis was conducted using a 10 dB reduction associated with implementation of BMPs, which may underestimate the level of noise attenuation that can be achieved by bubble curtains or other technologies (i.e., 20 dB; Caltrans 2009)

- Carlson et al. (2007) have provided evidence that as fish get larger there is less of an impact on them from sounds, and that the threshold for onset to injury to larger fish, such as sturgeon, is substantially higher (i.e. 213 dB re 1 μPa^2-s) for fish above 200 grams, than the West Coast criterion for fish > 2 gm (i.e. 187 dB re 1 μPa^2-s).

Because Atlantic sturgeon were not collected in the gill net sampling program no estimate of the number of fish within the ensonifed zone was calculated. However, because the Hudson River population size is considerably less than that for the shortnose, the number would be expected to be substantially less than the 482 and 365 shortnose sturgeon for the Short Span and Long Span, respectively.

While pile driving can potentially result in onset of injury to sturgeon in the immediate vicinity of the pile driving activity, it will not jeopardize the continued existence of shortnose or Atlantic sturgeon in the Hudson River. Their relatively small swim bladder and large size would suggest that the physiological impacts of pile driving on sturgeon may not be as great as for other species with larger swim bladders. Furthermore, NMFS has commented (FHWA 2003) that fish like shad and alewife are more susceptible to pressure waves due to their laterally compressed body shape, in comparison to the shortnose sturgeon’s fusiform shape. There is no critical habitat for shortnose or Atlantic sturgeon in the Hudson River.

While pile driving impacts resulting from constructing either Short or Long Span options may impact some individuals of these two species either behaviorally or physiologically, the activity would not jeopardize either population.

6.1.1.9. Effects to Marine Mammals from Pile Driving

Marine mammals rely on the use of underwater sounds to communicate, navigate, and/or obtain information about their environment (the afore-mentioned “auditory scene”) (Richardson et al. 1995; Southall et al. 2007). The ability of marine mammals to hear and respond to underwater sounds depends on auditory capability and thus whether the sound is within the hearing range of the animal. All marine mammals potentially found within the Hudson will be able to hear sounds from pile driving since the frequencies are well within the hearing range of the animal (Southall et al. 2007). Moreover, the hearing sensitivity of all of these species is sufficiently acute that they are likely to be able to hear, and behaviorally respond to, the sounds at very substantial distance from the pile driving. Indeed, they are likely to hear the sounds at far greater distances than any fish and move away from the sound well before they get to a location where the pile driving levels would be sufficient to cause potential injury.

Dolphins, harbor porpoises and seals make occasional use the Hudson River and may occur in the vicinity of the project. These species are marine, and only occur in the tidal Hudson River as transients. Given the scarcity of marine mammals in the study area, it is not possible to reliably estimate the number of animals that may even get close enough to hear pile driving sounds (or noises associated with other construction activities). Based on the few anecdotal observations cited above, the presence of these species in the vicinity of the project is rare and is likely attributable to either previously stressed / injured animals or healthy, but transient, individuals. In the case of the former, the pile driving sounds could exacerbate existing stressors and result in either sub-lethal or lethal effects, while in the case of the latter, healthy animals would be expected to retreat from the source of any sounds that produce discomfort. Nevertheless, because this portion of the Hudson River doesn’t provide areas for spawning, nursery, or overwintering, or migratory pathway for these species, any anthropogenic sound in the river is not expected to result in adverse effects to the movement, reproduction, feeding, or sustained population of these species.

6.1.2. Effects from Increased Vessel Traffic

The shortnose and Atlantic sturgeon are known to occur within the stretches of the river that include the project area; therefore, sturgeon also may be directly impacted by increased vessel traffic in these areas. Increased vessel traffic will occur during all phases of the work including mobilization and site preparation activities, dredging for channel access, substructure construction, superstructure construction, and bridge demolition. These activities may result in a substantial increase in commercial vessel traffic in the Tappan Zee Reach. The potential direct effects associated with increases in vessel traffic include potential disturbance of foraging and migratory adults and juveniles associated with an increase in surface activity, vessel-impact mortality and noise.

The increased surface activity and associated noise may be considered to have the potential to displace/disrupt adults and juveniles during foraging and migratory activities, if the sounds are loud enough to be heard by sturgeon, which generally have poor hearing sensitivity (Lovell et al. 2005; Meyer et al. 2010, 2011). The increase in the Hudson River shortnose sturgeon population over the past several decades however, demonstrates the ability of the sturgeon to coexist in areas where commercial and industrial vessel traffic overlap.

Vessel traffic has been reported as a source of mortality for Atlantic sturgeon as a result of direct collisions with the hull or propeller. Vessel-strike mortalities have the potential to impact Atlantic sturgeon populations in the Delaware River and New York Bight by reducing the egg-per-recruit ratio and thus, by reducing the overall reproductive potential of the population (Brown and Murphy 2010).

The majority of vessel related sturgeon mortality are likely caused by large transoceanic vessels, with fewer caused by smaller vessels. Large vessels have been implicated because of their deep draft [up to 12.2-13.7 m (40-45 feet)] relative to smaller vessels [<4.5 m (15 feet)], which increases the probability of vessel collision with demersal fishes like sturgeon, even in deep water (Brown and Murphy 2010). Smaller vessels and those with relatively shallow drafts provide more clearance with the river bottom and reduce the probability of vessel-strikes. Because the construction vessels (tug boats, barge crane, hopper scow) have relatively shallow drafts, the chances of vessel-related mortalities are expected to be low. The depth of the construction channel will be 4.3 m (14ft), which is considerably shallower than the typical depths [>6.1-9.1 m (20-30ft)] in which Atlantic sturgeon are found (Hatin et al. 2002). The maximum allowable draft of any of the construction vessels will be 3.2 to 3.6 m (10.5 to 12ft), however, under typical operating conditions, vessels will draft 2.1 to 2.4 m (7 to 8 ft), providing 1.8-2.4 m (6-7 ft) of clearance with the bottom at all times. Maximum allowable drafts will only occur under full load and while turning. Under working conditions, stationary tug boats will maintain 1.8 m (6 ft) clearance between the prop and the bottom and will only infrequently approach 1.1 m (3.5 ft) clearance. The large grain size of the gravel substrate used to armor the bottom of the construction channel is not the desired foraging substrate for sturgeon or their benthic invertebrate prey, which are typically found in fine-grained silt-clay sediments (Hatin et al. 2002, Hatin et al. 2007).

The increased vessel traffic associated with the Tappan Zee Bridge replacement is not expected to result in direct interactions with sturgeon, because the life stages present in this reach of the river tend to occupy the bottom meter of the water column over fine-grained substrates in the deepest water areas and would be below the draft of the vessels involved. Furthermore, if it is assumed that sturgeon will avoid areas of increased noise caused by vessel traffic and other construction-related activities, then the probability of vessel-related impacts is even less likely. This conclusion is consistent with previous NMFS consultations with regional construction projects (e.g., the opinion issued for the Van Houten Holding Corporation's berthing facility upgrades in Upper Nyack, New York, NMFS 2011, NAN-2010-00832-ESP).

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, and these do not appear to affect the behavior or migration of sturgeon that bypass this very noisy region each year. While noise levels from shipping in the estuary are not known, it is possible to get a first approximation based upon results of other studies which suggest that sound levels due to radiated vessel noise would be below thresholds for the onset of injury to fish (Wursig et al. 2002). Furthermore, because of the comparatively poor hearing ability of sturgeon (Lovell et al. 2005; Meyer et al. 2010, 2011), it is possible that many of the sounds which are audible to most species, are not audible to sturgeon.

Because these representative values of radiated vessel noise are well below the peak SEL of 206 dB re 1 µPa criterion 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 sturgeon.

6.1.3. Effects of Dredging

The frequency of dredging or disturbance of an area affects the invertebrate community and its ability to recover following each dredging event. Since sturgeon feed on benthos, a sizable loss of habitat due to dredging and temporary alteration of habitat 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 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 0.67 to 0.71 km^2 (165 to 175 acres) of bottom habitat—including about 0.02 km^2 (5.3 acres) of NYSDEC littoral zone tidal wetland and 0.65-0.69 km^2 (160-170 acres) of open water benthic habitat—would be dredged during three stages over a four year period for a duration of three months between August 1 and November 1 (see **Figure 11**). Dredging would be initiated during this window to avoid periods of anadromous fish spawning migrations. 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 and gravel. Since armoring would occur up to 6.1 m (20 feet) of the side slope, total acreage of hard bottom would be approximately 0.63 to 0.67 km^2 (155 to 165 acres). 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 once construction was completed. The rate of this transformation would begin at approximately 1 foot per year, likely decreasing as the bed nears it natural pre-dredged elevation.

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 temporary loss of the access channel area would represent a minor fraction of similar available habitat throughout the Tappan Zee region (1.2%) as defined by the Hudson River Utilities (RM 24-33), and an even smaller percentage of the riverwide benthic area (0.2%). 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 suggest that deposition within the dredged channel will occur at a rate of about one foot per year (see Appendix E of DEIS for deposition rate calculations). 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. 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 long-term adverse effect. Once in-water activities are 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.

6.1.3.1. Oyster beds

Oyster beds were mapped using side scan sonar imagery approximately two miles north and south of the existing bridge from depths of 2.4 to 9.1 m (8 to 30 feet). Seven potential oyster beds were identified south of the bridge and six potential beds to the north (see Appendix E-3 of the DEIS for a description of each of the beds). During the subsequent grab sample program 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. Dredging would remove about 0.05 km^2 (13 acres) of oyster beds, some or all of which may be permanently lost due to dredging and armoring of the bottom. A permanent loss of these oyster beds would result in an unavoidable adverse impact. Potential for implementation of oyster enhancement, relocation, or restoration projects will be explored and other mitigation strategies will be developed through consultation with the USACE, NMFS, USFWS, and NYSDEC. However, because of its sediment composition, oyster habitat is not considered optimal for sturgeon foraging.

In summary, with the exception of oyster beds that may be permanently lost, where access channels are dredged, there would be a temporary loss of habitat that could affect sturgeon that use the dredged area for foraging. These effects would occur as a result of a localized reduction in benthic fauna. However, the dredging footprint represents a very small percentage of the Hudson River Estuary and its soft bottom habitat. Thus, the temporary reduction of benthic fauna within the dredged area would not substantially reduce foraging opportunities for the river's sturgeon populations, because sturgeon are highly mobile and anadromous, moving up and down the estuary. As noted above, once in-water activities are completed, the dredged channels would be restored over time to their original elevations and the river's benthic community would recolonize those areas.

6.1.4. Effects of Shading

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 2**), the height-to-width ratio of the bridge varies along its length. **Table 7** 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 up to 70 feet. While there are no vegetated wetlands or SAV that could 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 0.22 to 0.29). The ratio for these same stations for the Replacement Bridge Alternative, Short and Long Span Options, are much higher, ranging from 0.348 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 1.23to 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 1.4896 to 1.8161, 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 7** 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 7**, 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 indicate that even if the Replacement Bridge Alternative was 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 7
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

The approximately 99,153-square foot permanent platform at the Rockland Bridge Landing would result in additional aquatic habitat affected by shading. Considering the extensive area of aquatic habitat not affected by shading within the study area, the additional shading caused by the permanent platform and by the bridge would not result in direct effects to to sturgeon.

6.2. Indirect Effects

6.2.1. Impacts Associated with Resuspended Sediment

Dredging, pile driving, and construction vessel prop wash have the potential to re-suspend bottom sediments in the vicinity of the activity. 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, which included a variety of fish species common to the proposed construction site and representative of tolerant and sensitive species (white perch (*Morone americana*), spot (*Leiostomus xanthurus*), silversides (Atherinidae), bay anchovies (*Anchoa mitchilli*) and menhaden (*Brevoortia* spp.)) 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 fishes can be classified as biological/physiological or behavioral. Among the biological/physiological impacts are: abrasion of gill membranes resulting in a reduction in the ability to absorb oxygen, decrease in dissolved oxygen concentrations in the surrounding waters and effects on growth rate. Behavioral responses by fishes to increased suspended sediment concentrations include impairment of feeding, impaired ability to locate predators and reduced breeding activity. Increased TSS can inhibit migratory movements as well. A study conducted by NOAA concluded that TSS concentrations as low as 350 mg/L could interfere with upstream migrations of various species (NOAA 2001). At high suspended sediment concentrations, mortality has also been documented. 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). The effects of habitat avoidance are not expected to have widespread consequences for the ecology of the fish community based on their ability to move from the impacted area and because the spatial distribution of the community is considerably greater than the predicted extent of increased suspended sediment concentrations and the dredge footprint.

Lethal and sublethal effects of suspended sediments on fish species common to the study area have been observed at concentrations above those expected during project construction. In terms of sublethal effects, a stress response (e.g., elevated corticosterol levels) was reported for striped bass (1,500 mg/L), white perch (650 mg/L) and hogchoker (1,240 mg/L) well above expected concentrations (Wilber and Clarke 2001). 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. Burton (1993) indicated that concentrations of suspended solids can reach thousands of milligrams per liter before an acute reaction is observed. Lethal effects were demonstrated between concentrations of 580 mg/L for sensitive species and 700,000 mg/L for more tolerant species. Lethal effects were not observed until suspended sediment concentrations exceeded 750 mg/L, at which point 100% mortality was observed for bluefish, Atlantic menhaden and white perch. More tolerant species exhibited 50% mortality at concentrations above 2,500 mg/L, including silversides (2,500 mg/L), spot (20,340 mg/L), cunner (28,000 mg/L) and mummichog (39,000 mg/L).

Sublethal effects on fish eggs and larvae have been reported in terms of slowed development, delayed hatching or reduced hatching success. Wilbur and Clarke (2001) in a literature summary of available data indicated that hatching is delayed for striped bass and white perch at concentrations of 800 mg/L and 100 mg/L, respectively, however, reduced hatching success (i.e., egg mortality) was not observed until concentrations reached 800-1,000 mg/L for these species. For eggs of Atlantic herring, there were no sublethal effects observed at suspended sediment concentrations of 300-500 mg/L (Wilber and

Clarke 2001), while eggs of blueback herring and Atlantic menhaden exhibited no change in hatching or development at a concentration of 1,000 mg/L (Wilber and Clarke 2001).

Modeling results indicated that 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. These changes are considered well within natural variation that has been observed within the Hudson River. For example, during the sampling conducted for the project TSS concentrations ranged from 13 to 111 mg/L. Data recorded at Poughkeepsie indicated that during higher freshwater flow periods the difference between suspended sediment concentrations can vary by 20 to 40 mg/L. Therefore, the TSS projected to occur as a result of the project's construction would be expected to 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 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.

While there are no studies on the effects of resuspended sediments on either the shortnose or Atlantic sturgeon they are routinely encountered in turbid waters (Dadswell et al. 1984) and as such are thought to be highly tolerant of suspended sediment at the levels that are generated by marine construction activities (NMFS 2011b). In fact, sturgeon feed on invertebrates that occur both on and within the bottom substrate, and as a consequence have evolved to tolerate high concentrations of suspended sediment. The action of feeding sturgeon itself may lead to substantial resuspension of sediments. In a study of Atlantic sturgeon feeding patterns in the Bay of Fundy, sturgeon feeding activity has been linked significant quantities of clay and silt becoming redistributed (Pearson et al. 2007). Within the area studied, these researchers estimated as much as 1,220 m^3 of sediment being resuspended during the six weeks during which peak sturgeon feeding activity occurred. NMFS concluded that the effect of suspended sediment concentrations in the range of 10-350 mg/L from dredging, pile driving and other construction activities for a marina project in the Haverstraw Bay region would be insignificant to shortnose sturgeon (NMFS 2011d). Citing the literature, NMFS indicated that the concentrations of TSS that would be expected to show adverse impacts to fish would be 580.0 mg/L for the most sensitive species, with 1,000 mg/L being more typical.

Hydrodynamic modeling has been used to project the path and extent of the plume of resuspended sediment that would result from sediment disturbing construction activities such as dredging and pile driving, and to anticipate the fate and transport of this plume within the Hudson River estuary.

Inputs to the hydrodynamic models included the following:

- Results of SedFlume[1] analysis of sediments within the vicinity of the area to be dredged conducted by Dr. Donald Hayes, that indicated sediments within the study area are highly susceptible to resuspension. Dr. Hayes is the director of the Institute for Coastal Ecology and Engineering at the

1 High Shear Stress flume (SEDflume http://www.erdc.usace.army.mil) is designed for estimating gross erosion rates of fine-grained and mixed fine/coarse-grained sediments and the variation of the erosion rate with depth below the sediment-water interface. The erosion data are used to predict stability for contaminated sediments, capping material, native sediment, or dredged material and are often incorporated into numerical sediment transport models. The flume is designed to erode sediment cores layer by layer. Each core layer is eroded by regulating flow over the core surface. The flume is operator-controlled, so the operator selects the range of shear stresses (starting at a low value and proceeding through higher values) for measuring erosion rate.

Universtiy of Louisiana at Lafayette Department of Civil Engineering and a recognized expert in the areas of dredging, sediment management, beneficial uses and contaminated sediment (Louisiana Sea Grant program (http://www.laseagrant.org/comm/experts/hayes.htm).

- Existing information to characterize the Hudson River Estuary within the study area, examples of which include bathymetry from the National Oceanic and Atmospheric Administration (NOAA) navigational charts, tidal data from US Geological Survey (USGS) and NOAA tide stations, USGS freshwater discharge, salinity and suspended sediment concentration data, and USGS suspended sediment concentration data.

- Results of numeric models developed by Dr. Hayes to estimate suspended sediment loadings that would result from dredging; pile driving, coffer dam installation, dewatering, and removal; and vessel movement as described below. Inputs to these models are presented below.

  - Suspended sediment generated by dredging—dredging area (up to approximately 173 acres (about 0.52 km^2, or 0.2 square miles) and volume (up to 1.37 million cubic meters, or 1.8 million cubic yards), rate of dredging [about 5,734 cubic meters (7,500 cubic yards) per dredge per 24 hour period with two dredges operating concurrently], use of environmental/closed bucket with no barge overflow and a conservative sediment loss rate of about 1 percent. This conservative loss rate, combined with the projected dredging rate and the sediment characteristics results in an average sediment resuspension rate for each dredge of 39 kilograms per minute (kg/min), and a maximum rate of 94 kg/min.
  - Suspended sediment generated by cofferdam construction and dewatering—In the absence of existing information on sediment resuspension rates associated with cofferdam construction, resuspension of sediment during installation of sheet pile for cofferdams was developed on the basis of results of suspended sediment monitoring conducted for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project during dredging and in-water construction activities. (http://biomitigation.org/bio_overview/subjects_overview.asp#water). Results of monitoring for that project indicated that installation of sheet pile for cofferdam construction resulted in average resuspension of bottom material that was about 30 percent of the average resuspension during dredging.
  - Suspended sediment generated by pile driving and dewatering—Existing information on sediment resuspension from pile driving and dewatering was similarly absent and was estimated to be approximately 40 percent of that observed during dredging on the basis of the suspended sediment monitoring for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project.
  - Suspended sediment generated by vessel movement and prop scour—As discussed previously a layer of gravel and sand would be placed at the bottom of the dredged channel to minimize sediment re-suspension. However, this layer would not prevent the resuspension of sediment that would be naturally deposited each day. Using an estimated depositional rate of sediment within the dredged channel of 104 kilograms per meter per day developed on the basis of van Rijn (1986) and total suspended sediment concentrations measured during studies conducted for the Replacement Bridge Alternative, the hourly scour rate of sediment as the vessels move along the channel was estimated as 8.7 kg per meter per hour (kg/m/hr).

As indicated in the construction timeline presented in **Figure 7**, 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 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.

6.2.1.1. Sediment Resuspension and Transport

The Long Span Option would have fewer total number of piers than the Short Span Option (see **Figures 12** and **13**), 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 12** and **13** 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 12** and **13**) 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 25** through **28** 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[2] 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 305 to 610 m (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 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

2 A mixing zone is an area in a water body within which the NYSDEC will accept temporary exceedances of water quality standards resulting from short-term disruptions to the water body caused by dredging or the management of dredged material. A mixing zone can be assigned at the site of dredging (NYSDEC 2004).

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[3] 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 25** and **27**).

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.

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3 The turbidity standard for Class SB waters is “No increase that will cause a substantial visible contrast to natural conditions.”

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 modest 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 be expected to result in any adverse effect to shortnose or Atlantic sturgeon in the Hudson River, which are extremely tolerant of elevated levels of suspended solids.

6.2.1.2. Sediment Quality

The results of sediment quality analyses are summarized in Tables 8, 9 and 10, and identify the samples classified as Class B (moderate contamination) or Class C (high contamination) for metals (see **Table 8**), SVOCs (see **Table 9**), and pesticides, PCBs, and dioxins (see **Table 10**) in accordance with NYSDEC's In-Water and Riparian Management of Sediment and Dredged Material (NYSDEC 2004). Contaminants observed that were classified as Class B or Class C included Total PCBs, Total PAH, mercury, dioxin/furan TEQ, Total DDT, DDD and DDE, arsenic, copper, and cadmium.While there are some locations for which certain contaminants fall under the Class B or Class C category, these concentrations typically apply to only the upper few feet and the concentrations of these contaminants decline to those meeting Class A (no appreciable contamination) category 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 between August 1 and November 1, 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 effects to sturgeon that may come into contact with the plume.

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.

Table 8
Results of Sediment Quality Analysis – 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 9
Results of Sediment Quality Analysis – SVOCs

Parameter	Sediment Criteria ERL[1] (µg/kg)	Sediment Criteria ERM[1] (µg/kg)	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)
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 10
Results of Sediment Quality Analysis – Pesticides, PCBs, and Dioxins

Parameter	Sediment Criteria					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)
	ERL[1] (µg/kg)	ERM[1] (µg/kg)	BA- Chronic[1] (µg/gOC)	BA- Acute[1] (µg/gOC)	WA[1] (µg/gOC)								
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).

6.2.2. Effects of 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), 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 (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.

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. Any effects to shortnose sturgeon due to increased water column suspended sediments from bridge demolition activities are expected to be minimal and would not be expected to materially affect shortnose sturgeon feeding opportunities or migrations.

6.2.3. Altered Predator-Prey Relationships

Shortnose and Atlantic sturgeon are benthic predators that forage in the substrate and consume primarily crustaceans, insects, mollusks and polychaete worms (Scott and Crossman 1973, Dadswell 1979, Pottle and Dadswell 1982, Dadswell et al. 1984, Bain 1994, Bain 1997, Bain 2001). Foraging habitat for both sturgeon species in the Hudson River is characterized by deep water and fine, silty sediments (Haley et al. 1996, Bain et al. 2000, Bain 2001) although shortnose sturgeon also feed in shallow areas and along river banks in water 1-5 meters deep, but concentrate in deeper water during late summer (Dovel 1978, Dadswell et al. 1984) where they remain during the winter months (Bain 1997). Within the study area, fine clayey silt substrates are common (**Figure 5**), but deep-water habitat is limited to the channel along the eastern shoreline. Despite the prevalence of fine sediment in the study area though, the primary sturgeon foraging habitat is located well upstream of the Tappan Zee region (Haley et al. 1996, Bain et al. 2000, Bain 2001). For sturgeon that forage within the study area, the most likely potential impacts of the Project are related to dredging of benthic feeding areas and habitat exclusion caused by pile-driving noise.

The dredging and armoring of the 165 to 175 acre (0.67 to 0.71 km2) access channel will create an area of reduced foraging opportunities for shortnose and Atlantic sturgeon during the construction period. However, the dredged area represents a comparatively small percentage of the available benthic area within the Tappan Zee region (1.2%) as defined by the Hudson River Utilities (RM 24-33), and an even smaller percentage of river-wide benthic area (0.2%). Because both sturgeon species typically forage at depths exceeding those in the proposed dredged location, this relatively shallow area is not likely to be preferred foraging habitat prior to dredging. Following dredging, water depths would still be relatively shallow at 4.3 m (14 feet) and the coarse gravel substrate used to armor the channel bottom would not likely support the preferred prey items of sturgeon. Benthic habitat outside of the dredged area would not be expected to change in terms of sediment grain size or forage opportunities for sturgeon.

Temporary habitat exclusion caused by pile driving noise is expected to create an ensonified zone that could be unavailable for foraging during certain periods of the day; however these periods would be limited to less than 12 hours daily during most pile driving, and less than 5 hours a day during the the time period when large piles are driven. Although noise levels in these areas may restrict diurnal foraging opportunities during pile driving, both species of sturgeon are known to forage nocturnally and would still be able to use the ensonified area during the night. There would also be considerable foraging habitat available within the study area and outside of the dredged channel and the ensonified area. Shortnose sturgeon, in particular, are known to travel up to 13.5 km (8.4 miles) within a day (McCleave et al. 1977), which means that construction activities would not prevent foraging as sturgeon could move through the study area to unimpacted foraging areas. The preferred foraging habitat in deep waters, specifically in the navigation channel, would remain available for foraging throughout the large majority of bridge construction based on the location and extent of modeled noise isopleths.

Atlantic sturgeon are less likely than shortnose sturgeon to be affected by potential loss of foraging habitat because their use the Hudson River is more intermittent. Adult females migrate directly to spawning grounds, which are deep, channel or off-channel habitats (Dovel and Berggren 1983) in the freshwater portions of the River, upstream of the study area (K. Hattala, pers. comm.). During the upstream spawning migration, females are thought to fast (Dadswell 1979, Smith 1985). Post-spawn Atlantic sturgeon remain in fresh water habitats upstream of the study area until emigration to coastal marine waters (Smith 1985). Furthermore, Atlantic sturgeon typically remain in water deeper than 7.5 meters (Bain et al. 2000). Therefore, use of the Tappan Zee region for foraging by Atlantic sturgeon adults is likely minimal and loss of benthic habitat due to dredging of the construction channel or from pile-driving noise is not likely to impact adult Atlantic sturgeon. Juvenile Atlantic sturgeon remain in the Hudson River for several years and are found primarily upstream of the study area between river kilometers 68 and 107 (RM 42 to 67) and in water depths from 10-25 meters (Bain et al. 2000), except from November through March when they occupy deep, channel habitats between km 19 to 74 (RM 12 to 45), which includes the study area (Dovel and Berggren 1983).

Several project-related factors reduce the likelihood of impacting sturgeon foraging in the study area, including the restricted schedule for pile driving and the relatively small area of unavailable foraging habitat within the 187 dB SEL_{cum} noise isopleths as well as the shallow depth and small spatial extent of the dredged access channel. These factors, coupled with the spatial distribution of juvenile and adult sturgeon and their primary foraging habitats within the Hudson River relative to the study area (i.e. primarily deep water and upstream) as well as the intermittent occupancy of the Hudson River by adult Atlantic sturgeon make it unlikely that any long-term indirect effects on sturgeon foraging would be realized as a result of the project's construction.

6.2.4. Long-Term Habitat Alteration

The area where the Replacement Bridge Alternative will be constructed is neither shortnose nor Atlantic sturgeon spawning habitat. Both these species spawn well north of the Tappan Zee Bridge with the principal spawning area for the shortnose being as far north as Albany. However, dredging of the access channel will result in a temporary modification of benthic habitat. Over time deposition processes would allow much of the benthic habitat to return to its pre-construction state. The rate of this transformation would begin at approximately 1 foot per year, likely decreasing as the bed nears it natural pre-dredged elevation. The temporary loss of the access channel area would represent a minor fraction of similar habitat available to sturgeon throughout the Tappan Zee Reach. Except for the permanent loss of up to 0.05 km^2 (13 acres) of oyster habitat, which would not be considered optimal shortnose sturgeon foraging habitat, a long-term habitat alteration would not occur.

6.3. Cumulative Effects

The assessment of cumulative effects addresses the potential impacts from the project and other projects proposed within, or in the vicinity of, the study area that may affect shortnose and Atlantic sturgeon. 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. 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). Within the study area, the proposed cable project would not have the potential to affect shortnose or Atlantic sturgeon spawning habitat.

Cumulative adverse impacts to shortnose and Atlantic sturgeon are not expected as a result of the cable project and maintenance dredging activities with the Replacement Bridge Alternative although project details would need to be forthcoming and potential impacts more rigorously evaluated by regulatory agencies. Collectively, these projects would not have the potential to affect spawning habitat within the study area. 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 shortnose sturgeon foraging or migration through the study area for either sturgeon species. 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 construction of the cable project and the Tappan Zee Hudson River Crossing Project.

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 Historic Area Remediation Site (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.

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 shortnose sturgeon, Atlantic sturgeon, or other anadromous fish species.

Chapter 7 Effect Determinations

7.1. Effect Determination for Listed and Proposed Species

The results of this BA indicate that:

1. For individual shortnose and Atlantic sturgeon within the immediate vicinity of pile driving and other in-water construction activities, there is a potential for injury.

2. Pile driving and dredging would have minimal effects to sturgeon migratory activities as there will always be large portions of the river width that will not be ensonified, and dredging will be limited to three month windows that will take place between August 1 and November 1 during three of the 4 ½ or 5 ½ construction years.

3. There is no designated critical habitat for shortnose sturgeon and none is proposed for Atlantic sturgeon.

4. Dredging of 0.67-0.71 km^2 (165-175 acres) for access channels will create an area of reduced foraging opportunities for both shortnose and Atlantic sturgeon due to loss of 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 condition. 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.

5. Incidental vessel strikes will be insignificant because sturgeon are generally found within one meter of the bottom in the deepest available water. Based on the types of vessels to be employed and their drafts, there should always be sufficient clearance between vessels and the river bottom.

6. Indirect effects from resuspended sediments are expected to be insignificant.

7. A review of the literature suggests that the likelihood of the project to affect the four other DPS of Atlantic sturgeon in any meaningful way is low.

The BA concludes that while the Replacement Bridge Alternative may potentially injure individual shortnose and/or Atlantic sturgeon in the immediate vicinity of the pile driving resulting in an incidental take, and dredging and armoring of the bottom will result in a temporary reduction in foraging opportunities, the project will not jeopardize the continued existence of the shortnose or Atlantic sturgeon populations of the Hudson River.

Based on the fact that marine mammals are rare, transients to the study area, the proposed project will not jeopardize the continued existence of the marine mammal species that have been reported in the Tappan Zee reach of the Hudson River.

There is a possibility that the Historic Area Remediation Site (HARS) will be used for the disposal of the project's dredged material. 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 effects threatened or endangered species, also including marine mammals.

7.2. Effect Determination for Critical Habitat

There is no designated critical habitat for the shortnose sturgeon and no critical habitat has been proposed for Atlantic sturgeon at this time. As a consequence, there will be no effect on critical habitat.

7.3. Overall Effect Determination

Overall project effects are summarized bekiw. **Table 11** that lists affected species and major project elements, and the effect determinations associated with each.

Table 11
Overall Project Effects

Jurisdiction	Federal Status	Common Name	Effect Determination for Pile Driving	Effect Determination for Permanent Loss of Habitat Due to Dredging	Effect Determination for Vessel Traffic	Effect Determination for Sediment Resuspension	Overall Effect Determination for Project
NMFS	Endangered	Shortnose Sturgeon	Likely to adversely affect	No effect	No effect	No effect	Likely to adversely affect
NMFS	Proposed for Listing	Atlantic Sturgeon	Likely to adversely affect	No effect	No effect	No effect	Likely to adversely affect
NMFS	Various	Marine Mammals	No effect	No effect	No effect	No effect	No effect

7.3.1 Reasonable and Prudent Measures to Minimize Take

As outlined previously, every effort will be made to ensure that the potential for incidental take of Atlantic and shortnose sturgeon is minimized by observing a number of environmental commitments and assurances. Briefly, these include: 1) pilot testing of various noise abatement and sediment containment measures during the PIDP, 2) reduction of noise impacts through the implementation of BMPs and by limiting the duration of pile-driving activities with impact hammers, particularly during biologically significant time periods (e.g., spawning migrations), 3) use of vibratory hammers to the fullest extent possible, 4) maintenance of a minimum 5,000-ft corridor of passage outside of the ensonified area to allow fish migration through the study area, 4) minimization of suspended sediments using cofferdams and silt curtains, 5) monitoring of water quality, noise and sturgeon during pile-driving to ensure re-consultation with NMFS if an incidental take is observed and, 6) limiting dredging to a three-month period from August 1 to November 1 for the three years of the construction period in which dredging would occur,

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Proposed Ecological Investigations within the Hudson River and along the I-287 Corridor, March 10, 2006

Letter from Julie Crocker to Melissa Toni August 24, 2010

Figures

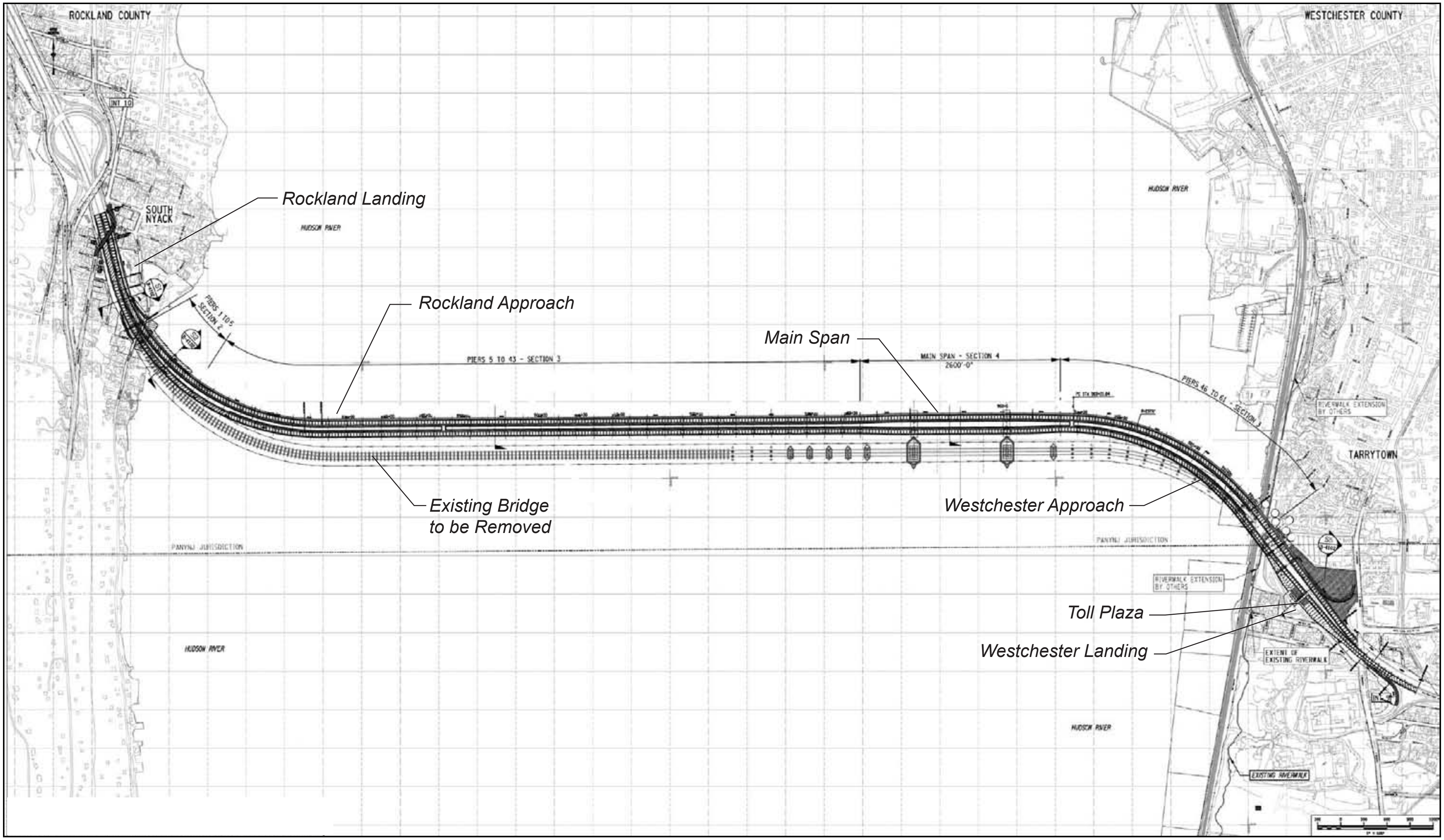
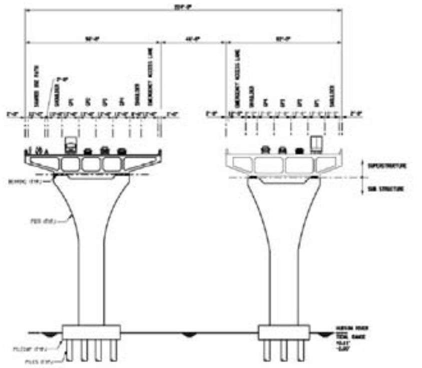


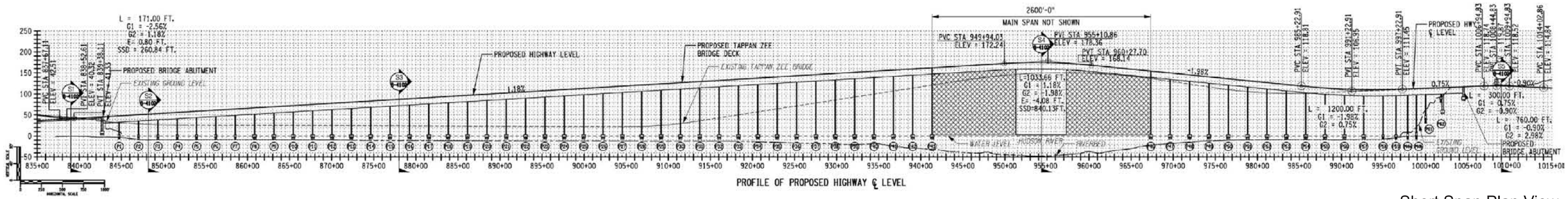
Figure 1

Approach Spans, Main Span, and Ancillary Facilities of the Replacement Bridge Alternative

Short Span Option

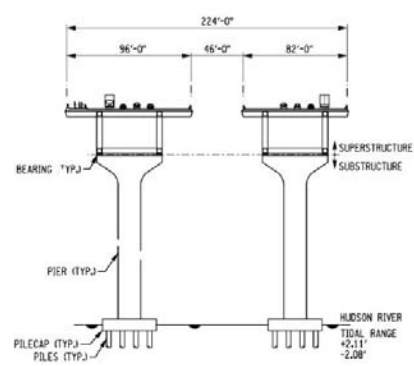


Short Span Cross-Section



Short Span Plan View

Long Span Option



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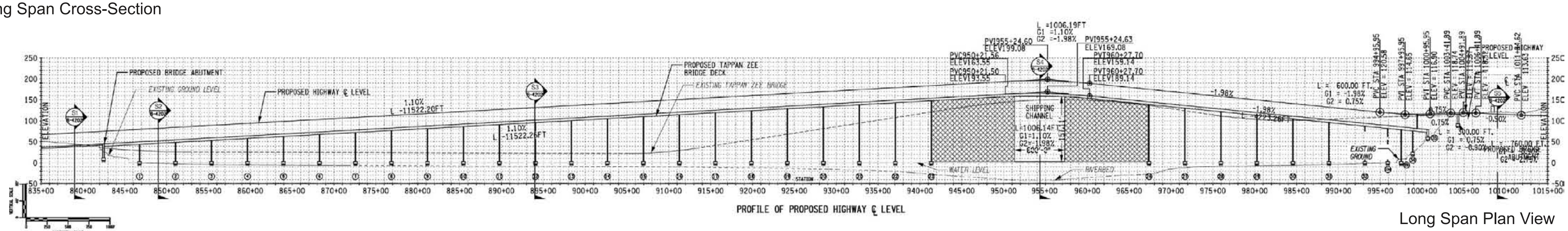


Long Span Plan View

Figure 2

Plan View of Short Span and Long Span Options

Example of Cable-Stayed Option (Oresund Bridge, Denmark/Sweden)

Example of Arch Option (Rendering)

Figure 3

Examples of Cable-Stayed and Arch Bridge Designs

1.4.12

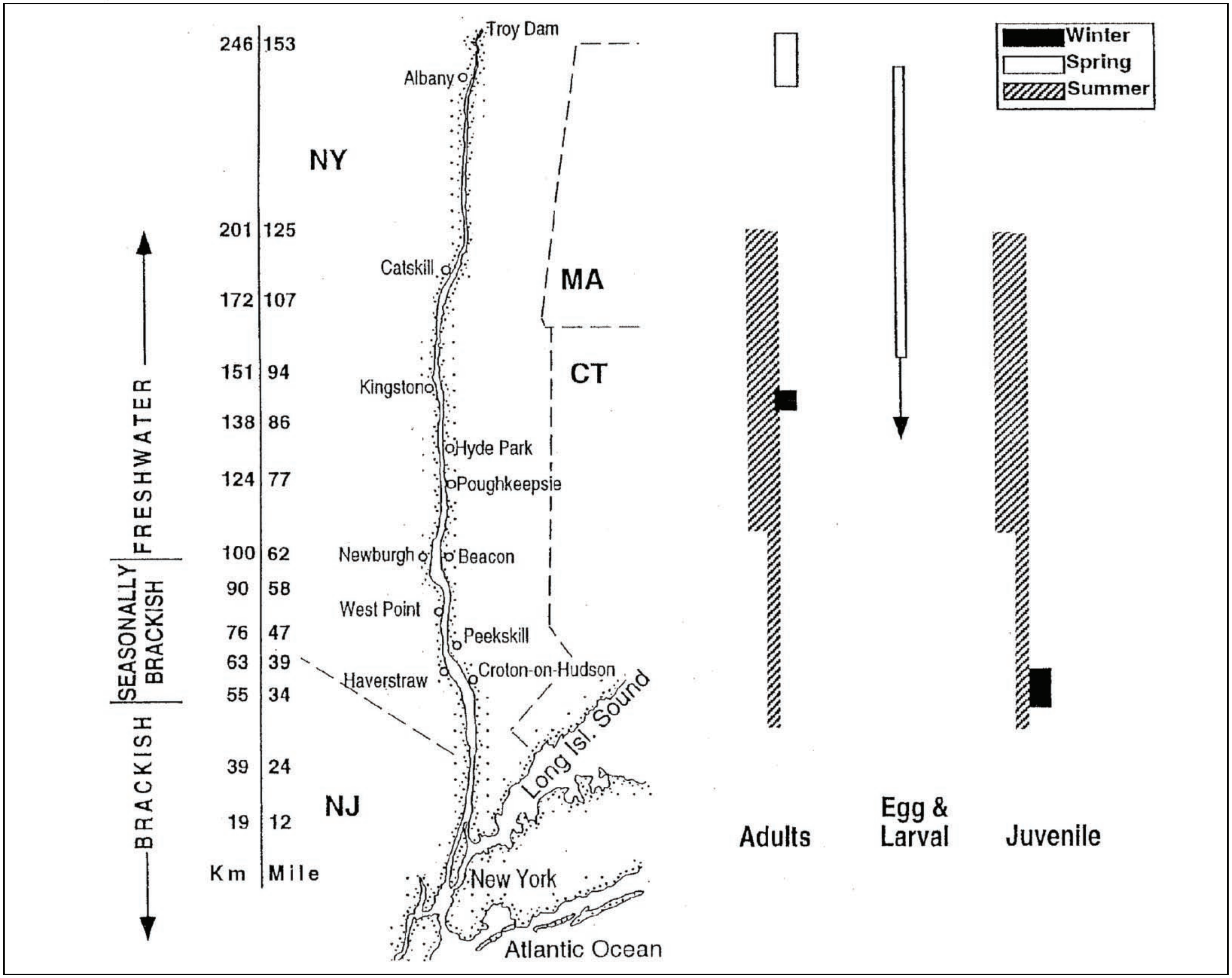


Figure 4

Distribution and Life History Pattern of Shortnose Sturgeon in the Hudson River Estuary by Major Life Stage and Season

Figure 5
Sediment Texture

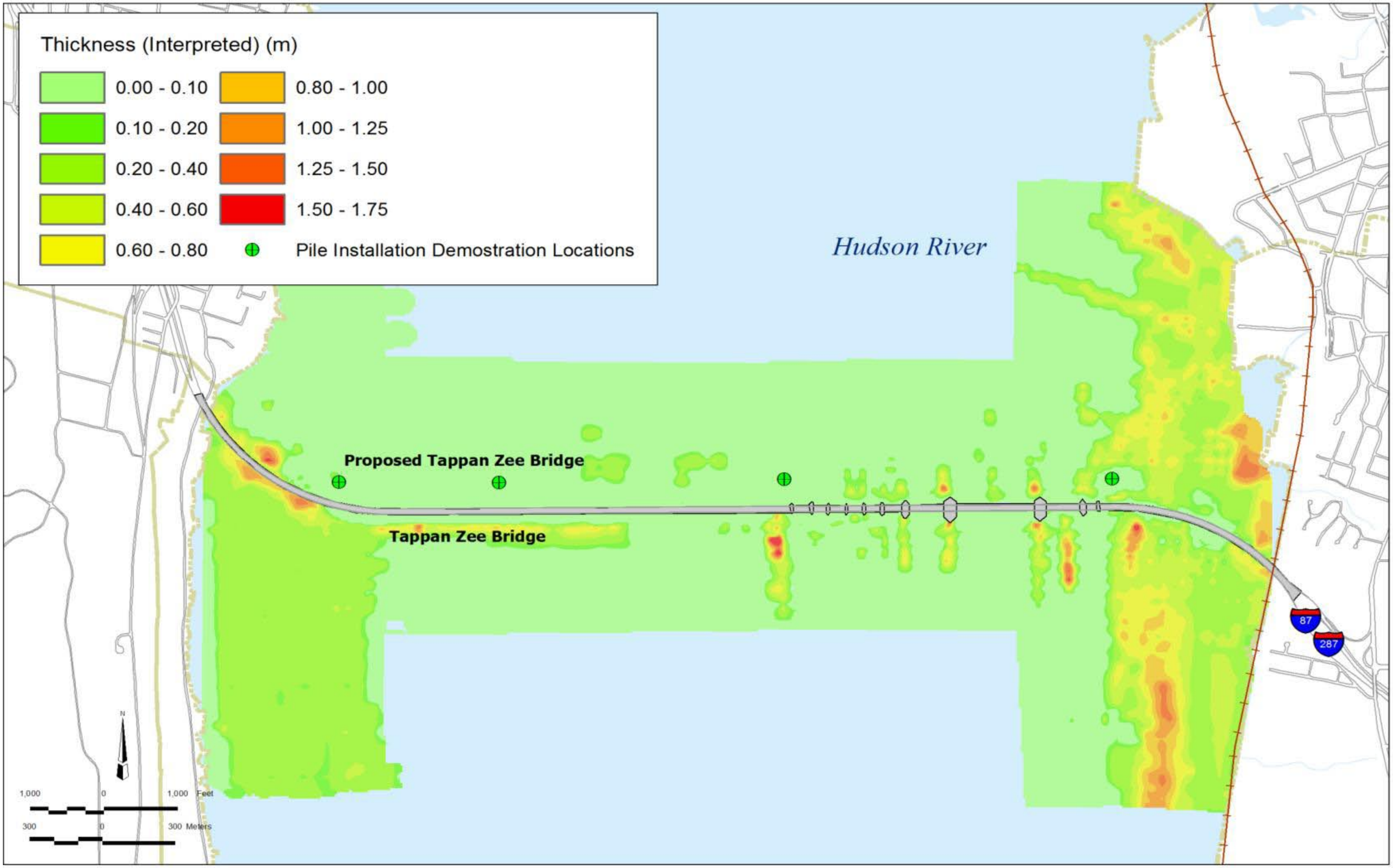


Figure 6
Recent Sediment Deposit Thickness

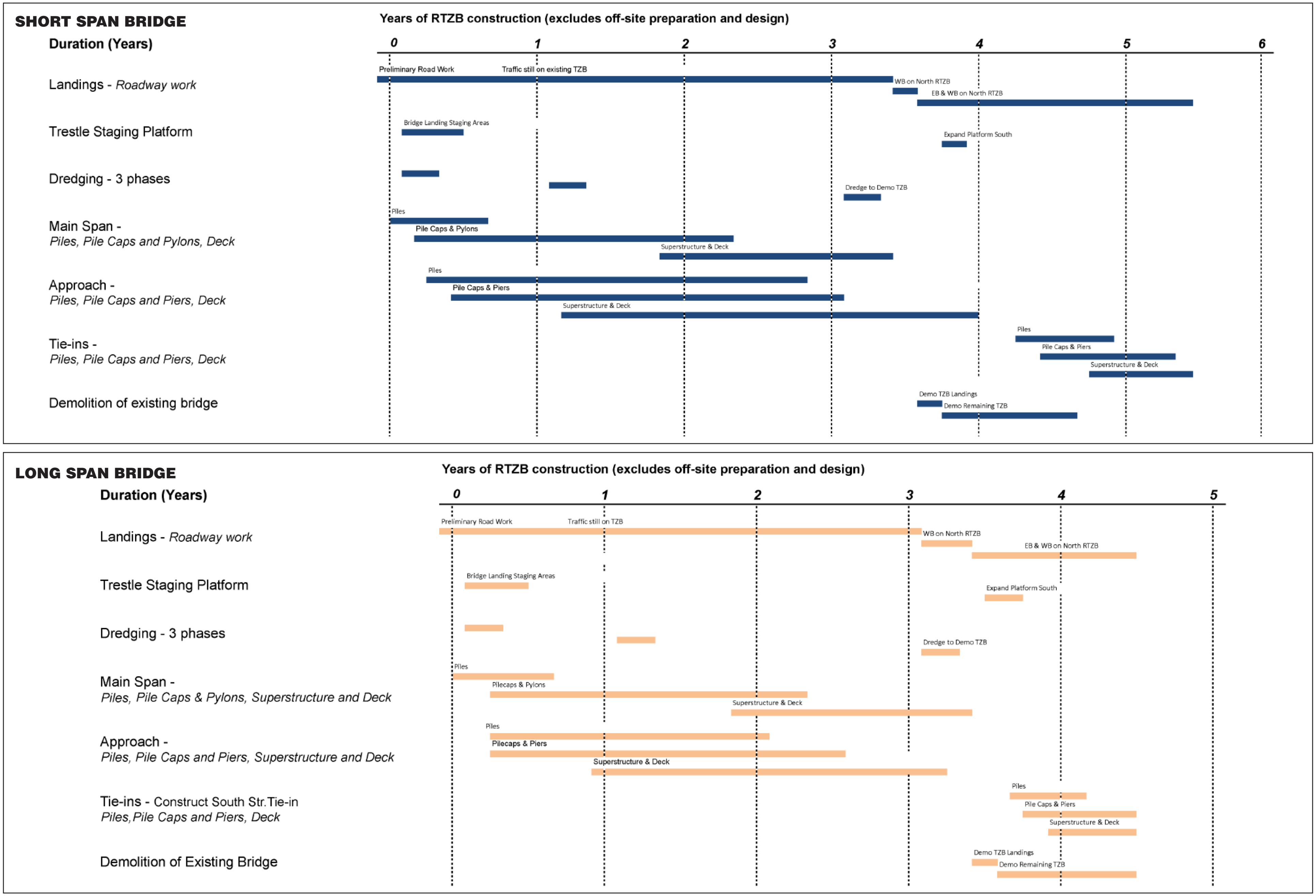


Figure 7

Construction Schedules for Short Span and Long Span Option

Construction Truck Routes

Potential Temporary Staging Areas

0 1/2 MILE
SCALE

Figure 8
Potential Upland Staging Areas

1.4.12

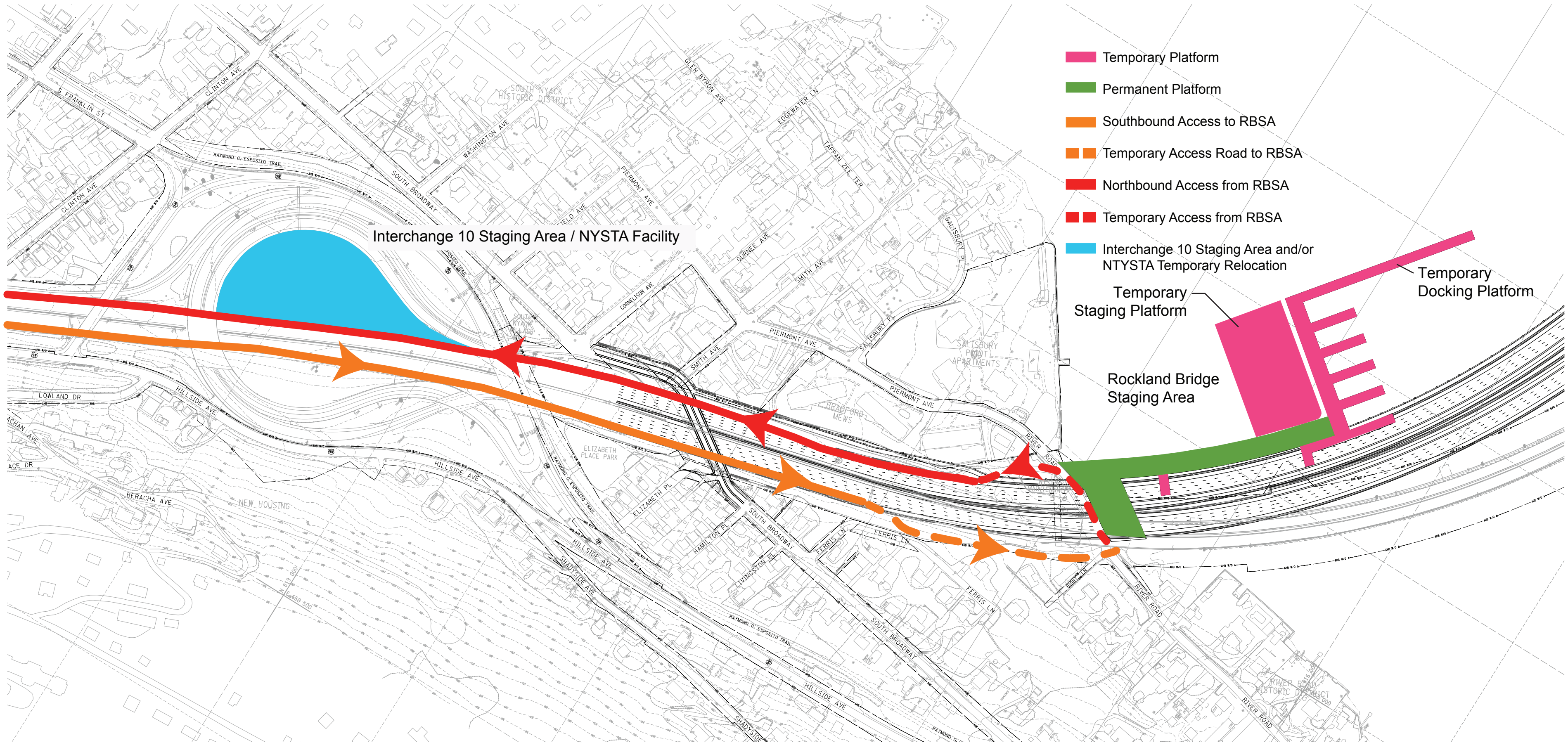


Figure 9
Rockland Landing Construction Access

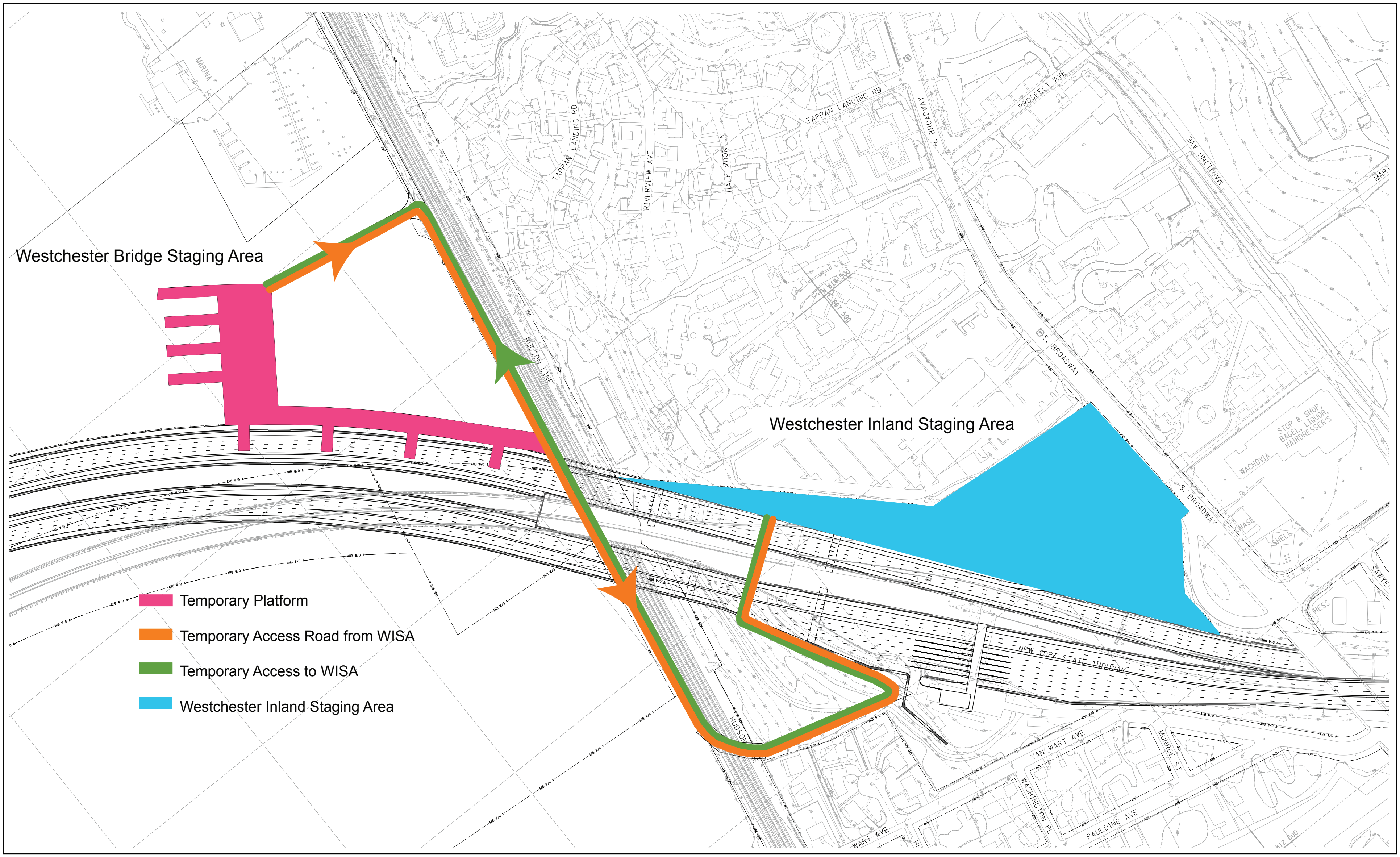
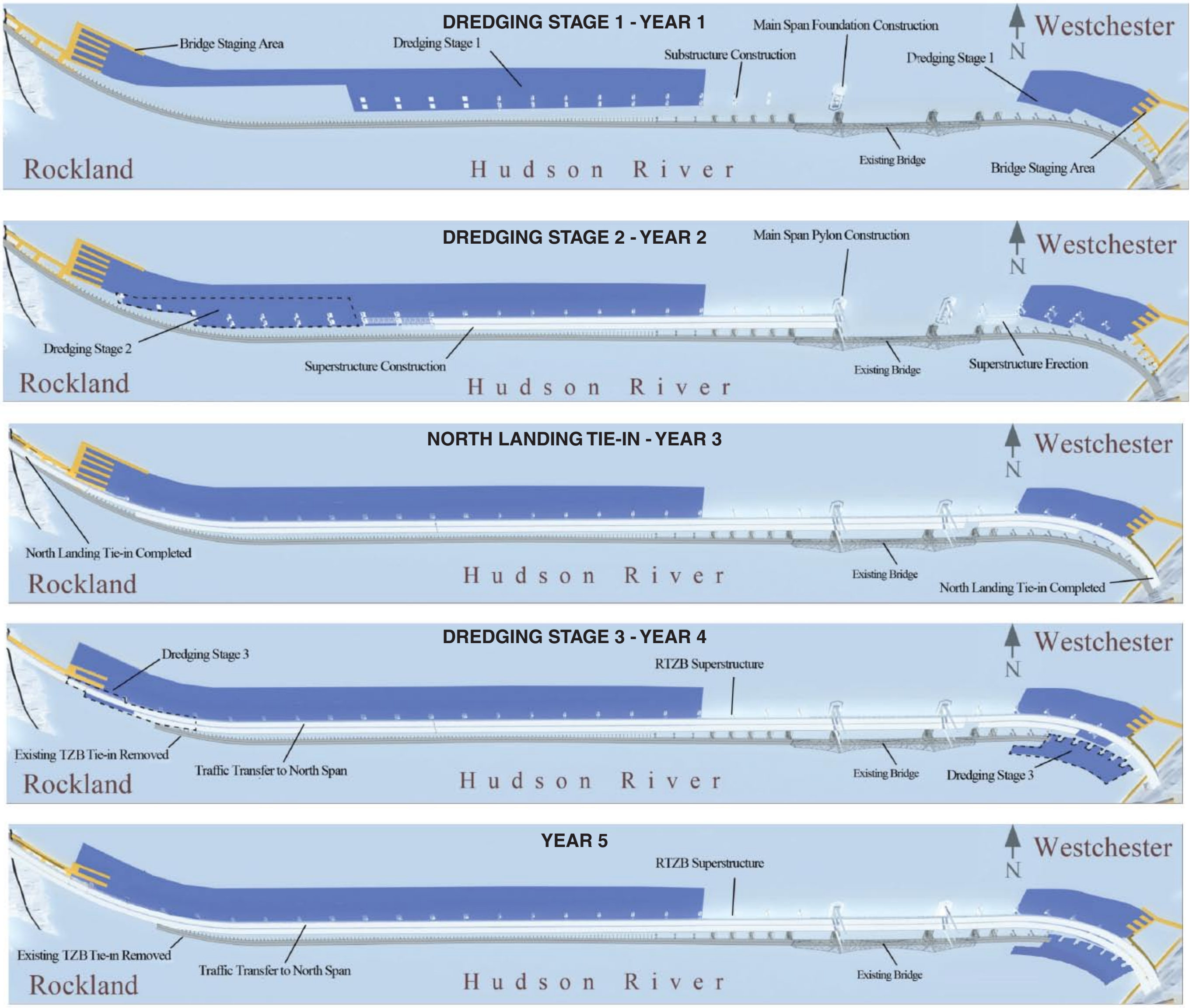


Figure 10
Westchester Landing Construction Access



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

Figure 11
Dredging Sequence, Years 1 to 5

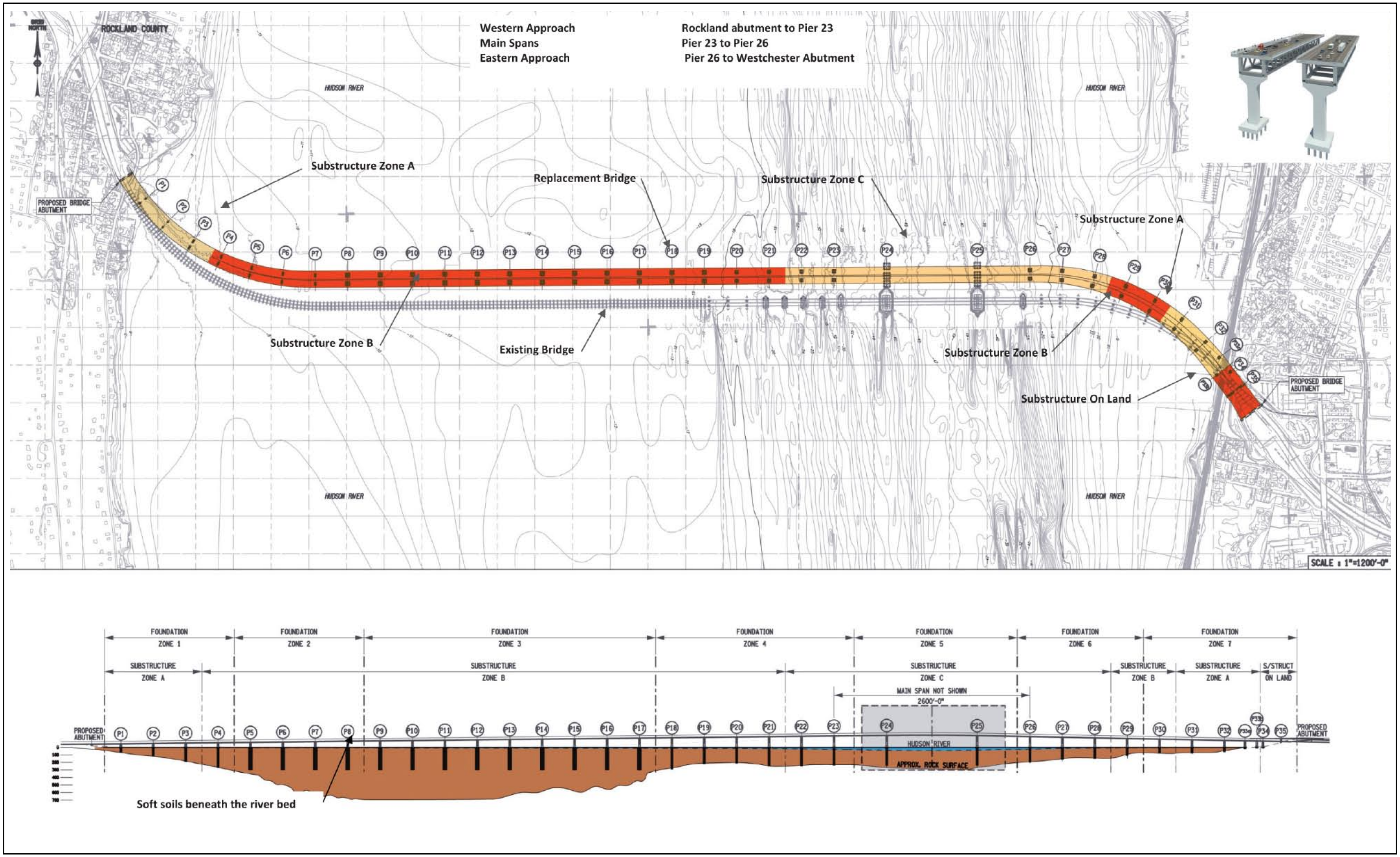


Figure 12

Construction Zones for Long Span Option

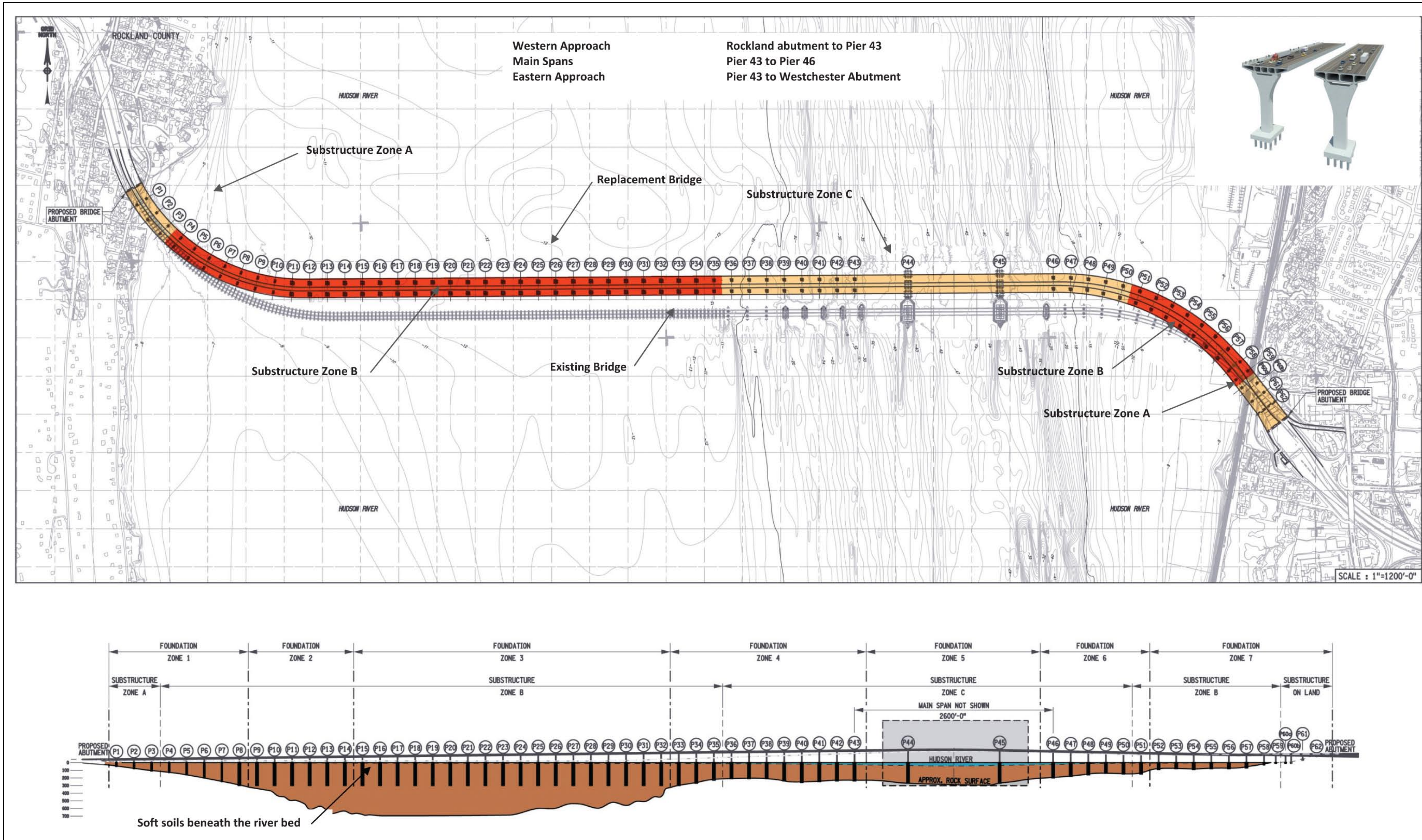


Figure 13
Construction Zones for Short Span Option

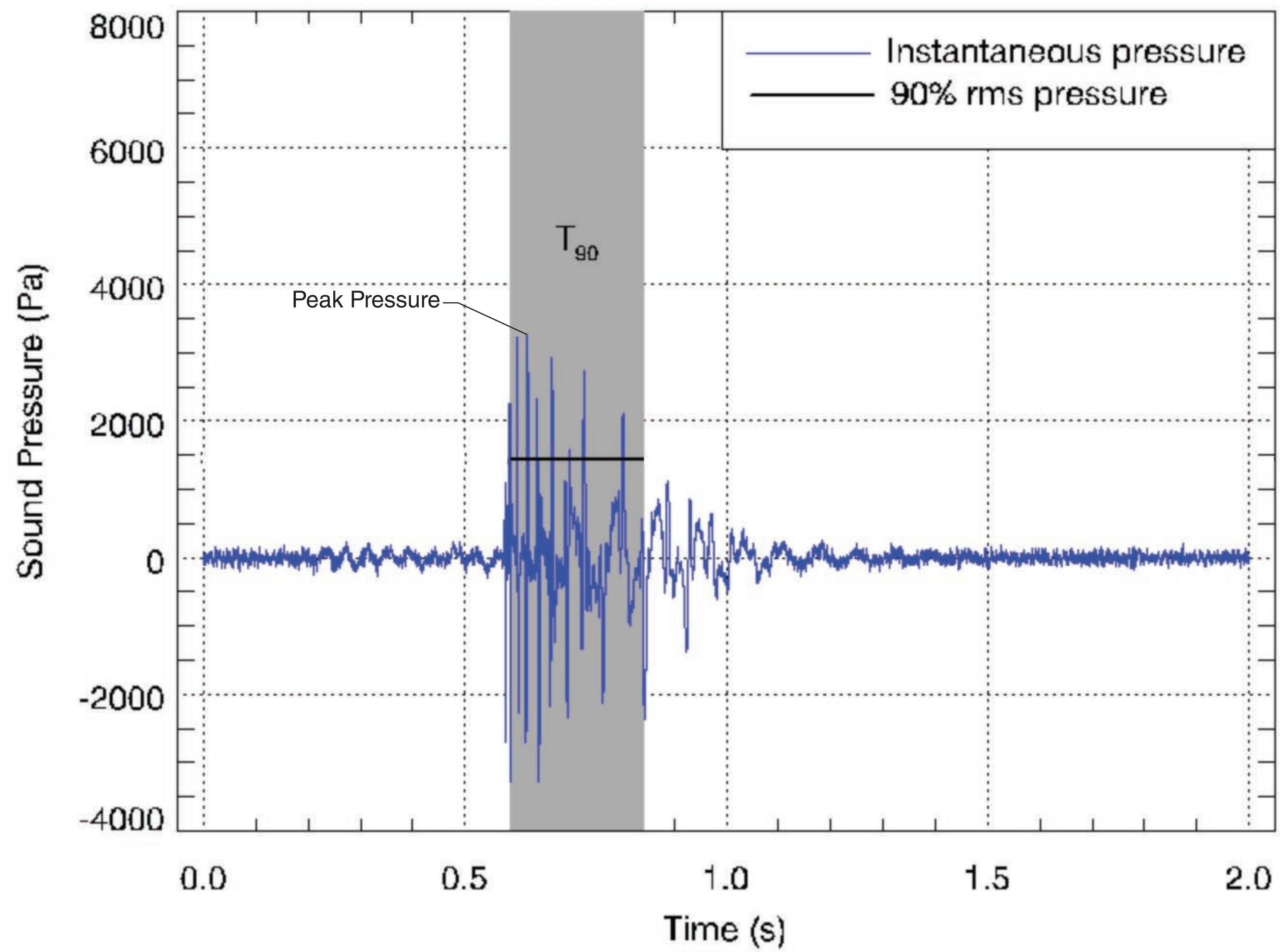


Figure 14
The Sounds of a Single Pile Driving Strike

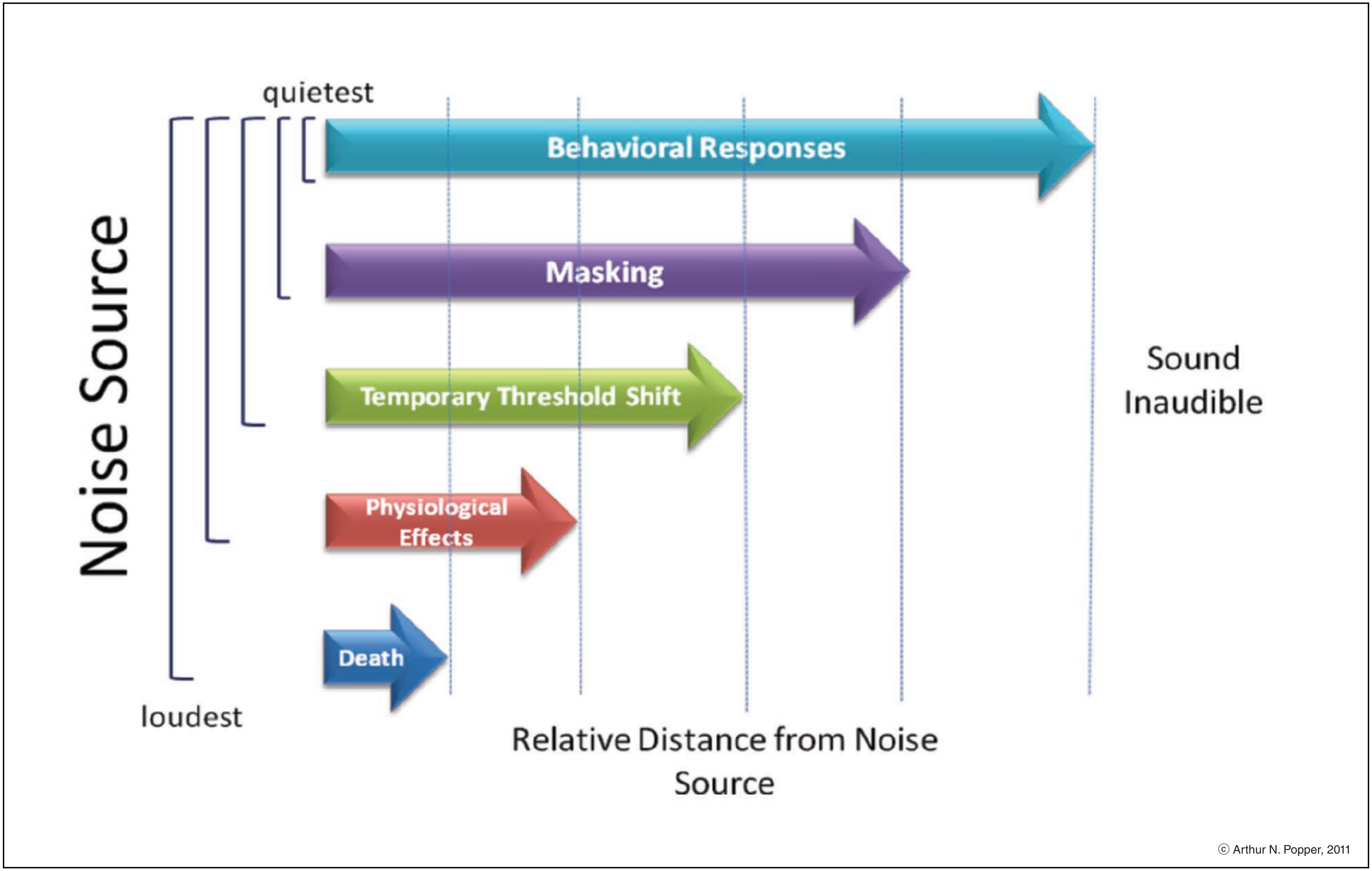


Figure 15

Relationship Between Noise Levels, Distance, and Potential Effects

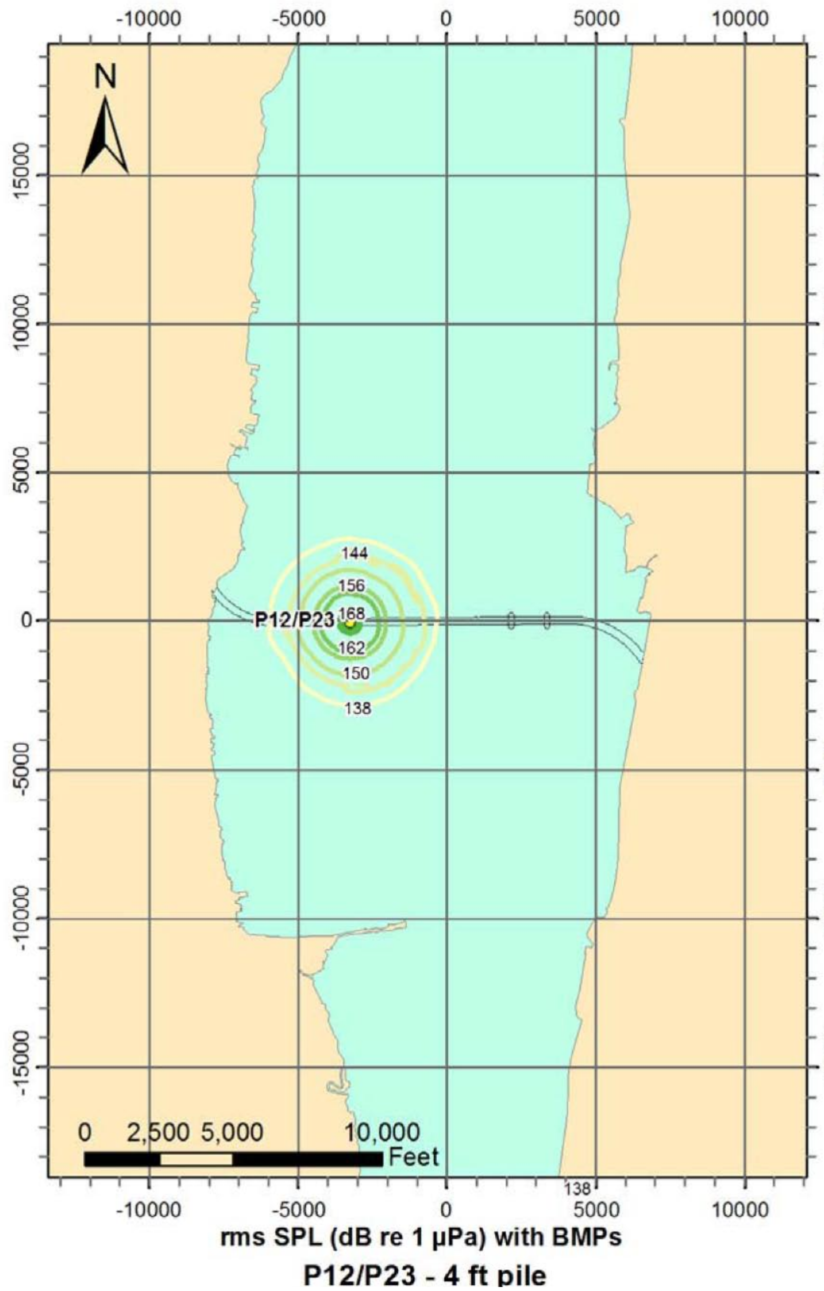


Figure 16

Isopleths for Root Mean Square (rms) Sound Pressure Level from Pile Driving for 4-foot Diameter Piles (with 10dB Reduction from BMPs)

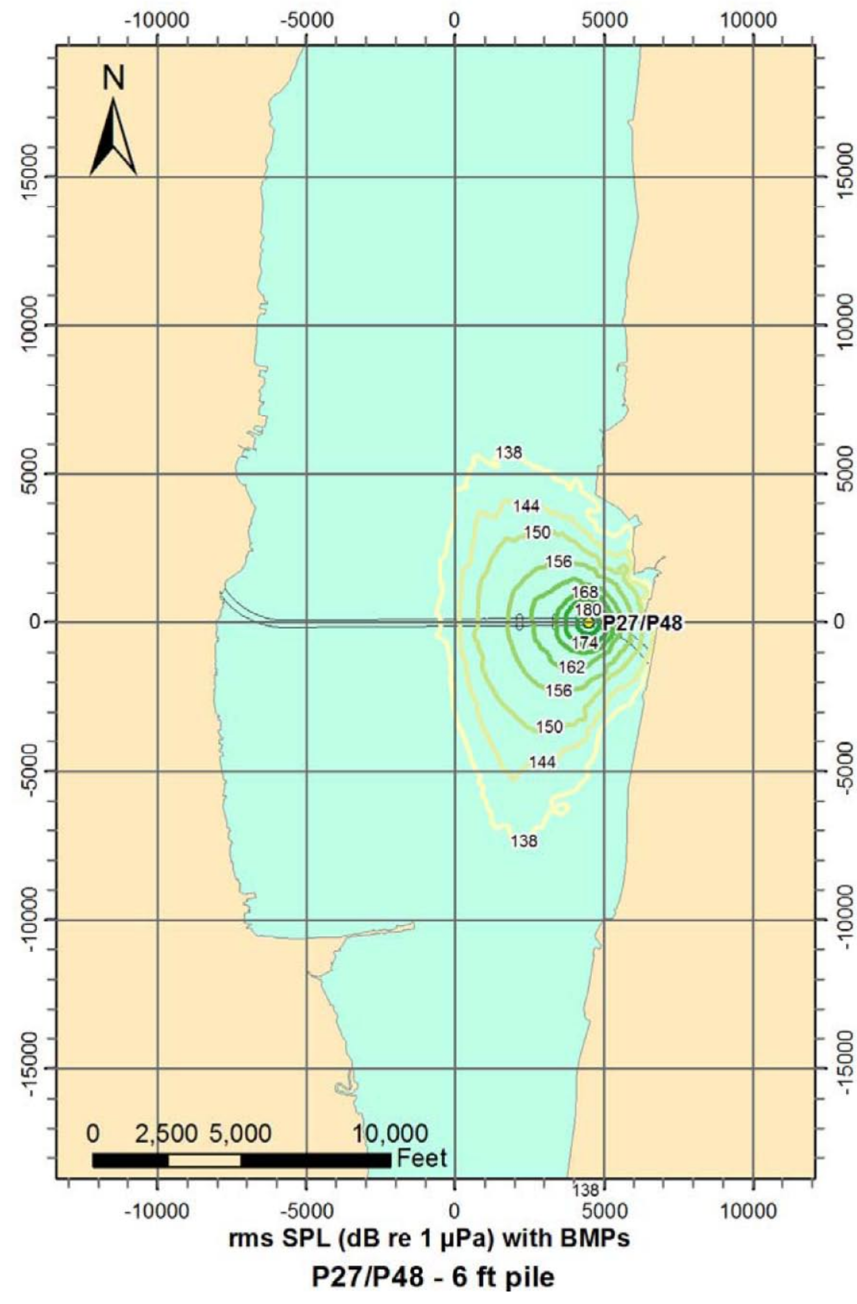


Figure 17

Isopleths for Root Mean Square (rms) Sound Pressure Level from Pile Driving for 6-foot Diameter Piles (with 10dB Reduction from BMPs)

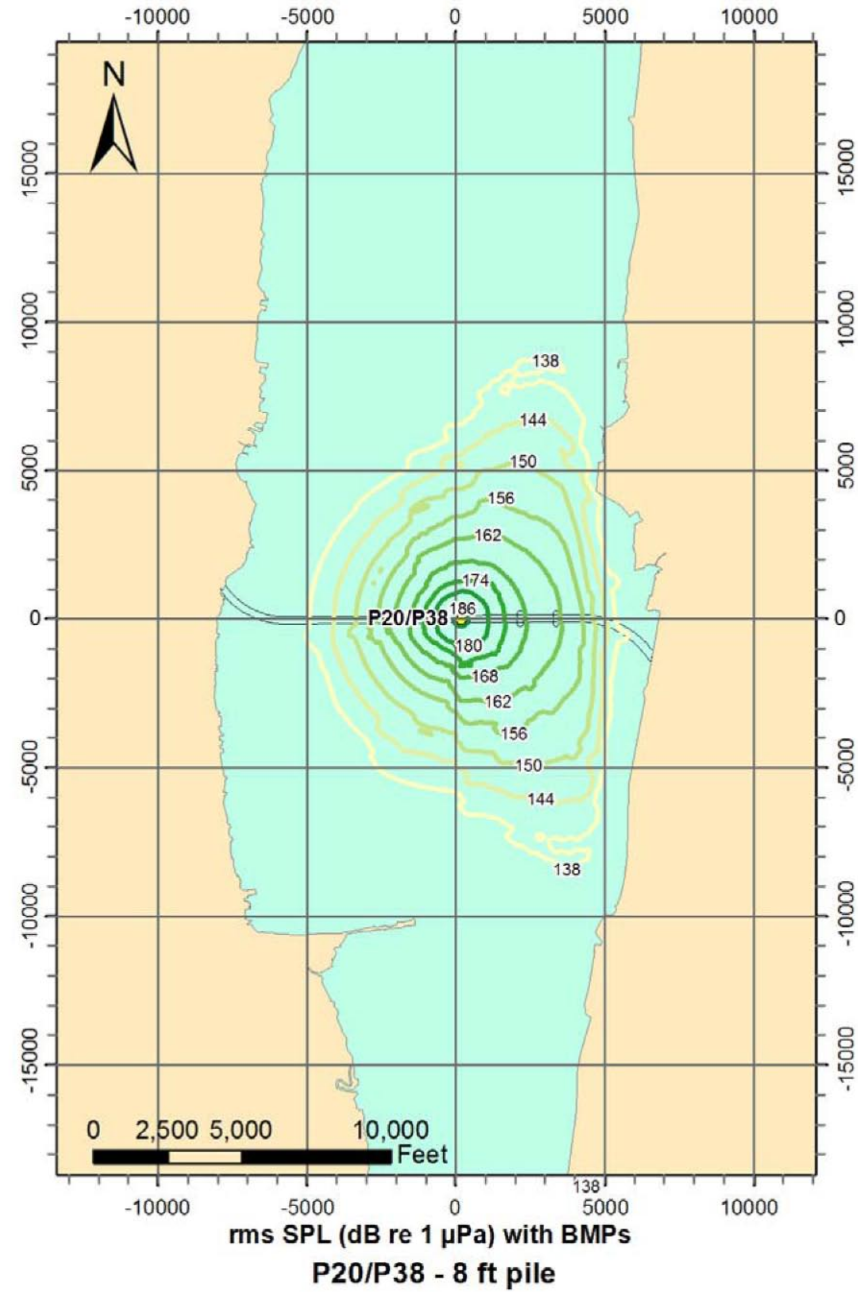


Figure 18

Isopleths for Root Mean Square (rms) Sound Pressure Level from Pile Driving for 8-foot Diameter Piles (with 10dB Reduction from BMPs)

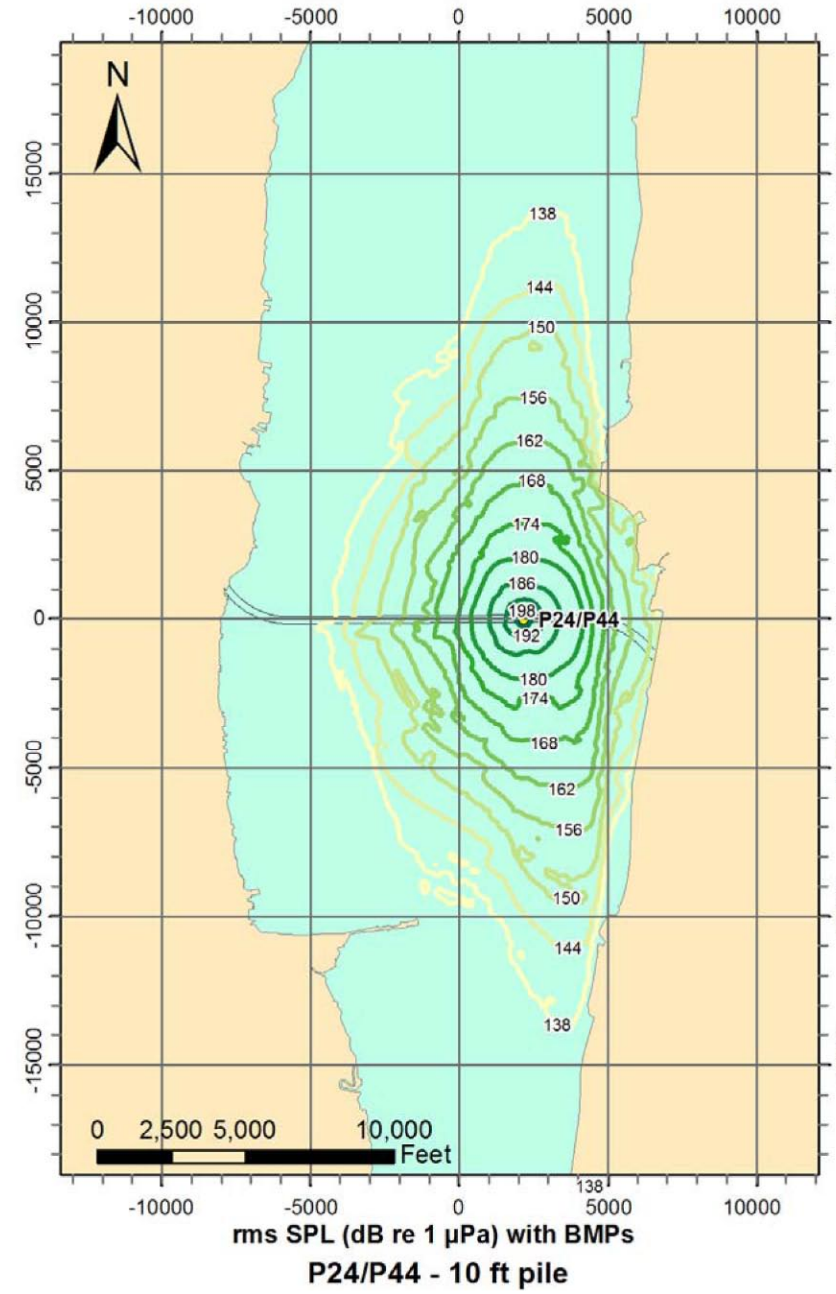


Figure 19

Isopleths for Root Mean Square (rms) Sound Pressure Level from Pile Driving for 10-foot Diameter Piles (with 10dB Reduction from BMPs)

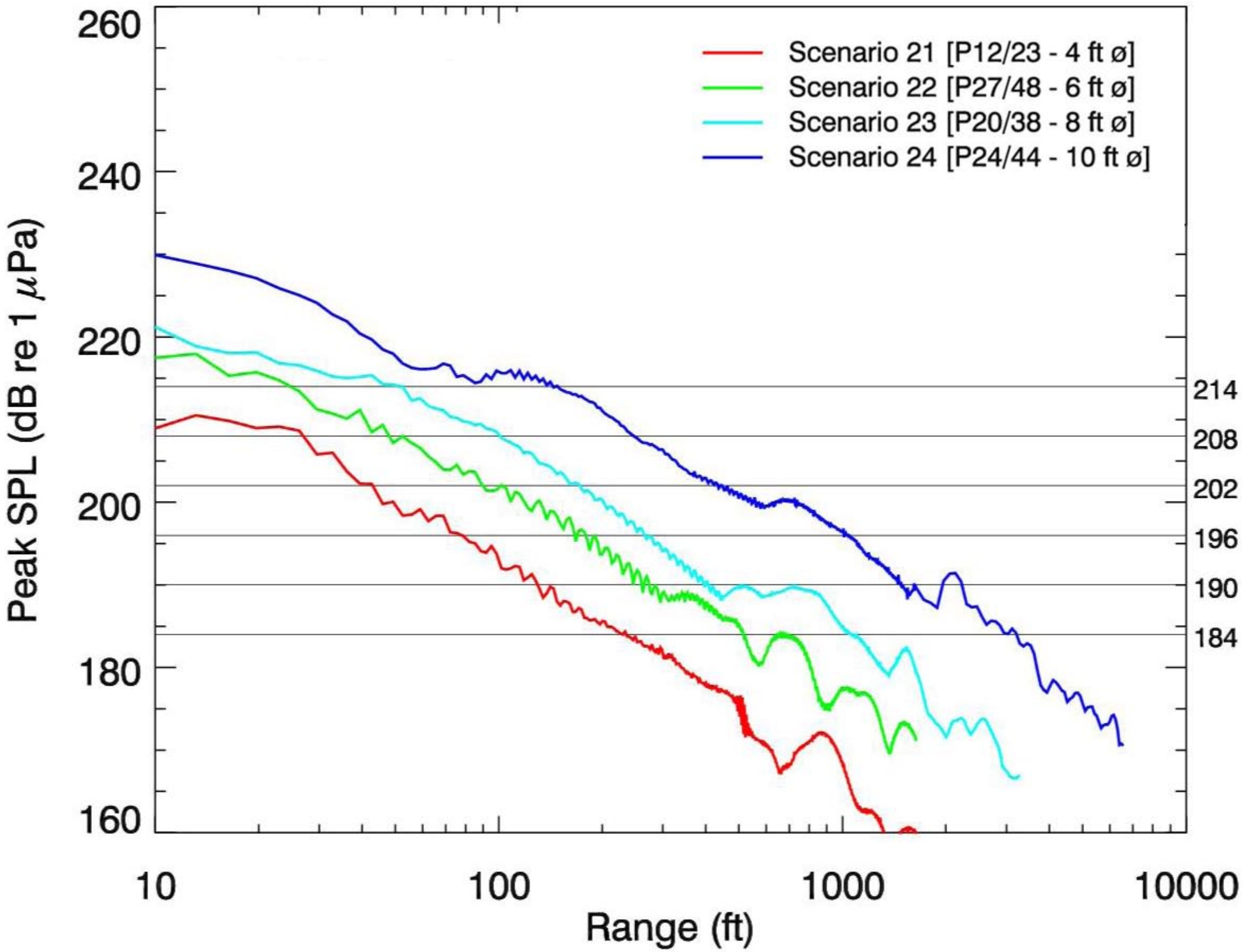


Figure 20

Attenuation of Peak Sound Pressure Level with 10dB Reduction from BMPs as a Function of Distance from Pile Driving for 4-, 6-, 8-, and 10-foot Diameter Piles

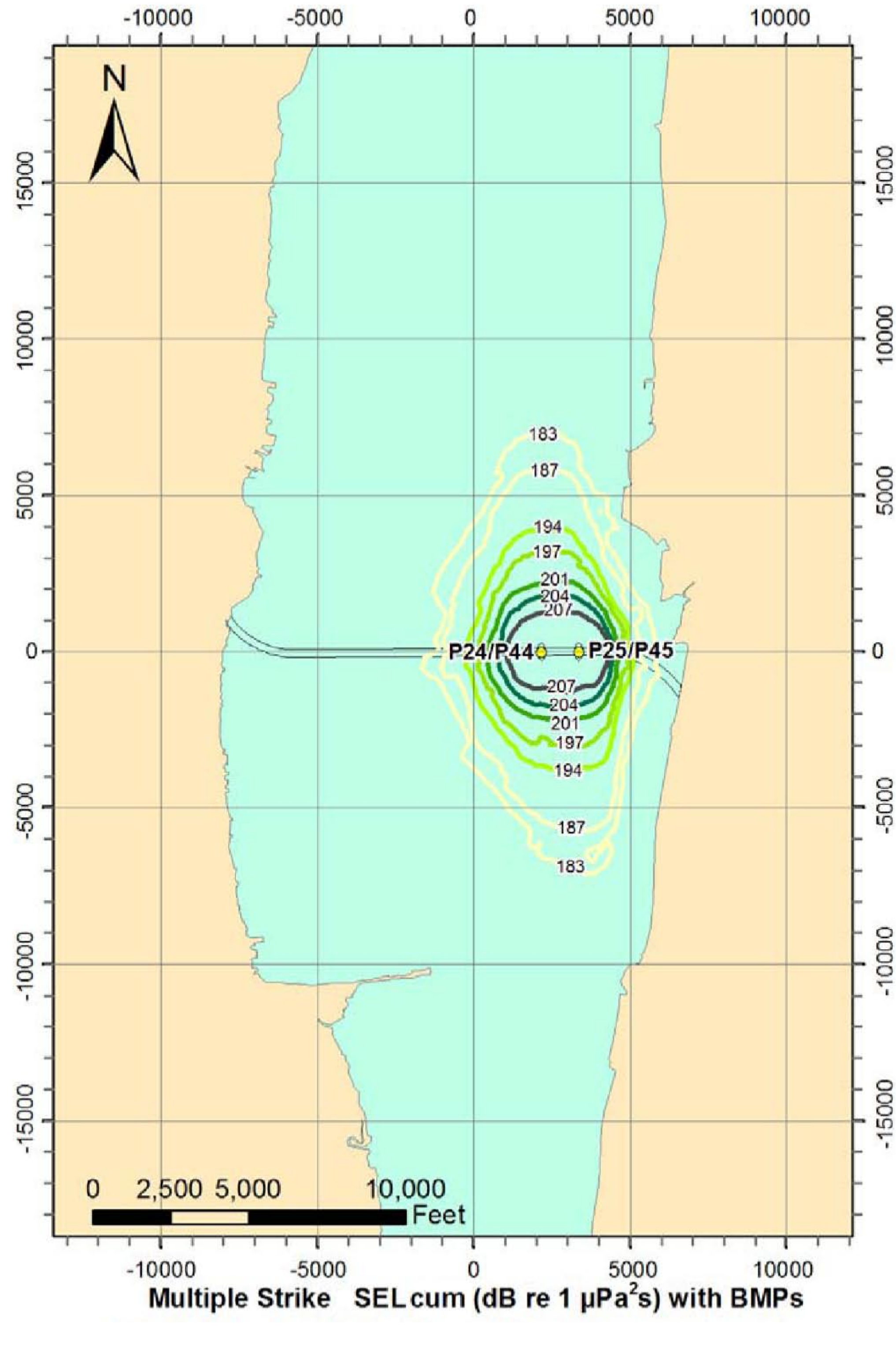


Figure 21

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

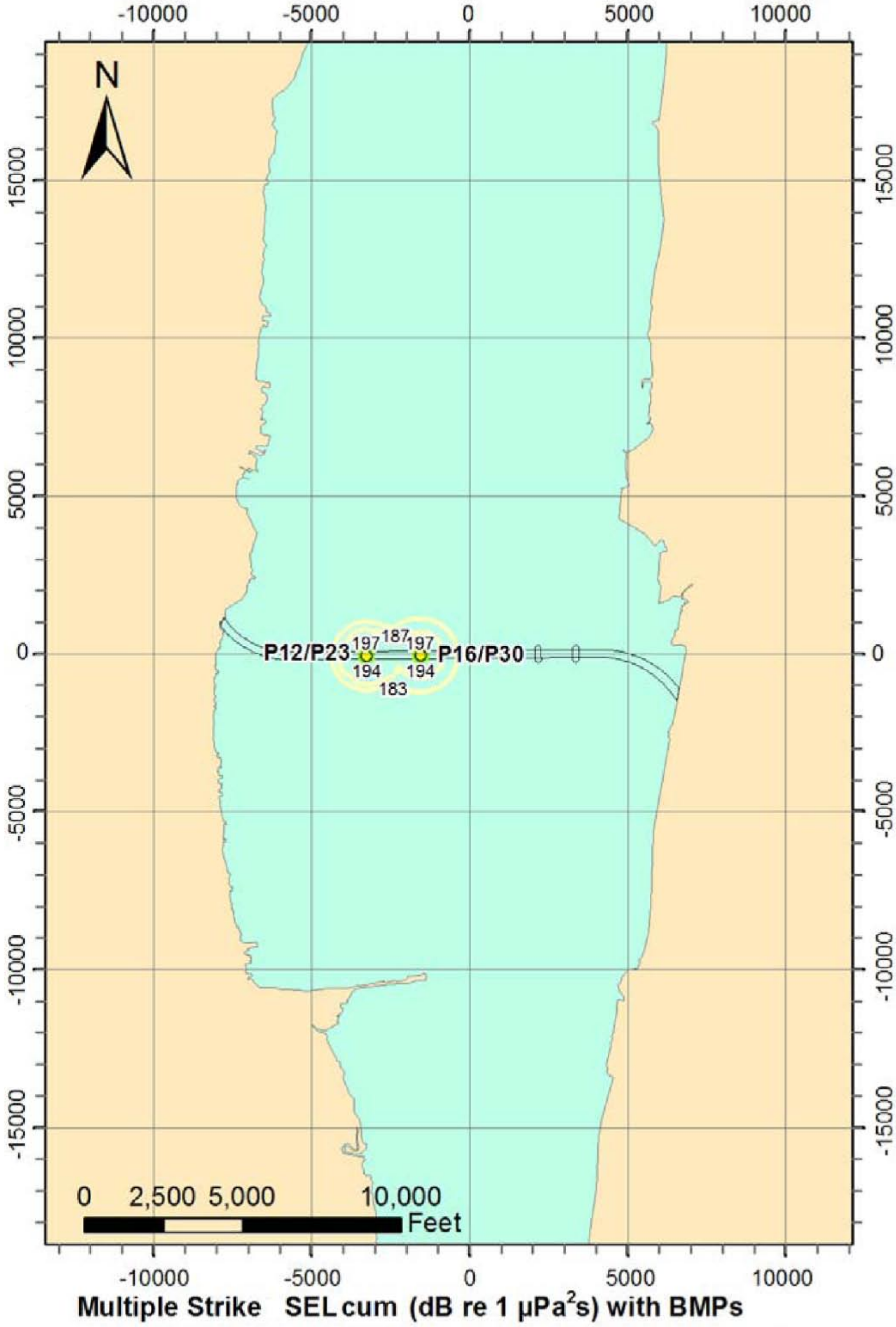


Figure 22

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

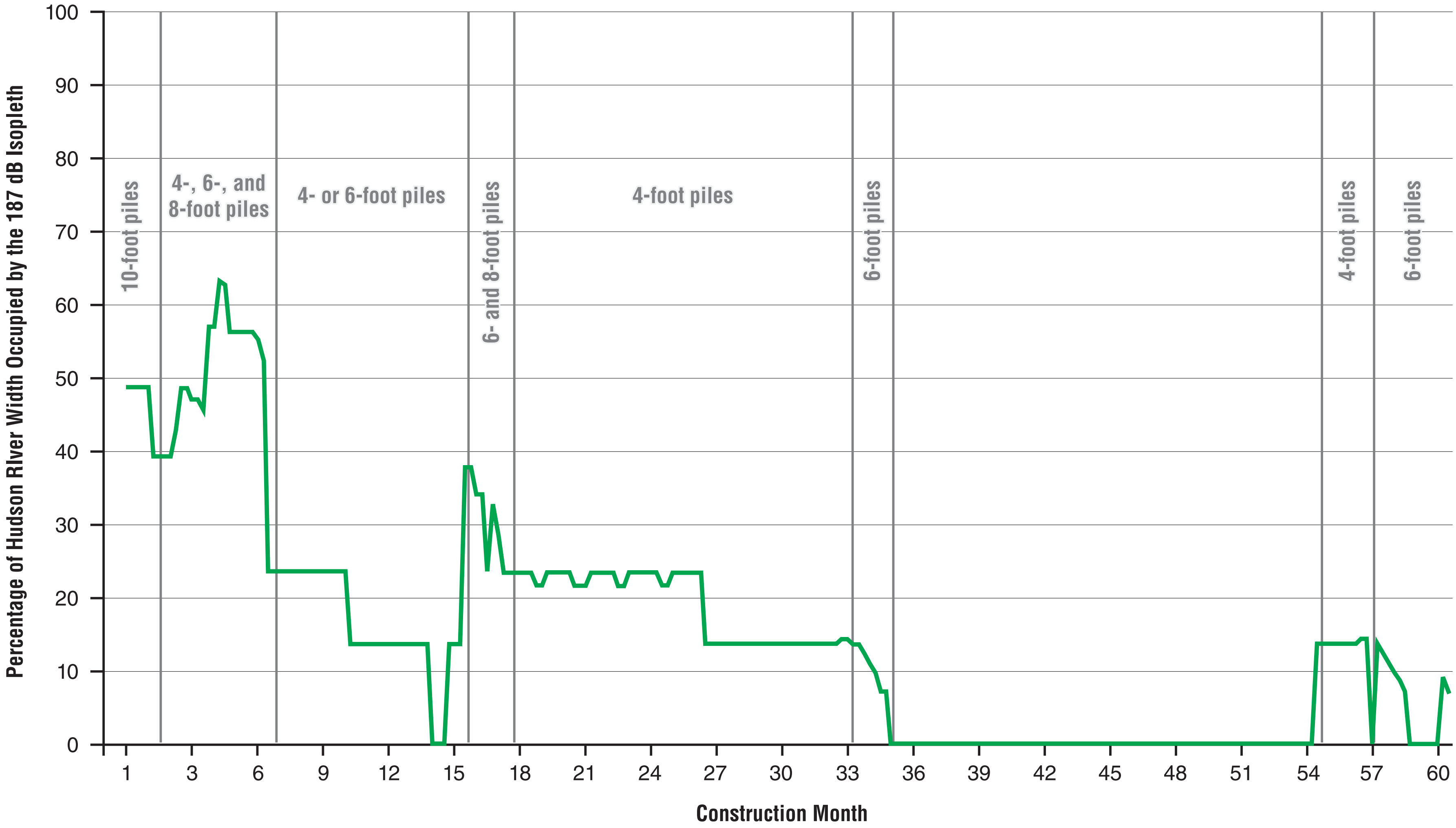


Figure 23

Percent of the Hudson River Width Occupied by the 187dB Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Short Span Option

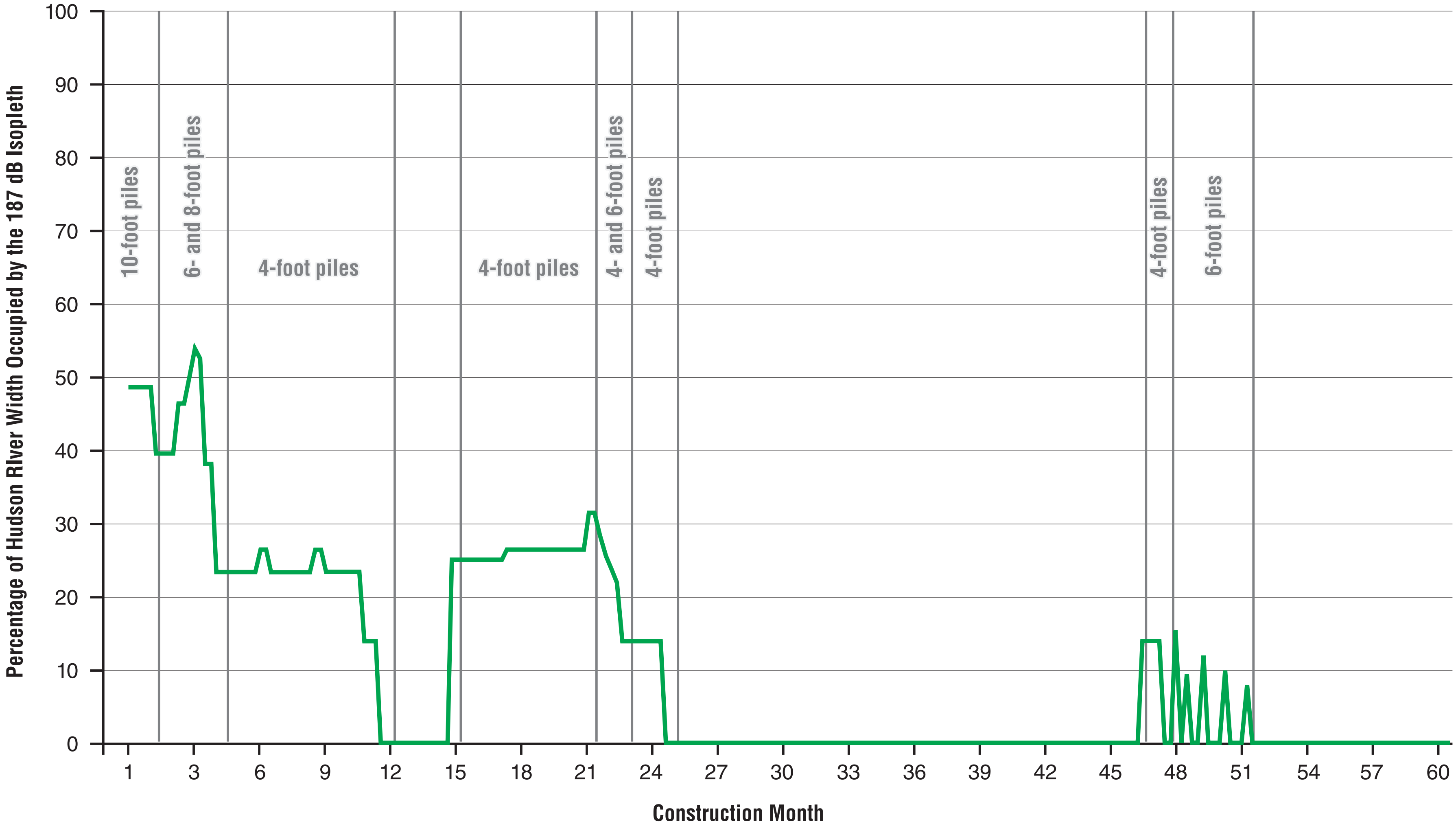
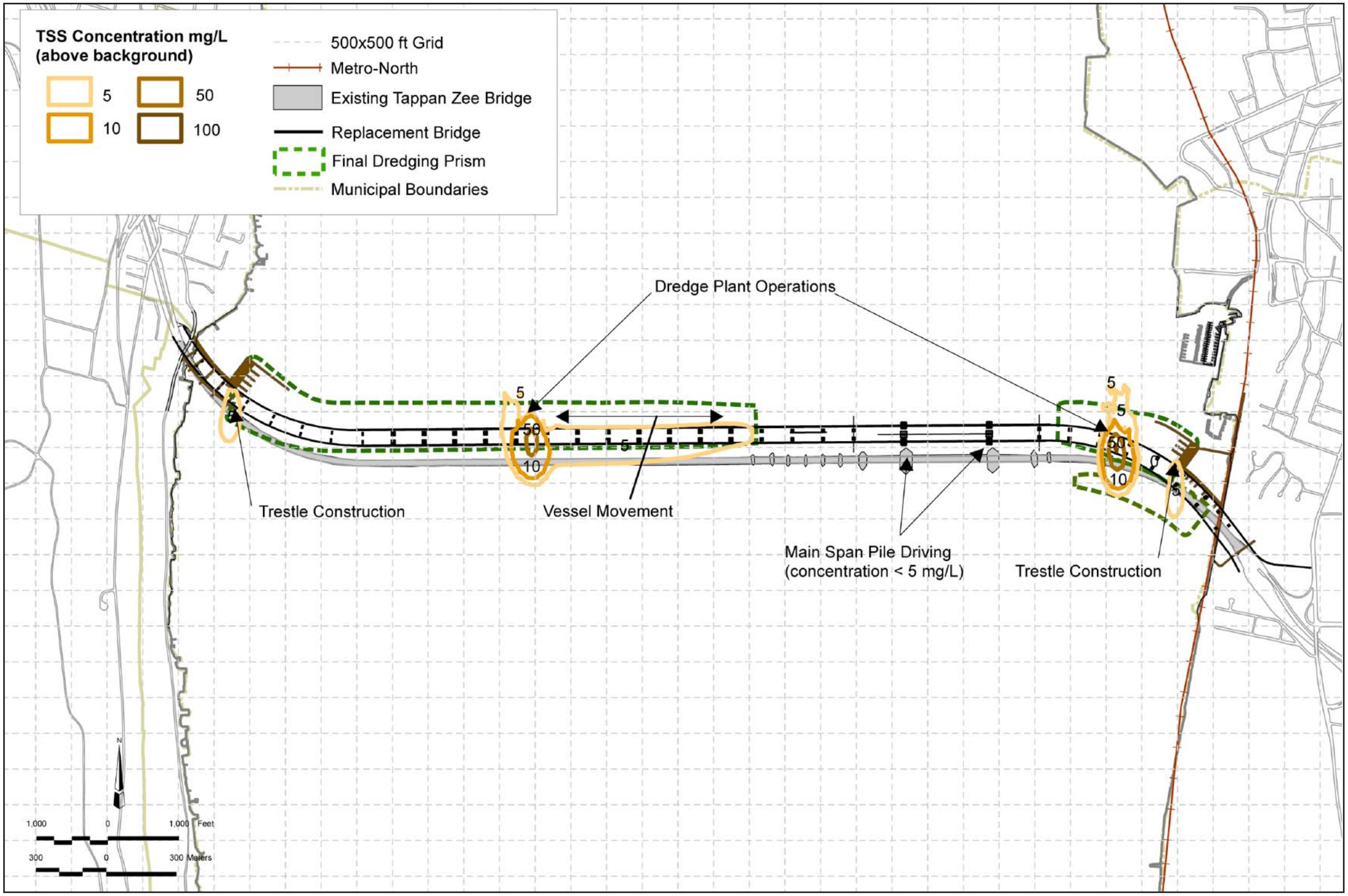


Figure 24
Percent of the Hudson River Width Occupied by the 187dB Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Long Span Option

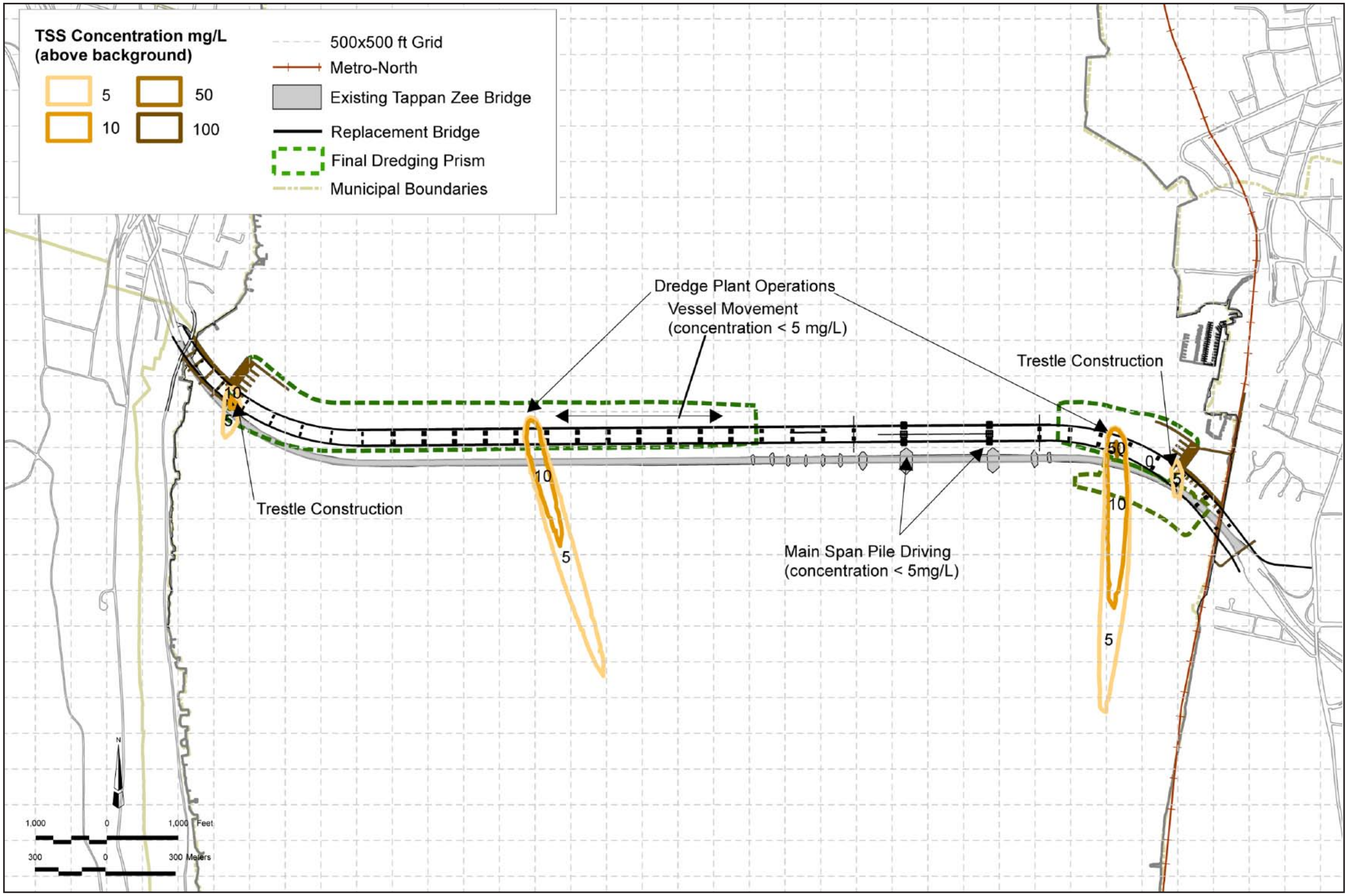


Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* During Stage 1 Dredging-Near Slack Tide

*Note: Short Span Option would be similar

Figure 25

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

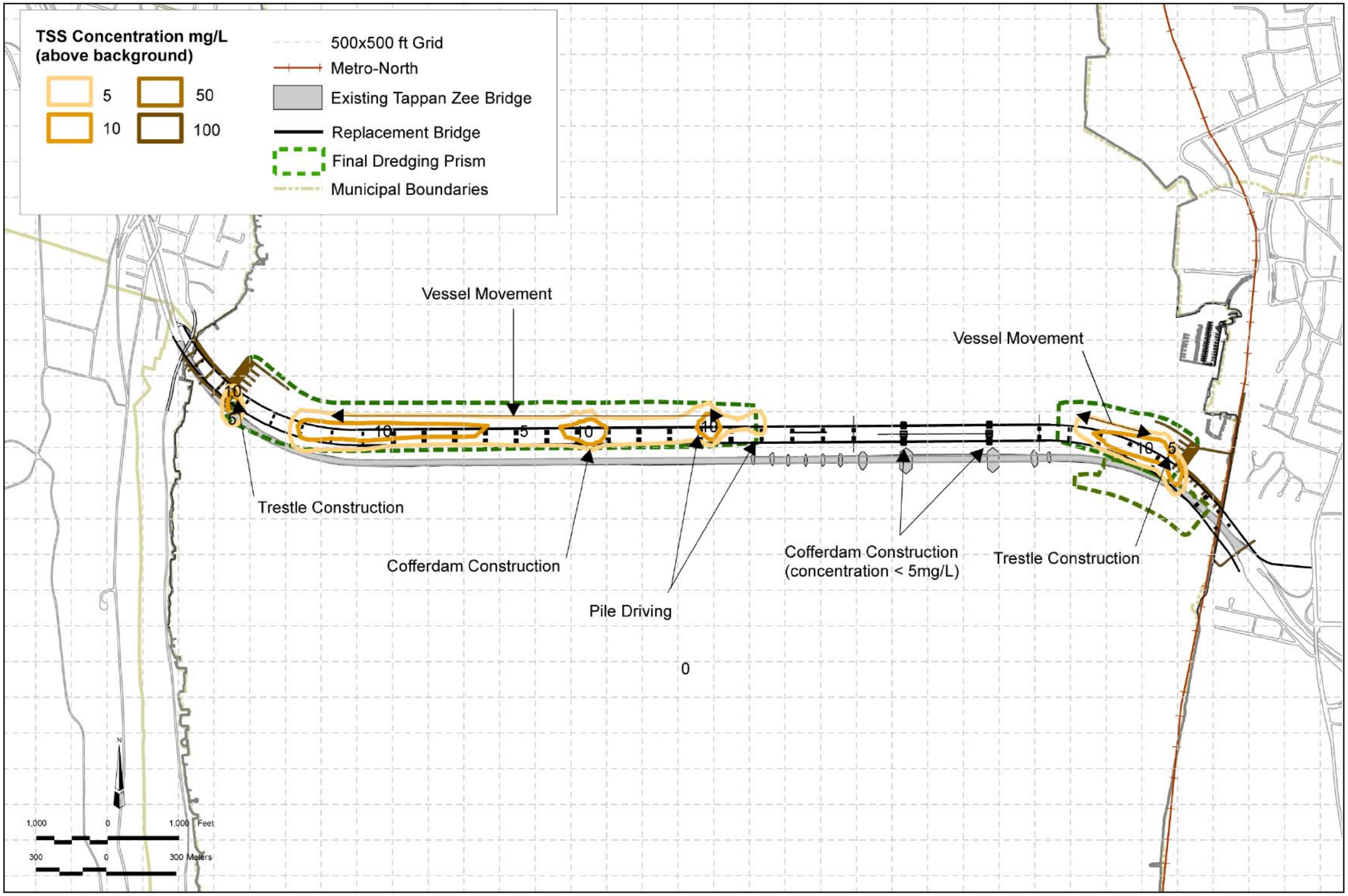


Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* During Stage 1 Dredging-Ebb Tide

*Note: Short Span Option would be similar

Figure 26

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

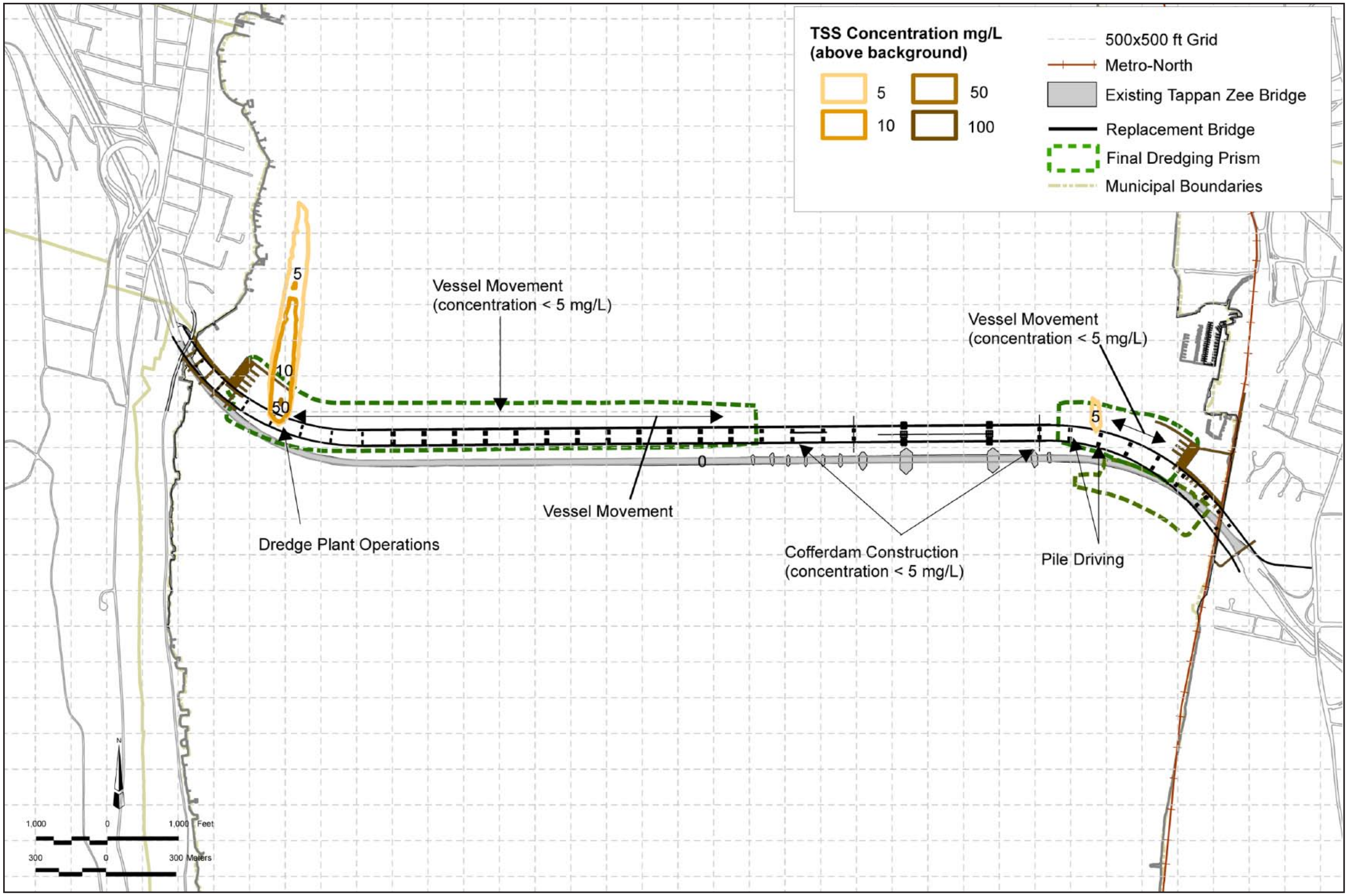


Projected Total Suspended Sediment Concentration for the Long Span Replacement Bridge Option* Zones C and B Construction After Dredging and Armoring – Near Slack Tide

*Note: Short Span Option would be similar

Figure 27

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 28

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